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EFFECTS OF ENERGY TRANSITION ON ELECTRICITY TARIFFS IN GHANA

BY

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A thesis submitted to the Institute for Oil and Gas Studies of the College of Humanities and Legal Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of a Master of Philosophy Degree in Petroleum and Energy Studies.

NOVEMBER, 2024

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DECLARATION

Candidate's Declaration

I therefore declare that this thesis is the product of my own unique effort and that no portion of it has been submitted, either at this university or elsewhere, for consideration for another degree.

Candidate's Name: Job Nagarmi Sowah

Signature: … … Date: ………………………..

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Name: Dr. Shafic Suleman

Signature: …………………………... Date: ………….………………

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ABSTRACT

The study examined the impact of energy transition and electricity tariffs in Ghana. Annual time series data from 1985 to 2021 were used for analysis. The research utilized the ARDL methodology to establish the short-term and long-term relationships among variables. To ensure that the variables were stationary within the context ARDL, a cointegration test was conducted. Additionally, a post-estimation test was performed to assess the model's robustness and stability. Based on the ARDL results, both electricity production from fossil fuels and electricity production from renewables were found to have a positive and significant impact on electricity tariffs in the short and long term. The cost of energy transition was found to have a positive effect on tariffs in the short run but a negative effect in the long run. Carbon emissions were found to positively influence tariffs in the long run and the short run. However, carbon emissions decreased significantly in the long run, leading to a decline in electricity tariffs. Considering these findings, the following recommendations are proposed: Ghana should prioritize and support funding for renewable energy projects, establish a favorable regulatory framework, and maintain policies that encourage the transition from fossil fuels to renewable energy sources. The government should also encourage public-private partnerships to share the risks and costs associated with renewable energy projects. Lastly, strong environmental regulations should be implemented and enforced to reduce the carbon intensity of the energy sector.

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KEYWORDS

Carbon emissions

Electricity generation

Electricity tariff

Energy transition

Renewable energy

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DEDICATION

To my mother and my father for their support and encouragement.

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LIST OF ACRONYMS

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag
BP	British Petroleum
CoPs	Conference of Parties
CUSUM	Cumulative Sum of Recursive Residuals
CUSUMSQ	Cumulative Sum of Squares of Recursive Residual
EC	Energy Commission
ECM	Error Correction Model
ECT	Error Correction Term
GET	Grand Energy Transition
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
NDCs	Nationally Determined Contributions
NET	National Energy Transition
P P	Phillip-Perron
PSRP	Power Sector Reform Programme
PURC	Public Utilities and Regulatory Commission
RET	Renewable Energy Technology
VAR	Vector Autoregressive
VECM	Vector Error Correction Model
WDI	World Development Indicators

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CHAPTER ONE

INTRODUCTION

Background to the Study

The energy sector is crucial in addressing climate change, as it is responsible for approximately two-thirds of carbon dioxide emissions in the world. The provision of electricity and key energy resources is instrumental in driving global economic prosperity. Since the 1970s, the global GDP has expanded approximately 4.5 times, accompanied by a significant surge in primary energy consumption. This consumption has risen from 155.22 exajoules (EJ) in 1965 to 556.63 EJ in 2020 (BP, 2021).

As of the end of 2020, the proven reserves of major fuels, namely oil, natural gas, and coal, suggest limited sustainability. These fossil fuels collectively account for 85 percent of global primary energy consumption. Transitioning to sustainable and renewable energy is imperative to address the problems posed by climate change and ensure a resilient and environmentally conscious energy future. Today, the world faces the significant challenge of global warming, with a key focus on reducing carbon emissions in international environmental policies. For a better and more sustainable future, it is critical to appreciate the relationship between economic development and energy use and to work toward increasing energy efficiency (Barasa and Olanrewaju, 2022).

Electricity is a pivotal energy form and holds a crucial role in socioeconomic progress. The worldwide electricity production, standing at 4,114 GW in 2005, rose to 5,699.3 GW in 2014, and its growth persists annually. In

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2014, over 60 percent of this generation was derived from fossil fuels, contributing to 42 percent of CO_2 emissions (BP, 2021). To effectively address the growing demand for sustainable energy, it is imperative to develop models for sustainable electricity production (Li et al., 2016). As indicated in the emissions gap report, the global greenhouse gas (GHG) emissions in 2018 amounted to about 55.3 $GtCO_2e$, with fossil fuel combustion in several operations, including electricity generation, accounting for 37.5 $GtCO_2$.

Achieving energy sustainability presents a problem for the developed and developing nations. Crafting a transition plan towards renewable energy sources tailored to each country becomes essential, taking into account indigenous resources and prevailing conditions. The shift towards renewable energy is universally acknowledged, driven by the goals outlined in the Paris Agreement. The global community is actively formulating decarbonization strategies to achieve a sustainable reduction in greenhouse gas emissions (Kabeyi & Olanrewaju, 2021). The transition procedure differs across countries, influenced by local, social, and economic factors. The complexity and inclusiveness of the energy transition are molded by various stakeholders, each driven by divergent interests. (Krzywda et al., 2021).

Africa is undergoing an energy evolution branded by a shift from traditional fossil fuels to cleaner and more sustainable energy sources. This evolution is driven by the need to mitigate climate change. According to Ibrahim (2021), Africa's energy transition involves deploying renewable energy technologies. These renewable sources offer vast potential, considering Africa's

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abundant renewable energy resources (Karekezi & Kimani, 2018). Governments and international organizations are actively fostering the growth and adoption of renewable energy through the implementation of policy frameworks and investment initiatives. (Ibrahim, 2021).

As of 2022, Africa accounted for approximately 7% of the global oil reserves and 9% of global natural gas reserves (EIA, 2022). Nigeria, which produces roughly 2.2 million barrels of crude oil per day, is among the world leaders in crude oil exports (BP, 2021). Africa's contribution to global CO2 emissions (the principal human cause of climate change) is about 4% of the total (IEA, 2020). That gap between Africa's fossil fuel reserves and its carbon footprint is another indication of the necessity for sustainable energy as well as the potential for Africa to play a key role in global efforts to address climate change.

Like many other countries, Ghana is gradually embracing the move from old fossil fuel-based electricity production to a more sustainable and renewable energy system, which is causing a huge shift in the nation's energy industry. The worldwide initiative to address climate change. Understanding the consequences of this transition is essential, especially considering Ghana's efforts to boost the proportion of renewable energy within its energy portfolio, particularly concerning its potential impact on electricity prices.

Ghana has historically relied on hydroelectric power and fossil fuels, such as oil and gas, for its energy needs (Dorvlo et al., 2019). The primary energy consumption mix for Ghana is about 33 percent renewables and 67 percent

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thermal largely dominated by natural gas. Nevertheless, the country holds considerable potential in renewable energy sources. (Asare et al., 2021). These resources offer prospects for diversifying the energy mix and decreasing dependence on imported fossil fuels. The Government of Ghana has shown a strong commitment to the energy transition by implementing various policies and initiatives.

International cooperation and investment have played a crucial role in supporting Ghana's energy transition. International agencies including the World Bank have provided technological and financial support to the country (Adanu, et al., 2020). These partnerships have facilitated the execution of renewable energy projects and local capacity development in the renewable energy sector. Electricity markets pay close attention to changes in a country's electricity costs. Specifically, the industry's level of competition and the growing importance of power in general. The cost of electricity affects domestic spending significantly and has a big impact on industrial competitiveness and patterns of energy use. Therefore, how energy costs fluctuate over time will help define and justify its important functions and, in the end, decide its pace of changes to notify stakeholders.

PURC was created in 1997 to regulate electricity prices and uphold competition in adherence to international standards. Section 2 of the PURC Act 538 establishes a governing board inclusive of various stakeholders, such as a representative from the domestic consumers, and individuals with expertise relevant to the Commission's affairs. Nevertheless, the Commission's effectiveness in fulfilling its mandate has often been impeded by political

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responses to public dissatisfaction regarding spikes in electricity prices and the limited public involvement in pricing decisions. (PURC, 2020).

Figure 1 depicts a growing end-user tariff trend from 2000 to 2021. According to the Ghana Energy Commission, this trend transfers Ghana from a low tariff to a very high tariff regime with unknown impacts on businesses and the economy as a whole. Such a trend might not be consistent with the electricity sector's ability to support the economy.

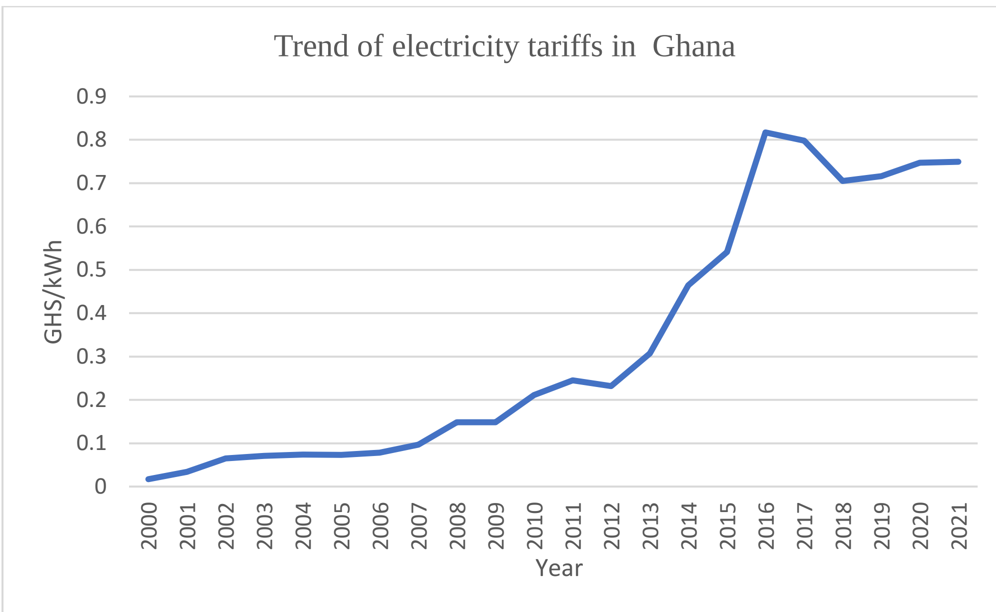

Figure 1: Trend in end-user tariff, 2000 – 2021

Source: Authors' construct (2024) based on data from the Energy Commission

Statement of the problem

The majority of globally generated electricity from power plants relies on fossil fuels. These energy resources are costly, limited, exhaustible, environmentally harmful, and pose security challenges due to the unequal distribution of primary resources among nations. Consequently, this situation

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becomes a source of energy insecurity. Sulphur dioxide (SO2), and Nitrous oxides (NOx) contributing significantly to global warming, thereby jeopardizing the existence of humanity and the environment. A sustainable energy transition is primarily driven by this concern which highlights the need for a greater uptake of clean, low-carbon, renewable energy sources. These alternative energy sources not only enhance and diversify power supply but also improve long-term accessibility in energy production and reduce the price of electricity. Additionally, they diminish reliance on fossil fuels and effectively reduce GHG emissions (Rathor & Saxena, 2020). This problem now begs the question: How can Ghana transition to these sustainable energy sources without compromising on end-user tariffs?

A global transformation in the production, transmission, distribution, and use of electricity is necessary to meet climate targets and avert catastrophic climate change. Humanity must achieve an equilibrium between the preservation of the environment and the demands of development. The main obstacles that renewable energy sources must overcome are those related to intermittency, grid stability, resource availability, accessibility, location, supply security, affordability, and sustainability. The escalating demand for electricity has prompted a greater dependence on fossil fuels, intensifying GHG emissions and, subsequently, worsening global warming (Wang, 2019). Transition problems are compounded by the fact that activities to foster a more sustainable, resilient, and equitable energy system disrupt established economic, political, and institutional

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dynamics. Consequently, matters of power and politics have become pivotal themes in the sustainability transition within the energy sector.

The energy transition poses significant challenges to tariffs, primarily stemming from the potential for high cost of power and the risk of stranded assets after energy transition. As societies shift towards sustainable and renewable energy sources, the initial costs of investing in new technologies and infrastructure can lead to high power generation costs, impacting overall electricity tariffs. Additionally, the transition may render existing energy infrastructure obsolete, resulting in stranded assets and financial implications for governments, investors, and energy companies. Balancing the need for cleaner energy with the economic challenges of higher costs and stranded assets requires careful planning, collaborative efforts among stakeholders, and effective policy frameworks to ensure a smooth and economically viable transition.

Scholarly works (Acheampong & Menyeh, 2021; Ibrahim, 2021 and Olaoye, et al., 2018) acknowledged the concept of energy transition and electricity tariffs. Notwithstanding, most of these studies usually elaborate on reviews but fail to econometrically establish the relationship and impact of the changing generation mix on electricity tariffs. Critically, there is a paucity of research evidence on energy transition and electricity tariffs in Ghana. The energy transition is a new research area in Ghana. There is not enough substantial research literature showing whether or not energy transition has occurred and its implications on electricity tariffs in Ghana. In light of this, this study evaluates

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how the energy transition may affect electricity tariffs in the short and long run to close the gap in the literature.

Purpose of the Study

The study seeks to examine the implications of the energy transition on electricity tariffs in Ghana. The study specifically seeks to:

1. Assess the impact of the energy transition on electricity tariffs in Ghana.
2. Examine the cost implications of energy transition on electricity tariffs in Ghana
3. Analyze the effects of carbon emissions on electricity tariffs in Ghana.

Research Questions

The research addressed the following questions:

1. To what extent does energy transition impact electricity tariffs in Ghana?
2. What are the cost implications of energy transition on electricity tariffs?
3. What is the impact of carbon emissions on electricity tariffs in Ghana?

Significance of the Study

The outcomes of the study can enlighten policy development and decision-making processes related to Ghana's energy transition. By understanding the implications of renewable energy integration on electricity tariffs, policymakers can design effective and efficient tariff structures that support the transition while ensuring affordability, accessibility, and sustainability. A successful energy transition is necessary to achieve the SDGs. To make sure that the switch to renewable energy sources is in line with sustainable development goals, and

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fostering equitable access to cheap energy, it is essential to understand the effects of the transition on electricity tariffs.

Electricity tariffs directly impact consumers, especially low-income households. Examining tariff structures helps identify affordability challenges and potential mitigation measures. It ensures that the transition does not disproportionately burden vulnerable populations and facilitates equitable access to affordable electricity. Assessing the environmental benefits and carbon emissions reduction achieved through the energy transition concerning electricity tariffs helps quantify the positive impacts and reinforces the case for a sustainable energy system. The study addresses a significant knowledge gap by providing specific understanding to the implications of the energy transition on electricity tariffs in the Ghanaian context. It contributes to the literature on energy transition and tariff structures, especially within the Ghanaian context, and helps bridge the gap between theoretical frameworks and practical implications.

Delimitations of the study

The study emphases specifically on Ghana and does not cover other countries. It examines the implications of energy transition in the context of the energy sector of Ghana. The study considers a specific period for analysis (1985-2021) which was determined based on the available data and the research objectives. It includes an analysis of historical trends in electricity tariffs, as well as a projection of future implications based on the energy transition plans and targets set by the Ghanaian government. The study examines how electricity pricing might change if fossil fuels were replaced with renewable energy sources.

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It includes a variety of cutting-edge sources and renewable energy technologies that are relevant to Ghana's energy transition. Limitations in data collection or access may restrict the depth and precision of the analysis. This may provide valuable contributions and implications for energy transition, and electricity tariffs in Ghana. However, the specific discoveries may not be directly generalizable to other countries or regions with different energy contexts, policy frameworks, or socio-economic conditions.

Organization of the Study

The work is organized into five different chapters to facilitate understanding of concepts and theories. Commencing with an introductory chapter, it provides an overview and background of the implications associated with energy transition and electricity tariffs. This chapter includes. Chapter two covers an extensive review of the literature surrounding theoretical, empirical, and variable considerations. Chapter three explains data sources and the methodological framework, along with the techniques employed in the research. Chapter four delves into the findings and engages in a discussion of the results obtained. The study concludes with a final chapter featuring a summary, conclusions derived from the findings, and recommendations for future research.

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CHAPTER TWO

REVIEW OF LITERATURE

Introduction

This chapter looks at the research-related literature. Information for this study was gathered through abstracts, books, journal articles, internet publications, published student thesis, and other sources.

Theoretical Framework

This section reviews the theories underpinning the study. The Grand Energy Transition which is the main theory guiding the study and other related concepts were reviewed in this section.

The Grand Energy Transition (GET)

The Grand Energy Transition which started in the middle of the 1800s, is expected to end in 200 years. Most of this change has already happened historically (Hefner,2009). It is possible to complete the shift by 2050 without depending on cutting-edge technologies. Unprecedented technological advancements have occurred in the modern era, and most of the necessary technology is at hand. By the middle of the century, the majority of people on Earth might be living in an environmentally sustainable economy free from severe pollution and large CO2 emissions provided that there is international cooperation and energy-conscious leadership. To do this, the Grand Energy Transition must be accelerated immediately through international cooperation and support for leaders who are conscious of energy issues.

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The Grand Energy Transition (GET) theory posits that to understand human energy needs across history and into the future, one should consider all energy sources in their diverse forms solid, liquid, and gas. This approach contrasts with the conventional focus on individual fuels like coal, oil, and natural gas. By adopting this perspective, we gain insight into how energy has naturally evolved alongside the progress of civilization. This theory unveils a remarkably straightforward shift that penetrates the complexities of politics, policy, and energy consumption. Through countless energy decisions rooted in economic value, the GET is shaping the possible winners and losers in the future energy landscape.

According to GET, humans will progress toward better fuels based on their state of matter. As a result, the fuels that mankind eventually settles on will change from solid (Hoffmann, 2012). Economic decisions will cause this to happen spontaneously, but political policy has the power to slow it down. Due to the high level of pollution caused by solid and liquid fuels, it is preferable if this occurs sooner rather than later. As soon as possible, coal should be removed from use as a power source because it has lost all of its usefulness. Although oil did bring civilization to its peak, it has also reached a stage where it may be phased out. However, our society finds it difficult to achieve this because of poor infrastructure and industrial interests (Bradford, 2008). The limited supply of oil, price volatility, pollution, and climate change contributions are all challenges with oil.

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Grand energy transitions are primarily influenced by three factors: individual behavior, leadership, and government involvement. The first one is by far the most significant (Sovacool, 2016). Due to its low cost and simplicity of acquisition, utilizing coal and oil in the past made the most sense for the average consumer. Spending money and delaying the changeover are the results of policies that go against what customers find convenient. In 2008, coal had already begun to lose popularity. Beginning to gain popularity among consumers is energy that is cleaner and more effective than coal and oil (Renn et al., 2016).

So far, the world has undergone three transitions. The initial shift entailed substituting wood with coal as the primary energy source, followed by a second transition where oil substituted coal as the predominant resource. The third transition reflects a worldwide dedication to switching fossil fuels with renewable sources. Despite this commitment, as of 2018, fossil fuels still constituted 80 percent of global energy consumption, with petroleum comprising 36 percent, coal 13.2 percent, and natural gas 31 percent. Energy transition signifies changes in the process influencing human societies, driven by technical, economic, and social transformations (Smil, 2010). It charts a new course for economic development and innovation, emphasizing a commitment to environmental integrity and sustainability in response to challenges posed. These transformations involve significant changes to societal subsystems, with the goal of achieving heightened sustainability (Barasa, 2019). Consequently, energy transitions necessitate adaptations to existing policies, technologies. Currently, the world is undergoing what is widely recognized as a fourth energy transition, primarily

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aimed at addressing global climate change through the decarbonization of energy supply and consumption patterns (Mitrova and Melnikov, 2019).

As described above, the Grand Energy Transition (GET) is in line with global initiatives, and countries like Ghana are making remarkable progress toward energy transition. Ghana is gradually moving away from fossils and in the direction of greener and more sustainable energy sources just like many other countries are doing. The country's growing emphasis on renewable energy. Ghana's dedication to cleaner energy not only fits in with the Grand Energy Transition's general goals but also shows a deliberate attempt to fight climate change and advance global sustainability. Ghana hopes to contribute to the global effort to ensure a more developed and sustainable energy future by adopting cleaner energy sources. This is in line with the larger ideas emphasized in the Grand Energy Transition framework (Hefner, 2009).

The Principle of Common Concern of Mankind

The Principle of Common Concern states that global issues including climate change, environmental degradation, nuclear proliferation, and the defense of human rights require international cooperation and collective action. This international law-based premise acknowledges the interdependence of world interests. It emphasizes how each country has a responsibility to reduce climate change causes and prepare for its negative consequences (Bowman, 2010). This principle which was established in agreements such as UNFCCC, emphasizes the need for global cooperation to stabilize GHG concentrations and reduce human

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interference with the climate system. To effectively tackle climate change, it emphasizes the significance of joint action while acknowledging that individual initiatives can have a global impact (Shelton, 2017).

The Principle of Common Concern has much to do with Ghana's energy transition and carbon emissions. Ghana's economy, water resources, and agriculture are all impacted by climate change, even with its comparatively low emissions. When this idea is applied to Ghana, it acknowledges that climate change is a worldwide problem that needs international cooperation. Ghana must support global efforts to conserve trees, use renewable energy sources, and promote sustainable habits even though its carbon footprint is low. The principle also emphasizes how crucial it is for industrialized countries to provide Ghana and other emerging countries with financial and technological support to help them adjust to climate change and transition to low-carbon economies.

The principle suggests that the costs and advantages of the energy transition should be distributed equally across nations (McCollum et al., 2017). Although certain countries may shoulder a greater burden in transitioning their energy infrastructure, every nation holds a collective responsibility to participate in the global initiative. This might entail exploring equitable and inclusive tariff systems that facilitate the growth and incorporation of renewable energy sources, ensuring accessibility and affordability for everyone (McCollum et al., 2017). This principle laid the foundation for the concept of common.

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The Principle of Common but Differentiated Responsibilities

The Principle of Common but Differentiated Responsibilities (CBDR) is based on the principle of common concern for mankind. It was established at the 1992 Rio Earth Summit and reiterated in the Framework Convention on Climate Change. It emphasizes that while all countries share responsibility for sustainable development, they have different capacities and environmental impacts (Stone, 2004). Industrialized nations should take on a greater responsibility in tackling global environmental concerns because of their superior technologies and resources (Deleuil, 2012). The CBDR emphasizes the distinct characteristics that each country possesses to offer the international community. Its activities are to customize development objectives according to national capabilities, guaranteeing equity. This idea is clear in environmental accords such as the 1997 Kyoto Protocol which set distinct emission reduction objectives for industrialized and developing nations and held the former responsible for reducing their greenhouse gas emissions.

The concept of CBDR suggests that industrialized countries have a higher obligation to reduce emissions in the context of Ghana's energy transition. It is expected of advanced economies to provide financial assistance, technological transfer, and capacity-building programs to developing countries like Ghana. Ghana can concentrate on modern renewable energy technologies and adapt its energy transition plans to meet its unique demands. The emphasis is on international cooperation, which guarantees fair access to resources and knowledge and helps Ghana smoothly make the switch to sustainable energy

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sources. This principle is crucial for a country like Ghana which is extremely reliant on fossil fuels for power needs. It pushes Ghana to customize its energy transition pace in terms of cost as the world shifts to more sustainable energy sources.

The Principle of Intergenerational Equity

The intergenerational equity principle is built on the Principle of Common but Differentiated Responsibilities. It highlights the need for present generations to behave responsibly to safeguard resources and future generations' well-being. It recognizes that the environment and prospects for future generations are greatly impacted by the decisions and policies of today (Spijkers, 2018). To guarantee the availability of cultural assets for future generations, this approach promotes sustainable resource use, ecosystem preservation, and asset protection. It aligns with the SDGs, which is to cater for current demands without compromising the ability of future generations to meet their own. To ensure the equitable distribution of benefits and costs across generations in environmental decisions, intergenerational equity necessitates long-term planning, future-focused policies, and consideration of future consequences, demands, and interests (Solow, 2017).

By integrating intergenerational equity into Ghana's energy policies, there is a need for long-term planning that focuses on renewable energy solutions, reducing environmental impact, and ensuring the equitable distribution of the benefits of sustainable energy across present and future generations (Oppong & Boateng, 2014). This principle stresses the importance of switching to clean energy sources, taking the long-term consequences of energy-related decisions

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into account, and making sure that the population benefits equally from the energy transition both now and in the future without compromising the environment for future generations (Shelton, 2017). It pushes Ghana to embrace energy policies that protect the environment, advance sustainable development, and save precious resources for future generations.

Generally, the principles of common concern, common but differentiated responsibilities (CBDR), and intergenerational equity collectively provide a comprehensive framework (IPCC, 2018). They emphasize collaborative global action in adopting cleaner energy sources to address shared challenges like climate change. CBDR acknowledges historical disparities, cooperatively developed countries to take differentiated responsibilities and support developing nations. Intergenerational equity stresses the ethical imperative of ensuring sustainable energy practices to protect the needs of future generations (UNDP, 2016). Together, these principles guide countries towards unified efforts in navigating the challenges of the energy transition, promoting environmental stewardship and equitable resource management for the benefit of current and future generations of the earth.

Conceptual Review

Definitions and concepts of energy transition

Although there is not a single definition for the phrase "Energy Transition" (Smil, 2010). According to Verbong et al. (2012), it is the eventual shift away from low-cost, centralized energy systems that are largely reliant on fossils. In the literature on energy transition, the term has been defined in two different ways.

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According to the IEA (2018), the phrase "energy transition" describes the long-term transition of the global energy system from sources based on high-carbon sources to sources based on low-carbon sustainable energy. A comprehensive transformation in electricity generation, distribution, and consumption patterns is required to address and advance energy security (IEA, 2018). Sovacool, (2015) thinks that energy transition refers to the profound systemic change that occurs when a given energy system shifts to a different, new, or more sustainable configuration. Sovacool highlights that energy transition is not simply a technological change, but a broader transformation that encompasses social, economic, and political dimensions (Sovacool & Dworkin, 2015).

Edomah et al., (2020) introduce an intuitive socio-technical paradigm to enhance the conceptualization of national energy transitions. They differentiate between transformative energy transition, wherein sustainable energy shifts results from a blend of community engagement and governmental policies, and interim energy transition and deliberate energy transition, where citizens or consumers propel sustainable energy transitions even in the presence of supportive governmental policies (Edomah et al., 2020).

From the above literature, it is evident that energy transition had significant implications for the energy sector, particularly in terms of changing the sources of electricity production. In many cases, transitioning to sustainable energy sources may initially incur higher costs, impacting electricity tariffs. As countries like Ghana aim to adopt more sustainable energy practices to address

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climate change and enhance energy security, there may be challenges in balancing the need for affordable electricity with the costs associated with the transition.

Government policies by Edomah et al., (2020), play a vital role in shaping the direction of energy transition. If Ghana pursues a transformative energy transition with attention to sustainable practices, it would require a combination of community involvement and supportive policies. In such a scenario, there might be policy interventions to manage the impact of electricity tariffs, potentially incorporating subsidies or other mechanisms to mitigate the short-term cost increases. On the other hand, if citizens or consumers in Ghana are the driving force behind sustainable energy transitions, the government may need to adapt its policies to support and incentivize these efforts. This could involve creating a regulatory environment that promotes the uptake of renewable energy technologies on an individual or community level.

Definitions and Concepts of Electricity Tariffs

Electricity tariff, similarly known as an electricity rate or price, denotes to the amount charged to consumers for the electricity they consume. It typically includes the costs associated with generation, transmission, distribution, and various regulatory charges and taxes (IEA, 2020). An electricity tariff represents the price at which electricity is sold to consumers. It encompasses the costs incurred in generating and delivering electricity to end-users, including the costs of production, transmission, distribution, and any additional charges or subsidies imposed by the government or regulatory bodies (IEA, 2020). Electricity tariff is the price charged to consumers for the use of electricity, which covers the costs of

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electricity generation, transmission, distribution, and any applicable taxes or surcharges. Tariffs can be structured in various ways, including fixed charges, variable charges, time-of-use rates, and demand-based charges.

According to a study by Joskow & Tirole (2006), electricity tariffs are designed to ensure cost recovery for electricity suppliers while providing appropriate price signals to consumers. Costa et al. (2020) assert that tariff design is a crucial policy tool to promote sustainable energy practices. They argue that well-designed tariffs can encourage energy efficiency, demand response, and the integration of renewable energy sources, contributing to environmental and economic objectives. Cost-reflective tariffs are electricity tariffs designed to align with the actual costs of generating, transmitting, and distributing electricity, ensuring that the prices charged to consumers accurately represent the underlying costs of the electricity system (Gallastegui et al., 2020).

In summary, the above studies become significant as they highlight the financial sustainability of energy providers, enabling them to cleaner and more sustainable technologies. A stable financial environment is crucial for the transition to a low-carbon energy system. In terms of energy transition, this becomes a powerful tool. Well-designed tariffs can encourage energy efficiency, demand response, and the incorporation (Costa et al., 2020). By adjusting tariffs to reflect the true costs of electricity generation and distribution, consumers are incentivized to make choices that align with sustainable energy practices. The studies emphasize that tariff design is a crucial policy tool for promoting sustainable energy practices. This includes encouraging energy efficiency and the

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adoption of renewable energy sources. By aligning tariffs with environmental and economic objectives, policymakers can drive the transition towards cleaner and more sustainable energy systems. Cost-reflective tariffs, as defined by Gallastegui et al. (2020), are designed to align with the actual costs of generating, transmitting, and distributing electricity. In terms of energy transition, this is particularly relevant. It ensures that the prices consumers pay accurately represent the underlying costs of the electricity system. This transparency is essential for fostering a fair and economically viable transition to a more sustainable energy.

A View of Ghana's National Energy Transition Targets

Ghana is actively operationalizing. This highlights the importance of the NET framework, outlining explicit objectives for attaining net-zero carbon emissions in Ghana. The NET integrates diverse policy documents, including the Renewable Energy Master Plan and Energy Efficiency Regulations.

The NET of Ghana is centered on decarbonization, improved energy security, efficiency, and access to lower GHG emissions. With an estimated cost of USD 562 billion, the for the NET is based on three primary hypotheses to achieve a net zero target by 2070. It is based on a baseline for 2021. These theories entail estimating a 5% annual rise in GDP, a 2% annual population increase, and a 1% annual growth in industrial equity, which would result in a change in the urban-rural share of industrialization from 56% to 85 (Sefa-Nyarko, 2024).

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Ghana's energy transition plan is marked by controversy in three key aspects. Firstly, there is criticism of the government's perceived slow pace in transitioning to net-zero emissions. The justifications provided by the government are analyzed critically with considerations extending to both domestic and international relations, highlighting the intersection of energy transition in Ghana with global geopolitics. Secondly, the country's decision to apply all available natural resources, including fossil energy, until 2050 for rapid development is contentious. The plan entails a gradual shift towards achieving net-zero emissions, with nuclear energy serving as the primary source, targeting the elimination of emissions in electricity generation by 2070 (Sefa-Nyarko, 2024). Although the peak of CO_2 emissions is expected in 2050, the Transport sector is foreseen as the largest contributor. The overall emissions from the Energy Transition by 2070 are projected to be negative, indicating that the country would release less CO_2 than it extracts from the atmosphere. This is largely dependent on nuclear energy sources, which while offering benefits also pose additional risks to both health and the environment (Sefa-Nyarko, 2024).

Finally, there is no clear indication that the government intentionally marginalized non-hydro-renewable energy in its energy transition plan. The installed capacity for green energy is slated to surge from 0.144 GW to 21 GW, while the overall installed capacity for electricity generation is expected to grow from 5.134 GW in 2021 to 83 GW by 2070. This marks a substantial increase of over 14,000% in green energy within the energy mix, transitioning from the current 0.144 GW to the projected 21 GW in 2070. Moreover, it is imperative not

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to underestimate the formidable operational and practical challenges associated with generating sufficient renewable energy to meet Ghana's domestic energy requirements. For example, Ghana's total solar and wind energy production capacity is expected to be limited to a maximum of 3 GW (Debrah et al, 2020). This indicates that it will need to explore other sources of energy to satisfy its estimated 83 GW of energy needs by 2070, which explains why nuclear energy is a top-priority alternative (Debrah et al, 2020).

Empirical Review

Due to issues with climate change and energy insecurity, the energy transition has grown in importance. The energy transition can lower electricity market prices. Multiple empirical research has examined this idea; the results are conflicting. This section examines the relevant empirical studies.

Energy Transition and Electricity Tariffs

What are the effects of energy transition on electricity tariffs? Considering the shift from long term? How can policymakers ensure that the ongoing energy transition, which incorporates a mix of thermal, solar, and hydro sources in Ghana's electricity generation, balances the objective of sustainability with the potential impact on electricity tariffs?

Adaduldah et al., (2014) examined the impact of renewable energy on day-ahead electricity pricing in Germany. They saw that the substantial growth in the use of sources nationwide has notably influenced the pricing of power in the day-ahead spot market, with supply expectations playing a significant role. The study revealed that, during days with ample wind and sunlight, this situation has

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occasionally resulted in negative electricity prices. This highlights the need for a more flexible tariff structure that can accommodate the fluctuations in renewable energy supply. Overall, the research highlights the transformative effect of renewable energy integration on electricity tariffs, calling for adjustments in tariff structures as part of the broader energy transition.

Gelabert et al., (2011) examined the cogeneration and renewable energy on the electrical system in Spain from hourly data. The results confirmed that marginal power prices decreased by V3.8/MWh for every 1GWh increase in generation. The findings suggest that a greater incorporation of renewable energy into the electricity production mix can lead to a reduction in marginal power prices. This reduction may be attributed to the low operating costs related to renewable energy sources compared to fossil fuel-based generation. As a result, such a shift could contribute to making electricity tariffs more competitive and potentially more affordable for consumers. This aligns with the goals of many countries striving to change to cleaner and more sustainable energy sources of which Ghana is inclusive.

Minlah et al., (2017) examined how the merit-order impacts of influence the divergence in prices within. They similarly assert that the progress in energy development leads to a reduction in electricity prices. McConnell et al., (2013) make analogous findings in relation to the Australian electricity market. They establish that lower marginal electricity prices are the outcome of increased PV electricity production. Both studies demonstrate merit-order effects, where increased renewable energy production, particularly from sources like solar

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power, leads to a reduction in electricity prices. This trend not only brings economic benefits to consumers and industries but also aligns with environmental sustainability goals by fostering a cleaner energy mix.

The findings from Wurzburg et al., (2013) analysis of Australia reveal a consistent pattern. The observed relationship suggests that low marginal pricing of electricity is closely linked to generators with lower marginal costs, particularly those involved in renewable energy generation. This pattern implies that an increased share of renewable energy can contribute to decreased electricity prices. Such results are significant, as they highlight the economic advantages of integrating renewables into the energy mix, supporting the goals of affordability and sustainability. This empirical evidence provides valuable guidance for policymakers and industry stakeholders in navigating the transition to a more economically sustainable energy landscape

Ausra's (2016) investigation into the Nord Pool area's power production mix and market pricing concludes that the overall has no noticeable effect on day-ahead market prices. However, an interesting assertion is made that the electricity market price could decrease with the increasing usage of renewable energy, indicating a potential positive impact on pricing dynamics. This suggests a shift in market trends, emphasizing the economic benefits and cost-effectiveness associated with renewable energy. Ausra's findings contribute valuable insights to discussions surrounding the evolving dynamics of energy markets and the potential influence of on market prices.

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Mohammadi (2009) in his analysis of annual pricing time series for electricity and fossil fuels spanning from 1960 to 2007 reveals that the long run effects of fossil fuels on the cost of power are essentially insignificant. However, fluctuations in the hard coal and natural gas markets have a direct influence on electricity prices. This underlines the complex dynamics of the energy transition, indicating that while the long-term influence of fossil fuels diminishes, short-term market fluctuations in specific fuel sources can promptly affect electricity tariffs. The findings emphasize the importance of considering both long-term trends and immediate market dynamics in energy transition strategies and policy formulation to shape the cost of electricity during the shift to cleaner energy sources.

Ferkingstad et al. (2011) utilized VECM and weekly prices for oil, natural gas, electricity, and hard coal. They explored the dynamic interactions in pricing within Germany. Their results show that, among the variables studied, natural gas has a more pronounced effect on electricity pricing compared to oil or hard coal. This insight is particularly relevant to energy transition, indicating that as countries shift from fossil fuels, the pricing dynamics of natural gas play a critical role in affecting electricity tariffs. The study stresses the necessity for policymakers to consider these specific influences when formulating strategies for a cleaner energy mix, offering valuable guidance for navigating the complexities of energy transition and its implications on electricity costs.

The study by Adom et al., (2018) reveals that hydro-based technology offers cost advantages over thermal technology in Ghana's electricity generation, leading to lower end-user prices. This finding is crucial for the country's energy

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transition, emphasizing the economic benefits associated with renewable energy and providing an incentive for a shift towards more sustainable and cost-effective energy sources. Lower electricity tariffs resulting from hydroelectric power can enhance affordability and accessibility, promoting economic development for citizens. However, the shift towards a combination of thermal and hydro energy in Ghana's energy mix, as noted in the Osei-Tutu et al. (2021) study, suggests the need for careful planning to balance the energy mix, and consider factors such as reliability, and long-term costs in shaping the future of the nation's electricity sector.

The desktop research conducted by Amanfo (2022) reveals a notable shift in Ghana's electricity generation infrastructure, signaling a transition from a historically hydro-dominated system to a more diversified mix, incorporating thermal, solar, and hydro sources.

This shift reflects a strategic response to climate change and a broader to sustainable energy practices. However, the study by Acheampong et al., (2021) suggests that despite this transition, thermal production is expected to continue being Ghana's primary energy source over the next decade, driven by current increases in thermal electricity supply. The evolving energy supply mix aligns with global efforts to incorporate renewable sources, but the persistence of thermal production may have implications for the country's energy transition goals. The findings underscore the dynamic nature of Ghana's, prompting the need for adaptive policies to balance the objectives of sustainability, affordability, and reliability in the electricity sector.

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It is obvious from the literature that the shift to a more diversified energy mix involves intricate economic considerations, with direct implications for electricity tariffs. While the transition introduces benefits such as better cost advantages with renewable based technology, the prevalence of thermal energy suggests challenges in achieving a fully sustainable and cost-effective transition (Amanfo,2022). The economic implications including the costs related with transitioning infrastructure, adapting to new technologies, and maintaining a reliable energy supply are crucial factors that policymakers in Ghana must carefully navigate, particularly in shaping electricity tariffs to reflect the evolving energy landscape and maintain affordability for end-users. Balancing the economic costs with the environmental benefits is essential to ensure a successful and transition in the Ghanaian context (Osei-Tutu et al., 2021).

The cost implications of energy transition and electricity tariffs

How do the cost implications of transitioning from fossil fuel electricity production systems to renewable sources impact the overall electricity tariffs for end-users, and what measures can be implemented to mitigate potential increases in consumer costs during this transition?

A study by the IEA (2021) indicates decreasing costs of low-carbon generation technologies and electricity tariffs. The findings suggest an accelerated shift towards cleaner energy, with the affordability of renewable sources and the cost-effectiveness of nuclear power making them attractive options. Traditional fossil fuels particularly coal face challenges, while gas-fired power generation gains resilience with lower prices. Policymakers may need to reassess existing

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policies to align with these trends, considering subsidies and incentives for low-carbon technologies to facilitate a smoother transition. Overall, the study highlights a positive trajectory towards sustainability and cost-effectiveness in the worldwide energy landscape, urging a re-evaluation of strategies to ensure a balance between environmental goals and affordable electricity tariffs.

Shu et al., (2017) examination of the association between the cost of wind power production and electricity prices, encompassing both spot and regulation pricing, has significant implications for the broader context of energy transition and electricity tariffs with notable cost considerations. The observed decrease in spot prices as wind power penetration increases suggests a potential cost benefit associated with higher wind energy integration. This finding shows the economic feasibility of transitioning towards renewable sources, aligning with the cost-efficiency goals of energy transition initiatives. Lower electricity prices, coupled with increased reliance on wind power not only contribute to sustainable practices but also have positive cost implications for consumers and industries. Energy planners can leverage these results to formulate strategies that strike a balance between the economic advantages of renewable energy and the affordability of electricity tariffs, thereby facilitating a smoother and more cost-effective transition to sustainable energy practice.

The study by Kyritsis et al., (2017) on the impact of sporadic solar and wind power generation on Germany's electricity pricing dynamics offers valuable insights that are directly relevant to the cost dynamics of energy transition. The findings, particularly regarding the increased volatility of electricity prices with

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higher wind power production indicate a critical aspect of the problems related with transitioning to renewable energy sources. This heightened volatility poses risks to the flexibility of the energy market, highlighting the need for robust strategies and infrastructure to manage fluctuations in supply and demand. The cost implications of such volatility, including potential disruptions and the need for advanced grid management systems become integral considerations in the overall assessment of the costs associated with energy transition. Stakeholders in their pursuit of sustainable energy practices, must carefully weigh these results to develop cost-effective strategies that mitigate the challenges posed by increased renewable energy integration.

Timilsina's (2020) analysis of over 4,000 levelized power costs for 11 technologies in the U.S. highlights the potential cost advantages of transitioning to renewable energy, with lower costs for most renewables compared to fossil fuels under certain conditions. However, the discrepancy between these cost estimates and recent low auction prices for solar power in some regions raises questions about the practicality of achieving such low costs. The results calls for the need to carefully recognize the economic benefits of renewable energy transition while addressing real-world challenges and market conditions to ensure a sustainable and financially viable shift.

Moreno et al. (2019) research on power pricing in the European Union highlights the impact of primary capital costs for sustainable renewable energy generation on electricity tariffs. The research emphasizes the need for government assistance mechanisms due to high upfront costs, suggesting that consumers may

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ultimately bear the costs of these support systems. The study finds that the government's backing of renewable energy programs contributes to rising electricity prices, raising concerns about the financial burden on consumers. This underlines the challenge of balancing the promotion of renewable energy within energy transition efforts while mitigating the potential increase in electricity costs for end-users. The findings serve as an indication to develop strategies that make the transition financially feasible for consumers and ensure the long-term success of renewable energy adoption.

The studies suggest a promising course for the country's energy transition, highlighting the potential benefits of decreasing costs in low-carbon technologies. Policymakers should align existing policies with global trends and incorporate incentives for sustainable technology adoption (Zhan et al., 2021). The economic advantages and potential cost savings from renewables present opportunities for a diversified and affordable energy mix in Ghana (Zhan et al., 2021). However, challenges related to increased volatility highlight the need for robust strategies to manage fluctuations in the energy supply. Ghana should anticipate initial investment challenges in transitioning, requiring careful planning and possible government-backed support mechanisms such as subsidies and incentives. Balancing the promotion of renewables with financial feasibility for consumers is crucial, emphasizing the need for context-specific approaches that address market dynamics, real-world challenges, and the overall cost of the transition for a successful and sustainable energy future.

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Carbon Emissions and Electricity Tariff

How do varying levels of carbon emissions impact electricity tariffs and what strategies can be implemented to mitigate these effects?

The study by Kanamura (2007) investigated the non-linear correlation between electricity prices and demand using a structural model. It looks at how carbon intensity, pricing mechanisms, and electricity demand affect electricity tariffs in a competitive market. The results imply that rising carbon costs are linked to increasing electricity prices, indicating a possible move away from fossil fuels and toward renewable energy sources. The ability of businesses to transfer costs to consumers, particularly for less elastic products, limits the efficiency of the carbon pricing scheme. The study emphasized how critical it is to strike a balance between increasing electricity prices and rising carbon costs since an unjustified electricity price increase could impede the shift to low-carbon production and harm consumer welfare. The outcomes of this this work have key policy implications for Ghana, as they underline the need to ensure equitable cost sharing between producers and consumers during the transition while simultaneously encouraging the development of cleaner energy.

In his study, Apergis (2018) performed a regression analysis to scrutinize the potential asymmetric connection between carbon intensity and electricity prices within the New Zealand economy. It is noteworthy that the data for this investigation were gotten from the Ministry of New Zealand Treasury. The empirical results disclose a long-term asymmetric influence of carbon prices on electricity prices, wherein solely positive alterations in carbon prices signify a

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complete pass-through effect. This emphasizes the nuances of the association between carbon pricing and electricity tariffs. The results highlight the importance of understanding how carbon pricing mechanisms can influence electricity prices. The asymmetric effects imply that positive changes in carbon prices may have a more pronounced impact on electricity costs possibly offering insights for policymakers aiming to integrate more renewables into the energy mix as part of emission reduction strategies. It emphasizes environmental objectives and the economic implications of carbon emissions on electricity prices as well as ensuring a balanced and effective transition towards sustainable energy.

Cotton and Mello (2014) study examines the effectiveness of Australia's emission trading scheme through the application of a sophisticated long-term structural modeling method. Employing a forecast error variation, the researchers uncover significant results. In the short term, emission prices exhibit a narrow effect on electricity prices. This phenomenon is attributed to improvement in the efficiency of coal plants observed in the period of study. This result when viewed with the idea of achieving energy transition, suggests that the initial stages of emission pricing might not exert immediate pressure on electricity tariffs. However, as coal plants become more efficient, there is an implicit recognition that longer-term shifts in the energy landscape such as integrating more renewable sources will play a more pivotal role in the overall effectiveness of emission reduction strategies. These findings show the importance of considering not only the immediate economic impacts but also the dynamic changes that unfold over time in the pursuit of a sustainable transition.

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Kiprotich et al., (2021) explored the complications of transitioning to renewable energy on the production costs and GHG emissions in East African countries. Utilizing capacity expansion scenarios and simulation methodology, the researchers explored the dynamics of this transition. Their findings revealed a complex and nonlinear relationship between the adoption of renewable energy sources and the associated costs of power supply. The implications extend to the environmental front, where the study emphasizes the potential for reducing greenhouse gas emissions through increased reliance on renewable sources. Moreover, the results have relevance for electricity tariffs, suggesting that the transition to renewables may impact the cost structure of power production and, by extension, influence electricity tariffs. This is important to this study as the country considers sustainable energy practices and ways to mitigate carbon emissions and ensure the affordability of electricity for consumers.

In summary, these studies by Kanamura, Apergis, Cotton and Mello, and Kiprotich et al. tell us about how carbon emissions and renewable energy impact electricity prices. Kanamura (2007) suggests that if carbon costs increase, companies might switch to renewables, but it is crucial not to burden consumers with all the costs. Apergis (2018) talks about understanding New Zealand, essential for using more renewables in emission reduction plans. Cotton and Mello (2014) find that Australia's emission trading has little short-term impact, emphasizing the need to shift to renewables for better emission reduction. Kiprotich et al.'s (2021) study on East Africa shows potential for reducing emissions and affecting electricity prices. Generally, the studies stress the

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importance of carefully planning strategies that consider both economics and environmental aspects for a successful energy transition, especially Ghana which is extremely dependent on fossil fuels for power generation.

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Table 1: Tabular Summary of empirical review of the World

Author(s)/Year	The focus of the paper	Methodology	Results	Gap
		WORLD		
Farhat et al., (2022)	the effects of grid tariffs on energy transition in Sweden	The study employed simulation and scenario analysis	The findings indicate that current network pricing will not be sufficient to allocate costs.	Insufficient network tariff model to be used in future electric energy systems. the inequitable cost distribution of current network prices.
Farsaei et al., (2022)	The effects of switching to low-carbon energy on the electricity market in the Nordic-Baltic region	Both the Greenfield Investment Model (REX) and the Enerallt Dispatch Model were utilized.	he findings indicate that the expansion of the transmission network has a remarkable impact on power prices.	This study did not fully address the spread of RES throughout all of Northern Europe.
Lin C. et al., (2022)	They look at the cost of shifting to renewable energy sources and try to find a more cost-effective solution that takes social efficiency into account in China.	For the analysis, they employed the Computable General Equilibrium model.	the findings show that real electricity prices are expected to increase by around 1.6% if energy transition is implemented, and power consumption across a range of industries would rise.	There was no indication of doing multiple comparisons to see if the findings would hold true in other provinces.
M. X. Lin et al., (2020)	The study explores the ways in which Taiwan and other nations use complete policy	They used textual and legal policy methodology.	The findings indicate that Taiwan is going through a national energy transition in accordance to the	The study failed to group policy packages into patterns so that other countries may use them as a guide for

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	packages or legislative measures to address the difficulties posed by the UN Sustainable Development Goals related to energy transition.		Sustainable Development Goals, which might be aided by policies relevant to the power industry.	crafting their own policies.
Gelabert et al. (2011)	the effect of cogeneration and renewable energy on the cost of power in Spain.	To estimate the various technologies, they employed ex-post empirical techniques.	The results demonstrated that marginal power prices decreased by V3.8/MWh for every 1GWh increase in renewable energy generation.	The study only took short-term effects into account. But they disregarded the long-term consequences.

Source: Author's construct (2024)

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A number of research that look at global energy transition concerns point to important issues as shown from table 1.

The urgent issue of equitable cost distribution in Sweden's energy transition was highlighted using scenarios and simulation by Farhat et al. (2022), who also highlighted the dearth of ideal network tariff models for cost allocation that is fair. The findings indicate that existing network pricing will not be sufficient to electricity allocated costs.

Farsaei et al. (2022) utilized the Greenfield investment model (REX) and the dispatch model to reveal the impact of transmission network development on electricity prices in the Nordic-Baltic countries. The study underscores the necessity for comprehensive analysis across all Northern European nations. The findings indicate that the expansion of the transmission network significantly influences electricity prices, particularly in the Baltic states.

In their study, C. Lin et al., (2021) examined China's shift to renewable energy sources. They found that real electricity prices are expected to increase by around 1.6 percent if the energy transition is implemented, and power consumption across various industries would rise nevertheless, the lack of many provincial comparisons hampered the study's ability for generalization.

According to M. X. Lin et al., (2020), Taiwan's energy policy response to the UN Sustainable Development Goals is lacking categorized policy bundles, which restricts the amount of other countries' orientations. Last but not least, Gelabert et al., (2011) concentrated on electricity pricing in Spain; nevertheless,

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their short-term viewpoint ignores the critical long-term consequences of renewables.

Global challenges such as ensuring fair cost distribution, thorough regional coverage, comparative analyses for wider applicability, specific policy references, and a comprehensive understanding encompassing both short- and long-term impacts of energy transition are collectively highlighted by these studies.

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Table 2: Tabular Summary of empirical review of Africa

AFRICA				
Author(s)/Year	**The focus of the paper**	**Methodology**	**Results**	**Gap**
Kiprotich et al., (2021)	To examine how the transition to renewable energy affects the cost of electricity generation and the emission of greenhouse gases in East African countries.	They applied modeling techniques and capacity augmentation scenarios.	they identified an intricate and non-linear connection between the integration of renewable energy sources and the expenses associated with power supply.	The study only focuses on East African countries.
Nsafon et al., (2023)	Emissions from the sustainable energy transition in Africa: just and policy implication	Thematic Review	The findings demonstrate the need for consideration of a number of issues pertaining to affordable access, economic growth, and energy security during Africa's transition to sustainable energy.	The study was not based on empirical data. It was more of a systematic review

Source: Author’s construct (2024)

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From the African perspective as outlined in table 2, Kiprotich et al., (2021) examined how East African countries are converting to renewable energy (RE) using capacity expansion scenarios and simulation. They found a complex and nonlinear association between the adoption of renewable energy and the cost of power supply through their examination of power production costs and GHG emissions. The research focused solely on countries in East Africa, offering distinct regional perspectives on the obstacles and prospects linked to the shift towards renewable energy.

A thematic assessment examining the policy and legal ramifications of Africa's shift to clean energy was conducted by Nsafon et al., (2023). The continent experienced numerous problems throughout this transformation, as highlighted by their findings in table 2. The results show that during Africa's shift to sustainable energy, several issues related to energy security, economic development, and affordable access must be taken into consideration. They underlined the significance of affordable energy access, economic growth, and energy security. The report emphasized how critical it is to overcome these issues for Africa to successfully and sustainably adopt clean energy.

In order to achieve a successful and inclusive transition to sustainable energy solutions in Africa, policymakers and stakeholders must address five critical concerns, which include energy security, economic growth, affordability, and regional specificities.

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Table 3: Tabular Summary of empirical review of Ghana

GHANA				
Author(s)/Year	**The focus of the paper**	**Methodology**	**Results**	**Gap**
Amanfo, (2022)	The study examined how Ghana's infrastructure experienced changes in electric power as a result of climate change.	They employ a desktop research methodology	The results suggest a significant transition from the previous dominance of hydroelectricity generation to a combination of hydro, solar, and thermal energy sources.	It failed to address the apparent conceptual and practical conflict between Ghana's renewable energy policy's goal and its implementation strategies.
Acheampong et al., (2021)	The change in Ghana's electricity mix and pricing structure.	Legal policy analysis	The results indicate that because of recent gains in thermal supply, thermal production will continue to be Ghana's primary energy source during the next ten years (2021–2030).	They ignored empirical analysis and that could serve as the best representation.
(Adom et al., 2018)	To investigate the dynamic influence of hydro-based technology on the pricing of electricity in Ghana.	Autoregressive distributed lag model	The findings indicate that hydro delivers better cost advantages over thermal technology and has a dynamic effect on the price of power by lowering end-user prices.	Additional renewable energy technologies have not been taken into account.
Osei-Tutu et al., (2021)	This study set out to ascertain whether there had been a transition in Ghana's electrical energy industry.	Literature review	The use of hydropower has been replaced by a combination of hydro and thermal energy in Ghana's electricity sector, with thermal energy accounting for roughly 69% of the generation mix in 2020.	The study failed to review Ghana’s new renewable energy agenda.

Source: Author’s construct (2024)

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Recent studies from Table 3 have shown Ghana's evolving energy environment, showing a move away from hydropower generation toward a more varied mix of hydro, thermal, and solar sources.

Amanfo (2022) examined how Ghana's infrastructure changed electric power as a result of climate change by employing a desktop research methodology. The outcomes display a significant change from the previous hydro-dominated electricity production to a combination of thermal, solar, and hydro sources. While Amanfo's research highlighted this shift, it did not account for the differences in how Ghana's renewable energy legislation was implemented.

The study by Adom et al., (2018) looked at the dynamic impact of hydro-based technology on the pricing of power in Ghana as summarized in Table 3. The ARDL model was used in the investigation. The findings indicate that hydro delivers better cost advantages over thermal technology and has a dynamic effect on the price of power by lowering end-user prices. Adom et al., failed to consider the integration of various renewable technologies.

Osei-Tutu et al., (2021) using a detailed literature analysis, the researchers set out to establish whether Ghana's electrical energy sector has experienced a transformation. According to the findings, Ghana has moved from solely relying on hydro energy to a combination of hydro and thermal energy, with accounting for roughly 69% of the generation mix in 2020. They acknowledged the shift in energy consumption from only hydropower to a

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combination of hydro and thermal sources; however, they did not include an analysis of Ghana's recent renewable energy regulations.

Finally, when considered collectively, these studies demonstrate Ghana's progress in energy development, but they also reveal the country's shortcomings in terms of renewable technological integration, and policy coherence which are all crucial elements of sustainable energy development.

Conceptual Framework

A crucial aspect of this study involves effectively conveying ideas through visual representation for the easy understanding of readers. According to Adom et al. (2016), the conceptual framework helps as the blueprint for any research, providing clarity and direction to the expressed ideas. Grant and Osanloo (2014) highlighted its significance, asserting that it forms the foundation upon which research is built. In alignment with the study's objectives, the conceptual framework for this research is depicted in Figure 2.

As demonstrated in the conceptual framework, the study recommends that energy transition has a direct impact on electricity tariffs either through electricity production from renewables or fossil fuels. However, fossil fuels (gas, diesel, and other fuels) will continue to increase electricity tariffs and carbon emissions in the short and long run. Moreover, electricity production from renewables (hydro, solar, and other renewables) may increase tariffs in the short run but has the potential to decrease tariffs and emissions in the long run.

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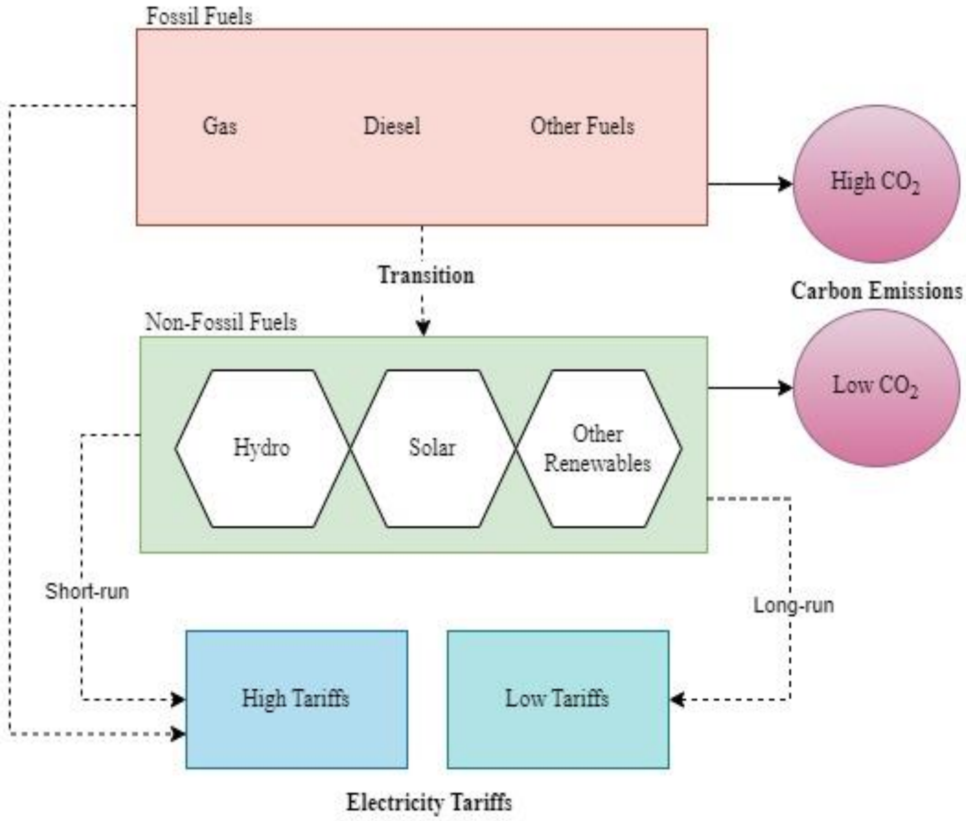

Figure 2: The Conceptual Framework

Source: Author's construct (2024)

Chapter Summary

The chapter evaluated literature from earlier work of renowned researchers and energy sector practitioners to contribute to the creation of a conceptual and theoretical framework suitable for the investigation. This chapter reviewed the grand energy transition theory which served as the study's guiding theoretical framework. Various concepts, including energy transition and electricity tariffs, were examined as part of the conceptual review. The study objectives are consistent with the evaluated empirical literature.

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CHAPTER THREE

RESEARCH METHODS

Introduction

This section considers details of the research methods and methodologies that will be used in the realization of the objectives identified in this case. It describes the research method and the appropriateness of the methodologies selected for this study.

Research design

The study considered the positivist philosophy taken into account the nature of objectives. The research adopted a positivist philosophy, as it posits that reality is stable and can be objectively observed without interference.

This philosophy allows for an impartial examination of social phenomena and the description of relationships between variables (Levin et al., 1988). Additionally, it supports a quantitative research approach, making it suitable for developing mathematical models to explore associations between variables.

According to Kothari (2004), quantitative is a technique that uses statistical data to compile a process and then evaluate it. In this approach, the researcher collects data using standard instruments that provide statistical expertise and testing approaches like experiments and polls (Creswell, 2003). More importantly, the methods produce precise, quantitative results that are simple to apply to large communities (Marshall, 1996). However, the testing of hypotheses that are developed before the data collection can be used to examine and validate theories regarding how and why testicular symptoms exist.

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Importantly, the study similarly employs an explanatory research design within the quantitative approach, aligning with its goal of providing explanations for observed for research outcomes. This methodology proves valuable for gaining an understanding of complex relationships. The energy sector is a complex one and thereby the choice of research design is best fit for contributing to informed decision-making in the realm of energy transition and tariff considerations.

Model Specification

The empirical model specification is derived from the existing literature by: Adom et al., (2018), Gelabert et al. (2011), (Kiprotich et al., 2021), Ausra (2016) and Thoenes (2014) and Mohammadi (2009).

Model Specification for Objective 1

The empirical model for objective one is given as:

$$ET_t = \beta_0 + \beta_1 EPF_t + \beta_2 EPR_t + \beta_3 EX_t + \beta_4 EM_t + \beta_5 \mathrm{EC}_t + \varepsilon_t \ldots\ldots(1) \quad t = 1, 2, 3.$$

Where ET; represents Electricity tariff, EPF represents Electricity production from fossil fuels, EPR represents Electricity production from renewable sources, EM is the annual Electricity imports, EC represents Electricity consumption, EX represents annual electricity exports, and $the\ \varepsilon$ error term. The subscript *t* denotes the period.

Model Specification for Objective 2

This objective considers **t**he cost implications of energy transition on electricity tariffs, the study specifies the empirical model as equation (2) below:

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$$ET_t = \beta_0 + \beta_1 EPR_t + \beta_2 \mathrm{EX}_t \, \beta_3 EM_t + \beta_4 EC_t + \varepsilon_t \dots\dots\dots\dots (2)$$

Where EPR represents the cost of energy transition and the other variables remain as defined earlier. β_0 represents the intercept term. β_1, β_2, β_3, $and\ \beta_4$ are the parameters.

Model Specification for Objective 3

Objective three was achieved by analyzing the effects of carbon emissions on electricity tariffs. The model is specified in equation (3) below:

$$ET_t = \beta_0 + \beta_1 COE_t + \beta_2 \mathrm{EC}_t \, \beta_3 EM_t + \beta_4 EX_t + \varepsilon_t \dots\dots\dots\dots (3)$$

Where COE represents Carbon Emissions, all previously defined variables remain unchanged β_0 represents the intercept term. β_1, and β_2 are the parameters.

Sources and type of data

In terms of statistical analysis, the role of data collection is vital and holds immense significance. Data were collected on several variables including Electricity Tariffs (ET) measured in kWh, Electricity production from fossil fuels (EPF), Electricity production from renewables (EPR), Electricity import (EM), Electricity consumption (EC), Electricity export (EX) all measured in billion kWh, and Carbon Emission (COE) measured in Kilo tons from 1985 to 2021 representing 37 years. The data span was selected purposely grounded on data accessibility on the variables of interest. A yearly time series secondary data was acquired from the World Development Indicators (WDI), Global Economy, Energy Commission (EC), and PURC.

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Variable Description

The analysis provides a list of the variables used. The predicted variable was electricity tariff (ET), while the predicting variables were electricity production from fossil fuel (EPF), electricity production from renewables (EPR), carbon emissions (COE) and the control variables were electricity consumption (EC), electricity import (EM), and electricity export (EX).

Electricity Tariffs

Electricity tariff refers to the pricing structure set by utility companies or regulatory authorities for the consumption of electricity. International Energy Agency (2018), explains that electricity tariffs are affected by numerous factors, such as the cost of generating electricity from different sources, infrastructure investments, fuel prices, government subsidies or taxes, and social or environmental policies. According to Joskow and Tirole (2006), electricity tariffs are designed to ensure cost recovery for electricity suppliers while providing appropriate price signals to consumers.

Electricity Production from Fossil Fuels

The term electricity production from fossil fuels (EPF) describes the process of producing electricity from fossils including coal, oil, and natural gas. Fossil fuels are widely available and have a high energy density, making them a vital source of energy for the production of electricity historically. The EPF process has raised concerns because of its implications on the environment, which include air pollution, GHG emissions, and climate change effects. The amount of electricity produced from fossil fuels is expressed in million kilowatt-hours.

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Electricity Production from Renewables

Electricity production from renewables (EPR) denotes producing electrical energy. Renewable energy sources have a far lower environmental impact and regenerate themselves naturally as compared to fossil fuels, preventing climate change, and promoting the use of renewable energy sources all depend on electricity production from renewables. This variable is used as a proxy for cost of energy transition. It measures the cost and investment involve from integrating more sustainable energy while reducing the use of fossil fuels. Carbon intensity, pricing mechanisms, and electricity demand are some of the elements that influence how renewable energy and electricity tariffs relationship. Higher electricity prices are associated with rising carbon costs, highlighting the need for strategic policies that balance the shift to cleaner energy sources while preserving consumer welfare.

Carbon Emissions

The term "carbon emissions" describes the atmospheric release of carbon compounds, most notably CO2. The main cause of these emissions is human activity, which includes deforestation, industrial processes, burning fossil fuels for energy, and a variety of other activities. Carbon that has been stored in fossil fuels is released into the atmosphere when they burn, taking the form of carbon dioxide. The greenhouse effect is mostly caused by carbon emissions, which raise the atmospheric concentration of greenhouse gases. This enhanced greenhouse effect is a major driver of climate change, as it traps heat and leads to global warming, impacting ecosystems, weather patterns, and sea levels. Reducing

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carbon emissions is a key focus of efforts to mitigate climate change and transition to more sustainable and environmentally friendly energy sources. Increasing prices for electricity correlate with increasing carbon costs, suggesting a possible move toward electricity production from renewables. To balance this transition and ensure lower carbon emissions and fair electricity pricing dynamics, strategic policies are necessary.

Electricity Consumption

The entire amount of energy used by individuals, households, companies, industries, and other entities within a specific time period is known as electricity consumption. It is a crucial measure of the required electricity output and is commonly expressed in megawatt-hours (MWh) or kilowatt-hours (kWh) units. In general, there is a clear association between electricity tariffs and the consumption of electricity. Increased prices are frequently the outcome of higher consumption levels; these increases reflect the cost of supplying and maintaining the infrastructure needed to meet the growing demand for electricity. This link emphasizes how utility companies' pricing structures and consumer patterns of consumption of electricity are economically interdependent.

Electricity Import (EM)

Electricity Import (EM) typically describes the process of purchasing or receiving electrical energy from another country. Countries often engage in electricity import and export to meet their energy demands, stabilize their power grids, or take advantage of cost-effective energy sources available in neighboring regions. It is measured by the annual import of electricity in billion kWh.

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Electricity Export (EX)

The term electricity export (EX) describes the sale or supply of electrical energy generated within a given geographic region to another region, sometimes via transmission lines or networked power grids. This enables the use of excess electricity produced in one location in another area that could have a demand or need for more power. It is measured by the annual export of electricity in billion kWh.

The variables used in this investigation are listed in Table 4 along with the theoretical and empirical literature reviewed.

Table 4: Variables, data source and expected signs

Variable	Description	Source	Expected sign
ET	Electricity tariff	PURC/EC	
EPF	Share of electricity production from fossil fuels	WDI	Positive
EPR	Share of electricity production from renewables including hydro	WDI	Positive/negative
EC	Total Electricity Net consumption	WDI/Global Economy	Positive
EM	It is measured by the annual import of electricity in billion kWh.	Global Economy	Positive
EX	It is measured by the annual export of electricity in billion kWh.	WDI	Positive/ negative
COE	Carbon Emissions	WDI	Positive

Source: Author's Construct, (2023)

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Pre-model Estimation

Some preliminary analysis was conducted to understand the nature of the data set to choose the best estimation technique and procedure to achieve the study objectives. For this study, summary statistics, stationary tests, bounds cointegration tests among variables was taken into consideration.

Estimation Procedure and data analysis for ARDL

To analyze the objectives of this study, it is essential to employ an estimation technique that addresses potential endogeneity issues. Given the use of time series variables, ensuring their stability becomes crucial. To achieve this, the study conducted stationary tests, one of the several types available for checking the degree of integration of variables. The Augmented Dickey-Fuller test (ADF) and Philip Perron (PP) unit root tests were employed to assess the stationarity of variables.

The results of the ADF and PP tests indicated that the series comprised a combination of variables integrated of order zero (I (0)) and (I (1)). Specifically, the unit root tests at the first difference revealed that all variables were integrated of order one (I (1)). With no variables integrated of order two (I(2)) based on these findings, the decision was made to utilize the ARDL model for estimation.

Autoregressive Distributed Lag (ARDL)

The ARDL technique for co-integration was chosen for this study for three primary reasons. Pesaran and Shin (1999) introduced this technique, and Pesaran, Shin, and Smith (2001) later expanded on it. Firstly, unlike other multivariate co-integration approaches such as the Johansen approach, the ARDL method allows the use of OLS to analyze the co-integration relationship once the lag order has

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been established. Secondly, ARDL stands out as it does not need pre-testing variables for unit roots, unlike the Johansen technique, making it appropriate whether the variables are I(0), I(1), or mutually co-integrated. Additionally, the ARDL method performs well with smaller or limited sample sets.

For the primary objective of assessing the impact of energy transition on electricity tariffs (ET), the econometric model used is the ARDL model, formulated as follows:

ARDL Estimation for Objective 1

$$\Delta ET_{i=}\beta_o + \sum_{i=1}^{p} \delta_i \Delta ET_{t-i} + \sum_{i=1}^{q} \theta_i \Delta EPF_{t-i} + \sum_{i=1}^{q} \gamma_i \Delta EPR_{t-i} + \sum_{i=1}^{q} \sigma_i \Delta EX_{t-i} + \sum_{i=1}^{q} \varphi_i \Delta EM_{t-i} + \sum_{i=1}^{q} \psi_i \Delta EC_{t-i} + \beta_1 ET_{t-1} + \beta_2 EPF_{t-1} + \beta_3 EPR_{t-1} + \beta_4 EX_{t-1} + \beta_5 EM_{t-1} + \beta_6 EC_{t-1} + \lambda ECT + \varepsilon_t \quad \ldots\ldots\ldots\ldots(4)$$

ARDL Estimation for Objective 2

The objective two was to examine the cost implications of energy transition on electricity tariffs. The econometric model employed for this purpose is the ARDL model, specified below:

$$\Delta ET_{i=}\beta_o + \sum_{i=1}^{p} \delta_i \Delta ET_{t-i} + \sum_{i=1}^{q} \theta_i \Delta EPR_{t-i} + \sum_{i=1}^{q} \gamma_i \Delta EM_{t-i} + \sum_{i=1}^{q} \sigma_i \Delta EX_{t-i} + \sum_{i=1}^{q} \varphi_i \Delta EC_{t-i} + \beta_1 ET_{t-1} + \beta_2 EPR_{t-1} + \beta_3 EM_{t-1} + \beta_4 EX_{t-1} + \beta_5 EC_{t-1} + \lambda ECT + \varepsilon_t \quad \ldots\ldots\ldots\ldots(5)$$

ARDL Estimation for Objective 3

Objective three aims to analyse the effects of carbon emissions on electricity tariffs. The econometric model used for this purpose is the ARDL model, specified below:

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$$\Delta ET_{i=}\beta_o + \sum_{i=1}^{p} \delta_i \,\Delta ET_{t-i} + \sum_{i=1}^{q} \theta_i \,\Delta COE_{t-i} + \sum_{i=1}^{q} \sigma_i \,\Delta EC_{t-i} + \sum_{i=1}^{q} \varphi_i \,\Delta EM_{t-i} + \sum_{i=1}^{q} \psi_i \,\Delta EX_{t-i} + \beta_1 ET_{t-1} + \beta_2 COE_{t-1} + \beta_3 EC_{t-1} + \beta_4 EM_{t-1} + \beta_5 EX_{t-1} + \lambda ECT + \varepsilon_t \quad \ldots\ldots\ldots\ldots(6)$$

Post-Estimation Test

Several tests were conducted after estimation to evaluate the model's robustness and goodness of fit used in the study. As part of this analysis, a serial correlation test was executed to validate the accuracy of the model-derived estimations. The investigation employed tests recommended.It can assess higher order autoregressive moving average (ARMA) errors and remains meaningful even in cases with lagged dependent variables, a contrast to the DW statistic. The LM test specifically evaluates the null hypothesis that there is no serial correlation within the selected maximum lag time.

To ascertain the normality characteristics of the error term, a normality test was applied to address normality concerns. Additionally, a heteroscedasticity test was carried out to verify the efficiency of the coefficients. To assess the stability of the model coefficients over the study period, a structural stability test was conducted. This test utilized the Cumulative Sum (CUSUM) of recursive residuals and the Cumulative Sum of Squares (CUSUMSQ) of recursive residuals, following the methodology proposed by Pesaran & Pesaran (1997).

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Chapter Summary

This section investigates into the research approach and the methodologies employed to examine the implications of the energy transition on electricity tariffs in Ghana. The study adopts a quantitative method and employs a time-series design to establish robust procedures for analyzing data. To comprehensively address this objective, the (ARDL was used to ascertain the relationship between the expected dependent variable and the various predictive variables. Additionally, the study made use of secondary data from 1985 to 2021.

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CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The chapter discusses the presentation of data, the of the data, and the discussion of the results obtained from the study. The initial part presents summary statistics and stationarity test, whereas the latter section elaborates on the results derived from the ARDL along with their nature, strength of association, and interpretations.

Descriptive Statistics of Variables

Table 5: Descriptive Statistics

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
ET	37	0.07598	0.06307	0.008	0.21
EPF	37	2.72027	3.56233	0.02	13.64
EPR	37	5.943514	1.275466	3	8.33
EM	37	0.2740541	0.321977	0.01	1.05
EC	37	7.430541	3.673193	2.48	18.27
EX	37	0.541081	0.370673	0.19	1.8
COE	37	7.897297	5.526627	1.9	21

Source: Author’s construct (2024)

Table 5 furnishes the examined in this study, enabling an evaluation of data distribution. The mean signifies the variables' average value, and the standard deviation reflects the degree of deviation from the mean. Furthermore, the values depict the study's range.

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Between 1985 and 2021, Ghana experienced an average increase of 0.076 percent in electricity tariff (ET), with a deviation of 0.63 percent. The ET ranged from a minimum of 0.008% to an extreme of 0.210%.

Between 1985 and 2021, electricity production from fossil fuel (EPF) had, with a standard deviation of 3.56%. The highest recorded value for EPF was 13.64 percent, while the lowest was 0.02 percent. These figures highlight the significant contribution of fossil fuel sources to Ghana's electricity generation and the considerable variability in reliance on these sources over time.

The annual growth rate of Electricity Production from Renewables (EPR) in Ghana averaged 5.94 percent, with a deviation of 1.27 percent, indicating a positive course in the country's renewable energy sector. With a growing dependence on renewable sources, there is stabilizing or even reducing electricity tariffs in the long run. The maximum and minimum values for EPF were 3.00 percent and 8.33 percent respectively. These values show the growing of on the overall energy mix, which may have implications for electricity pricing strategies within the study period.

The descriptive statistics revealed that the Electricity Consumption (EC) showed an average value of 7.43 percent. The recorded values ranged from a maximum of 18.27 percent to a minimum of 2.48 percent. This indicates a significant variation in electricity consumption levels. Furthermore, the deviation from the mean value was recorded to be 3.67 percent, emphasizing the extent of deviation from the average consumption.

Again, the average electricity exported was 0.54%. This means that, on average, 0.54% of the total electricity generated was exported. the actual export

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values varied. The maximum recorded value for electricity export was 1.80%, indicating a relatively higher proportion of electricity being exported over the period of the study. Again, the minimum recorded value stood at 0.190%, representing a relatively lower proportion of electricity being exported from 1985 to 2021.

During the period from 1985 to 2021, the analysis of Electricity Import (EM) data revealed that the maximum recorded value for electricity import was 1.05 percent, while the minimum value was 0.010 percent. On average, the percentage of electricity imports was 0.27 percent. There was a variation of 0.322 percent from the mean, indicating the extent of deviation from the average import level. These findings provide important insights into the range and dynamics of electricity import over the analyzed timeframe.

Lastly, the descriptive results of Carbon emissions (COE) revealed an average of 7.89%, with a notable standard deviation of 5.53%. From 1985 to 2021, the minimum recorded value for COE was 1.9%, indicating relatively lower carbon emissions, while the maximum recorded value stood at 21 percent, reflecting a significant increase in carbon emissions from 1985 to 2021. These statistics provide a vital understanding into the average and fluctuation of carbon emissions, highlighting the importance of monitoring and addressing carbon emissions and its associated impacts on end-user tariffs in Ghana.

Stationarity Test

The study evaluated by using and Philip-Perron (PP) unit root tests. This evaluation was crucial to understanding the implications of energy transition on

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electricity tariffs while avoiding spurious regression results. The analysis revealed that most variables were non-stationary at their original levels, except for electricity production from fossil fuels (EPF) and electricity production from renewables (EPR). However, after taking the first differences, the plotted data indicated that all variables became stationary. This stationarity was a crucial factor in selecting appropriate models like the ARDL to examine the connections among the variables of interest in the short and long run.

Table 6: ADF Test for Stationarity at Levels

Variables	t-Stats	Critical value			Decision
		1%	5%	10%	
ET	-1.007	-3.675	-2.969	-2.617	Non-stationary
EPF	3.737	-3.675	-2.969	-2.617	Stationary
EPR	-3.313	-3.675	-2.969	-2.617	Stationary
EC	2.350	-3.675	-2.969	-2.617	Non-Stationary
EX	-1.104	-3.675	-2.969	-2.617	Non-stationary
EM	-2.349	-3.675	-2.969	-2.617	Non-stationary
COE	2.166	-3.675	-2.969	-2.617	Non-Stationary

Source: Author's construct (2024)

Tables 6 and 7 present. In Table 6, it is for all variables were not significant at the 1%, 5%, and 10% significance levels, except for electricity production from fossil fuels and electricity production from renewables. Consequently, the null hypothesis, which posits the presence of a unit root for electricity tariff, electricity consumption, electricity export, electricity imports, and carbon emissions at their original levels, was not rejected. This implies that these variables are not stationary at their levels, indicating they are not integrated of order zero (I(0)).

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Table 7: ADF Test for Stationarity at First Difference

Variables	T Statistics	Critical value			Decision
		1%	5%	10%	
ET	-6.722	-3.682	-2.972	-2.618	Stationary
EPF	-4.164	-3.682	-2.972	-2.618	Stationary
EPR	-6.303	-3.682	-2.972	-2.618	Stationary
EC	-4.152	-3.682	-2.972	-2.618	Stationary
EX	-4.966	-3.682	-2.972	-2.618	Stationary
EM	-7.974	-3.682	-2.972	-2.618	Stationary
COE	-7.339	-3.6 82	-2.972	-2.618	Stationary

Source: Author's construct (2024)

On the contrary, the null hypothesis, which suggests that electricity production from fossil fuels and electricity production from renewables have a unit root and remain at their original levels, was not supported by the evidence. This means that both variables are stable and do not exhibit any significant long-term trends (I(0)). However, from Table 7, it is evident that all variables attained stationarity at 1 p%, 5%, and 10% levels of significance after being subjected to the first difference. ADF statistic reached statistical significance at these levels for all first difference estimates. Therefore, signifying the existence of a unit root (non-stationarity), was rejected for all variables when evaluating their first differences.

To validate and confirm the results obtained from the ADF test, the root test was conducted. The p-values of the PP statistic for all variables, except electricity production from fossil fuels and electricity production from

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renewables, did not reach statistical significance at a 5 percent significance level. This indicates that electricity tariff, electricity consumption, electricity export, electricity imports, and carbon emissions were non-stationary at their original levels. However, the p-values of the PP statistic for electricity production from fossil fuels and renewables were statistically significant at all levels of significance. This suggests that electricity production from fossil fuels and renewables is stable and does not exhibit any significant long-term trends (I(0)).

Table 8: Philips Perron Test for Stationarity at Levels

Variables	T Statistics	Critical value			Decision
		1%	5%	10%	
ET	-0.931	-3.675	-2.969	-2.617	Non-stationary
EPF	7.453	-3.675	-2.969	-2.617	Stationary
EPR	-3.245	-3.675	-2.969	-2.617	Stationary
EC	2.454	-3.675	-2.969	-2.617	Non-Stationary
EX	-1.229	-3.675	-2.969	-2.617	Non-stationary
EM	-2.273	-3.675	-2.969	-2.617	Non-stationary
COE	2.166	-3.675	-2.969	-2.617	Non-Stationary

Source: Author's construct (2024)

However, upon implementing the first difference, all variables exhibited stationarity. The null hypothesis, suggesting the presence of a unit root (indicating non-stationarity), was refuted as the p-values of the PP statistic proved to be statistically significant at the 1 p%, 5%, and 10% levels of significance for all estimates derived through the differencing of variables.

The outcomes from the show that the series comprises a mix of variables integrated at order zero (I(0)) and order one (I(1)). The unit test results suggest that all variables are integrated at order one (I(1)). These findings affirm the absence of variables integrated at order two (I(2)). Consequently, the ARDL

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methodology was employed for estimation. Subsequent sections offer a comprehensive analysis of the cointegration test results, along with outcomes from both the long-run and short-run viewpoints.

Table 9: Philips Perron Test for Stationarity at First Difference

Variables	T Statistics	Critical value			Decision
		1%	5%	10%	
ET	-6.784	-3.682	-2.972	-2.618	Stationary
EPF	7.453	-3.682	-2.972	-2.618	Stationary
EPR	-6.796	-3.682	-2.972	-2.618	Stationary
EC	-4.139	-3.682	-2.972	-2.618	Stationary
EX	-4.848	-3.682	-2.972	-2.618	Stationary
EM	-8.061	-3.682	-2.972	-2.618	Stationary
COE	-7.055	-3.682	-2.972	-2.618	Stationary

Source: Author's construct (2024)

Bounds Test for Cointegration

During the initial stage of the the examination focuses on identifying long-term relationships. As the study utilized was applied in the bounds test, aligning with the guidance outlined by Pesaran and Pesaran (1997) for annual data.

Empirical Estimation and Discussions

Empirical objective 1: The impact of energy transition on electricity tariffs.

To evaluate the impact of energy transition on electricity tariffs in Ghana, the research adopted the for co-integration to estimate relationships in the short and long run. To estimate the effects of energy transition on tariffs, it was imperative to explore the long-run correlation between variables using the bound

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test. The outcomes of this examination are detailed in Table 10. The results indicated that the F-statistic (9.577) surpassed the upper bound critical value set by Pesaran et al., (2001). Therefore, at significance levels ranging from 1 to 10 percent, suggesting no and the possibility of co-integration among the variables were dismissed. With the establishment of among the series, the study can now proceed to estimate relationships in both the short and long terms.

Table 10: ARDL Bound Test Results of Cointegration

Variables	F-Statistics	K	Decision
ET, EPF EPR EX EM EC	9.577295	5	Cointegration exist
Critical value bounds (Significance)	lower bound $I(0)$		Upper Bound $I(1)$
10%	2.08		3
5%	2.39		3.38
1%	3.06		4.15

Source: Author's construct (2024)

Short-run relationship of the impact of energy transition on electricity tariffs.

Table 11 presents the short-run ARDL (1, 4, 4, 4, 4, 0) results on the model. It has electricity tariff (ET) as the dependent variable, EPF and EPR as policy variables, and electricity export (EX), electricity imports (EM), and electricity consumption (EC) as control variables.

In Table 11, it is evident that the term was -0.683 and statistically significant at the. This indicates that about 68 percent of errors from the past year, distracting long-term equilibrium, are rectified annually. In simple terms, Ghana's electricity tariff quickly readjusts to its long-term equilibrium in more than half a

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year after addressing short-term imbalances, quickly recovering from the shocks of the previous year.

The previous lag of electricity tariff has a significant implication on the current electricity tariffs. This that an increase in the previous year's electricity tariffs has a significant effect on the current electricity tariffs. It is also clear from the results that the lags of each variable in the model except the first lag of electricity import and the fourth lag of electricity export were significant at a 5% indicating that all the previous years of electricity production from fossil fuels, electricity production from renewables, electricity consumption, electricity export and electricity import has a significant influence on current tariff performance either positively or negatively except the first lag of electricity import and the fourth lag of export at a significance level of 5 percent.

The findings in Table 11 suggest that in the short run, a percentage increase will lead to a corresponding increase in electricity tariffs by 0.0436 at a statistical significance of 5%. This emphasizes the potential economic consequences associated with continued reliance on fossils for electricity production. The observed positive relationship between fossil fuel-based electricity production and tariff increases highlights the urgency of transitioning to more sustainable and renewable energy sources. Embracing cleaner energy alternatives not only but also presents an economic incentive by potentially stabilizing or reducing electricity tariffs in the long run. The results emphasize the importance of strategic energy transition policies to ensure both environmental sustainability and economic viability in the Ghanaian energy sector.

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This discovery corresponds with the findings of Mohammadi (2009), which highlight the dependence on fossil fuels for electricity production. In the specific context of Ghana's energy scenario, the results imply that an intensified use of fossil in the short term leads to an escalation in electricity tariffs. Due to fluctuations in supply and demand, geopolitical occurrences, and various market dynamics, the prices like natural gas, can undergo significant fluctuations. Changes in fossil fuel prices directly affect the cost of power production, potentially leading to an increase in electricity prices.

Comparing short-run results, it is evident that a 1% increase in electricity production from fossil fuel increases electricity tariff by 0.0436. Similarly, a 1% increase in electricity produced from renewables increases by 0.051. Both findings are significant at 5%. This suggests that certainly changes in electricity production sources do result in changes in electricity tariffs, with renewables showing a slightly stronger effect than fossil fuels within the short. This aligns with existing literature that recognizes the role of renewables in shaping electricity., high tariffs associated with electricity from renewables are influenced by factors such as initial investment costs in building renewable infrastructure, ongoing technological advancements, intermittency challenges and grid integration costs. Although these factors may lead to higher tariffs in the short-run, it is expected that prices associated with renewable energy will decline in the long run as economies of scale become possible, technology progresses, and regulatory frameworks change, making renewable energy more economically competitive.

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However, a comparative assessment between fossil fuels and renewables in the short run reveals that electricity production from renewables tends to be more expensive. This cost disparity may be attributed to the higher technology costs associated with renewables, such as solar PVs, as identified by previous studies (Reichelstein & Yorston, 2013). Even though thermal plants have cost advantage over renewable generation in the short run, it is important to consider the high carbon emissions associated with fossil fuels. However, continuous dependence on fossil fuels will mean the country is compromising the principle of common concern, intergenerational equity (future generations) and the theory of grand transition.

Consequently, the findings suggest that, in the short run, Ghana may face a cost advantage in electricity production from fossil fuels compared to renewables. This insight emphasizes the need for a gradual transition in the short term, allowing for a balanced and economically viable integration of renewable sources into the energy mix (Osei-Tutu et al., 2021).

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Table 11: Short run ARDL Results for Objective 1 (1, 4, 4, 4, 4, 0) model based on AIC. Dependent variable: ET

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.021304	0.020454	1.041586	0.3221
ET(-1)	0.306528	0.116012	2.642204	0.0246
EPF	0.043623	0.010465	4.168506	0.0019
EPF(-1)	-0.036531	0.006389	-5.717513	0.0002
EPF(-2)	0.068315	0.013282	5.143296	0.0004
EPF(-3)	-0.054154	0.013795	-3.925478	0.0028
EPF(-4)	0.054037	0.012205	4.427445	0.0013
EPR	0.050693	0.008029	6.31394	0.0001
EPR(-1)	-0.021314	0.003301	-6.456403	0.0001
EPR(-2)	0.031456	0.004166	7.550173	0.0000
EPR(-3)	-0.03236	0.00695	-4.655995	0.0009
EPR(-4)	0.018484	0.004502	4.106051	0.0021
EX	-0.132533	0.015137	-8.755687	0.0000
EX(-1)	0.064855	0.016273	3.98544	0.0026
EX(-2)	-0.077016	0.017508	-4.398998	0.0013
EX(-3)	0.055594	0.021284	2.612067	0.0259
EX(-4)	-0.035491	0.016749	-2.118956	0.0601
EM	0.069783	0.011793	5.917111	0.0001
EM(-1)	-0.008435	0.01171	-0.720284	0.4878
EM(-2)	-0.045688	0.016143	-2.83019	0.0178
EM(-3)	-0.036689	0.014319	-2.562309	0.0283
EM(-4)	0.039987	0.013123	3.047237	0.0123
EC	-0.045875	0.009694	-4.732074	0.0008
ECT(-1)	-0.693472	0.066957	-10.35692	0.0000
R-squared	0.995415	Mean dependent var		0.084157
Adjusted R-squared	0.985328	S.D. dependent var		0.061945
S.E. of regression	0.007503	Akaike info criterion		-6.74697
Sum squared resid	0.000563	Schwarz criterion		-5.70395
Log likelihood	134.325	Hannan-Quinn criter.		-6.39603
F-statistic	98.68509	Durbin-Watson stat		2.486071
Prob(F-statistic)	0.000000			

Source: Author's construct (2024)

However, in Table 11, electricity export was significant in affecting electricity tariffs at 5% significance level, implying a percentage rise in electricity export decreases electricity tariff by 0.132. Electricity import has a positive impact and significantly affects tariffs implying that a kilowatt increase in electricity import will increase electricity tariffs by 0.0697. Finally, electricity

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consumption also affects tariffs but negatively at a, this suggests a kilowatt increase in electricity consumption reduces tariffs by 0.0458 in the short run.

Long run relationship of the impact of energy transition on electricity tariffs.

To address the research objective of establishing a between energy transition and electricity tariffs, this part gives the results of the long-term estimation. The long-term model were estimated taking into account the co-integration between the variables in this model. Table 12 provides a thorough breakdown of the results. Based on the model was estimated.

Table 12 displays coefficients with their signs. Specifically, the results reveal a negative impact of electricity export and electricity consumption on electricity tariffs, while electricity production from electricity production from renewables, and electricity imports exhibit a positive correlation with electricity tariffs.

From Table 12, of electricity production from fossil fuels is significant at a 5% level of significance. This means that a 1% increase in the country's fossil fuel electricity production will result in a long-term increase in electricity tariffs by 0.108%. This positive effect of EPF on electricity tariffs tends to support the argument raised by Thoenes (2014) that electricity prices adjust to changes in the price of fossil fuels over the long run. However, the results conflict with the argument by Ferkingstad et al., (2011) who concluded that oil and hard coal have less effect on electricity prices. Additionally, it is more expensive to produce electricity from fossil fuels in the long run than in the short run. This may be attributed to the switch to renewable sources, the finite nature of fossil fuels, less discovery in the future, and carbon pricing for burning fossil fuels in the long run.

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Hence high electricity production from fossil fuels is associated with high electricity tariffs in Ghana which has the potential to decrease economic activities in the long run.

Moreover, the electricity production from renewables coefficient displayed a positive sign and achieved significance at the 5% confidence level. This suggests that a percentage increase in electricity produced from renewable sources would result in a long-term rise of approximately 0.067 percent in electricity tariff in Ghana as demonstrated in Table 12. Again, when examining the long-term outcomes, generating electricity from renewable proves to be cheaper than from fossil fuels throughout the study period. This implies that should Ghana invest more into renewable sources today; the effects will reduce electricity tariffs as compared to fossil fuels in the long run. According to Jacobson et al. (2017), advances in technology like improved efficiency and lower manufacturing costs are mostly responsible for the drop in prices for electricity from renewable sources. These developments have made it possible to produce renewable infrastructure at economies of scale, which has helped to lower costs. Encouraging investments in renewable projects and establishing a favorable regulatory environment have been made possible by supportive government policies and incentives (IEA, 2021). Improved financing mechanisms combined with increased competition as the renewable energy sector develops and matures combine to significantly and sustainably lower electricity tariffs from renewable sources, making them more competitive and economically appealing (Lazard, 2021). These with the argument put forth by Adom et al., (2018), affirming that renewables present clear cost advantages over thermal technology.

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Furthermore, at 5% significance level, Table 12 shows that power exports had a substantial effect on electricity tariffs. This implies that over time, electricity tariffs will drop by 0.179 percent for every percentage rise in electricity exports. However, imports of electricity had a favorable impact and a considerable influence on tariffs; as a result, an increase in imports of power will eventually increase electricity tariffs by about 0.0273 percent. This might occur from the price of electricity reflecting the cost of imports.

At a significance level of 5%, electricity consumption has a long-term negative effect on tariffs. This implies that for every percentage rise in electricity consumption over time, tariffs will decrease by about 0.066 percent. This is the case because we believe that to encourage competition and drive down power prices, the generation side should eventually be unbundled.

Table 12: Estimated Long-Run Coefficients using the ARDL Model for Objective 1 **(1, 4, 4, 4, 4, 0) selected based on AIC. Dependent Variable: ET**

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
EPF	0.108572	0.011718	9.265504	0.0000
EPR	0.067715	0.011951	5.665878	0.0002
EX	-0.179662	0.048986	-3.667657	0.0043
EM	0.027339	0.020813	1.313583	0.2183
EC	-0.066153	0.011941	-5.539848	0.0002
Constant	0.030721	0.029571	1.038887	0.3233

Source: Author’s construct (2024)

Figure 3 shows the trend relationship between energy transition and electricity tariffs in Ghana. The initial years saw a significant impact of electricity

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production from fossil fuels(EPF) on tariffs, thus, increase EPF is associated with increase electricity tariffs (ET). However, the introduction of more electricity production from renewables (EPR) from 2012 saw a decrease in tariffs over the period. Moreover, there was sharp increase in tariffs from 2015 and that is attributed to power crises in 2014 but tariffs eventually went down as more renewables were introduced afterwards. The implication is that electricity production from thermal plants may reduce tariffs within the short run however, it is advisable for the country to consider renewable technology in the long run since it reduces tariffs as compared to thermal plants.

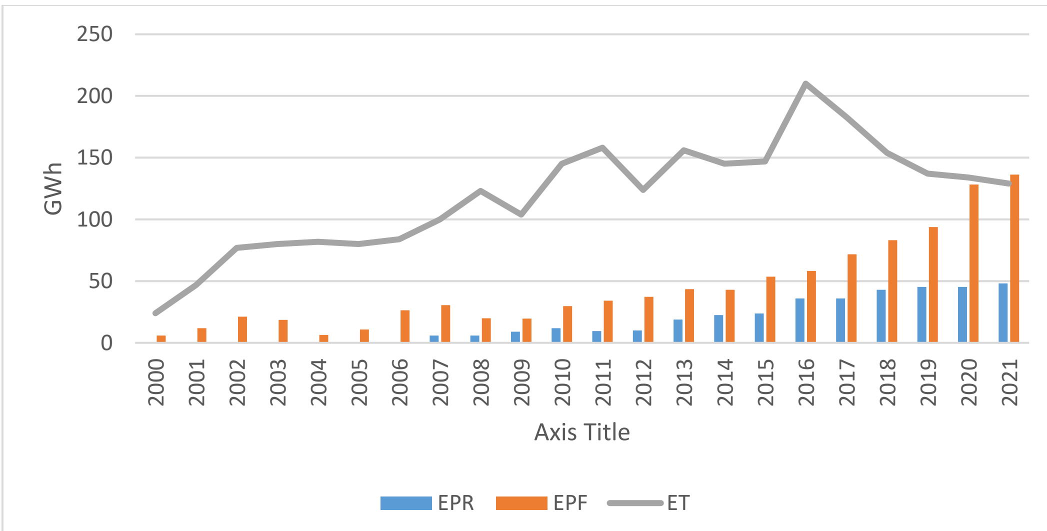

Figure 3: Trend showing the impact of energy transition on electricity tariffs in Ghana

Source: Author's construct (2024)

Post-Estimation and Stability Test

Numerous tests were carried out to evaluate the significance of the variables and address potential concerns related to serial correlation, normality, and heteroscedasticity to validate the model accuracy. As din Table 13, the results reveal the successful completion of these tests. Notably, the modified R-square

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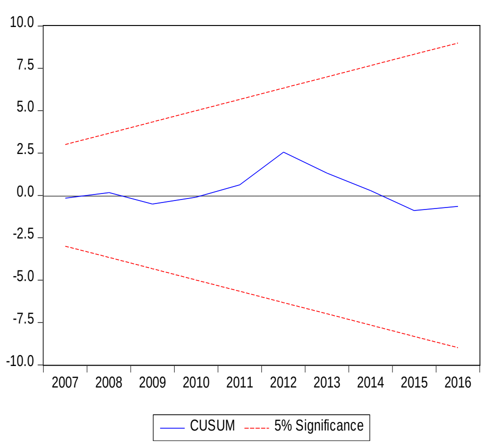
underscores the model's robustness, signifying that the independent variables explain nearly 98 percent of the variability within the model. Additionally, the findings from (F (2,8) = 0.707; p = 0.521) indicate an absence of serial correlation in the model. Collectively, these results affirm the model's appropriateness and reliability in explaining the inherent relationships among the considered variables.

Table 13: Post-Estimation and Stability Test

Type of tests	LM version	F version
Serial correlation	CHSQ(2) = 4.958 [0.083]	F (2,8)= 0.707 [0.521]
Heteroscedasticity	CHSQ(22) = 17.846 [0.715]	F (22,10)= 0.535 [0.893]
Normality	Jarque-Bera = 0.585 [0.746]	Not applicable

Source: Author's construct (2024)

Moreover, the heteroscedasticity test supported the null hypothesis, which stated that there were no heteroscedasticity problems. This hypothesis was strongly supported by, which yielded probability values of 0.715 and 0.893. A normality test was used to investigate the normal distribution of the long-run model. The results showed a p-value of 0.746 above the standard significance level of 0.05. This conclusion categorically dispels any doubts about the long-run model normality.



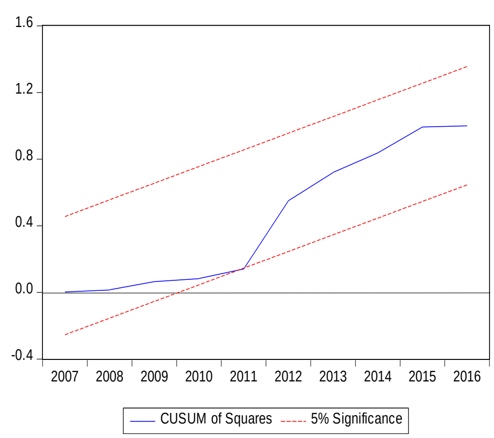


Figure 4: CUSUM and CUSUMSQ for Model Stability

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Furthermore, the stability test graphs, as shown in Figure 3, in particular the CUSUMSQ and CUSUM showed that all estimated model coefficients were stable during the period of the study. Interestingly, over the course of the study, these coefficients continuously fell within the crucial 5 percent range, confirming the estimated model stability and dependability.

Empirical objective 2: the cost implications of energy transition on electricity tariffs.

The objective was to evaluate the cost implications of energy transition on electricity tariffs between 1985 and 2021 by using annual data. This section contains the estimation results that show the short-term cost implications of energy transition on electricity tariffs in Ghana.

Incorporating renewable energy (RE) into Ghana's generation mix is needed to shift to a sustainable future. The current energy landscape is essentially dominated by thermal plants of 67 percent against RE of 33 percent, signaling the dire need for a paradigm shift. This transition primarily involves the This in turn is expected to promote environmental sustainability, leading to a subsequent reduction in carbon emissions and bolstering long-term energy security. Ghana therefore seeks to create a more robust and environmentally sound energy terrain by strategically increasing the share of renewables in its energy generation mix. This move will essentially set Ghana on course for the global pursuit of a sustainable future.

In Table 14, the co-integration result indicates the between the variables. Rejecting as the F statistic (6.2971) exceeds the upper threshold of the 5 percent significance level. With the series confirming co-integration, our study is well-

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equipped to estimate both short- and long-term relationships, establishing a robust foundation for the analysis.

Table 14: ARDL Bound Test Results of Cointegration

Variables	F-Statistics	K	Decision
ET, EPR EX EM EC	6.297128	4	Cointegration exist
Critical value bounds (Significance)	lower bound $I(0)$		Upper Bound $I(1)$
10%	2.2		3.09
5%	2.56		3.49
1%	3.29		4.37

Source: Author's construct (2024)

Short run relationship of the cost implications of energy transition on electricity tariffs

The subsequent phase involves shaping the short-term dynamic association between the after establishing the long-term cointegrating model. In this scenario, the ARDL model incorporates lagged values for each level variable, demonstrated as a linear combination with the error correction term. Table 16 presents the results obtained from the ARDL model, examining the cost implications of energy transition within the ARDL framework.

The ARDL results obtained in Table 15 at the 5% significance level show a significant positive short-term impact of the previous year's electricity tariff on the current electricity tariff. This implies that Ghana's power tariff is affected by the previous year's tariff performance.

The coefficient of, -0.383, means that about 38% of the deviations in long-term tariff growth from the shocks of the previous year revert to long-run equilibrium in the current year. In accordance with established principles, a higher

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absolute value of the error correction coefficient indicates a more rapid adjustment of the variables back to their long-term.

The coefficient linked to electricity generation from renewables (EPR) has a positive outcome on electricity tariffs in the at a significance level of 5%. The that an increase in energy transition costs of 1%, increased electricity tariffs by 0.00807%. This emphasizes how important the cost of energy transition is in determining the short-term dynamics of Ghana's power sector. The is the cause of the high short-term cost (IEA, 2021). Costs are further increased by adding renewable energy sources to the grid, upgrading energy systems, and putting in place the required energy storage technologies (IRENA, 2019). These factors together with the requirement for specialized skill development and workforce training add to the immediate financial difficulties linked to Ghana's power sector's energy transition.

The study exposed a and positive association between electricity import and electricity tariffs. In particular, there was a short-term increase in electricity tariffs of about 0.0294 percent for every 1 percent increase in electricity imports. This suggests that during the study period, imports of power have significantly impacted Ghana's electricity tariffs. Price increases may be influenced by the imported cost of electricity, which would explain the positive relationship. Moreover, at a 5 percent significance level, consumption of electricity has a positive short-term influence on electricity tariffs in Ghana. This suggests that in the short term, tariffs will rise by about 0.0121 percent for every percentage increase in electricity consumption.

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Finally, results from Table 15 indicate that all lags of each variable in the short-run model, except for electricity export, the first and second lag of electricity consumption were significant at. This suggests that the previous years' values of electricity production from renewables, electricity consumption, and electricity imports significantly impact the current tariff performance, either positively or negatively in the short run

Table 15: Short run ARDL Results (1, 4, 0, 4, 3) model based on AIC. Dependent variable: ET

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.04481	0.022727	-1.971674	0.0662
ET(-1)	0.616586	0.112839	5.464286	0.0001
EPR	0.008076	0.001735	4.656052	0.0003
EPR(-1)	-0.000253	0.001589	-0.159407	0.8753
EPR(-2)	-0.004509	0.00154	-2.928363	0.0098
EPR(-3)	-0.003268	0.001374	-2.378236	0.0302
EPR(-4)	-0.005129	0.001445	-3.548504	0.0027
EM	0.029412	0.009053	3.248786	0.005
EX	0.024999	0.016909	1.478421	0.1587
EX(-1)	0.023614	0.016562	1.425769	0.1732
EX(-2)	0.032462	0.020588	1.576777	0.1344
EX(-3)	0.001338	0.02157	0.062008	0.9513
EX(-4)	-0.077383	0.03107	-2.490592	0.0241
EC	0.012063	0.004517	2.670923	0.0167
EC(-1)	-0.003083	0.00525	-0.587263	0.5652
EC(-2)	0.008615	0.00506	1.702428	0.108
EC(-3)	-0.010198	0.004205	-2.425204	0.0275
ECT(-1)	-0.383414	0.054447	-7.042008	0.0000
R-squared	0.984016	Mean dependent var		0.084157
Adjusted R-squared	0.968031	S.D. dependent var		0.061945
S.E. of regression	0.011076	Akaike info criterion		-5.861769
Sum squared resid	0.001963	Schwarz criterion		-5.090841
Log likelihood	113.7192	Hannan-Quinn criter.		-5.602375
F-statistic	61.56142	Durbin-Watson stat		1.589615
Prob(F-statistic)	0.000000			

Source: Author’s construct (2024)

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Long-run relationship of the cost implications of energy transition and electricity tariffs

In this section, we examine the long-run cost implications of energy transition on electricity tariffs in Ghana. We estimated the long-run factors using the ARDL model, considering variable co-integration. The results, outlined in Table 16, were obtained through.

In contrast to the short-term findings as shown in Table 16, the analysis indicated that the cost of the energy transition negatively affects electricity tariffs in the cost of transitioning from fossil fuels to renewable energy sources, there will be a long-term decrease in electricity tariffs of about 0.0133 percent in the long-run. These findings affirm the research conducted by Cevik & Ninomiya (2023), signifying that Europe. Their study revealed an average impact of 0.6 percent for every 1 percentage point increase in the share of renewable energy.

The observed decline in electricity tariffs associated with an increased share of renewable energy holds significant implications for the cost dynamics of energy transition. Aligned with the findings of Cevik & Ninomiya (2023), this reduction can enhance the economic viability of renewable energy sources, potentially. This may attract investments and accelerate the transition toward sustainable energy solutions (Cevik & Ninomiya, 2023). However, it is crucial to acknowledge the short-term costs related to initial investments in renewable infrastructure and grid upgrades (IEA, 2021; IRENA, 2019). Striking a balance between these short-term challenges and the long-term benefits of a sustainable energy transition is essential for policymakers and industry stakeholders to

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formulate effective strategies and ensure a successful and economically viable shift toward renewable energy sources.

Also, the results are significant for CO_2 emissions for the country since integrating more renewable sources will reduce emissions and the associated environmental costs. The results are imperative for intergenerational equity and common concern as Ghana plays its role in securing a sustainable energy future for its generation without compromising the environment.

Additionally, the findings outlined in Table 16 show the impact of electricity imports on tariffs is substantial and positive. It infers that a percentage rise in electricity imports will lead to a corresponding rise in tariffs, approximately by 0.0767 percent in the long run. These results could be credited to the complex interplay between imported electricity costs and their direct reflection on the final pricing structure, emphasizing the nuanced relationship between international energy trade and domestic tariff rates.

Finally, electricity consumption also exerts a positive influence on tariffs in the level. This signifies that a percentage increase in electricity consumption will raise tariffs by about 0.0192 percent in the long term.

Table 16: Estimated Long-Run Coefficients Results for Objective 2 using the ARDL Model (1, 4, 0, 4, 3) selected based on AIC. Dependent Variable: ET

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EPR	-0.013258	0.005703	-2.32459	0.0336
EM	0.07671	0.028567	2.685307	0.0163
EX	0.013116	0.070392	0.186332	0.8545
EC	0.019291	0.01412	1.366269	0.1908
Constant	-0.11687	0.070864	-1.649229	0.1186

Source: Author’s construct (2024)

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Figure 5 confirms the results of objective 2 showing the cost of transitioning from fossil fuels to renewables. that the cost of energy transition (EPR) increases initially with tariffs (ET) indicating initial investment involved in renewable technology. However, the cost of energy transition started reducing from 2012 when renewable penetration became significant in the country's generation mix. This was due to intensification of renewable energy policy and the government target to achieve 10 percent penetration. Furthermore, it is evident from figure 4 that as energy transition increases specifically from 2017, the cost declined. This decrease has the potential to improve renewable energy economic sustainability and increase their market competitiveness. This could draw funding and hasten the switch to sustainable energy sources. However, this is expected to happen in the long run (Cevik & Ninomiya, 2023).

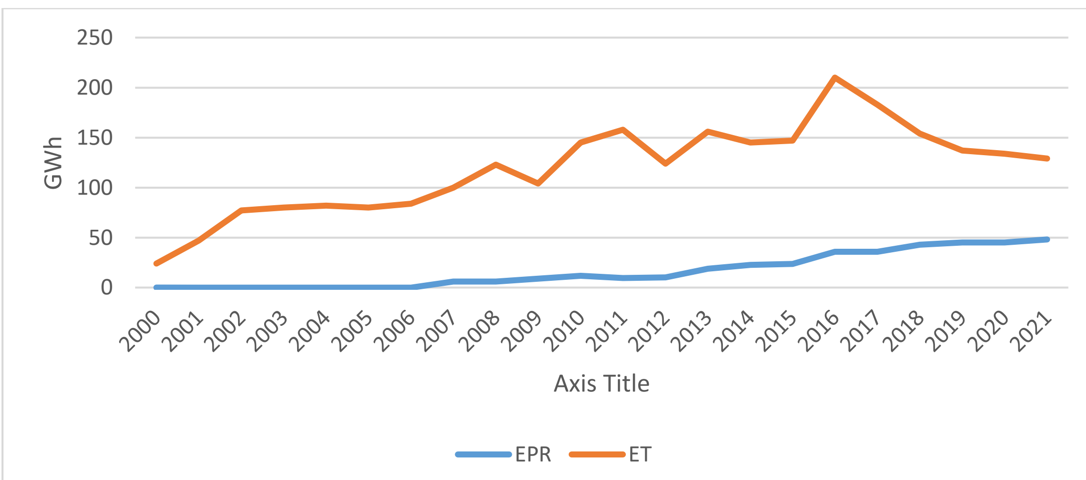

Figure 5: Trend showing the cost of energy transition and electricity tariffs

Source: Author's construct (2024)

Post-Estimation and Stability Test

Post-estimation tests were completed by the model, as shown in Table 17. The adjusted R-square showed that the independent variables were responsible for

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98 percent of the model's variability. There was no serial correlation in the model, according to F (2,14) = 0.546; p = 0.591).

Furthermore, the heteroscedasticity test confirmed the of the null hypothesis by signifying the lack of heteroscedasticity problems using the probability values of the Breusch-Pagan-Godfrey test (0.906 and 0.576). Moreover, the long-run model's normal distribution was validated by the normality test (p (0.499) >0.05), eliminating any doubts about it.

Table 17: Post-Estimation and Stability Test for Objective 2

Type of tests	LM version	F version
Serial correlation	CHSQ(2) = 2.390 [0.3027]	F (2,14)= 0.5466 [0.591]
Heteroscedasticity	CHSQ(16) = 15.694 [0.474]	F (16,16)= 0.906 [0.576]
Normality	Jarque-Bera = 1.388 [0.499]	Not applicable

Source: Author's construct (2023)

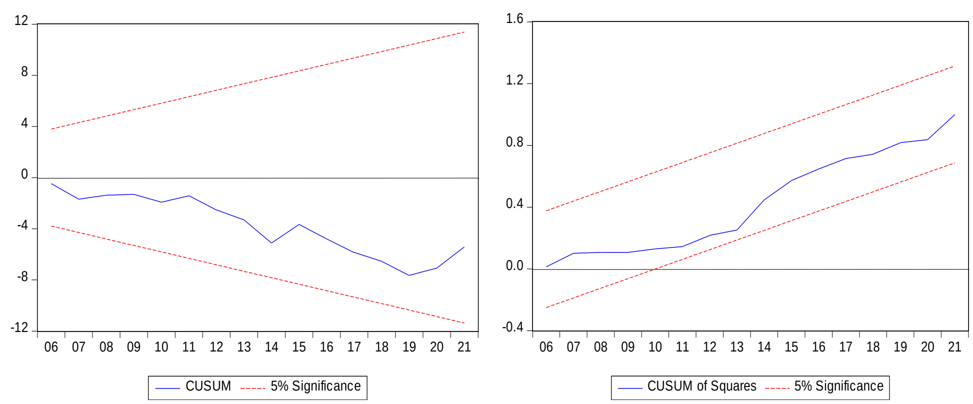

Figure 6: CUSUM and CUSUMSQ for the model stability

The the stability tests clearly show that the coefficients were steadily consistent throughout the study, as seen in the CUSUM and CUSUMSQ graphs shown in Figure 4. The coefficients were found to be reliable and stable

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throughout study, as they consistently fell within the set critical boundaries of 5 percent limits.

Empirical objective 3: the effects of carbon emissions on electricity tariffs.

Using yearly data, the third objective sought to evaluate how carbon emissions affect electricity tariffs. The are shown in this section, along with both of carbon emissions on electricity tariffs in Ghana. Even though, it was found in Objective 1 that electricity generation from thermal plants has a cost advantage over renewable generation in the short run. However, it comes with high carbon emissions which violates the principle of intergenerational equity and common concern for mankind and puts our future generations at risk.

The co-integration which show the association between the variables are displayed in Table 18. Because the F statistic (4.918634) is the upper bound of the, rejecting the null hypothesis that there is no co-integration was necessary. Given the established co-integration of the series, our study is ready to estimate the short-and long-run relationships, providing a solid foundation for the analysis.

Table 18: ARDL Bound Test Results of Cointegration for Objective 3

Variables	F-Statistics	K	Decision
ET, COE EC EM EX	4.918634	4	Cointegration exist
Critical value bounds (Significance)	lower bound $I(0)$	Upper Bound $I(1)$	
10%	2.2	3.09	
5%	2.56	3.49	
1%	3.29	4.37	

Source: Author's construct (2023)

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Short-run relationship showing the effects of carbon emissions on electricity tariffs

Following the establishment of the long-term cointegrating model, the subsequent phase involves showing the short-term dynamic interconnection between the variables within. In this instance, the ARDL model incorporates lag values for each level variable, portrayed as a linear combination with the error correction term. Table 19 showcases the outcomes of the ARDL model examination of the impacts of carbon emissions within the ARDL framework. The choice of the particular model was guided by the AIC criterion.

The results presented in Table 19 which were produced using the ARDL model indicate a significant positive impact at the 5 percent significance level of the previous year's electricity tariffs on the current in the short run. This suggests that the outcome of the previous year's tariff has a impact on Ghana's electricity tariffs.

Again, the results show that all lags of each variable in the short-run model are insignificant in determining electricity tariffs except the fourth lag of electricity imports and electricity exports at. This suggests that the previous years' values of electricity export and electricity import significantly impact the current tariff performance positively in the short run.

Table 19 illustrates the observed effects, which shows that a proportionate increase in carbon emissions in the short run causes an equivalent increase in electricity tariffs by 0.025 percent at a 5% level of significance. The results confirmed the works of Kanamura (2007) and Mostafa (2014). Their findings

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concluded that rising carbon costs translate into higher electricity prices through electricity production, pointing to the possibility that firms will choose more renewable energy sources in place of fossil fuels while producing their goods. The carbon intensity increases firms' production costs according to their carbon intensity, which helps reduce CO2 emissions. However, because firms can pass on the cost to consumers, especially for less elastic products, the system's impact is constrained (Mostafa, 2014).

Increased energy consumption brought on by economic growth is one of the reasons contributing to the rise in carbon emissions, along with the continued reliance on for industrial processes and the production of electricity (Smith et al., 2020). Increased greenhouse gas emissions have negative consequences for the environment, the climate, and human health (Jones & Williams, 2019). Significantly, the intricate dynamics of electricity tariffs are also influenced by these emissions. Electricity tariffs are under pressure to rise, representing the true environmental cost of power generation, as carbon-intensive energy sources are subject to increased environmental levies and regulatory costs (IEA, 2021). This relationship between the price of electricity and carbon emissions highlights how vital it is to switch to more sustainable and clean energy sources.

Finally, as shown in Table 19, the control variables therefore, electricity consumption, electricity export, and electricity imports were insignificant in the short-run at a 5 percent significance level.

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Table 19: Estimated Short-Run Results for Objective 3 using the ARDL Model (4, 4, 4, 4,) selected based on AIC. Dependent Variable: ET

Variable	Coefficient	Std.Error	t- Statistic	Prob.*
ET(-1)	0.791785	0.186254	4.251103	0.0028
ET(-2)	-0.540853	0.275539	-1.962891	0.0853
ET(-3)	0.639808	0.244541	2.616359	0.0308
ET(-4)	-1.264267	0.389537	-3.24556	0.0118
COE	0.025015	0.006551	3.818626	0.0051
COE(-1)	-0.010561	0.007525	-1.403411	0.1981
COE(-2)	0.003362	0.005952	0.564829	0.5877
COE(-3)	-0.00877	0.005548	-1.580717	0.1526
COE(-4)	0.012014	0.007869	1.526769	0.1653
EC	-0.013193	0.008948	-1.474422	0.1786
EC(-1)	0.007885	0.011004	0.716511	0.4941
EC(-1)	-0.006367	0.01233	-0.516406	0.6195
EC(-3)	-0.007137	0.00985	-0.724584	0.4894
EC(-4)	0.008197	0.005103	1.606363	0.1469
EM	-0.012615	0.014349	-0.87913	0.405
EM(-1)	-0.005072	0.015999	-0.317009	0.7594
EM(-2)	-0.04366	0.020114	-2.17059	0.0618
EM(-3)	0.009625	0.020388	0.472115	0.6495
EM(-4)	0.035398	0.015026	2.355839	0.0463
EX	-0.026718	0.018537	-1.441312	0.1875
EX(-1)	-0.014133	0.0255	-0.554226	0.5946
EX(-2)	0.053195	0.031117	1.709519	0.1257
EX(-3)	0.015101	0.028087	0.537629	0.6055
EX(-4)	0.061721	0.021798	2.831533	0.0221
C	-0.01593	0.025123	-0.634093	0.5437

R-squared	0.993645	Mean dependent var	0.084157
Adjusted R-squared	0.974581	S.D. dependent var	0.061945
S.E. of regression	0.009876	Akaike info criterion	-6.299306
Sum squared resid	0.00078	Schwarz criterion	-5.165588
Log likelihood	128.9385	Hannan-Quinn criter.	-5.917844
F-statistic	52.1199	Durbin-Watson stat	2.825481
Prob(F-statistic)	0.000002		

Source: Author’s construct (2024)

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Long-run relationship of the effects of carbon emissions on electricity tariffs

This section presents the findings from long-run estimation in the pursuit of the research objective to establish a long-lasting association between carbon emissions and electricity tariffs in Ghana. The long-run model coefficients were carefully estimated to take into consideration the co-integration of variables. Table 20 presents a detailed analysis of these findings, shedding light on the complexities of the lasting relationship. The Akaike Information Criterion (AIC) served as a guide for estimating the long-run ARDL model, providing a thorough and reliable analytical method to shed light on the complex dynamics of Ghana's carbon emissions and electricity tariffs in the context of the energy transition.

Table 20 shows that the coefficient associated with carbon emissions achieves statistical significance at the. This suggests that a 1 percent rise in the country's carbon emissions is directly associated with a long-term increase in electricity tariffs of about 0.0153 percent. This result emphasizes how significantly carbon emissions affect the long-term dynamics of electricity tariffs in Ghana. The results confirmed the argument by Kanamura (2007) that increasing carbon costs leads to higher electricity prices, indicating the likelihood of firms reducing their reliance on in production and opting for more renewables but contradicts the findings by Cotton and Mello (2014) who concluded that carbon intensity has minimal impact on electricity tariffs.

A comparison examination of the results shows that electricity tariffs have decreased significantly relative to. This trend implies that carbon emissions exhibit higher intensity in the short term but diminish in the long run. The short-

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term spikes in emissions underline Ghana's significant dependence on for power generation (Osei-Tutu et al., 2021). The apparent decrease in carbon emissions, however, is explained by the long-, as seen by the falling electricity prices linked to power generation practices. This change is in line with international efforts to move away from energy sources and toward cleaner, more sustainable energy alternatives.

A combination of factors is responsible for the long-run decrease in electricity tariffs., advancements in the energy sector have produced more economical and efficient ways to generate power (Smith, 2020). Economies of scale are also important; as energy infrastructure grows, average costs for producing power decrease (Jones et al., 2020). Long-term energy infrastructure investments, such as building new power plants and improving the grid, increase operational efficiency and therefore lower costs (Brown & Johnson, 2019). To reduce carbon emissions, government policies and regulations have also been crucial in encouraging the use of sustainable practices and cleaner energy sources. Furthermore, the heightened competition in the market stimulates efficiency and innovation, which helps to further the general decline in electricity prices (IEA, 2021). Because Ghana relies more on thermal energy sources, carbon emissions may be higher in the short term, but over time, integrating more renewables work together to reduce emissions intensity.

Furthermore, the results shown in Table 20 demonstrate a substantial effect of electricity exports on electricity tariffs at 5 percent level of significance. This implies that for every 1 percent rise in electricity exports, there is a predicted

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gradual increase in electricity tariffs of about 0.0176 percent. On the other hand, the analysis shows that electricity imports were insignificant in determining electricity tariffs in the long run of significance.

Table 20: Estimated Long-Run Coefficients Objective Results for 3 using the ARDL Model (4, 4, 4, 4) selected based on AIC. Dependent Variable: ET

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COE	0.015333	0.003577	4.286327	0.0027
EC	-0.00773	0.005516	-1.40104	0.1988
EM	-0.01188	0.015067	-0.78872	0.453
EX	0.064917	0.017634	3.681455	0.0062
C	-0.0116	0.019077	-0.60798	0.5601

Source: Author’s construct (2024)

The results as shown in Figure 5 indicate the trend relationship between CO_2 emissions and electricity tariffs (ET). It can be seen that carbon emissions(COE) increase with electricity tariffs (ET) initially. This was due to heavy reliance on thermal plants increasing carbon emissions however, from 2015, as more renewables were introduced into the country’s generation, declined reflected in electricity tariffs. Ghana's carbon emissions may be higher in the short run but over time, will help to lower emissions intensity. The relationship between electricity tariffs and carbon emissions emphasizes how important it is to move to cleaner, more sustainable energy sources.

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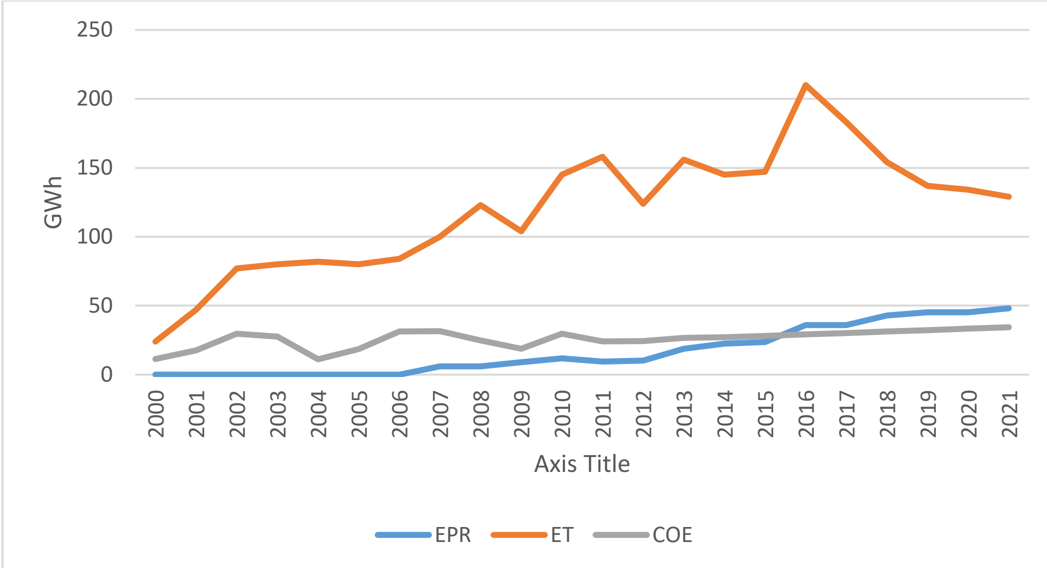

Figure 7: Trend showing carbon emissions and electricity tariffs

Source: Author's construct (2024).

Post-Estimation and Stability Test

To verify the validity of the model, various diagnostic tests were executed to assess the significance of the variables and address potential issues related to serial correlation, normality, and heteroscedasticity. The outcomes of these tests, presented in Table 20, confirm their successful completion. Remarkably, the adjusted R-square indicates that the independent variables elucidate nearly 99 percent of the variability within the model, underlining its robustness. Furthermore, the results from the LM Test ($F(2,6) = 0.346$; $p = 0.671$) affirm the absence of serial correlation.

All of these results confirm that the model is appropriate and trustworthy for explaining the basic relationships between the variables that are being studied.

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Table 21: Post-Estimation and Stability Test for Objective 3

Type of tests	LM version	F version
Serial correlation	CHSQ(2) = 21.138 [0.064]	F (2,6)= 0.346 [0.672]
Heteroscedasticity	CHSQ(24) = 20.7986 [0.651]	F (24,8)= 0.535 [0.865]
Normality	Jarque-Bera = 0.176 [0.915]	Not applicable

Source: Author's construct (2023)

The asserting the absence of heteroscedasticity problems received additional support through the heteroscedasticity test. The results of the Breusch-Pagan-Godfrey test, yielding probability values of 0.064 and 0.865, strongly reinforced this hypothesis. A normality test was employed to assess the normal distribution of the long-run model, yielding a p-value of 0.915, exceeding the standard significance threshold of 0.05. This outcome decisively dismisses any concerns regarding the normality of the long-run model.

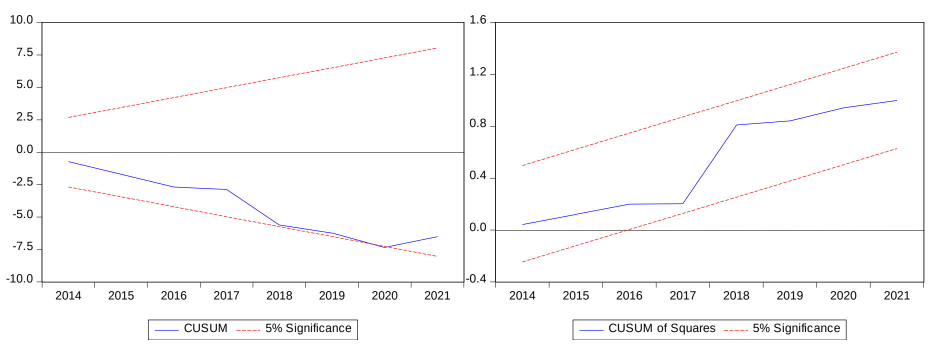

Figure 8: CUSUM and CUSUMSQ for Model Stability

Furthermore, the stability test graphs the CUSUMSQ and CUSUM shown in Figure 4 further suggest that all estimated model coefficients remained stable throughout the investigation. Throughout the course of the investigation, these coefficients notably remained within the crucial 5 percent range, offering solid proof of the estimated model's stability and reliability.

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Chapter Summary

This chapter explored into the analysis and interpretation of results. The objective was to identify trends and establish between independent variables and the dependent variable.

This section delves into the analysis and interpretation of findings. The aim was to understand patterns and establish connections between independent. To achieve this, descriptive statistics and regression analysis were employed. Additionally, the research utilized the ARDL model to investigate the long and short-term implications of energy transition on electricity tariffs in Ghana.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This section encompasses a summary, conclusions and recommendations. The summary offers a brief overview of the research problem, objectives, methodology, and findings. The conclusions clarify the overall results of the study, particularly addressing the findings concerning the research questions. The recommendations put forward specific actions that relevant organizations should consider. Furthermore, the chapter suggests potential paths for future research.

Summary

The study looked at the implications of energy transition on electricity tariffs in yearly time data covering the years 1985 to 2021 using ARDL model. The research involved regressing electricity tariffs on electricity production from fossil fuels, electricity production from renewables, carbon emissions, electricity consumption, electricity exports, and imports. The main objective of this study was to look at these variables within the short- and long-run relationships in the Ghanaian setting. The study used the ARDL method of cointegration to investigate these dynamics and provided a thorough examination of the relationships between the variables across the given time frame.

Using the tests, the stationarity of the variables was tested as the first stage in the estimate procedure. The findings showed that after the first difference in each variable, they all became stationary.

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The study looked at the relationships between energy transition and electricity tariffs. The F-statistic and LM test, which show the feasibility of the estimated model, were validated by the evaluation of diagnostic which remained below the 5 percent critical boundary threshold throughout the research.

The cointegration analysis disclosed a significant long-term association among electricity tariffs, production of electricity from fossil fuels, from renewables, , electricity consumption, electricity exports, and imports. A transient correlation between the variables was discovered by the error correction model. The long-term outcomes were reflected in the short-term results, which were consistent over the two periods. It is interesting to note that most variables, whether positive or negative, had stronger and more significant long-term effects on electricity tariffs than short-term.

According to the results estimated from the ARDL in the, electricity production from fossil fuels and electricity production from renewables showed a positive and considerable effect on electricity tariffs. The cost of energy transition had positive significant effects on tariffs in the short run but adverse effects in the long run. Carbon emissions were seen to impact tariffs positively in the long and short run. However, carbon emissions reduced drastically in the long run reflecting a decline in electricity tariffs. It was found that exports of electricity had a negative effect on tariffs. However, there was a clear and positive correlation between electricity tariffs, electricity imports and consumption. Additionally, the short-term results confirmed the long-term findings; yet,

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during the investigation, the long-term coefficients of expected variables exceeded the short-term effects.

Finally, the diagnostic test results indicate that the model satisfies critical tests at standard significance levels such as the heteroscedasticity, serial correlation, and normality tests. Additionally, the stability of the variables was confirmed by the graphs of CUSUM and CUSUMSQ. These findings suggest that the model operates robustly and consistently, providing assurance regarding the precision of its forecasts and results.

Conclusions

The key was to examine how transitioning from fossil fuels to renewables as a source of electricity affects electricity tariffs in Ghana. Research on various energy transitions and electricity prices has attracted a lot of attention.

The investigation of the relationship between energy transition indicators and electricity costs has drawn considerable attention from development practitioners, energy experts, researchers, and policymakers, especially in light of the unpredictable finite nature of and their associated consequences on climate change. Henceforth, the research delved into examining the impact of energy transition on electricity tariffs. It concentrated on three pivotal issues: the association between energy transition, the cost of energy transition on electricity tariffs, and the on electricity tariffs in Ghana. Drawing from the study's findings, the subsequent conclusions were drawn:

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The study has verified the existence of both associations among important variables, including electricity production from, electricity production from renewables, electricity consumption, electricity export, and imports. These results are consistent with the empirical literature. In Ghana, the analysis of these variables on electricity tariffs were useful within the study period. The results suggest that an increase in electricity production from renewables collectively contribute to high electricity tariffs in the. Comparatively, the study concluded that it is more expensive to produce electricity from fossils than to produce from renewables, and therefore energy transition is necessary for Ghana's electricity industry but at their own pace.

Again, the cost of energy transition was to exhibit a positive relationship in the however, the relationship became negative with electricity tariffs in the long term. This implies that the cost of energy transition may increase tariffs in the short run but has the potential to reduce the same tariffs in the long run due to the integration of more renewables through technological advancement and economies of scale in the Ghanaian electricity sector.

Finally, carbon emissions were found to increase electricity tariffs. However, it was evident that long-run electricity tariffs have decreased significantly relative to short-term tariffs. This pattern suggests that short-run carbon emissions are more intense than long-run emissions because, the integration of more renewables in Ghana's electricity generation mix in the long

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run, has the potential to reduce which will reflect in tariffs through generation cost.

Recommendations

Objective 1 Recommendation

The study recommends to government through the ministry of energy to promote and prioritize, create a welcoming regulatory framework, and maintain policies that stimulate the shift from fossils to renewables. In the long run, this offers significant economic advantages (reduces electricity tariffs) over fossil fuel-based electricity production, thus helping the economy and the environment. It also fits with the global trend.

The study advised that Ghana create and carry out a comprehensive energy transition plan in addition to giving investments in sources top priority. This plan of action ought to provide a detailed road map for gradually decreasing dependence on fossil fuels while increasing the proportion of renewable energy in the energy mix as a whole. Workforce development, smart grid integration, public awareness campaigns, and infrastructure development should all be taken into account in the plan.

Objective 2 Recommendation

Given the potential long-term decrease in electricity tariffs associated with the cost dynamics of energy transition, promoting collaboration between the private and public sectors is crucial for policymakers. Government should promote public-private partnerships so that the risks and costs of renewable projects can be shared. Leveraging the strengths of both sectors, this partnership

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can accelerate the development and deployment of sustainable energy solutions. The experience, creativity, and capital from the private sector can be brought in through public-private partnerships, increasing the likelihood of the country economically meeting its renewable energy goals. The country can also encourage smart grid system for renewables to avoid the cost of integrating them into national grid.

Objective 3 Recommendation

Given the statistically significant association between carbon emissions and increase in electricity tariffs, Ghana ought to think about putting strong environmental regulations into place and enforcing them in order to lower the carbon intensity of the sector. Establish regulations to promote the use of greener energy sources and to reward the reduction of carbon emissions. This could require establishing carbon pricing schemes, establishing emission reduction targets, and offering financial incentives to companies that finance renewable energy initiatives. Ghana could and eco-friendly energy landscape by harmonizing its regulations with global standards and optimal procedures. This would ultimately mitigate the influence of carbon emissions on electricity prices.

Recognizing the decrease in long-term electricity tariffs associated with the integration of renewable energy sources from the results, Ghana should actively promote and incentivize investments in renewable energy infrastructure. Prioritize long-term energy infrastructure investments, such as building new renewable power plants and enhancing the grid to improve operational efficiency. Fostering a investments will not only contribute to the reduction of carbon

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emissions but also support the long-term decline in electricity tariffs, aligning with global trends towards cleaner and more sustainable energy solutions.

Areas for Future Research

Some potential directions for future research include:

Assessment of Policy Effectiveness: Assess the efficiency of existing regulations and policies concerning Ghana's energy transition and electricity pricing. Examine the impact of various policy interventions in promoting the adoption of renewable energy sources, diminishing greenhouse gas emissions, and ensuring a dependable and affordably priced power supply. These interventions may encompass incentives, subsidies, and regulatory frameworks.

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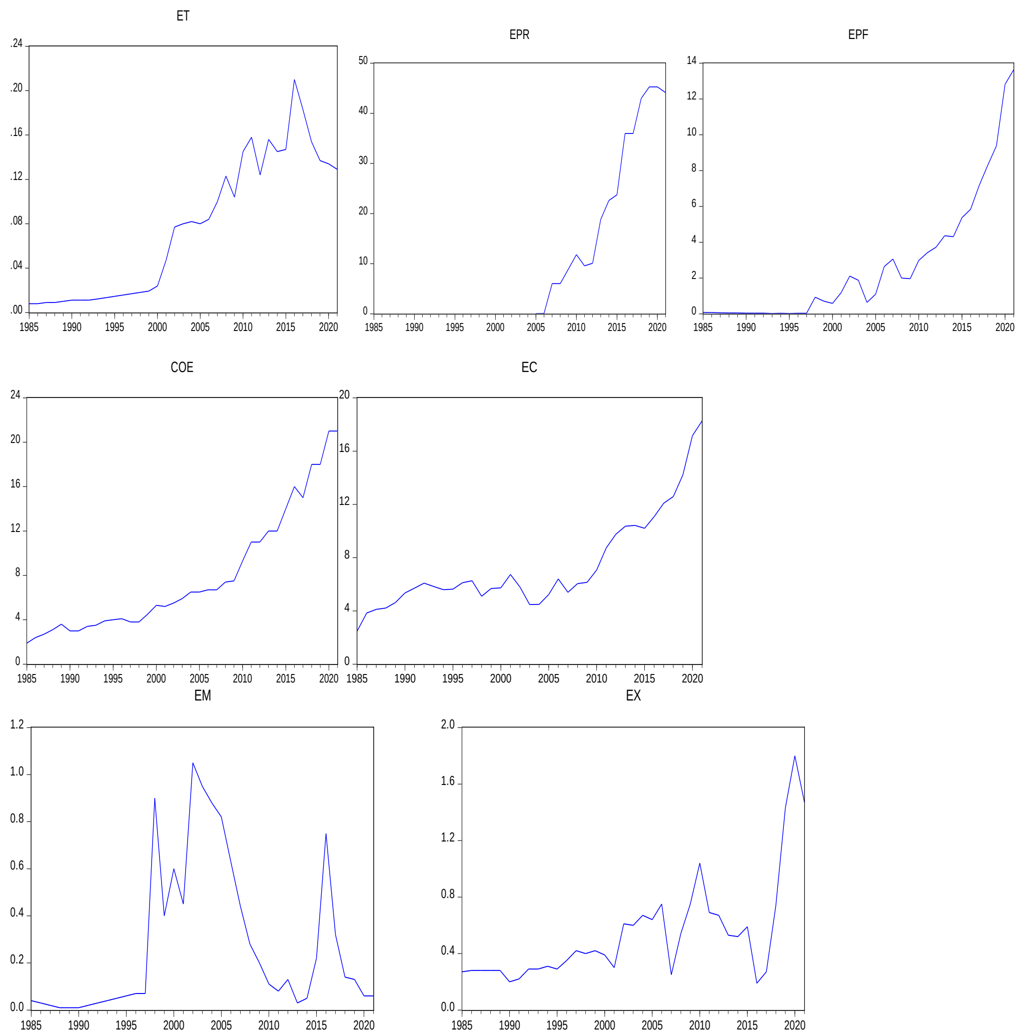
APPENDIX

APPENDIX A
GRAPH OF VARIABLES AT LEVEL



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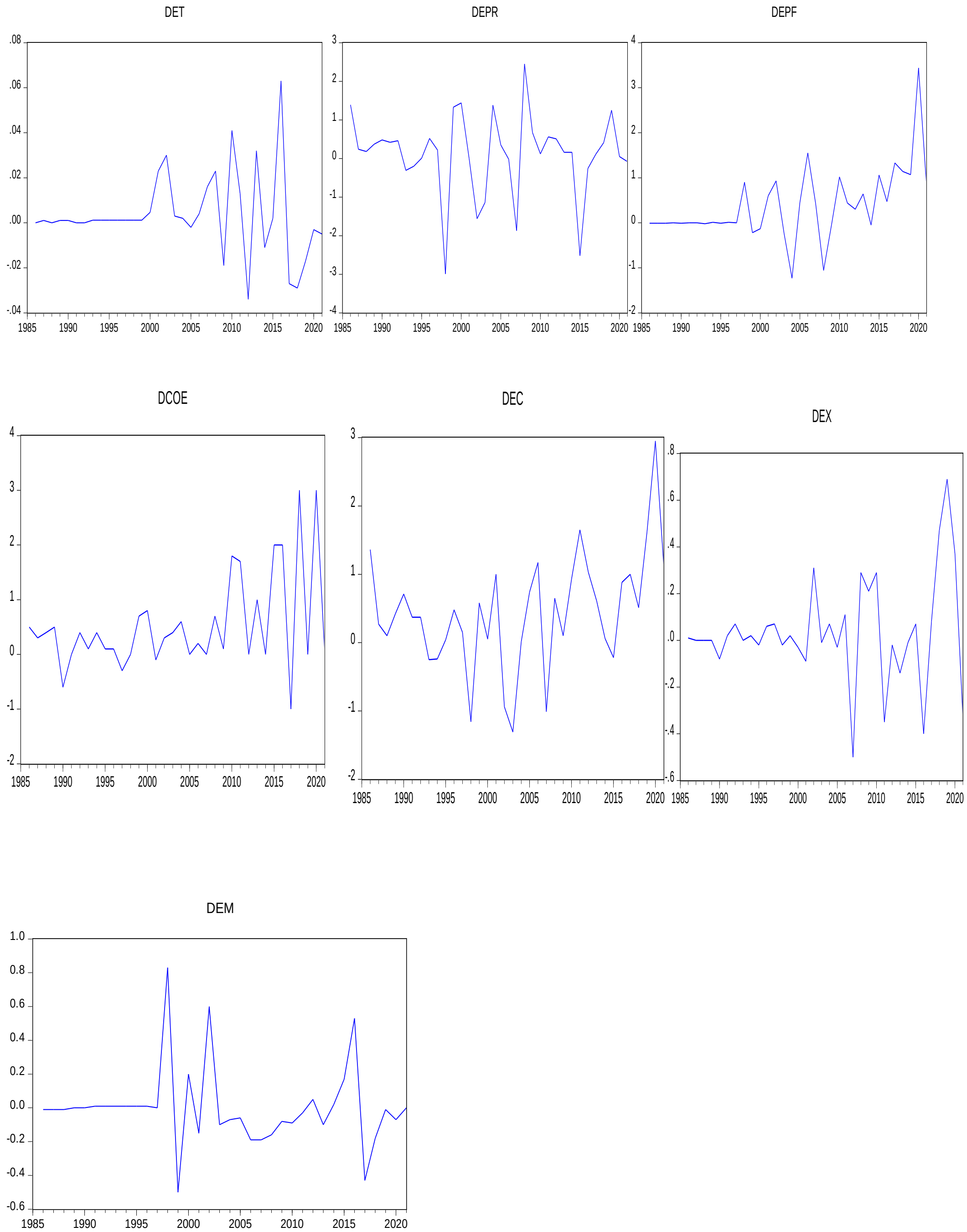
APPENDIX B
GRAPH OF VARIABLES AT FIRST DIFFERENCE



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