UNIVERSITY OF CAPE COAST

VULNERABILITY OF THE ECONOMY OF GHANA TO THE RENEWABLE ENERGY TRANSITION DYNAMICS

BY

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DECLARATION

Candidates Declaration

I, Clement Oteng, hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

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ABSTRACT

Renewable energy transition is a major mitigation strategy for climate change. Yet, its implications on emerging petroleum economies such as Ghana are sparse. This study analyses the vulnerability of the economy of Ghana to the renewable energy transition dynamics. The study uses data from the WB, BoG, US EIA and Census Bureau, Federal Reserve Economic Data, PURC, and PIAC. The study employs the dynamic ARDL simulation and state-space models. From the simulated scenarios, the study concludes that energy transition at five percent and business as usual increase access to electricity up to the sixth year after which access to electricity decreases. Also, renewable energy transition scenarios increase energy availability after the second year until after the eighth year, when it increases energy availability at a decreasing rate. Again, the study concludes that the IEA's investment scenarios have negative consequences on Ghana's oil exports between 2020 and 2040. Further, the study concludes that business-as-usual energy transition scenario increases employment by more than five percent transition scenario in the industrial sector, five percent scenario hampers employment in the agriculture sector, while both scenarios of renewable energy transition increase employment in the services sector up to the next six years. However, each scenario reduces vulnerable employment. Based on the findings of the study, the study recommends that Ghana should continue with the energy mix strategies and systematically integrate renewables into the overall energy mix. Again, petroleum authorities should look out for more countries that would import crude oil from Ghana. Also, Ghana must craft a crucial policy framework that supports energy transition and must address the upstream barriers and challenges of renewables by making it easy for the private sector to invest in renewables. Ghana must organise retraining and education programmes for Ghanaians to take up the opportunities in the renewable energy sector to mitigate employment vulnerabilities. Moreover, Ghana should operate its refinery to be able to absorb much of the crude oil produced in the country rather than relying on foreign consumption.

KEY WORDS

Dynamic simulation model

Emerging petroleum economies

Renewable energy transition

State-space model

Vulnerability of the economy of Ghana

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DEDICATION

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LIST OF ACRONYMS

ABFA	Annual Budget Funding Amount
APC	Announced Pledges Case
ARDL	Autoregressive Distributed Lag
BP	British Petroleum
CGE	Computable General Equilibrium
CO_2	Carbon Dioxide
FDI	Foreign Direct Investment
FPSO	Floating Production Storage and Offloading
GCC	Gulf Corporation Council
GDP	Gross Domestic Product
GHGs	Greenhouse gases
GNPC	Ghana National Petroleum Corporation
GoG	Government of Ghana
GSS	Ghana Statistical Service
IEA	International Energy Agency
IID	independently and identically distributed
ILO	International Labour Organisation
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
MELR	Ministry of Employment and Labour Relation
MoE	Ministry of Energy
MoF	Ministry of Finance

MMbbl	One million barrels of oil
MMscf	Million standard cubic feet
MRT	Multilateral Resistance Term
NAICS	North American Industrial Classification System
NARDL	Non-Autoregressive Distributed Lag
NDPC	National Development Planning Commission
NEECs	Net Energy Exporting Countries
NEICs	Net Energy Importing Countries
NR	Natural Resources
NZE	Net Zero Emission
OPEC	Organisation of the Petroleum Exporting Countries
PIAC	Public Interest and Accountability Committee
PRMA	Petroleum Revenue Management Act
REP	Renewable Energy Production
SDGs	Sustainable Development Goals
SSA	Sun-Sharan Africa
STEP	Stated Policies Scenarios
TEN	Tweneboa Enyenra Ntomme
TVP	Time-varying Parameter
UN	United Nations
WB	World Bank
WTI	West Texas Intermediate

CHAPTER ONE

INTRODUCTION

Background to the Study

There is an ongoing race towards world climate goals, alongside the promotion and development of electric cars and the encouragement for sources of renewable energy (Kriskkumar & Naseem, 2019). This is because global warming most likely results from greenhouse gases (GHGs) emissions from fossil fuels. These carbonic substances get into the atmosphere largely through the generation, transformation, and adoption and use of fossil fuels. Unfortunately, largely used energy sources in the world are fossil fuels and the global demand for oil and gas is increasing significantly annually. According to British Petroleum (BP) (2022), fossil fuels account for more than 82 percent of the total consumption of primary energy globally as indicated in Figure 1.

From Figure 1, sources of fossil fuels including crude oil is a fundamental fuel that captures about 37.6 per cent of the overall world energy consumption whilst the share of gas in the global consumption of energy rises to over one-fifth (BP, 2022; Heard, Brook, Wigley, & Bradshaw, 2017). Coal accounts for not less than 32 percent of the world's consumption of energy. For the two decades before 2015, there was a high CO2 concentration in the atmosphere from 360ppm to more than 400ppm. Carbon dioxide emission from fossil fuels in 1995 rose from almost 6.4Gt C year^{-} to 9.8Gt C year^{-} in 2013 (Boden & Andres, 2016). The global temperature continues to rise with the record warmest year in 2016 (Heard, et al., 2017) and the hottest month of all time is July of 2021.

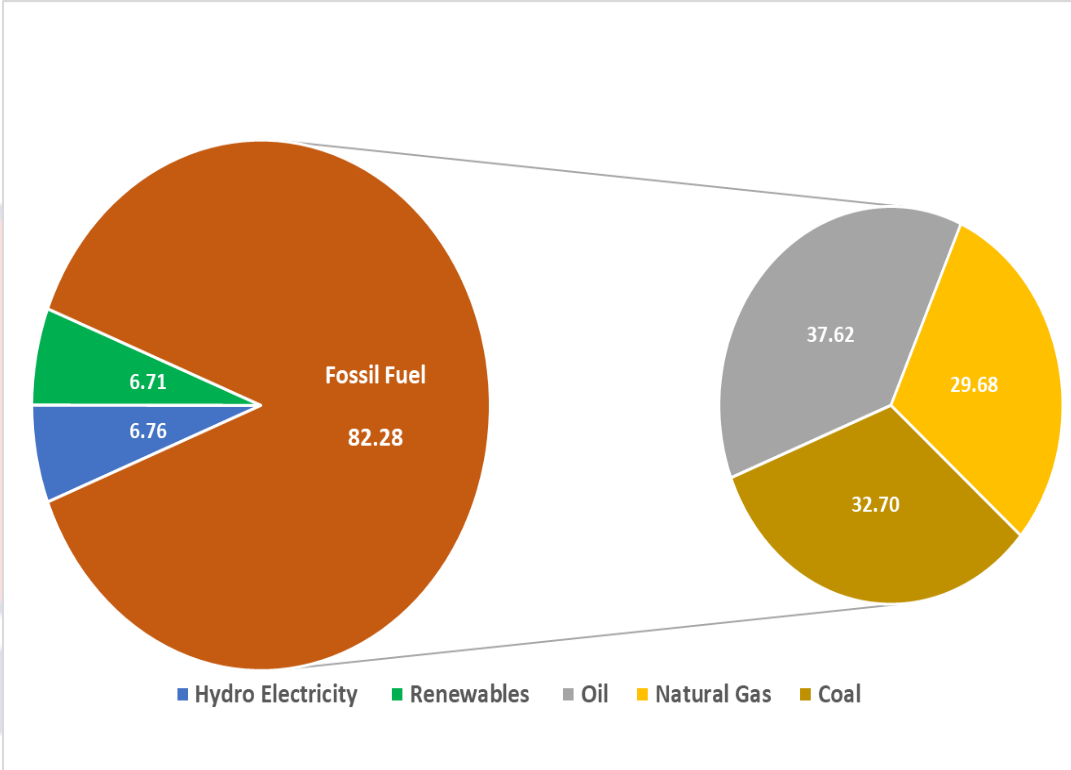

Figure 1: Percentage Share of Primary Energy

It is, therefore, not surprising to assume that the fight against climate change must largely begin with the advocacy to end or reduce drastically, the production and use of fossil fuels. Due to the attended consequence of greenhouse effects, the present century is witnessing a gradual shift in the energy mix (United Nations [UN], 2018). Environmental issues in recent years have boosted renewed attention in driving the need towards social, environmentally friendly, and economic manner. The damaging effects of fossil fuels on the environment, however, create strong grounds for a decreasing share in fossil fuel consumption in the mid-term and achieving net zero by 2050 (UN, 2022). Also, the COVID-19 pandemic and the current wars such as Russia-Ukraine have created the need to adopt zero or reduce dependence on petroleum and less carbon dioxide-emitting energy sources often known as clean energy sources.

With the high stake of modern society and the global environment, such an approach to reducing carbon emissions and achieving Sustainable Development Goals (SDGs, specifically, goal 7) is by making access to modern, sustainable, reliable, and affordable energy by 2030 (UN, 2018). Yet, 771m people continue to lack electricity access in the world as of 2019 (International Energy Agency [IEA], 2019): woefully, 74 per cent representing 578m comes from the SSA with some countries having a high lack of electricity access shown in Figure 2. Also, 80 per cent of the SSA population does not have clean technologies and fuels for cooking (EIA, 2019). Although SSA has made strides in expanding energy access since 2013, the COVID-19 pandemic is probably to reduce the pace, this is in light of energy investment dropping by 18 per cent because of the pandemic. According to the IEA predictions, energy demand would be 60 per cent by 2030 more than current demands.

Figure 3 shows the trend in electricity access for the period 1990 to 2020 in Ghana. In Ghana's case, there has been a looming signal for intensifying energy sector investment in light of 4.6m people not having electricity access in 2020 (Ghana Energy Commission, 2020). Furthermore, 75 per cent of households in Ghana do not have access to perpetual clean fuels and technologies to cook. Besides, only an average rate of 0.3 per cent of Ghanaians afford to use electricity as a primary source for cooking. Consequently, this signals further investment in the energy sector, although investment in this sector is very much capital intensive.

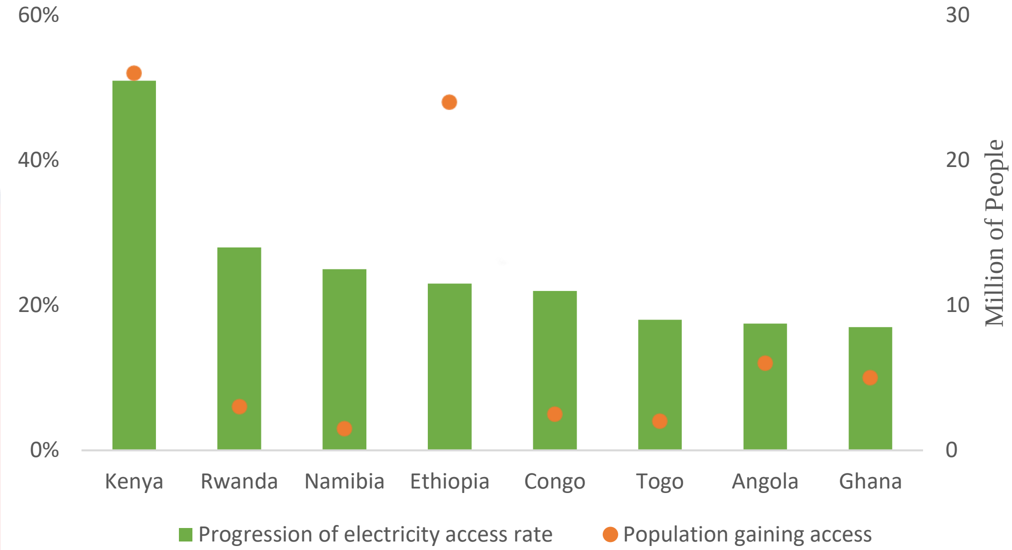

Figure 2: Access to Electricity Progress in Leading SSA Countries

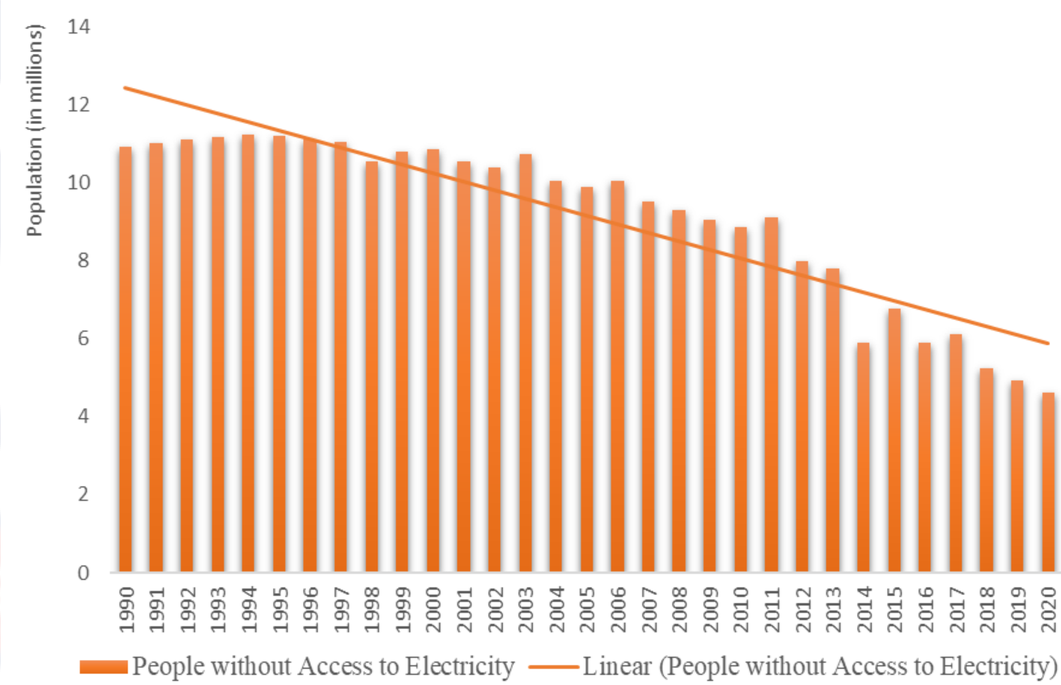

Figure 3: Ghana's Energy Accessibility for Three Decades

According to the World Bank estimates, investments of about US$20b are required annually to achieve universal electrification across SSA. Of this figure, almost

US$10b is needed every year to bring and supply power and keep the power on in Central and West Africa.

Again, the ILO estimates that in 2017 global unemployment was over 190 million people, representing an unemployment rate of 5.6% compared to the unemployment level of 169.8 million forming an unemployment rate of 5.5% in 2007 (ILO, 2018; 2016). In Africa, an estimated 37.8 million people were unemployed. This represents an unemployment rate of 7.9% in 2017 and it is projected to heighten by 2.3 million while the associated rate of unemployment stays constant at 7.9% per year from 2017 to 2019 (ILO, 2018). The report further indicates that the size of unemployment in SSA was 29.1 million in 2017, and it worsened to 30.2 million in 2018 and 31.3 million in 2019 with corresponding unemployment rates of 7.2% and 7.3% respectively. Youth (15-24 years) constitute about 60% of the jobless population in Africa with the youth unemployment rate more than double the national and adult rates (Ighobor, 2017).

These realities present a challenge that may militate against the accomplishment of the agenda 2030 of which climate change is crucial. These demands include credible, evidenced-based plans for an energy system that almost or wholly avoids fossil carbon source exploitation and production. Another approach is to meet scalable rising demands for energy of almost nine to 10 billion people by 2050, and maybe more than 12billion by the end of this century (Bradshaw & Brook, 2014; Heard, et al., 2017). These processes logically start with displacing coal, gas and oil in the generation of electricity, but ultimately expanding to end virtually all fossil hydrocarbon that are utilised in residential and industrial heat, transportation and other energy services. Thus, clean energy sources are potent in providing energy with little or no carbon footprint on the environment (Hafner & Tagliapietra, 2020). Consequentially, renewable energy usage is admonished as the most efficient primary energy source in the face of climate change. Additionally, it is established that renewable energy sources are abundant and more sustainable than other sources.

These advantages of renewable energy over fossil fuels in terms of hydrocarbon emissions have made energy transition proponents to push for a global consensus to, as much as possible, transit to renewable energy (Othieno & Awange, 2016; Simelane & Abdel-Rahman, 2011). Consumption averages of renewables have gone up globally due to these efforts (Amoah et al., 2020). The International Energy Agency (IEA) (2018) simulates that by 2023, renewables share to meet increasing demand for energy would increase by one-fifth to reach 12.4 per cent globally. Other studies such as Demirbas (2009) estimate that renewables contribution will reach 34.7 per cent by 2030 and 47.7 per cent by 2040. This implies that by the end of 2030, almost 35 per cent of the global energy supply mix will come from renewable sources, which is a great relieve for renewable energy proponents.

In spite of all these, contemporarily, there have been many studies and scholars that have highlighted various dynamics in the energy transition discourse. The issue they mostly discus is energy transition’s role in achieving the global target of reducing worldwide mean temperature to 2.0°C from the current levels of 14.51°C and with further decline to 1.5°C above pre-industrial levels (Paris

Agreement, 2015). Other discussions focus on the possibility of energy transition to curb energy insecurity within and between countries and regions (Hafner & Tagliapietra, 2020; Othieno & Awange, 2016; Simelane & Abdel-Rahman, 2011). Energy security has become a major concern worldwide. Given the perception that economic progress is closely tied to affordable energy sources, it is challenging to envision governments suggesting measures that would demand citizens to significantly reduce their consumption and, consequently, make significant changes to their way of life. Other scholars who recognise the importance of renewable energy in reducing global warming, are also of the view that full energy transition (i.e. transition from the over-reliance on the use of fossil fuels to 100% renewables) is a threat to energy equality and energy security since renewables like solar and wind are intermittent making them unpredictable and unreliable.

Regardless of the side of the debate, worldwide energy transition either in part or in whole will have some consequences on emerging petroleum-producing economies such as Ghana. This is because fossil fuels and renewables are mostly considered as substitutes, which should rather be considered as complements. The effect on these economies might differ relative to the country's dependence on oil production and revenue (Iledare, 2015). By extension, all things being equal, the impact is expected to be higher in emerging oil-dependent countries. Evident to this is the different impacts the oil demand shock emanating from COVID-19 has had on various oil-producing countries (Narayan, 2020). According to the BP (2020), recent COVID-19 had an enormous impact on global economy and energy markets through price deterioration. This shows that energy transition has the potential to cause serious major economic crises among oil-dependent economies. This crisis might be felt mostly in petroleum dependent economies such as Ghana.

Macroeconomic indicators trends in petroleum economies and their volatility can be affected by demand shocks that persist for a longer period and also increases in the intensity of this overtime. Such a possible shock to the petroleum industry is an increase in demand for its substitutes (i.e. renewables). Suggestions that increasing renewable energy usage, all things being equal, decreases the use of fossil fuels, although both renewables and fossil fuels can increase at the same time. This decrease might significantly impact on the agents in the petroleum economy of emerging economies and thus make them vulnerable. Also, given that renewable energy is a substitute for fossil fuels and it is to be done piecemeal, it might increase the volatility of petroleum indicators and increases the vulnerability of petroleum-producing countries and by extension affecting energy security, energy inequality, and employment.

Statement of the Problem

Average production capacity of oil keeps declining with an average of 176Mbbls per day in September 2021 and 175.83Mbbls in July 2022 (International Trade Administration, 2022). According to Ghana's Public Interest and Accountability Committee (PIAC) (2021), upstream revenue declined significantly by 25 per cent from 2019 revenue of US$925 million to 2020 revenue of US$639 million. Decline in government revenue could affect government expenditure and by extension employment since expenditure demand on income. Thus, the variability in global crude oil demand makes the economy of Ghana very vulnerable. Yet, Ghana has to fuel the economy for development.

It is noteworthy that in Ghana, unemployment and informal employment are high and growing, youth unemployment is high, and vulnerable employment has the greatest share of total employment. There is continuous surge in working poverty among the working class. In 2017, the unemployment rate in Ghana was estimated at 8.4 percent (GSS, 2019), which was higher than that of Africa (7.9%) and the world (5.6%). Between 2006 and 2017, the national unemployment rate increased from 3.1 percent to 8.4 percent (Figure 1.4). Currently, unemployment rate at 13.4 percent is lower for males (11.6%) than females (15.5%) and is higher for population between 15 and 24 years (32.8%). The rate is higher for females between 15 and 24 years (36.7%) than for males between 15 and 24 years (29.3%). Unemployment rate is 19.7 percent and is lower for males (17.4%) than females (22.3%) for population between 15 and 35 years (GSS, 2022).

The situation is more threatening with the youth than other age categories. Between 2006 and 2017, youth unemployment rate bloated from an estimated 6.6 percent in 2006 to 25.9 percent in 2015, but decreased to 18.5 percent in 2017. Moreover, from 2006 to 2017, the youth unemployment rates were more than double the national unemployment rates. In 2015 it stood at 25.9 per cent compared to 11.9 per cent for the country, and in 2017 the rate was 18.5 per cent relative to the national unemployment rate of 8.4 per cent (Figure 4). An estimated 77 per cent of the Ghanaian youth has at most basic education qualification affecting their chances of employability (National Development Planning Commission [NDPC],

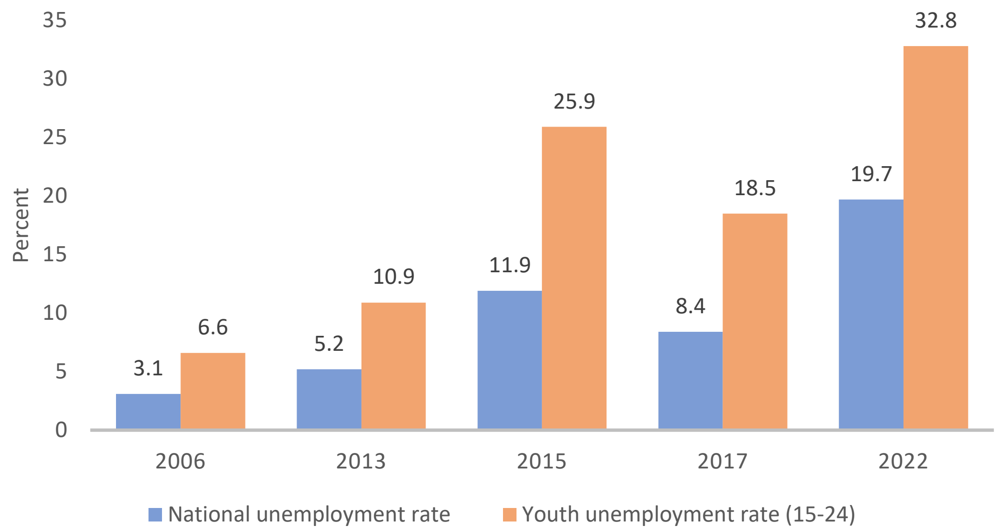

Figure 4: National and Youth Unemployment Rates in Ghana (2006-2022)

2019). The unemployment situation is expected to worsen given the unending and ravaging the impacts of the COVID-19 pandemic on businesses, employment and the demand for petroleum products.

According to ILO (2020), 85.8 percent of employment in Africa is in informal sector. Also, one characteristic of the youth unemployment in Ghana is that it is higher among females due to relatively low educational attainment among females; and predominantly an urban (11.4%) than rural (5.2%) phenomenon largely due to rural-urban migration (GSS, 2019). The growth of youth population is about three times higher than that of the entire population. It is estimated that about 300,000 youth enter the labour market annually seeking for employment of various kinds, but only about 2.0 percent is able to secure formal jobs (LO/FTF, 2016). This is an indication of willingness and desire of jobless and unemployed youth to work and the poor health of the economy. The industrial sector, especially manufacturing, which is principally associated with employment-intensive growth is struggling behind the service and agriculture sectors.

Unemployment, however, circumvents gains associated with decent employment and potentially makes its victims poor and dependent on others. Thus, increasing the dependency ratio. Joblessness and unemployment constitute a major threat to all the benefits associated with employment. Prolonged unemployment has significant implications for the affected individuals, the society in which they live, and for those responsible for designing and implementing labour market polices (Shumway, 1993). Moreover, long unemployment duration subjects the victims to poverty, loss of self-esteem, depression, poor health, delayed marriage, and increased likelihood of divorce (Kunze & Suppa, 2017; Doiron & Mendolia, 2012). They commit suicide more than the employed, hence an existence of association between unemployment and suicide (Blakely, Collings & Atkinson, 2003) and deviant acts like commercial sex, robbery, and political unrest (Baah-Boateng, 2013). It presents a threat to peace and security of a country. The recent xenophobic attack and shop looting in South Africa are a manifestation of frustrated and dissatisfied unemployed youth.

Another issue of concern is the discrepancy in energy use between the poor and the rich. It is estimated that the rich consume over 50 percent of all energy, while the poorest billion consume just below four percent (Freris & Infield, 2022). These are extra sources of tension and of accusation that the developed economies are profligate in the use of energy. Reliable supply of electricity remains elusive across many countries in the SSA. Most cities in SSA have erratic electricity supplies but large swaths of the continent's rural areas have no power at all. IEA (2021) asserts that 43 percent (almost 600m people) of Africans lack electricity accessibility with 590 million of them in SSA. These electricity shortages that plague many SSA countries, including Ghana, are a serious drain on the economic growth and development of the continents. For example, despite progress in Ghana to achieve SDGs 7, planned and currently available efforts to provide energy and access to electricity barely outpace population growth (Figure 5 & Figure 6).

Per the current status, 13.7 per cent of Ghanaian lack access to electricity, 27.4 percent of population in the rural and 4.8 percent of urban population lack access to electricity (GSS, 2022). These realities present a challenge that may militate against the accomplishment of the agenda 2030. Those at the bottom of the energy security, (i.e the poor), are more vulnerable energy disruptions system, either physical and economic infrastructure echoed in price fluctuations. As usage of modern (and often more easily disrupted) energy forms increase, this vulnerability may also increase. Hence, countries with high levels of poverty and ruthless energy modernisation programmes are more vulnerable to energy security threats. Therefore, efforts for million people to access electricity and clean cooking should accelerate even more.

World Bank (2018) and BP (2020) indicate that there are low levels of production, consumption, and usage of modern energy in Africa. Ghana just like its neighbouring countries faces other several economic and social problems such as energy insecurity, energy inequality, poverty, illiteracy, power crisis among others. As an SSA country, Ghana identifies herself with these challenges of energy availability, affordability and access. For instance, as few as 25 per cent of households in Ghana have access to clean fuels and technology for cooking, with an average growth of 0.3 per cent of Ghanaians affording to use electricity as a primary source for cooking (Energy Commission, 2020) although electricity coverage is 86.3 per cent of the proportion of households (GSS, 2022).

This reality indicates that 75 per cent of households still rely on polluting fuels and technologies for cooking. The coverage of 86.3 per cent also does not profess an uninterruptible power supply against the demand. It is an undeniable fact that energy access is crippling most economies in developing countries. The Energy Commission of Ghana indicated that, from 2000 to 2019, Ghana's electricity consumption patterns moved tremendously from largely industrial to residential. This, however, signals the threat of how expensive power is to industries in Ghana (Menyeh, 2021).

Petroleum exploration and production in Ghana present a good opportunity to leverage on to increase energy access, make energy more affordable and improve energy availability. Under prevailing economic conditions and technologies, petroleum exploration and production efforts increase the country's chances of increasing oil and gas recoverable reserves. Consequently, when there is optimal extraction, it gives the country investment opportunities from revenues accrued from the sector at a given favourable price which could affect employment and government expenditure. Recent discoveries of fossil fuel across Africa could fit well with the continent's industrial growth and its need for reliable energy.

However, there has been global demand for renewables due to negative

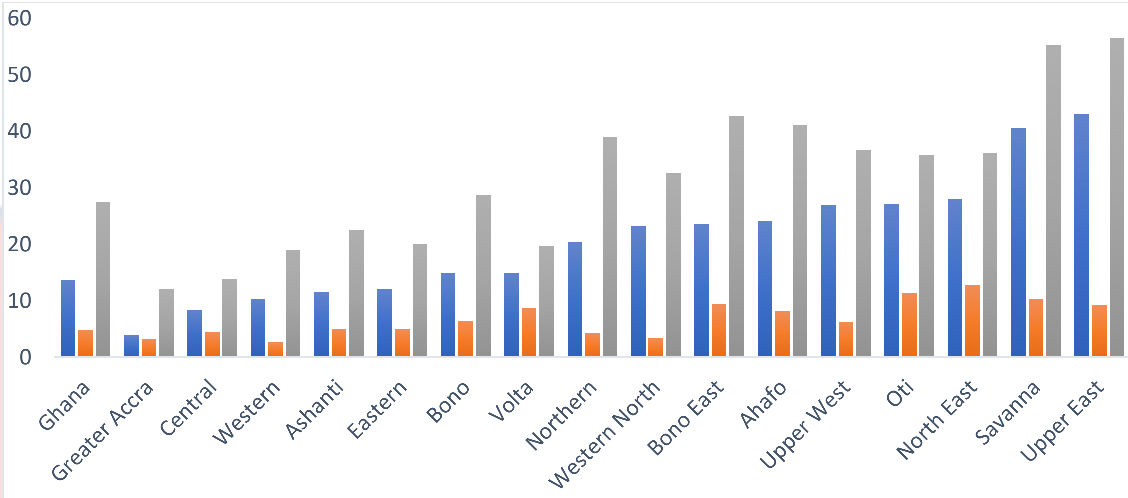

Figure 5: Number of People without Access to Electricity in Ghana in 2023 (%)

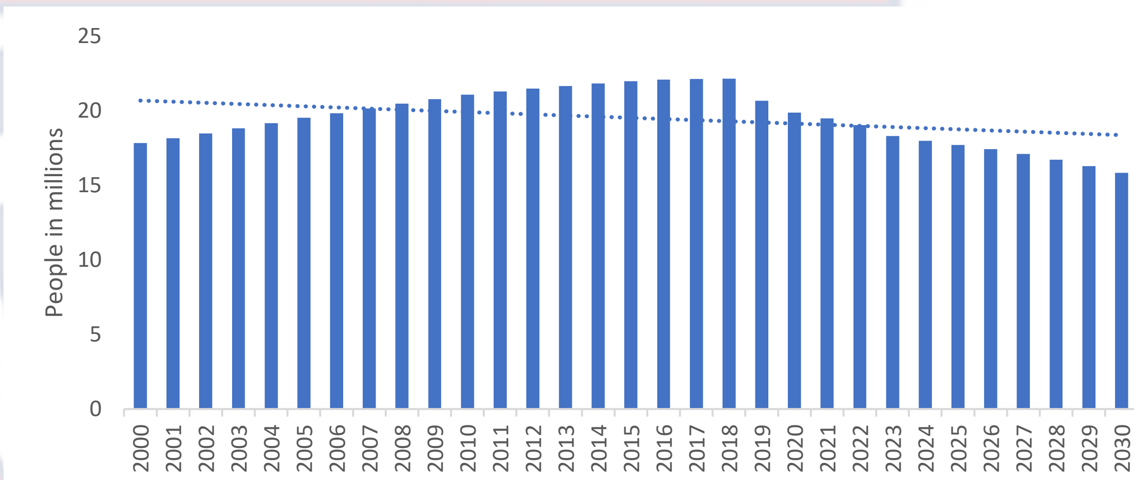

Figure 6: Number of People without Access to Clean Cooking in Ghana

connotations from the use of unclean energies. Renewables including geothermal, wind, biomass, solar, and hydroelectricity do not emit carbons into the atmosphere. This means that, renewables can provide energy without emission of carbons on the environment (Hafner & Tagliapietra, 2020). Hence, to achieve climate change goals, renewables are portrayed to be the most efficient primary energy source. Moreover, renewable energy sources are asserted to be more easily accessible, available and more sustainable than other sources. The advantages of renewable energy over fossil fuels have made energy transition advocates push for a global consensus to, as much as possible, transit to renewable energy (Othieno & Awange, 2016; Simelane & Abdel-Rahman, 2011).

Further, other empirical studies have been conducted. To analyse the effect of energy transition from fossil fuel to renewable or clean energy sources on economies of the world, Akinyemi, et al. (2017) investigate energy transition in Africa and the associated trade-off and synergies relating to trade and energy security. Scholarly works such as Heard, et al. (2017); Jacobson, et al. (2013); Loftus, et al. (2015) have been done on the feasibility of renewable energy sources. Afonso, Marques, and Fuinhas, (2017); Li et al. (2021); Silva, et al. (2012) explore the relationship between renewable energy sources and economic growth. These insightful studies focus on economic growth, specifically aggregated GDP of the selected countries in their empirical analyses.

However, different sectors of the economy of a country are most probable and expected to be balanced by either a surplus or a deficit of other sectors. GDP consists of many macroeconomic variables and summing them up might not reflect the true situation of global renewable energy demand effect. These remarks lead this study to suspect that aggregation measures are susceptible to biasness, which is an important shortcoming of their studies. For better analyses of an economy, GDP has to be disaggregated. We achieve a better and deeper understanding and thus an extra precise valuation of the primary energy transition from fossil fuel to clean energy on the vulnerability of an economy by disaggregating the macroeconomy.

Additionally, Bridge and Gailing (2020); Mori (2018); Sgouridis, et al. (2016) have conducted extensive mapping and analyses of the cost of clean or renewable sources technology options to energy systems. With these studies, the implication of energy transition on existing patterns of employment and cost accumulation must emerge as crucial concerns for public policy. Yet, the vulnerability of emerging crude oil-producing countries to energy transition has not been extensively discussed. There are scanty studies on identifying with great precision which specific emerging petroleum-producing countries in the Gulf of Guinea might be most sensitive and impacted by such changes. Also, other thoughtful studies have not considered comprehensive sectoral analyses. This obscures variation by sector type. Expected fall in production trends is news to various economic agents in the petroleum economy, be it shareholders of the companies (households), petroleum firms or the government. This is also true in the cases of the various sectors of the economy. This study addresses the issues and limitations identified in the existing insightful research and the challenging questions about country and geographic vulnerability. Our study analyses the vulnerability of the economy of Ghana to the primary energy transition from fossil fuel to renewable energy with a specific focus on energy trilemma, petroleum subsector, and employment in Ghana.

Aim of the study

Our study aims to evaluate the implications of the energy transition to renewable energy in Ghana. The study has a special focus on the effects of energy transition on energy security, crude oil export, and employment in Ghana.

Objectives of the study

The general objective of this study is to analyse the effect of energy transition dynamics on the macroeconomy of Ghana. Specifically, the study seeks to:

- quantify the effect of renewable energy transition on energy security in Ghana.
- analyse the extent to which renewable energy transition affects the demand for petroleum from Ghana.
- estimate the effects of renewable energy transition on employment in Ghana.

Research Questions

- does renewable energy transition affect energy security and access in Ghana?
- what is the effect of renewable energy transition on petroleum supply from Ghana?
- what is the effect of renewable energy transition on employment creation in Ghana?

Relevance of the Study

This study recognises universal deficiencies in the evidence, highlighting precisely the lack of attention paid to the necessary ancillary services provisions, cost, and macroeconomic indicators implications. Also, there is a bias in the literature to deal with the energy security of importers and not that of exporters. Most of the scholarly works deal with the energy security consideration of the advanced countries consisting mainly of countries that import energy. It is therefore clear that there is still a sufficient gap to contribute to the literature by considering the economy of Ghana concerning global and local renewable energy production and consumption. Therefore, this study analyses the likely implications of the energy transition from fossil fuel to renewable energy on Ghana's energy security and access, petroleum economy, employment and government revenue.

Trends in petroleum indicators or a combination thereof are very important to various stakeholders and players in the industry for planning and decision-making purposes. It guides upstream, midstream and downstream stakeholders to forecast their incomes and to make investment decisions. This information is also used by governments to predict future petroleum revenues as well as to make investment and expenditure decisions. Applicable and appropriate policies can then be integrated with these opportunities in expansion capacity of developing economies from the energy transition. Thus, success of developing countries would be appropriate policies and regulation implementations by policymakers.

Scope of the Study

This study estimates the effect of global renewable energy transition from fossil fuels to renewable energy sources using times series analyses. The study focuses on Ghana, an emerging petroleum exporting country in Sub-Saharan Africa. The study uses renewable energy production as proxy for energy transition. Key indicators such as energy security employment, government expenditures and petroleum sub-sector are used for the analyses.

Organisation of the Study

The rest of our study is presented as follows: Chapter Two presents detailed description of the energy transition and energy outlook of Africa and Ghana. Chapter Three presents the literature reviews of the study. It concentrates on the effects of energy transition on energy security and access in Ghana related to first objective of the study. The chapter focuses on the extent of the global energy transition rates on the petroleum economy of Ghana which is the second objective of the study and effect of energy transition on the macroeconomic indicators of Ghana. Theorical reviews are presented under Chapter Three. The next section, which is Chapter Four, focuses on the methodology of the study in relation to the objective of the study. This chapter is followed by Chapter Five which presents the descriptive and summary statistics of the data of the study. Chapter Six presents the results, findings and the discussions of the results of the study. The last section, Chapter Seven provides the summary of the study, conclusion and recommendations of the study.

CHAPTER TWO

ENERGY TRANSITION, ENERGY MARKETS OUTLOOKS AND EMPLOYMENT IN GHANA

Introduction

The growth of population, industrialisation, and urbanisation in Africa are all contributing to its growing influence on global energy consumption patterns. This chapter presents the reviews of energy outlook in Africa and Ghana. The chapter describes the dynamics of energy transitions and proceeds to describe the energy outlooks of Africa with specification of Ghana. The chapter brings out energy issues and power generation in Africa and Ghana. Again, this chapter presents situation of employment in Ghana.

Energy Transition Dynamics

The growing trends in GHGs emissions and the restrictions of petroleum production has resulted in the transition of energy. Thus, many countries exporting oil and companies that produce oil currently shift from their attention from fuels dominated by fossil to no or low carbon emission sources of energy. It is estimated that hydrogen would be one of the main determining factors to achieve these potentials since hydrogen has higher energy content (Bedani, Depetri, & Ruggeri, 2020). Several organisations provide consensus forecasts that renewables share in the energy mix rises in the near future (Fattouh, Poudineh, & West, 2019).

Energy transition refers to the significant and fundamental change in the global energy industry, moving away from the current energy mix that is heavily dependent on fossil fuels towards a new energy mix that relies on sources with zero carbon emissions. Energy transition is driven mostly by changes in technology, the desire to reduce costs and inefficiency, population growth, economic growth, exhaustion of existing energy resources among others (Nwaneto et al., 2018). In the intervening time, carbon pricing and the European Union's Emission Trading Scheme policies are also being developed for a gradual energy shift to low or zero-emitting carbon sources (Johnston, 2020). However, it has been discovered that the global energy transition cannot easily be accomplished with just a simple flip of a switch. The global energy transition requires some time. Again, the energy transition requires a huge investment of capital, materials and energy (Solé, et al., 2018).

Consequently, there are intricacies in the energy transition and the processes are beyond just the replacement of one source of fuel (that is, fossil fuels) with another energy source (that is, renewables). Nevertheless, certain developed Asian nations, such as China and India, are developing energy strategies that tackle both air quality and emissions issues while simultaneously accommodating the anticipated growth in energy requirements. China has prioritised using natural gas in displacing residential and commercial heating by using coal. Also, there has been a change in the US stated emissions commitment (Johnston, 2020). The dynamics of transition of energy have elevated certain global important questions for the petroleum. Johnston (2020) discusses how oil and gas industries can navigate a changing strategic landscape while still generating returns for their shareholders. Nevertheless, certain oil and gas companies around the world are retorting in different means.

These include diversification of business models, provisions of support for growth decarbonization technologies such as capture and storage, reexamination of geopolitics and geography to reduce exposure, and adoption of environment that focuses on climate and social governance into business models.

The Energy Sector in Ghana

Electricity Sector

From Figure 7, generation of installed electricity capacity improved from 3,795MW in 2016 to 5,288MW in 2020. This represents an improvement of 39.3 per cent, with dependable capacity increasing from 3,521MW to 4,842MW in the same period. Installed generation capacity without embedded capacity as at the end of 2020 is 5,134MW representing an expansion of 2.9 per cent from 2019. The dependable capacity is 4,710MW which is 3.1 per cent more than it was recorded in 2019 as depicted in Figure 7.

The energy mix in 2020 remains in 2020, the energy mix remained moderately stable with hydro contributing about 29.9 percent to total capacity installed. Traditional thermal plants make a contribution of 69 per cent to the total installed capacity whereas renewables contribute 1.1 per cent in the same period. Since 2015, thermals surpass hydro as the leading source to generate electricity in Ghana.

Fuel Consumption

Thermal plants account for 69 per cent of the country's total installed generation capacity. Natural gas, light crude oil, and heavy fuel oil are the primary fuel sources for thermal plants. Natural gas is used as the primary fuel source in up

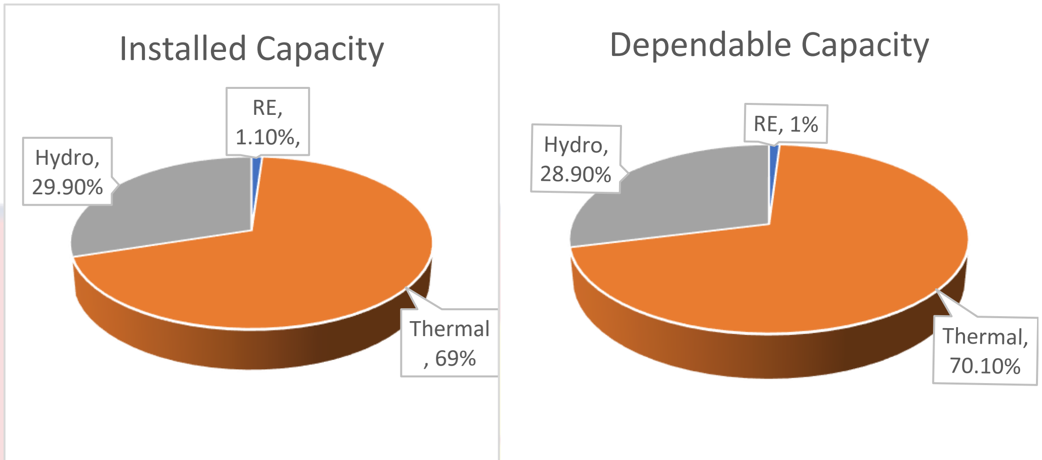

Figure 7: Shares of Renewable, Hydro, and Thermal Capacity in 2020

to 89 percent of installed thermal plants due to its comparative advantage over oil in terms of indigenousness, cost, and environmentally friendly.

The various fuels and the quantities consumed by thermal plants in 2020 are depicted in Table 1. Total gas that is delivered for electricity production in 2020 is 95,632MMscf, 5.4 per cent short of projected in Ghana. Approximately, 361,110bbls of light crude oil is used as against the projected barrels of 495,732bbls. Additionally, 200,327bbls of diesel is used to generate electricity. More than 90 per cent is utilised to operate the KTPP but 8.5 per cent is utilised by Cenpower plants. The rest of 1.3 per cent goes to the Early Power. Heavy fuel oil which is utilised to operate the AKSA plant is more than the projected 212,859bbls to reach 564,601bbls in 2020.

Production of Crude oil in Ghana

The production of crude oil and petroleum continues to be exploited from three fields – Jubilee, Tweneboa Enyenra Ntomme (TEN) and Sankofa Gye Nyame fields. As depicted in Figure 8, since 2016, crude oil production has increased due

Table 1: Ghana's Fuels used by the Thermal Plants in 2020

Power Plant	GAS (MMscf)		LCO		DFO(Barrels)		HFO	
	Proj.	Actual	Proj.	Actual	Proj.	Actual	Proj.	Actual
TAPCO	9,955	7,811	-	-	-	-	-	-
TICO	14,410	11,663	-	41,937	-	-	-	-
AMERI	13,058	11,666	-	-	-	-	-	-
SAPP	9,030	21,030	-	-	-	-	-	-
TTIPP	1,824	1,801	-	-	-	-	-	-
CENIT	3,572	7,346	-	-	-	-	-	-
TT2PP	65	677	-	-	-	-	-	-
KARPOWER	26,405	23,646	-	-	-	-	-	534
TROJAN	-	-	-	-	-	-	-	-
KTPP	6,592	3,039	-	-	-	180,423	-	-
AKSA	-	-	-	-	-	-	212,859	564,067
CENPOWER	10,508	2,544	495,732	319,173	-	16,931	-	
AMANDI	5,709	1,408	-	-	.		-	-
EARLY POWER	-	-	-	-	-	2789	-	-
GENSER	-	-	-	-	-	-	-	-
Total	101,126	95,632	495,732	361,110	-	200,327	212,859	564,601

Source: Energy Consumption (2021)

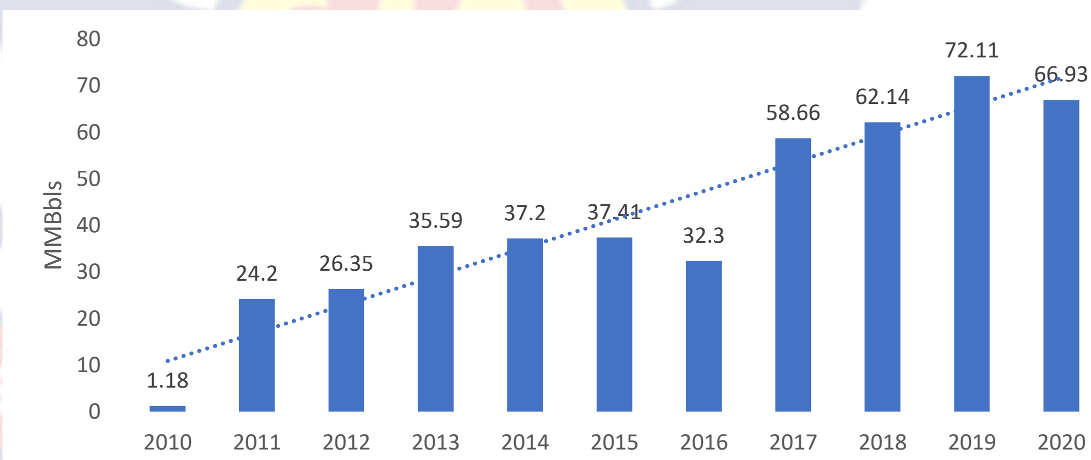

Figure 8: Crude Oil Production since 2010

to the commissioning of the TEN and Sankofa fields. The global oil price collapse, which was mostly brought on by the COVID-19 epidemic, had an adverse effect on oil production. In 2020, 66.93MMBbls of crude oil are produced from the three commercial fields compared to 72.11MMBbls in 2019. The Jubilee and TEN Fields' decreased output was the cause of the production decline in 2020.

The Jubilee field produced 30.42MMBbls of crude oil in 2020 compared to 32.58MMBbls in 2019. As a result of a scheduled outage from January 24 to January 31, 2020, to carry out a Wet Fuel Gas project, the Jubilee field's output fell to its lowest level in January 2020. The project aims to improve gas production capacity on the Floating Production Storage and Offloading (FPSO). In contrast to the 22.32MMBbls produced in 2019, the TEN field produces 17.80MMBbls of crude oil in 2020. This decrease was mostly related to an increase in water cut (water production rate with oil) and the delay in the Ntomme-09 well coming online. Early in August, the Ntomme-09 well began to produce, increasing TEN productions by around 5MBbls barrels per day. With 18.70MMBbls of crude oil production in 2020 compared to 17.21MMBbls in 2019, the Sankofa field saw an increase of 8.7 percent. The FPSO's nearly 100 percent availability, reliable production operations, and the startup of the OP-9 and OP-10 producer wells were credited with the growth.

Petroleum industry in Ghana has grown in size and in activities working with zero rig to four rigs in exploring for hydrocarbons. By 2019, crude oil produced offshore Ghana grow from 1.4MBbls per day in 2010 to 214MBbls per day in 2019. On the Deepwater Tano Cape Three Points block, Aker’s new discoveries show that, production is set to more than double from a little less than 200MBbls per day to 420Mbls per day by 2023. Over the recent past, petroleum production in Ghana has generally seen positive trends (Figures 8 and 9). This is more so in pre-COVID 19 periods. Oil production has generally been increasing but with large error margins. The trend of oil production however levelled and later dipped in the COVID-19 era.

Similarly, as indicated in Figure 9, gas production has generally been on the rise. The slope of the trend of gas production in Ghana, however, lowered in the COVID-19 era. According to PIAC (2018), development in exploration and production activities in the upstream sector remains intense, probably sustained by the comparatively high and stable crude oil prices ranging from US$70 to US$79 mostly in 2018. The activities at the Greater Jubilee Field continued to produce year-round. Production of oil from the reservoirs of the Ntomme and Enyenra in the Tweneboa-Enyenra-Ntomme (TEN) Field continued steadily during 2018. According to the PIAC 2018 report, a total of more than 62MMBbls of crude oil is produced from the three fields of production in Ghana—TEN, Sankofa Gye Nyame (SGN) and Jubilee—in 2018. In comparison with 2017 total crude oil production of 59MMBbls, there is a 5.93 percent increase in 2018. The average achieved price by the GNPC of US$68.487 per barrel for all three producing fields is both higher than government's 2018 estimated benchmark price of US$54.43 per barrel. This contributes to a higher revenue outturn for the year (GNPC, 2018).

Oil Revenue and the Fiscal Budget of Ghana

These variabilities in world oil prices affect many aspects of the economy of oil-producing countries (IEA, 2013). In Ghana's first 10 years of oil discovery, the petroleum industry in Ghana has been experiencing highly unpredictable crude oil price settings ranging from US$47.54 to US$65 per barrel (Petroleum Commission Ghana, 2017). However, as indicated in Figure 9, in 2019, a total of

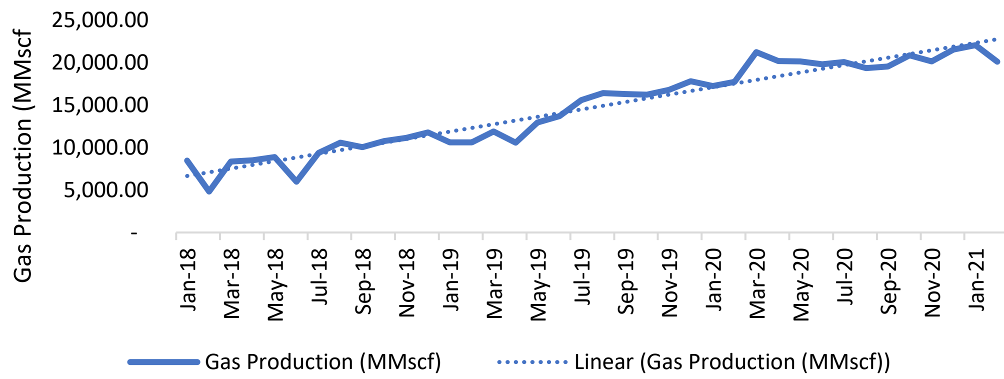

Figure 9: Gas Production in Ghana

Source: Authors' Construction using data from PIAC (2023)

US$925,035,879.84 in revenue is accrued. This is a decline of 5.33 per cent of 2018 revenue. The total revenue of the year 2020 declined further to US$638,643,030.56. From Figure 10, it is clear that since the inception of crude oil production (December 2010) to 2020, petroleum revenues have been fluctuating. This could be due to the price variability of global oil prices impacted by the global energy transition. This implies that global oil price variability might affect other sectors of the economy if Ghana relies so much on the revenue stream from crude oil. As shown in Figure 10, oil contribution to the budget is unstable.

This shows that the discoveries of crude oil in Ghana have the potential to cause serious major economic crises (Buchberger, 2011). According to BP (2020), the recent COVID-19 pandemic has had a huge impact on the global economy and energy markets through price deterioration. Ghana as a crude oil net exporter is not exempted. Ghana's revenue from oil exports will decline due to instabilities in the economy of the world and the high unpredictability of prices of crude oil.

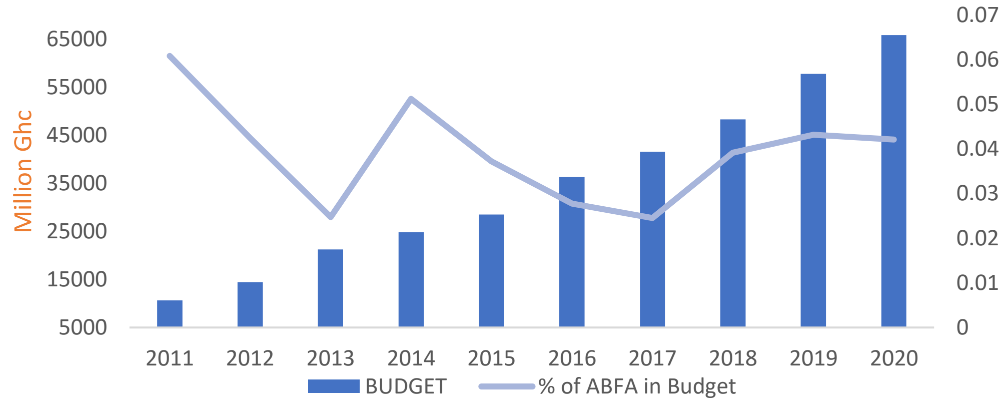

Figure 10: Percentage share of Oil Revenue to Budget

Source: Author's own construct (2023)

Major Importing Economies of Crude Oil from Ghana

According to the Observatory of Economic Complexity (2023), Ghana exported US$3.57billion in crude petroleum, which makes it the 27th largest global crude petroleum exporter in 2021. In the same period, crude petroleum was the second most exported product from Ghana. The main destination countries of crude petroleum exports from Ghana are the US, China, South Africa, India, and Thailand. The US imported US$1.18 billion (representing about 33% of total exports), China imported US$888 million (approximately, 25% of total crude petroleum export from Ghana), South Africa imported US$525 million (about 15% of total crude petroleum export from Ghana), India imported US$245 million (approximately, 7% of total crude petroleum export from Ghana), and Thailand imported US$234 million (approximately, 7% of total crude oil export from Ghana).

Figure 11 shows the average all-time crude oil imports from Ghana from 2011 to 2019. It is observed that China, South Africa, the US, India, Italy, the UK,

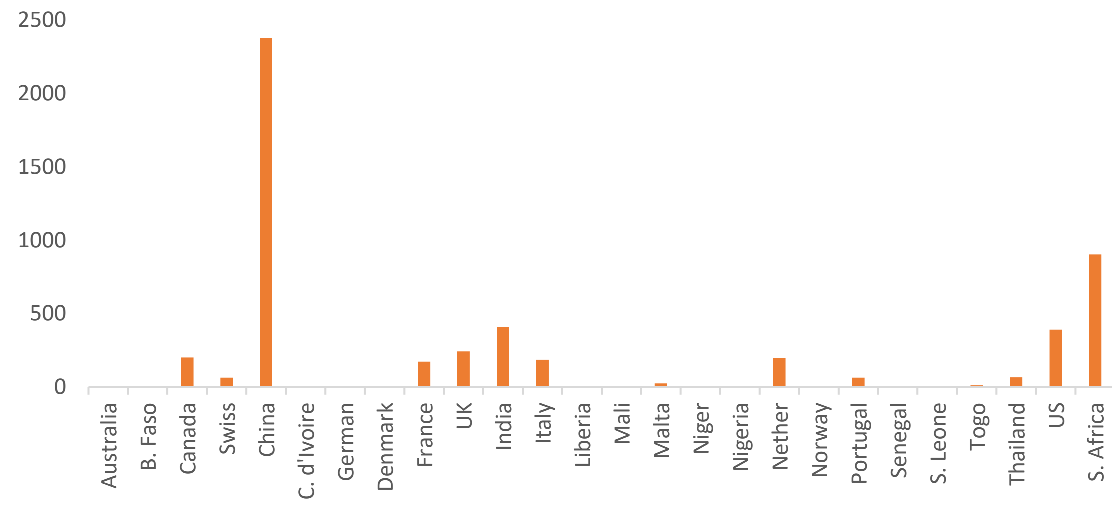

Figure 11: Average all-time Importers of Ghana's Crude Oil from 2011-2019 (in million US$)

Data: World Integrated Trade Solutions

and Canada are the major imports of crude oil from Ghana. China has the largest share of crude oil imported from Ghana. Based on these, our study focuses on the effect of energy transition in the US, China, Canada, India, and Italy.

Renewable Energy Transition and Energy Security in Ghana

The massive abilities to utilise petroleum to expand energy access lays the fundamental foundations to embark on industrialisation (Bazilian, et al., 2013), which drives economic growth and development (Opoku & Yan, 2018). The universal call to action is very explicitly contained in the Agenda 2030 for Sustainable Development, which stakes high energy by making access to modern, sustainable, reliable, and affordable energy by 2030. The 2020 report from the Energy Commission of Ghana indicated that, from 2000 to 2019, Ghana's electricity consumption patterns moved tremendously from largely industrial (64%)

to residential. This, however, signals the threat of how expensive power is to industries in Ghana (Menyeh, 2021).

Although Ghana's Energy Commission claims electricity coverage of 82.5 per cent, it does not profess an uninterruptible power supply against the demand. From the year 2000 to 2019, the overall per capita consumption of electricity increased at a yearly average growth of 1.3 per cent. The total primary energy supply per capita has increased at an annual average growth rate of 0.6 per cent, from 0.33Ktoe/capita in 2000 to 0.37Ktoe/capita in 2019. Nevertheless, the gradual rise in energy consumption, in the light of increasing population, points to an increase in the availability and accessibility of affordable energy.

However, there has been global demand for renewables due to negative connotations from the use of unclean energies. Renewables including geothermal, wind, biomass, solar, and hydroelectricity do not emit carbon into the atmosphere. This means that renewables can provide energy without the emission of carbon into the environment (Hafner & Tagliapietra, 2020). Hence, to achieve climate change goals, renewables are portrayed to be the most efficient primary energy source. Moreover, renewable energy sources are asserted to be more easily accessible and more sustainable than other sources. The advantages of renewable energy over fossil fuels have made energy transition advocates push for a global consensus to, as much as possible, transit to renewable energy (Othieno & Awange, 2016; Simelane & Abdel-Rahman, 2011).

In spite of all these, countries in SSA rarely have the potential and capacity to adapt and adjust to renewable energy transition, particularly for consumption.

SSA countries do not have the economic and technical ability to utilise renewables. Other discussions focus on the possibility of energy transition to curb energy inequity and security within and between countries and regions (Hafner & Tagliapietra, 2020; Othieno & Awange, 2016). According to the BP (2020), there are low levels of production, consumption, and usage of modern energy in Africa. Therefore, this study analyses the effect of renewable energy transition on energy security and access in Ghana.

Renewable Energy and the Macroeconomy

The global economy already faced a global economic growth downslide precipitated by escalated trade tensions across notable economies in Europe and Asia (IMF, 2019). By 2020, global growth had plummeted, due to the COVID-19 pandemic, with projected negative growth at 4.4 percent and about 90 million people projected to fall into absolute deprivation (IMF, 2020). In IMF's projections, about 70 per cent of the already low-income developing countries will continue to have at least 30 per cent of government tax revenues to service public debts while the number of emerging economies using more than 30 per cent of tax revenues is set to increase in both 2020 and 2021 by more than 10 per cent.

Ghana, like many low-income developing countries exporting crude oil, expects to finance a significant portion of its current and future national budget from the export revenues from crude oil consumption which is a major CO_2 emitter and a climate change contributor. Climate change concerns have lingered for more than three decades because of the adverse effect it has on the preservation of the earth's atmosphere. A major contributor to climate change, CO_2, is largely driven by anthropogenic activities in energy production and consumption (BP, 2021). Furthermore, urbanisation acceleration levels could affect urban air quality owing to the burning of coal and diesel increases. As a global response, SDGs 7 and 13 provide a framework for all countries in the world to make commitments towards less CO_2 pollution and to limit global temperature from above 2^oC to 1.5^oC. Favourably, renewables costs are falling (IRENA, 2019) hence, reinforcing the expectation to switch to renewables from conventional fossil fuels. Solar PV module prices have declined by almost 80 percent, while wind turbine prices have reduced by about 30 to 40 percent, according to the IRENA (2019).

Hence, the global energy transition from fossil fuels to renewable energy sources in decades past as shown in Figure 12. The Stated Policies Scenarios (STEP) and Announced Net Zero (NetZero) pledges would increase renewables from 12% to 35% in the Announced Pledges Case (APC) of the total supply of energy in 2050. This will hamper oil and coal production. Sources of renewables would reach novel levels as indicated in the APC. This would increase from 30% in 2020 to 70% in 2050 of the total supply of electricity, while there would be an increasing decrease in coal. Nuclear power and renewables are going to displace the use of fossil fuels in the NZE. This causes fossil fuel shares to decrease from 80% to 20% by 2050. As a replacement for the use of fossil fuels, renewables would a dominant in the power sector. More than 66.67% of the energy supply would be from bioenergy, solar, geothermal, wind, hydro-energy, and solar. The capacity of solar PV would rise by about 20-fold by 2050 while would be about 11-fold. Net zero means a huge decline in the use of fossil fuels. Fossil fuels would decline by

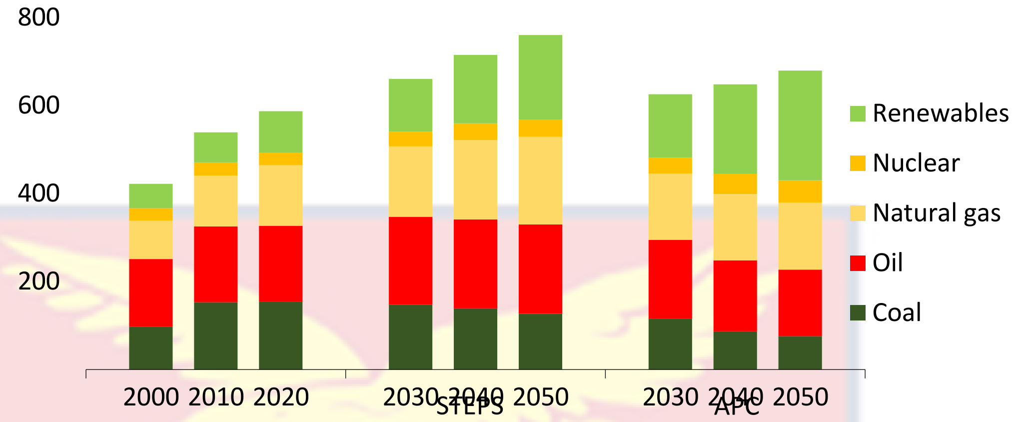

Figure 12: Total Energy Supply by Source in STEPS and APC

Sources: IEA (2021)

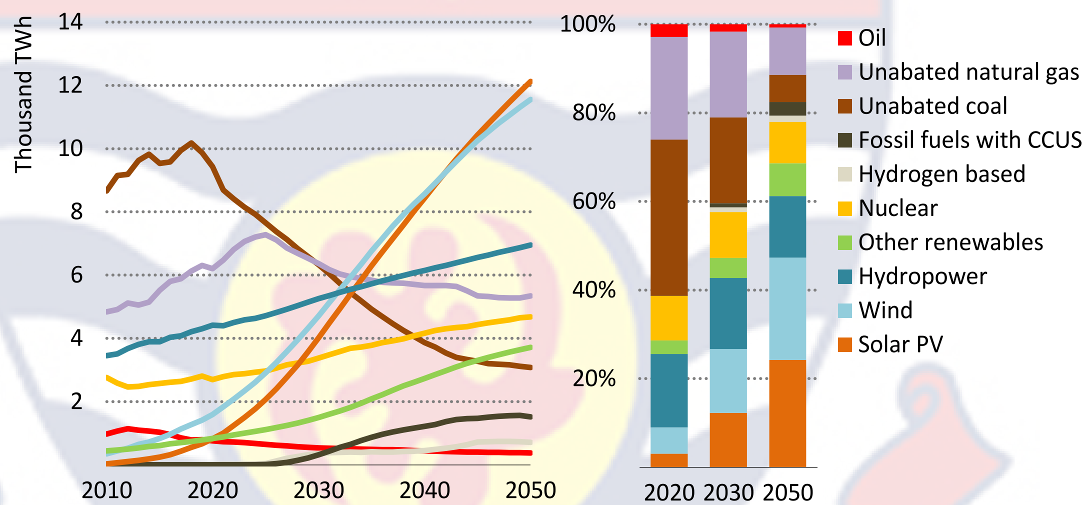

Figure 13: Global Electricity Generation by Source in the APC

about 80% to 20% in 2050. The remaining fossil fuels in 2020 would utilised for production of plastics and in CCUS facilities (IEA, 2021).

The IEA (2021) asserts electricity would account for more than 50% in the energy consumption by 2050. The achievement of this would be as a result of an increase in generation of electricity by 200% in 2050. Renewables shares in generation of electricity would rise from 29% to almost 70% by 2050. This is driven by wind and solar PV, which are rising faster than the others (Figure 13). It is estimated that wind and solar PV generations combined would be more than 50% of the supply of electricity in 2050. In 2050, hydropower will continue to rise and emerge as the third-largest source. “Nuclear power increases steadily too, maintaining its global market share of about 10 per cent. Natural gas use in electricity increases slightly to the mid-2020s before starting to fall back, while coal’s share of electricity generation falls from around 35 per cent in 2020 to below 10 per cent in 2050. At that point, 20 per cent of the remaining coal-fired output comes from plants equipped with CCUS. At the same time, no additional new final investment decisions should be taken for new unabated coal plants, the least efficient coal plants are phased out by 2030, and the remaining coal plants still in use by 2040 are retrofitted” (IEA, 2021).

However, the dramatic improvement in quality of air in the atmosphere observed during the Great Lockdown period in April during the early days of the pandemic, especially in China, has, more than ever, rekindled the commitments of global energy players towards renewable energy sources in the face of growing CO_2 emissions. Hence, the IEA (2020) projects a steep rise in demand for renewable energy sources while the demand for oil, gas and nuclear mildly increases whereas demand for coal falls. The heightened compliance to the energy transition agenda by key players in the global energy markets following the COVID-19 pandemic, exporting countries, most especially the emerging petroleum countries that rely heavily on petroleum revenues can expect a quickened fall in oil revenues and economic performance (Khan & Shaheen, 2020).

A rapid projection of a contraction in global oil demand accordingly of energy transition by IEA and BP is anticipated to surge renewable energy consumption and a fall in the price of crude oil. For instance, the IEA's (2021) simulates that energy demand will contract by six percent, the largest in 70 years in terms of percentages and the largest ever in absolute terms and, that Covid-19 impact on energy demand in 2020 was seven times more than financial crisis in 2008 impacts on demands for energy globally. The IEA further projects oil demand to decline by nine percent per day on average across the year, which would return consumption of oil to the levels of 2012. The fall in oil demand caused by a persistent rise in countries' consumption of renewables is premised on the constant fall in solar PV panels and wind turbines unit costs.

The global transition towards renewable energy sources has the propensity to worsen the fiscal space risks and employment of high debt distress economies, like Ghana, that rely on crude oil revenues covering a large share of public spending on healthcare provision, education, etc other than domestic use and refine of the crude shown in Figure 14. From Figure 14, the reduction in oil and natural gas production will have extensive consequences for both nations and companies involved in their extraction and production. The decline in petroleum demand, and the decline of international prices petroleum leading to historically low net income for producer countries. As we transition towards alternative energy sources, there won't be a need for new petroleum fields. This will lead to a concentration of petroleum supplies among a few low-cost producers. As for oil, OPEC's share of the global supply will increase from 37% in recent years to 52% in 2050, which is the highest level ever seen in the history of petroleum markets.

The yearly income per person in oil and gas producing nations is expected to decline significantly by about 75%, from US$1,800 to US$450 by the 2030s. This decline in income could have negative consequences on society. Even though there is a need for structural reforms and the generation of new revenue sources, it is unlikely that these measures will fully compensate for the decrease in income resulting from the reduced production and sale of oil and gas (IEA, 2021). Figure 2.8 implies that decline in oil and gas from 2011-2020 levels to the levels of 2021-2030 will lead to drop in per capita income from US$1,780 to US$720 and further decreases to US$ 240 in the 2041-2050 NZE scenarios.

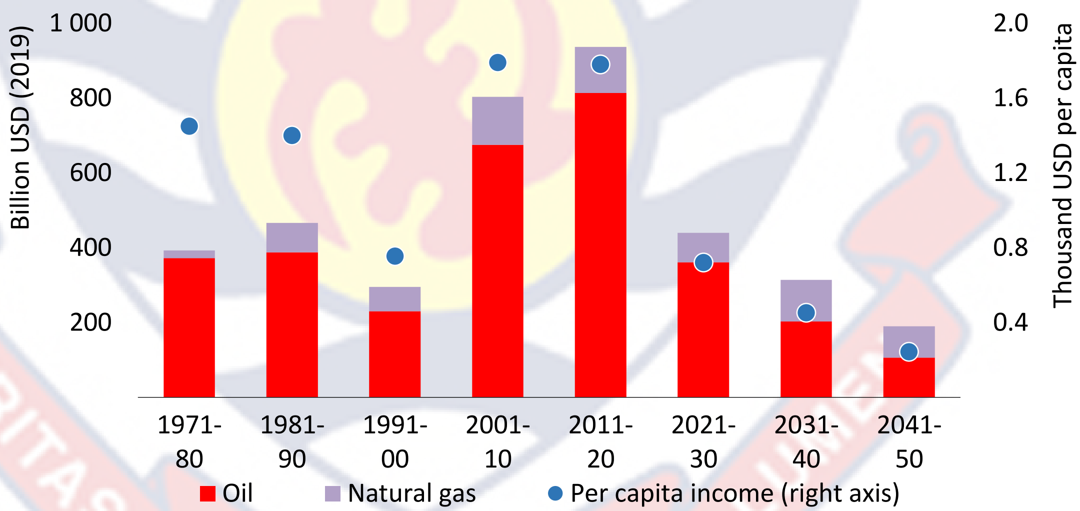

Figure 14: Income from 0il and Gas Sales in Producer Economies in the NZE

According to Khan and Shan (2020), transition from fossil fuels to renewables poses grave challenges for those economies depending on fossil fuels. In spite of having large revenue from oil, these countries that export oil do not have adequate diversified industrial base and technology. Their non-oil outputs are always non-tradeable, related with low-skilled as telecommunication, transportation, and restaurant while many of the tradeable outputs are imported. Any global decrease in demand for petroleum poses a strategic threat to the economic and financial variability of the countries exporting oil and it affects the revenue from exports and budget of the government which hamper the macroeconomic performances (Akinlawon & Iledare, 2015; Cherif, et al., 2021; Khan & Shaheen, 2020). Additionally, the public sector constitutes significant employment shares of these countries that export oil financed from volatile oil revenues.

Thus, renewable energy transition globally might come with a worrying impact for Ghana which, in recent times, depends on oil revenue. A decline oil prices and reduction in demand for oil affects macroeconomic growth, national budget, and export revenues (as shown in Figure 9). There are uncertainties about the macroeconomic effects of the NZE scenarios. These uncertainties are due to hosts of factors such as financing of government expenditures, changes in bills of consumers, health improvement benefits, broad impact of changes in consumer behaviour, and capacities for productivity spillovers from accelerated energy innovation.

Evidence from existing literature on the implications of the energy transition on low-incomes developing countries have not been exhaustive on government expenditure and employment. Therefore, this study analyses the vulnerability of the macroeconomy of emerging petroleum country, in this case

Ghana, due to global energy transition from fossil fuels. The speed of adjustments to which the individual key importing countries of Ghana's crude oil would transition to renewable energy sources would impact Ghana's economy is unknown. In the face of the growing indebtedness of emerging petroleum economies and the diminishing oil revenues inherent in the global energy transition, this study investigates the vulnerability of Ghana's economy to the global energy transition.

Energy Transition and the Petroleum Economy of Ghana

Government of Ghana, via the GNPC, plans to increase production of oil and gas from the current 190,000bbls per day to 2MMbbl of crude oil and from 140m to 200m cubic feet of natural gas per day to 1.2b cubic feet per day of gas with an anticipated yearly revenue generation of about GH₵140.7b (US$65b) soon. This requires a progressive and attractive environment and fiscal regimes for investment in petroleum extraction and production to explore the rich natural resource for development. Fossil fuels discovered off the coast of Ghana is of high quality, presenting Ghana with a clear opportunity to translate benefits from petroleum to drive economic transformation through increasing access to energy.

As a result, oil and gas discoveries offshore Ghana have accelerated global interest and investment and have also been termed as one of the least-covered magnets from global oil firms, according to Bazilian et al. (2013). Despite these accolades globally for Ghana's oil and gas potential, increases in proved reserves have been slow, reflecting the slow efforts in petroleum exploration and development. This could be due to energy transition and global prices of oil crash between 2014 and 2015 which made countries exporting oil to increase high standard of living through fiscal revenue from oil and products related to oil (Bradshaw, et al., 2019; Khan & Shaheen, 2020).

The energy transition might pose a great concern to the demand for petroleum. The petroleum industry becomes susceptible to energy transition from fossil fuels to renewables. In spite of having large revenue from oil, these countries that export oil do not have adequate diversified industrial base and technology. Their non-oil outputs are always non-tradeable, related with low-skilled as telecommunication, transportation, and restaurant while many of the tradeable outputs are imported. Any global decrease in demand for petroleum poses a strategic threat to the economic and financial variability of the countries exporting oil and it affects the revenue from exports and budget of the government which hamper the macroeconomic performances (Cherif, et al., 2021; Khan & Shaheen, 2020). However, the heightened compliance to the energy transition agenda by key players in the global energy markets following the COVID-19 pandemic, exporting countries, most especially the emerging petroleum countries that rely heavily on petroleum revenues can expect a quickened fall in crude oil revenues and performance of the economy (Khan & Shaheen, 2020).

The dramatic improvement in quality of air in the atmosphere observed during the Great Lockdown periods, has, more than ever, rekindled the commitments of global energy players towards renewable energy sources in the face of growing CO_2 emissions. However, evidence from existing literature on the implications of the energy transition on developing countries including Ghana and other SSA countries have not been exhaustive on sustainability of the petroleum industry. The extent to which the global energy transition affects petroleum economy of Ghana when the major importers of Ghana's petroleum is rarely known. Therefore, the critical questions worth probing in Ghana's case would be, what will be the speed of transition by the major importer of Ghana's crude oil: US, Italy, India, and Canada in the global energy transition agenda? How does the speed of global transition impact on Ghana's crude oils export between now and 2040?

Therefore, this study analyses the vulnerability of the economy of Ghana to the energy transition from fossil fuels to renewable sources at different rates. The speed of adjustments to which the main importing countries of Ghana's crude oil would transit to renewable energy sources would impact its petroleum production and capacity is unknown. Hence, the study assesses Ghana's petroleum export to energy transition from fossil fuels to renewables and the speed of adjustments by the US, Italy, China, India, and Canada.

Unemployment Situation in Ghana

Ghana had the rank of a middle-income country in 2007 based on its elevated per capita GDP, after the rebasing of national accounts in 2010 by the Ghana Statistical Service (Kwakye, 2012). This leads to an increase in the economy's yearly average growth to 8.5 percent between 2006 and 2011 from the 5.2 per cent registered from 1984 to 2010 (Baah-Boateng, 2018). The Ghanaian economy records an estimated real GDP growth of 14 per cent on the back of the country's commercial production of oil in 2011, positioning Ghana as one of the fastest growing economies worldwide in that year. In 2017, the economy's GDP grows at an estimated 8.1 per cent (MoF, 2021). These growth achievements have not meaningfully impacted the employment levels in Ghana.

The performance of Ghanaian labour market since the implementation of the SAP and successor policies and programmes remains a major challenge to whatever is achieved during the period (Panford, 2001). The strong growth performance over the past three decades could actually reflect in the lives of the citizens through creation of many and quality jobs. However, this has failed to happen over the years. The ILO reports that in 2008, the Ghana economy witnesses a decline in employment elasticity of growth from 0.64 during the 1990s to 0.4 between 2005 and 2008. In fact, this picture is not anything different from the situation in other countries in Africa. In spite of the recorded robust growth performance, employment creation remains a major challenge. Employment situation has been deteriorating with unemployment trends assuming upward trajectory.

The ILO estimates that in 2017 global unemployment is in excess of 190 million people, representing unemployment rate of 5.6 per cent compared to unemployment level of 169.8 million forming unemployment rate of 5.5 per cent in 2007 (ILO, 2019; 2018). In Africa, an estimated 37.8 million people are unemployed. This represents unemployment rate of 7.9 per cent in 2017 and it is projected to heighten by 2.3 million in 2019 while the associated rate of unemployment stays constant at 7.9 per cent per year from 2017 to 2019 (ILO, 2018). The report further indicates that the size of unemployment in Sub-Sahara Africa was 29.1 million (7.2%) in 2017, and it is projected to worsen to 30.2 million in 2018 and 31.3 million in 2019 with corresponding unemployment rate of 7.2 per cent and 7.3 per cent respectively. Youth (15-24 years) constitutes about 60 per cent of the jobless population in Africa with youth unemployment rate more than double the national and adult rates (Ighobor, 2017).

The unemployment situation in Ghana is alarming. Unemployment and informal employment are high and growing, youth unemployment is extremely high, and vulnerable employment has the greatest share of total employment. There is continuous surge in working poverty among the working class. In 2017, the unemployment rate in Ghana is estimated at 8.4 per cent (GSS, 2019) which is higher than that of Africa (7.9%) and the world (5.6%). The registered 8.4 per cent unemployment rate though lower than the 11.9 per cent recorded in 2015 (GSS, 2016), it is considered higher given current economy performances. Between 2006 and 2017, the national unemployment rate rose from 3.1 percent to 8.4 percent.

The situation is more threatening with the youth (15-24 years) than other age categories. Between 2006 and 2017, youth unemployment rate bloats from an estimated 6.6 per cent in 2006 to 25.9 percent in 2015, but decreases to 18.5 percent in 2017. Moreover, from 2006 to 2017, the youth unemployment rates are more than double the national unemployment rates. In 2006, the youth unemployment rate is estimated at 6.6 percent relative to 3.1 percent registered for the entire country; in 2013 the rate is 10.9 percent against 5.2 percent for the nation; in 2015 it stands at 25.9 percent compared to 11.9 percent for the country, and in 2017 the rate is 18.5 percent relative to the national unemployment rate of 8.4 percent. An estimated 77 percent of the Ghanaian youth has at most basic education qualification affecting their chances of employability (National Development Planning Commission [NDPC], 2019). The unemployment situation is expected to worsen given the continuous ravaging impacts of the COVID-19 pandemic on businesses and employment. One characteristic of the youth unemployment in Ghana is that it is higher among females (9.2%) than males (7.5%) due to relatively low educational attainment among females; and predominantly an urban (11.4%) than rural (5.2%) phenomenon largely due to rural-urban migration (GSS, 2019).

The economy is not able to generate enough jobs to meet the demand mainly because of rapid population growth, youth bulge, unbridled trade liberalisation and high lending rates (Otoo, 2018; Panford, 2001). The industrial sector, especially manufacturing, which is principally associated with employment-intensive growth is struggling behind the service and agriculture sectors (Figure 15).

The growth of youth population is about three times higher than that of the entire population. It is estimated that about 300,000 youth enter the labour market annually seeking for employment of various kinds, but only about two per cent is able to secure formal jobs (LO/FTF, 2016). This is an indication of willingness and desire of jobless and unemployed youth to work, the poor health of the economy, and the fast-deteriorating state of employment situation in Ghana. Since people cannot afford to remain unemployed and jobless in a society where there is absence of social support system for the unemployed, many jobseekers have been compelled to join the informal economy where there are no regulations, rights at work, social dialogue, and social protection. The informal economy has become a haven for the jobless, unemployed, and other job seekers, largely the youth and women.

This constitutes one of the reasons for the persistently high informal employment in Ghana. Available data suggest that of every 10 Ghanaian workforce, more than seven are engaged in informal enterprises and employment (as depicted by percentages in Figure 16).

The ILO 2018 World Employment Social Outlook (WESO) reports that, in 2017, an estimated 66 percent of total employment in Sub-Sahara Africa is in the informal or vulnerable employment. The report further describes Sub-Sahara Africa as the region with the highest rate of informal employment worldwide (ILO, 2018). This makes the employment situation in Ghana more disturbing because the 66 per cent described as the highest rate among the regions globally is about 5.3 percentage points lower than the rate (71.3%) recorded for Ghana in the same year. The high levels of unemployment and informal employment subject many Ghanaians particularly, the youth and women to economic hardship, migration and various forms of social exclusion. In 2013, an estimated 24.2 per cent of Ghanaian population is classified as poor (Otoo, et al., 2015). It is estimated that, from 2013 to 2017, the number of poor increases by nearly 400,000 (GSS, 2018).

Unemployment, however, circumvents gains associated with decent employment and potentially makes its victims poor and dependent on others. The consequences of unemployment on the life of an individual are enormous. Joblessness and unemployment constitute a major threat to all the benefits associated with employment. Long unemployment duration subjects the victims to severe hardship and challenges in diverse forms including poverty, loss of self-esteem, depression, poor health, delayed marriage, and increased likelihood of divorce (Kunze & Suppa, 2020; Doiron & Mendolia, 2012). Usually, unemployed people tend to migrate with the hope of finding jobs. Unemployment frustrates and creates dissatisfaction among jobseekers, and in most cases forces them into deviant acts (Baah-Boateng, 2013). It presents a threat to the peace and security of a country.

Unemployment induces migration aspiration and eventual migration among job seekers. Individuals and families migrate mainly to seek better economic opportunities elsewhere, either temporarily or permanently (Bonifacio, 2013). While many of the migrations are induced by economic prospects, others are driven by social well-being and quality of life. However, some people also leave their places of origin due to political contention and even dramatic variations in the environment in terms of temperatures and climate (Afifi & Jäger, 2010). In 2016, a projected 5,636 Ghanaians entered Italy by sea; where most of such irregular migrants usually find themselves in vulnerable situations (Ministry of Employment and Labour Relation [MELR], 2020; International Organisation for Migration [IOM] - Ghana, 2017). Thousands of youths and women loss their lives on the back of irregular migration annually. Available information indicates that between January and June of 2021, over 2,000 migrants mainly from West African countries died in their attempts to enter Europe through Spain and by sea using inflatable boats (AfricaNews, 2021, July 7). The rising reports of Ghanaian migrants trapped in forced labour, hazardous work, and sexual exploitations in the Gulf states is a demonstration of the lack of adequate employment opportunities, frustration and

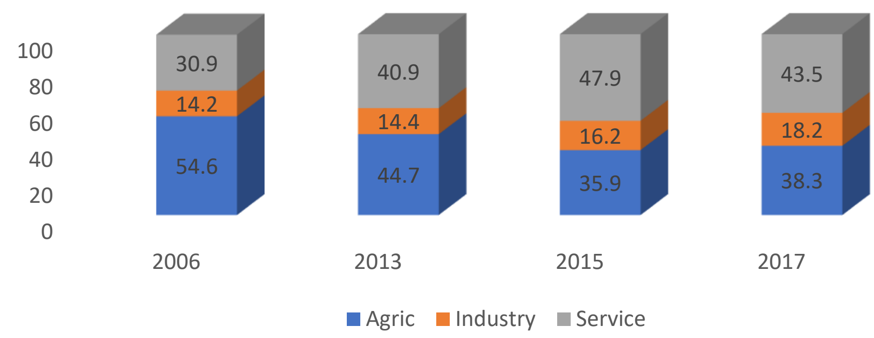

Figure 15: Employment Share by Sector (2006-2017) in Percentages

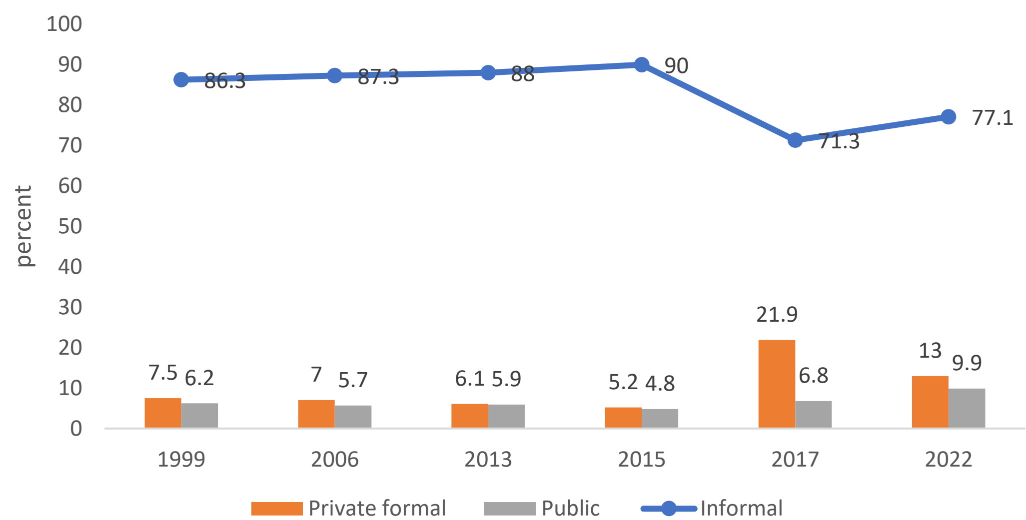

Figure 16: Employment Share by Institutional Sector (2006-2022) in percentage

desperation among the unemployed and jobless youth and women in Ghana.

The devastating impact of unemployment on an individual's subjective perception of social integration cannot be overemphasised, and such an effect tends to heighten the longer the unemployment duration (Pohlan, 2019). Unemployment impedes the fulfillment of an individual's self-esteem and self-perception. Most people lose their social ties and sense of belonging due to prolonged unemployment. Unemployment adversely influences income which eventually precludes individuals from meaningful engagement in economic, social, political and cultural undertakings. It poses a threat to relationships and marriages since it raises the probability of divorce or separation (Doiron & Mendolia, 2012).

According to Iledare and Olatubi (2004); Kaku (2018), discovery of crude oil is at all times associated with relieve and great optimism. However, just after few years into exploration and production, several oil producing economies begin to experience some negative shocks (Acquah-Andoh, et al., 2018). Crude oil production has not been able to create the jobs that it is expected and envisioned for its discovery. Attention can therefore be pai to the renewable energy production. There are abundant renewable energy sources in Ghana such as wind, solar, biofuels, hydropower and others. The question is can the production of renewable energy have impact on employment in Ghana? This study therefore seeks to analyse the effect of production of renewable energy on the employment rate and government expenditures of Ghana.

Summary of the Chapter

This chapter described in details the energy outlooks for Ghana. The production of crude oil, primary energy consumption and sources of energy in Ghana are presented. The global trends in renewable energy production and consumption were described in details. The chapter proceeded further to describe the revenue trends of cruel oil and how energy transition affects the macroeconomy of Ghana. The presentations of the chapter were mostly in figures.

CHAPTER THREE

LITERATURE REVIEW

Introduction

Theorical reviews are presented under this chapter from papers on topics related to the research problem are highlighted. The empirical reviews are also discussed in this chapter. It scrutinizes what various authors and academic scholars have studied and written about renewable energy and its effects. It presents studies on the effects of energy transition on energy security and access related to first objective of the study. Also, it focuses on the extent of the global energy transition rates on the petroleum economy which is the second objective of the study and effect of energy transition on employment in relation to the third objective. The objective is to acquire knowledge about the past, progressions, and future trajectories, to identify and justify the existing knowledge gaps that our study addresses.

Theoretical Reviews

The review of theories underpinning the study that relate to the objectives of evaluating the effect of renewable energy on energy security includes the perspective of liberalism and critical Theories. The theory that is related to the study objective of analysing the effect of energy transition on Ghana's petroleum export is the imperfect trade substitution theory while the dutch disease and human capital theories are concerned with employment creation objectives.

Perspective of Liberalism and Critical Theories of Energy Security

According to Wilson (2019), for the contemporary economy to function, reliable and economical energy supplies are crucial since they fuel infrastructure and industries. A liberal theory framework's fundamental presumptions are based on interstate cooperation and conflict. Neoliberal institutionalism, which emphasises liberalism and the function of institutions, has supplanted realism in the framework of energy politics, though not in practice, which is why it continues to be the dominating paradigm in this area. Liberals emphasise the participation of numerous actors like the UN, WB, and World Trade Organisation, as well as the banks of regional blocs to influence the energy supplies. They accept the state's crucial role in the international system when it comes to energy. For example, at the COP26, countries pledged to transit to clean power by 2040 (World Economic Forum, 2022). Also, in 2017, the WB ceased lending for coal-fired power station in 2010 and it was pressured from lobby groups in 2017 to stop the US$1bn (£750m) to developing countries every year for oil and gas lending lobby groups (WB, 2017). All these can affect affordable and reliable energy supplies.

The contribution of these entities and groups outside international borders implies that domestic trade unions; actors of the government such as the parliaments, presidents, state official and ministers; lobbying and local NGOs; NGOs; and individuals are important players. Even though tensions might exist among multinational cooperations and states, according to the liberal viewpoint, these could be in cooperation to achieve the best (Hancock & Vivoda, 2014). They play critical roles in energy security. The realist paradigm focuses on states pursuing their self-interest and attaining power in their relations with other states. On the other hand, liberalism acknowledges that global actors are not limited to states and that other actors can also have an impact on the global order. In a realist world, interest-driven power struggles are deemed crucial, and states prioritize their security.

In contrast, the liberal perspective holds that energy security cannot be achieved solely through the exertion of power, and that cooperation among states and other global actors is necessary to ensure environmental security. The liberal approach extends its focus beyond states to include international energy organizations, energy markets, as well as national and international energy corporations (Kilinç-Pala, 2021). This approach emphasizes the use of legal, economic, and institutional means to manage global energy relations in a coordinated manner, thus guaranteeing access to energy and ensuring energy security. By adopting a coordinated institutional approach from this perspective, transaction costs can be lowered, leading to reduced energy prices. Energy liberals argue that, without giving special significance to energy, the energy sector should be open to market forces, similar to other non-food commodities, and that the state's primary responsibility is to protect property rights and maintain market competitiveness. They believe that this approach will result in optimal energy demand and supply, ultimately leading to energy security.

Applying this theory, Nye (2004) and Keohane's (1984) argument does not completely disregard the conventional view of using military power. Instead, they suggest that traditional approaches should be complemented by cooperation to address modern vulnerabilities and weaknesses. For example, the US can achieve energy security by deploying naval forces to the Persian Gulf, but the same goal can be accomplished through other means, such as expanding domestic oil reserves, implementing an oil tax to encourage domestic protection, and strengthening collaboration with other international organisations (Keohane 1984; Nye 2004; Iledare, 2010).

The liberal perspective on energy security acknowledges the interdependence among global actors and their reliance on each other's energy security. Centralized states share a common interest in protecting and expanding market conditions, and conflict among great powers is viewed as slow as long as the current economic order prevails. Scholars studying the US withdrawal from Iraq and China's large investments in the region have adopted a liberal approach, crediting the stability of Iraq's energy flow to the international market and the common interests served. The liberal paradigm of the energy market is based on “the principles of a free market economy, where a competitive market will lead to optimal conditions for all actors. However, the energy supply chain appears to be more like an oligopoly than a perfect market. Despite this, liberalism emphasizes that energy exchange among states will result in mutual interdependence, leading to moderation among states in the global system. Realists, however, argue that this interdependence will result in an imbalance in favor of one side and ultimately lead to fragility for the more dependent side and the global system. Therefore, realists believe that liberal policies will not enhance states' security in the long run.

The critical theories that belong to the last category have a broad framework that examines the interplay between economic issues and the cultural-historical context, and considers the role of gender in economic relations both domestically and globally". According to Bridge, et al. (2018), a critical perspective is one that contextualizes a problem, such as energy, within its historical and cultural setting. Rather than disregarding or keeping social context constant, as many sciences do in their pursuit of scientific truth, a critical perspective actively seeks to comprehend how social and material conditions shape the problem. Bridge, et al. suggest that the aim of a critical perspective is to understand and explain in ways that promote social and environmental improvement, by being mindful of social structures and material practices.

Critical theory not only challenges the existing global order but also critiques the problem-solving approaches derived from that order (Cox, 1981). According to Okur and Ongur (2014), critical theory exposes how the boundaries and biases within international relations are influenced by economic, political, and historical contexts, which shape values and interests. In recent times, the definitions of energy and security have undergone changes, leading to significant shifts in the conceptualization of energy security. The transformation of energy into a security concern necessitates policy changes in the energy sector and the establishment of a robust position in the energy landscape. The evolving field of energy security studies has been greatly influenced by the changing dynamics of economic, environmental, political, and military factors (Buzan, et al., 1998).

Baumann (2008) suggests a definition of energy security that emphasizes the contributions of private or political actors in ensuring higher levels of safety. This definition outlines four interconnected dimensions of energy security: international policy, economic, geopolitical, and security policy dimensions. Critical perspectives on energy security surpass conventional analyses focused on states, interests, or institutions, and instead offer intellectual and sociological insights into the transformations observed in energy markets and politics.

Critical approaches to energy security focus on the individual level of analysis by connecting it with energy poverty. They move beyond the state-centric and instead offer sociological and intellectual enlightenment of the changes in energy markets and politics. These approaches, often considered normative and radical, argue that the interests of global elites and the most powerful states and corporations are served by the existing energy systems. They highlight the severe effects of climate change and pollution on people's health in some regions of the world. Critical perspectives aim to comprehend the energy sector in a way that challenges existing power hierarchies and seeks optimal energy production and consumption. By doing so, they offer alternative ways of thinking that cut across conventional divides, enabling the identification of relationships and processes that are often obstructed in conventional analyses. Applying critical theories can be useful in linking energy security with Ghana's context.

Imperfect Substitution Trade Theory

The world is moving towards a renewable energy transition in response to the challenges posed by climate change. Renewables including solar, wind, and hydropower, are being adopted as a means of reducing GHG emissions and mitigating the impacts of climate change. However, the adoption of renewables is not a straightforward process, and it is subject to the dynamics of the market, including the imperfect substitution theory. The Imperfect Trade Substitution theory is a concept in international trade that suggests that even in the absence of trade barriers, countries may not fully specialise in the production of goods that they have a comparative advantage in, and may still trade with each other (Goldstein & Khan, 1985; Rose, 1991; Rose & Yellen, 1989). This is because there are various factors that can prevent complete specialisation and perfect substitution of goods. The theory of imperfect substitution suggests that products or goods are not perfect substitutes for one another. This means that even if two products seem similar, they cannot be fully replaced by one another because they have unique characteristics that differentiate them. The process of transitioning from fossil fuels to renewable energy, however, is not without challenges. One of the key challenges is the concept of imperfect substitution, which suggests that renewable energy sources may not be perfect substitutes for fossil fuels. Wind, solar, and hydropower, may not be perfect substitutes for fossil fuels. Although renewable energy sources can provide energy, they have unique characteristics that make them distinct from fossil fuels.

One such factor is transportation costs. Even if a state has a comparative advantage in producing a certain good, the cost of transporting that good to other countries may be prohibitively high, making it more economical to produce the good domestically or in a nearby country. Another factor is technological differences between countries. An economy might have a comparative advantage in producing a good, but if they do not have the technology or expertise to produce it efficiently, they may not be able to compete with other countries and may instead import the good. Finally, there may be factors such as cultural differences or trade regulations that can limit the extent to which countries trade with each other, even if they have a comparative advantage in certain goods. Overall, the ITS theory suggests that while trade can be beneficial for countries, it may not always lead to complete specialization and perfect substitution of goods. Instead, countries may still trade with each other even if they have a comparative advantage in producing certain goods.

The Imperfect Trade Substitution theory can also be applied to the transition to renewables. According to Fleiter et al. (2018), while countries may have comparative advantages in producing certain types of renewables, such as solar or wind power, there are factors that can limit complete specialisation and perfect substitution. One such factor is the availability of natural resources. Thus, an economy with abundant solar resources may have a comparative advantage in producing solar panels, but may not be able to fully specialise in this area if they lack the raw materials needed for production (Fleiter et al., 2018). Another factor is the level of technological development. Even if a country has a comparative advantage in producing a certain type of renewable energy, they may not have the technology or expertise to do so efficiently, which could limit their ability to compete with other countries in the global market (Fleiter et al., 2018). Furthermore, trade regulations and cultural differences can also play a role in limiting the extent to which countries can trade in renewable energy sources, despite their comparative advantages. The imperfect substitution theory highlights the complexities involved in the transition to renewable energy sources, and suggests that countries may not fully specialise in the production of renewable energy goods and services, even if they have a comparative advantage in doing so.

Dutch Disease Theory

The Dutch disease theory is a situation where economies with little or no natural resources face high economic growth as compared to countries with natural resources (Sachs & Warner, 1995). That is, countries that have abundant renewable energy sources might abandon other sources of energy that might be detrimental to the economy. Chen (2019) and Barder (2006) took into consideration Dutch disease as the adverse consequence of petroleum exploration on a macroeconomy resulting from domestic currency appreciation. This might cause the export of the economy to be less competitive on the market despite the fact it boosts imports of goods and services. This is because it has become inexpensive relative to goods produced domestically, which results in the less industries coming up in the economy and hampers the economic growth (Humphreys, et al., 2007). This hinders the macroeconomic steadiness and the competitiveness of the manufacturing and agricultural sectors and an economy's sustainability externally. Renewable energy transition due to the availability of renewables could affect the macroeconomic stability. Corden and Neary (1982) asserted that this macroeconomic instability can occur mainly through two channels—spending and resource movement—effects.

The resource movement effect refers to a scenario where there is a shift in labour from other industries to the renewable energy sector due to the growing demand for labour in this thriving sector, as posited by Corden (1984) and Pegg (2010). This movement of labour leads to increased wages in the renewable energy sector due to higher marginal productivity. Consequently, it implies a decline in the productivity of traditional and non-conventional exports due to a reduction in the factors of production. The higher wages in the renewable energy sector also prompt labour in other sectors to demand wage increases that do not align with their productivity levels, potentially resulting in inflation.

Goods prices in the tradable sector remain unaffected as they are determined by the global market. However, a shift in the production factors would cause a rise in demand for non-tradable goods, which are domestically priced, leading to an increase in their price. According to Arezki and Ismail (2010); Sala-i-Martin and Subramanian (2003), this, in turn, could cause the real exchange rate to appreciate. Acheampong and Baah-Kumi (2011) pointed out that this results in a challenge of deindustrialisation within the economy. It is only feasible for skilled labour to move into the renewable energy sector if they possess the necessary skills required for the job.

Neary and Van Wijnbergen (1986) suggested that a surge in income resulting from increased revenue from oil discoveries results in the spending effect. Renewables production leads to a rise in government revenues via tariffs, royalties, and direct involvement in renewable energy production. This revenue will impact the fiscal balance and public debt levels of the government as a portion of it is allocated towards financing the government's budget and reducing the need for borrowing (Dartey-Baah, et al., 2012). The revenue obtained from the production of renewable energy is intended to be directed towards non-renewable energy sectors, specifically the agricultural sector, as the production of renewable energy might negatively impact these sectors. Government spending will boost household income, resulting in a rise in aggregate demand for both traded and non-traded goods which could cause inflation.

Human Capital Theory

Human capital comprises any stock of energies (including renewables in our current generation), knowledge, skills, habits and characteristics that enhance workers' productivity and ultimately contribute positively to making them industrially efficient (Kenny, 2019). According to Schultz (1961), human capital is one of the essential resources that aid national growth of the modern economy. Becker (1964) established that human capital is valuable in the production process because it raises productivity of a worker in all tasks but with some degree of variation across tasks, industries and situations. In this case, provision of renewable energy should be able to make labour more efficient and productive.

With the onset of discipline of human capital discipline, some scholarly writers and researchers in particular extensively interrogated the medium through which human capitals promote socio-political development and freedom (Fitzimons, 1999; Sen, 1999; Grubb & Marvin, 2004). The human capital concept can be grouped into different categories based on the varied perspectives of academic disciplines (Fitzimons, 1999). The first argument emphasises the individual aspects. Schultz (1961) acknowledged human capital to be analogous to property classical paradigm of labour force concept, and further conceptualised that the human productive capacity is much greater than all forms of wealth combined. Some studies (Youndt, Subramaniam, & Snell, 2004; Garavan, Morley, Gunnigle, & Collins, 2001) have established that the human capital could be closely associated with energy, education, knowledge, skills, and abilities.

Another argument is about the human capital processes of its accumulation developed through education undertakings like compulsory basic education, post-secondary education, and vocational education (Alan, Altman, & Roussel, 2008). The third proposition is in line with the production-oriented argument of human capital. Romer (1990) considered the human capital as an essential source of economic productivity. Also, human capital can be thought of as a combination of factors including intelligence, work, initiatives, education, experience, training, energy, and trustworthiness that influence the value of a person's marginal productivity (Frank & Bernanke, 2007). Within the context of the production-oriented standpoint, the human capital is considered as the stock of knowledge and skills found in the ability to perform for the purpose of producing economic value (Sheffrin, 2003). Moreover, Rodriguez and Loomis (2007) explained human capital as the individual specific traits such as socio-economic wellbeing, attributes, skills, knowledge, and competencies easing socio-economic and personal creations.

Good human capital enhances labour market outcomes for workers in terms of employability, earnings among others. Workers with specific education and training have limited motivation to exit a company, and companies also have less incentive to sack them than workers with little or no education and training (Becker, 1964). The implication is that quit and dismissal rates are negatively correlated with the level of education and training. Moreover, a person's success is in the labour market is influenced by investments in human capital including education, training and experience in the labour (Shumway, 1993; Becker, 1974). Thus, highly developed human capital enhances employability, reduces unemployment, and shortens the length of unemployment spells among job seekers, all other things held constant.

Empirical Literature Review

This section reviews related studies undertaken by other researchers. Specifically, this review considers studies on energy security and accessibility with specificity on renewable, effects of renewable energy consumption on petroleum exports of Ghana, and effects of renewable energy on macroeconomic indicators of Ghana. The rationale is to be abreast of the existing studies on the topic under study. It helps to identify gap(s) in the existing studies on the issues being studied, thereby avoiding duplication of studies. The summary of the empirical reviews is presented in Table 2.

Effect of Renewable Energy on Energy Security

The contribution of energy to the sustainable development of every economy is well placed in literature with greater consensus held that, in the absence of availability, accessibility, affordability, and reliability of modern and clean energy services and technologies, sustainable development becomes unattainable (Bhattacharyya, 2013). Aslanturk and Kıprızlı (2020); Augutis, Martišauskas, Krikštolaitis, and Augutienė (2014); Nie and Yang (2016) examine renewable energy strategies and energy security. The results of these studies indicate that strategies of renewable energy enhance energy security by reducing emissions and reducing consumption of conventional energy. Khennas (2012), investigating the major drivers of energy access in North and Sub-Saharan Africa, underscores the need for a significant amount of financial resources for long-term investment and development strategies to ensure energy accessibility. Khennas argues that expanding the energy infrastructure base for the North and Sub-Saharan economies is a precursor for increasing energy access. Long-term investment in the energy sector will require enormous revenue, the oil exploration and production to some of these economies in the Sub-Saharan regions.

To determine the governing factors of development of renewable energy in Chana, Wang, Wang, Wei, and Li (2018) apply a Divisia index approach in forecasting these requirements between 2020 and 2030 using the Grey relational model. The findings of the study indicate that energy securities have the most important influence on the development of renewables. Energy security and substitution rate have comparatively closer relations with new and total consumption of renewables which play key roles than other factors. The analyses of the scenario results indicate that robust and unending policies of renewables would aid in achieving sustainable energy development for China and a strong synergy between energy security and renewables could come up in the future.

However, Gökgöz and Güvercin (2020) show that low-priced and plentiful natural gas exploration and production restrict the research on energy technologies predominantly after 2010 in the energy markets. The analyses of the study based on the data envelopment analysis indicate that biofuels and wind energy technologies are the efficiency leaders in research and development. This is because each amount spent on them has a greater impact than other renewables types on energy security.

In another study, Ibrahiem and Hanafy (2021) empirically explore the relationships among the use of energy, economic growth, consumption of renewables, CO2 emissions, trade openness, population, energy security, and FDI in North African countries. The authors utilise Panel ARDL and Granger causality approaches for the analyses. The study shows that FDI, economic growth, CO2 emissions, and trade openness activate renewable energy. According to the authors, this is the reason policymakers are not able to overlook them as they design policies that aim to accelerate the change to renewable energy. Conversely, the use of energy, energy security, and population hinder renewable energy. Besides, there is a reciprocal cause-and-effect relationship between energy security and economic advancement, and factors such as energy security, foreign direct investments, and environmental degradation contribute to the development of renewable energy sources.

Bekhrad, Aslani, and Mazzuca-Sobczuk (2020) assess the potential renewable energy of Andalusia and the its associated effect on the energy supply security. The authors calculate the total level of Andalusia's energy security and make comparism with other countries. The results reveal that solar, on/off-shore wind, and bio-energy are the most promising renewables to achieve energy security.

Also, Cox, Beshilas, and Hotchkiss (2019); Ríos-Ocampo, Arango-Aramburo, and Larsen (2021) analyse and measure the renewables progressive increase impact on energy security in short-term electricity markets. The authors develop dynamic system models to evaluate different scenarios and certainties' levels. The study is based on the analyses of different renewables' shares impacts on energy security over resilience, reserve margin, reliability, and vulnerability measures. The results of the study indicate that high renewable resource shares have impacts on energy security. That is, renewables impact resilience, reliability, vulnerability and reserve margins. Also, they might reduce the spot price due to zero variable costs and therefore lower conventional firms' profit in the short-run and give closure to firms in the middle term and long term.

Similarly, Lucas, Francés, and González (2016) utilise panel data to examine the impact of renewables on energy security in European Union countries. Different concepts of energy security are employed. The study indicates relationship between energy security and deployment of renewables. The study, however, shows that the relationship is not forthright and relies on a particular strategy of energy security, which is connected to diverse energy security conceptualisations.

In contradiction to the previous studies, Brew-Hammond (2010) analyse the challenges ahead of universal energy access in Africa, and the author emphasises that in the quest to achieve enhanced energy access as guided by the agenda 2020, economies in Africa will require an enhanced approach to mobilising both foreign and domestic finances. The author emphasises that energy should be used for income generation to ensure economic development. Brew-Hammond (2010) also acknowledges that in as much as economies may want to ensure energy access, funding remains a constraint. Oil revenue, therefore, could provide a competitive advantage in financing such developments.

Chirambo (2017), on the other hand, also analyses project reports, policy briefs, case studies, and research publications in the investigation of sub-Saharan Africa's journey towards the achievement of SDG7 (Agenda 2030). The author concludes that sub-Saharan Africa might be unable to achieve the desired energy access. This is because it is observed that although there have been efforts with the abundant crude oil, electrification of the rural parts of the region is key.

Differing in perspective, Viviescas, et al. (2019) analyse the renewables contribution potentials in ensuring security of energy in the short- and long-terms. The authors adopt two main approaches to analyse the variability and seasonality of renewables in the Latin America and their probable complementarities, possible impacts on future long-terms solar and wind resources as a result of climate change. Applying General Circulation Models, the study shows a lower variability for solar when compared to wind for both monthly and hourly scales. However, Bhattacharyya (2012), using a simple multi-dimensional sustainability analysis, argues that despite efforts of several economies in ensuring energy access, the initiatives to enhance energy access are neither sustainable nor developmental driven. Bhattacharyya opinionated that too much emphasis has been placed on electrification, yet in achieving development and sustainability, there is the need for a rebalancing approach to energy access. From the foregoing literature, funding and policy initiatives for energy sustainability remain key. This, according to Bazilian et al. (2013), will require the utilisation of wealth accrued from oil to increase energy access. This lays good foundation for industrialisation and puts the economy on the path of economic growth and development.

Pueyo, Bawakyillenuo, and Osiolo (2016), in a report, evaluate the costs and returns of renewables by making comparison between Ghana and Kenya. The report suggests that allocating funds for the provision of green electricity in sub-Saharan Africa should be guided by financial viability and affordability. The study recommends policymakers to provide solutions to these key issues. In the work of Demski et al. (2017), the authors opine that, as heavy emphasis is placed on climate-friendly energy policies, affordability brings another challenge. The authors suggest that policy initiatives in addressing the challenge of affordability should go beyond energy pricing. Deichmann, Meisner, Murray, and Wheeler (2011) opine that fast-tracking development in SSA would demand funds in expanding electricity access. Diechmann et al. focusing on the renewable energy expansion in rural SSA, suggest to economies to decarbonise the fuel mix.

Diawuo, Scott, Baptista, and Silva (2019) assess the costs of climate change contributions in the case of Ghana's electricity system. The authors, using scenarios, find that it will require US$13 to US$17 billion to expand Ghana's generation capacity to ensure access which will result in an additional cost of 11-39 US$/tonne to meet different emission targets by 2040 to ensure environmental sustainability. Pueyo (2018) affirm that Ghana faces budgetary constraints and that ensuring energy security and environmental sustainability will require new sources of finance.

Azzuni, et al. (2020); Hamed and Bressler (2019) indicate that the vulnerable political situation in Israel and Jordan emphasises renewables contributions security of energy through the generation of domestic electricity. The growing reliance on natural gas in these two countries and striking nature of oil shales and nuclear options have effects on deployment of renewables. Despite the fact that these two countries emit little GHG, increasing the renewables amounts is very important to maintain climate change goals. Nepal, Musibau, and Taghizadeh-Hesary (2020) evaluate the role renewables paly to deliver security of energy in the ASEAN region using Westerlund cointegration and granger tests in evaluating the relationships. It is indicated that, there exists a long-run relationship between renewables and security of energy for the region which is consisted with other estimators.

Latif, Raza, Chaudhary, and Arshad (2020) examine the association among demand for energy, energy crisis, energy security and supply, and renewable energy capacity in Pakistan. The authors apply scenarios and Market-Allocation methods on nonrenewables and renewables during the period of 2014-2035 in proving the energy situation. The results indicate that renewables are the best option that reduce risks of energy. Trifonov, Trukhan, Koshlich, Prasolov, and Ślusarczyk (2021) seek to evaluate the degree of changes of renewables shares, structural complex, and the energy security levels in Asian and European countries. The analyses of the study are based on modeling and determination of the structural features of energy security are shown to be interconnected. The high degree of influence of renewables on energy security in these countries is proven in the application of the developed scenarios for its intensification. According to the study, energy security for these countries is growing.

It could be deduced from the afore-reviewed studies that different factors influence energy security in different countries and regions. Individual specific-characteristics, locational factors, and state policies on energy transition in some jurisdictions influence energy security and access to transit from fossil fuel to renewables. Thus far, literature shares the consensus that ensuring energy accessibility, affordability, and sustainability requires conscious financing. Also, in spite of the extensive studies on energy security none considered the case of developing countries such as Ghana where financing is a big issue. In Ghana, very little if any could be said empirically about technical knowledge on renewable energy production to influence energy security. Since studies have been silent on renewables on the effect of energy security on Ghana, this study seeks to expand on the existing studies on energy security situation in Ghana, and the growing knowledge on renewables in general by examining the effect of energy transition on energy security and access in Ghana.

Effects of Renewable Energy on Export of Petroleum

Umbach (2010) analyses geopolitical and global dimensions of international energy security in the future and how it influences the European markets. The author discusses to which extent the EU's newly proclaimed Energy Action Plan and their common energy policies are sufficient to handle geopolitical and worldwide issues. The study asserts that if the union is able to implement their agreed decisions, the petroleum demand of the EU could decrease considerably and freeze at current levels. Considering this perspective, it can be demonstrated that Russia's energy policies, along with its utilization of energy as a political tool to advance its economic and geopolitical objectives, will ultimately undermine its own long-term strategic interests. This will aid in the reduction of gas export of Gazprom to a very significant amount in the EU markets than the original forecasts. This is achievable due to the cautious efforts of the union to reduce overall gas demands and diversification of the union’s imports of gas.

Waziri, Hassan, and Kouhy (2018) analyse the impact of increased renewable energy consumption in advanced countries with high income (NEICs) on Nigeria's exports of petroleum. They use a macroeconomic annual time-series dataset from 1980 to 2014 and apply an ARDL bounds testing approach. The results of both the short-term and long-term ARDL models indicated that the increased consumption of renewable energy in developed NEICs had a negative effect on Nigeria's exports of oil and gas, leading to a significant decrease in revenue generated from these exports.

Van Hoang, et al. (2020) evaluate the effect of renewable energy consumption on industrial production utilising the wavelet techniques and granger causality. Their study finds that there is positive co-movement between industrial production and consumption of biomass energy in the long run. The granger causality test reveals bi-directional predictability between consumption of renewables and industrial production in periods of crisis.

Bilgili (2015) employ wavelet analyses to find that consumption of renewable energy has positive effects on industrial production in the US. In the same vein, Ben-Salha, Hkiri, and Aloui (2018) examine the lead-lag relationship between aggregate and sectoral consumption of energy and the output using the wavelet power spectrum and cross wavelet over the 2005–2015 period. The results of the study indicate that the industrial sector exhibits the highest intensity of wavelet coherence with the sectorial output. This result confirms the interest to study the relationship between disaggregated consumption of renewable energy and industrial production, specifically, petroleum production, as it is done in this study. This study is related to the consideration of the fossil fuel industry which has come under serious criticisms in the face of global climate change goals.

However, Xie, Zhang, and Wang (2021) employ Global Malmquist-Luenberger method and find that the relationship between energy consumption transition and productivity is inverse N and non-linear. That is, too high or too low degree of consumption of energy transition does not enhance productivity.

In Marques, Fuinhas, and Manso (2010) work, their research identifies a substitution effect between natural gas and renewable energy sources, revealing a positive correlation between natural gas prices and the proportion of renewables in the energy supply. However, only a few studies have found evidence of complementarity between these energy inputs. For instance, Kumar, Fujii, and Managi (2015) highlight complementarity between renewables and non-renewables among their findings. Additionally, Lee, Zinaman, Logan, Bazilian, Arent, and Newmark (2012) propose a complementary relationship between renewable energy sources and natural gas, attributing this relationship to environmental, political, economic, and technical factors.

Shrimali and Kniefel (2011) find that in the US, there is a positive relationship between the total net energy generation and the proportion of renewable energy sources, such as wind, solar, biomass, and geothermal energy. On the other hand, Stockl and Zerrahn (2020) study the degree of substitution between renewable and non-renewable energy sources, and concluded that a balanced mix of various renewable energy sources can replace the conventional non-renewable energy sources. There is currently a significant degree of uncertainty when it comes to predicting future oil demand, as indicated by recent forecasts and scenarios.

Bradshaw, Van de Graaf, and Connolly (2019), according to their findings, the shale revolution and the decreasing costs and swift adoption of renewable energy are establishing the groundwork for a new oil landscape that poses a challenge to the economic well-being of oil-exporting nations. The study also reveals that future oil demand dynamics exhibit considerable uncertainty, presenting a comparative evaluation of the world's major oil exporters, specifically Russia and Saudi Arabia.

Stern (2012) argues that the lack of agreement regarding the relationship between energy products can be influenced by various factors, including the nature of the data used, sample size, methodological framework employed, and the specific class of economic variables considered. Due to the limited research conducted on the impact of energy transition on oil-exporting nations, this study seeks to investigate the substitution dynamics between crude oil and renewable energy. This will be achieved by estimating the import demand function for four major countries that heavily consume crude oil. Additionally, the study aims to identify the long-term relationship between the dependent variable and a set of explanatory variables for each country in the sample. The research also examines the economic, structural, and demographic factors that influence the demand for crude oil in countries that rely on oil imports.

In Khan and Shaheen (2020) study, the authors of this study use a dynamic framework to examine the extent of substitution between renewables and fossil fuels with time-varying parameters within a state-space model. Their analysis specifically focuses on four major countries that heavily rely on oil imports. The study utilises annual time series data spanning from 1991 to 2018, encompassing variables such as crude oil imports, gross domestic product, crude oil prices, renewable energy consumption, population growth, real effective exchange rates, and industrial production indices for each country in the sample. The findings reveal a statistically significant, albeit small, negative elasticity between renewable energy consumption and the demand for imported crude oil in India, China, and Japan. However, the substitution effect is found to be both statistically insignificant and small for the US.

Onyije, Nwaozuzu, and Iledare (2018) evaluate the dynamic nature of the global energy landscape in order to provide Nigerian economic and policy makers with relevant information. This will help position the country appropriately to maintain its relevance both regionally and globally. Onyije et al. utilize global statistics and scenarios related to energy supply and demand dynamics to assess the implications for Nigeria's oil and gas sector, as well as identify potential market opportunities. The analysis conducted in the study reveals that Nigeria's oil and gas exports may encounter intense competition in the international oil market (Onyije et al., 2018).

These impressive studies have analysed the effect of renewable energy consumption on the economy of petroluem economies. In spite of the abundance of studies on crude oil, there are very few studies on emerging oil-producing countries such as Ghana. Most of the studies mainly focus on countries that are members of OPEC and countries in the Middle East, whereas studies on emerging oil economies from SSA such as Ghana are limited. The analyses available have been mainly on panel analyses, stressing on advanced exporters and producers of crude oil which include the Gulf Corporation Council (GCC) countries, the OPEC countries and the ASEAN-5 (Philippines, Singapore, Malaysia, Thailand and Indonesia).

The analyses have always been on the effect of renewables consumption on the OPEC countries. These countries are advanced in terms of petroleum production and export. Some of these countries do not even rely heavily on export of petroleum. Also, the analyses are made on the import of petroleum by the importing countries. The use of import values may be misleading since the importing countries always import from different countries and therefore the analyses may be erroneous. To fill these gaps, the study analyses the effect of renewable energy consumption by importing countries on the effect of petroleum export of Ghana. Using a single country study allows you to account for the variability of a peculiar character of that country.

Effect of Renewable Energy on Employment

Almutairi (2020) examines dynamic effect of oil prices fluctuations on unemployment using a bivariate SVAR model and finds that positive oil price shocks decrease unemployment in Saudi. Raifu, et al. (2020) employ both linear and non-linear autoregressive distributed lag and find that there is little effect of oil prices changes on unemployment rate in Nigeria in the short-run but NARDL shows that in the long-run increases in oil prices make the unemployment situation worse but decreases has no effect. This implies a long-run asymmetric relationship between employment and oil prices changes. Using bivariate GARCH-in-Mean VAR, Koirala and Ma (2020) find that increase in oil prices reduces employment growth mostly in the private sector although the public sector is not affected.

Similarly, Michieka and Gearhart (2019) find long- and short-runs causality between oil prices dynamics and employment in four sectors in the top oil producing regions in the USA. Alkhateeb et al. (2017) discover that higher prices of oil have a significant effect on employment in Saudi Arabia. All these insightful studies have concentrated on other economies and have neglected the unemployment situation in Ghana which could be attributed to a lot of factors that could include global energy transition. Studies have to be conducted on Ghana relating unemployment or employment rate to energy transition. The persistence increases in renewables may have significant impact on employment. Hence, this study fills the gaps by analysing effect of energy transition on employment or unemployment in Ghana.

Khan and Shaheen (2020) analyse the degree of substitution of fossil fuels for renewables using a dynamic framework of time-varying parameters. The study results reveal that there is a significant negative elasticity between consumption of renewables and demand for imported oil for the Asian countries. To examine renewable energy consumption impacts, Fan and Hao (2020) estimate the relationship among GDP, FDI, and renewable energy consumption in China. The authors find a continued long-run equilibrium relationship among them, showing boosts in the renewable energy consumption in case of a modest slowdown in FDI and GDP. Similarly, Le, Chang, and Park (2020) analyse and find that there are significant relationships between economic growth and renewable energy consumptions in 120 sampled countries.

Grabara, Tleppayev, Dabylova, Mihardjo, and Dacko-Pikiewicz (2021) evaluate the existing relationship among economic growth, FDI and consumptions of renewable energy in two countries—Uzbekistan and Kazakhstan. Using the Granger causality test and Johansen co-integration test approaches, they find that there is a two-way link between FDI and consumption of renewables. The empirical results verify the existence of co-integration between the series. In different studies, Alper and Oguz (2016); Saidi and Omri (2020); Shahbaz, Raghutla, Chittedi, Jiao, and Vo (2020); Troster, Shahbaz, and Uddin (2018) examine the causality that exists amongst consumption of renewables, labour, capital and economic growth by utilising ARDL and asymmetric test approaches. The study finds that renewable energy consumption impacts economic growth positively.

Similarly, Inglesi-Lotz (2016); Rahman, and Velayutham (2020); Zafar, Shahbaz, Hou, and Sinha (2019) evaluate the cross-sectional dependence on the Asia-Pacific Economic Cooperation. Applying the Continuously Updated Fully Modified OLS, the results of the study show the stimulating role of consumption of both renewables and non-renewables in economic growth. Also, the individual country analyses indicate positive relationship between economic growth and renewable energy those Asia-Pacific countries.

Conversely, Wang, Zhang, and Wang (2018) find that “renewable energy consumption does not improve the situation of the human development process in Pakistan using two stage least square. More, interestingly higher the income of the country the lower is level of human development. Additionally, the CO_2 emission is helpful to improve human development index. Furthermore, causality analysis confirms feedback hypothesis between environmental factor and human development process in the long run path. Also, Ivanovski, Hailemariam, and Smyth (2021) use local linear dummy variable estimation of the non-parametric modelling technique and find that consumption of renewable energy has no significant impact on economic growth on OCED nations.

In view of pressing unemployment problems, policy makers across all parties jump on the prospects of renewable energy promotion as a job creation engine which can boost economic well-being. Böhringer, Keller, and Van der Werf (2013)’s analytical model shows that initial labour market rigidities in theory provide some scope for such a double dividend. However, the practical outcome of renewable energy promotion might be sobering. The computable general equilibrium analysis of subsidised electricity production from renewable energy sources in Germany suggests that the prospects for employment and welfare gains are quite limited and hinge crucially on the level of the subsidy rate and the financing mechanism. According to the study, if renewable energy resources subsidies are financed by labour taxes, welfare and employment effects are strictly negative for a broad range of subsidy rates. The use of an electricity tax to fund RES-E subsidies generates minor benefits for small subsidy rates but these benefits quickly turn into significant losses as the subsidy rate exceeds some threshold value.

Majid (2020) finds that that the majority of employment in the renewable sector is contract based, and that employees do not benefit from permanent jobs or security. Again, the study fins s that continuous work in the industry has the potential to decrease poverty and most poor citizens encounter obstacles to entry-level training and the employment market due to lack of awareness about the jobs and the requirements. Further Majid finds that few renewable programmes incorporate developing ownership opportunities for the citizens and the incorporation of women in the sector and the inadequacy of data makes it challenging to build relationships between employment in renewable energy and poverty mitigation.

By conducting a meta-analysis of the empirical literature on the net employment effects of renewable energy, Stavropoulos and Burger (2020) evaluate the extent to which the reported net employment effects are driven by the applied methodology. The authors find that the reported conclusions on net employment effects are to a large extent driven by the methodology that is applied, where Computable General Equilibrium (CGE) and I/O methods that include induced effects and studies that consider only the near future in their study period (up to 2020) are generally less optimistic about net employment creation in the wake of the energy transition. In addition, the authors find that policy reports have a greater tendency to report a positive net employment effect than academic studies.

Blanco, Ferasso, and Bares (2021) evaluate the effects of the regional production of clean energy, identifying the employment generated in the renewable sector. The adopted methodology is the shift-share analysis, frequently used by researchers to analyse territorial differences. The study results indicate important differences, at regional level, in the production of this type of energy. Likewise, the authors use constant shift and constant share methodology to make a forecast on the evolution of the sector from the data of last published years. The results obtained in the study allow the identification of the regions that show a favourable evolution to the energy change and identifies the projects that generate employment and production in the sector.

Zhao and Luo (2017) study the development of renewable energy in China by examining the driving force of environment quality, regulation and employment on renewable energy generation. The authors adopt renewable energy as a metric for environment quality, and test the relationship between renewable energy and income using Environment Kuznets Curve (EKC) theories. The impact of employment on renewable energy is tested, and dummy variables are used to indicate when the regulation was in effect. The results show that there exists a quadratic relationship between renewable energy and income. But the results fail to provide that the renewable energy generation is a job creator when the lagged unemployment rate is included as an explaining variable. The authors consider the employment population, and the finding shows that the employment can promote the development of renewable energy. The regulation has significantly positive impacts on renewable energy. The interaction of income and employment show that along with the income increases, the impacts of employment on renewable energy decrease.

Nasirov, Girard, Peña, Salazar, and Simon (2021) analyse the impact of renewable energy technologies from the perspective of job creation opportunities in Chile. For this purpose, Nasirov, et al. introduce an analytical assessment model that is used to assess the direct impacts on employment generated by several policy scenarios aimed at reducing CO_2 emissions. The direct impacts on employment in Chile are calculated up to 2026 according to three energy scenarios constructed using the SWITCH-Chile energy model. The empirical results show that renewable energy technologies (solar PV, wind, hydro) can generate more employment per unit of energy than coal and natural gas. According to the scenario projecting the largest reduction of CO_2 emissions, which features a dominant participation of renewable energies, up to 20,958 jobs can be created in the Chilean energy sector by 2026" (Nasirov et al., 2021, p. 3-7).

In contributing to the discourse on dynamic nexus of consumption of renewables and employment, Apergis and Salim (2015) employ nonlinear cointegration and causality analysis. The study reveals mixed results about the impact of consumption of renewables on unemployment. Even though there is positive effect of renewables consumption, disaggregated data across particular regions, such as Latin America and Asia, indicates the favourable effects on rates of unemployment. This means that renewable energy consumption effects on employment relies on energy efficiencies and the renewable energy technologies adoption costs which differ from the regions of the study. Ibrahiem and Sameh (2020); Moyo, Dingela, Kolisi, Khobai, and Anyikwa (2017) use the ARDL and find that clean energy (renewables) has an adverse impact on unemployment. However, Özsoy and Özpolat (2020) find that there is a bidirectional causality relationship between renewable energy and employment in the countries in the BRICS (Brazil, Russia, India and China) and MIST (Mexico, Indonesia, South Korea, and Turkey) with bootstrap granger causality analysis.

It is clear that these impressive studies focus on economic growth, specifically aggregated GDP of the selected countries in their empirical analyses. However, different sectors of the economy of a country are most probable and expected to be balanced by either a surplus or a deficit of other sectors. GDP consists of many macroeconomic variables and summing them up might not reflect the true situation of global oil demand effect. These remarks lead this study to suspect that aggregation measures are susceptible to biasness, which is an important shortcoming of their studies.

GDP of Ghana has to be disaggregated for better analyses. We can only achieve a deeper understanding and thus an extra precise valuation of the global energy transition from fossil fuel to clean energy on the vulnerability of the Ghanaian economy by using time series analyses. Also, some of the studies have been conducted on countries that have advanced in petroleum production. This study identifies general deficiencies in the evidence, highlighting specifically the lack of attention paid to the necessary provisions, cost, and macroeconomic indicators implications. Also, there is a bias in the literature to deal with the energy security of importers and not that of exporters. Most of the scholarly works deal with the energy security consideration of the advanced countries consisting mainly of countries that import energy.

It is therefore clear that there is still sufficient scope to contribute to literature by considering the experiences of Ghana in dealing with the global energy transition. Hence, the need to conduct the effect of transition from fossil fuel to renewables on employment in Ghana. Our study analyses energy transition on the vulnerability of employment in Ghana. Thus, the study focuses on determining whether share of renewable energy production affects employment in Ghana.

Conceptual Framework for Renewable Energy Transition and Economic Outcomes

Accordingly, the impact of renewables production and exploration on economic outcomes (energy accessibility, availability, affordability, government revenue, employment and petroleum exports from Ghana) is of three pathways. The conceptual framework of this is presented in Figure 17. The first pathway is where processed produced renewables and natural gas are refined or processed and supplied to the domestic market, thereby impacting economic outcomes (energy accessibility, availability, affordability, government revenue, employment and petroleum exports from Ghana).

The second pathway is when the renewable energy and natural gas serves as an input for Ghana's thermal plants to generate electricity and increase electricity extension; consequently, improving energy accessibility, availability, affordability, government revenue, employment and petroleum exports from Ghana. Although, Ghana's renewable energy and natural gas is not sufficient to fire the thermal plants, through the West Africa Gas Pipeline, Natural gas is imported to Ghana, albeit the unreliability of the refineries since it relies on Light Crude oil.

The third pathway, mostly concerned by the Ghanaian government, is the receipts accrued from the renewable energy production. This is because petroleum production accrues revenue to government. The main fiscal instruments applied by government to export of petroleum rents are carried and participating interests (59.47%), royalties (24.4%), and corporate income tax (15.91%), although surface rentals (0.13%) and additional oil entitlements have also contributed. Ghana's petroleum revenue management (in terms collection, allocation and utilisation) is then guidedby the Petroleum Revenue Management Act (PRMA) 2011 (815). From the petroleum revenue management framework, out of other major areas of revenue allocations, the Annual Budget Funding Amount (ABFA) serves as the key conduit for petroleum revenue to support development financing. The PRMA recommends that not less than 70 percent of the ABFA is utilised for public expenditure; thus, supporting Ghana's annual budget. This serves as channels to expand Ghana's electricity infrastructure base and make energy available, accessible and affordable through subsidising electricity tariffs and LPG prices.

The conceptual framework displays the diverse channels via which the production and consumption of renewable energy affect energy accessibility, availability, affordability, employment and petroleum exports from Ghana. Energy security and access have a direct correlation with economic performance. This economic performance includes employment and rate of unemployment as well as government revenues which affect government expenditure. All these economic performances have been found in the literature to be positively affected by production of crude oil. Thus, the exportation of crude oil could cause the increase in government revenue through trade.

According to the PIAC (2012), governments initiate the oil revenue spending effect, as it receives taxes, royalties, and trade tariffs from international trading. Additionally, the government gets a share of the revenue generated from the production of crude oil. This revenue is utilised to finance the government's expenditures, which can have an impact on the fiscal balance position. The government utilizes this revenue to finance various sectors such as agriculture, health, education, and infrastructure, which helps to improve their performance. There is still inadequate investment in distribution infrastructure although there is excess grid capacity (Acheampong, et al., 2021).

The energy sector supplies energy to various sectors including agriculture, manufacturing, and services, which benefit from the availability of electricity and fuel. These sectors also impact the exchange rate and inflation. Export and import

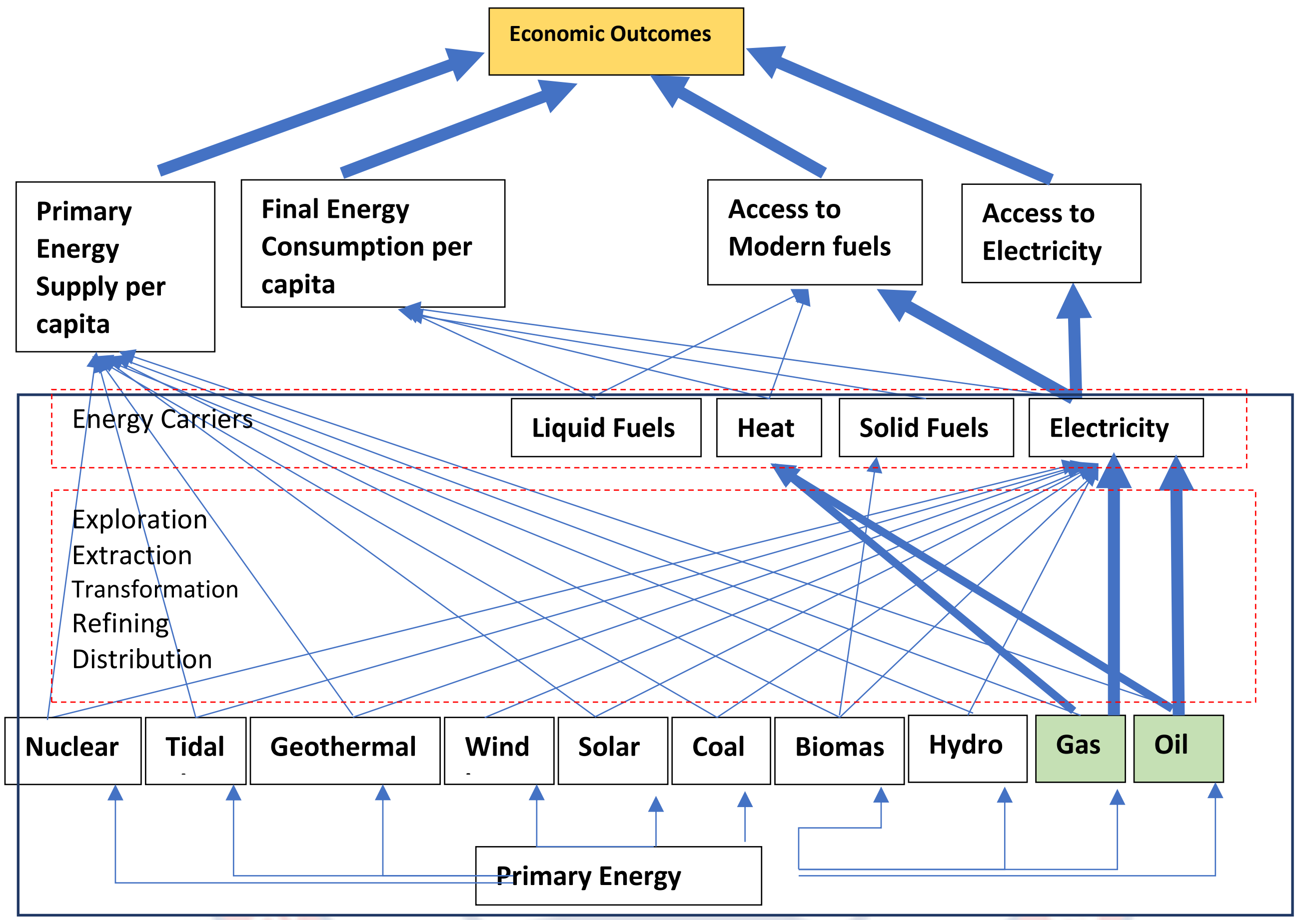

Figure 17: Conceptual Framework of Renewable Energy Transition on Economic Outcomes

of goods and services by these sectors influence the exchange rate. Additionally, the cost of production in these sectors has a direct impact on inflation since it is reflected in the prices of goods and services. If production costs are low, the prices of goods and services tend to decrease, and vice versa. Furthermore, the market availability of goods and services can also affect prices. If goods and services are scarce, prices tend to rise due to high demand, and if they are abundant, prices tend to fall due to low demand.

With this in mind, transition from fossil fuels to renewables might affect the macroeconomy of Ghana. As such, renewable energy production and consumption should be able to accrue revenue to the government to achieve all these economic outcomes before its adoption. Consumption of renewables might affect the level of employment and government revenue. This is because many developing countries such as Ghana do not have sufficient and available technologies to harness the renewable energy. According to Amoah et al. (2020), this is due to unfavourable market conditions, low average income levels, weak institutions, and technical inability to harness renewables. There is, therefore, the need to examine the effect of energy transition on the macroeconomy of Ghana in terms of government revenue and employment.

Summary of the Empirical Reviews

Table 2 displays the summary of the empirical literature reviewed related to the objectives of our study. The authors, methods, objectives, and the gaps identified in the various studies are presented.

Table 2: Summary of the Empirical Reviews

Author(s)	Paper Objective	Methods	Gaps
Effect of Renewable Energy on Energy Security			
Chana, et al. (2018)	Energy security and substitution rate in China	Grey relational approach	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Ibrahiem and Hanafy (2021)	Relationship among economic growth, trade openness, and energy security in North Africa	Panel ARDL	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Bekhrad, et al. (2020)	Effect of renewable energy on energy supply security of Andalusia	Dynamic system models	This study considers only energy availability, which is just an aspect of energy security and does not consider energy affordability and accessibility.
Lucas, et al. (2016)	Impact of renewable energy on energy security in the EU	Panel analysis	The study is purely descriptives without quantifying the effect and magnitude of the effect of renewables on energy security. Also, the study focuses only on EU, which is an advanced union. This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Chirambo (2017)	Energy and energy security of SSA	Systematic reviews	The study reviews of reports and policy of energy transition without making any statistical argument about the effect of energy transition.
Viviescas, et al. (2019)	Renewable and energy security in Latin America	General circulation models	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Bhattacharyya (2012)	Rebalancing approach to energy access	Simple multi-dimensional sustainability analysis	The study considers only electricity accessibility without considering the other indicators of energy security.

Nepal, et al. (2020)	Role of renewable on energy security in ASEAN Region	Westerlund cointegration and granger test	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Latif, et al. (2020)	Energy security, supply and renewable energy capacity in Pakistani	Market-allocation method	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Effect of Renewable Energy on Petroleum Demand			
Waziri, et al. (2018)	Effect of consumption of renewables on oil and gas in Nigeria	ARDL	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Shrimali and Kniefel (2011)	Net energy generation and share of renewable in the US	Qualitative	No empirical analysis is conducted and also This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Stockl and Zerrahn (2020)	Substitution between renewable and nonrenewable	Qualitative	No empirical analysis is conducted in this study and does not quantify the effect of substitution between renewables and non-renewables.
Bradshaw, et al. (2019)	Renewable energy and new oil order on Russia and Saudi Arabia	Scenario analysis	The study focuses on advanced petroleum -producing countries and neglects emerging petroleum economy, which might suffer much from energy transition.
Khan and Shaheen (2020)	Substitution between renewables and fossil fuels in Japan, China, US, and India	Time varying parameter	The study focuses on advanced petroleum-producing countries and neglects emerging petroleum economy, which might suffer much from energy transition.
Onyije, et al. (2018)	Dynamism in global energy landscape in Nigeria	Scenario analysis	This study neglects emerging petroleum economy and focuses on advanced petroleum producing economies, which might not suffer much from energy transition.
Effect of Renewable Energy and Employment			
Zhao and Luo (2020)	Renewable energy and driving force of employment	Environmental Kuznets Curve	The study fails to provide if renewable generation is a job creator or not in its analyses.

Blanco, et al. (2021)	Clean energy and employment	Shift-share analysis	The study conducts an analysis at regional level without considering the idiosyncratic effect of the countries involved.
Alper and Oguz (2016)	Causality existing among renewable consumption and labour	ARDL and asymmetric test	The study is not able to simulate the effect of energy transition and also neglects emerging petroleum economy and focused on advanced economies which might not suffer much from energy transition.
Saidi and Omri (2020)	Causality existing among renewable consumption and labour	ARDL and asymmetric test	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Shahbaz, et al. (2020)	Causality existing among renewable consumption and labour	ARDL and asymmetric test	The study is not able to simulate the effect of energy transition and also neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Troster, et al. (2018)	Causality existing among renewable consumption and labour	ARDL and asymmetric test	The study is not able to simulate the effect of energy transition and also neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Wang, et al. (2018)	Consumption of renewable energy and human development	Two stage least square	The study uses CO_2 as proxy for renewable, which is problematic. This is because CO2 emissions do not only come from fossil fuels.
Stavropoulos and Burger (2020)	Net employment and renewables	Computable General Equilibrium	The study puts so much assumptions on the macroeconomy in order to estimate the effect renewables on net employment.
Majid (2020)	Renewable and employment	Qualitative	No empirical analysis is conducted in this study and does not quantify the effects of renewables on employment.
Nasirov, et al. (2021)	Renewables and job creation opportunities	SWITCH-Chile energy model	The study uses CO_2 as proxy for renewable, which is problematic. This is because CO2 emissions do not only come from fossil fuels.

Ibrahiem and Sameh (2020)	Consumption of renewables and employment	Bidirectional causality analysis	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.
Ozsoy and Ozpolat (2020)	Consumption of renewables and employment in the BRICS	Granger causality analysis	This study neglects emerging petroleum economy and focuses on advanced economies which might not suffer much from energy transition.

Summary of the Chapter

This chapter presented the review of relevant existing literature of the objectives of the study. The theoretical and the empirical reviews were presented. This helped to identify the existing gaps in the literature and how this this contributes to fill those gaps in the literature. The conceptual framework for energy security and how renewable energy affects energy security, government expenditure, employment was presented. Also, effect of renewable energy transition on energy security and access, petroleum economy, and employment were discussed and presented.

CHAPTER FOUR

RESEARCH METHODS

Introduction

The methodology of the study in relation to the objectives of the study are discussed in this chapter. The chapter presents the research design of the study, the theoretical and the empirical models of the study relevant to the objectives of the study. The sources, types, and definition of data are presented in this chapter.

Research Paradigm

Generally, people attempt to appreciate the world and how it operates from varied perspectives often termed as paradigm. A research paradigm is fundamentally a benchmark for the conduct of research, which is influenced by a particular ideology or tradition informed by assumptions, values and belief systems, practices and techniques, and offers an organized method of enquiry (Jankowicz, 2005). Rehman and Alharthi (2016) posited that a research paradigm is composed of four essential components such as the ontology which has to do with beliefs about reality; epistemology emphasizing the knowledge and how to acquire it; methodology of the strategy, action plan, design or process that influences individual's adoption of research methods (Crotty, 1998); and methods highlighting the exact mode of collection and analysis of data (Rehman & Alharthi, 2016).

According to Guba and Lincoln (1994), research activities are normally guided by two basic paradigms such as positivism and constructivism. Positivism is anchored on knowledge acquired through data collection such as observations and interpreted in an objective manner (Hovenkamp, 1990). This research paradigm is premised on the assumption that reality exists independently of humans, hence the investigator has no direct influence on the data collected which potentially eliminates any form of normative conjectures from the study (Friedman, 1953). The ontological and epistemological stances of positivism are realism and objectivism respectively. The positivists endeavor to understand cause-effect relationships between variables, and when such relationships are finally established, they can be foretold with certainty in some other time in the future. Positivists are biased towards quantitative research.

On the contrary, constructivism is actually a theory that relies on observation and scientific study of how people acquire knowledge. This paradigm maintains that people form their own knowledge and appreciation of the world by means of experiencing things around them and reflecting on such experiences. When people experience something new, they have to relate or reconcile it with what they already know. This may change their belief and accept the new information as important or may discard it as irrelevant making them the active originators of their knowledge. The implication is that advocates of constructivism strive to build perceptions of human issues on the basis of personal and social experience and they rely on qualitative methods rather than quantitative (Guba & Lincoln, 1994). From the perspective of constructivism, individuals resort to their personal experience and exposure in the society to make meaning out of a given situation. But, constructivism and its qualitative methods of investigation have been criticized as being idiosyncratic, experiential and prone to value judgement which is a threat to objectivity (Essilfie, 2020; Friedman, 1953).

There is also a third paradigm known as the mixed method utilised by researchers. This paradigm is a hybrid of the positivism (quantitative methods and facts) and the constructivism (qualitative methods and personal experiences). It allows a much more detailed investigation about a given phenomenon being study since it adopts both quantitative and qualitative methods of enquiry.

Research Design

Three research design are identified—descriptive, exploratory, and explanatory studies. This study takes on an explanatory research strategy since the goal of the study is to analyse the vulnerability of the economy of Ghana to renewable energy transition dynamics. This method is able to analyse the impact of an increase in energy transition and how it will impact the economy of Ghana.

Justification of the Adoption of Positivist Approach

Considering the objectives of this study, the positivist paradigm is employed. This paradigm is adopted because the positivists maintain that reality is stable and can be observed and described from an independent perspective without meddling the phenomena under investigation (Levin, 1988). The positivists maintain that only the knowledge obtained by direct observation is factual and trustworthy. Thus, the positivists assert that knowledge generation process that is not anchored on the positivist philosophy is fundamentally disregarded as scientific and ultimately invalid (Hirschheim, 1985). Consequently, facts acquired through activities such as observing and measuring are considered objective, truth and valid. Therefore, the investigator relies on facts rather than human interests and subjective opinions.

Positivists organise knowledge generation process based on quantification, which is crucial to enhance exactness in describing parameters and the discernment of the correlation among them. A positivist approach to research and knowledge is rooted in a real and objective interpretation of the available data. This paradigm enables researchers to observe social processes in a less biased manner and to identify correlations between the variables under investigation. It also permits the use of a quantitative research approach, which is suitable for constructing mathematical models to investigate the connections between numerical data.

Moreover, the positivists mostly adopt the quantitative techniques including surveys, structured questionnaires, certified statistics from private, national and international organisations. The positivists stress quantitative approaches such as observation, measurement, reliability and validity in the process of investigation. The use of a quantitative approach enables researchers to establish a causal structure within the social world and eliminate the influence of human factors by employing quantitative tools, such as multivariate statistical analysis, to analyze data. This study utilizes such an approach.

Modelling the Effect of Renewable Energy Transition on Energy Security

Our study employs the dynamic ARDL simulation model to analyse the effect of energy transition on energy security. The ARDL model initiated by Pesaran, et al. (2001) to establish the long- and short-term effects of effect of energy transition, energy transition represented by share of renewable energy consumption, which is the percentage of total final energy consumption.

ARDL Model

If the variables of interest have different orders of integration or are not non-stationary, the Johnson cointegration test cannot be used directly as it requires all variables to be I(1). Instead, an ARDL model can be employed. This model, based on ordinary least squares, can be applied to both non-stationary and mixed order time series by taking into account sufficient lags to capture the data generating process in a general-to-specific modeling framework. By using a simple linear transformation, a dynamic ECM could be derived from the ARDL. This model integrates short-term dynamics with long-term equilibrium, thus preventing issues such as spurious relationships that arise from non-stationary time series data and preserving long-term information.

This study models the empirical specification in analysing the effect of energy transition, represented by renewables consumption and production, on energy security (affordability, availability and accessibility). From the empirical literature reviewed, the study adopts the ARDL. The ARDL is able to give both the short-run and the long-run estimations. The Also, the ARDL is able to select the right lag structure of the model from both the exogenous and endogenous variables. The ARDL is preferable technique when the order of the variables are integrated of I(0) or I(1), or a combination of both I(0) and I(1).

The ARDL is more robust in a small sample size when there is a single long-run relationship between the underlying variables. Again, given the inter-relative nature between renewable energy and macroeconomic indicators, the ARDL model is more appropriate to addressing possible endogeneity issues. Pesaran and Shin

(2001) indicated that appropriate modification of the orders of the ARDL estimation technique is more enough to simultaneously correct the problems of endogenous covariates and the residual serial correlation. However, the ARDL is not robust to estimate presence of integrated stochastic trends of I(2) or higher.

The generalised ARDL (p, q) model is specified as:

$$Y_t = \gamma_{0i} + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta_i' X_{t-i} + \varepsilon_{it} \qquad (1)$$

Where p is associated with the lag values of the dependent variables while the lag values of the independent variables take the value q, $Y_t'$is a vector, and the variable $(X_t')'$ are allowed to be purely I(0) or I(1); β *and* δ are parameters to be estimated; γ is the constant term; i= 1, …, k; p and q are optimal lag orders of explained and explanatory variables; $\varepsilon_{it}$is a vector of the error terms. The explained variable is a function of its, the lagged and current values of other explanatory variables in the equation.

Stationarity Test

ARDL model is specified to ensure higher order, this ensures that variables are integrated of a diverse order. That is a combination of I (0) and I (1) order or just I (1). The study considered both the Augmented Dickey-Fuller and Philip-perron tests in determining the presence of unit roots in the study variables. When uncertain if the variables are in the same order such as I(0), or I(1) or I(2), Pesaran, Shin, and Smith (2001) established a bound checking technique to check the presence of relationship among the variables. This bound test is estimated as:

$H_0: \beta_1 = \beta_2 = \beta_n = 0$: $\beta_1 = \beta_2 = \beta n = 0$:

that is the variables are not co-integrated and

$H_1: \beta_1 \neq \beta_2 \neq \beta_n \neq 0$:

that is the variables are co-integrated.

The co-integration test is determined using two bounds asymptotic critical values. All of the regressors are assumed to be I (1) in the upper bound, and I (0) in the lower bound.

Unit Root Tests

A time series variable is non-stationary if the data does not fluctuate around the mean; that is at least one of the moments depends on time. A time series may either be a trend stationary series or difference stationary series. A trend stationary occurs when the data becomes stationary after detrending whilst a difference stationary occurs when the data becomes stationary after differencing. To check the stationarity of the variables, the ADF and the PP unit root tests are utilised. The tests are conducted to ascertain the order of integration of the variables used to ensure reliability of the analyses. The results of the ADF and the PP tests are presented in the appendix.

Empirical Model Specification of the Effect of Renewable Energy on Energy Security

Energy access as the dependent variable in equation (1) is net energy supply. The net energy supply is measured in kilowatt and included to take care of sources of energy consumed by the transport sector, agricultural sector, and industrial sector other than electricity.

$$Access = f(REC, fossil_{cons}, GDP_{energyuse}, pop) \quad (2a)$$

The empirical models are estimated in the following models:

$$\Delta y_{i,t} = a_0 + \sum_{i=1}^{p} a_1 \Delta y_{i,t-i} + \sum_{i=0}^{P} a_2 \Delta REC_{t-i} + \sum_{i=0}^{P} a_3 \Delta fossil_{cons,t-i} + \sum_{i=0}^{P} a_4 \Delta GDP_{energyuset-i} + \sum_{i=0}^{P} a_5 \Delta POP_{t-i} + \lambda_1 y_{i,t-i} + \lambda_2 REC_{t-1} + \lambda_3 fossil_{cons,t-1} + \lambda_4 GDP_{energyuse,t-i} + \lambda_5 POP_{t-1} + \lambda ECT_{t-1} + \mu_t \quad (2b)$$

Where $y_{i,t}$ is energy security (affordability, availability, accessibility), REC is renewable energy transition (the percentage share of renewable energy consumption in the total final primary energy consumption), $fossil_{cons}$ is consumption of fossil fuels, $GDP_{energyuse}$ is GDP per unit of energy use, POP is logarithmic of population, a_s, and λ_s are beta coefficients, t the time period, and μ_t *is the r*andom disturbance error term. λ is the speed of adjustment coefficient, ECT captures the speed at which disequilibrium in the dependents variables is corrected.

Modelling the Effect of Renewable Energy Transition on Petroleum Demand from Ghana

In this section, we model the effect of renewable energy transition of various countries on the demand for petroleum from Ghana. The theoretical model adopted is the Imperfect Trade Substitution Model proposed by Goldstein and Khan (1985); Rose and Yellen (1989); and Rose (1991). The Time Varying Parametre is employed to empirically analyse the results.

Theoretical Model Specification

Following the works of Rose (1991); Goldstein and Khan (1985); and Rose and Yellen (1989), our study adopts the Imperfect Trade Substitution (ITS) model. This model is a trade model for two countries engaging in trade. This model assumes that goods produced domestically (in this case, renewables) and those that are imported (in this case, crude oil) are imperfect substitutes. We argue here that renewables and crude oil are imperfect substitutes since they cannot easily be substituted for each other. However, they can be substituted in certain situtaions. The model supposes that when it comes to the volume of goods imported by citizens of the domestic economy, there is a positive correlation with domestic income and a negative correlation with import prices relative to other countries. Likewise, the volume of imports by foreign economies from the domestic economy is positively linked to the income of foreign economies and inversely correlated with relative prices. The ITS model can, thus, be stated as:

$$Q_{dm} = f(Y, p_m) \quad (3)$$

$$Q_{dm}^{*} = f(Y^{*}, P_m^{*}) \quad (4)$$

Where $Q_{dm}(Q_{dm}^{*})$ represents the quantity of goods imported by the domestic (foreign) economy, while $Y(Y^{*})$ indicates the level of income measured in domestic (foreign) output. The relative import price of goods imported into the domestic economy is represented by p_m, and P_m^{*} represents the corresponding relative price of imports abroad. Models (3) and (4) are the Marshallian demand functions, which are characterised by positive relative income elasticities and negative price expectations.

According to Rose and Yellen's (1989) perspective, the supply of exports is heavily influenced by the price comparison between exportable goods and other items as indicated in the model:

$$S_{qx} = f(p_x) \quad (5)$$

$$S_{qx}^{*} = f(P_x^{*}) \quad (6)$$

Where the equation describes the of export from either domestic or foreign economy expressed as $S_{qx}(S^*_{qx})$; the relative prices of exports is expressed as the ratio of the price of exported goods in domestic currency, p_s to the domestic price level (p), denoted as p_x; likewise, the relative price of export from the foreign economy is represented as p_x, which is calculated as P^*_x divided by P^*.

The domestic economy's relative import prices can be expressed as:

$$p_m = E \times \frac{P^*_x}{p} = \left(E \times \frac{P^*_x}{p}\right) \times \left(\frac{P^*_x}{p}\right) \equiv q \times P^*_x \quad (7)$$

Where the exchange rate (nominal) is denoted E; accordingly, the domestic currency of foreign exchange and $q\left(q = E \times \frac{P^*_x}{p}\right)$ expresses the exchange rate (real). In the same way, we express the relative price of foreign imports as:

$$P^*_m = \frac{P^*_x}{p} \quad (8)$$

At the point of balance, the quantities of goods exchanged and the prices of exports in each country are determined by the conditions outlined in Equations (9) and (10)

$$Q_{dm} = S_{QX} \quad (9)$$

$$Q^*_{dm} = S^*_{QX} \quad (10)$$

Rose and Yellen (1989) assert that trade should not essential be equal zero when capital flows are present. Model (3)—(10) could be calculated for the imports and exports levels and the relative price ratios, which are denoted as P^*_x and P_x, by considering the diverse factors and determinants that would influence imports demands domestically. In achieving the second objective, the study analyses the effect of global renewable energy on export of petroleum from Ghana with specificity on the US, Canada, Italy, India, and China. The study employs a time-varying parameter approach within the state-space model.

Time Varying Parameter (TVP)

Our study employs a TVP (state-space, SS) model in estimating an import demand model for crude oil contrary to other studies that adopt cointegration approaches. The TVP demand model explains the size and fluctuations in oil import demand in response to changes in certain explanatory factors. This approach incorporates both seasonal and random components within a classical time series model. Rather than using separate models based on autoregressive (AR), moving average (MA), or exponential smoothing techniques, the state-space approach integrates these models and employs a unified estimation procedure (Khan & Shaheen, 2020). SS models possess qualities such as flexibility, generality, and transparency. Moreover, state-space models are well-suited for dealing with non-stationary data series, and they can effectively handle serially correlated errors by incorporating them into the errors of the state vector (Khan & Shaheen, 2020; Durbin & Koopman, 2012).

The primary benefit of a SS model lies in its ability to perform structural analysis of the research question. It allows for the individual modeling of key components of a data series, such as seasonal, trend, calendar, and cyclical variations, as well as the effects of explanatory variables, before formalizing the state-space specification (Durbin & Koopman, 2012). Additionally, SS models possess a recursive nature, enabling them to adapt to changes in the system's structure. This flexibility sets SS models apart from other conventional computational frameworks. Our study specifies the petroleum demand model while making use of SS approach for each of the main economies that import crude oil from Ghana and evaluates the elasticities for each regressor in the model.

In evaluating this, the study focuses on renewables consumption in the US, Italy, China, India, and Canada. Our study analyses both the total import demand and for each of these economies. By integrating the theory of Marshallian demand, our study formulates the import demand model for crude oil as the function of GDP per Capita, real price of crude oil, real effective exchange rate, and domestic consumption of renewable energy expressed in logarithmic form.

Our study stipulates import demand for crude oil from Ghana for all these countries as:

$$Import_{it} = f(REC_{it}, PCGDP_{it}, RR_{it}, Ind\_index_{it}, WTI_{it}) \quad \forall_i = 1 \dots K, t = 1 \dots T$$

(11)

Where $Import_{it}$ designates the real value of crude oil imports by country i at time period t, WTI_t is the West Texas Intermediate per barrel, real oil price, $PCGDP_{it}$ is GDP per capita for each country at time t, REC_{it} characterises the country-specific consumption of renewable energy, and RR_{it} is the real effective exchange for each country, and Ind_index_{it} is the industrial production index of the country.

A TVP model within the SS framework consists of a state or transition and measurement equations and are represented as:

Measurement equation

$$Q_t = X_t \beta_t + \mu_t \tag{12}$$

$$\mu_t \sim iid\ N(0, \sigma^2)$$

Transition equation

$$\beta_t = \theta_t + \vartheta\beta_{t-1} + \quad v_t \tag{13}$$

$v_t \sim iid\ N(0, \delta), E(e_t V_s) = 0$

Where Q_t is $1x1$ vector of export/import of crude oil, X_t is a $kx1$ vector of regressors—crude oil price, GDP per capita, renewable energy, and real effective exchange as well as the constant term. The TVP model in the SS framework involves several elements. β_t represents a vector of unobserved variables with dimensions of kx1, while θ_t represents a vector of constant coefficients to be estimated, also with dimensions of kx1. ϑ represents a kxk matrix of constant parameters. The error terms in the measurement and transition equations are denoted as u_t and v_t, respectively, and they follow a normal distribution that is independently and identically distributed (IID). The diagonal variance and covariance matrix is represented by Q. The transition vector, β_t, contains unobservable components and encapsulates all the information in the system at each time point. Model (12) demonstrates that the new state vector is obtained through a linear combination of the previous state vector and an error process. Model (13) enlightens that the observed variables are dependent on the transition vector. Kalman (1960) outlines the recursive procedures to obtain filtered and smoothed estimates of the time-varying coefficients β_t. The equations of predictions are:

$$\beta_{\frac{1}{t-1}} = T\beta_{\frac{1}{t-1}} \tag{14}$$

$$P_{\frac{1}{t-1}} = TP_{\frac{1}{t-1}}T' + Q_t \tag{15}$$

Finally, transformation of the estimates recursively is presented as:

$$\beta = \beta_{\frac{1}{t-1}} + P_{\frac{1}{t-1}} X(Q_t - X'^{\beta_{\frac{1}{t-1}}})(XP_{\frac{1}{t-1}} X + H_t) \quad (16)$$

$$P_t = P_{\frac{1}{t-1}} - P_{\frac{1}{t-1}} X'XP'_{\frac{1}{t-1}} / (X'P_{\frac{1}{t-1}} X + H_t) \quad (17)$$

Our study evaluates the SS model via the Kalman filter, and parametres are examined by maximising the likelihood function. The approach takes in or encompasses two steps. At the first step, this approach examines β incorporating all available information at time period $t - 1$ and then after, at the second step, the approach updates the estimates of β by utilising the forecast errors from the first step to calculate values for time t. The Kalman filter offers comprehensive insights into the values of β and υ at every time step, allowing us to assess the implication of each explanatory variable in influencing the demand for imported crude oil in each country. Consequently, we proceed to formulate our time-varying parameter model, taking into account the theoretical underpinnings of the fundamental energy demand model.

Empirical Model Specification

Following Khan and Shaheen (2020); Harvey (1991), the study transforms Equation (18) and specifies the parameters of exported or imported crude oil demand model as time-varying coefficients. The regressors are represented as:

$$lnImport_{i,t} = \beta_0 + \beta_{1,t} lnREC_{i,t} + \beta_{2,t} lnPCGDP_{i,t} + \beta_{4,t} RR_{i,t} + \beta_{5,t} Ind\_index_{i,t} + \beta_{6,t} WTI_{i,t} + +\mu_t \quad (18)$$

$$\beta_0 = \beta_{0,t-1} + v_{0,t} \quad (19)$$

$$\beta_1 = \beta_{1,t-1} + v_{1,t} \quad (20)$$

$$\beta_2 = \beta_{2,t-1} + v_{2,t} \quad (21)$$

$$\beta_3 = \beta_{3,t-1} + v_{3,t} \tag{22}$$

$$\beta_4 = \beta_{4,t-1} + v_{4,t} \tag{23}$$

where "Equation (18) represents the measurement equation, and equations (19–23) are transition equations. A transition equation indicates the evolution of parameters over time. Our study estimates the time path of time-varying parameters along with variances of disturbance term through the Kalman filter (Khan & Shaheen, 2020; Kim & Nelson, 1999). In this context, our study transforms the time-varying parameter model into state-space form and applies maximum-likelihood techniques to estimate the model. Since the Kalman filter is a recursive process, the model needs to have plausible initial values; for this purpose, firstly, our study applies the OLS to estimate the parameters of the model; and then secondly, we use the estimates from OLS as initial values (Durbin & Koopman 2001). Our study is constrained by the limited availability of the data related to renewable energy consumption; therefore, the sample covers the period from 2010 until 2020. However, state-space models are capable of handling the statistical challenges posed by a relatively smaller sample size" (Khan & Shaheen, 2020, p. 440).

Modelling the Effect of Renewable Energy Transition on Employment

We model the effect of renewable energy transition on employment in Ghana. The theoretical model adopted is the Dutch Disease Model as indicated by Corden and Neary (1982); Corden (1984); and Rudd (1996). The dynamic ARDL simulation model is employed to empirically analyse the results.

Theoretical Model Specification

To determine the vulnerability of employment in Ghana to the energy transition from fossil fuels to renewables, our study adopts the "Dutch disease model described by Corden (1984); Corden and Neary (1982); Rudd (1996). The model explains the negative effect of discovery and exploitation of a booming sector on non-booming and non-tradable sectors of an economy. The core model of the Dutch disease theory posits three sectors of the economy. These are booming sector, in this case, renewable energy sector, lagging sector (agricultural and manufacturing sectors) and non-tradable sector (services sector). The booming sector and the lagging sector face a given world price. The output of each sector is produced by a factor specific to that sector and by labour which is assumed to be mobile between the sectors. The model assumes that all factors are internationally immobile and factor prices are flexible. A boom in the renewable energy sector is assumed to occur through technology-induced rise in productivity, windfall discovery of new resource, and rise in world price of oil. The model distinguishes between two separate effects on the lagging sector and the non-tradable sector. These are the resource movement effect and the spending effect.

The spending effect considers the situation where incomes from the booming sector (renewable energy sector) is spent directly by factor owners or indirectly through taxes collected and spent by the government on the non-traded sector (services sector) provided the income elasticity of the non-traded sector is positive. This raises the price of the non-traded sector relative to the price of the traded sectors (booming and lagging) leading to appreciation of the real exchange rate. This draws resources out of the booming and lagging sectors into the non-tradable sector and shifts demand away from the non-tradable sector to the booming and lagging sectors. The resource movement effect occurs when there is movement of labour from the lagging and non-tradable sectors to the booming sector due to a rise in marginal product of labour in the booming sector. At a constant wage, the demand for labour increases in the booming sector leading to a direct deindustrialisation or de-agriculturalisation of the economy.

Specifically, the model can be written as:

$$D = f(SE, RM) \quad (24)$$

Where D represents decline in manufacturing sector or agricultural sector which affect employment and government revenue, SE represents spending effect, and RM represents resource movement effect. In line with our study, the model is re-specified as:

$$NOS = f(SE, REC) \quad (25)$$

Where NOS is non-oil sectors, SE is spending effect, and REC is renewable energy transition which represents the natural resource (renewable energy). The non-oil sectors (NOS) are the agricultural sector, manufacturing sector and services sector.

Our study augments the Dutch disease model (Equation (24) with service sector, education, export of fossil fuels as shown in equation (25). The services sector is included to capture the employment which probably benefits from renewable energy production. The inclusion of inflation (CPI) is included to capture the spending effect from the increase in income in the economy" (Rudd, 1996). The function of the model is specified as:

$$NOS_t = f\left(GDP_{energyuse}, REC, fossil_{cons}, educ, POP, CPI\right) \quad (25)$$

Empirical Model Specification of Employment

Empirical Equation (26) examines the impact of renewable energy transition on employment. The equation is specified as:

$$Emp_{i,t} = \beta_0 + \beta_1 REC_t + X_t'\beta_2 + \varepsilon_t \quad (26)$$

The ARDL estimation is presented as:

$$\Delta Emp_{i,t} = a_0 + \sum_{i=1}^{p} a_1 \Delta Emp_{i,t-i} + \sum_{i=0}^{P} a_2 \Delta REC_{t-i} + \sum_{i=0}^{P} a_3 \Delta GDP_{eneryuse1,t-i} + \sum_{i=0}^{P} a_4 \Delta Educ_{t-i} + \sum_{i=0}^{P} a_5 \Delta fossil_{cons,t-i} + \sum_{i=0}^{P} a_6 \Delta POP_{t-i} + \sum_{i=0}^{P} a_7 \Delta CPI_{t-i} + \lambda_1 Emp_{i,t-i} + \lambda_2 REC_{t-1} + \lambda_3 GDP_{energyuset-i} + \lambda_4 Educ_{t-1} + \lambda_5 fossil_{cons,t-1} + \lambda_6 POP_{t-1} + \lambda_1 CPI_{t-i} + \lambda ECT_{t-1} + \mu_t \quad (27)$$

Where Emp_i is of employment in the manufacturing, agriculture, and the service sector, REC is renewable energy transition (the percentage share of renewable energy consumption in the total final primary energy consumption), $fossil_{cons}$ is consumption of fossil fuels, $GDP_{energyuse}$ is GDP per unit of energy use, $Educ$ is education, POP is population, CPI is inflation, a_s and λ_s are beta coefficients, t the time period, and μ_t is the random disturbance error term. λ is the speed of adjustment coefficient, ECT captures the speed at which disequilibrium in the dependents variables is corrected.

Model Simulation using the Dynamic ARDL Model

Besides understanding the overall impact of a shock, which is indicated by the long-term multiplier, it is often valuable to determine the time it takes for specific effects of the shock to fade or to quantify the extent to which the shock has dissipated after a certain number of periods. The median and mean of the lag distribution of exogenous variables give statistics about the adjustment pattern a series dependent variable makes to disequilibrium. Again, to overcome the problem of point estimate, increased emphasises have been placed to evaluate the extensive series of substantive implications from their statistical models in recent times among economists and social scientists. This has been mainly useful in OLS models with autoregressive processes. King et al. (2000) suggests that technological advancement for a computing power have brought about a new era to engage in simulation-based approaches. To comprehensively analyse the substantive effects, it is necessary to consider various quantities of interest, including the long-term effects, as well as median and mean lag lengths as asserted by De Boef and Keele (2008). In AR models, the most effective approach to observe the long-term effects of exogenous variables is to simulate predicted values and confidence intervals for specific scenarios across a designated number of time intervals.

For the purpose of this study, the study selects the dynamic simulation ARDL model with cointegration variables entrenched in a VAR time series (Jordan & Philips, 2018; Johanssen, 1988). Applying dynamic ARDL simulations has gained recognition, especially, in analyses of energy, health and environmental economics. The model algorithm is valuable for cointegration, short and long run equilibrium relationships in both level and differences (Sarkodie & Owusu, 2020). The advantage of the dynamic ARDL simulations is that, it has a visualisation interface in examining the likely counterfactual variation in the anticipated adjustable basing on the concept of ceteris paribus (Sarkodie & Owusu, 2020). The application of the novel dynamic ARDL simulation follows simple but technical guidelines. The ARDL bound testing procedure utilised in the dynamic ARDL simulation necessitates a strict I(1) dependent variable (Jordan & Philips, 2018; Sarkodie & Owusu, 2020). Thus, the only probable participant for cointegration is a endogenous variable that is I(0).

The method is considered to evaluate the effects of a group of regressors effects on a dependent variable with measurement variables that are taken in isolation over time. That is, a single equation model framework. Conversely to OLS, both the lagged and current values of regressors are taken into account in an ARDL framework and the assessed effect on the dependent variable can be either observed steadily on future time steps or instantaneously (Shabbir, et al., 2020). Dynamic ARDL simulation techniques are being used in many works in capturing shocks in climatic and socioeconomic indicators (Sarkodie, et al., 2018; Sarkodie & Owusu, 2020; Shabbir et al., 2021). Our study gives specifics based on policy inputs in accounting for potential shocks owing to current energy transition to renewables. The study selects the regression models utilising dynamic simulations ARDL model via 1000 simulations of the vector of parametres from a multivariate normal distribution.

The empirical model for energy security is stated as:

$$y_{it} = a_i + a_2 REC_t + a_3 GDP_{energyuset} + a_4 fossil_{cons,t} + +a_6 pop_t + \lambda_1 Q_{t-i} + \lambda_2 REC_{t-1} + \lambda_3 pop_{t-i} + \lambda_4 GDP_{energyuset-1} + \lambda_5 fossil_{cons,t-1} + e_t \quad (28)$$

The empirical model for employment is stated as:

$$Emp_{it} = a_i + a_2REC_t + a_3GDP_{energyuset} + a_4fossil_{cons,t} + a_5educ_t + a_6pop_t + a_7CPI_t + \lambda_1Q_{t-i} + \lambda_2REC_{t-1} + \lambda_3pop_{t-i} + \lambda_4GDP_{energyuset-1} + \lambda_5educ_{t-1} + \lambda_5fossil_{cons,t-1} + \lambda_5CPI_{t-1} + e_t \quad (29)$$

where y represents all the dependent variables of the energy security and Emp represents employment of the ARDL simulation analyses. Some of the variables are taken in their percentages, others are taken in their raw forms whiles others are taken in their logarithm forms. Ghana in its Nationally Determined Contributions (NDCs) plans to achieve between 10 percent and 20 percent of renewable energy penetration in her energy mix by 2030. Our study, therefore, states the business-as-usual to be one percent and rapid transition to be five percent annually to these targets.

Our study forecasts import demand for Ghana's petroleum into 2030 by specifying a baseline model as Equation 30.

$$G_t = \theta + \beta t + \varepsilon_t \quad (30)$$

Where G_t is petroleum imports demand to other countries in years t calculated; t is the period at which economic outcome is forecasted; θ is a scalar; β is a vector of parameters; whereas ε_t is the general stochastic disturbance term. The forecast is based on historical data on petroleum exports from Ghana. The study estimates Equation 31 using the TVP. Based on different assumed energy transition rates, δ, Equation 30 is expanded as:

$$pet_{t+1} = \delta G_t + G_t \quad (31)$$

Where $\delta = \left[\frac{(G_{t+1} - F_t)}{G_t} \times 100\right]$, which is the percentage change in economic outcomes at time, $t + 1$ (a future date). To determine the effect of the renewable energy transition on petroleum demand from Ghana at different transition rates, we set $\delta = IEA\ and\ BP\ Transition\ Scenarios$.

The IEA transition rates include one percent annual increase in energy investment; energy demand declining by six percent; oil demand contracting by nine percent; and energy efficiency increasing by four percent. For China, BP projects that their demand for oil in the both the rapid and NZE scenarios to increase by just one percent and the business-as-usual to increase by four percent. Averaging the BP and IEA transition scenarios, our study defines rapid transition to be 2.3 percent, NZE to be 4.6 percent, and business-as-usual to be 0.3 percent increases in renewables.

Data Sources and Description

Data points are largely based on periods for which data is available for all the variables under study. Variables of interest pertaining to the impact of renewables on energy security include affordability, availability, and energy accessibility. Data of variables such as energy accessibility, fossil fuel consumption, and energy use are obtained from the Energy Commission. The GDP data is sourced from the Bank of Ghana. Data is also obtained from Public Utilities Regulatory Commission (PURC) Ghana, such as data on energy affordability. To quantify the vulnerability of petroleum subsector of Ghana to the global energy transition dynamics, secondary time series data are sourced. The variables used include total exports/imports of petroleum, price of crude oil, exchange rate, industrial production, income (GDP per capita), and consumptions of renewables. While export of petroleum, consumptions of renewables, and price of crude oil capture petroleum economy, GDP per capita, industrial production, and exchange rate capture the macroeconomy. Data on export of petroleum and data for the analyses of petroleum imports/exports from Ghana are obtained from PIAC, OECD, US EIA, and Federal Reserve Economic Data, while data on crude prices are obtained from BP.

The data covers the periods from when Ghana started exporting crude oil to 2021 (i.e., from 2001 to 2021). This study models Ghana as a small open economy that exports crude oil to the rest of the world as a price taker in the global crude oil market. Table 4.1 presents the definition, measurement, and expected sign of the variables of the studies. Those without expected signs are the independent variables such as energy security (energy affordability, availability, and accessibility), employment, and imports/exports of petroleum. It then set out empirically the threat pathways from the energy transition of a net zero emission of CO_2 by 2050 on Ghana's petroleum exports.

To examine the effect of renewable energy transition on energy security, we use consumption of fossil fuels, GDP per energy use, and population. To evaluate the effect of renewable transition on employment, the variables used for the analyses include employment and unemployment rates, total renewable energy consumption, inflation, exchange rate, interest rate, and imports and exports of petroleum. Our study expects renewable energy transition and GDP per energy use to positively affect energy security and employment while the study expects fossil fuel consumption and population to decrease energy security and employment in Ghana. However, education and inflation (CPI) are expected to positively affect employment. The consumer price index (CPI) captures the spending effect of energy. CPI is used as proxy for inflation.

Table 3 gives the summary description of the variables of our study and their expected directions to energy security, oil import demands, and employment. The measurements of the variables are also presented. The weighted averages of bilateral exchange rates adjusted for relative consumer prices are utilised in calculation of real effective exchange rates. Industrial Production Index measures real output for all facilities located in all the countries manufacturing, mining, electric, and gas utilities relative to a base year. Production Industrial Production Index and GDP per capita (PCGDP) are expected to positively affect crude oil demand from Ghana while renewable energy transition (REC), crude oil price (WTI and Brent), and exchange rate (RR) are expected to negatively affect crude oil import demand from Ghana.

Energy Security

Energy supply security dimensions—affordability, and availability, adaptability, and affordability—are central considerations to the environmental sustainability target and economic development in Africa. Energy plays crucial role in the creation of economic growth conditions globally. It is very difficult to run a shop or deliver goods and commodities without energy. However, it is practically not possible to operate a factory or an industrial without energy. Electricity access is very crucial to human development. Electricity is essential for basic economic and residential activities such as refrigeration, lighting, and running and using household appliances. Individuals and households' electricity access is one of the

Table 3: Definition and Apriori Expectations

	Variable	Definition	Expected sign
Accessibility	Access to energy	Number of people with access to electricity (in percentages)	
Affordability	Energy affordability	Ability to afford energy, which is end-use energy prices by fuels with or without taxes or subsidies	
Availability	Availability of energy	Energy availability consists of energy supplies efficiency and end-user intensity.	
Clean	Clean cooking energy	Access to clean cooking energy (measured in percentages)	
Vulnerable	Vulnerable employment	Contributing family workers and own-account workers as a percentage of total employment (for male, female and total)	
Emp	Employment	Percentage of total labour force employment	
REC	Renewable energy transition	The share of renewable energy in total final energy consumption	+/-
$GDP_{energyuse}$	Gross Domestic Product per unit of energy use	GDP per unit of energy use	+
CPI	Inflation	Consumer price index as weighted average of prices of consumer goods and services	+
$fossil_{cons}$	Consumption of fossil fuel (percentage of total energy consumption)	Fossil fuel consumption consists of coal, oil, petroleum, and natural gas products	
POP	Population	Population of the country	+
Educ	Education	Share of the tertiary enrollment of total enrolment	+
Import	Value of crude oil export/import	Conventional crude oil—export/import, metric tonnes, thousand	
WTI/Brent	Prices of oil	WTI; Europe Brent Spot Price in US dollar per barrel	-
PCGDP	GDP per capita	Gross Domestic Product per capita.	+
RR	Real effective exchange rate	Real Broad Effective Exchange Rate, Monthly, Not Seasonally Adjusted (2010=100)	-

clearest and undistorted indications of a country's energy poverty status and for that matter energy accessibility, availability and affordability.

Availability is the physical availability of energy resources, including oil, natural gas, coal, uranium, hydropower, wind power, solar power, and other renewable sources. It also includes the ability to produce and import energy resources. Accessibility is to the ability of consumers to access energy resources, including the availability of infrastructure such as pipelines, transmission lines, and distribution networks to transport energy resources from production sites to end-users. Affordability is to the cost of energy resources, including both the production costs and the price paid by end-users. Energy resources must be affordable to ensure that they are accessible to consumers.

Bhattacharyya (2012) opines that energy access has no universal definition. However, a perusal of definitions from researches reveals commonalities that provide the scope to defining energy access. Consequently, authorities such as the IEA and the WB, attesting to the lack of international or generally accepted definition, proposes a definition of energy access encompassing the common definitions from literature (IEA, 2020). That said, there have been similarity across definitions that contain the following: a) household access to a minimum level of electricity, and b) household access to safer and more sustainable cooking and heating fuels and technologies (IEA, 2020).

Grounded on the commonalities in definitions, in a broader sense, the WB's Energy Sector Management Assistance Programme, corroborating with international partners under the Sustainable Energy for All initiative, which defined energy access as the ability to acquire energy for all required energy applications, where the energy is affordable, adequate, uninterruptible, dependable, convenient and safe (World Bank, 2019). This implies the access and utilization of energy supply for the desired energy services by all end users (Bhatia & Angelou, 2015).

As a result, Bhatia and Angelou (2015) implicitly segregates energy accessibility into access to energy services (inclusive of energy utilising equipment) and access to energy supply (exclusive of energy utilising equipment). Although these definitions capture the possible varied applications of energy due to access, it somewhat has the likelihood to accommodate the inefficient use of energy. Delineating energy accessibility brings to fore what counts as energy accessibility for several economies. The Poor People's Energy Outlook (PPEO) (2013, 2016) emphasises the regional conceptualisation of energy accessibility. PPEO (2018) posits that attaining global energy access has been disproportional. Achieving agenda 2030 requires global efforts of ensuring growths about five times higher than the 2012 to 2014 growth rate in energy accessibility (IEA, 2020; WB, 2017). By 2030 only as low as 674 million people will have energy accessibility from the numerous 1.1billion people without access to energy (IEA). Over 2.6billion remain still lacking access to clean cooking facilities relying on primitive sources of energy (IEA, 2020).

Energy plays crucial role in the creation of economic growth conditions globally. It is very difficult to run a shop or deliver goods and commodities without energy. However, it is practically not possible to operate a factory or an industrial without energy. Electricity access is very crucial to human development. Electricity is essential for basic economic and residential activities such as refrigeration, lighting, and running and using household appliances. These activities cannot be substituted by other energy forms. Individuals and households' electricity access is one of the clearest and undistorted indications of a country's energy poverty status and for that matter energy access, availability and affordability.

These three variables have annually been reported by the International Energy Administration to evaluate how countries performance in easing access to energy. Electricity accessibility, according to IEA, is a discrete measure of people who are connected to the electricity grid or possess a renewable stand-alone system or mini-grid connection of appropriate capacity to deliver the minimum bundle of energy services. For access to clean cooking facilities, the IEA database refers clean cooking access as percentage of households that depend mainly on fuels (natural gas, LPG, electricity and biogas) other than biomass fuels (including charcoal, animal dung, tree leaves, fuelwood, and crop residues), coal or kerosene for cooking.

The principal component analysis is used to generate the energy security index of availability, affordability, and accessibility. Since energy security must sum up to one, applying equal weights gives the relative contribution of each of these three dimensions as: $\frac{1}{3} = 0.333$.

Renewable Energy Transition

The primary focus lies on the variable of interest, which is the proportion of renewable energy in the overall consumption of primary energy. It forms the basis of the chapter. Renewable energy transition is switching towards renewables including as solar, wind, hydropower, geothermal, and biomass from coal, oil and gas. The switch is driven mainly by the need to achieve climate change goals, reduction of air pollution. Energy transition is a complex and multifaceted process involving diverse actors, including governments, energy companies, investors, and consumers. Key elements of this transition include the development of renewable energy infrastructure, such as wind farms and solar panels, the integration of renewable energy into existing energy systems, the adoption of policies and regulations that support the growth of renewable energy, and changes in consumer behavior to encourage the use of renewable energy. Energy transition offers the potential for significant economic and social benefits.

Employment

The number of people employed or unemployed are used for the study analyses. Employment in this study is measured in diverse forms including youth employment, female employment, male employment and other forms of employment. The measurement of employment is based on the labour force. The rate of employment or unemployment is utilised in this study. This measurement of employment is from different sectors of the economy. Vulnerable employment and gender analyses of employment are also used.

Crude Oil Price

The brent price is used for all the countries except the US. Brent is a blended crude stream produced in the North Sea region serving as a basis or marker in pricing some crude streams. For the US, West Texas Intermediate (WTI) is used. WTI is a crude stream that is produced in the Southern Oklahoma and Texas serving as a basis or marker for pricing numerous other crude streams. It is also traded in the domestic spot market at Cushing, Oklahoma. Again, the data points for the US are monthly data series whiles the rest of the other countries are quarterly data series.

Summary of the Chapter

This chapter presented the methodology of the study in relation to the objectives of the study. The chapter presented the research design of the study, the theoretical and the empirical models of the study relevant to the objectives of the study. The sources, types, and definition of data were all presented in this chapter. The chapter employed the ARDL models to establish the long-run and short-run relationship between renewable energy and energy security and access in Ghana for the empirical models of the first objective and the long-run and the short-run relation between renewable energy and employment and government expenditures. Also, the time-vary paramtre approach within the state-space model used to analyse the effect of renewable energy production in US, Canada, China, Italy, and India on the petroleum export of Ghana was discussed. The apriori expectation of each variable was presented. All the necessary tests of the models used were discussed including the bound test, stationary test, and unit roots test. The lag selection was also presented in this chapter. The measurements of the variables were also discussed.

CHAPTER FIVE

DATA AND DESCRIPTIVE ANALYSIS OF MODEL VARIABLES

Introduction

The chapter begins with the results of the pre-estimations and the descriptive statistics of the variables of the study. The results and the descriptive statistics are presented in the forms of tables and figures.

Descriptive Statistics and Data Analysis

Descriptive statistics of the data for objectives one and three are presented in Table 4. It details the number of observations, mean, standard deviation, and minimum and maximum values of the variables under this chapter. All the values are converted to three decimal places unless otherwise stated. Table 4 indicates that all the variables understudied have 84 observations except for energy availability, which has 83 observations. Access to clean cooking energy *(clean)* (measured as the percentage of the population with access to clean cooking fuels and technologies) has a mean of 15.828 per cent, approximately 16 per cent. This means that, on average, 16 per cent of the population of Ghana has access to clean cooking. The standard deviation of 10.254 per cent shows that there is a dispersion of about 10 per cent from the mean. The minimum percentage access to clean cooking is six per cent and the maximum value is 87 per cent.

This is mainly due to government efforts to provide clean cooking technologies. Ghana started the National Clean Cookstove Programme (NCCP) in 2010, a comprehensive project aimed at encouraging the country's adoption of clean cooking technologies. The NCCP is successful in promoting awareness about the

Table 4: Descriptive statistics of variables of the study

Variable	Obs	Mean	Std. Dev.	Min	Max
Clean	84	15.828	10.254	5.89	87
Urban energy accessibility	84	78.5	3.38	72.8	96.8
Rural energy accessibility	84	42.403	21.146	7.860	85.5
Energy accessibility	84	63.008	14.003	41.250	870
Agriculture employment	84	46.415	9.462	29.750	55.120
Services Employment	84	37.922	7.049	30.840	49.210
Industry employment	84	15.666	2.621	13.870	21.050
Total employment	84	67.343	1.203	64.534	69.176
Educ	84	8.065	6.161	0.786	20.142
Affordability	84	0.546	0.242	0.210	0.820
Availability	84	9815.141	3479.082	5360.61	16667.06
Female vulnerable emp	84	84.969	5.067	75.19	91.030
Male vulnerable emp	84	70 .710	7.740	56.43	79.980
Total vulnerable emp	84	77.464	6.582	65.100	85.250
Female unemployment	84	5.371	3.170	2.760	10.730
Male unemployment	84	4.660	3.151	4.330	10.180
Unemployment	84	5.572	2.178	2.170	10.460
$Fossil_{cons}$	84	14.322	13.665	.048	40.422
$GDP_{energyuse}$	84	12.340	1.894	8.400	16.781
Ren_waste	84	38.412	20.181	26.171	72.17
CPI	84	262.11	157.540	112.010	1401.100
REC	84	52.892	8.724	41.480	69.320
POP	84	26.14e+7	5947878	18.78e+7	30.18e+7

Source: Author's Compute (2023)

health and environmental benefits of clean cooking, as well as in providing financial and technical assistance to homes and companies to assist them in making the transition to clean cooking solutions.

In the urban areas, *(urban energy accessibility)* there is a minimum value of 73 per cent who have access to energy (measured as the % of the urban population with electricity access) with a maximum value of 96.8 per cent and a standard deviation of 3.38 and a mean of 78.5. This means that energy accessibility in the urban areas in Ghana is high. It is observed that the dispersion from the mean is below five, which means that the distribution of energy accessibility within urban areas is not far. This implies that many urban areas have had higher energy accessibility. In the rural areas in Ghana, the maximum percentage value for access to electricity (*rural energy accessibility*) is 86 per cent while the minimum value is eight per cent with a standard deviation of 21 per cent and a mean of 42 per cent. This means that energy accessibility in rural areas is lower than in urban areas. Also, with a standard deviation of 21, it can be asserted that many areas in the rural areas have not had energy accessibility in Ghana during the period of this study.

The population of Ghana with energy accessibility has been ranging from 14 per cent to 87 per cent with a mean of 63 per cent and a standard deviation of 14 per cent. This means that out of the total population, the highest percentage with energy accessibility is 87 per cent in the periods' understudy. It is generally observed, even in this current generation, that most of the rural areas in Ghana do not have electricity accessibility. According to the GSS (2022), electricity accessibility in rural areas is more than 27 per cent as of 2022. The percentage of people in rural areas without accessibility is even higher in all the regions except for rural areas in Central, Greater Accra, Western, Volta, and Ashanti.

Also, energy affordability has a mean value of GH₵0.546/kWh with a standard deviation of GH₵0.242/kWh and minimum value of GH₵0.210/kWh and a maximum value of GH₵0.82/kWh. This means that energy affordability in Ghana has been ranging from GH₵0.210/kWh to GH₵0.820/kWh. The dispersion from the mean is GH₵0.242/kWh. This shows that the level of dispersion is much when it comes to energy affordability. There has been a vast discrepancy in energy affordability in Ghana. Looking critically at the affordability reveals that consumers in Ghana who fall within the 0-300kWh bracket have witnessed a price increase from GH₵0.65/kWh to GH₵0.894/kWh representing an increment of about 34 per cent. It is estimated that the electricity tariffs in Ghana have been fluctuating around 35 per cent. As of 2021, the average end-user electricity tariffs have stood at GH₵0.75/kWh (around US$0.09). remaining the same as the preceding year, this followed an upward trend observed since 2010. In 2010, on average, GH₵0.210/kWh was paid for electricity.

From Table 4, the average number of fossil fuel consumption (measured as % of fossil fuel energy consumption of total energy consumption) is 14.322 per cent with a minimum and maximum of 0.049 per cent and 40.422 per cent respectively and a standard deviation of about 14 per cent. This implies more than 10 per cent dispersion from the mean. It is observed that the range of the minimum and maximum is extremely high with high disparity. GDP per unit of energy use ($GDP_{energyuse}$), measured as constant 2017 PPP in US$ per kg of oil equivalent averages 12.340kg with a standard deviation of 1.894kg. The values of the GDP per unit of energy use range from 8.400kg to 14.074kg. This implies that on average, GDP per unit of energy use, Ghana could remain at approximately 12kg in Ghana. The minimum value of the population of Ghana is approximately 19 million people and the highest value is 30 million people with a standard deviation of approximately six million and a mean of 26 million people. This implies that the population of Ghana has been ranging from 19 million to 30 million people with an average of 26 million people.

Total agriculture employment *(agriculture employment)* (measured as the percentage of total employment in agriculture) has a mean of 46.415 per cent, approximately 46 per cent. This means that, on average, 46 per cent of the employed population of Ghana is in the agriculture sector. The standard deviation of 9.462 per cent shows that there is a dispersion of less than 10 per cent from the mean. The minimum percentage of agriculture employment is 29.750 per cent and the maximum value is 55.120 per cent. In the services sector, *(services employment)* there is a minimum value of 30.840 per cent of those who are employed with a maximum value of 49.210 per cent and a standard deviation of 7.049 and a mean of 37.922. This means that those employed in the services sector have always been more than 30 per cent. The level of employment in services as a share of total employment in Ghana saw no significant changes in 2019 in comparison to 2018 levels. It remained at almost 49.21 per cent. Nevertheless, 2019 still represents a peak in the share in Ghana with 49.21 per cent. The population of Ghana employed in the industry sector (*industry employment*) has been ranging from 13.870 per cent to 21.050 per cent with a mean of 15.666 per cent and a standard deviation of 2.621 per cent. This means that out of the total population employed, the highest per cent employed in the industrial sector is 21.050 per cent in the periods' understudy. It is, therefore, not surprising that the industrial sector has the lowest contribution GDP of Ghana.

Furthermore, education, which is measured as the percentage of gross tertiary education enrolment after secondary school, ranges from 0.786 per cent minimum to 20.142 per cent maximum with a mean of 8.065 per cent, and a standard deviation of 6.161 per cent. Thus, since 2001, tertiary education in Ghana has increased from approximately one per cent to more than 20 per cent in 2021. The government's commitment to education is one of the main reasons for the increase in the level of education in Ghana. The government has made a significant investment in education over the years, and this has led to an increase in access to education. According to the World Bank (2018), the GoG has increased its spending on education from 2.40 per cent of GDP in 2000 to 6.20 per cent in 2017. This increased spending has enabled the government to provide free education at the basic level, which has increased enrollment in primary schools. Another reason for the increase in the level of education in Ghana is the expansion of educational infrastructure. The government has invested in building new schools and improving existing ones. This has led to an increase in the number of schools and classrooms, making it easier for children to access education. Additionally, the government has invested in teacher training programmes, which has led to an increase in the number of qualified teachers in the country. This has improved the quality of education in Ghana and has contributed to the increase in enrollment in schools.

Vulnerable employment has a mean of 77.464 per cent with a standard deviation of 6.582 per cent. The minimum vulnerable employment is 65.10 per cent and the maximum is 85.250 per cent. In Ghana, the percentage of vulnerable employment is quite high. For females, the mean vulnerable employment is 84.969 per cent with a standard deviation of 5.067 per cent. The minimum vulnerable employment for the female is 75.190 per cent and the maximum is 91.030 per cent. For males, the mean vulnerable employment is 70.710 per cent with a standard deviation of 7.740 per cent. The minimum vulnerable employment for males is 56.430 per cent and the maximum is 79.980 per cent. Based on data from the ILO, the mean of vulnerable employment in Ghana is 77.464 per cent, with a standard deviation of 6.582 per cent. This means that the majority of Ghanaians work in vulnerable employment, which is a cause for concern, especially among females. It is important to note that vulnerable employment is not limited to low-skilled workers. Even those with high levels of education can find themselves in vulnerable employment, especially in the informal sector. One of the reasons for the high level of vulnerable employment in Ghana is the lack of formal job opportunities. The formal sector in Ghana is small, and most jobs require high levels of education and experience. This means that many people are forced to work in the informal sector, where they are exposed to poor working conditions and low wages.

Ghana has a mean unemployment rate of 5.572 per cent, with a standard deviation of 2.178 per cent. This means that the majority of the population is employed, but there are still significant pockets of unemployment that need to be addressed. The minimum unemployment rate in Ghana is 2.17 per cent, while the maximum is 10.46 per cent. A low mean unemployment rate indicates that the majority of the population is employed and contributing to the economy. These lower rates could be due to Ghana's steady economic growth over the past decade, with an average growth rate of around six per cent per year. This growth has led to the creation of new jobs in sectors such as manufacturing, construction, and services. Also, Ghana has made efforts to diversify its economy, moving away from traditional sectors such as agriculture and mining. This has led to the creation of new industries and job opportunities. The government of Ghana has implemented policies to promote job creation, such as the Youth Employment Agency, and Nation Builder Corps, which provide training and job opportunities for young people.

Renewable energy consumption (*REC*), which is estimated to be renewable energy consumption (percentage of total final energy consumption) has a maximum value of 69.320 per cent and a minimum value of 41.480 per cent with a standard deviation of 8.724 per cent and a mean of 52.892 per cent. This is mainly because renewable energy consumption in Ghana is dominated by the use of renewable hydroelectricity. One of the primary reasons for Ghana's high renewable energy consumption is the country's abundant natural resources. Ghana has a diverse range of renewable energy sources, including hydropower. The country's hydropower potential alone is estimated to be around 2,000MW, with only a fraction of this potential currently being utilised. Ghana's abundant natural resources have made it possible for the country to generate a significant amount of its energy from renewable sources.

Renewable and Access to Electricity

Figure 18 displays renewable energy and electricity accessibility in Ghana. it is observed that in 2001, the share of renewable energy was more than 69 per cent while electricity accessibility was, approximately, 45 per cent. The difference between renewable energy consumption and electricity accessibility was more than 24 per cent. Furthermore, it is observed that from 2001 to 2006, consumption of renewable energy was more than electricity accessibility. This is because, in those periods, Ghana depended on renewable hydropower to generate electricity. However, after 2007, electricity accessibility exceeded the consumption of renewable energy. Moreover, it is observed that there was a sharp drop in consumption of renewable energy from approximately 70 per cent in 2001 to about 45 per cent in 2006. It is observed that renewable energy consumption has consistently been decreasing with an average of 2.5 per cent annually. The consumption of renewable energy in 2020 was approximately 42 per cent. This is a sharp drop of more than eight per cent since Ghana discovered crude oil. This decline in renewable energy consumption could be due to the power crises Ghana has been experiencing over the years. These power crises have made various governments sign many power contracts with independent power producers. This has favoured electricity accessibility to be increasing. In 2020, access to electricity was, approximately, 83.5 per cent of the total population of Ghana.

This increase in access to electricity is not surprising since Ghana achieved a lower medium-income status. The plausible reason could be that while Ghana has made progress in developing its renewable energy sector, it may not have been enough to keep pace with the country's growing demand for electricity. Limited investment in

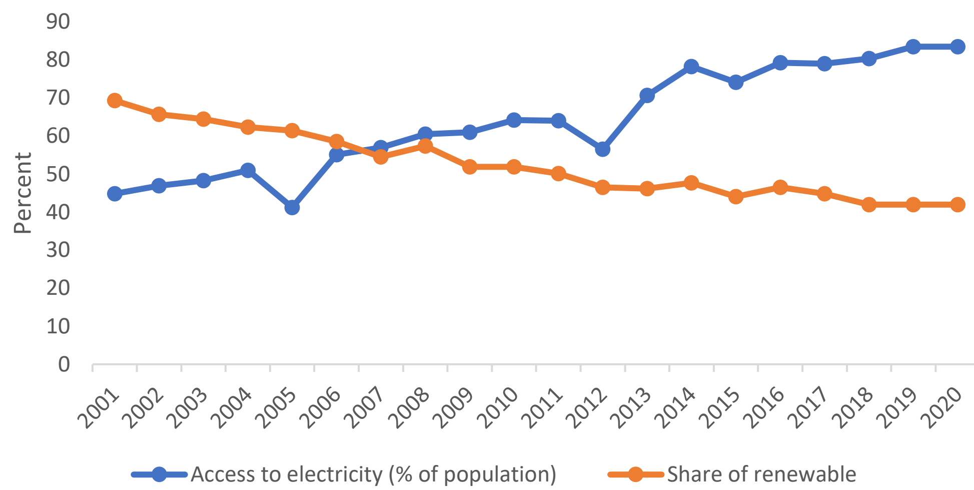

Figure 18: Renewable and Electricity Accessibility

Source: Author's Construction (2023)

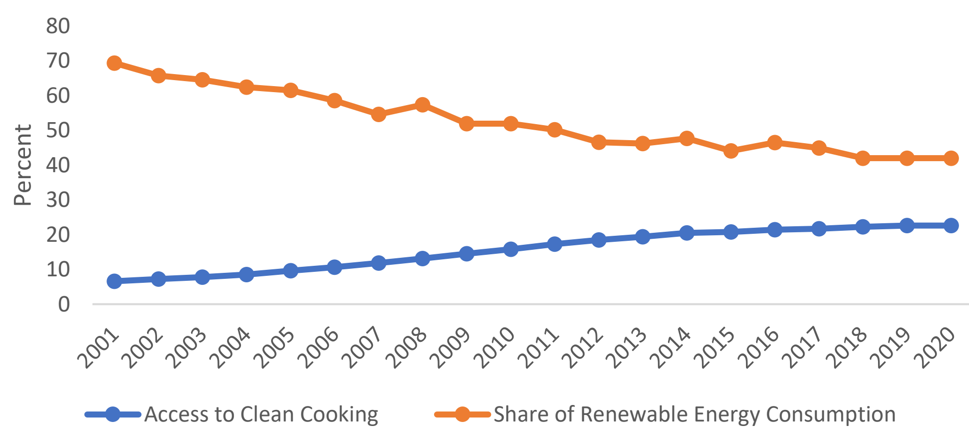

Figure 19: Access to Clean Cooking and Renewable Energy Transition

Source: Author's construct (2023)

renewable energy infrastructure and technologies may have contributed to a decrease in renewable energy consumption. Ghana might have increased its reliance on traditional energy sources, such as fossil fuels, to meet its growing energy demands. This could be due to a variety of factors, including cost, availability, and infrastructure limitations.

Access to Clean Cooking Fuel and Renewable Energy Transition

Figure 19 depicts the trends of the percentage of access to clean fuels and technologies for cooking and the percentage of renewable energy transition from 2001 to 2020. It is observed that access to clean fuel and technologies for cooking has been increasing while the renewable energy transition has consistently been decreasing. In 2001, there was more than 69 per cent reliance on renewable energy until 2007 when it fell to less than 55 per cent. In the same period, access to clean fuels and technologies for cooking increased from, approximately, 6.6 per cent to approximately 11.8 per cent. Renewable energy consumption kept decreasing after 2008. However, within the same time frame, access to clean fuels and technologies for cooking increased from, approximately, 11.8 per cent to, approximately, 22.6 per cent.

Access to clean fuel and technologies for cooking kept increasing to, approximately, 28 per cent in 2020. Meanwhile, renewable energy consumption kept decreasing with an average percentage of 2.12. The increase in access to clean fuel and technologies for cooking can partly be attributed to the increase in access to technologies and income levels of Ghanaians. These trends of access to clean cooking technologies could be due to the implementation of policies by the government. The GoG has been prioritising increasing clean cooking accessibility as part of its efforts to promote clean cooking. Some of the policies of the government include the National LPG Promotion Policy. This has led to LPG use in Ghana. however, it is noteworthy that the consumption of renewable energy continues to exceed accessibility to clean cooking technologies.

Energy Availability and Consumption of Renewable Energy

Figure 20 shows energy availability and renewable energy consumption in Ghana. It can be observed that there is an upward trend in energy availability while there is a downtrend in the consumption of renewable energy.

That is, energy availability has increased from 7,277.12GWh in 2001 to as high as 16,153.70GWh in 2021. Plausibly, in recent times, Ghana has attracted significant investments in the energy sector, including from international organisations and private companies. This has led to the construction of new power plants, the expansion of existing ones, and the installation of new transmission and distribution infrastructure. Also, Ghana has diversified its energy mix by investing in renewable energy sources such as solar, wind, and biomass. This has increased the resilience of the energy sector and reduced Ghana's dependence on imported fossil fuels. Further, Ghana is a member of the West African Power Pool (WAPP), which has enabled Ghana to import and export electricity to and from neighbouring countries, increasing the availability of electricity in the country.

Energy Affordability and Consumption of Renewable Energy

Figure 21 depicts the trend of consumption of renewable energy and energy affordability. It shows that energy affordability has been declining. The prices of energy have increased from 0.075GHCkWh to 0.7GHCkWh. This could be because Ghana relies heavily on imported fossil fuels, such as crude oil and natural gas, to generate electricity. The price of these fuels is subject to international market fluctuations, which can result in significant increases in the cost of electricity. Also, despite the significant investments in expanding the national grid, there are still

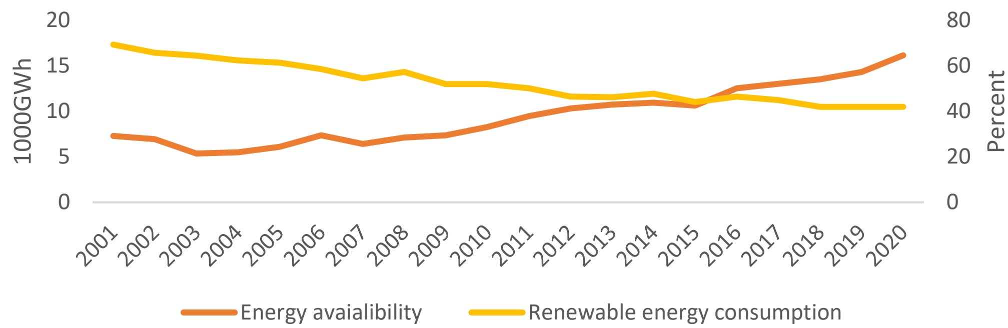

Figure 20: Renewable Energy Consumption and Energy Availability

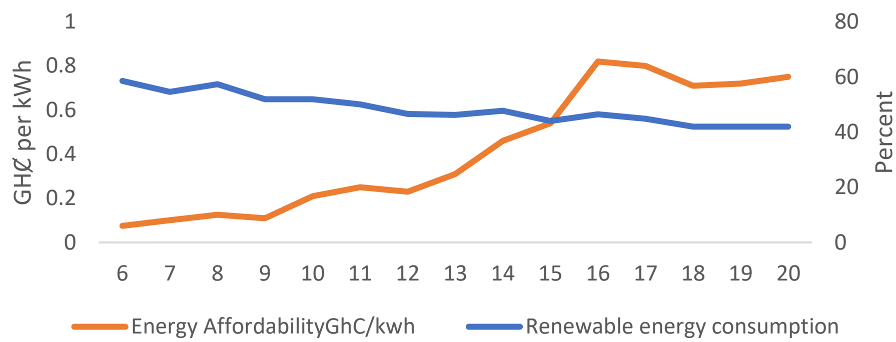

Figure 21: Energy Affordability and Consumption of Renewable Energy

many areas in Ghana where access to electricity is limited. This can result in higher costs for those who do have accessibility, as the cost of transmission and distribution is spread across a smaller customer base. Further, Ghana's power generation infrastructure is outdated and inefficient, which can result in higher costs for consumers. In addition, the country's reliance on fossil fuels means that power generation is often more expensive than it would be with more modern, renewable energy sources.

Renewable Energy Share of Consumption in the US and Crude Oil Imports from Ghana

Figure 22 depicts the monthly US consumption of renewable energy and its crude oil imports from Ghana from 2016 to 2021. The import of crude oil has been

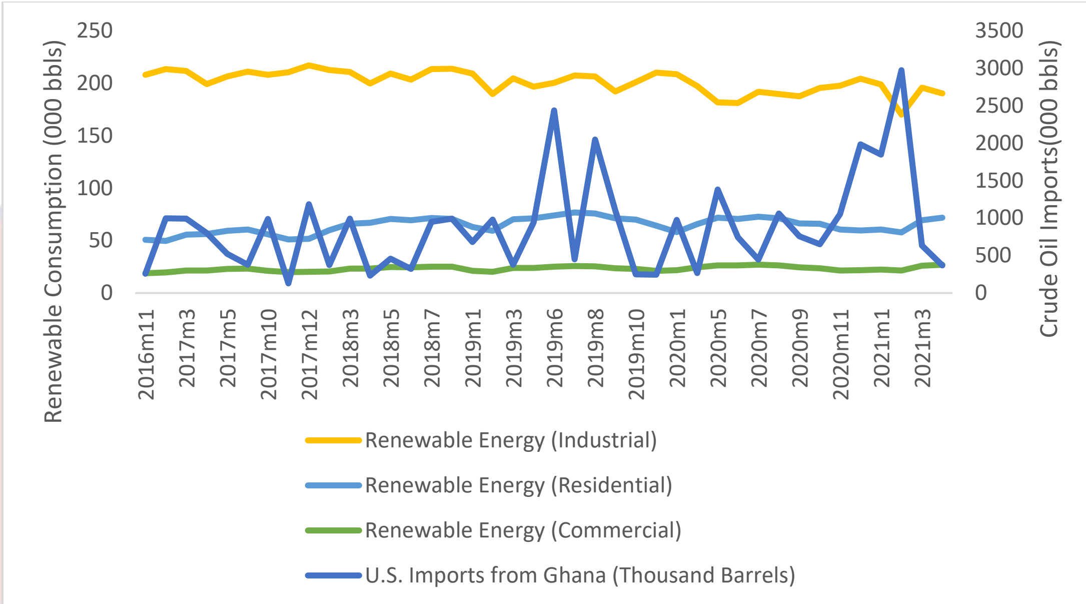

Figure 22: US Renewable Energy and Crude Oil Imports from Ghana

Source: Author's construct (2023)

fluctuating throughout the period. Crude oil import from Ghana rises from 257MBbls in November 2016 to 996MBbls in January 2017. The highest import (2.975MMBbls) is recorded in February 2021. The minimum import is recorded in November 2017 with a value of 129MBbls. It shows that the US industrial sector consumes more renewable energy than crude oil imports from Ghana from 2016 to January 2021. However, after that, there is a drastic drop in imports of crude oil from Ghana from 2.975MMbls to 371MBbls. This massive drop could be due to the impact of Covid-19 on the petroleum economies of the world and improvement in renewable energy consumption.

Residential consumption of renewable energy rises from 50.64 trillion Btu in November 2016 to 60.505TBls in July 2017 after it drops to 51.085TBls in November 2017. The highest consumption of renewable energy consumption by residential purposes is 74.094TBls which is recorded in June 2019. Renewable energy consumption for commercial purposes rises from 19.602TBls in January

2017 to 21.62TBls in April 2017. Afterwards, it was stable around 23TBls. The highest consumption is 26.356TBls in May 2020 and the minimum consumption is 20.3TBls in February 2019.

From Figure 22, it is depicted that the consumption of renewable energy by both commercial and residential does not have many impacts on crude oil imports from Ghana. This could be because the residential and the commercial do not depend so much on crude oil for their activities. They might depend on refined products from crude oil. Also, the consumption of renewable energy for residential purposes is relatively stable as well as that for commercial purposes. This is mainly because crude oil from Ghana is light crude, which is normally used in the generation of electricity. Also, light crude oil is a key feedstock for the production of petrochemicals, which are used to make a wide range of consumer goods such as plastics, synthetic fibres, and pharmaceuticals.

US Industry Production and Crude Oil Import from Ghana

From Figure 23, it is observed that the import of crude oil from Ghana has had an upward trend from 2016 to 2021 shown by the liner projection line. Also, there is an upward trend in the US industrial sector production depicted by the linear projection line. The minimum value of industrial production is 85.843 which occurred in May 2020. The industrial sector production has been stable and might not have a great effect on the import of crude oil from Ghana. although it can be said that when industrial production increases, US crude oil import from Ghana rises relatively smaller. This could be due to the great lockdown that happened in the US and globally and the shutdown of firms and industries. This could also be

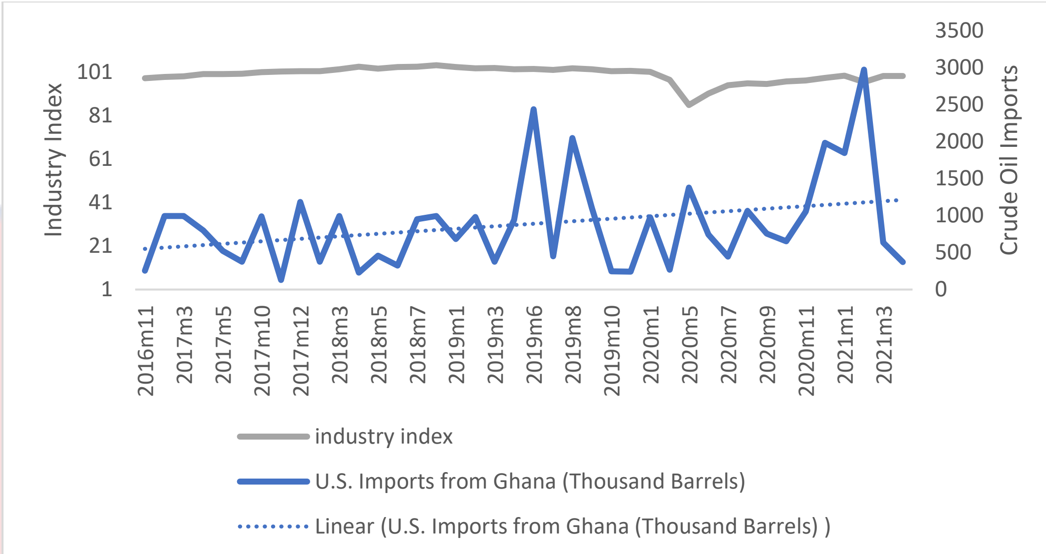

Figure 23: US Industry Production and Crude Oil Import

Source: Author's construct (2023)

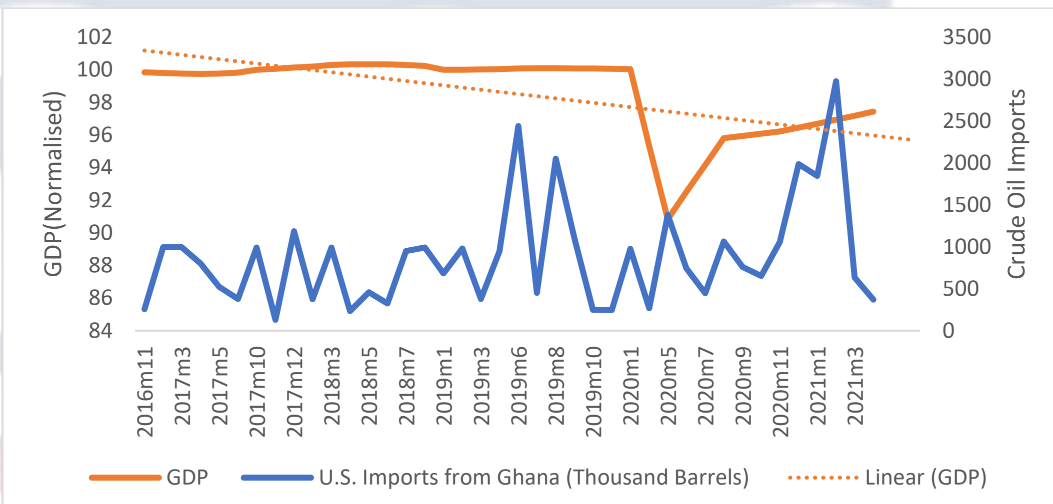

Figure 24: US GDP and Oil Import from Ghana

Source: Author's Construct (2023)

because the industry sector in the US depends not only on crude oil but also on renewable energy production shown in Figure 23.

Income of the US and Crude Oil Import from Ghana

Figure 24 shows the level of income and crude oil imports from Ghana. It is indicated that there is a downward trend in GDP since 2016. This is mainly influenced by the sharp drop in income from 100.047 in January 2020 to 90.833 in May 2020. It is also shown that income levels in 2020 are relatively smaller than the previous income level of the US. This might be due to the effect of the COVID-19 pandemic on the economies of the world. Again, it is shown that relatively, the income of the US has an effect on crude oil import from Ghana. As income level increase, imports of crude oil increase but with a relatively smaller effect.

Descriptive Statistics of the US Data

Table 5 details the descriptive statistics of the US data. All the variables have 84 observations. From Table 5.2, the U.S. Imports from Ghana of crude oil and petroleum products (measured in thousand barrels) (*us_import*) has a mean of 788.819 thousand barrels with a minimum value of 129 thousand barrels and a maximum value of 2975 thousand barrels. The standard deviation is 577.516 thousand barrels. This implies that the dispersion is 577.516 thousand barrels.

The total solar energy consumption, consumption of solar energy by all the sectors of the economy, (*totalsolar*), is 75.192 trillion Btu on average with a minimum consumption of 0.345 trillion Btu and maximum consumption of 144.167 trillion Btu. The dispersion from the mean is 30.913 trillion Btu. The total wind energy consumed (*totalwind*) by all the sectors of the economy has an average consumption of 211.442 trillion Btu and minimum consumption of 33.122 trillion Btu and maximum consumption of 352.26 trillion Btu with 48.556 dispersion from the means. Total renewable energy consumption (REC), has a mean of 904.374 trillion Btu. This implies that, on average, the US consumes 904.374 trillion Btu of renewable energy. The minimum consumption of renewable energy is 0.759 trillion

Table 5: Summary Statistics of the US Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Usimport	84	788.819	577.516	129	2975.000
RECsolar	84	75.192	30.913	0.345	144.167
Totalwind	84	211.442	48.556	33.112	352.260
TotalREC	84	904.374	173.991	0.759	1088.891
PCGDP	84	54760.780	3649.758	48726.580	61855.520
RR	84	113.907	13.886	6.710	123.920
Usindprodindex	84	99.816	3.580	84.202	104.166
WTI	84	53.245	12.254	16.550	81.480

Source: Author's own compute (2023)

Btu and the maximum is 1088.891 trillion Btu with a standard deviation of 173.991 trillion Btu. Again, from Table 5, GDP per capita *(PCGDP*) which means the income of the US has mean of US$54,760.780 with a standard deviation of US$3,649.758. This implies that there is a dispersion of US$3,649.758 from the mean. According to the US Census Bureau, the median income was US$68,703 in 2019. This implies that half of the households had income above US$68,703, while the other half had income below US$68,703. The mean income of US$54760.780 is lower than the median income because the income distribution is not evenly distributed. The mean income is pulled down by the lower-income households, who are more than the high-income households. the standard deviation of US$3,649.758 means that there is a dispersion of US$3,649.758 from the mean. This implies that most of the incomes in the US are close to the mean income of US$54,760.780. The minimum value of the GDP per capita of the US is US$48,726.580 with a maximum value of US$61,855.520. These high values are because the US is one of the largest economies in the world and is known for its high standard of living.

The US real effective exchange rate minimum of 70.544 percentage points and a maximum value of 48.778 percentage effective exchange rate (*RR*) has a mean value of 113.907 with a standard deviation of 13.886. The maximum value of the real broad effective exchange rate is 123.920 with a minimum value of 6.71. This implies that the RR in the US ranges from 6.71 to 123.920. Furthermore, from Table 5.2, the US industrial production index, (*Usindprodindex*), has a mean value of 99.816 with a dispersion from the mean value of 3.580. The industrial production index has a minimum value of 84.202 and a maximum value of 104.116. This implies that industrial production in the US is effective and strong since both the minimum and the maximum values are closer to 100. This shows the importance of the US economy on the impact of the petroleum economy of Ghana. The US demand for rapid transition could affect the crude oil industry globally.

Moreover, from Table 5, crude oil price (*WTI*) has an average price of US$53.245/bbl with a standard deviation of US$12.254/bbl. The minimum crude oil price in the US is US$16.55/bbl and the maximum price is US$81.48/bbl. This implies that the price of crude oil could decrease to as low as US$16.55/bbl and increase to as high as US$81.48/bbl with US$12.254/bbl dispersion from the mean. This shows the nature of the variability of crude oil prices.

Descriptive Statistics of Major Countries Renewable Energy and Crude Oil Demand from Ghana

Figure 25 presents renewable energy consumption in China, Canada, Italy and India and the import demand for crude oil from Ghana. Crude oil imported from Ghana, in general, shows downward trends as indicated by the linear projection line. It has been decreasing from May 2017 to May 2021. This trend of the decrease could be due to the global Covid-19 pandemic which affected the world economy, particularly, the petroleum markets. The import demand for crude oil from Ghana by China is $ 188.05 million in May 2017, although fluctuating, it keeps increasing up to $ 324.13 million in March 2019. In April 2019, there is a $0 import of crude oil from Ghana. also, in June 2021, there is $0 crude oil demand from Ghana. The highest import of crude oil from Ghana is $ 466.57 million in October 2018. Generally, there is fluctuation in China's crude oil imports from Ghana.

Figure 25 also shows the trend of renewable energy consumption, represented by solar energy. It is indicated by the linear projection line that there is an upward consumption of renewable energy in China, India, Italy, and Canada boosted by solar energy. Solar energy consumption has been rising from 5.3terawatt hours to 14.36terawatt hours. The highest consumption of solar energy 24.67terawatt hour which occurs in both November 2020 and December 2020. Figure 25 shows that as renewable energy consumption increases, import demand for crude oil from Ghana decreases indicating both the linear trend lines and the fluctuations of both commodities.

Industrial Production of China and Crude Oil Import from Ghana

Figure 26 indicates the trends of industrial production and crude oil import demand from Ghana. It shows that industrial production in China has been stable over the years. There are not enough fluctuations in industrial production except in February 2020 where there is a fall in industrial production to 86.5. The highest production index is recorded in Mach 2021 with a value of 114.1. This

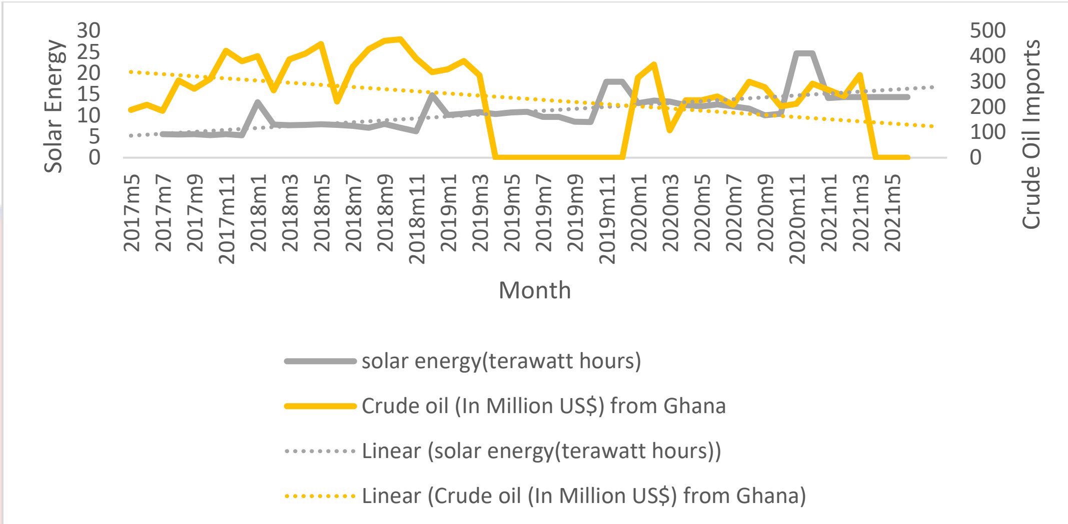

Figure 25: Renewable Energy and Crude Oil Import from Ghana

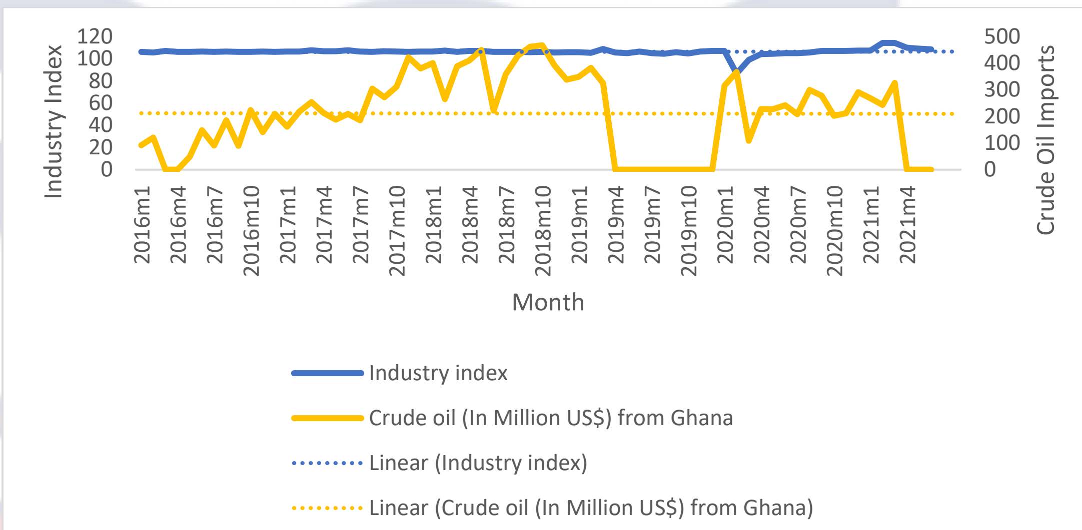

Figure 26: China's Industrial Production and Crude Oil Import from Ghana

Source: Author's construct (2023)

shows the stability of industrial production in China. Figure 5.9 shows that the crude oil import demand for China from Ghana does not influence industrial production in China. The linear projection lines of both commodities have not been influenced by each other. This implies that industrial production in China cannot be affected by the crude oil imported from Ghana.

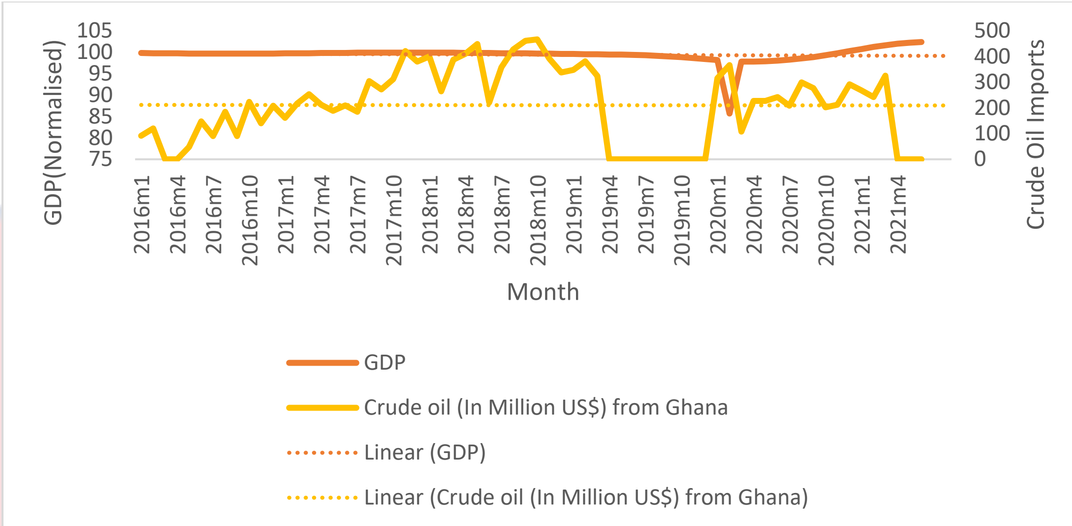

Figure 27: China's income and crude oil import from Ghana

Source: Author's construct (2023)

China's Income and Crude Oil Import Demand from Ghana

Figure 27 shows the stability of the income of China since 2016. Although there is a fall in income from 98.381 in December 2019 to 85.683 in February 2020 there is an upward trend. The highest income is recorded in June 2021 with a value of 102.378. The figure shows that fluctuations in crude oil imports from Ghana do not influence the fluctuations in income.

India Industrial Production and Crude Oil Imports from Ghana

Figure 28 shows the trends of industrial production and crude oil import demand from Ghana to India. It is depicted that crude oil import demand from Ghana for India has an upward trend as projected by the liner projection line. Crude oil demand for India fluctuates throughout the period. The highest crude oil demand from Ghana has a value of US$ 466.57 million in October 2018. Also, industrial production has an upward trend. The highest industrial production is 119.241 recorded in November 2018.

Figure 28 indicates the relationship between crude oil import demand from India from Ghana and industrial production in India. Generally, it shows that as industrial production goes up, crude oil import from Ghana goes up as well for most of the periods. This implies that industrial production in India could depend on crude oil from Ghana to increase their output. With the inclusion of income, the trend of crude is virtually the same. The figure, however, shows that fluctuations in income do not affect the fluctuations in crude oil import demand for India from Ghana. This indicates that crude oil is income inelastic.

Renewable Energy Transition and Crude Oil Demand for India

Figure 29 indicates the energy transition and crude oil import demand for India from Ghana. It shows the trends of renewable energy consumption in India. Renewable energy consumption has shown some forms of fluctuation for most parts of the period although there are some stabilities for some periods. It is observed that renewable energy has some form of influence on the import demand for crude oil from Ghana. Upward trends in renewable energy consumption have a downward effect on crude oil import demand.

Industrial Production and Crude Oil Import Demand for Italy

Figure 30 shows that there is relative stability in industrial production in Italy indicated by the linear projection line. However, there are fluctuations in the crude oil import demand for Italy. There is a drastic drop in industrial production in January 2020 value of 104.591 to 843.793 in May 2020. Also, there is a drastic drop in crude oil import demand from Ghana from US$324.13 million in March 2019 to US$0 in April 2019. The highest industrial production is 110.491 which is

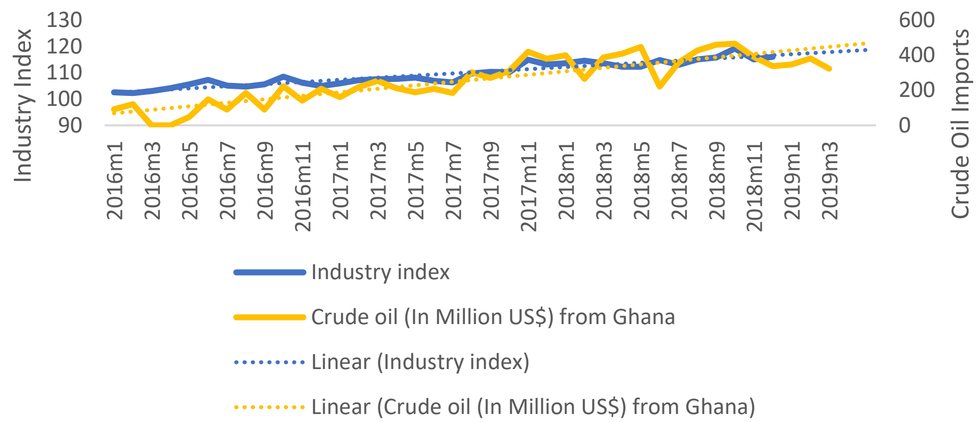

Figure 28: India's industrial production and crude oil from Ghana

Source: Author's construct (2023)

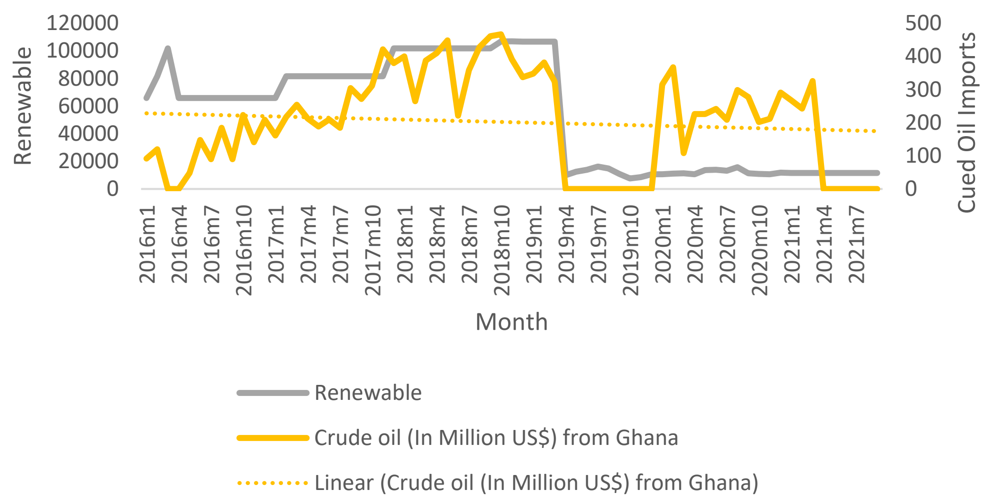

Figure 29: Energy transition and crude oil demand for India

Source: Author's construct (2023)

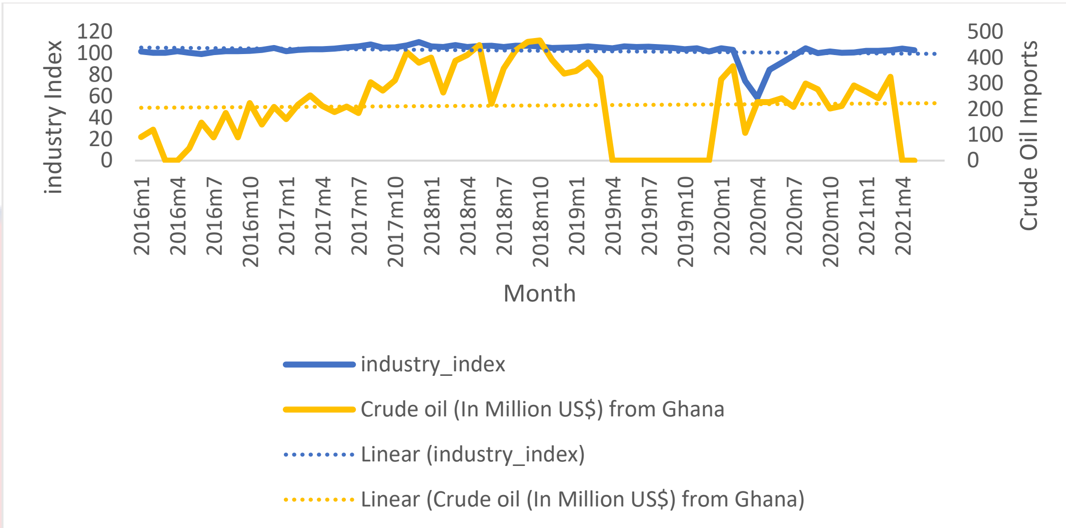

Figure 30: Industrial production and crude oil demand for Italy

Source: Author's construct (2023)

recorded in December 2017. The highest crude oil demand from Ghana has a value of US$466.57 million in October 2018. Figure 30 shows that fluctuations in crude oil import demand for Italy from Ghana are not influenced by industrial production in Italy. Increase and decrease in industrial production in Italy do not have influences on crude oil import demand for Italy from Ghana.

Renewable Energy Transition and Crude Oil Import Demand for Italy

Figure 31 indicates renewable energy consumption and crude oil import demand for Italy from Ghana. The figure shows that there are periods of stability and fluctuations in renewable energy consumption.The highest value of renewable energy consumption is 393,470 recorded in October 2019 and July 2020. The lowest value is 167,998 recorded in May 2021. It shows that the energy transition does not influence crude oil import demand from Ghana.

Figure 32 shows the trends of income and crude oil import demand from Ghana to Italy. The figure shows that there are no links between income to crude

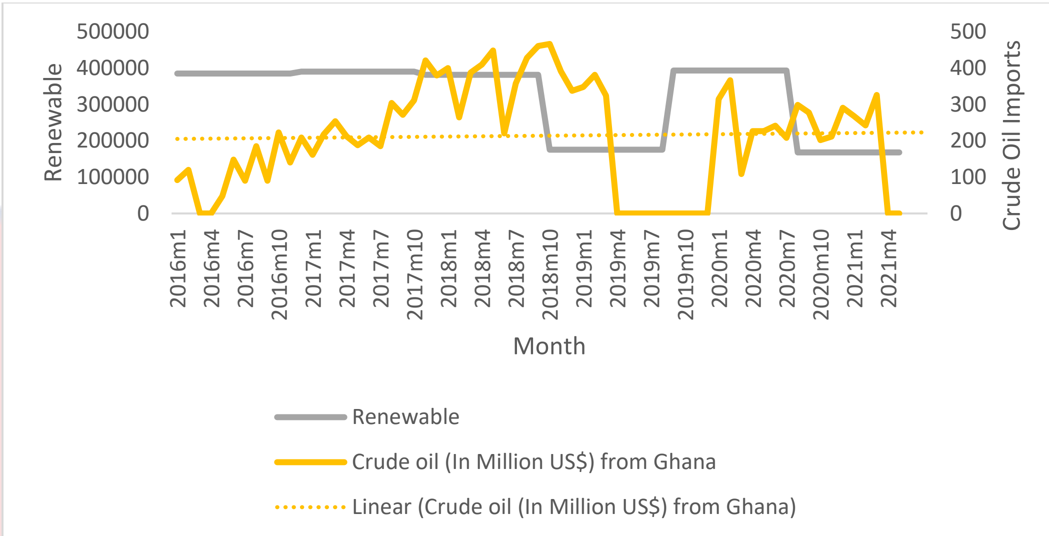

Figure 31: Renewable energy transition and crude oil demand for Italy

Source: Author's construct (2023)

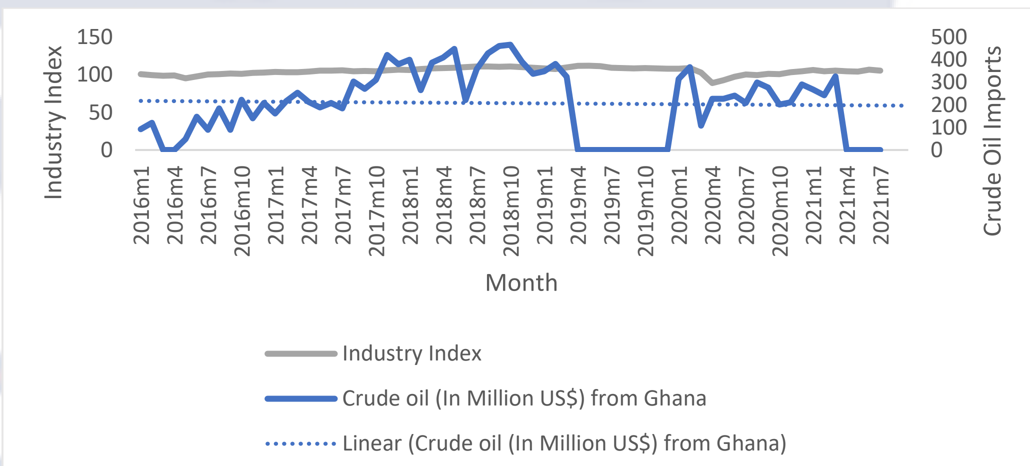

Figure 32: Canada's industrial production and crude oil imports from Ghana

Source: Author's construct (2023)

oil demand from Ghana from January 2016 to June 2020. After this period, crude oil demand and income tend to move in the same direction. This implies that crude oil import demand from Ghana and income in Italy have no connections. It indicates that there is no link between industrial production in Canada and crude oil imported from Ghana. The link between crude oil import demand from Ghana and industrial production in Canada is very difficult to predict with certainty. There are high levels of fluctuations in the crude oil import demand from Ghana. This unpredictability could affect the petroleum economy of Ghana. The figure shows that the only period of stability is from April 2019 to December 2019. This implies there was stability in crude oil demand for Canada from Ghana in 2019. However, fluctuations in renewable energy consumption are recorded in all the other periods. The highest value of crude oil import demand is US$466.57 million recorded in October 2018. The highest value of renewable energy consumption is 68.52 recorded in January 2021. The projection of crude oil import demand for Canada, shown by the linear projection line, is decreasing while that of renewable energy consumption is increasing. It shows that energy transition and crude oil import demands have some forms of links for some periods.

Summary Statistics of the Data for Other Four Countries

Table 6 gives details of the descriptive statistics of the countries' understudy and the variables used in attaining the objective of the chapter. Four countries, including China, Italy, India, and Canada are used.

Crude oil price (*Brent*) has a mean value of $57.037 per bbl with a maximum value of $83.54 per bbl and a minimum value of $18.38 per bbl. The standard deviation is $13.849 per bbl. This means that crude oil prices have been fluctuating. There are variabilities associated with crude oil prices with a deviation of approximately $14 per bbl. This implies that the prices of crude oil cannot be predicted.

The industrial production index of China has a mean value of 106.063 with

Table 6: Summary Statistics of the Four Countries

Variable	Obs	Mean	Std. Dev.	Min	Max
Brent	84	57.037	13.849	18.38	83.54
China					
Indprodindex	84	106.063	3.073	86.500	114.100
PCGDP	84	6286.451	2820.656	2359.568	11188.3
RR	84	123.623	2.980	118.860	130.940
Chinaimport	84	198.547	149.089	0.000	466.570
REC	84	9.981	4.305	5.300	24.670
India					
Indproindex	84	118.613	11.050	102.290	139.858
PCGDP	84	1332.574	398.056	777.734	1941.815
RR	84	100.464	2.305	94.6	104.59
Indiaimport	84	193.032	150.603	0	466.57
REC	84	54135.28	39349.27	7635	106780
Italy					
Italyimport	84	198.547	149.089	0	466.57
REC	84	315,674.7	102,602.2	167,998	393,470
RR	84	95.653	1.023	93.04	97.79
PCGDP	84	31937.880	1343.401	29353.820	34081.09
Indproindex	84	102.589	7.452	58.595	110.491
Canada					
REC	84	71.034	10.878	59.225	95.687
Canadaimport	84	98.547	149.089	0	366.57
RR	84	82.223	1.895	76.38	87.11
PCGDP	84	42061.150	1942.953	38185.220	45109.250
Indproindex	84	104.967	4.727	88.988	112.059

Author's own compute (2023)

a minimum value of 86.500 and a maximum value of 114.100. The standard deviation is 3.073 and has 68 observations. For Italy, the production index has a mean value of 102.589 with a standard deviation of 7.452, a minimum value of 58.595 and a maximum value of 110.491. For India, it has a mean value of 118.613, a minimum value of 102.290, a maximum value of 139.858, and a standard deviation of 11.50. For Canada, the industrial production index has a mean value of 104.967. The minimum value is 88.988 and the maximum value is 112.059 with a 4.727 standard deviation and 84 observations. India has the highest industrial production index mean value while Italy has not lowest industrial production index relatively.

The maximum value of GDP per capita (PCGDP) of China is 102.554 and the minimum value is 85.500 with a standard deviation of 3.073. The income of Italy has a maximum value of 101.046 and a minimum value of 85.601 with a standard deviation of 3.780. For India, the maximum value of income is 101.167 and the minimum value is 83.480 with a standard deviation of 4.028. The mean value is 118.613. For Canada, the income has a means of 98.659, with a maximum value of 100.572, a minimum value of 87.470, and a standard deviation of 2.944. China has the highest mean and maximum income values. This is expected as China is the second-largest economy in the world. India has the minimum income value. Generally, it is accepted that out of these four countries, India is considered to be relatively the poorest.

The exchange rate in China has a mean value of 123.623 with a maximum value of 130.940 and a minimum value of 118.860. The dispersion of 2.98 from the mean. For India, the exchange rate has a mean value of 100.464 with a minimum value of 83.480 and a maximum value of 104.59. The standard deviation is 2.305. For Italy, the maximum value of the exchange rate is 97.79 and the minimum value is 93.04. The mean value is 95.653 with a standard deviation of 1.023. for Canada, the mean value of the exchange rate is 82.223. The maximum value of the exchange rate in Canada is 87.11 and the minimum value is 76.38 with a standard deviation of 1.895. China has the maximum mean exchange rate while Canada has the minimum mean exchange rate. These results are not surprising since China is noted for higher currency depreciation.

From Table 6, it is observed that China's crude oil import demand from Ghana (*chinaimport*) has a mean value of US$198.547 million with a maximum value of US$457.570 million and a minimum value of US$0.00 million. India crude oil import from Ghana (*indiaimport*) has a mean value ofUS$193.032 million with a maximum value of US$466.57 million and a minimum value of US$0.00 million. Crude oil import demand for Italy from Ghana (*italyimport*) has a mean value of US$198.547 million and a maximum value of US$466.57 million and a minimum value of US$0. Canada crude oil import demand from Ghana (*canadaimport*) has a mean value of US$98.547 million with a maximum value of US$366.57 million and a minimum value of US$0. On average, China has the maximum mean value of imports of Ghana's petroleum. This implies that the rapid transition in China will have more effect on the petroleum economy of Ghana. However, there are some periods these countries do not import crude oil from Ghana.

Renewable energy transition (power generation from solar energy in China measured in terawatt hours) (*solar*) has a mean of 9.981terawatt hours, a maximum of 24.670terawatt hours and a minimum of 5.30terawatt hours. For India, renewable energy has a mean of 54,135.28megawatt with a maximum of 106,780megawatt, a minimum value of 7,635megawatt and a standard deviation of 39,349.27megawatt. This represents 38.7 per cent of the overall installed capacity in India. For Italy, renewable energy production has a mean of 315,674.7. The maximum renewable energy production is 393,470 while the minimum is 167,998 with a standard deviation of 102,602.2. Energy transition in Canada, measured as the percentage of electricity, has a mean of 71.304 per cent. The maximum percentage is 95.687 per cent and the minimum is 59.225 per cent. The high percentages are because of the utilisation of hydroelectricity and other renewable sources of energy in Canada. With these high energy transitions in these countries, the petroleum economy of Ghana could be affected.

Renewable Energy and Vulnerable Employment

Figure 33 shows the trends of vulnerable employment in Ghana since 2001 covering the period understudy. It is observed that the consumption of renewable energy and all the types of vulnerable employment has been declining. This is because Ghana has experienced steady economic growth in recent years, which has created more formal and better-paying jobs. The government has also implemented policies to promote job creation and economic development, such as the One District, One Factory initiative. The government has implemented several labour market policies to promote formalisation and to reduce vulnerable employment, such as the National Apprenticeship Programmes, which provides training and support to apprentices in the informal sector.

Unemployment and Consumption of Renewable Energy in Ghana

Figure 34 shows the trends of unemployment and consumption of renewable energy and how related they are. The trends depict that unemployment among males, and females and total national unemployment have been declining from the rate in 2001 to 2021. The trends show that the rate of unemployment in

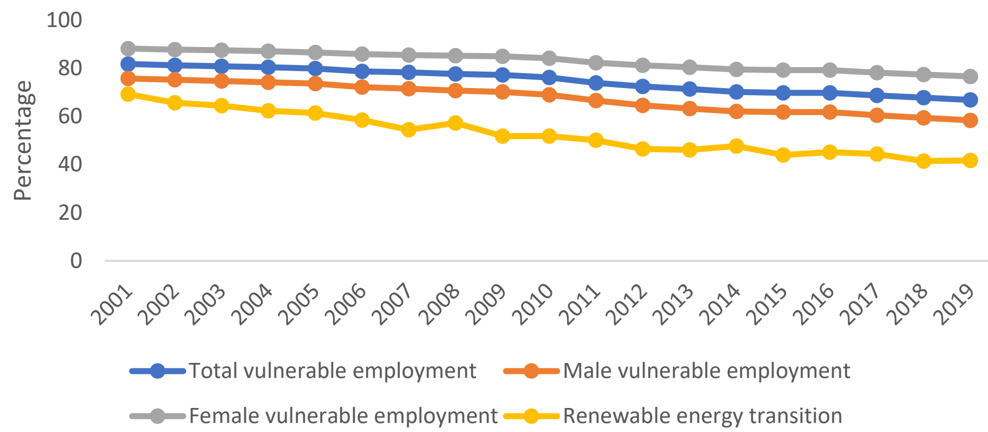

Figure 33: Renewable Energy and Vulnerable Employment in Ghana

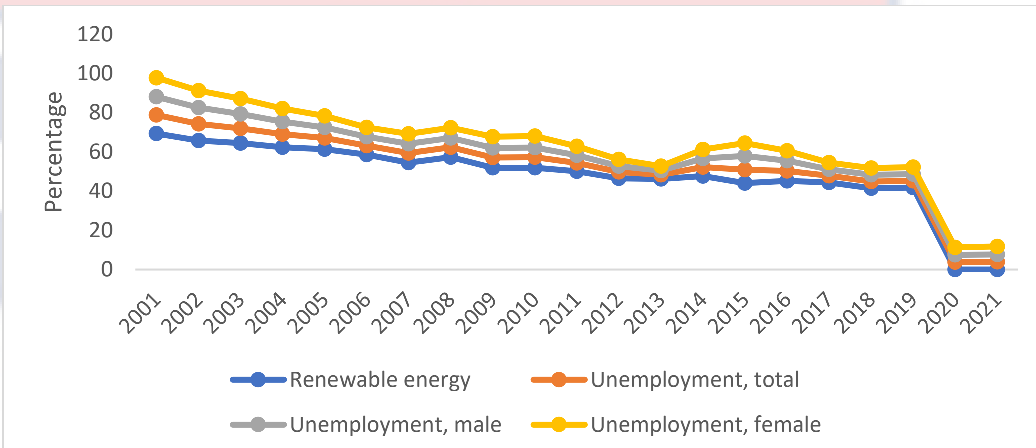

Figure 34: Renewable Energy and Vulnerable Employment in Ghana

2021 is as low as 3.98 per cent. Again, the trends show that consumption of renewable energy and unemployment move together and have the same direction. Plausibly, the GoG has made significant investments in education and training, which has improved the skills and employability of workers. For instance, the Free Senior High School policy has increased access to secondary education, which can lead to better job opportunities. The growth of small and medium-sized enterprises in Ghana has contributed to job creation and reduced unemployment.

Employment and Consumption of Renewable Energy in Ghana

Figure 35 shows the trends of employment in all three main sectors of the economy of Ghana. The sectors and how they co-move with the consumption of renewable energy are depicted. It is shown that employment in the agriculture sector continued to be the highest from 2001 until 2014 and in the same period, employment in the industry sector is the lowest. Employment in the industrial sector continues to be the lowest for the entire period from 2001 to 2019. This is not surprising that agriculture has been contributing the largest share of GDP in Ghana. The economy of Ghana has been mostly based on agriculture. It is noteworthy that the agriculture sector has received massive support from all successive governments. Currently, there is Planting for Food and Jobs and Planting for Export, which may increase employment in the agriculture sector. However, the industry sector has been facing many challenges including power outages.

The statistics indicate that in 2001, more than 55 per cent were active in the agriculture sector while about 31 per cent were active in the services sector and about 14 per cent were active in the industry sector. These trends kept almost the same from 2002 up to 2014 when the distribution of employment in the services sector has been highest since then. This is because the economy of Ghana has undergone significant changes in recent years, with a shift towards services-based industries. This shift is a result of government policies aimed at diversifying the economy and promoting growth in sectors such as finance, telecommunications, and tourism. Also, Ghana's agriculture sector is largely made up of small-scale farmers who often lack access to modern farming technologies and infrastructure,

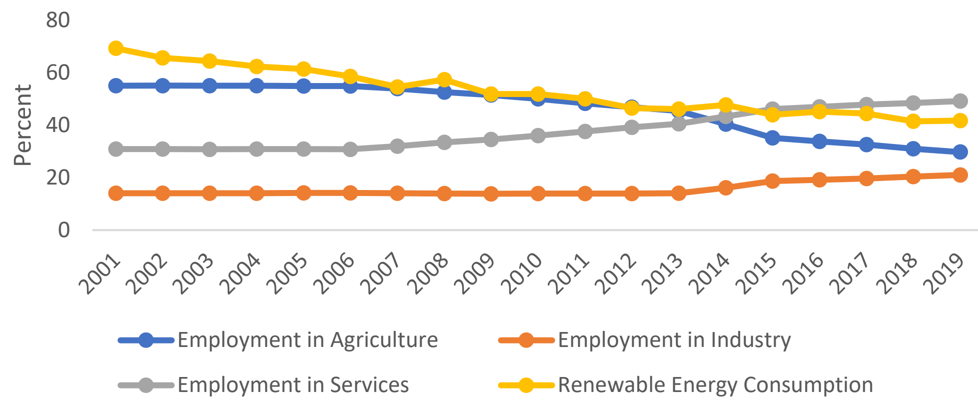

Figure 35: Trends of Sectorial Employment and Consumption of Renewable Energy in Ghana

making it difficult to compete with larger, more mechanised farms in other countries. As a result, many Ghanaians have turned to the services sector for employment opportunities.

It is observed that when the consumption of renewables is high, there is a decline in employment in the agriculture sector. Employment in the industry sector has been appreciating with declines in the consumption of renewables, especially since 2013 to date. This might be due to the discovery of crude oil in Ghana. Despite this appreciation, employment in the industrial sector continues to be the lowest and lags behind employment in the other sectors. The industry sector in Ghana has struggled to compete with other countries in the region due to high energy costs, a lack of skilled labour, and limited access to financing. This has resulted in a relatively small industry sector, with fewer employment opportunities compared to the services sector.

Stationarity Test

According to Baek, et al. (2019), the basic appeal of the ARDL method is that it is used if the covariates are $I(0)$ or $I(1)$. However, ARDL cannot be employed if the independent variables are $I(2)$ and/or the regressands are $I(0)$. Due to this, this study tests unit roots in all variables. Appendix A provides Augmented DF and PP unit root results at levels and first difference. In levels, the Phillip Perron tests give all the test statistics are $I(1)$ except for percentage of GDP to total investment, Real effective exchange rate, Government expenditure on education, total (percentage of government expenditure), and General government final consumption expenditure (percentage of GDP). The rest are $I(1)$ with no $I(2)$. These results from the unit root tests imply that this study can rely on the F-statistics to indicate that there is cointegration among the variables. The null can be rejected which indicates strong cointegration among the variables that are selected.

The stationarity test in Appendix A shows that the series are integrated of I (0) and I (1) series. In this case, the bounds test for cointegration proposed by Pesaran, et al. (2001) is used instead of the usual Johansen Cointegration. The estimation technique to apply is not VAR but the ARDL model. The study, therefore, proceeds to estimate Equation 5, Equation 6 and Equation 7 in determining whether renewable energy has an effect on energy security in Ghana. In the first difference, a maximum lag of two years on the variables is imposed.

Maximum Lag Selection

Appendix B depicts the outcomes of the LR, AIC, SBIC and HQC criteria for determining the maximum lag length. A lag length of 2 is used for the ARDL model where all the criteria are minimised are chosen. The lag order 2 is sufficient enough for the estimates to reflect the effect of renewables on energy access through expenditure on energy. This is done in order not to have too many lags that could result in a loss of degrees of freedom and insignificant statistical coefficients due to a possible presence of multicollinearity. Again, ARDL requires a maximum lag order of I(1).

Unit Root Tests

A time series variable is non-stationary if the data does not fluctuate around the mean; that is at least one of the moments depends on time. A time series may either be a trend stationary series or difference stationary series. A trend stationary occurs when the data becomes stationary after detrending whilst a difference stationary occurs when the data becomes stationary after differencing. To check the stationarity of the variables, the ADF and the PP unit root tests are utilised. The tests are conducted to ascertain the order of integration of the variables used to ensure the reliability of the analyses. The results of the ADF and the PP tests are presented in Appendix A.

Chapter Summary

The chapter provided a detailed description of the data of the study including renewable energy transition, and Ghana's crude oil demand by various major importing countries such as the US, Canada, Italy, and India. It also presented the summary and descriptive statistics of the variables used in the analyses. Trends of energy security indicators, crude oil demands, employment and unemployment were presented. The trends were depicted in figures while the summary statistics were presented in tables.

CHAPTER SIX

EMPIRICAL RESULTS AND DISCUSSIONS

Introduction

This chapter presents the empirical results and discussions of the study in relation to the objectives of the study. It begins with the analyses and discussions of the effects of renewables on security of energy and access in Ghana. The chapter continues with the effect of global renewable energy production on petroleum export of Ghana. Finally, the chapter presents the results on the effect of renewable energy transition on employment in Ghana.

Estimated Model of Renewable Energy Transition and Energy Accessibility in Ghana

This section analyses the effect of the energy transition on energy accessibility in Ghana. The results are presented in Table 7. The number of lags of the variables employed using the ARDL model is presented for the analyses. From Table 7, the share of renewable energy consumption has a negative and significant effect on energy accessibility in the long run. That is, a one per cent increase in the share of renewable energy consumption reduces energy accessibility in Ghana by 18.36 per cent and it is significant at one per cent. This is because there is not much infrastructure for renewable energy in Ghana. It is not surprising since Ghana has been experiencing power crises even with the construction of new dams and the introduction of solar panels and others. There are few solar panel installations and virtually no wind power and other renewable energy in Ghana apart from hydroelectricity. However, in the short run, the share of renewable energy consumption has a positive effect on energy accessibility. This could be because Ghana normally uses renewable energy in the interim to solve energy crises.

Table 7: Renewable Energy and Energy Accessibility in Ghana

	Coefficients	Standard Errors
ADJ L.Accessibility	-1.041***	0.105
LR		
REC	-18.36***	2.719
$fossil_{cons}$	0.289***	0.055
$GDP_{energyuse}$	24.56***	2.763
POP	-39.88***	6.026
SR		
D.REC	11.292***	3.579
D.$fossil_{cons}$	0.325***	0.057
D.$GDP_{energyuse}$	-86.565***	17.954
D.POP	0.374***	0.093
_cons	-368.884***	100.985
N	76	

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

Sources: Author's computation (2023)

However, GDP per energy use has a positive and significant effect on energy accessibility in Ghana in the long run. That is, a one per cent increase in GDP per energy use increases energy accessibility by 24.562 per cent and is significant at one per cent (p-value=0.000). In the long run, GDP per energy use growth could lead to increased investment in energy infrastructure, such as power plants and transmission lines, which can increase the overall energy supply in the country. This could lead to lower energy prices and greater accessibility to energy for households and businesses. Additionally, as the economy grows, individuals and businesses might have more resources to invest in energy-efficient technologies, which can also increase energy accessibility over time. In the short run, an increase in GDP per energy use has a negative effect on energy accessibility. One per cent increase in GDP per energy use in the short run decreases energy accessibility by 86.565 and it is significant at one per cent. In the short run, GDP per energy use might decrease energy accessibility in Ghana because economic growth can lead to increased demand for energy, and the country may not have enough infrastructure to support this increased demand. This could lead to energy shortages and higher energy prices, which can make energy less accessible to some individuals and businesses.

Consumption of fossil fuels has a positive and significant effect on energy accessibility in Ghana. An increase in consumption of fossil fuels by one per cent increases energy accessibility by 0.289 per cent and it is significant at one per cent (p-value=0.000) in the long run. In the short run, an increase in the consumption of fossil fuels increases energy accessibility by 0.325 per cent. This means that the consumption of fossil fuels has a beneficial impact on energy accessibility in Ghana.

It is also shown that an increase in the total population of Ghana decreases energy accessibility in the long run but an increase in population in the short run decreases energy accessibility. This is because as the population increase, many people would move to new areas where the extension of electricity has not yet gotten to. The expansion of electricity in Ghana has over the years indicated that Ghana is not able to meet its electricity demand. There are many instances where people do not have electricity for over a week.

ECM_{t-1} is -1.041, indicating convergence to long-run equilibrium after a shock to the share of renewable energy consumption, the total population of Ghana, GDP per energy use, and fossil fuels consumption. This means that it takes about approximately one month for shocks to be converged.

The finding of this study shows that energy transition has negative effects on energy accessibility in Ghana. This might be because Ghana has a lot of challenges in the adoption of the energy transition. These challenges include but are not limited to economical and technology (Amoah et al., 2020). Petroleum exploration and production in Ghana, therefore, presents a great opportunity to leverage to increase energy accessibility. Under prevailing economic conditions and technologies, petroleum exploration and production efforts increase the country's chances of increasing oil and gas recoverable reserves to make energy more accessible. According to Bazilian et al. (2013), energy accessibility will require the use of oil wealth for expansion of energy accessibility, which lays a good foundation for industrialisation and puts the economy on the path of economic growth and development. Also, Diawuo, et al. (2019) assess the costs of contributing to climate change targets in the case of Ghana's electricity system and find that it will require US$13 to US$17 billion to expand Ghana's generation capacity to ensure access which will result in an additional cost of US$11 to US$39 per tonne to meet different emission targets by 2040 to ensure environmental sustainability.

The findings of our study contradict that of Nepal, et al. (2020) who evaluate renewable energy's role to supply security of energy in the ASEAN region and find positive long-run relationships among renewables and energy security for ASEAN economies.

Effect of Renewable Energy Transition on Availability of Energy

To evaluate the effect of the energy transition from fossil fuels to renewables on energy availability in Ghana, the study utilises the share of renewable energy consumption for the analyses. Table 8 presents the effect of the energy transition on energy availability in Ghana. The ARDL model is used to estimate the results. For this analysis, both the long- and short- runs estimates are presented. From Table 8, it is observed that the lag of primary energy availability has a positive and significant effect on the current level of primary energy availability in Ghana. This implies that the level of availability of primary energy in the previous quarter increases the availability of energy in the current quarter. This is because, as we use energy in the previous period, we turn to use more of it in the current period. In the current period, population increase, booming economic activities due to previous use of energy, adjusting to current lifestyle and others can affect current primary energy availability.

Consumption of fossil fuels has a positive and significant effect on primary energy availability in the long run. That is, a one per cent increase in the consumption of fossil fuels increases the level of energy availability by 0.004 per cent and it is significant at five per cent (p-value=0.038). This is not surprising results since fossil fuels are known to have a significant effect on energy availability. Fossil fuels provide a high intensity of energy to industries and commercial and residential usages.

Due to this, fossil fuels are extremely energy impenetrable. This means that small quantities of fossil fuels could produce much more energy needed. This

Table 8: Renewable Energy Transition and Energy Availability in Ghana

ADJ		
L1.Availability	0.543***	0.095
LR		
REC	0.099	0.595
$fossil_{cons}$	0.004**	0.002
$GDP_{energyuse}$	1.755***	0.457
$L.GDP_{energyuse}$	1.919***	0.438
POP	3.047***	0.681
L.POP	2.374***	0.677
SR		
D.REC	-0.357***	0.131
$D.GDP_{energyuse}$	2.667***	0.410
D.POP	3.450***	0.711
_cons	-2.068	5.494
N	76	

Standard errors are in brackets. * p<0.1, ** p<0.05, *** p<0.01

quality of fossil fuels might have led to coal adoption in Europe as against wood fuels as a source of fuel which eventually led to the industrial revolution. Hence, the consumption of fossil fuels increases energy availability in Ghana. So, exporting fossil fuels will reduce the level of energy availability. Most of the fossil fuels from Ghana are exported to other countries to increase the energy availability and intensities in those countries. Ghana must therefore start to use its fossil fuels for local consumption. These results contradict the study of Singh, Nyuur and Richmond (2019) that energy trade is believed to be effective to promote the growth of energy-importing countries. However, these results confirm that of Asif (2009) who finds that importing energy could exert growth-depressing pressure effects on the economy of the country importing energy by increasing their import bills.

As shown in Table 8, the consumption of renewable energy has a positive but insignificant effect on energy availability in Ghana. This might be due to the limited renewable energy infrastructure in Ghana. While Ghana has made significant progress in recent years to increase its renewable energy capacity, the country still faces significant challenges in developing the necessary infrastructure to support widespread renewable energy adoption. For example, there is a lack of transmission infrastructure to transport renewable energy from remote areas to urban centres, and the grid system is not well-equipped to handle variable renewable energy sources.

GDP per energy use has a significant and positive effect on energy availability in Ghana. Also, the lag of GDP per energy use increases the energy availability level. One per cent increase in GDP per energy use increases the level of primary energy availability by 1.755 per cent and it is significant at five per cent (p-value=0.016). This means that GDP per energy use, as already discussed, has a positive effect on primary energy availability. This implies that as Ghana increase its expenditure on energy to correspond to the level of income, the level of energy availability also increases. This is because as income increases, people can adopt and use more energy equipment and products. When the income of people was poor goes up, these people's demand for energy increases along the extensive margin as these people purchase more energy-using assets. People who could not initially use electronic gadgets are now able to do so. They can now afford more effective means of doing things. As income rises and there is an expansion of coverage of electricity, families formerly living in poverty will buy water pumps, refrigerators, washing machines, air conditioners and other household and industrial electrical appliances. The country can engage in industrial production by importing or buying more machines, equipment and others that use energy. That is, an increase in the level of energy availability relies not only on the maximisation of utility but also on citizens' current appliances.

Population and lag of population increase energy availability in Ghana. One per cent increase in population increases energy availability by 3.047 and it is significant at one per cent (p-value=0.000). These are unsurprising because as more people are added to the population, they tend to use a lot of energy which could increase the provision of energy to meet their energy needs and thereby increase energy availability. Greater population density leads to higher demand for energy. Population increase leads to higher demand for electrical appliances and industries will have to plan to meet demand. This will lead to an increase in energy availability.

In the short run, an increase in the consumption of renewable energy has a negative effect on energy availability in Ghana. That is, a one per cent increase in the consumption of renewable energy reduces energy availability by 0.375 per cent and it is significant at one per cent (p-value=0.000). This might be due to the unavailability of renewable energy throughout the year to meet energy demand. Renewable energy production in Ghana is at its initial stage and the lowest level of production. It is, therefore, not able to produce enough energy to increase the level of energy availability. Only a few people in Ghana demand renewable energy to supplement the already existing energy sources. This is mostly influenced by the initial high cost of adopting renewable energy.

Again, in the short-run, GDP per energy use and the first difference of GDP per energy use have a positive effect on energy availability in Ghana. As income increases, as already discussed, we tend to demand more energy for residential, commercial, industrial and agricultural purposes. Producers and energy investors can invest more in energy generation and supply to be able to meet energy demands. This then causes the level of energy intensity to increase. Hence, GDP per energy use has a positive effect on energy availability in Ghana.

ECM_{t-1} is 0.545, indicating convergence to long-run equilibrium after a shock to share of consumption of renewable energy, the population of Ghana, GDP per energy use, and consumption of fossil fuels. This means that it takes about approximately one year and six months for shocks to be converged.

Effect of Renewable Energy Transition on Energy Affordability

Our study evaluates the effect of the energy transition on the affordability of energy in Ghana presented in Table 9. From Table 9, it is observed that an increase in the consumption of renewable energy has a negative effect on energy affordability in Ghana. That is, a one per cent increase in consumption of renewable energy decreases energy affordability by 6.926 per cent and it is significant at one per cent (p-value=0.000). This means that less consumption of renewable energy is preferred to more of it. Although the demand for use of energy in Ghana is fairly inelastic, consumers can switch to other cheaper forms of energy such as the use of wood, charcoal and others, which are relatively cheaper than renewables. In general, the prices of renewable energy are very high, especially, in their initial stages. Many people in Ghana, both in the urban and rural areas, are not able to afford renewable energy at the current prices. The price of solar is more than three times the price of fossil fuel. This makes it not economical for many people to

Table 9: Renewable Energy Transition and Energy Affordability in Ghana

ADJ		
L.affordability	-0.114**	0.050
LR		
REC	-6.926***	0.331
$fossil_{cons}$	0.165***	0.045
$GDP_{energyuse}$	14.378***	4.334
POP	-109.375***	17.621
L1.POP	15.058	18.485
SR		
D.REC	-22.699***	6.920
$D.GDP_{energyuse}$	-51.695***	19.129
D.POP	-247.067***	35.307
_cons	-51.710	51.710
N	76	

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

afford it. Rational consumers would choose a less expensive product if those products offer the same level of utility. In the nutshell, the energy transition has a negative effect on energy affordability in Ghana. This evidence is presented in both the short- and the long-run estimates.

Furthermore, one per cent consumption of fossil fuels has a 0.165 per cent positive effect on energy affordability. This shows that Ghana must consume its fossil fuels to increase energy affordability. This is because fossil fuels are cheaper resources that can be used to meet the needs of every society. It naturally follows that an abundance of these resources would lead to improved economies and more stable nations. Many industries in developing countries in SSA heavily depend on fossil fuels to survive and hence its consumption will affect productivity. This is because fossil fuels are relatively cheaper and their demand can be higher than other sources of fuels.

Moreover, an increase in income (GDP per energy use) would increase energy affordability. This is not surprising as it has already been discussed. The least well-off population are particularly constrained since the share of their budget represented by their energy affordability is very large and this corresponds to a level of energy services that are below that of the better-off countries. These countries face also face a strong capital constraint for investment in energy equipment, energy production and distributions. This result confirms that of Chang (2015) who found that energy consumption increases with income in emerging markets and developing economies. The increase in energy demand mainly comes from low- and middle-income economies. Thus, raising income in these economies increases their energy demand. People in non-high-income economies tend to use more energy as they become wealthier. As these consumers' income increases, instead of choosing to maintain the same utility level, they rather opt to spend their additional income to increase their energy use, in the processes they drive up the energy demand.

From Table 9, it is observed that an increase in population has a negative effect on energy affordability in the short run but no significant effect in the long run. This result is surprising because it is expected that an increase in population should increase energy consumption and by extension increase prices, as indicated by the law of demand. This could be due to the fact Ghana has excess energy to meet the energy needs of the rapidly increasing population. The provision of energy use is more than enough to meet the demand for energy as the population increases.

In the short-run, a one per cent increase in income reduces energy affordability by 51.695 per cent and it is significant at a one per cent level (p-value=0.000). This implies that in Ghana, an increase in GDP per energy use reduces energy affordability. This result contradicts the generally accepted view that an increase in income would increase energy affordability in the short run. Notwithstanding, the reason could be that power outages are experienced in Ghana. Consumption of energy might be low relative to income. Consumers could have purchasing power but there will be no energy available. This could also be that consumers might want to take precautions as income increases. These rational consumers might make intertemporal consumption decisions. Consumers might want to spread their income distribution across a period. This could decrease energy affordability.

It is observed that the ECM_{t-1} is -0.114, indicating convergence to the long-run equilibrium of energy affordability after a shock to the share of renewable energy consumption, the population of Ghana, GDP per energy use, and consumption of fossil fuels. This means that it takes about approximately two years and five months for shocks to be converged. It is therefore not surprising that these variables do not have a significant effect on energy affordability in the long run.

Model Simulation using the Dynamic ARDL Simulation

Simulation results are presented in this section for the renewable energy transition models developed and estimated in the methodology section. Quantitative measures are available to evaluate and determine how closely the simulated variables fit the corresponding actual data. We believe that scholars are neglecting some of the most meaningful substantive inferences from autoregressive models. Specifically, the most effective way to observe the long-term effects of exogenous variables in autoregressive models is through simulating the predicted value and the confidence interval for a given scenario over a given number of time intervals. In this study, we create 15 long-term dynamic simulations of up to two scenarios for OLS models with the lagged dependent variable. We use these simulations to make inferences about the long-term effects of variables. One can determine if the variations in predicted probabilities are statistically different across time and scenarios.

Effect of Renewable Energy Transition on Energy Accessibility in Urban and Rural Areas

In analysing the effect of the energy transition on energy accessibility in both the urban and the rural areas in Ghana, the ARDL point estimates are presented in Appendix D. Table 10 presents the simulated effects of the renewable energy transition on energy accessibility in the urban and rural areas in Ghana. The second column presents the effect of energy accessibility with an emphasis on rural areas while the third column emphasises urban areas.

It is observed that the renewable energy transition has a positive and statistically significant effect on energy accessibility in urban areas and rural areas. However, the effect in urban areas is about 11 percentage points greater than in rural areas. That is, an increase in renewables by one would lead to a 2.722 per cent increase in electricity in the rural areas and it is significant at one per cent. This is mainly because there is already existing infrastructure in the urban areas. Notwithstanding, this implies that a shift towards renewable would increase energy accessibility in the urban and rural areas of Ghana. This means that to increase energy accessibility in urban and rural areas, Ghana must transition to renewable energy. However, the consumption of fossil fuels increases energy accessibility in

Table 10: Energy Transition and Energy Accessibility in the Rural and Urban Areas in Ghana

Energy Accessibility	Rural	Urban
REC	2.722***	22.1***
	(0.706)	(1.86)
$fossil_{cons}$	0.021	21.959**
	(0.195)	(10.561)
$GDP_{energyuse}$	1.073	6.362
	(1.848)	(4.402)
POP	-.415**	-14.259***
	(.192)	(2.731)
LagREC	4.565	-1.040***
	(3.169)	(0.219)
$Lagfossil_{cons}$	.027	16.899*
	(.0564)	(9.808)
$LagGDP_{energyuse}$	1.861***	13.084
	(.6194)	(38.950)
LagPOP	-.409**	
	(.189)	
_cons	-13.385	-4.480***
	(14.590)	(0.952)
N	40	44
r-square	0.972	0.999
Adjusted r-square	0.968	0.999

Standard errors are in brackets. * p<0.1, ** p<0.05, *** p<0.01
Sources: Author's computation (2023)

urban areas but has no effect in rural areas. Hence, to increase energy accessibility in urban areas, Ghana must increase its fossil fuel consumption.

From Table 10, it is observed that, in urban areas, the population has a significant negative effect on energy accessibility. This is expected as population increase puts much pressure on infrastructure and social amenities. This is because as the population increase, many people would move to new areas where the extension of electricity has not yet gotten there. Some new urban localities do not yet have connections to the national grid and as the population increases, people are forced to settle in these areas. An increase in rural population reduces energy accessibility by 0.415 and it is significant at five per cent. This implies that as the population of the rural areas increases in Ghana, energy accessibility decreases. This is because, as the population in the rural areas increases, they begin to compete for the already insufficient electricity available. Some rural areas have just one solar panel for the whole community hence increase in population would reduce energy accessibility.

The third column shows that the lag of renewable energy transition has no significant effect in the rural areas but a negative significant effect on energy accessibility in the urban areas. This implies that there is a non-negligible negative effect of renewables on access to electricity in urban areas. This is not surprising because there have not been many productions of renewable energy in Ghana. There are few solar panel installations and virtually no wind power and other renewable energy in Ghana apart from hydroelectricity. This could be due to the initial high cost of renewables.

Furthermore, it is also shown that other variables such as GDP per unit of energy use and its lag have an insignificant effect on energy accessibility in urban areas but significant positive effects in rural areas. This could be because governments tend to neglect energy accessibility and focus on other things such as the construction of interchanges, traffic lights and others. For example, Ghana has a rural electrification programme which concentrates on connecting rural areas with electricity accessibility to the national grid. These programmes can be detrimental to urban electricity accessibility but improve rural areas' electricity accessibility.

Figures 6.1 and 6.2 depict the simulated effect of the renewable energy transition for the next 15 years on energy accessibility in rural and urban areas. In the rural areas, both the business-as-usual and five per cent transition rates do not significantly impact energy accessibility. The transition scenarios have the same upper and lower bands. This implies that the rate of renewable energy transition does not have any effect on rural areas' energy accessibility in Ghana. Figure 36 and Figure 37 shows that the vulnerability of energy accessibility in both scenarios has the same impact. Each scenario has no significant impact on the vulnerability of energy accessibility in rural areas over the next 15 years period. This is not surprising since the rural areas in Ghana already engage in renewable projects such as the use of renewable wastes and combustibles. This is because, even if renewable energy sources are introduced, the lack of proper infrastructure such as electricity grids, transmission lines, and distribution networks can make it difficult to distribute the energy to rural areas. Building such infrastructure can be costly, which may limit the implementation of renewable energy sources in rural areas. Also, already, there is a low demand for energy in rural areas, which might make it difficult for renewable energy sources to be economically viable. This can be due to a lack of economic activity or low population density in rural areas.

However, in the urban areas, after the current year, each transition scenario increases energy accessibility up to the eighth year. After the eighth year, each scenario reduces energy accessibility. It is noteworthy to state that, both before and after the eighth year have no significant impacts on energy accessibility in urban areas. Possibly, Ghana lacks the necessary infrastructure to support renewable energy systems. For example, Ghana does not have transmission lines or distribution networks to connect renewable energy systems to the grid or to reach remote areas. Building this infrastructure can be expensive and time-consuming, which can further limit access to renewable energy.

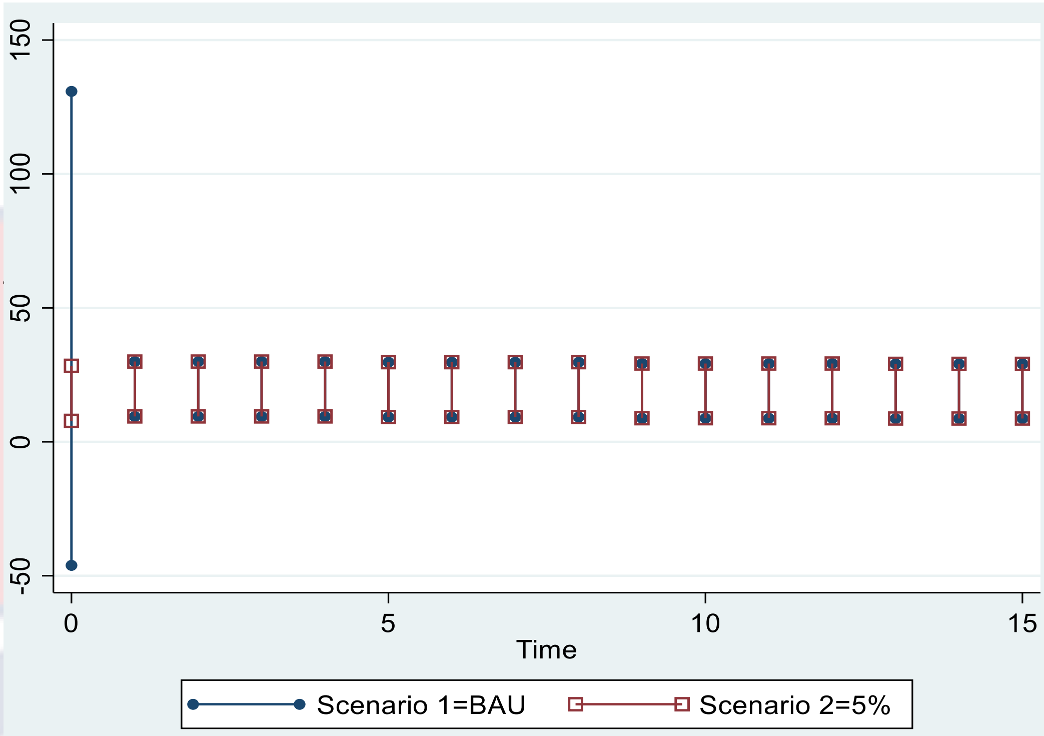

Figure 36: Energy Transition Scenarios on Rural Energy Accessibility

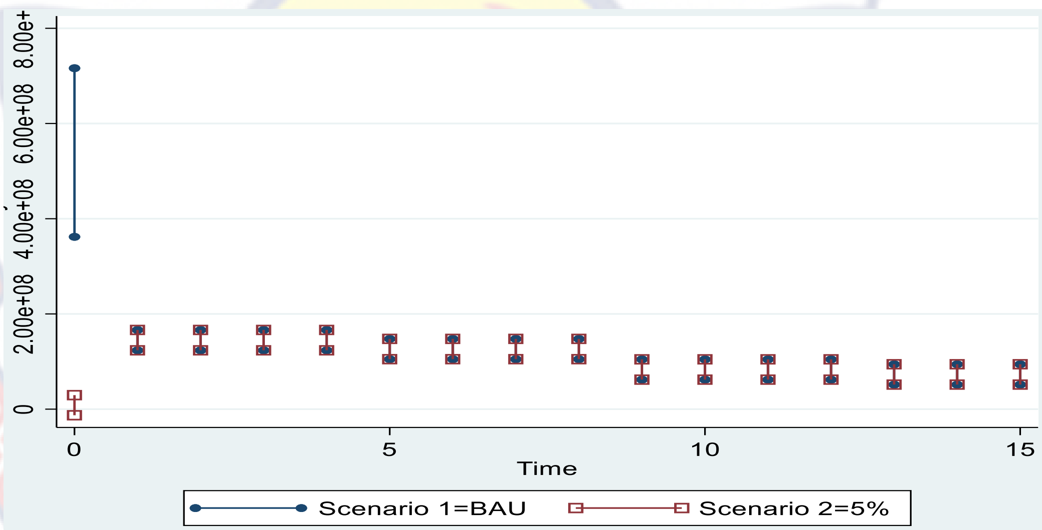

Figure 37: Energy Transition Scenarios on Urban Energy Accessibility

Effect of Transition Scenarios on Energy Accessibility

Table 11 indicates the dynamic ARDL simulation results for access to energy. From the simulated results, renewable energy has a negative significant impact on access to energy. That is, an increase in the share of renewable energy by one per cent will lead to a 1.009 per cent decrease in access to energy in Ghana and it is significant at one per cent (p=value=0.000) while the lag of renewable energy share will have no impact on access to energy. The lag in access to energy has a significant positive impact on energy accessibility. This implies that as access to electricity increases in the previous years, the current access to energy will increase. Thus, the provision of energy accessibility now will lead to more access to electricity. Fossil fuel consumption has a significant but positive impact on access to energy.

The lag of GDP per energy use increases energy accessibility. That is, as the previous GDP per energy use increases, it positively affects current electricity accessibility. However, the lag of population has a negative impact on access to electricity while consumption of fossil fuels has a negative but insignificant impact on access to electricity in Ghana.

From Figure 38, it is indicated that energy transition at five per cent and business as usual (at 1%) increase access to electricity up to the sixth year after which access to electricity decreases. They overlap each other after the sixth year. However, business as usual has the slowest negative effect on energy access. It is inferred that an energy transition scenario of five per cent will have statistically higher energy before the sixth year. This depicts that the energy mix will be very important after the next six years in influencing electricity access. This could be because as the share of renewable energy increases, it becomes more difficult for the average Ghanaian to afford them. Currently, few people can afford solar panels.

Table 11: Energy Transition Scenarios on Energy Accessibility

Energy Accessibility	Coef.	Std. Err.	P>t
Laccessibility	.839	.070	0.000
REC	-1.009	.2196	0.000
$fosils_{cons}$	.0305	.059	0.605
$GDP_{energyuse}$	2.612	.566	0.000
Pop	.415	.192	0.035
LagREC	4.565	3.169	0.154
$Lagfossil_{cons}$	.027	.0564	0.629
$LagGDP_{energyuse}$	1.861	.6194	0.004
Lagpop	-.409	.189	0.034
_cons	-13.385	14.590	0.362
N	83		
r-square	0.972		
Adjusted r-square	0.968		

Author's own compute (2023)

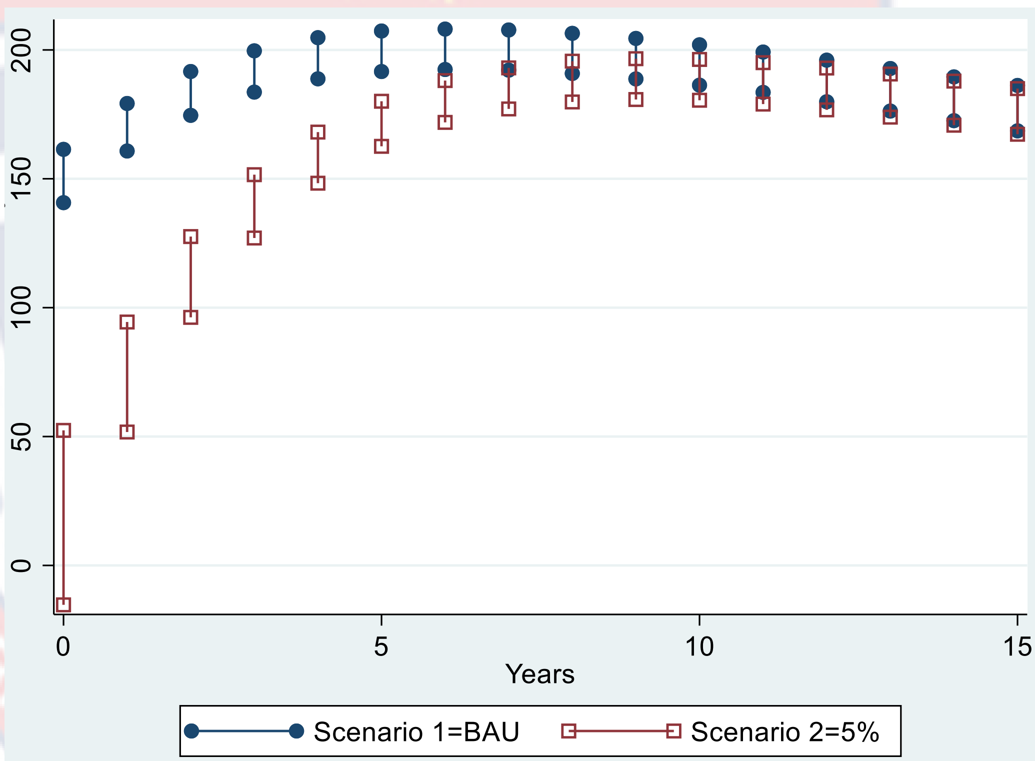

Figure 38: Energy Transition Scenarios and Energy Accessibility

Renewable Energy Transition and Energy Availability and Affordability

Table 12 indicates the effect of the energy transition on the vulnerability of energy availability and affordability in Ghana. It is observed that the renewable energy transition has a positive and statistically significant effect on energy

Table 12: Renewable Energy Transition and Energy Availability and Affordability

Energy	Availability	Affordability
REC	0.223	2.10***
	(0.581)	(1.86)
$fossil_{cons}$	0.002	1.959**
	(0.007)	(0.561)
$GDP_{energyuse}$	0.154**	6.362
	(0.069)	(4.402)
POP	-0.048*	-1.259***
	(0.026)	(0.731)
LagREC	0.546	-1.040***
	(0.539)	(0.219)
$Lagfossil_{cons}$	0.005	16.899*
	(.007)	(9.808)
$LagGDP_{energyuse}$	0.063	13.084
	(0.067)	(38.950)
LagPOP	0.044	0.164**
	(0.026)	(0.068)
_cons	2.578	-4.480***
	(1.942)	(0.952)
N	82	82
r-square	0.835	0.867
Adjusted r-square	0.817	0.854

Standard errors are in brackets. * p<0.1, ** p<0.05, *** p<0.01
Sources: Author's computation (2023)

affordability. That is, an increase in renewable transition by one would lead to a 2.10 per cent increase in energy affordability and it is significant at one per cent. The lag of the energy transition has a negative and significant effect on energy affordability. That is, previous renewable energy transition decreases energy affordability in Ghana. This means that to increase energy affordability, Ghana must transition to renewable energy. In the case of Ghana, the energy transition has the potential to increase energy affordability in the long run. Ghana currently relies heavily on imported fossil fuels, which can be expensive and subject to price volatility.

By transitioning to cleaner and more sustainable sources of energy, such as solar and wind power, Ghana could reduce its reliance on expensive imported fuels and generate energy domestically at a lower cost. Moreover, the development of renewable energy infrastructure in Ghana can lead to more competition in the energy market, which can lower energy prices and increase affordability for consumers. Additionally, renewable energy systems can often be more cost-effective in remote or rural areas, where it may be expensive to extend the electricity grid. However, it is important to note that the initial investment in renewable energy infrastructure can be expensive, and it may take some time for the benefits of reduced energy costs to fully materialise. This is the reason for the lag of renewable energy to decrease energy affordability.

It is observed that energy transition and its lag have no significant effect on energy availability. This is because Ghana's infrastructure for renewables is still developing, and the country continues to depend heavily on conventional fossil fuels such as oil and gas in electricity generation. While renewables are being increasingly utilised, their capacity to generate energy is still limited, and the infrastructure needed to transport and store renewable energy is lacking. However, the consumption of fossil fuels increases energy affordability but has no significant effect on energy availability. Hence, to increase energy affordability, Ghana must increase its fossil fuel consumption. Similarly, the lag of consumption of fossil fuels has a significant positive effect on energy affordability and no significant effect on energy availability.

Furthermore, it is also shown that GDP per unit of energy use has a significant positive effect on energy availability but insignificant positive effects on affordability. When a country's GDP per unit of energy use is high, it can signal that the country is using energy more efficiently. This can encourage the adoption of more energy-efficient technologies and practices, which can reduce energy waste and increase the overall availability of energy. A high GDP per unit of energy use can also signal to investors that a country is economically stable and efficient, which can attract investment in energy infrastructure and production. This can increase the overall availability of energy in the country.

From Table 12, it is observed that population significantly reduces energy availability. One of the main reasons for this is the limited infrastructure and investment in the energy sector in Ghana. The country's energy infrastructure is not robust enough to meet the growing demand, which can lead to frequent power outages and energy shortages. Additionally, Ghana heavily relies on hydroelectric power generation, which can be affected by droughts and changes in weather patterns. When water levels in the country's hydroelectric dams are low, the amount of electricity generated is reduced, leading to energy shortages. Furthermore, the high population growth rate in Ghana has also resulted in rapid urbanisation, which has put a strain on energy resources in urban areas. The demand for electricity in cities and towns is high, and this has led to a significant reduction in energy availability.

Also, from Table 12, the population has a significant negative effect on energy affordability. This is expected as population increase puts much pressure on infrastructure and social amenities. As the population grows, the demand for these traditional sources of energy also increases, leading to higher prices and reduced affordability. The country's energy generation and distribution systems are not robust enough to meet the growing demand, leading to frequent power outages and shortages. As a result, energy prices can increase due to the high cost of generating and distributing energy.

Figure 39 depicts the vulnerability of energy availability to renewable energy transition for the next 15 years in Ghana. Figure 39 shows that the vulnerability of energy availability in both scenarios has a different impact. Each scenario has a significant impact on the vulnerability of energy availability over the next 15 years period. The energy transition scenario with a five per cent rate has a higher positive impact on energy availability than the business-as-usual scenario.

However, it is observed that a five per cent energy transition rate will decrease energy availability for up to the next 10 years. After 10 years, a five per cent energy transition scenario will increase energy availability. The business-as-usual scenario will increase energy availability over the next 15 years. It is even observed that the impact on energy availability becomes greater each year compared to the previous year. This implies that energy availability is vulnerable to the energy transition dynamics in Ghana. This is not surprising since Ghana's energy transition to renewables is still in its early stages, and the necessary policies, incentives, and infrastructure to support this transition are not yet fully in place. This makes it challenging to attract investment in renewable energy projects and to ensure a reliable and affordable energy supply for Ghanaians.

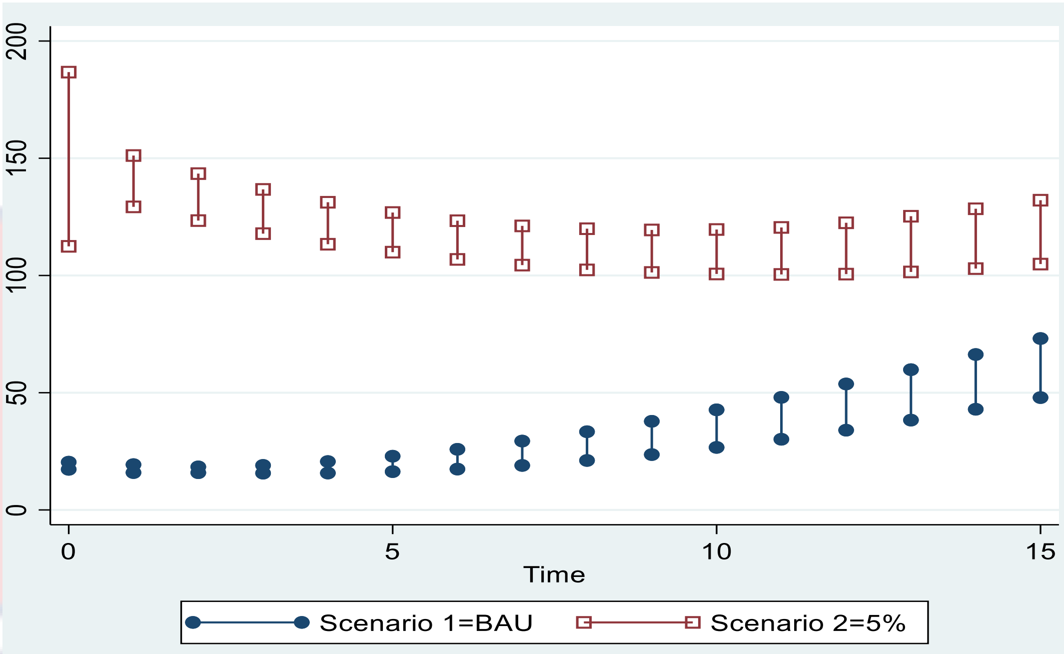

Figure 39: Energy Transition Scenarios and Energy Availability

Effect of Transition Scenarios on Energy Security

Table 13 indicates the dynamic ARDL simulation results of the impact of the energy transition on energy security in Ghana. It shows that renewable energy has insignificant positive impacts on energy security. The previous values of renewable energy transition have a positive but insignificant effect on energy security. This is unsurprising since energy security in Ghana has always been on crude oil utilisation. Energy transition should have a significant impact on energy security, as it involves shifting away from traditional energy sources that may be subject to supply disruptions or price volatility, towards more diverse and resilient sources of energy. For example, a transition towards renewables can reduce dependence on imported fossil fuels, which are often subject to geopolitical tensions and supply disruptions. Ghana, like many other countries, is vulnerable to energy security challenges due to its dependence on imported fossil fuels and its

Table 13: Energy transition scenarios on Energy Security

Energy security	Coef.	Std. Err.	P>t
Lagsecurity	.957	.034	0.000
REC	.117	.168	0.487
$fosils_{cons}$	.004	.002	0.071
$GDP_{energyuse}$	-.090	.020	0.000
Pop	.007	.008	0.375
LagREC	.060	.157	0.701
$lagfossil_{cons}$	.004	.002	0.035
$LagGDP_{energyuse}$	.089	.019	0.000
Lagpop	-.006	.008	0.419
_cons	-.600	.573	0.298
N	82		
r-square	0.986		
Adjusted r-square	0.984		

Author's construct (2023)

reliance on a limited number of power sources. Conversely, this finding is different from the findings of Aslanturk and Kiprizli (2020); Nie and Yang (2016); Rios-Ocampo, et al. (2021) who found that renewable energy strategies can lead to energy security. However, Ibrahiem and Hanafy (2021) found a negative relationship between renewable energy and energy security.

Consumption of fossil fuels has significant positive effects on energy security in Ghana. This means that a one per cent increase in fossil fuels consumption leads to a 0.004 per cent increase in energy security and it is significant at 10 per cent. This is not surprising since Ghana, in recent times, has been exploiting crude oil. Fossil fuels have a high energy content, making them a popular source of energy for transportation, electricity generation, and heating. This finding contradicts that of Nie and Yang (2016) who found that reduction in the consumption of fossil fuels leads to energy security.

GDP per energy use has a negative impact on energy security while previous energy security has a positive impact on current energy security. This is counterintuitive because an increase in GDP per energy use typically means that the economy is growing and that energy demand is increasing. If this demand is not met by an increase in energy supply, it can lead to energy insecurity. Also, an increase in GDP per energy use can lead to an increase in the consumption of energy-intensive goods and services, such as air conditioning, refrigeration, and transportation. This can lead to an overall increase in energy consumption, which can put a strain on the energy infrastructure and make it more vulnerable to disruptions. Further, an increase in GDP per energy use can also lead to an increase in energy imports, which can make a country more dependent on external sources of energy. This can be a risk to energy security if there are disruptions to the supply chain, or if the cost of energy imports rises.

Figure 40 indicates the effects of different energy transition scenarios on energy security in Ghana. Although both scenarios of energy transition increase energy security, it shows that the business-as-usual scenario has a minimal positive impact on energy security after the second year while the energy transition scenarios at just five per cent have the largest positive impact on energy security. This means that Ghana can achieve energy security by increasing the renewable energy transition of any scenario for the next seven years. However, after the eighth year, both continue to have a positive effect but at a decreasing rate. Energy transition at a five per cent scenario continues to have higher positive impacts on energy security. Ghana to increase energy security, the transition to renewable energy must increase rapidly at least at the rate of five per cent.

This is mainly due to the abundance and availability of forms of renewable

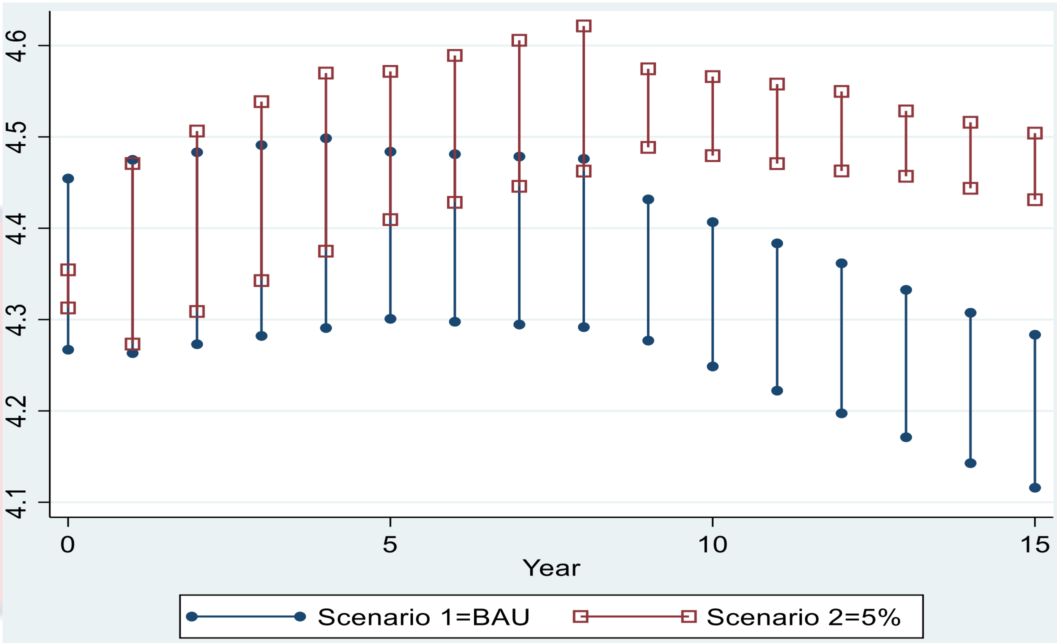

Figure 40: Energy Transition Scenarios on Energy Security

Author's construct (2023)

energy sources such as solar. Ghana has a tropical climate with daily temperatures ranging from 77 degrees Fahrenheit to 95 degrees Fahrenheit. It can be very humid at times. Ghana experiences an average of six hours of shine in a day. The coastal areas have an average annual temperature of 260C and between $8H^{0}C$ and $10H^{0}C$, there is an average rainfall of $29H^{0}C$. In the southern part of Ghana, June tends to be wet with an average monthly value of 152 and 254mm of rainfall while the northern parts tend to be relatively dry. During dry months, rains are likely to fall below 10hrs each month (Ghana Meteorological Agency, 2022). This calls for energy transition advocates call for rapid renewable energy transition.

Conceivable, renewable energy technologies costs, such as solar panels and wind turbines, may be prohibitively expensive for some households and communities in Ghana. The high upfront costs of renewable energy technologies may make them unaffordable for low-income households, particularly those in rural areas. This could limit the potential for renewable energy to increase energy access and security in those areas. Also, the intermittent nature of some renewables without additional investments in energy storage technologies could limit their ability to provide reliable energy access. For example, if there is inadequate wind or sunlight, the energy produced by these technologies might be deficient to meet demand. Some areas in Ghana may not be suitable for certain types of renewable energy technologies. For example, areas with low wind speeds may not be suitable for wind turbines, while areas with high levels of shading may not be suitable for solar panels.

Furthermore, Ghana has a history of power shortages and blackouts, particularly during times of peak demand. Renewable energy technologies adoption could help to address these issues by increasing the overall capacity of the electricity grid. However, the intermittent nature of some renewable energy sources could also exacerbate these issues by creating additional variability in the energy supply. Geographically, the deployment of renewable energy technologies may be concentrated in areas that are already well-served by the electricity grid, rather than in areas with low levels of energy access and security. This could limit the ability of renewable energy projects to improve energy access and security in areas where it is most needed. Moreover, it is asserted that Ghana has an inadequate investment in electricity infrastructure, particularly in rural areas and therefore renewable transitions are not enough to address the underlying infrastructure issues that contribute to low levels of energy accessibility and security in the country. These factors must be considered to ensure that the benefits of renewable energy technologies are shared equitably among all members of society.

Effect of US Renewable Energy Consumption on Import Demand for Ghana' Crude Oil

Table 14 presents the responsiveness of crude oil imports from Ghana to the energy transition in the US. From Table 14, the total consumption of solar energy in the US has a negative and statistically significant effect on the demand for crude oil from Ghana. In Column 3, total wind energy consumption has a negative and statistically significant effect on the import demand of crude oil from Ghana. In Column 4, total renewable energy consumption has a negative and statistically significant effect on the import demand of crude oil from Ghana. These estimates are related to the substitutability of renewables for imported crude oil from Ghana. These imply that the energy transition has a detrimental effect on the demand for petroleum from Ghana.

The energy transition in the US has a negative impact on crude oil demand from Ghana because the US is one of the largest consumers of crude oil in the world, and any significant reduction in its consumption has a ripple effect on the global crude oil market. As the US transitions towards renewables, its demand for crude oil is likely to decrease over time. This decrease in demand will lead to a decrease in the price of crude oil, making it less profitable for countries like Ghana to export their oil. Ghana is an oil-producing country and relies heavily on its oil exports to generate revenue for its economy. If the demand for crude oil from the US declines, it will have a negative impact on Ghana's oil exports and, consequently, it's economy. Additionally, as the US shifts towards renewables,

Table 14: US Renewable Energy Consumption and Crude Oil Demand from Ghana

US import	Consumption of Renewables		
	SOLAR	WIND	REC_{total}
Solar	-0.003***		
	(0.0001)		
Wind		-0.003***	
		(0.0001)	
REC_{total}			-0.004***
			(0.0003)
PCGDP	0.062***	0.050***	0.067***
	(0.005)	(0.005)	(0.005)
RR	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.001)
Industry prod.	-0.059***	-0.050***	-0.052***
	(0.003)	(0.003)	(0.003)
WTI	0.005***	0.005***	0.004***
	(0.001)	(0.001)	(0.001)
_cons	684.535***	643.745***	784.905***
	(20.342)	(20.647)	(19.093)
N	84	84	84

may invest less in oil exploration and production globally, including in Ghana. This could further reduce Ghana's ability to export its oil and negatively impact its economy.

These findings corroborate that of Khan and Shaheen (2020) who found that energy transition has a negative effect on prospects for petroleum-exporting countries in Asia. However, these findings contradict those of Marque et al. (2010); who found a positive association between substitution for renewables and natural gas to the energy supply and Kumar et al. (2015) and Lee et al. (2012) reported complementarity between non-renewables and renewables.

GDP per capita has a positively weak and statistically significant effect on US import demand for Ghana’s petroleum. It shows positive and statistically significant income elasticity for the US for crude oil import demand from Ghana.

That is, an increase in income by one per cent induces less than a one per cent change in demand for imported crude oil from Ghana. For instance, a one per cent increase in income in Column 2 induces a 0.062 per cent change in demand for crude imported from Ghana and it is significant at one per cent (p-value=0.000). In Column 3, it induces a 0.050 per cent change in import demand for crude oil from Ghana and in Column 4, it induces a 0.067 per cent increase in demand for crude oil imported from Ghana. Thus, there is a weak relationship between income and import demand for crude oil. This shows that the crude oil from Ghana has fairly income-elastic demand. Changes in income do not have an equal effect on the demand for crude oil imports.

Plausibly, a higher GDP per capita in the US generally means that there is a greater demand for energy, including petroleum. As the US economy grows, the demand for energy-intensive goods and services, such as transportation and manufacturing, increases, which can lead to an increase in petroleum consumption. Furthermore, the US is a major consumer of petroleum products, and a significant portion of the petroleum consumed in the US is imported from other countries, including Ghana. If the US economy is growing and the demand for petroleum is increasing, it may rely more heavily on imports to meet this demand, which could lead to an increase in petroleum demand from Ghana. Again, an increase in GDP per capita in the US could also lead to an increase in investment in Ghana's petroleum sector. If US companies see an opportunity to profit from the increased demand for petroleum in the US, they may invest in Ghana's petroleum industry to increase production and exports to the US. These results confirm the results of

Tsirimokos (2011) which shows income inelastic crude oil demand for some countries which are members of the OECD. The results, however, contradict that of Khan and Shaheen (2020); Lin and Atsagli (2017) who find that demand for crude oil imported from other countries is relatively more income elastic in the US, which implies that further growth in the economy of the US induces more demand for crude oil imported.

The real broad exchange rate has a positive and statistically significant effect on crude oil demand from Ghana. Appreciation of the exchange rate has a positive effect on the petroleum economy of Ghana. One per cent appreciation of the exchange rate induces a 0.010 per cent increase in import demand for crude oil from Ghana. However, the magnitude of exchange rate elasticity is smaller than one, which indicates a less exchange rate-sensitive import demand for crude oil from Ghana. This means that a currency depreciation of the US Dollar leads to more import demand for crude oil from Ghana.

Moreover, industrial production in the US has a negative effect on the demand for crude oil from Ghana. In Table 14, an increase in industrial production causes a 0.059, 0.050, and 0.052 per cent reduction in the demand for crude oil in Columns 2,3 and 4 respectively. This shows the weak elasticity of industrial production on crude oil import demand from Ghana. One possible explanation is that when industrial production in the US slows down, it may lead to a decrease in demand for energy and raw materials, including crude oil, which is used as a feedstock for a wide range of industrial processes. Also, crude oil import from Ghana is normally used to generate electricity or petrochemical products.

The crude oil price has a weak positive and statistically significant effect on the import demand of crude oil from Ghana. For instance, a one per cent increase in crude oil price in Column 2 causes a 0.005 per cent decrease in crude oil import, in Column 3, it causes a 0.005 reduction and in Column 4, it causes a 0.004 per cent decrease in crude imported from Ghana. These elasticities magnitudes are far less than one which indicates less price-sensitive import demand for crude oil from Ghana. Thus, the weak responsiveness to changes in demand for crude oil from a change in prices of crude oil.

Effects of Renewable Energy Transitions by other Countries on Crude Oil Import Demand from Ghana

To analyse the effect of the renewable energy transition on the import demand for petroleum from Ghana, other countries including China, India, Italy, and Canada are also considered. This is done to present concrete pieces of evidence of the effect of the energy transition by the world's largest importers of petroleum from Ghana on the petroleum economy of Ghana. For policy purposes, these countries are considered in analysing the effect of the renewable energy transition. These are countries that have the highest import demand for Ghana's petroleum and are major leaders of climate change and energy transition campaigners. The results of the analyses are presented in Table 15.

It is observed that the energy transition in China decreases crude oil import demand from Ghana. Thus, 1.0terawatt hour of renewable energy transition reduces crude oil import demand by US$0.053 million and it is significant at one per cent (p-value=0.000). China is one of the largest importers of crude oil from Ghana and its rapid energy transition will affect the petroleum economy of Ghana. However,

Table 15: Renewable Energy in selected Countries on Crude Oil Imports from Ghana

Country	Statistics	REC	PCGDP	RR	Ind_index	WTI	Constant	N
China	Final stage	-0.053	-0.162	0.014	0.082	0.008	98.69	84
	RMSE	0.004	0.010	0.003	0.007	0.001	3.028	
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	
India	Final stage	0.849	0.010	0.017	0.034	-0.018	338.277	84
	RMSE	0.020	0.004	0.004	0.003	0.001	29.226	
	P-value	0.000	0.019	0.000	0.000	0.000	0.000	
Italy	Final stage	-0.023	0.408	0.122	-0.003	0.604	-53.71	84
	RMSE	0.003	0.009	0.005	0.002	0.027	0.901	
	P-value	0.000	0.000	0.000	0.06	0.000	0.000	
Canada	Final stage	-0.037	-0.044	0.054	0.012	0.053	491.586	84
	RMSE	0.001	0.007	0.007	0.002	0.007	12.248	
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	

this elasticity of demand for crude oil in China is relatively weak since it is less than one. Thus, the renewable energy transition in China is less elastic. This implies that the renewable energy transition in China does not lead to great significant impact cost on the economy of Ghana.

This is because imported crude oil from Ghana in China ends up in electricity generation or is used in petrochemical products. Light crude oil is also used as a feedstock for petrochemical production. It is refined into chemicals such as ethylene and propylene, which are used to make plastics, synthetic fibres, and other products. Ghana's oil production is relatively small compared to major oil-producing countries like Saudi Arabia, Russia, and the US. As a result, changes in global oil demand due to energy transitions in individual countries or regions may have a relatively small impact on the overall market for crude oil. Furthermore, Ghana's crude oil is a heavy grade, which is less suitable for refining into lighter products such as gasoline and diesel which are in high demand in China's transportation sector. Therefore, Ghanaian crude oil may not be as directly affected by changes in Chinese demand for transportation fuels.

For India, the increase in energy transition has a positive impact on the crude oil import demand from Ghana. An increase in energy transition increases import demand from Ghana for India by US$0.849 million and it is significant at a one per cent level (p-value=0.000). This shows strong elasticity for crude oil import demand for India from Ghana. This implies that the energy transition in India increases crude oil import demand from Ghana. This could be because India has still not improved its level of renewable energy sources. Sources of renewables which includes tidal waves, wind, solar and others have not yet reached the levels that could affect crude oil demand. India will, therefore, demand crude oil for its economic activities. According to the 2021 monthly renewable energy generation report in India, in January 2021, renewable energy generation in India decreased by 1.95 per cent as compared to December 2020. This could positively affect crude oil imports from Ghana. The channel through which renewable energy consumption in India could indirectly lead to an increase in crude oil demand from Ghana is through increased demand for petrochemical products. While renewable energy sources are typically not used to produce plastics, petrochemicals are often derived from crude oil. Therefore, if there is increased demand for plastics due to economic growth or industrialisation in India, this could indirectly drive-up demand for crude oil from Ghana.

However, an increase in the energy transition in Italy decreases crude oil import demand for Italy from Ghana. That is, a 1.0GW increase in the energy transition to renewable energy decreases crude oil import demand from Ghana for Italy by US$0.023 million and it is significant at one per cent (p-value=0.000). This could be since, Italy in recent years, has been advocating for renewables. In Europe, Italy is ranked third for both consumptions of renewable power and thermal and electrical production from resources from renewable. Italy is one of the few countries in Europe and the world at large that has reached 2020 renewable energy targets of 18.2 per cent. According to International Trade Administration, the Integrated National Plan for Energy and Climate of Italy gives the strategy of the country from 2021 to 2030 in connection with the efficiency of energy, selfconsumption, decarbonisation and generation of distribution and energy security. This is to bring to 30 per cent the share of renewable energy in the final gross energy consumption. It is therefore not surprising that the renewable energy transition in Italy has a negative impact on crude oil import demand from Ghana. This means that a rapid energy transition from crude oil to renewables would affect the petroleum economy of Ghana.

The transition of energy to renewables in Canada has a negative effect on crude oil import demand from Ghana. One GW increase in renewable energy reduces crude oil import demand by US$0.037 million and it is significant at one per cent (p-value=0.000). This is because Canada has substantial renewable resources such as biomass, solar, geothermal, and wind thanks to its large landmass and diversified geography that could be utilised to produce energy. According to the government, Canada is a leader in the use and production of energy from renewables. It is estimated that about 18.9 per cent of the total supply of primary energy in Canada is from renewable energy. Moving water provides about 59.3 per cent of the generation of electricity in Canada. Which makes it the second-largest producer of hydroelectricity globally. These could be the possible reasons it has the lower demand for crude oil imports from Ghana.

This implies that the energy transition in Canada could negatively affect the petroleum economy of Ghana. From Table 6.9, it is observed that all the countries' energy transition harms the petroleum economy of Ghana except India. Heterogenous countries make heterogeneous investment decisions in energy sources. Countries that are using lower hurdle rates are more, in general, willing to invest and mostly invest heavily in solar, nuclear and wind. For low hurdle rates reduces the investment cost of renewable energy more than coal and crude oil-powered plants. These empirical results validate the study of Waziri, et al. (2018) who reveal that consumption of renewables in advanced countries of NEICs affects Nigeria's petroleum exports negatively in both the short-run and the long run, in so doing instigating substantial reduction in the revenue sums being made therefrom. Also, Khan and Shaheen (2020) find the elasticity between crude oil import demands and consumption of renewables for Japan, China, and India, even though there was a small size magnitude. Conversely, Stockl and Zerrahn (2020) advocate that a well-adjusted mix of diverse renewables types could substitute the conventional non-renewables.

There is a negative relationship between income and crude oil import demand from Ghana for China and Canada. That is, an increase in income in these countries decreases the demand for crude oil from Ghana. These countries have higher nationally determined contributions towards the reduction of greenhouse gases. This could be the plausible reason the increase in income in these countries leads to a reduction in crude oil demand from Ghana. However, an increase in income in Italy and India increases crude oil import demand from Ghana. India is an emerging economy and as such increase in income could cause an increase in demand for crude oil to boost their economy. As some countries progress in terms of GDP per capita, they tend to demand more petroleum while others tend to switch to renewables. This could be due to the disparities in the results.

However, demand for crude oil import from Ghana is relatively weaker income elastic for India and Canada than the income elasticity for China and Italy. The findings for India and Italy corroborate that of Jabir (2009) and the finding for China and Canada contradict those of Jabir (2009) who finds that income plays a central role in the determination of oil imports. Also, these findings confirm that of Gorus, et at. (2019) who find imports of oil to be more sensitive to variations in income than prices of oil variations. The studies state that one of the key engines of the increase in crude oil demand is undoubtedly economic growth.

An increase in industrial production in China, India, and Canada increases crude oil import demand from Ghana. For instance, an increase in industrial production in China, India, and Canada would increase crude oil demand from Ghana by 0.082, 0.034, and 0.012 respectively and they are all significant at one per cent (p-value=0.000). This may be because industrial production requires high levels of energy in which crude oil plays a key role. Many industrial countries in the world rely heavily on petroleum. However, there is an inverse relation between the industrial production index in Italy and crude oil import from Ghana. This implies that crude oil import demand from Italy is negatively affected by industrial production in Italy. This is unsurprising since there is a high level of renewable energy consumption in Italy. Italy is assumed to be among the first five countries with the highest production and consumption of renewables.

These findings for India, Canada, and China contradict those of Van Hoang, et al. (2020); Bilgili (2015) who find that there is positive co-movement between industrial production and consumption of renewables (biomass energy) and not petroleum in the long run. However, the finding for Italy supports these studies. There is bi-directional predictability between consumption of renewables and industrial production in periods of crisis which is related to the consideration of the fossil fuel industry which has come under serious criticism in the face of global climate change goals. Also, the findings contradict Xie, et al. (2021) who find that the relationship between energy consumption transition and productivity is inversely related and non-linear.

From Table 15, it is observed that the exchange rate has a direct relationship with crude oil import demands for all the countries understudy. They are all significant at one per cent. This implies that the depreciation of the exchange rates in these countries leads to an increase in crude oil import demands. Since prices of crude oil are normally quoted in US$, the US performances in contrast to currencies for international bilateral might influence oil prices and hence crude oil demands. The depreciation of the dollar indicates oil becomes comparatively cheaper for consumers in terms of local currencies in these countries which spurs imports of crude oil demands. On the contrary, the depreciation of the exchange rate of the US$ stimulates real economic activity and hence demands crude oil via its wealth effects which could arise from financial assets that are non-dollar. This could reasonably give explanations for the effect of the RR variable in the oil import demand models. This means that the exchange rate has a relevant positive contribution to the importation of crude oil in these countries. This confirms the economic theory that a fall in the exchange rate causes imports to fall. This could also be because of already higher import demands existing in the economy. These contradict Odo, et al. (2017) that crude oil import negatively affects the exchange rate and support that of Marbuah (2017) that exchange depreciation stimulates oil imports.

It is observed that prices of crude oil significantly affect crude oil import demands for all four listed countries. Crude oil import demands from Ghana have an inverse relationship with the price of crude in India. That is, an increase in crude oil price leads to a decline in demand for crude oil imports for India. For China, Italy, and Canada, an upsurge in crude oil prices causes an increase in import demand for crude oil and it is significant at one per cent (p-value=0.000). This implies that crude oil import demands are price elastic even though it is very weak for all the countries. Theoretically, an increase in the prices of goods leads to a decrease in the quantity demanded. Demands for crude oil import should be price inelastic if not for renewables.

However, crude oil is not a product that can easily be substituted for just like other commodities. Price changes in crude oil should not affect its demand. It is, therefore, not surprising that crude oil demands go up even when prices go up. This could also mean that crude oil prices go up when there is high demand for crude oil and these countries are heavily dependent on energy for economic activities from the generation of electricity to manufacturing and transportation with virtually no close substitutes. This could also be because the study does not analyse the short-run and long-run effects of prices. This finding confirms that of Marbuah (2017); Ozturk and Arisoy (2016) that crude oil import demands are less price elastic.

Effect of Transition Scenarios on Import Demand for Ghana's Petroleum

The various energy transition pathways from both the IEA and BP have profound consequences for emerging oil exports of a small, open petroleum economy such as Ghana. To start with, the IEA and the BP present several policy scenarios towards achieving a decarbonated world by 2050 or 2070 including investment scenarios in energy. In this regard, the study considered three investment scenarios which are, 'No new investment in oil green fields', 'Investment in existing fields' and, 'Sustainable Development Scenario (SDS). These investment scenarios, as shown in Figure 6.6, will have grave consequences for Ghana's oil export if global efforts to shift from fossil fuels to renewables materialise per the transition scenarios. It is observed that no new investment scenario decreases Ghana's oil export to the world most than the investment in the existing fields and the SDS. The SDS has the lowest impact on oil export from Ghana to the rest of the world. The SDS might decrease 2021 export of, approximately, 83MMBbls to, approximately, 60MMBls by 2040 while the no new investment decreases oil export to, approximately 16MMBbls by 2040 and investment in existing fields will decrease oil exports to, approximately, 35MMBbls by 2040.

This is because, when no new investments are made in Ghana's green oil fields, Ghana will lose about 80 per cent of its 2019 export volumes (about 90MMBbls) to global energy transition and at a rate of about one per cent per annum decline, Ghana's exports are projected to vanish by 2050. However, continuous investment in existing oil fields such as for enhanced oil discovery will

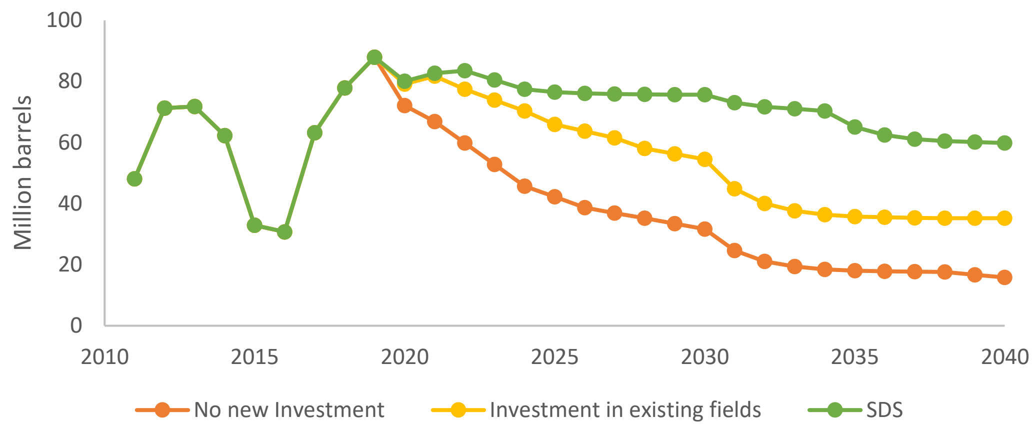

Figure 41: Ghana's Annual Oil Exports to the World under Investment Transition Scenarios for 2011-2040

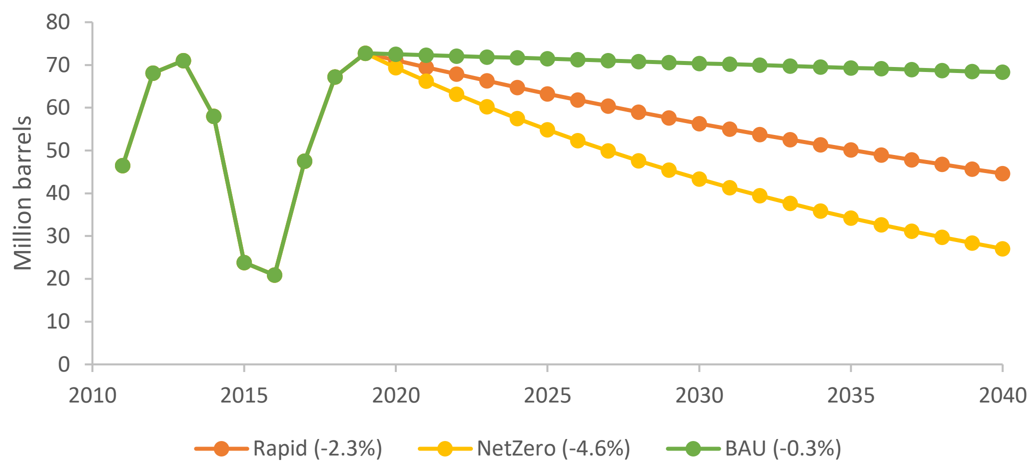

Figure 42: Ghana's Annual Oil Export to the World under Transition Scenarios for 2011-2040

manage the decline in oil exports to about 35MMBbls while the Sustainable Development Scenario (SDS) scenario will manage the fall up to 60MMBbls.

Furthermore, under transition pathways, Ghana's oil exports to the rest of the world are expected to decline sharply in the NetZero assumption, by 4.6 per cent annually, to about 28MMBbl. This is depicted in Figure 41. A rapid transition will cause Ghana to lose about 2.3MMBbl to energy transition while in a BAU scenario, Ghana will do about what it is currently exporting annually by the end of 2040.

No investment means that there is little or no exploration or production of oil. This can lead to a decrease in oil exports because there may not be enough oil to meet demand. In addition, if the cost of producing oil is high and there is no investment to reduce those costs, then oil exports may become less competitive compared to other sources of energy. Also, if there is no investment in alternative sources of energy, then the oil demand may not decrease as quickly, which means that the reduced supply could lead to higher prices. Higher prices can make it more expensive for countries to purchase oil, which could lead to a decrease in demand for oil exports from Ghana as importing countries may seek more affordable alternatives such as renewables.

Also, the projection of China's marginal increase in oil consumption and imports has the potential to cause an increase in Ghana's export to China, especially in the BAU scenario as shown in Figure 43. The net effect of energy transition scenarios between China and the rest of the world on Ghana's oil export shows a less steep decline in oil exports between 2020 and 2040 as a result of increases in Ghana's oil exports to China over the period (see Figures 42 and 43). Specifically, while the NetZero assumptions would cut Ghana's oil export to Canada (as shown in Figure 44) and Italy (as shown in Figure 45, which is similar to that of India) below 30MMbbl, Ghana's export to China will save Ghana about 10MMbbls to keep oil exports above 40MMbbl by 2040. The net effects on the other scenarios are also positive. This, therefore, highlights the important role China will play in cushioning or otherwise Ghana's loss of oil exports to the global energy transition.

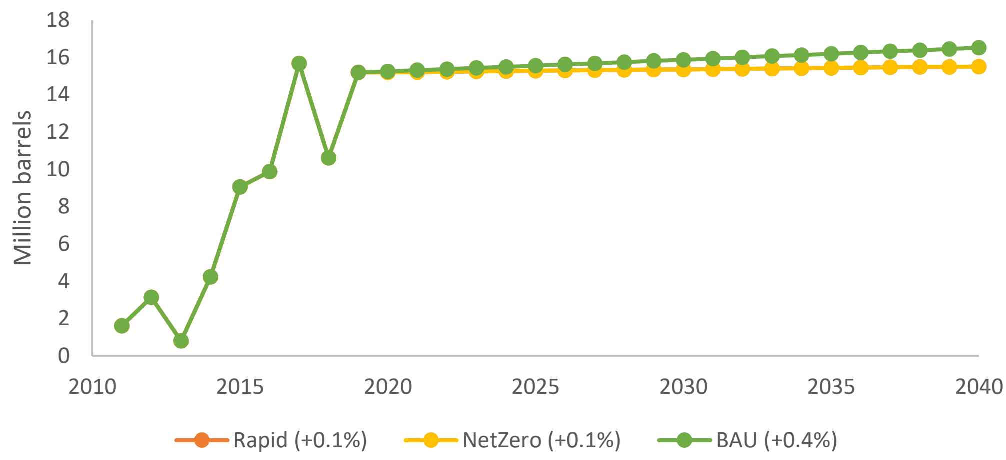

Figure 43: Ghana's Annual Oil Export to China under Transition Scenarios for 2011-2040

Source: Authors (2023)

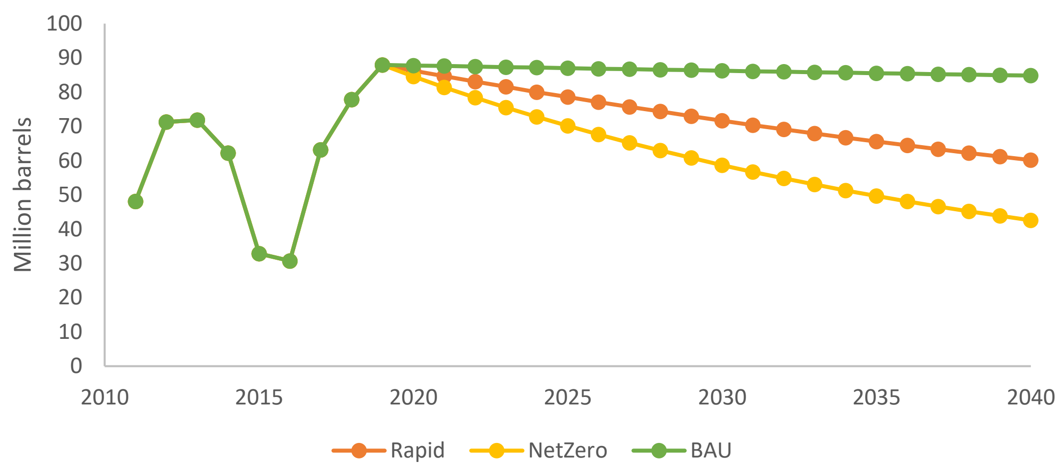

Figure 44: Ghana's Oil Export to Canada under Transition Scenarios for 2011-2040

Source: Authors (2023)

Ghana heavily relies on the export of crude oil, and a shift towards renewable energy may have a negative impact on the economy. This could occur if demand for crude oil decreases due to the adoption of renewable energy sources, leading to lower prices and reduced export revenues.

Again, Figure 46 depicts the annual oil exports to the US. The export of oil to the US will decline to approximately 45MMBbls by 2040 in the rapid scenario.

While the NZE transition scenario will decrease oil export to the US by 27MMBbls. The business-as-usual scenario decreases oil exports to the US by 68MMBbls. These higher declines in oil exports in the US, Canada, Italy, and India as compared to oil exports to China are mainly because of policies and strategies adopted by these countries. Their speed of transition is diverse. China has different approaches and timelines towards energy transition, which is the reason for the varying impacts on import demand for crude oil from Ghana.

From these scenarios, renewable energy production can potentially reduce petroleum demand as it provides alternative sources of energy that are cleaner and more sustainable. This is because fossil fuels and renewables are treated as substitutes rather than complementary goods. According to the IEA (2020), renewables such as wind, solar, and hydropower have the potential to displace up to 27 per cent of the world's total demand for oil by 2050. Renewable energy technologies are becoming increasingly competitive with fossil fuels in terms of cost, and in some cases, they are already cheaper than oil (IRENA, 2020). For instance, the cost of solar power has dropped by over 80 per cent in the last decade, making it one of the most affordable sources of electricity (IRENA, 2020).

Also, it is asserted that renewables use aids in energy price stability by reducing dependence on volatile fossil fuel markets. Renewable energy transition could promote energy independence by reducing reliance on imported petroleum. Many countries are heavily reliant on imported petroleum, which can be vulnerable to supply disruptions and price volatility. That is, renewables reduce petroleum demand through diversification of the energy mix. As renewable energy

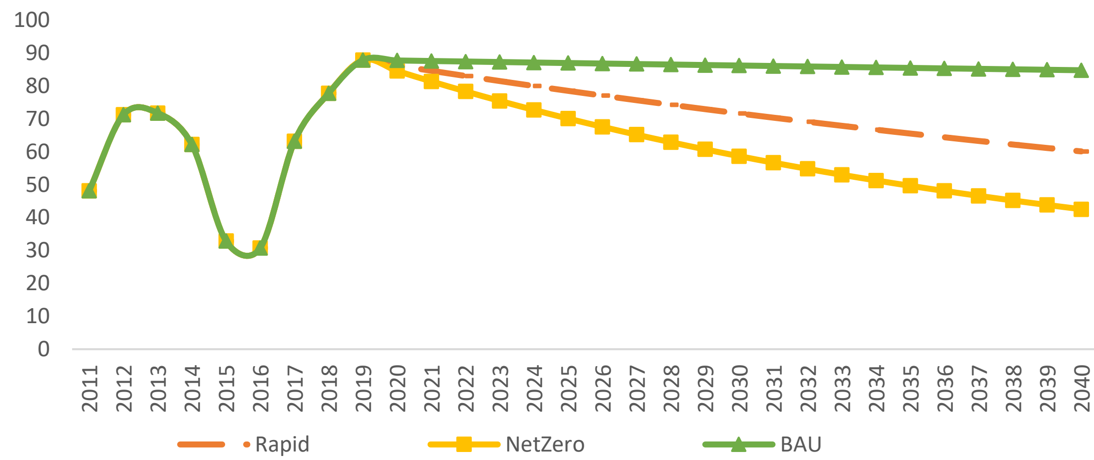

Figure 45: Ghana's Oil Export to Italy under Transition Scenarios
Source: Authors (2023)

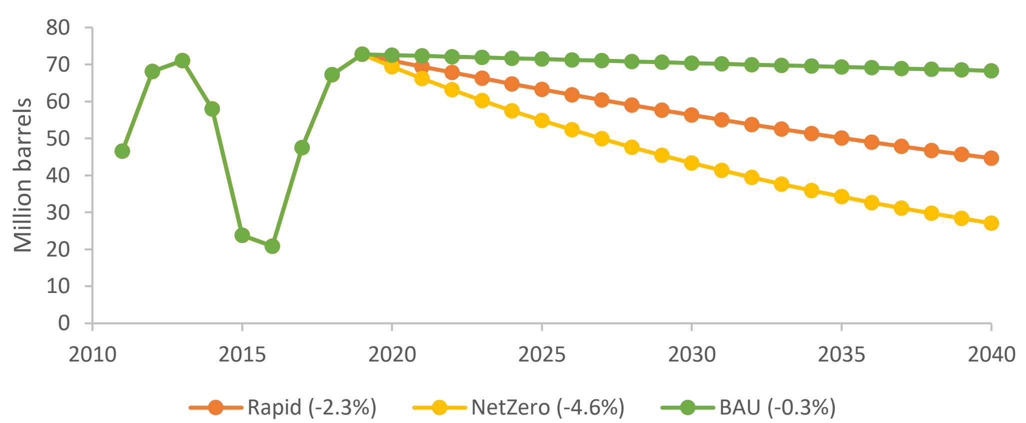

Figure 46: Ghana's Annual Oil Export to the US under Transition Scenarios for 2011-2040

technologies become more cost-competitive and efficient, they can increasingly replace petroleum as a primary source of energy (IRENA, 2020).

Effects of Renewable Energy Transition on Employment in Ghana

To analyse the effect of the renewable energy transition on employment in Ghana, employment is categorised into three main sectors—industry, agriculture and service sector employment. From Table 16, it can be seen that the lag of employment has a negative effect on employment. For instance, in the industry

Table 16: Effect of Renewable Energy Consumption on Employment

Variable	Manufacturing	Agriculture	Services
ADJ			
Total Employed			
L1.	-.219**	-.215*	-.216**
	(.109)	(.107)	(.106)
LR			
REC	.479	-.039	.432
	(1.675)	(4.271)	(2.603)
$GDP_{energyuse}$	.168	-.204	.030
	(.238)	(.601)	(.370)
$fossil_{cons}$	.070	.224*	.152**
	(.052)	(.124)	(.072)
Educ	.076*	.293	.216***
	(.039)	(.494)	(.054)
Pop	-.001	-.077**	.077***
	(.012)	(.032)	(.020)
CPI	-0.062***	-0.050***	-0.067***
	(0.005)	(0.005)	(0.005)
SR		Table 6.10	
Total Employed			
LD.	-.054	-.057	-.055
	(.164)	(.164)	(.163)
REC			
D1.	-.159	-.781	.943
	(.529)	(1.321)	(.817)
LD.	-.038	-.065	.104
	(.529)	(1.327)	.830
$GDP_{energyuse}$			
D1.	.164	-.452	.287
	(.167)	(.415)	(.255)
LD.	.037	-.130	.092
	(.168)	(.421)	(.259)
	(.015)	(.042)	(.028)
LD.	.028*	-.064	.037
	(.016)	(.041)	(.027)
$fossil_{cons}$			
D1.	.039***	.041	.002
	(.014)	(.037)	(.023)
Edu			
D1.	.041***	-.021	.019
	(.015)	(.042)	(.028)
LD.	.027*	-.065	.039
	(.016)	(.041)	(.028)
Pop			
D1.	-.007	-.037	.044***
	(.009)	(.023)	(.015)
	0.4189	0.1074	0.0059
CPI	-.038***	-.040	.002
	(.014)	(.037)	(.024)
_cons	3.778	9.971	7.866
	(2.563)	(7.378)	(4.516)
N	58	58	58

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

sector, the lag of employment reduces employment by 0.219 per cent and it is significant at a five per cent level (p-value=0.050). For the agricultural sector, the lag of employment reduces employment by 0.215 per cent and it is significant at the 10 per cent level (p-value=0.052). For the service sector, the lag of employment reduces employment by 0.216 per cent and it is significant at a five per cent level (p-value=0.047). These imply that previous employment in all sectors has a negative effect on the current employment levels. This means that more than 20 per cent of disequilibria from a shock in government expenditures converge to the long-run equilibria within three months. This means that previous employment levels can reduce employment in current years. This is not surprising since the economy of Ghana is not able to absorb employment seekers year in and year out. This is because, in Ghana, the sectors are not able to create more jobs for the unemployed each year. Some sectors recruit and employ people for more than even three years.

In the long run, renewable energy consumption has an insignificant effect on employment in all the sectors—industry, agriculture and service sectors. In the short run, renewable energy consumption has a negative insignificant effect on employment in the industry and agricultural sectors but a positive and insignificant effect on the services sector. This could be because renewable energy consumption and production are not on large scale in Ghana and have just been introduced. The number of solar panels and wind are still low. Also, it is mostly used by the rich for basic house activities such as cooking and heating water during power outages. Conversely, studies such as Ibrahiem and Sameh (2020); Moyo, et al. (2017) indicate that renewables harm unemployment.

In the long run, education has a significant positive effect on employment in the industry and services sectors in Ghana except for the agricultural sector. An increase in education increases employment in the industry sector by 0.76 per cent and it is significant at a one per cent level (p-value=0.059). For the service sector, an increase in education increases employment by 0.216 per cent and it is significant at a one per cent level (p-value=0.000). In the short run, education has an insignificant effect on employment in both the agriculture and service sectors. For the industry sector, an increase in education increases employment by 0.041 per cent and it is significant at one per cent (p-value=0.010). This implies increasing human skills as postulated by the human capital theory might increase employment. People must be trained to acquire what could be fit for employment.

Consumption of fossil fuels has a positive insignificant effect on employment in the industrial sector in the long run. This could be because most industries in Ghana do not rely on fossil fuels for production. Almost all industries in Ghana are established where there is an electrical connection to the national electricity grid. Hence, most of them are connected to the national grid as sources of power. But in the short run, the consumption of fossil fuels increases employment in the industry. The excess demand for energy by the industrial sector implies an increase in the activities of the industrial sector which leads to an increase in employment in the short run. In the long run, energy demand might not lead to an increase in employment since the improvement in technology could impact labour demand for certain services.

However, an increase in the consumption of fossil fuels increases employment in the agriculture sector by 22.4 per cent and it is significant at 10 per cent (p-value=0.078). This implies that as Ghana increases consumption of its fossil fuels, unemployment in the agriculture sector reduces by about 22 per cent. This could be because the revenue accrued from the consumption of fossil fuels might be used to finance agricultural activities in Ghana. The agriculture sector of Ghana has since the 1970s continues to receive much focus with several programmes and policies to increase productivity. These policies and strategies include but are not limited to Food and Agricultural Sector Development Policies, Planting for Food and Job Policy launched in 2018 (Azumah, et al., 2022) and others.

For the services sector, an increase in consumption of fossil fuels increases employment in the services sector by 15.2 per cent and it is significant at a five per cent level (p-value=0.041). This is because as Ghana consumes its fossil fuels, it implies that the services sector can engage in other activities such as trading, exchanging, and education among others that could rake in revenues and able to create jobs for the citizens. This benefits the service sector. In the short-run, fossil fuel consumption has a positive significant effect on the industrial sector but has insignificant effects on the agriculture and service sectors.

From Table 16, GDP per energy use has insignificant effects on employment in all the sectors of the economy in the long run. An increase in income has positive insignificant effects on the industrial and services sectors but negative and insignificant effects on the agricultural sector. This is contradictory to economic theories that income leads to an increase in demand, which will require an increase in investments, which could lead to firms willing to employ more. This action leads to the creation of jobs and an increased rate of employment. The long-run results are similar to the short-run estimates.

In the long run, an increase in population leads to a reduction in employment in the agriculture sector by 7.7 per cent and it is significant at five per cent (p-value=0.024). This means that, as the number of people increases, job creation potential in the agricultural sector declines. This is because an increase in the number of people puts a lot of pressure on agricultural land and farmlands for agricultural purposes decline. Also, farmers begin to have smaller and smaller land for farming and the idea of giving birth to aid in farming activities no longer exists. For the services sector, an increase in population leads to a 7.7 per cent increase in employment and it is significant at one per cent (p-value=0.000). This implies that as the number of people increases, job creation in the services sector goes up. Plausibly, there would be an increase in demand for products that the services sector supplies. For example, there would be a need for more education services, legal services, financial services and others. The services sector would be able to employ more people to meet these rising demands. In the short-run, the population has a positive significant effect on the only services sector.

Inflation, in the long run, has negative effects on employment in all sectors of the economy. For instance, an increase in inflation decreases employment in the industry sector by 0.062 per cent, in the agriculture sector by 0.05 per cent, and in the services sector by 0.067 per cent and all are significant at one per cent. However, in the short run, inflation has a significant negative effect on only the industry sector. The main reason for this is that sustained inflation can lead to an increase in interest rates, which can in turn reduce investment and job creation. Inflation can also erode the purchasing power of wages, which can lead to reduced consumer spending and lower demand for goods and services. This can ultimately result in businesses scaling back production and laying off workers. Additionally, inflation can increase uncertainty and reduce confidence in the economy, which can further discourage investment and hiring. When inflation is high, it can be difficult for businesses to plan for the future, as they may be unsure of the costs of raw materials, labour, and other inputs. This can lead to reduced investment and hiring, as businesses may be hesitant to make long-term commitments in such an uncertain environment.

Effects of Energy Transition on Employment in Ghana

To analyse the effect of energy transition scenarios on employment in Ghana, several employment measurements are used in our analyses. Some of the indicators are vulnerable employment, female and male employment rates, as well as sectorial employment. The analyses on the vulnerable, female and male employment vulnerability to energy transition are presented in Appendix F. The point estimates of energy transition reduce vulnerable employment for males, females and both sexes. It is observed that both scenarios will decrease vulnerable employment for males and females. However, energy transition decreases female vulnerable employment more than that of males. Also, the energy transition has greater impacts on unemployment after the 9th year. The point estimates of energy transition decrease unemployment among, males, females, and both sex.

Effect of Transition Scenarios on Employment in the Industry Sector

The transition to renewable energy can have significant impacts on employment creation in the industry sector. Table 17 shows the impact of the energy transition on employment in the industrial sector of Ghana. It indicates that the renewable energy transition has a positive impact on employment in the industry sector. That is, an increase in renewable energy will increase employment by 11.4 per cent and it is significant at one per cent (p-value=0.002). This is not surprising because the bulk of Ghana's producing industry depends almost entirely on electricity connected to the national grid as their source of energy. According to Armah (2022), crude oil is responsible for 52 per cent of the energy consumption in the formal industrial sector.

As Ghana shifts towards clean energy, there will be a need for skilled workers in the renewable energy sector. This includes jobs such as engineers, technicians, and installers for solar, wind, and hydroelectric power systems. This could potentially create new job opportunities and reduce the country's dependence on traditional energy sources, which can positively impact the industry sector's employment. Also, renewable energy projects require significant investment, which can lead to increased economic activity and job creation in related industries. This includes industries such as construction, transportation, and manufacturing, which can benefit from the increased demand for renewable energy infrastructure. Again, transitioning to clean energy can also lead to improved energy efficiency in the industry sector. Energy-efficient technologies and practices can help industries reduce their energy consumption and costs, which can increase their

Table 17: Energy Transition Scenarios on Industry Employment

Employment in industry	Coef.	Std. Err.	P>t
Linindustry	0.949	0.029	0.000
REC	0.114	0.035	0.002
$GDP_{energyuse}$	-0.003	0.089	0.975
$fossil_{cons}$	0.002	0.009	0.836
Educ	0.390	0.193	0.047
POP	-0.007	0.031	0.823
CPI	-0.034	0.001	0.000
LagREC	0.089	0.497	0.858
$lagGDP_{energyuse}$	0.089	0.091	0.332
$lagfossil_{cons}$	0.0004	0.009	0.957
Lageduc	0.213	0.493	0.147
LagPOP	0.004	0.030	0.887
LagCPI	-0.021	0.009	0.006
_cons	-0.744	2.216	0.738
N			
r-square	0.984		
Adjusted r-square	0.982		

competitiveness and profitability, leading to potential job creation. The transition to clean energy can reduce air pollution from traditional energy sources and improve the health and well-being of the workforce, which can positively affect employment in the industry sector.

All the exogenous variables have an insignificant impact on employment in the industry sector. For example, an increase in fossil fuel consumption increases employment in the industrial sector by 0.002 per cent. An increase in education increases employment in the industry sector by 0.390 per cent and it is significant at five per cent (p-value=0.045). The lag in industrial sector employment has a positive and significant impact on its employment. That is, the previous quarter's employment in the industry sector increases current employment in the current quarter. This is mainly because one industry will lead to siting and springing of many other firms. The lag of education has a positive impact on industry sector employment. The lag of GDP per energy use, consumption of fossil fuels, renewable energy transition, and population has no significant impacts on employment in the industry sector while inflation and lag of inflation have a negative impact on industrial employment.

Renewable energy transition scenarios on employment in the industry sector of Ghana have been displayed in Figure 47. It is observed that business-as-usual transition scenarios have a higher overall positive impact on industry employment than the five per cent transition scenario in the industrial sector. However, the business-as-usual scenario has a decreasing impact on employment in the industry sector while the rapid scenario has an increasing impact on employment in the industrial sector. This implies that renewable energy transition at a higher rate will increase employment in the industry sector.

This is not surprising. The plausible reason is that the advocacy for renewable energy transition is increasing and hence demand more renewable energy activities. For example, jobs in the fossil fuels industry may be lost as demand for these fossil fuels decreases, while new jobs may be created in the renewable energy sector as their demand increases. The overall impacts of employment depend on the pace and scale of the transition to some extent, as well as the availability of retraining programmes and support for affected workers. This could be because the industry sector usually relies on cheap energy sources to benefit from economies of scale. When resources are cheaper, firms can demand more to increase their production capacity. The prices and cost of renewables have

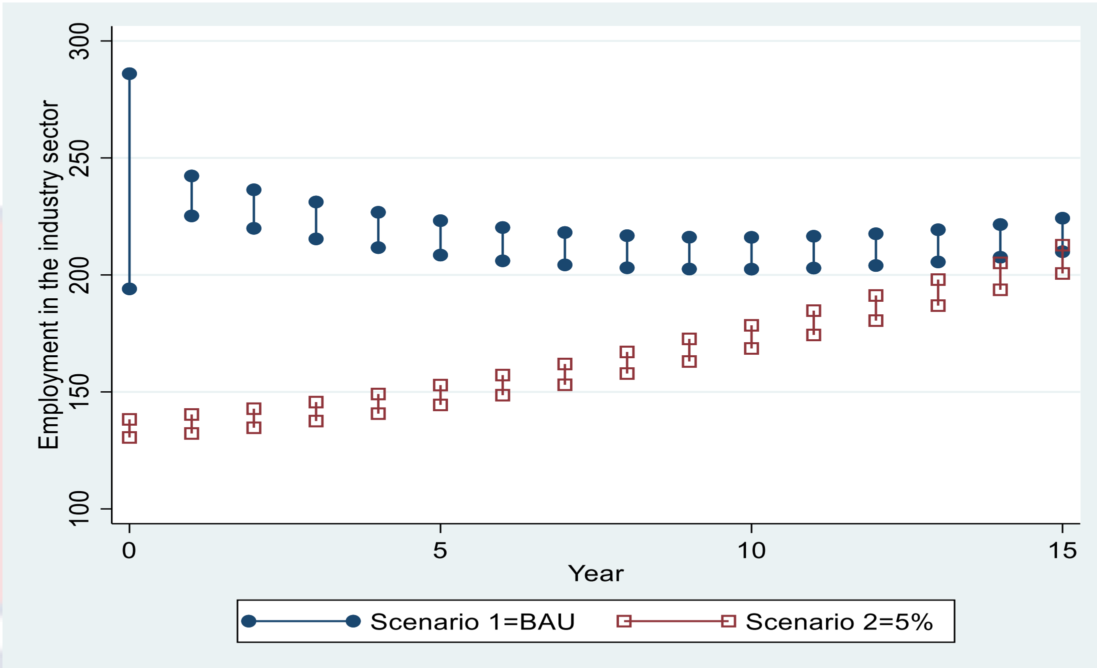

Figure 47: Energy Transition Scenarios on Employment in the Industry Sector

been decreasing for the past decades. It is even asserted that prices and costs of renewables are cheaper in their current state than any other energy transition, including oil. It is expected that the cost of renewables will be far cheaper in the next decades. Hence, the renewable energy transition will have a positive impact on employment in the industry sector in Ghana.

This might be because renewable energy technologies adoption could lead to a decrease in energy costs for industries, which could increase their competitiveness and profitability. Also, renewables might ensure a constant supply of energy and energy access. This could lead to an increase in employment opportunities in these industries. As noted by Appiah et al. (2022) and Asante et al. (2021), the adoption of renewable energy technologies could lead to cost savings for industries that rely on electricity for their operations. Again, the transition towards renewable energy technologies could lead to the emergence of new industries, which could create new employment opportunities. For example, the development of solar panel manufacturing, installation, and maintenance industries could create new jobs in Ghana. This intuition is consistent with the economic theory of creative destruction, which suggests that the emergence of new industries can lead to job creation. In the same vein, the deployment of renewable energy technologies could lead to the development of new industries that require formal sector employment in regions that are currently underserved.

As noted by Appiah et al. (2022), the deployment of renewable energy technologies in the northern regions of Ghana could create new industry sector employment opportunities in those regions. Furthermore, transitions towards renewable energy technologies could lead to changes in consumer behaviour that could positively impact the industry sector. For example, if consumers become more environmentally conscious and demand products that are manufactured using renewables, this could increase demand for products from industries that have adopted renewable energy technologies, leading to an increase in employment opportunities in the sector. The adoption of renewable energy technologies could lead to improvements in the health and well-being of the population, leading to increased productivity and economic activity. For example, the use of cleaner cooking technologies could reduce indoor air pollution, leading to improved health outcomes for households. This could indirectly create employment opportunities in the industry sector through increased economic activity.

Effect of Transition Scenarios on Employment in the Agriculture Sector

Table 18 presents the impact of the renewable energy transition on employment in the agriculture sector. The results indicate that only the lag of

Table 18: Energy Transition Scenarios on Agriculture Employment

Employment in agriculture	Coef.	Std. Err.	P>t
Lagric	0.923	0.029	0.000
REC	-0.741	0.075	0.000
$GDP_{energyuse}$	-0.390	0.193	0.047
$fossil_{cons}$	0.016	0.020	0.443
Educ	0.490	0.674	0.469
POP	-0.007	0.068	0.913
CPI	0.391	0.193	0.047
LagREC	0.061	1.076	0.955
$lagGDP_{energyuse}$	0.167	0.202	0.412
$lagfossil_{cons}$	0.013	0.020	0.513
Lageduc	0.004	0.002	0.035
LagPOP	0.005	0.067	0.938
LagCPI	0.012	0.050	0.513
_cons	8.735	5.334	0.106
N	83		
r-square	0.993		
Adjusted r-square	0.992		

energy transition decreases employment in the agriculture sector by 0.741 per cent and it is significant at one per cent (p-value=0.000). Renewable energy has been noted to affect agriculture production. Armah (2022) notes that crude oil is responsible for 96.7 per cent of the energy consumption in the agriculture sector. Another plausible reason is the use of agricultural land for large hydro construction. Also, flat agricultural lands are used for the installation of solar cells. Again, the supply chain of renewable energy from production to consumption will shift employment in the agriculture sector to other sectors of the economy. Similarly, GDP per energy use has a significant negative impact on employment in agriculture. This could be due to the fact that economic growth leads to shifting away from an agrarian economy to services and manufacturing.

However, exports of fossil fuels and education have no significant impact on employment in the agriculture sector while inflation has a negative impact on employment in the agriculture sector. The previous quarter of renewable energy consumption, GDP per energy use, consumption of fossil fuels, and population have no impacts on agriculture employment. However, the lag of education has a positive significant impact on employment in the agriculture sector. This could be mainly because those who previously graduated have not found jobs in the formal sector and might engage in the agriculture sector to look for jobs requiring their skills and knowledge.

Renewable energy transition scenarios on employment in the agriculture sector of Ghana have been displayed in Figure 48. It is observed that five per cent of energy transition scenarios have a negative impact on employment in the agriculture sector while the business-as-usual scenarios have a positive impact on agriculture sector employment. This implies that renewable energy transition scenarios at five per cent will cripple employment creation in the agriculture sector. This could be because the agriculture sector usually relies on cheap energy sources to benefit from economies of scale.

When resources are cheaper, the agriculture sector can demand more to increase its production capacity. For instance, farmers and farm-based organisations that use mechanised irrigation use diesel and petrol to power their machines. These products are relatively cheaper than solar plants in Ghana. Furthermore, even though the supply chain of renewable energy would affect agricultural employment, the majority of the employed in Ghana and other SSA countries are in the informal agriculture sector. About 85.8 per cent of employment in these countries is in the informal sector (ILO, 2020), where agriculture dominates the sector. Hence, the renewable energy transition has a negative impact on employment in the agriculture

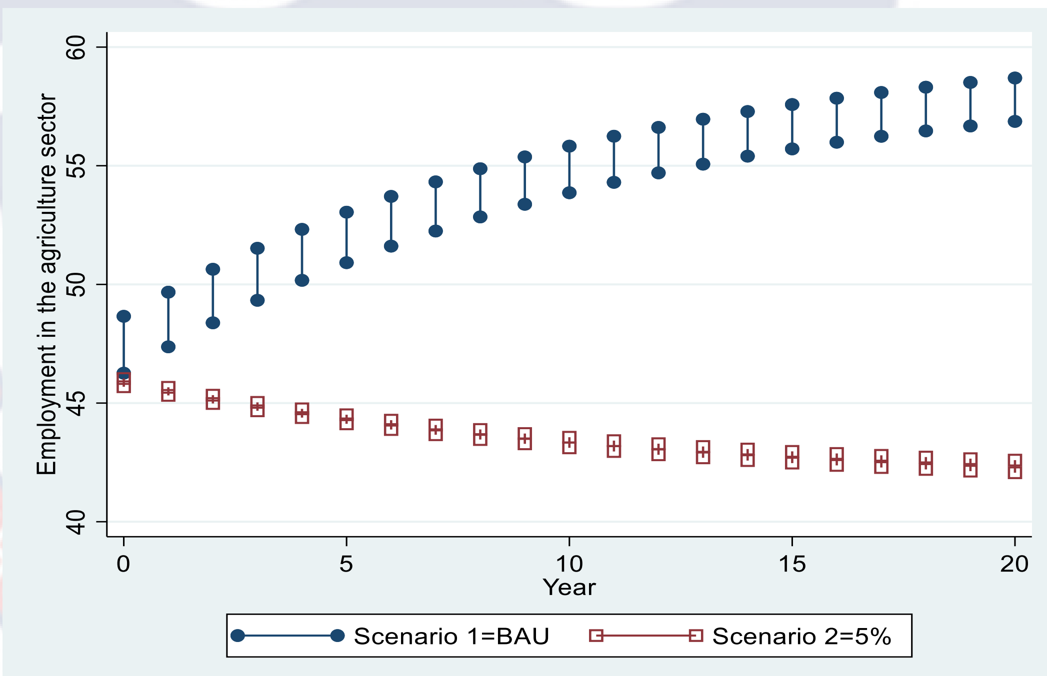

Figure 48: Energy Transition Scenarios on Employment in the Agriculture Sector

Also, the negative effects on agriculture sector employment could be due to a reduction in the demand for agricultural products. Renewable energy production often requires large areas of land, which may be converted from agricultural land to renewable energy transition. The development of renewable energy projects requires large tracts of land to be used. This creates competition for land between farmers and energy companies. This conversion reduces the availability of arable land for agriculture, leading to a reduction in the production of agricultural products. This, in turn, reduces the demand for labour in the agriculture sector, leading to job losses. Also, the shift in employment opportunities as renewable energy transition becomes more predominant might be able to create new employment opportunities in the renewable energy sector. However, these opportunities may require different skills and qualifications than those required in the agriculture sector, leading to a shift in employment opportunities away from agriculture.

Another reason could be due to changes in labour markets where the renewables transition might lead to changes in wages, job security, and working conditions, as indicated by the job search theory. These changes might make agricultural employment less attractive relative to employment in the renewable energy sector. Furthermore, the substitution of labour for renewable energy projects often relies on highly automated technology, which requires fewer workers to operate and maintain compared to traditional agriculture. This can lead to a reduction in the demand for labour in the agriculture sector, resulting in job losses. Renewable energy projects are often located in rural areas, which can lead to an outflow of labour from rural areas—where agriculture employment dominates—towards urban areas. This can result in a reduction in the supply of labour in the agriculture sector.

Renewable technologies adoption could lead to changes in consumer behaviour that can adversely affect the agriculture sector's employment. For example, if electricity costs decrease attributable to renewable technologies adoption, consumers may shift away from using biomass for cooking, which could adversely impact the market for biomass fuels. This, in turn, could negatively impact the livelihoods of small-scale farmers who rely on biomass fuel production for their income. Furthermore, the renewables transition might divert financial resources away from the agricultural sector, leading to a decrease in employment opportunities. This is particularly relevant for small-scale farmers who may not have the resources to invest in renewable energy technologies. As noted by Osei-Boakye et al. (2018), the high upfront costs of renewable energy technologies could be a barrier for small-scale farmers who need financial support to invest in their farms.

This confirms the results of Carr and Bluestein (2019) who found that the negative impact of renewable energy production on agriculture sector employment can be attributed to several factors, including competition for land, labour substitution, changes in production patterns, geographic distribution, and economic displacement.

Effect of Transition Scenarios on Employment in the Service Sector

Table 19 presents the impact of the renewable energy transition on employment in the services sector. All the covariates have a positive impact on employment in the services sector except for inflation. However, the renewable energy transition has a positive impact on service sector employment in Ghana.

Table 19: Energy Transition Scenarios on Services Sector Employment

Employment in the service sector	Coef.	Std. Err.	P>t
Lagservice	0.937	0.031	0.000
REC	0.362	0.047	0.000
$GDP_{energyuse}$	0.377	0.121	0.003
$fossil_{cons}$	0.018	0.013	0.172
Educ	0.114	0.035	0.002
POP	0.010	0.043	0.818
CPI	-0.166	0.098	0.095
LagREC	0.490	0.674	0.469
$lagGDP_{energyuse}$	-0.269	0.128	0.039
$lagfossil_{cons}$	0.014	0.012	0.270
LagPOP	-0.007	0.043	0.876
LagCPI	-0.473	2.148	0.578
Lageduc	0.140	0.045	0.002
_cons	0.582	3.022	0.848
N	83		
r-square	0.995		
Adjusted r-square	0.994		

An increase in the share of the renewable energy transition will increase employment in the services sector by 0.362 per cent and it is significant at one per cent (p-value=0.000). This implies that an increase in renewable energy will lead to an improvement in employment in the services sector.

The previous quarter's employment in the services sector increases current employment in the service sector by 0.937 per cent and it is significant at one per cent (p-value=0.000). This means that increased employment in the service sector will have a positive impact on subsequent employment in the sector. As indicated by Armah (2022), crude oil is responsible for 92 per cent of the energy consumption in the transportation subsector of the services sector. The lag of education has a significant positive impact on employment in the services sector while the lag of GDP per energy use has a significant negative impact on the sector. However, lags in the share of the renewable energy transition, consumption of fossil fuels and population have no significant impact on employment in the services sector.

It is observed that inflation has a negative impact on services sector employment. This is possible because inflation can increase the cost of providing services, as businesses may have to pay higher wages to employees, purchase more expensive equipment and supplies, or pay higher rent and utilities. This can lead to higher prices for consumers and may reduce demand for services. Inflation can also reduce consumers' purchasing power, as the cost of living increases and their income may not keep up with the rising prices. This can lead to a decrease in demand for services as people have less disposable income to spend. Furthermore, inflation can affect interest rates, which can have an impact on the services sector. For example, if inflation is high, the central bank may raise interest rates to control it, which can lead to higher borrowing costs for businesses in the services sector.

Renewable energy transition scenarios on employment in the services sector of Ghana have been displayed in Figure 49. The figure shows that both scenarios of renewable energy transition have a positive impact on employment in the services sector up to the next six years. The business-as-usual scenario has a greater impact on employment in the services sector while the rapid scenario has a lower impact on employment in the services sector. This implies that renewable energy transition scenarios will be able to create jobs in the services sector for this period. This could be because many technicians are required to work on renewable energy value chains, including from production to distribution.

The transition to renewable energy requires significant investments in new energy infrastructure, such as wind turbines, solar panels and energy storage systems. These investments can have a significant impact on the economy, particularly if they are offset by saving from reduced fossil fuel use. Importers and exporters are both involved in the renewable energy trade such as the sale of solar panels, and wind turbines, servicing the plants and all the supply chain of renewable energy create jobs. This creates economics of scope. Hence, the renewable energy transition has a positive impact on employment in the services sector in Ghana.

However, after the sixth year, these investment activities might have slowed down if not peaked. Intuitively, renewable energy projects require a significant amount of capital investment and might divert financial resources away from the services sector, which might reduce the number of available funds for investment in the services sector, resulting in a reduction in employment opportunities. This is exclusively true for small and medium-sized enterprises that operate in the services sector that are resources constrained to invest in renewable energy technologies.

As noted by Appiah (2020), SMEs in the services sector may be left behind in the transition to renewable energy due to a lack of access to finance and technical expertise. As noted by Asafu-Adjaye et al. (2016), the transition to renewable energy may lead to job losses in the services sector if the sector is not adequately supported. The reason could also be that renewable energy projects are often located in rural areas, where the services sector may be less developed. This may result in an outflow of labour from the services sector towards the renewable energy sector, resulting in a reduction in services sector employment opportunities.

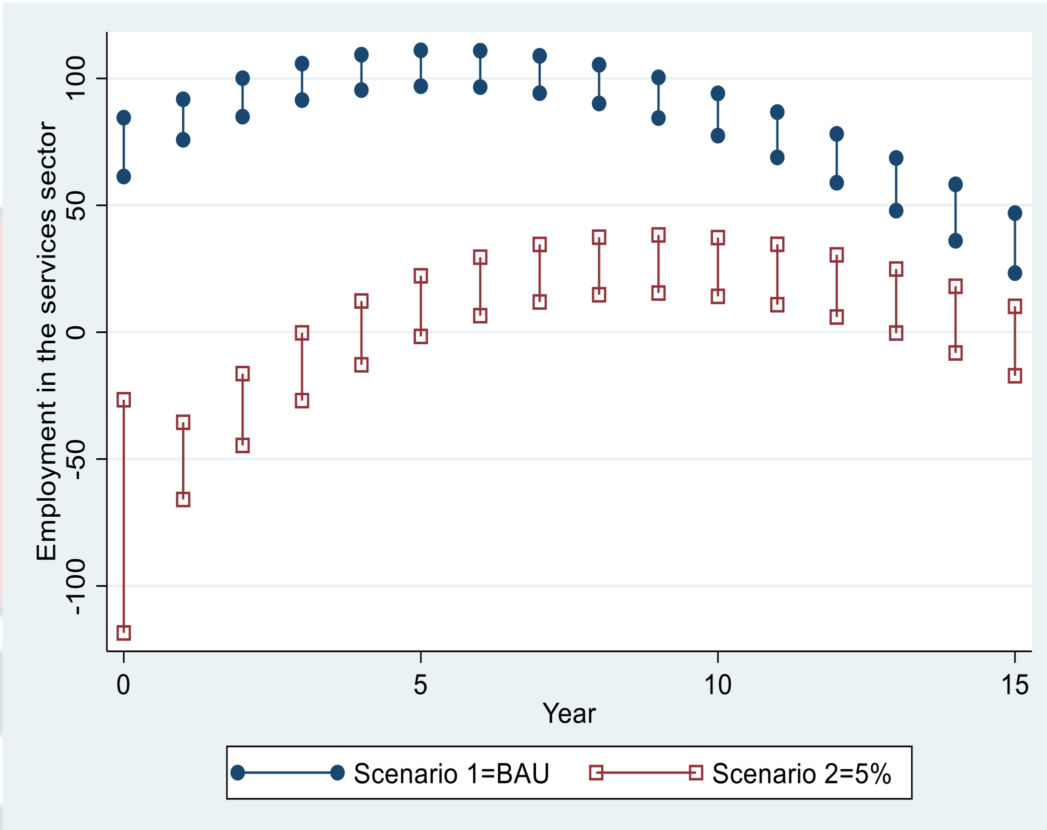

Figure 49: Energy Transition Scenarios on Employment in the Service Sector

Historically, Ghana depends on traditional biomass for energy, such as wood and charcoal. The shift towards renewable energy may lead to a reduction in demand for such biomass, which could negatively impact the services sector. For example, the production and sale of charcoal is an important source of income for many people in Ghana, especially in the services sector. Also, Ghana has a long history of relying on fossil fuels for electricity generation. The shift towards renewable energy sources could lead to a reduction in demand for labour in the fossil fuel sector, which could indirectly impact the services sector. This means that the renewable energy transition must be managed in a way that minimises job losses in the fossil fuel sector.

This corroborates the findings by Etwire and Boateng (2017) that, the transition to renewables could result in reduced employment opportunities in the charcoal production and sales sector.

Effect of Energy Transition on Employment in Ghana

Table 20 presents the effect of the point estimates of the energy transition on employment in Ghana. It is observed that energy transition has a positive impact on employment. An increase in the energy transition will increase employment by 0.949 and it is significant at one per cent. Also, the consumption of fossil fuels and education increase employment. These indicate the importance energy plays in economic development. However, inflation and surprisingly, GDP per energy use harm employment. renewable energy transition has a positive impact on service sector employment in Ghana.

Renewable energy transition scenarios on total employment in Ghana have been displayed in Figure 50. It is shown that both scenarios of renewable energy transition have a positive impact on total employment up to the next six years. The business-as-usual scenario has a greater impact on total employment while the rapid scenario has a lower impact on total employment in Ghana. This implies that renewable energy transition scenarios will be able to create jobs for this period. This could be because many hands are required to work on the renewable energy value chain, including from production to distribution. The transition to renewable energy requires significant investments in new energy infrastructure and energy systems. These investments can have a significant impact on the economy, particularly if they are offset by saving from reduced fossil fuel use. Renewable energy trade in all the supply chains of renewable energy creates jobs.

Table 20: Energy Transition Scenarios on Total Employment

Total Employment	Coef.	Std. Err.	P>t
Lemployment	0.949	0.029	0.000
REC	0.114	0.035	0.002
$GDP_{energyuse}$	-0.003	0.089	0.975
$fossil_{cons}$	0.410	0.009	0.001
Educ	0.390	0.193	0.047
POP	-0.007	0.031	0.823
CPI	-0.114	0.035	0.002
LagREC	0.089	0.497	0.858
$lagGDP_{energyuse}$	0.089	0.091	0.332
$lagfossil_{cons}$	0.0004	0.009	0.957
Lageduc	0.213	0.493	0.147
LagPOP	0.004	0.030	0.887
LagCPI	0.213	0.493	0.147
_cons	-0.744	2.216	0.738
N			
r-square	0.984		
Adjusted r-square	0.982		

Author's own compute (2023)

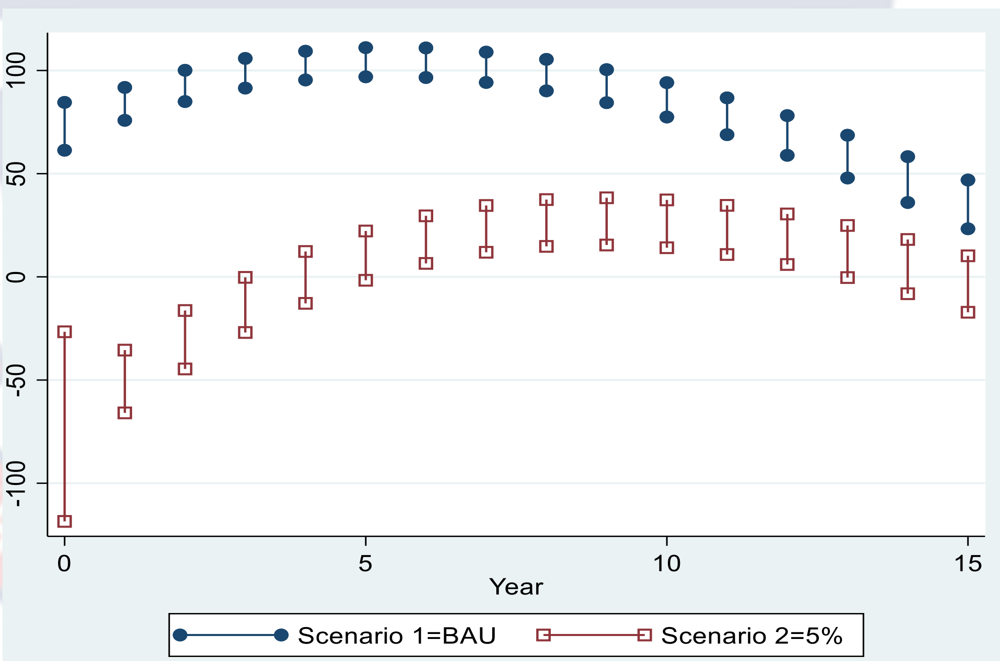

Figure 50: Energy Transition Scenarios on Total Employment

Nevertheless, after the sixth year, investments would have slowed down leading to a reduction in total employment. The renewable energy transition requires a significant amount of capital investment in energy and might divert funds away from the subsector, reducing the number of available funds for investment in the other sectors, and resulting in a reduction in total employment opportunities. Appiah (2020) asserted that due to inadequate access to funds and expertise, some sectors might be negatively affected. Furthermore, Asafu-Adjaye et al. (2016) noted that the transition to renewables might lead to job losses, particularly in the services sector if the sector is inadequately supported. Again, an outflow of labour from other sectors to the renewable energy sector causes an excess supply of labour in the sector which might affect total employment opportunities. The shift towards renewable energy may lead to a reduction in demand for other sectors, which could negatively impact employment in the long run. The renewable energy transition could lead to a reduction in demand for labour in the fossil fuels sector, which could indirectly impact the other sectors. This means that the renewable energy transition must be managed in a way that minimises job losses in the fossil fuels sector.

Summary of the Chapter

This chapter presented the results and discussions of the study concerning the objectives of the study. The chapter began with analyses and discussions of the effects of renewables on the security of energy and access in Ghana. The chapter continued with the effect of global renewable energy transition dynamics on the petroleum export of Ghana. Finally, the chapter presented the results of the effect of the renewable energy transition on employment in Ghana. The results were presented in tables and figures. Furthermore, the simulated models on various scenarios of renewable energy transition were also presented and discussed.

CHAPTER SEVEN

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

Renewables are estimated as the most effective primary energy sources in the face of climate change. This makes energy transition advocates push for a global consensus to transit to renewable energy. Due to these, there is an ongoing promotion and development of electric cars and the encouragement for the production and consumption of renewable energy. These efforts have made the average renewable energy consumption rise globally. Studies and scholars have indicated energy transition roles in achieving the global target of reducing the increase in the global average temperature. Other discussions focus on the possibility of the energy transition to curb energy inequity and insecurity within and between countries and regions since renewables like solar and wind are intermittently making them unpredictable and unreliable. Regardless of the side of the debate, global energy transition either partly or wholly will have some consequences on emerging petroleum-producing economies such as Ghana, which, debatably, receives a lot of foreign revenues from petroleum. This is because fossil fuels and renewables are mostly considered substitutes instead of complements.

Our study, therefore, analyses the vulnerability of the economy of Ghana to global energy transition dynamics. Specifically, our study analysed the effect of the energy transition on energy security, petroleum import demand from Ghana, and employment in Ghana. Our study is grounded in the energy ladder, critical, liberalism, imperfect substitution, Dutch disease, and human capital theories. The sources of data are the WDI of the WB, BoG, US EIA and Census Bureau, Federal

Reserve Economic Data, PURC, and PIAC. Using quantitative analyses, the study employs the ARDL models to establish the long- and short-run relationships between global energy transition and Ghana's energy security, and employment. Further, the study employs the state-space models to estimate the effect of the energy transition on the petroleum import demand from Ghana. The dynamic ARDL simulations model is employed to simulate the impact of various energy transition dynamics.

Summary of the Key Findings

Our study finds that renewable energy transition has a positive and statistically significant effect on energy accessibility in urban areas and rural areas. Renewable energy transition has a positive and statistically significant effect on energy affordability. Renewable energy has an insignificant positive effect on energy security. Consumption of fossil fuels has a significant positive effect on energy availability, affordability, accessibility, and security.

Again, our study finds that, in rural areas, both the business-as-usual and five percent transition rates do not significantly impact energy accessibility. For urban areas, each transition scenario increases energy accessibility up to the eighth year. After the eighth year, each scenario reduces energy accessibility for the urban areas. From the total accessibility, renewable energy has a negative significant impact on access to energy. Each scenario has a significant impact on the vulnerability of energy availability over the next 15 years period. The business-as-usual scenario has the minimum positive impact on energy security after the second year while the energy transition scenarios at five percent have the largest positive impact on energy security.

Moreover, our study finds that the total consumption of solar energy in the US has a negative and statistically significant effect on the demand for crude oil from Ghana. Total wind energy consumption has a negative and statistically significant effect on the import demand of crude oil from Ghana. Total renewable energy consumption has a negative and statistically significant effect on the import demand of crude oil from Ghana. Energy transitions in China, Italy, and Canada have negative effects on crude oil import demand from Ghana. However, the energy transition in India has had positive effects on the crude oil import demand from Ghana.

Also, our study finds that both the no new investment scenario and rapid transition scenarios have negative impacts on Ghana’s oil export to the world more than the investment in the existing fields and the SDS scenarios. The SDS has the lowest impact on oil export from Ghana to the rest of the world. The projection of China's marginal increase in oil consumption and imports has the potential to cause an increase in Ghana's export to China, especially in the BAU scenario. The net effect of energy transition scenarios between China and the rest of the world on Ghana’s oil export shows a less negative impact on oil exports. The export of oil to the US, Italy, Canada, and India will decline in the rapid scenario. While those NZE transition scenarios have negative impacts on oil export but with lower margins.

Furthermore, our study finds that the point estimates of energy transition have significant negative effects on vulnerable employment for males, females, and both sexes. Both scenarios have significant negative effects on vulnerable employment for males and females. However, energy transition decreases female vulnerable employment more than that of males. Also, the energy transition has greater impacts on unemployment after the 9th year. The point estimates of energy transition decrease unemployment among, males, females, and both sex. Consumption of fossil fuels has significant positive effects on employment.

Moreso, our study finds that renewable energy transitions have significant positive impacts on employment in the industry and services sectors. The renewable energy transition has a significant negative impact on agriculture sector employment. In general, the energy transition has a significant positive impact on employment.

Last but not least, our study finds that business-as-usual transition scenarios have a higher overall positive impact on industry employment than the five percent transition scenario in the industrial sector employment. However, the business-as-usual scenario has a decreasing impact on employment in the industry sector while the rapid scenario has an increasing impact on employment in the industry sector. Five percent of energy transition scenarios harm employment in the agriculture sector while the business-as-usual scenarios have a positive impact on agriculture sector employment. Both scenarios of renewable energy transition have a positive impact on employment in the services sector up to the next six years. The business-as-usual scenario has a greater impact on employment in the services sector while the rapid scenario has a lower impact on employment in the services sector. Both scenarios of renewable energy transition have positive impacts on total employment up to the next six years. The business-as-usual scenario has a greater impact on total employment while the rapid scenario has a lower impact on total employment in Ghana.

Conclusions

Our study concludes that renewable energy transition increases energy accessibility in urban areas and rural areas. Renewable energy transition increases energy affordability. Renewable energy does not affect energy security. Consumption of fossil fuels increases energy affordability, availability, accessibility, and energy security.

Again, our study concludes that, in rural areas, both the business-as-usual and five percent transition rates have no impact on energy accessibility. For urban areas, each transition scenario increases energy accessibility up to the eighth year. After the eighth year, each scenario reduces energy accessibility for the urban areas. From the total accessibility, renewable energy transition reduces energy accessibility. Each scenario reduces the vulnerability of energy availability over the next 15 years period. The business-as-usual scenario has a minimum increase in energy security after the second year while the energy transition scenarios at five percent have the largest increase in energy security.

Moreover, our study concludes that the consumption of solar, wind, and total renewable energy in the US decreases the demand for crude oil from Ghana. Energy transitions in China, Italy, and Canada decrease crude oil import demand from Ghana. However, the energy transition in India increases crude oil import demand from Ghana.

Also, our study concludes that no new investment scenario and rapid transition scenarios decrease Ghana's oil export to the world more than the investment in the existing fields and the SDS scenarios. The SDS has the lowest impact on oil export from Ghana to the rest of the world. China's marginal increase in oil consumption and imports increase Ghana's oil export to China, especially in the BAU scenario. The net effect of energy transition scenarios between China and the rest of the world on Ghana's oil export shows less decline in Ghana's oil exports. The exports of oil to the US, Italy, Canada, and India decline in the rapid scenario. While NZE transition scenarios decrease Ghana's oil export but with lower margins.

Furthermore, our study concludes that the point estimates of energy transition decrease vulnerable employment for males, females, and both sexes. Both scenarios decrease vulnerable employment for males and females. However, energy transition decreases female vulnerable employment more than that of males. Consumption of fossil fuels increases employment. Also, the energy transition has greater impacts on unemployment after the 9^{th} year. The point estimates of energy transition decrease unemployment among, males, females, and both sex.

Moreso, our study concludes that renewable energy transitions increase employment in the industry and services sectors and decrease agriculture sector employment. In general, energy transition increases employment in Ghana. Last but not the least, our study concludes that business-as-usual transition scenarios increase industry employment by more than five percent transition scenario in the industry sector employment. However, the business-as-usual scenario has a decreasing impact on employment in the industry sector while the rapid scenario has an increasing impact on employment in the industry sector. Five percent of energy transition scenarios decrease employment in the agriculture sector while the business-as-usual scenarios increase agriculture sector employment. Both scenarios of renewable energy transition increase employment in the services sector up to the next six years. The business-as-usual scenario has a greater increasing impact on employment in the services sector than the rapid energy transition scenario. Both scenarios of renewable energy transition increase total employment for up to the next six years. The business-as-usual scenario has a greater impact on total employment than the rapid scenario on employment in Ghana.

Policy Implications of the Study

In the first place, the study recommends that Ghana should continue with the energy mix strategies and systematically integrate renewables in the overall energy mix to minimise these vulnerabilities. GoG should not rush to transit into renewable energy. Ghana should continue to use crude oil while trying to integrate other renewable energy into its energy sources. Ghana should have an energy transition plan that does not jeopardise energy security and accessibility in some locations.

Again, Ghana should diversify the countries it exports crude oil to. The Government of Ghana and the petroleum authorities should look out for more countries that would import crude oil from Ghana. This would reduce overreliance on major oil importers of Ghana's crude oil. Furthermore, the Energy Commission and the Ministry of Energy must diversify their business models to ensure and emphasise that the energy system remains secure and reliable as they transition to renewable energy sources by developing and building redundant systems and investing in grid infrastructure upgrades. This will increase energy accessibility.

Also, the Ministry of Energy (MoE) should address the upstream barriers and challenges of renewables and make it easy for the private sector to invest through concessional finance blending with climate fund grants. There must be retraining and education programmes by the citizens to take up opportunities in the renewable energy sector to mitigate the unemployment vulnerabilities in the services and agriculture sectors. The MoE can mitigate these unemployment vulnerabilities by implementing policies to support renewable energy such as subsidies for renewable energy investment. The GoG must encourage the local supply chain for renewables infrastructure to create jobs in the industry sector.

Moreover, to reduce the impact of the global energy transition on the petroleum subsector, the Ministry of Energy should operate its refinery—making Tema Oil Refinery functional—to be able to absorb much of the crude oil produced in the country rather than relying on foreign consumption. Operation of Ghana's refinery would help in getting the product for electricity generation at cheaper prices. This would help to increase energy accessibility, affordability, and availability to every part of Ghana at all times throughout the year.

Furthermore, energy transition should be managed by the GoG and the Ministry of Energy in a way that minimises job losses in the agriculture sector. Policymakers must carefully consider the trade-offs between renewable energy production and agriculture sector employment to develop policies that are sustainable and equitable. The deployment of renewable energy technologies should be carefully planned to avoid conflicts with agriculture, particularly in areas where agriculture is a major source of livelihood.

Limitations of the Study

In the first place, one of the limitations of the study is insufficient data. A study on the vulnerability of the economy of Ghana or of this nature would ideally require the use of data with a large number of observations but this thesis employed data from 2011 to 2020 due to data unavailability. There were no quarterly data for some of the variables. Therefore, the best statistical methods such as extrapolations were used to generate quarterly data, which have their limitations. These might bias the magnitudes of the long- and short-run relationships between variables.

Secondly, the studies could not collect qualitative data from experts and policymakers. Qualitative data makes a better interpretation of the results and findings of the study. Some interpretations require expert opinions which this study could not collect data on.

Suggestions for Further Studies

To expand the frontiers of research of this study, this study could be used as the basis for further study to observe how the rates of transition of energy can impact the petroleum sub-sector of Ghana. This study used dynamic ARDL simulations and state-space parameter models for estimating the effect of the energy transition, other methods such as the Computable General Equilibrium model could be employed for the analyses. Future studies can consider energy transition implications on energy security at district and regional levels since each district and region has unique characteristics. Again, future studies could collect qualitative data for a better interpretation of the results.

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APPENDICES

Appendix: A

Phillips-Perron and Augmented Dickey-Fuller Unit Root Test Results

	Phillips-Perron		Augmented Dickey-Fuller	
Variable	Level	1st Difference	Level	1st Difference
Urban electricity accessibility	-1.107	-9.025***	-1.450	-6.190***
Energy accessibility	-.629	-9.257***	-0.897	-6.079***
Rural electricity accessibility	-1.188	-9.082***	-1.291	-5.414***
Clean	5.297	-19.142***	-0.670	-2.306*
Ren_waste	-3.162**		-2.363*	
$GDP_{energyuse}$	2.162	-15.331***	1.178	-2.526**
$Fossil_{cons}$	-0.572	-20.529***	-1.554	-5.205***
Educ	-0.477	-9.056***	-2.276	-4.351***
REC	-2.309	-9.050***	-2.804	-4.342***
POP	-1.293	-9.165***	10.180	-4.591***
Rurpop	-.051***		-5.355***	
Urbpop	-.050***		-5.357***	
Eudc expend	-1.936	-7.684***	-1.864	-7.684***
Agriculture employ	2.241	-6.432***	1.651	-6.987***
Industry employ	3.038	-9.030***	2.168	-9.037***
Service employ	-0.433	-6.854***	-0.493	-7.290***

Note: *** 1%, ** 5%, and * 10% rejection region

Appendix B: Bound tests

		10%		5%		1%		p-value	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Energy accessibility	F	2.36	3.51	2.79	4.04	3.74	5.20	0.082	0.331
	t	-2.55	-3.87	-2.88	-4.24	-3.51	-4.95	0.072	0.458
Energy availability	F	2.349	3.517	2.772	4.049	3.721	5.221	0.048	0.237
	t	-2.541	-3.852	-2.865	-4.223	-3.504	-4.940	0.071	0.447
Agriculture employ	F	2.315	3.534	2.736	4.077	3.684	5.279	0.000	0.004
	t	-2.509	-3.808	-2.838	-4.187	-3.489	-4.922	0.240	0.681
Services employ	F	2.315	3.534	2.736	4.077	3.684	5.279	0.000	0.002
	T	-2.509	-3.808	-2.838	-4.187	-3.489	-4.922	0.356	0.771
Industry employ	F	2.342	3.521	2.765	4.055	3.714	5.233	0.006	0.054
	T	-2.535	-3.843	-2.859	-4.215	-3.501	-4.937	0.002	0.069

Appendix C: Diagnostic Test

Diagnostic Test for Energy Security

Diagnostics	Chi-square	Prob(chi-square)	Decision
Breusch-Godfrey LM test for autocorrelation	0.245	0.6204	No serial correlation
White's test for homoskedasticity	35.00	0.4204	Residuals are homoscedastic

Author's own compute (2023)

Diagnostic Test for Energy Access

Diagnostics	Chi-square	Prob(chi-square)	Decision
Breusch-Godfrey LM test for autocorrelation	0.245	0.6204	No serial correlation
White's test for homoskedasticity	35.00	0.4204	Residuals are homoscedastic

Author's own compute (2023)

Diagnostic Test for Employment

Diagnostics	Chi-square	Prob(chi-square)	Decision
Breusch-Godfrey LM test for autocorrelation	0.246	0.620	No serial correlation
White's test for homoskedasticity	34.00	0.520	Residuals are homoscedastic

Author's own compute (2023)

Appendix D

Clean Cooking Fuels and Technology Accessibility

ADJ		
L.clean	0.025	(.017)
LR		
REC	-12.018	(9.222)
$fossil_{cons}$	0.116	(.114)
$GDP_{energyuse}$	-27.72	(29.810)
POP	-38.74**	(18.252)
SR		
D.clean	-1.005***	(.030)
_cons	-19.709***	(6.608)
N	76	

Energy Transition and Energy Accessibility in Urban and Rural areas

Access to Electricity in the Rural Areas		
	Urban	Rural
ADJ		
L.Accessibility	-0.166**	-1.057***
	(.079)	(.104)
LR		
REC	-18.337	-34.95***
	(13.269)	(5.188)
$fossil_{cons}$	0.053	-0.598***
	(.191)	(.108)
$GDP_{energyuse}$	-12.715	30.09***
	(13.884)	(5.237)
POP	-2.739	-103.917***
	(1.952)	(11.741)
SR		
LD.Accessibility	-0.227***	0.372***
	(.048)	(.372)
D.REC	80.43	20.37***
	(52.932)	(6.904)
D.$fossil_{cons}$		0.736***
		(.113)
D.$GDP_{energyuse}$		-131.0***
		(32.085)
_cons	-138.177	-302.2*
	(227.334)	(177.044)
N	76	76

Effect of Renewable Energy Transition on Clean Energy Accessibility in Ghana

Access to clean energy	Coef.	Std. Err.	P>t
REC	5.123***	.172	0.000
$fossil_{cons}$	.062*	0.042	0.094
$GDP_{enrgyuse}$	.494*	.292	0.097
Pop	.133	.156	0.396
LagREC	-3.351	2.506	0.185
$lagfossil_{cons}$	.011	.046	0.804
$lagGDP_{energyuse}$	.999**	.437	0.025
Lagpop	-.121	.153	0.432
_cons	-9.639	11.167	0.391
r-squared	0.965		
Adjusted r-square	0.962		

Standard errors are in brackets. * p<0.1, ** p<0.05, *** p<0.01

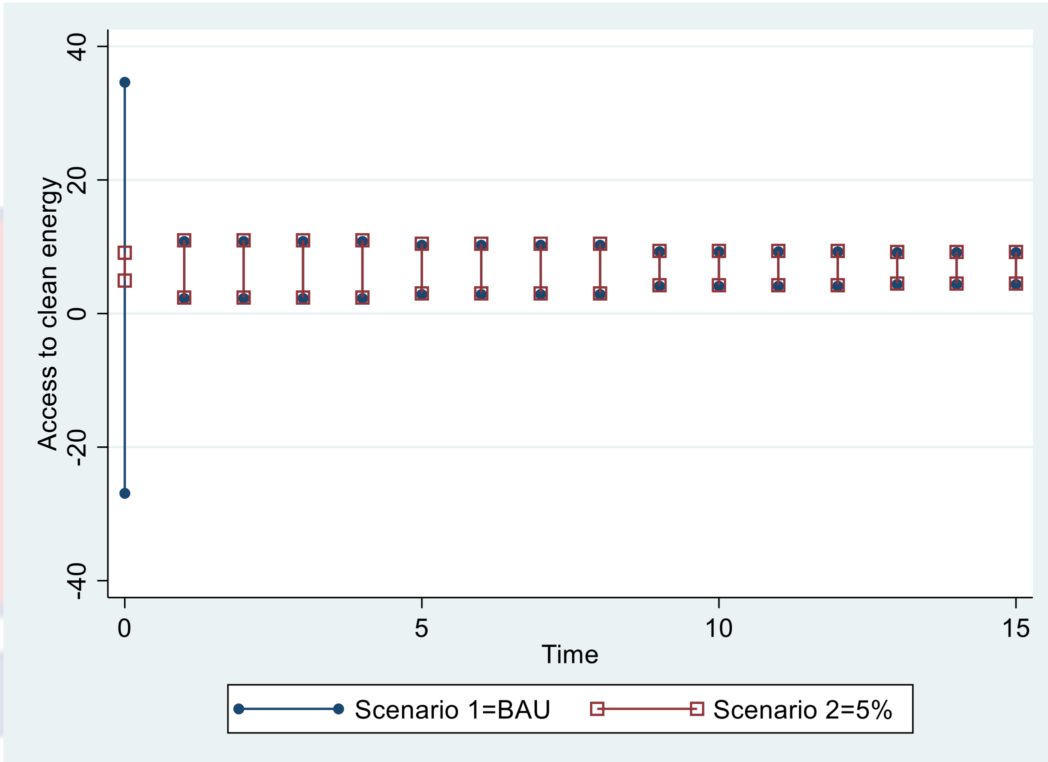

Figure A: Energy Transition and Clean Energy Accessibility

Appendix E: Dynamic simulation results

Dynamic Simulation Results for Agriculture

t	Sv	pv_1	lower_1	upper_1	pv_2	lower_2	upper_2	pv_3	lower_3	upper_3	pv_4	lower_4	upper_4
0		47.323	46.601	48.002	45.861	45.685	46.030	33.081	31.706	34.363	33.259	31.943	34.494
1	4.516	48.228	47.562	48.879	45.251	45.067	45.427	35.148	33.901	36.330	35.215	34.015	36.343
2	4.516	49.055	48.434	49.673	44.693	44.506	44.874	37.036	35.889	38.130	37.001	35.898	38.045
3	4.516	49.810	49.215	50.402	44.184	43.994	44.368	38.760	37.694	39.772	38.632	37.612	39.606
4	4.516	50.500	49.937	51.069	43.720	43.519	43.914	40.335	39.347	41.270	40.122	39.168	41.025
5	4.432	51.191	50.655	51.746	43.356	43.151	43.561	41.834	40.914	42.720	41.543	40.643	42.387
6	4.432	51.822	51.310	52.347	43.025	42.812	43.242	43.203	42.343	44.027	42.842	42.001	43.643
7	4.432	52.398	51.900	52.907	42.722	42.500	42.950	44.454	43.648	45.223	44.027	43.241	44.785
8	4.432	52.924	52.447	53.413	42.445	42.215	42.684	45.595	44.839	46.319	45.110	44.383	45.820
9	4.238	53.546	53.078	54.037	42.334	42.090	42.579	46.779	46.068	47.461	46.240	45.552	46.914
10	4.238	54.114	53.665	54.582	42.232	41.983	42.481	47.861	47.200	48.501	47.272	46.629	47.902
11	4.238	54.632	54.196	55.080	42.139	41.887	42.393	48.848	48.235	49.454	48.215	47.611	48.803
12	4.238	55.106	54.694	55.530	42.055	41.800	42.313	49.750	49.182	50.322	49.075	48.505	49.632
13	4.191	55.573	55.170	55.984	42.011	41.753	42.274	50.607	50.066	51.157	49.895	49.344	50.422
14	4.191	55.999	55.612	56.396	41.972	41.712	42.237	51.390	50.875	51.909	50.644	50.126	51.145
15	4.191	56.388	56.012	56.775	41.935	41.674	42.202	52.106	51.618	52.602	51.328	50.838	51.807
Dynamic Simulation Results for the Industry													
0		15.647	15.446	15.877	15.953	15.875	16.041	13.827	13.687	13.991	13.897	13.763	14.055
1	4.516	15.479	15.283	15.702	16.107	16.025	16.196	13.757	13.618	13.916	13.856	13.724	14.009
2	4.516	15.318	15.127	15.536	16.254	16.173	16.343	13.690	13.553	13.847	13.816	13.686	13.968
3	4.516	15.164	14.979	15.377	16.395	16.312	16.483	13.626	13.488	13.783	13.778	13.648	13.931
4	4.516	15.015	14.833	15.222	16.531	16.447	16.622	13.564	13.428	13.721	13.741	13.611	13.895
5	4.432	14.864	14.684	15.065	16.651	16.567	16.744	13.496	13.361	13.654	13.697	13.566	13.849
6	4.432	14.718	14.542	14.915	16.767	16.679	16.864	13.430	13.296	13.588	13.654	13.523	13.806
7	4.432	14.578	14.408	14.771	16.878	16.787	16.976	13.367	13.233	13.523	13.613	13.482	13.765

8	4.432	14.444	14.280	14.633	16.984	16.891	17.085	13.306	13.171	13.462	13.574	13.443	13.725
9	4.238	14.294	14.131	14.484	17.064	16.965	17.171	13.226	13.091	13.377	13.514	13.383	13.665
10	4.238	14.149	13.991	14.336	17.140	17.039	17.251	13.149	13.013	13.299	13.456	13.325	13.606
11	4.238	14.011	13.854	14.194	17.214	17.110	17.327	13.075	12.940	13.227	13.401	13.270	13.550
12	4.238	13.878	13.723	14.055	17.284	17.178	17.400	13.004	12.869	13.156	13.349	13.216	13.495
13	4.191	13.745	13.591	13.921	17.347	17.236	17.464	12.931	12.796	13.081	13.293	13.161	13.439
14	4.191	13.618	13.466	13.790	17.406	17.293	17.526	12.861	12.725	13.013	13.239	13.107	13.385
15	4.191	13.496	13.345	13.664	17.464	17.349	17.586	12.793	12.658	12.946	13.187	13.056	13.335
Dynamic Simulation Results for the Services Sector													
0		37.132	36.561	37.698	38.203	38.090	38.323	30.595	30.346	30.845	30.660	30.439	30.884
1	4.516	36.279	35.758	36.790	38.239	38.124	38.359	30.340	30.107	30.582	30.456	30.234	30.678
2	4.516	35.499	35.016	35.974	38.272	38.156	38.392	30.107	29.875	30.344	30.268	30.053	30.488
3	4.516	34.785	34.326	35.229	38.302	38.186	38.422	29.894	29.668	30.123	30.097	29.880	30.315
4	4.516	34.132	33.701	34.542	38.329	38.213	38.451	29.698	29.472	29.921	29.940	29.725	30.154
5	4.432	33.565	33.161	33.950	38.385	38.270	38.506	29.551	29.326	29.770	29.828	29.616	30.035
6	4.432	33.047	32.672	33.409	38.437	38.320	38.557	29.416	29.190	29.630	29.725	29.514	29.927
7	4.432	32.573	32.219	32.907	38.483	38.367	38.605	29.292	29.069	29.502	29.631	29.420	29.830
8	4.432	32.139	31.803	32.448	38.526	38.409	38.649	29.179	28.959	29.387	29.545	29.333	29.744
9	4.238	31.813	31.496	32.110	38.637	38.518	38.763	29.147	28.930	29.351	29.537	29.329	29.733
10	4.238	31.515	31.208	31.806	38.738	38.618	38.865	29.117	28.901	29.320	29.531	29.322	29.726
11	4.238	31.243	30.948	31.523	38.831	38.708	38.961	29.090	28.875	29.293	29.524	29.316	29.720
12	4.238	30.993	30.709	31.269	38.915	38.791	39.046	29.066	28.851	29.269	29.519	29.311	29.714
13	4.191	30.782	30.506	31.051	39.010	38.883	39.144	29.061	28.846	29.263	29.531	29.321	29.728
14	4.191	30.589	30.320	30.852	39.097	38.966	39.232	29.056	28.841	29.258	29.542	29.331	29.739
15	4.191	30.413	30.150	30.670	39.176	39.045	39.312	29.051	28.837	29.254	29.552	29.341	29.749
Dynamic Simulation Results for the Energy Accessibility													
0		4.359	4.267	4.454	4.334	4.313	4.354	3.767	3.636	3.898	3.774	3.645	3.903
1	4.516	4.369	4.263	4.475	4.371	4.273	4.471	3.806	3.663	3.946	3.813	3.671	3.950
2	4.516	4.378	4.273	4.483	4.407	4.309	4.506	3.844	3.703	3.981	3.849	3.710	3.985
3	4.516	4.386	4.282	4.491	4.440	4.343	4.539	3.879	3.740	4.014	3.884	3.746	4.017
4	4.516	4.394	4.291	4.499	4.471	4.375	4.570	3.913	3.776	4.046	3.917	3.781	4.048

5	4.432	4.391	4.301	4.484	4.491	4.409	4.572	3.934	3.814	4.054	3.937	3.819	4.055
6	4.432	4.388	4.298	4.481	4.509	4.428	4.589	3.954	3.835	4.073	3.956	3.840	4.073
7	4.432	4.385	4.295	4.479	4.526	4.446	4.606	3.973	3.856	4.091	3.975	3.859	4.090
8	4.432	4.382	4.292	4.476	4.543	4.463	4.621	3.991	3.875	4.108	3.992	3.878	4.106
9	4.238	4.355	4.277	4.432	4.533	4.489	4.575	3.984	3.885	4.081	3.984	3.889	4.077
10	4.238	4.329	4.249	4.407	4.525	4.479	4.566	3.976	3.878	4.074	3.976	3.881	4.070
11	4.238	4.304	4.222	4.384	4.516	4.471	4.558	3.969	3.870	4.067	3.968	3.873	4.063
12	4.238	4.281	4.197	4.362	4.508	4.463	4.550	3.963	3.863	4.061	3.961	3.865	4.056
13	4.191	4.253	4.171	4.333	4.495	4.457	4.528	3.951	3.852	4.046	3.948	3.854	4.042
14	4.191	4.226	4.143	4.308	4.482	4.444	4.516	3.939	3.840	4.036	3.936	3.840	4.031
15	4.191	4.200	4.116	4.283	4.470	4.431	4.504	3.928	3.828	4.025	3.925	3.828	4.020
Dynamic Simulation Results for the Electricity Accessibility													
0		57.483	54.756	60.146	42.188	41.087	43.240	43.728	42.701	44.783	43.728	42.702	44.784
1	4.516	53.439	51.273	55.513	42.239	41.153	43.318	43.662	42.633	44.723	43.662	42.634	44.724
2	4.516	50.478	48.858	52.151	42.277	41.192	43.356	43.613	42.583	44.673	43.613	42.584	44.674
3	4.516	48.310	46.934	49.716	42.304	41.222	43.384	43.578	42.546	44.637	43.578	42.547	44.638
4	4.516	46.722	45.428	47.989	42.324	41.240	43.405	43.552	42.519	44.610	43.552	42.520	44.611
5	4.432	45.646	44.428	46.865	42.426	41.333	43.511	43.619	42.588	44.672	43.619	42.589	44.673
6	4.432	44.858	43.715	46.028	42.500	41.402	43.586	43.669	42.640	44.723	43.669	42.641	44.724
7	4.432	44.281	43.205	45.418	42.554	41.452	43.639	43.705	42.678	44.760	43.705	42.679	44.761
8	4.432	43.859	42.808	44.984	42.594	41.491	43.679	43.732	42.705	44.787	43.732	42.706	44.788
9	4.238	43.749	42.682	44.861	42.823	41.714	43.911	43.951	42.920	45.004	43.951	42.921	45.005
10	4.238	43.669	42.602	44.776	42.991	41.888	44.083	44.112	43.089	45.165	44.112	43.090	45.166
11	4.238	43.610	42.543	44.718	43.114	42.020	44.208	44.229	43.208	45.283	44.229	43.209	45.284
12	4.238	43.567	42.500	44.673	43.204	42.117	44.299	44.315	43.295	45.369	44.315	43.296	45.370
13	4.191	43.584	42.517	44.687	43.318	42.235	44.411	44.427	43.405	45.487	44.427	43.406	45.488
14	4.191	43.596	42.529	44.699	43.401	42.325	44.499	44.508	43.481	45.567	44.508	43.482	45.568
15	4.191	43.605	42.538	44.708	43.462	42.391	44.564	44.568	43.539	45.628	44.568	43.540	45.629

Author's own construct (2023)

Appendix F: Energy Transition and Employment in Ghana

Energy transition and unemployment in Ghana

	Unemployed, female	Unemployed, male	Unemployed, total
REC	-.224*	-0.160	0.027
	(0.131)	(0.144)	(0.103)
$GDP_{energyuse}$	-1.624***	-1.566***	-0.996***
	(0.150)	(0.165)	(0.118)
$Fossil_{cons}$	.407***	0.189	0.443***
	(0.113)	(0.123)	(0.088)
Educ	.612***	0.585***	0.697***
	(.121)	(0.134)	(0.095)
Femalepop	2.695***		
	(0.278)		
Malepop		1.530***	
		(0.234)	
POP			2.749***
			(0.189)
CPI			
_cons	-102.839***	-49.068***	-126.287***
	(18.191)	(17.320)	(13.114)
r-squared	0.763	0.763	0.749
Adjusted r-square	0.753	0.753	0.739

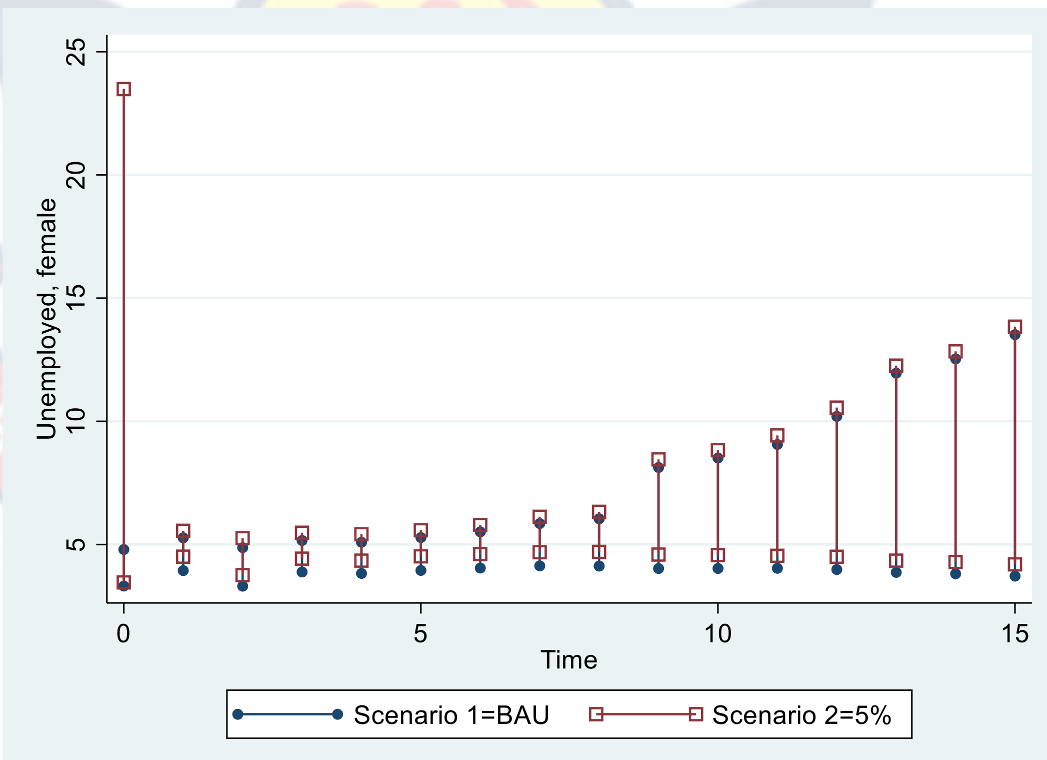

Figure B: Energy transition and female unemployment

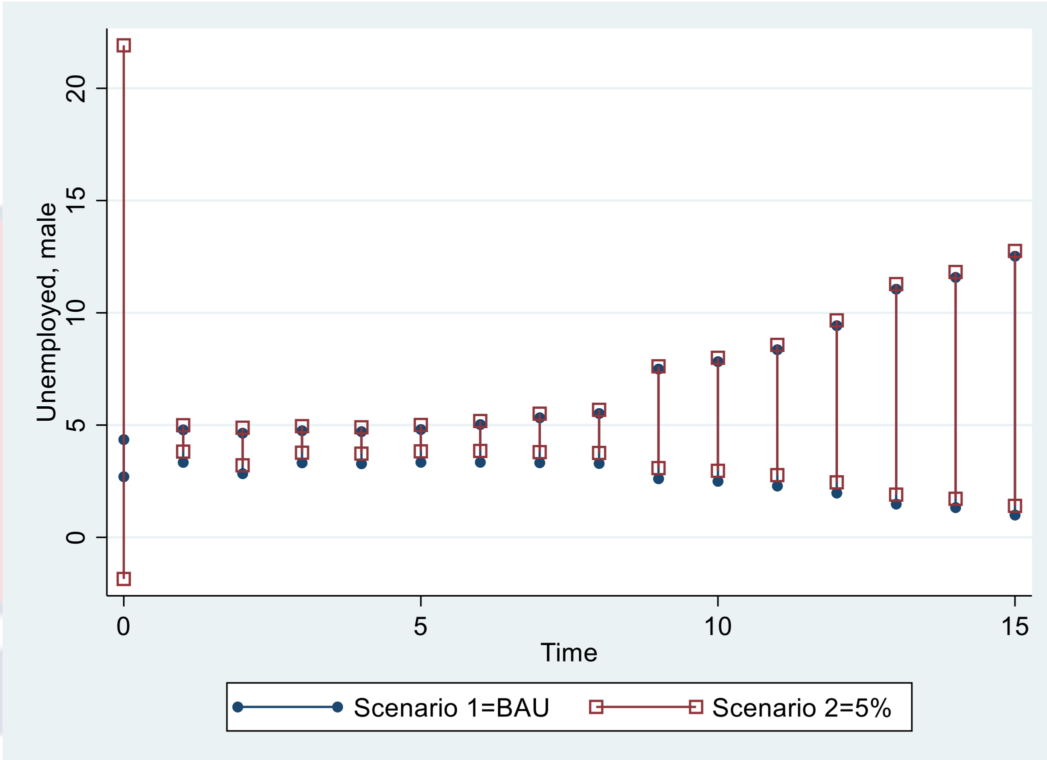

Figure 6.3b: Energy transition and male unemployment

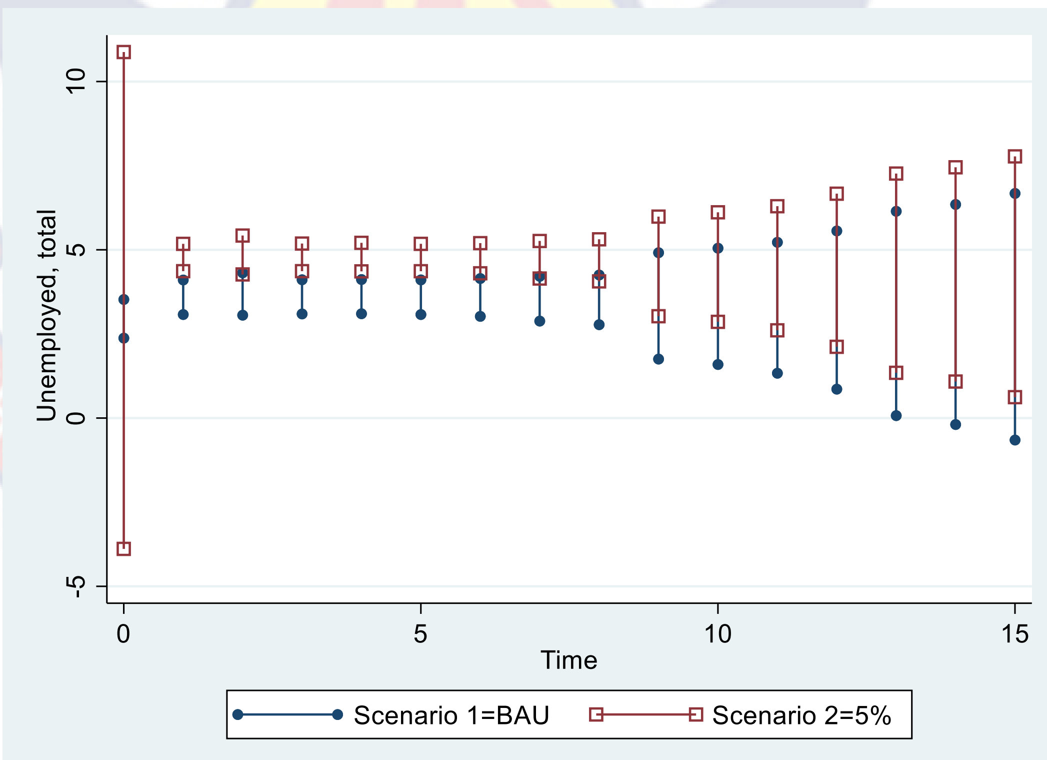

Figure C: Energy transition and unemployment

Energy Transition and Vulnerable Employment

	Vulnerable employment, female	Vulnerable employment, male	Vulnerable employment, total
REC	-0.109***	-0.199***	-0.166***
	(0.036)	(0.050)	(0.049)
$GDP_{energyuse}$	-0.271***	-0.262***	-0.266***
	(0.041)	(0.057)	(0.049)
$Fossil_{cons}$	.407***	0.076*	0.076**
	(0.113)	(0.042)	(0.036)
Educ	-.511***	-.831***	-0.705***
	(0.033)	(0.046)	(0.039)
Femalepop	0.142*		
	(0.076)		
Malepop		0.306***	
		(0.080)	
POP			0.304***
			(0.078)
CPI			
_cons	74.822***	48.657***	56.427***
	(4.974)	(5.951)	(5.428)
r-squared	0.994	0.995	0.995
Adjusted r-square	0.994	0.995	0.995

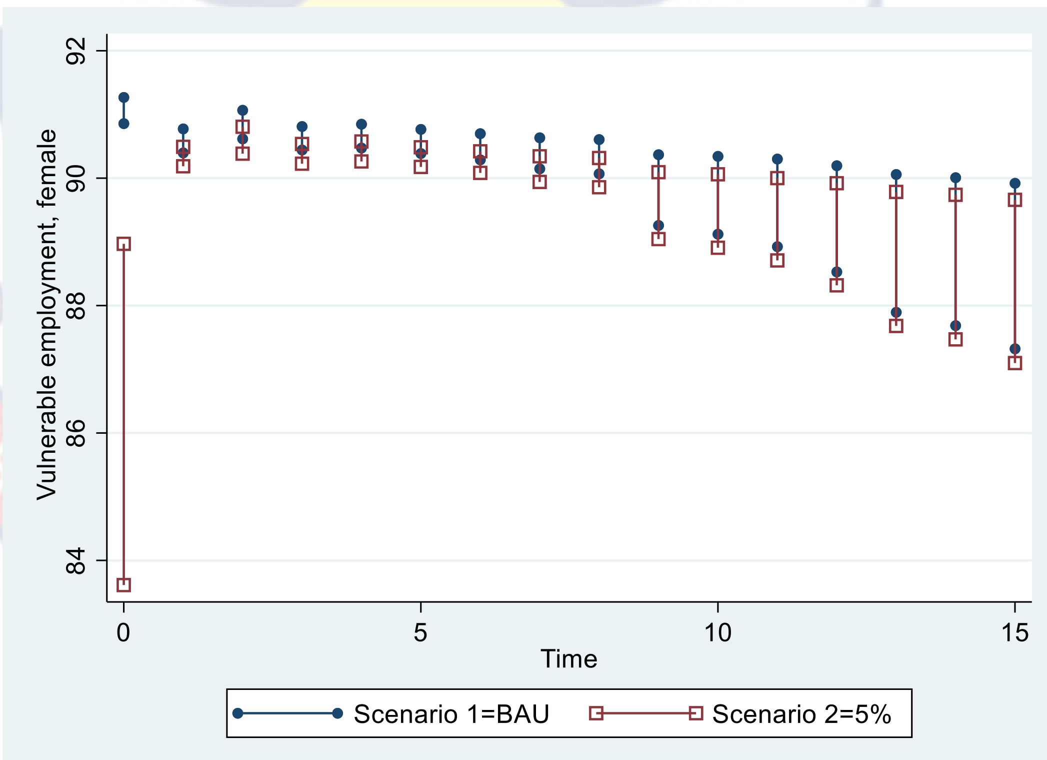

Figure D: Energy transition and vulnerable employment, female

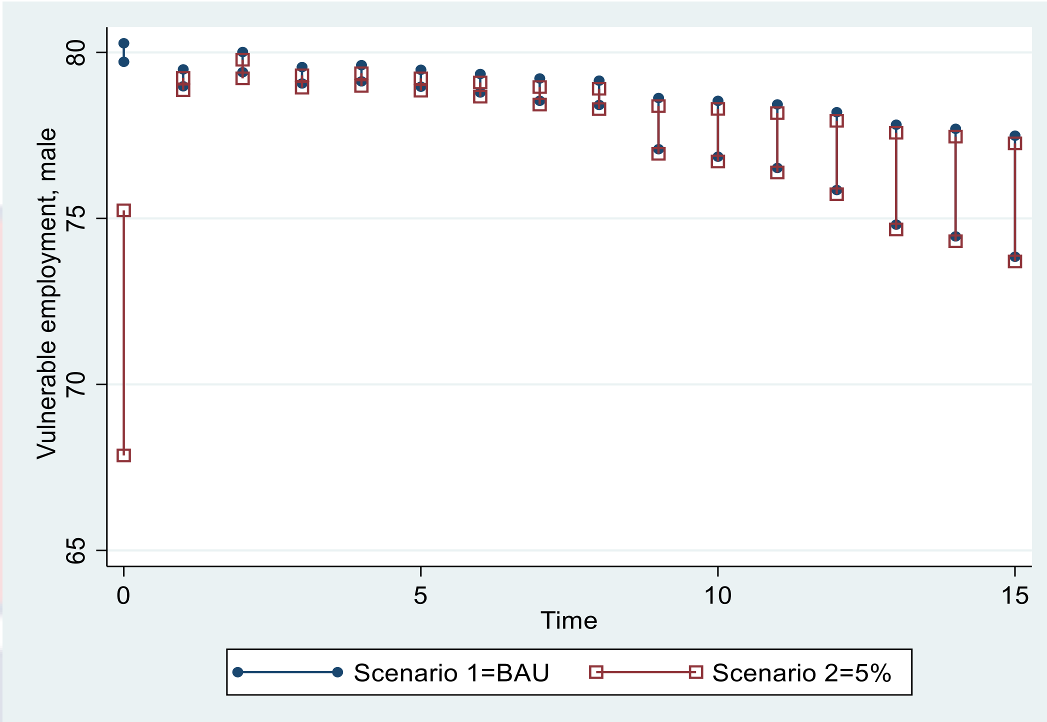

Figure E. Energy transition and vulnerable employment, male

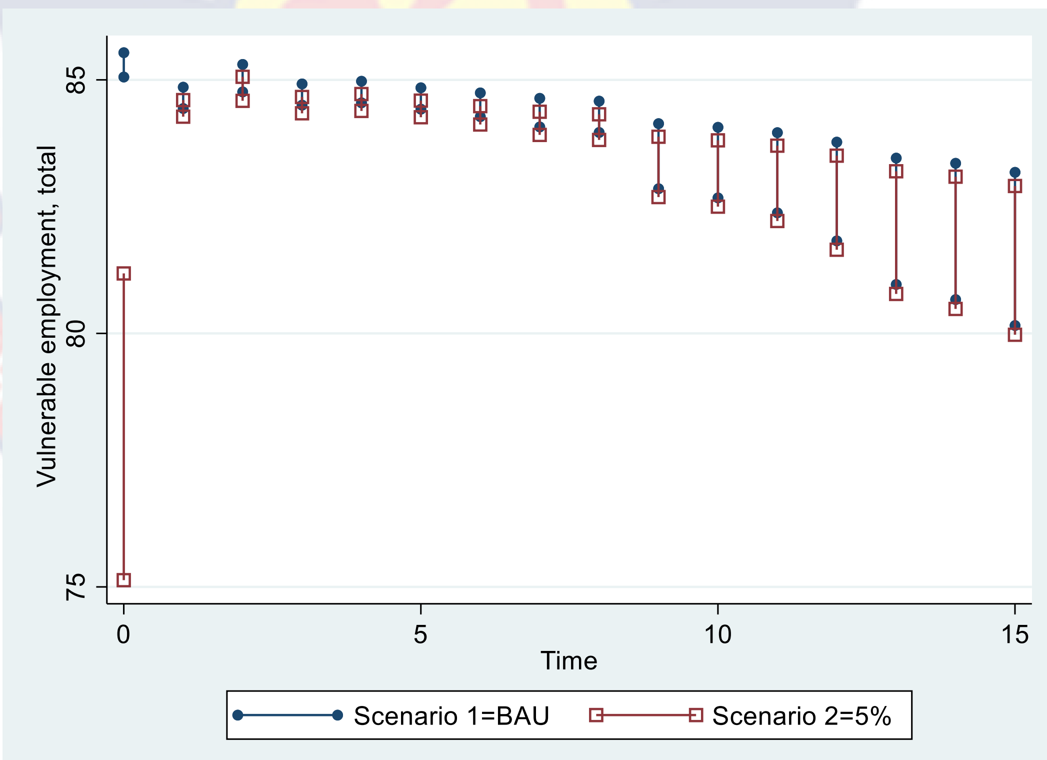

Figure F: Energy transition and vulnerable employment, total