ESSAYS ON ENERGY CONSUMPTION AND OIL RESOURCE MANAGEMENT IN OIL PRODUCING AFRICAN COUNTRIES

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This thesis is submitted in partial fulfilment for the award of the Doctor of Philosophy (PhD) in Economics and Finance of the University of Portsmouth, UK
DECLARATION

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

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Papers related to this study


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ABSTRACT

In September 2011, the UN General Secretary declared his vision of making modern energy accessible to all by 2030. Unfortunately, less than 50% of the population of Sub-Saharan Africa have access to modern forms of energy. This implies that Africa requires sustained investment in the energy sector. In order to provide investment guide and policy recommendations, this thesis seeks to investigate the determinants of renewable energy, energy efficiency practices and natural gas demand in oil producing African countries. The choice of these types of fuel is dictated by the fact that, renewable energy, energy efficiency and natural gas have been considered the solution to the hydra-headed problems of energy security, energy access and climate change in Africa. The thesis contributes to the energy economics literature in four main ways. First, the thesis applies spatial analysis to the issue of ‘oil curse’ which has often been associated with oil producing African countries since investments in energy will require finance which can be provided by proceeds from oil resources. Second, the effect of natural resource depletion and energy-related carbon emissions on renewable energy consumption is examined. Third, the natural gas consumption behavior of oil producing African countries is examined. Finally, the Product Generational Dematerialisation (PGD) is applied to the energy efficiency of fossil fuels and electricity consumption in Ghana. The thesis finds among other things that both economic and technical factors affect the demand for natural gas and renewable energy. Further, the results reveal that the consumption of both fossil fuel and renewables have not been efficient. Finally, the thesis confirms the oil curse hypothesis. However, how conducive the investment climate in a particular country has positive bearings on neighbouring countries.

Whilst the study seeks to recommend for more investment into energy supply and demand, attention should be given to three factors: availability, the environment and finance. Whereas, renewable energy sources, natural gas and efficiency abound in Africa and are environmentally friendly, finance may be a major hindrance to investments. Therefore, the sixth chapter of this thesis, examines how oil resources are managed so that it can help fund investments in energy. The chapters are therefore linked by the need for oil producing African countries to harness the finances to invest in available and clean sources of energy.

The thesis recommends that oil producing Africa should open their economies for international trade, invest in commercial sources of renewable energy, build strong accountability institutions,
channel oil revenues into productive sectors and educate the public on energy efficiency not just electricity efficiency.
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ABBREVIATIONS
AfDB – African Development Bank
ARDL-Autoregressive Distributed Lag
BPD – Barrels Per Day
EIA – Energy Information Administration
GMM – Generalized methods of moments
GUM – General Unrestricted Model
IEA - International Energy Agency
IIS – Impulse Indicator Saturation
LPG – Liquefied Petroleum Gas
LNG – Liquefied Natural Gas
OPAC – Oil Producing African countries
PAM – Partial Adjustment Methods
PGD – Product Generational Dematerialisation

PPM – Parts Per Million

PTLS – Panel Two Stage Least Squares


SSA – Sub-Saharan Africa

SDM – Spatial Durbin Model

STSM - Structural time series model

TCF – Trillion Cubic Feet

UEDT – Underlying energy demand trend
CHAPTER 1: INTRODUCTION

‘And God said, let there be light, and there was light. God saw that light was good’ (genesis, 1:3-4).

1.1 Background of Thesis

Light and Energy have become the fulcrum around which life revolves. This is because energy facilitates communication, transformation of raw materials into finished and semi-finished goods, production of synthetic materials, transportation and information processing (Lackner, 2010). Energy is important both for the demand and supply side of the economy. At the demand side of the economy, energy is an important utility consumers use to satisfy their heating, lighting and transport needs (Chontanawat et al. 2006). At the supply side, energy is an input to production and an influence on labour and capital such as electricity to power machines and oil to lubricate engines. Medlock (2009) posits that lack of access to modern forms of energy is one of the main challenges of Africa’s development. This is because the manufacturing, service, residential and the agriculture sectors all use appliances and machines such as tractors, air-conditions, photocopy machines and printers, which rely on one or forms of energy to function. Medlock (2009) argues that development occurs when nations change from manpower means of production to mechanical and technological means of production. This transition relies on energy to occur and makes energy a vital denominator for growth.

1.2 Motivation of Thesis

The role of energy consumption in development has been a bone of contention between neo classical theories and ecological economics theories. The neo classical theory propounds that output depends on labour and capital. Energy is assumed to be consumed indirectly through capital and labour. The proponents of the neo classical theory suggest that energy is not demanded for its own sake. They argue that, because it has derived demand, the consumption of energy is dictated by macroeconomic conditions (Lermit and Jollands, 2001). Solow (1974) suggests that in the presence of diminishing energy resources, technological progress and substitution possibilities can drive economic growth. He posits that, further growth beyond the equilibrium stage is only possible through technological progress. Higher growth is achieved
through increased quantity of capital and labour, their quality or their substitutability or technological progress. Energy is not as important as capital and labour in the production function. Energy consumption is therefore as a result of economic growth.

On the other hand, theories of ecological economics indicate the relevance of energy resources for production. According to them, an economy is an open sub-unit of the global ecosystem upon which the survival of labour and human capital depends. Energy is required to create more capital or trigger technological progress. For labour to be effective, it needs energy in the form of light, food, heat and transportation. By extension, Stern and Cleveland (2004) suggest that energy is vital for economic growth. They argue that, even in the presence of technological progress, energy is still needed for production and that technological progress is simply finding an efficient means of production to replace an inefficient one. Therefore using the relative cost of energy in the production as a yardstick to measure its relevance is an under-estimation.

Despite the differences in their viewpoints, both classical and ecological theories agree that energy is important. Due to the vital role energy plays, emerging countries such as China, India and Brazil and developing ones in Africa are identifying alternative sources of sustainable energy supply. However, in as much as energy is vital for development, its use can have a negative consequences on the environment in the form of carbon emissions, acid rains and environmental pollution. The consumption of energy such as crude oil and coal could lead to an increase in global warming since energy is major a contributor to the emission of CO2, which is a key greenhouse gas (Bhattacharyya, 2011). In addition, the IEA emphasis in a 2010 report that the growth of carbon emissions in the atmosphere after the industrial revolution has been principally driven by the consumption of fossil fuels. Again, the threat of nuclear disasters such as the Fukushima nuclear disaster and radioactive waste disposal makes nuclear a challenging option. This makes renewable energy and natural gas the ideal sources of energy for Africa for two main reasons since the ultimate policy goal has been to limit energy consumption without detriment to economic growth. This is because, if such reductions in energy consumption influence economic growth negatively, it will affect the choice, the comfort, convenience and the welfare desired by consumers (Mckinsey, 2006). First, renewable energy is carbon neutral and inexhaustible (Olah et al., 2008) and abundant especially in Africa. Africa is one of the few continents where renewable energy sources like the sun, water bodies, wood and waste are
available all year round. Second, natural gas is abundant and the cleanest type of fossil fuel (Akansu et al. 2004).

Moreover, Dincer (2000) posits that energy supply and use do not only affect global warming but also influence energy poverty. With less than 50% of entire African population having access to modern form of energy, Sokona et al. (2012) suggest that the most immediate energy priority of Africa is to expand energy access to achieve social and economic goals. This requires investments in a clean and reliable energy sources. However, energy investments require long lead times and huge capital. For instance, natural gas can be transported only through pipelines or as Liquefied natural gas, both of which are expensive. This means that the knowledge of current demand patterns and the factors that affect demand will be a valuable asset for both planning and investment decisions such as production, transportation, refinery, storage and distribution (Abdel-Aal, 2008). Again, renewable energy supply has been found to be intermittent since it relies on the availability of the sun, river, waste or wind and therefore needs careful planning before it is deployed. This implies that modelling of the factors that influence natural gas, renewable energy and other sources of energy will help to design consistent and sustainable energy policy.

Energy demand modelling is important for four main reasons according to Ryan and Plourde (2009). First, demand estimates help to understand the magnitude of energy demand responses to changes in price, income and other factors. In addition, it helps to predict future energy demand trends since the knowledge of how past economic and non-economic factors have affected demand trends can help forecast energy demand. Thirdly, energy plays a vital role in the production function and therefore the knowledge of its demand characteristics can help understand the extent of substitutability between energy and other factors of production. Finally, the knowledge of energy demand trends can help manage global warming. This thesis therefore seeks to evaluate the role of both economic and non-economic factors on energy consumption and investigate the contribution of oil revenues to Africa’s growth. According to Pindyck (1979), the essence of modelling energy demand is to overcome the limited understanding of the nature of energy demand and design appropriate responses to changes in the determinants energy consumption.
Whilst energy consumption could lead to economic growth, oil revenues have been the key growth driver in countries such as Indonesia and Norway. The story has been different in Africa. Aryeetey et al. (2012) find that Africa is developing in all fronts such as human capital development, growth in the service sector and reduction in poverty except in one area: They indicate that the major problem in Africa is the transmission of its oil revenues to economic growth. This calls for reliable estimates of the effect of oil rents on economic growth and ascertain whether the oil curse is influenced by geographical proximity in Africa.

In this thesis, the relationship between oil resources and economic growth in oil producing African countries is studied by departing from existing in two main ways. First, the effect of spatial effect and trade associations among oil producing African studies on economic growth is studied. Second, four different measures of oil resources, that is oil revenues, oil production and oil reserves are used to ascertain whether the choice of the oil resource variable influence the ‘oil curse hypothesis’. Further, the effect of Kaya Identifier and other determinants on renewable energy and natural gas consumption are investigated. Finally, the PGD is applied to energy efficiency study in Ghana.

1.3 Research Contribution

1.3.1 Renewable energy demand

According to a forecast by the Energy Information Administration (2011), global energy demand will increase by 53% between 2008 and 2035. This has led to increased investments and supply of conventional fuels such as coal and crude oil (Byrne and Wang, 2014). However, this approach only satisfies short term demand at the expense of long term structural growth since both coal and crude oil are non-renewable. Therefore, the emphasis should be on renewable energy investments. Apart from the fact that renewable energy comes from infinite sources such as the sun, it is also environmentally friendly and promotes job creation. For instance, every million US dollars invested in renewable energy creates four permanent jobs. These jobs are created directly through direct-employment and indirectly through economic growth enhancing effects such as using solar panels to power a fridge to sell water. The thesis focuses on the growth enhancing effects since it is assume to be higher than the direct effects (Singh et al,
2001). The same amount invested in renewable energy creates more than sixteen permanent jobs (Singh et al, 2001). This chapter therefore focuses on the determinants of renewable energy demand since the knowledge of these predictors can guide policy making and investment decisions in renewable energy.

With dearth of studies on renewable energy demand in oil producing African countries, this chapter contributes to the existing literature in two main ways: First, the thesis examines the effect of the Kaya Identity (energy related carbon emissions) and energy resource depletion on renewable energy in oil producing African countries. The Kaya Identity (energy related carbon emissions) is calculated as Population*GDP per capita* energy intensity* carbon intensity (Kaya, 1990). Second, though renewable energy consumption-economic growth causality has been widely investigated in Africa, the factors that influence renewable energy demand has been given less attention. This study contributes to the renewable energy demand literature by studying these factors.

1.3.2 Natural Gas Demand
As at 2014, the total amount of natural gas discovered in Sub-Saharan Africa was 359 TCF (Santley et al, 2014). If produced efficiently over 30 years, this can transmit into160 Gigawatts of power, which is double the existing total installed capacity for Sub-Saharan Africa. In addition to its availability, natural gas has been considered the cleanest form of fossil fuel (Akansu et al. 2004). Therefore, natural gas is considered a bridge-fuel between non-renewable and renewable energy due to its attractive environmental qualities. With Africa’s quest to provide electricity and curb global warming at the same time, natural gas become a vital fuel. A continent that has more than 50% of its population with no access to power, these discoveries are timely and calls for investments (Brew-Hammond, 2010). Motivated by power shortage and recent high profile discoveries of natural gas in Africa, this chapter examines the predictors of natural gas demand in oil producing African countries. Natural gas is traded regionally so there are the North American, European and Asia-Pacific gas markets, Africa has no gas market although there are bilateral agreements such as the West Africa Gas Pipeline. Given the complexity of the market,
the interplay of factors that influence the market and the interdependence of these factors, a quantitative model representing the demand side of the market will guide energy policy decisions.

This chapter applies the automatic variable selection software (Autometrics) in an unrestricted general to specific model to estimate natural gas demand in oil producing African countries. This model is able to consider non-quantifiable unobservable factors that affect the demand of natural gas. Again, since gas is environmentally friendly, relative to coal and crude oil, the effect of energy-related carbon emissions on gas demand is examined.

1.3.3 Energy Efficiency

Energy efficiency generates substantial financial savings and improves environmental quality at the same time (Reddy, 2003). In an era when the combined power generation of all 54 countries in Africa is less than that of Spain, energy efficiency becomes the antidote to equitable power distribution and cost savings. Whilst effort has been made in the advanced countries to promote technology and efficiency, little is known about efficiency in emerging economies in Africa. Therefore, the Institute of Natural Resources Africa, of the United Nations University, identified energy efficiency as one of the pillars of sustainable development in Africa. Whilst the availability of power has been identified as a condition for development, about a quarter of the population of countries such as Ghana pay lifeline tariffs (PURC, 2015). That is, their electricity consumption is highly subsidized by the government. This means, monies that would have been used for infrastructure development are channelled into electricity subsidies. Therefore, energy efficiency can present an opportunity for financial savings and development. Ghana has the second highest electricity access rate in Africa and therefore ideal as a case study for this chapter.

This chapter departs from existing studies in two ways. First, a Product Generational Dematerialization (PGD) indicator is used to measure aggregate energy efficiency of Ghana. Second, the study seeks to identify the energy efficiency practices of SMEs in rural Ghana and also examine the barriers to energy efficiency practices.
1.3.4 Spatial analysis of oil resource management
Whereas chapters 3 to 5 focus on the identification of the determinants of demand and the need to invest in energy sources that are available and clean, chapter 7 looks at how oil resources are managed and the factors that will drive economic growth to promote investments. Specifically, chapter 7 examines the impact of spatial variables on economic growth and investigates the determinants of economic growth in oil producing African countries. The knowledge of these growth drivers will lead to the design of the right policies that can help channel oil revenues into investments in renewables, natural gas and efficiency.

It has been argued that local policies in one country may influence policies in nearby countries (Brueckner, 1998; Brueckner and Saavedra, 2001). There is also evidence for policy learning or experiential diffusion from proximity, or a geographic perspective (Sabatier and Jenkins-Smith 1993; Borgatti and Cross 2003). The principal causal mechanism for policy learning and diffusion in a geographic context is most obviously simple exposure by proximity. After such exposure, the process of adoption can occur for a variety of reasons that include influence mechanisms, mimicry, and active learning (Bird 2009, Karch 2007). This implies that, how a country manages its oil resources can influence the decisions and growth of neighbouring countries.

According to Anselin (2003) variables in an econometric function interdepend across regions and space. In addition, he argues that observed variations in the dependent variable may arise from unobserved or latent influences. These latent variables include culture, infrastructure, lifestyle, regulations, recreational activities which have no available sample data but can be accounted for by relying on neighbouring values taken by the dependent variable. This means that ignoring the independence between variables can lead to inconsistent and bias estimates. Due to economic partnerships, geographical proximity and cultural similarities among oil producing African countries, it is possible that the variables are interdependent or influenced by cross border latent variables. Lesage (2005) posits that spatial econometrics model is capable of incorporating dependence among observations that are close in geographical proximity. Conceptually, the presence and treatment of spatial interdependence between variables and countries requires special econometric treatment such as the inclusion of spatial lags (Monteneiro, 2009).

This chapter contributes to the oil curse hypothesis literature by evaluating the role of spatial effects on the oil revenue-economic growth relationship. Ross (2012) defines the oil curse as a
case where countries that are rich in petroleum resources experience economic instability, civil wars and less democracy. The oil curse hypothesis implies that petroleum resources have negative influence on economic growth. Again, the study uses four different measurement of oil resources (oil revenues, oil rents, oil reserves and oil production) to ascertain whether the choice of oil variable influence the ‘oil curse hypothesis’. The oil curse is more pronounced in Africa than any other continent. There is a need to reverse this trend especially for new oil economies such as Ghana. This study uses a spatial panel data analysis to investigate the oil curse.

1.4 RESEARCH QUESTIONS
Based on the motivation and contributions highlighted above, this thesis seeks to answer the following research questions:

1.4.1 Renewable Energy Demand
1. How does the Kaya Identity affect renewable energy demand in oil producing African countries?
2. What is the impact of energy resource depletion, income, price and population on renewable energy demand in oil producing African countries?
3. How does the past values of renewable energy consumption affect current demand?

1.4.2 Natural Gas Demand
4. What is the effect of GDP, energy resource depletion, CO2 and price on natural gas consumption in oil producing African countries?
5. How different are natural gas demand estimation of dynamic panel two stage least square model from the Arrellano and Bond (1991) generalized method of moments (GMM)?
6. What is the shape of the underlying energy demand trend of natural gas demand for each of the country studied?

1.4.3 Energy Efficiency
7. What are the energy efficiency practices of small and medium scale enterprises in rural Ghana?
8. What are the barriers to energy efficiency among SMEs in rural Ghana?
9. How efficient is Ghana in terms of electricity and fossil fuel consumption?
1.4.4 Spatial analysis of oil resource management
10. Is there evidence of spatial dependence between economic growth and its predictors in oil producing African countries?
11. What are the determinants of economic growth in oil producing African countries?
12. Is there a spatial heterogeneity among the variables and does this affect the oil resources-economic growth relationship?

1.5 JUSTIFICATION FOR THE METHODOLOGY
Africa is homogenous in areas such as agriculture and peasant farming, natural resource ownership and management, and hereditary succession (Levine, 1973). However, the continent is heterogeneous in other ways such as language and culture. These differences and similarities can influence how oil resources are managed. In this thesis, the geographical and economic distance and relationship among oil producing African countries are factored into a panel spatial model to examine the relationship between oil resources (oil production, oil reserves and oil rents) and economic growth. According to Burnett et al. (2013), there are three types of spatial dependence that can affect the relationship between economic growth and its determinants. These are the spatial lag model which incorporates the lag value of the dependent variable in which the economic growth in country (i) is affected by the growth in country (j). Auffhammer (2007) states that the spatial lag model implies that the growth in one country has a likelihood of influencing the growth in a neighbouring country. The second is the spatial Durbin model (SDM) which involves spatial lag value of the dependent variable and spatial lag value of the predictors. This implies that, not only economic growth of country (i), but growth predictors such as oil rents, oil production, oil reserves, and quality of democratic institutions, trade openness and investment also influence economic growth in country (j). The final type is the spatial error correction model in which the error terms of various spatial units are correlated. Spatial error however indicate omitted variables and if left unattended can lead to bias estimates and inference (Burnett et al., 2013). Spatial method therefore helps to consider and test for types of spatial dependence among the variables, helps to understand the spill over of economic growth and growth determinants and ascertain whether economic and geographic distance influence the oil curse hypothesis.
Chapter 4 examines the predictors of renewable energy demand in oil producing African countries and uses three main methods. These are the Arellano Bond dynamic panel generalized method of moments, panel fixed effect and two way random effects models. Kiviet et al. (2014) posit that the panel GMM has the advantage of flexibility, generality, and ease of use, efficiency and robustness. In addition, Omri et al. (2014) suggest that the Arellano Bond dynamic panel GMM helps to overcome the problem of endogeneity. It has been argued by Clark and Linzer (2012) that when choosing between fixed and random effects, researchers usually strike a balance between how to balance variance and bias. This can be decided to employ the Hausman test to decide between the two. Clark and Linzer (2012) further argue that what matters in the decision is the size of the dataset and the level of correlation between the covariate and the unit effects. In order to enhance the robustness of the estimates, a panel GMM, fixed effect and two-way random effect are used in chapter 4 after applying different diagnostic tests.

Chapter 5 studies the elasticities of natural gas demand in oil producing African countries. Three main methods are used. These are the Arellano Bond dynamic panel GMM, and a panel two stage least squares a general unrestricted error correction model which features Impulse Indicator Saturation (Hendry et al., 2008) through Autometrics. According to Nielsen (2009), the general unrestricted model is able to account for all other potential factors that affect the demand for natural gas but which are difficult to measure. Hunt et al. (2003) identify some of these factors as efficiency of the capital appliance through which natural gas is consumed, the lifestyle of consumers and energy related regulations and collectively termed these factors the underlying energy demand trend (UEDT).

Finally, chapter 6 applies the PGD to energy efficiency study in Ghana. Even though sustainable energy consumption indicators abound, for instance, Eco-index, environmental sustainability index and the composite sustainable development index, it has been suggested that they are not sufficient to measure dynamic energy efficiency (Labuschagne et al, 2005). According to the International Energy Agency (IEA) (2006), these indicators measure static efficiency. The PGD on the other hand evaluates simultaneous changes in population and energy consumption (Ziolkowski and Ziolkowska, 2015).
1.6 LINKAGE AMONG THE CHAPTERS
The energy sector in Africa requires huge investments to promote the ‘UN access to all’ campaign since less than 50% of Africa’s population have access to modern forms of energy. But, where will the investment come from? Most African countries depend on donor support to finance their budget (Unwin, 2004). This thesis seeks to ascertain how oil revenues contribute to economic growth so that recommendations can be made to channel oil proceeds to finance investments in the energy sector. However, departing from previous literature, this thesis’ original contribution is to assess how neighbouring countries and trade associations influence how oil revenues are managed.

Further, since energy investments require long lead times, it is vital to examine drivers of demand in oil producing African countries to guide investment decisions and policy design in the energy sector. Finally, oil and coal have been found to be major contributors of carbon emissions, this study concentrates on renewable energy, energy efficiency and natural gas, which are considered to emit relatively low carbon. The thesis therefore looks at how oil producing African countries will manage their oil proceeds efficiently and attract investments to invest in clean sources of energy.

1.7 STRUCTURE OF THE THESIS
This thesis comprises of 8 chapters. Chapter 1 (Introduction) provides a background to the study and covers the contribution of the thesis, research questions, and the overview of the methodologies applied in this thesis. In this regard, a brief overview and the contributions of each chapter is discussed. In addition, the linkage among the chapters and the justification for the methodologies applied in this thesis are discussed.

The chapter 2 reviews the literature and traces the economic growth and energy demand trend of Africa. The chapter examines energy production and consumption in Africa and discusses the relationship between energy consumption and economic growth. The chapter also looks at renewable energy economics and the relationship between renewable energy consumption and economic growth. Finally, chapter 2 looks at natural resource management and examines the oil curse hypothesis. The chapter ends with the identification of literature gaps and the limitations of the literature.
Chapter 3 focuses on the research philosophy. Consequently, the chapter traces the history of energy modelling and the importance of capturing technical progress in energy demand models. Further, the chapter focuses on the research paradigm and the types of research methodologies.

Chapter 4 studies the predictors of demand for renewable energy in oil producing African countries. The chapter begins with a detailed background and a discussion on the contribution of the study to the literature on renewable energy demand. Three different models are introduced in this chapter. These are the dynamic panel generalised method of moments, a panel two-way random effect model and a panel fixed effect model. The results are similar across models and consistent with previous findings in the renewable energy demand literature.

In Chapter 5, elasticities of natural gas demand in oil producing African countries. The background provides justification for investment in natural gas since it is clean and available. The general unrestricted model (GUM) is applied since it has the ability to capture non-quantifiable unobservable factors such as lifestyle and culture that affect the demand of natural gas. Further, the dynamic panel generalised method of moments and the panel two-stage least squares are applied in this chapter. The findings suggest that oil producing African countries have been inefficient in terms of natural gas consumption.

Chapter 6 employs the Product Generational Dematerialization (PGN) indicator examine energy efficiency in Ghana. The chapter discusses energy efficiency initiatives of the country and examines the importance of demand side management. Further, the chapter employs a subjective evaluation method to study energy efficiency practices of small and medium scale enterprises in rural Ghana are looked. Again, barriers to energy efficiency practices are also studied. The results from both the PGN and the subjective evaluation method are discussed.

Chapter 7 revisits the oil curse hypothesis. In departing from existing literature, the chapter examines whether there is spatial homogeneity or spatial heterogeneity among the variables. Four different variables, namely oil reserves, oil revenues, oil production and oil rent to separately represent oil resources in four different equations. Further, 3 different methods are employed in this chapter. First, a cross-sectional method is applied, then a panel method and finally a spatial econometric method. Generally, the results confirm the oil curse hypothesis. However, the findings indicate that when a country has benign investment environment, it has positive impacts on neighbouring countries. Finally, chapter 8 summarises the key findings of the thesis and provides direction for future research. Again, the limitations of the thesis and
policy recommendations are discussed in chapter 8. Chapter 2 follows this chapter and discusses energy demand theories, natural resources management, renewable energy economics, the relationship between energy consumption and economic growth and the oil curse hypothesis.

In chapter 1, a background to the thesis and motivation of the thesis are discussed. Further, chapter 1 provides an overview of the research objectives and the linkages among the 8 chapters. The purpose of chapter 1 is to provide the significance of the thesis and build a foundation for the other 7 chapters in the thesis. In order to understand the concepts, theories and constructs mentioned in chapter 1, Chapter 2 provides an overview of theories and empirical studies relating to energy demand and natural resource governance.
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction
The UN General Secretary declared in September 2011 his vision of making modern energy accessible to all by 2030 (Dora et al. 2014). However, less than 50% of the population of Sub-Saharan Africa have access to modern forms of energy (Birol and Economist, 2014). Since energy provision takes long lead times and huge capital outlay, this thesis seeks to identify the factors that influence energy demand so that such estimates can serve as guide to policy design and investments.

Higher demand for energy through increased population and per capita growth has become a matter of concern for policy makers. According to Arrow et al. (2004), global industrial output increased by a factor of 40 in the last 100 years whilst global energy consumption has increased by a factor of 16 by the same period. Such an increment could threaten energy security and increase global warming since energy is major a contributor to the emission of CO2, which is a key greenhouse gas (Bhattacharyya, 2011). Again, the quest for economic development of a modern society seems to be impossible without energy. However, recent developments such as increased and volatile energy prices and possible maturing and depletion of some oil wells like the continental shelf have made it difficult for policy makers to come out with sustainable energy policies. Meanwhile, energy consumption contributes both positively (transport, light, heat) and negatively (global warming) to society. This means that, policies should allow energy consumption to play its vital role in the economy whilst suggesting means through which the negative impact on the environment is minimized.

In this chapter, literature on energy production and consumption in Africa, the energy consumption-economic growth nexus, renewable energy economics, oil resource governance and the relationship between energy consumption and carbon emissions is examined.

2.2 Energy production and consumption in Africa
According to UNCTAD (2012), the average annual growth of Africa from 1970 to 1980 was 4.22%. This decreased to 1.81% from 1980 to 1990 and increased to 2.6% in 1990 to 2000 and
further increased to 5.28% in 2000-2010 before reducing to 3.79% (from 2008 to 2012). Africa’s growth has been punctuated by social and economic tensions, conflicts, corruption and global economic events (AEO, 2013). Despite these challenges, Africa recorded a growth rate of 6.6% in 2012, dropping to 4.8% in 2013 and 3.9% in 2014. This growth has principally been driven by high prices of commodities such as gold and oil.

According to a report by the Africa Development Bank (AfDB) in 2009, though 38 out of 53 African countries are net oil importers, oil production seems to be increasing over time. The increased in oil production can be attributed to new discoveries in places such as Ghana, Tanzania and Cote D’ivoire and increased production from existing fields, relatively conducive investment climate and advances in technology. The oil production trend reported in figure 1 shows an increasing tendency with a sharp decrease in 1981 and 2010. The 1981 reduction in oil production was influenced by reduction in demand especially from industrial countries as a result of the oil price hikes in the 1970s. This led to energy conservation policies, substitution of oil-fired plants with nuclear plants, coal and gas in power generation. Again, the collapse of OPEC oil price structure in December 1980 affected the production of African members negatively. However, in 2010, a combination of factors led to the sharp decrease in production. Prominent among these factors are the insurgency in Nigeria, Arab Spring in Egypt, Tunisia and Libya and conflicts in Sudan. Despite this downward, new production in Ghana and other new fields in Cote D’ivoire led to a gradual increase from 2011.

Figure 2. 1. Oil production in Africa
According to data from the Energy Information Administration, Africa produced 6229 thousand barrels of oil per day in 1980 but increased production to 9353.09 thousand barrels per day in 2013.

![Proved oil reserves in Africa](Image)

**Figure 2.2. Proved oil reserves in Africa**

In the past 20 years, oil reserves in Africa have grown by 25% (AfDB, 2009). There are three types of reserves. These are proved, probable and possible reserves. Depending on technological advances, economic factors such as increased oil prices, geographical factors and progressive fiscal regime and conducive business environment, the level of reserves can rise. According to the EIA (2013) Sub-Saharan Africa contains 62.6 billion of crude oil reserves and produced 6 million barrels of liquid fuel a day in 2012 representing 7% of total global output. Libya, Nigeria, Algeria and Angola contribute about 85% of the total reserve of Africa. According to the May 2012 edition of the Oil and Energy Trends, Algeria can produce at the 2011 production rate for 18.6 years, Libya production will be for 75.9 years, Nigeria, 39.7 years, Ghana, 20.1 years and Tunisia, 15.5 years. However countries like South Africa and Mauritius are running out of oil with a potential estimate of 3 years using 2011 production rate. In terms of oil
production, Nigeria tops with 2.6 million barrels (bpd) a day followed by Algeria at 1.8 million bpd and Angola at 1.7 million bpd (Oil and Gas Journal, 2012).

![Graph showing CO2 emissions from oil consumption and natural gas consumption](image)

**Figure 2.3.** CO$_2$ emissions from oil consumption and natural gas consumption (including natural gas flaring)

Natural gas is environmentally friendly relative to other fossil fuels. Bhattacharyya (2011) posits that natural gas emits 30% less CO2 as compared to oil and about 70% less as compared to coal. In addition to these advantages, natural gas is widely abundant in Africa. Therefore as countries yearn to reduce the environmental impact of energy consumption, natural gas comes only second to renewable energy in terms of emissions. According to figure 2.3, natural gas emits less emission than oil consumption even if flaring is added relative to oil consumption. This affirms the environmentally friendly attributes of natural gas.
Natural gas is principally used in households for cooking, for power generation, for fertilizer manufacturing and as a transport fuel. The IEA (2011) forecasts that the share of natural gas in global energy mix will increase from 21% in 2010 to 25% in 2035. This increase is principally driven by increased use of natural gas in transportation, low growth in nuclear energy and discovery of conventional and unconventional gas. In Africa, there have been a series of natural gas investments such as pipelines that is making natural gas available to the market and encouraging demand. Notable among them are the West African Gas Pipeline which stretches from Nigeria through Benin and Togo to Ghana and huge gas discoveries in Mozambique, Nigeria, Angola and Tanzania. In terms of natural gas reserves, the African Development Bank estimates that Algeria, Egypt, Libya and Nigeria possess about 91% of Africa’s gas reserves. Ernst and Young in a report in 2012 describes natural gas as a ‘prime mover’ for broader economic development in Africa. According to the BP statistical review (2012), natural gas consumption in Africa has been growing at an annual rate of 6% since 2010. BP (2012) estimates that Egypt and Algeria accounted for 70% of Africa’s total gas consumption in 2011. Natural gas
is a bridge fuel between non-renewable energy and renewable energy in Africa. Oil producing countries like Egypt, Ghana, Nigeria, and South Africa are investing in both natural gas infrastructure and renewable energy. In Ghana and South Africa, a law on feed-in tariff to encourage renewable energy investment and consumption has been passed. Since such policies may bear fruit in the medium to long term, natural gas can has been identified as the transition fuel.

![Figure 2.5. Primary energy production and consumption in Africa](image)

Africa has about 15% of the world’s population but consumes only 3% of global commercial energy (AfDB, 2009). This notwithstanding, Africa produces 12% of global commercial energy. According to figure 2.5, Africa produced 17.402 Quadrillion British thermal unit (Btu) of primary energy in 1980 but increased production to 35.997 Btu in 2012 representing an increase of 106.85%. In terms of consumption, Africa consumed 6.802 Quadrillion Btu in 1980 but consumed 17.335 Quadrillion Btu in 2012 representing 154.848%. This implies that energy consumption is growing faster than production in Africa.
Access to energy contributes to social development and factor productivity and therefore economic development (Dunkerley, 1985). In Sub-Saharan Africa, access to modern energy such as electricity is just 31% of the population (IEA, 2010). Out of about 1.4 billion people without access to energy globally, 585 million are in sub-Saharan Africa, 400 million in India and 1.19 billion live in the rural areas. These statistics threaten sustainable development and may hinder development and prevent many countries from achieving the Millennium Development goals. In terms of the oil producing African countries, access to both renewable and non-renewable sources of energy has been increasing over the last four decades. For instance, from 1971 to 2011, renewable energy consumption increased by 0.4% annually. According to the IEA (2007), 47% of primary energy consumed in Africa in 2006 was from Biomass and other traditional energies. The challenging issue is that some of these traditional energies are not traded on the market (Bhattacharyya and Timilsina, 2010). This makes data for such types of energy and their prices unavailable. However, as economic structure changes from rural-agrarian to urban-industrial, the role of the informal sector and traditional energy declines because of changes in lifestyle, technology and fuel mix (Bhattacharyya and Timilsina, 2010). In this study, different functions are specified for non-renewable (natural gas) and renewable energy demand. Again, factors which are usually ignored in energy demand studies in Africa such as technological progress, lifestyle and other non-economic factors are considered in this study.

2.3 Renewable energy economics

According to Sims et al. (2007), fossil fuels provided 85% of global primary energy. The IEA (2010) estimates that this was the same percentage of fossil fuel in global energy in 2008. In the same year, the consumption of fossil fuels accounted for 56.6% of all greenhouse gas emissions (Rogner et al., 2007). Due to this, Kankam and Boon (2009) have suggested that there is the need to shift from fossil fuel consumption to renewable energy if both developed and developing economies wish to pursue sustainable development goals. This is because renewable energy release relatively low carbon and comes from a sustainable source. Renewable energy consumption is a major component in any effort to combat climate change (Heal, 2009). In his inaugural address, President Obama asked America to harness the energy of the sun, wind and soil to power the cars and fuel the factories. This is due to the fact that renewable energy is
carbon neutral and comes from a source that replenishes itself (Reiche, 2010). Several countries have set renewable energy target. In America, the Department of Energy has a target of 25% of electricity generation from renewable energy by 2025 (Heal, 2009). The European parliament on the other hand has agreed to 20% target from renewable energy in total energy consumption by 2020 (Aune et al. 2012). Several African countries have similar targets. According to Mohammed et al. (2013), Africa seeks to generate 15% of total energy consumption from renewable energy by 2020. These consumption targets coupled with high oil prices have led increased investment in renewable energy. The United Nations Environment Programme (UNEP) in a report in 2011, estimates that investment in renewable increased from $33 Billion in 2004 to $211 Billion in 2010. Factors that have accounted for this rise in investment in renewables include global effort to combat climate change, energy security concerns, the desire to achieve the millennium development goals (MDGs) and declining cost and competitiveness of recent renewable technologies (Giovannetti and Ticci, 2011).

Despite having almost 10% of the world’s oil reserves, Sub-Saharan Africa is one of the poorest regions in the World (UNECA, 2011). This has been a result of years of corruption, natural resource revenue mismanagement, weak institution and conflicts. Giovannetti and Ticci (2011) however consider Sub-Saharan’s wealth in its untapped sources of renewable energy. According REN21 (2009), Africa has 8% of global hydro potential and together with Middle East, account for 57% of global solar potential. This notwithstanding, about 50% of the population lack access to electricity (Giovannetti and Ticci 2011). The African Development Bank suggest that the energy problem of Africa goes beyond access to include low generational capacity, large financing gap, high distribution losses, unreliable power supply and underdeveloped energy infrastructure (AfDB, 2010). Briceno-Garmendia et al. (2008) estimates that these energy challenges cost 0.8% of Africa’s GDP. Renewable energy types include solar, hydro, geothermal, wind, and biofuels, tidal and waste to energy. According to Johnstone et al. (2010), the major factors militating against increased renewable energy consumption is its intermittency nature and high initial cost of renewable energy technology. The IEA (2006) distinguishes between three types of renewable energy technologies. These are (i) first generation technologies which have already matured such as biomass, hydropower and geothermal, (ii) second generation technologies which are at the growth stage such as solar, wind and modern forms of bioenergy
and (iii) Third generation technologies which are at the introductory stage such as improved geothermal, concentrated solar and ocean energy.

2.3.1 Renewable energy consumption and economic growth

Renewable energy consumption minimizes environmental impact of energy consumption, improves stability and reliability of energy supply and enhances energy security (Voivontas et al. 1998). It also helps countries meet emissions targets such as the one set up by the Kyoto Protocol and European Union. The World Bank (1999) has also indicated that renewable energy consumption improves access to clean and modern energy in rural areas which are connected to the national electricity grid. Despite these advantages, the consumption of renewable has not grown as compared other sources of energy. Painuly (2001) argues that the reasons for relative low growth in renewable energy are economic barriers such as high capital cost, market barriers and technological barriers. On cost, Stern (2007) estimates that the economic impact of global warming could reduce global GDP by 25% whilst the mitigation of global warming through the use of renewables and efficiency cost 1% of global GDP.

There is empirical evidence that steady flow of renewable technology influence sustainable economic growth positively (Aghion and Howitt, 1998). The debate has been the means through which such technologies are transmitted into economic growth and how they are measured. Wilkins (2012) indicates that technology represents the bigger cost of renewable energy development and that, most developing economies like the ones in Africa do not have access to such technologies. This study is therefore necessary to ascertain the contribution of renewable energy to economic growth and to guide policy makers and businesses to invest more in renewable energy technology since more usage will drive down cost.

Renewable energy consumption has been growing faster than non-renewable energy growing at a rate of 3% per annum (IEA, 2009). According to Apergis and Payne (2012), the increased growth in renewable energy consumption has been due to environmental concerns about fossil energy consumption, volatility of oil prices and energy security concerns. The signing of the Kyoto Protocol and the establishment of carbon certificate traded markets like the European Union Emission Trading Scheme (EU ETS) has help increase the use of renewable energy. Since
these emissions related Initiatives are confined to the developed world, the few studies on the relation between relation renewable energy consumption and economic growth have been restricted to the developed economies.

Apergis and Payne (2010) examine the relationship between renewable energy and economic growth in OECD countries from 1985 to 2005. They find that there is a bidirectional causal relationship relation between renewable energy and economic growth in both the short and the long run. Menyah and Rufael (2010) find a unidirectional relationship running from renewable energy consumption to economic growth in the USA from 1960 to 2007. The findings of Manyeh and Rufael supports that of Sadorsky (2010) who finds that economic growth leads to the consumption of renewable energy in G7 countries in the long run.

2.4 Economic growth and energy consumption studies

The efficiency law of thermodynamics indicates that minimum amount of energy is required to carry out transformation of matter or production of physical work. According to Baumgartner (2004), when such transformation happens in finite time, more energy is required. Since all transformation requires work and is the basis of growth, it means, all economic processes require energy (Stern, 2010). Therefore, energy is a vital resource for economic growth.

Energy has been found to be one of the key determinants of the industrial revolution (Allen, 2011). Indeed, the role of energy demand to economic growth cannot be under-estimated. However, the relationship between economic growth and energy consumption is not conclusive in the literature. For instance, Ozturk (2011) reviewed the energy economics literature and found that energy consumption can granger cause economic growth or vice versa. These conflicting results may be as a result of data quality, type of econometric modelling, variable selection, and differences in the timeframe of the study and the geographic and economic structure and conditions of the country under study. There is therefore the need for further study into the relationship between energy consumption and economic growth especially in developing countries where such studies are limited.

To overcome the problem of variable selection, Stern (2000), uses a simple production model to examine the relationship between energy consumption and economic growth in the United States
by including capital and labour. He argues that the inclusion of capital and labour helps to reduce spurious effect and also highlight energy’s contribution to the production function. Stern (2000) uses vector auto-regression to model GDP as a function of energy consumption, labour and capital. The findings of the study suggest a cointegration between energy consumption, labour, capital and GDP and that energy consumption Granger causes economic growth. This supports the Growth Hypothesis and implies that energy conservation measures without technological advancement and efficiency can affect the economic growth of the United States. This is because, since economic growth depends on energy consumption, reducing energy consumption can reduce growth.

Paul and Bhattacharya (2004) investigate the causal relationship between energy consumption and economic growth in India by employing different models from 1950 to 1996. That is, the Granger causality test and error correction model. They examine the relation between economic growth, total energy use, population and fixed capital formation. Using the same data for the different models, they find that, in the long run, causality run from economic growth to energy consumption when the Engle-Granger model is used. However, in the Granger causality test, the causality runs from energy consumption to economic growth. This supports the findings of Stern (2000). Stern (2000) argues that the standard bivariate methods such as Granger (1969) may fail to detect additional channels of causality and produces contradicting results. Again, a developing country like India with a large rural population, the role of non-commercial energy sources such as renewable energy cannot be ignored when examining the relationship between output and energy consumption.

In order to expand the variable selection, Ang (2008) adds pollutant emissions to economic development and energy consumption in a model. He examines the causal dynamic relationship between these variables in Malaysia and how they relate. He uses per capita GDP as a proxy for economic development and includes per capita CO₂ emission, per capita commercial energy use and three dummy variables to cater for the Asian financial crises in 1973, 1979 and 1997. The vector autoregressive model and the Johanssen Cointegration test are employed to test the relationship and the causality among the variables. He finds that causality runs from energy consumption to economic development in both the short run and long run. The findings also suggest that that pollution emission and energy use are positively related. These findings confirm
the growth hypothesis. However, exclusion of both labour and capital from the model might have influenced the marginal effect of energy in the model.

In Africa, few studies test the causal relationship between economic growth and energy consumption. One of such studies is Odhiambo (2009). He uses the ARDL bounds testing approach to examine the causal relationship between energy consumption and economic growth in Tanzania. The purpose of the study was to investigate the intertemporal relationship between total energy consumption and economic growth and also examine the relationship between electricity consumption and economic growth. He uses real GDP growth as a proxy for economic growth and total energy consumption per capita and electricity consumption. The findings suggest that there is a stable long run relationship between energy and economic growth. Results from the causality test indicate a unidirectional causality running from energy consumption to economic growth. Electricity consumption Granger causes economic growth in the short run. The ARDL Cointegration approach has some distinct advantages over other cointegration techniques according to (Harris and Sollis, 2003). First, the ARDL does not impose restrictive conditions. This means that, it can be applied whether the variables are integrated in order one, order zero or partially integrated. Again, the ARDL generate a valid test statistics and unbiased long run estimates even if some of the variables are endogenous. This notwithstanding, Hamid et al (2010) argue that the assumption of ARDL restricts consideration to cases where there exists at most one cointegration equation between the variables. This is the major disadvantage of the ARDL approach to cointegration since ARDL estimation is valid only in the case of a single co integrating relation. In the event of more than one cointegration relation, ARDL estimation may not be valid .The ARDL becomes a model of choice only when the degree of integration of the variables cannot be ascertained. It has also been argued that the ARDL provides a low degree of freedom when it is used to estimate a regression with small sample size (Fatai et al, 2003).

Manyeh and Rufael (2010) expand the studies economic growth and energy consumption nexus in Africa by introducing pollutant emissions. They investigate the long run causal relationship between economic growth, pollutant emissions and energy consumption in South Africa for the period 1965 to 2006. Following Stern’s study, they build a multivariate framework and introduce capital and labour in addition to energy consumption and GDP. They use the ARDL developed by Pearson et al (2001) is used to test the cointegration among the variables. They use the Toda
and Yamamoto (1995) approach to estimate the long run causality between output capital, labour, CO\textsuperscript{2} and energy consumption. The study finds an evidence of a short run and long run relationship among the variables. More specifically, the study finds a significant relationship between pollutant emissions and economic growth. The Granger causality test indicates a unidirectional causality running from energy consumption to economic growth, from energy consumption to CO\textsuperscript{2} and from pollutant emissions to economic growth.

Yuan et al (2010) use the Grey incidence analysis to test the relationship between economic development and energy consumption in China at the Aggregate and disaggregate levels. China’s development is divided into four main stages on the basis of political and economic events. GDP and value added of primary, secondary and tertiary industries are used as a proxy for economic development. Total consumption and the consumption of coal, crude oil, natural gas, wind power and hydropower are used to represent Chinese total energy consumption. The findings indicate a time-varying relationship between energy consumption and economic development. There is a high correlation between GDP and coal consumption. The study also finds a high correlation between secondary Industry and energy consumption. Though the study provides some useful recommendations for China, it fails to show the direction of causality which could have helped China’s energy policy.

Contributing to the literature on the energy consumption- economic growth nexus, Tsani (2010) uses the Toda and Yamamoto (1995) approach to study the causal linkages between energy consumption and economic growth in Greece. Further, he seeks to ascertain the level of energy consumption dependence of Greece and the pattern of energy consumption at the aggregate and disaggregate level. At the aggregate level, he found a unidirectional causality running from energy consumption to economic growth. However, the study finds a bidirectional relationship between industrial and residential energy consumption and economic growth. The neutral hypothesis is confirmed between transport energy consumption and economic growth. The methodology overcomes the problem of pre-test bias by bypassing both cointegration and unit root pre-test.

Bartlelet and Gounder (2010) build two multivariate models to investigate the relationship and causality between economic growth and energy consumption in New Zealand from 1960 to 2004. First, they construct a demand model with GDP, energy prices and energy consumption. Then, they construct a production function with labour, capital, energy consumption and
employment. The long run estimation of the demand model indicates a cointegration relationship GDP, energy prices and energy consumption. The short run analysis suggests that GDP Granger causes energy consumption.

The Toda and Yamamoto (1995) method of VAR and the Vector Error Correction Model (VECM) are applied to investigate the evidence of cointegration and causality between energy consumption and economic growth in Australia. Shahiduzzaman and Alam (2012) use a multivariate model to estimate a single sector production function for five decades. Following the work of Stern (2000), they include energy, capital and labour as different inputs in the production function. Like Stern (2000), employment rate was used as a proxy for both Capital and labour. They find a long run relationship between capital, labour, and energy. When the thermal energy aggregation was used, they find a weak causality between energy consumption and economic growth. However, when the quality adjusted energy aggregation is introduce; strong bidirectional causality was found between energy consumption and economic growth.

There are varied conclusions on the energy consumption and economic growth relationship in Africa Countries. Most of the studies concentrate on electricity consumption and economic growth and also use bivariate models. For example, Adom (2011) investigates the relationship between economic growth and electricity consumption Ghana. He uses the Toda and Yamamoto (1995) approach to test and estimate the relationship between electricity consumption and economic growth from 1971 to 2008. The results indicate a unidirectional causality running from economic growth to energy consumption. Kwakwa (2011) examines the relationship and causality between disaggregated energy and economic growth, agricultural sector and the industrial (manufacturing) growth in Ghana from 1971 to 2007. Electricity and fossil fuels are used as proxies for energy consumption. Using the Johansen Cointegration test, he finds a unidirectional causality from overall growth and agriculture to fossil fuels and electricity consumption but bidirectional causality between manufacturing and energy consumption.

In summary, both panel and time series models have been applied to study energy demand. The essence is to incorporate both heterogeneous and homogeneous characteristics of the variance structure. Again, most econometric studies are undertaken in developed economies, the few on Africa examine the causal relation between energy consumption and economic growth in either a bivariate or multivariate framework.
This thesis departs from existing studies to estimate elasticities of different determinants on renewable energy, energy efficiency and natural gas demand. The essence is to examine the responsiveness of renewable and natural gas demand to changes in income, price, investments, human capital development, carbon emissions and natural resource depletion.

### 2.5 Energy consumption, Rebound and Carbon emissions

Environmental challenges such as global warming, acid rain and depletion of the ozone layer has often been associated with energy consumption (Sardianou, 2007). Due to the global nature of these environmental challenges, the United Nations Convention on Climate Change (UNFCC) sets out emissions target for developed countries through Kyoto Protocol from 2008 to 2012. The main targeted gases that the Kyoto covers include carbon dioxide (CO₂), Methane (CH₄), Nitrous Oxide (N₂O) and Sulphur Hexafluoride (SF₆). Wuebbles and Attul (2001) find that the rising greenhouse gases can be attributed to the increased consumption of fossil fuels. According to Knopf et al. (2010), the amount of fossil fuels reserves not yet used have the potential to add CO₂ beyond any scenario currently estimated.

Nordhaus (2009) estimates that the social cost of CO₂ emission is $8 per ton. However, using a discount factor 0.1%, Stern (2006) finds the social cost of carbon emissions to be $85 per ton. Pehnt (2006) therefore campaigns for the use of renewable energy since it has an infinite source and emit extremely low carbon as compared to fossil fuels. Johnstone et al. (2010) suggest that apart from environmental goals, investment in renewable energy help to achieve other public policy goals such as energy security.

#### 2.5.1 Rebound Effect

Technology policies and behavioural changes can led to reduction in the usage of energy and reduce carbon emissions. However, the gains from energy usage will result in reduction in the per unit price of energy services (Greening et al., 2000). As a result, consumption of energy services should increase or rebound, partially offsetting the impact of the efficiency gain in energy usage. According a hypothesis on energy efficiency by Jevon (1865), energy use rises as consumers become more efficient. That is, consumers tend to consume more goods (frequency
and quantity) whilst producers tend to produce more when efficiency rises. This hypothesis forms the basis of the rebound effect. Contributing to the discussion on the rebound, Berkout et al. (2001), posit that energy savings especially through technological progress that induces lower prices lead to enlarged purchases or inefficiency behaviour. In order to promote sustainable energy efficiency behaviour, effort should be made to incorporate technological improvement and high energy prices into energy policies to serve as deterrent to inefficiency behaviour.

2.6 Natural resources and economic development

Structuralist economics perspective argue that economies that depend mainly on primary commodities such as oil tend to have lower growth than resource poor countries (Sindzingre, 2009; Aty, 2001; Baldwin, 1956). On the other hand, new institution economists such as Alexeev and Conrad, (2009), Mehlum (2006) and Gylfason (2001) argue that the discovery or production of oil does not necessarily have any harmful effect on economic growth. Rather, the policies and institutions countries put in place to manage oil revenues can make oil a blessing or curse. The Structuralists cite Equatorial Guinea, Gabon, Nigeria and Venezuela as countries where oil production has had harmful economic consequences. The new institution economics perspective however cite Indonesia, Norway and UK as countries where oil production has led to economic gains.

Adam Smith argued that projects of mining and resource extraction instead of replacing capital consumes the capital that are employed (Lederman and Maloney, 2007). Therefore policy makers should give less attention to such projects. This assertion is supported by Prebisch (1959) who asserts that the slow growth of Latin America in the 1950’s can be attributed to the high emphasis on natural resources which has little capacity for technological progress. According to Sachs and Warner (2001), these attributes of natural resources imply that the long term development of resource dependent countries is negatively affected. Further to this, natural resources have been found to weaken economies (Aty, 2001). Tornell and Lane (1999) suggest that, natural resource dependent countries suffer from voracity effect where different interest
groups attempt to capture the economic rent obtained from natural resource exploration and exploitation. According to Murshed (2004), that point source natural resources such as oil have relative high negative impact on economic development.

Since 1859, the role of natural resource rent in economic development has been investigated. For instance, Cairness (1859) examines the effect of gold discovery on the industrial sector of Australia in the mid 1850’s. He finds that gold discovery had a negative impact on economic development. However, natural resources have positive effects too. According to Barbier (2007), rural population of developing economies directly depend on natural resources and the environment for their livelihood through direct exploitation, agriculture activities and livestock rearing. At the macro level, natural resource is a source of foreign exchange, employment and opens the economy for investment.

There are two types of natural resources. These are renewable resources such as solar, water bodies, forest, wind and non-renewable resources such as coal, oil, natural gas and minerals (Jannson, 1994). Both types of resources are important for economic development. For instance, Folke (1991) posits that renewable resources such as genetic and floral libraries help to control pollution by absorbing carbon emissions that are generated through the consumption on non-renewable energy. The non-renewable forms a major part of the energy mix of many countries and facilitate mobility, transformation of resources, lighting and heating.

Woolcock (2001) provides another classification of resources. These are the point source resource and diffused resources. According to Addison et al (2002), the point resources such as oil, gold, and other minerals are concentrated in terms of revenues and production. Due to this, there is a high propensity to engage in rent-seeking and other non-productive means micro and macro mismanagement. On the other hand, the diffused resources spread production and revenues throughout the economy. Examples of these resources are fisheries and agriculture produce. According to Easterly (2001), diffused resources are directly consumed either at the micro or macro level.

Theories of ecological economics suggest that all production raw materials and processes begin with natural capital in the form energy and raw materials. However, the transformation of these natural resources requires man-made capital. This means that, production requires both natural and made resources which imply that natural and man-made resources are complements and not
substitutes (Cleveland, 1991). This assertion is supported Daly (1992) who argues that due to the nature of natural capital, it is impossible to substitute it with man-made capital. To enhance sustainability, non-renewable resource should be exploited at a rate equal to investments in renewable resources whilst renewable energy resources exploitation should not exceed regeneration rate (Barbier, 1987). In addition, emission should not exceed the environment’s assimilation capacity (Jannson, 1994). This implies that there is a need to maximize economic development whilst maintaining the sustainable consumption of both renewable and non-renewable energy resources.

Matsuyama (1992) derives the linkages model to analyse the contribution of natural resources to economic growth and investigates the role of natural resource in a model in which manufacturing is characterized by learning-by-doing. He concludes that forces that push the labour force away from manufacturing and toward agriculture (natural resource) lower the growth rate of the economy by reducing the learning-induced growth of manufacturing. Because the learning effects are external to the firm, market equilibrium is not efficient. However, Sachs and Warner (1999) argue that the linkage model is less relevant for a natural resource sector such as oil production, which uses very relatively little labour and therefore does not directly draw employment from manufacturing.

Sachs and Warner (1995) find significant evidence that there is a negative relation between natural resource such as oil and per capita growth. Davis (1995) presents evidence that the resource curse is not a general problem. In considering the role of natural resource in economic development, Jannson (1994) suggests that there is a need to assess the ecologically sustainability of the resource, the equitable distribution of the resource benefits between the current and the future generations, regional effects, and the consideration of the environment and species. Indeed, Auty (1994) believes that the role of natural resources in development can be positive or negative subject to policies, level of development and the type of resources.

2.7 Oil resource management
The IEA (2014) forecasts that Sub-Saharan African will receive $3.5 trillion in oil revenues in 2040. However, due to missed opportunities to transform oil revenues into economic growth in the past, it is challenging to ascertain how this revenue can help. According to Toto...
(2009), the commonest feature among oil producing countries in Sub-Saharan Africa is poverty, lack of access to basic services such as electricity and health care and corruption. However, in terms of per capita, there have been improvements in countries such as Angola, Gabon, Ghana and Congo though this has not really translated into poverty alleviation and sustainable development path (Toto-Same, 2009). In order to utilize the oil revenues optimally, Ross (2012) calls for strong institutions and planning for fluctuating oil prices. The literature on oil discovery, oil production and oil revenue management identifies several negative characteristics that are associated with oil producing countries. Among them are the Dutch disease, terms of trade effect, poor quality of institutions, civil conflict, rent seeking and corruption as likely mediums through which resource abundance hinders growth (see for instance Boos and Holm-Muller, 2012; Brunnschweiler and Bulte, 2008; Alexeev and Conrad, 2009).

2.7.1 Dutch Disease
The Dutch disease describes an economy where a booming sector and a lagging one co-exist due to natural resource discovery. For instance, in an open economy, when a windfall such as oil, gas or gold find occurs, it leads to current account surplus which leads to the appreciation of the local currency under a flexible interest rate regime. This makes the non-natural resource sector uncompetitive and leads to high domestic prices (Sachs and Warner, 2001). In other words, the natural resource earnings are absorbed by the domestic non-tradable sector which leads to real appreciation of the local currency (Corden and Neary, 1982). These high prices of local produce leads to a stagnated export sector which deprive the economy of the benefits of export-led growth and increase unemployment. Krugman (1987) indicates that resource boom even if it is temporal leads to hysteresis. That is, a permanent loss in an economy’s competitiveness. This is because, when a country’s manufacturing base is eroded due to natural resource windfall and negative effect of exchange rate, the manufacturing sector cannot return to competitiveness even if exchange rate returns to normal. The export of manufacturing goods therefore becomes stunted. This makes export raw materials bias since the contribution of the service, manufacturing and the technical sectors are reduced. In a nutshell, a resource boom can crowd out the other productive sectors and human capital development of the economy and lead to decrease in export and productivity (Matsuyama, 1992). Again, there is lack of incentive to invest in the knowledge industry which affect the development of human capital (Gylfason,
All these factors acting together or separately, slow growth in resource rich countries (Frankel and Romer, 1999).

It has been argued that the relative slow growth of oil producing African countries in the 1980’s and 90’s cannot be wholly attributed to the Dutch Disease (Toto Same, 2009). Salai-Martin and Subramanian (2003) provide evidence that Nigeria’s relatively poor economic performance can be attributed to negative productivity growth and waste in physical capital accumulation instead of the Dutch Disease. This is because, when oil revenues are invested without proper coordination and long term focus, it leads to waste and corruption as the emphasis is on quantity and not quality (Bevan et al , 1999). When quality is sacrificed for quantity, productivity suffers. An example is the tree planting exercise by the Ghana government in the Savannah region although it is known that the trees cannot survive in the hot sun. This has led to waste and corruption which is been investigated.

### 2.7.2 Rent Seeking

Lane and Tornell (1996) attributes the resource curse to the ‘voracity effect’. The voracity effect is the loss of the gains of the windfall through corruption, weak institutions and excessive rent-seeking among competing interest groups. According to Bardhan (1997), corruption which is a key consequence of rent-seeking has been proven to a prime anti-growth factor. Gylfason (2001) posits that one of the key determinants of rent-seeking is policy maker’s confusion between wealth creation and wealth extraction. Economic rent is the excess of revenue derived from an economic activity over the sum of its supply prices of capital, labour and any other related inputs required to undertake the activity (Garnaut and Ross, 1983). In other words, resource rent is the true value of the natural resource, the difference between the revenues generated from extraction of the resource and the extraction cost and the cost of factors of production and their opportunity cost (Dickson, 1999). Watkins (2001) suggests that economic rent is the value of the resource at the point of production less all prior cost incurred, including a suitable return on investment.

In a nutshell, there is evidence (see Isham et al. 2005; Manzano and Rigobon, 2007) to suggest that the effects of resource abundance on economic growth differ according to whether the resource is a point resource, for example., oil and gold that are mined from a narrower geographic base, or a diffuse resource, for instance, livestock or agricultural yield from big and small farms. The point source resources tends to weaken institutions, thus economic
performance, more than the diffused resources (Isham et al., 2005; Manzano and Rigobon, 2007).

2.7.3 Oil Price Volatility
According to Caballero (2000), oil rents are volatile and therefore bad for investment decisions, income distribution and economic growth. These can distraught the programme and projects of the government and contribute to the oil curse. Mickesell (1997) suggests that the volatility of international oil prices leads to unpredictable revenue inflows and fluctuates government revenues. The swings in government revenues affect public expenditure, discourage private investment and leads to high government borrowing during ‘bust’ periods (Katz et al. 2004). This borrowing are most of the time spent on consumption and therefore does not expand the economy or lead to long term growth (Toto-Same, 2009).

2.8 Summary of literature
This chapter looks at the relation between economic growth and energy consumption. It can be concluded that, the methods in estimating the relation have been varied and the findings seems to be conflicting. Four main types of relationships have been reported in the literature. The first is the growth hypothesis where energy consumption leads to economic growth which suggest that energy is a direct or indirect complement to capital and labour in the production process. Hence a decrease in energy consumption reduces GDP. The second is the feedback hypothesis where energy consumption simultaneously influence each other. The third is the neutrality hypothesis where there is no relation between energy consumption and economic growth. Finally, the conservation hypothesis suggest that economic leads to increased energy consumption.

Third, the literature review looked at oil resource governance. Whilst it makes economic sense that oil revenues should lead to growth, this has not been the case in Africa. The causes of the ‘oil curse’ was examined in the literature review. The relative slower growth in oil producing African countries has been attributed to the Dutch Disease, rent seeking and oil price volatility. Finally, energy demand situation in Africa is looked. The literature reveals that both the production and consumption of energy has been increasing in Africa. However in terms of natural gas, Algeria, Angola, Egypt and Nigeria consume more than the rest of Africa put together.
The thesis adds to the existing literature in the following ways; first, the impact of geographical dimensions on the oil resource-economic growth nexus is investigated by applying a spatial economic econometrics. Second, the PGD is applied to the efficiency of specific types of energy such as electricity to provide customised recommendations. Third, the impact of energy-related carbon emissions on renewable energy is also investigated in this study. Fourth, a stochastic trend, is used to proxy for unobservable factors that affect natural gas demand but on which there are no quantitative data.

Chapter two reviews theoretical concepts and empirical studies on natural gas, renewable energy and oil resource management. In addition, various methods that have been applied in studying the determinants of renewable energy and natural gas are discussed in chapter 2. This review provides the foundation for chapter three to discuss in detail the various philosophies and methods underpinning this research. Chapter three follows this chapter and looks the research philosophy. The chapter has five main sections. This chapter examines the types of research and looks at the types of methodology. Further, chapter three traces the history of energy demand modelling and discusses both time series and panel models. Finally, the chapter argues for the need to incorporate stochastic trends in energy demand functions and the reasons for selecting the methods used in this thesis.
CHAPTER 3: RESEARCH PHILOSOPHY

3.1 Introduction
This chapter seeks to discuss the research strategy applied in this thesis and provides an overview of research concepts and the types of research methods. The chapter also examines different philosophical approaches to research and the major implications arising from such differences.

3.2 Research Paradigm
The term paradigm has its roots from the Greek word “paradeigma”. It means a model, pattern or example (Barker, 1992). According to Baker (1992), Adam Smith in his book “Powers of the mind” describes paradigms as “a shared set of assumptions”. He continues by saying that “paradigm is the way we perceive the world; water and the fish. The paradigm explains the world to us and helps us to predict its behaviour”. Covey (1989) describes paradigms as the way a researcher see the world in terms of perceiving, understanding and interpreting, a theory, explanation, model or map. Therefore, in beginning a research, a researcher has a mental map and questions that need answers.

There are several questions that require answers in research. These questions include ‘what to research?’ and ‘how to research?’(Remenyi et al., 1998). However, according to Holden and Lynch (2004), central to the researchers’ answers is their perspective on ‘why research?’ Indeed, the answers to these questions do not only provide the basis for the selection of a suitable methodology but also the philosophical underpinnings of the research. Kumar (2009) highlights the need for appropriate methodology to answer these questions.
According to Saunders et al. (2007), research is made up of six main decisions. The first stage is the research philosophy which can either be positivism, pragmatism, realism or interpretivism. The second stage is the research approach which can be induction, deduction or abduction. In the third stage is the methodological choice which encompasses quantitative, qualitative or mixed methods. The fourth decision is the research strategies whether to use experiment, case studies, surveys, archival study or narrative inquiry. The fifth decision is to determine the time horizon. This can be cross-sectional or longitudinal. Finally, there should be a decision on data collection methods and method of analysis.
Depending on the objective of the study and data availability, a particular philosophy can be applied. In order to put this thesis in the right perspective, few of the concepts have been clarified below:

**Positivism** is a research philosophy which challenges the notion of an absolute truth of knowledge and calls for the need to identify and evaluate the causes that influences outcomes (Bryman and Bel 2011). Generally, positivism seeks to generate hypothesis that can be tested. A major advantage of positivism is that it recognises that one cannot be absolute about claims of knowledge when studying behaviour and actions of the human species (Creswell 2009).

**Interpretivism** on the other hand goes beyond testing absolute truth about a phenomenon to understand human behaviour and why certain actions are taking.

These notwithstanding, Grix (2002) posits that the principal stages of any research is the ‘trinity’ of ontology, epistemology and methodology. Therefore questions and issues relating to the

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**Table 3.1 research layers and decisions that should be taken at each stage.**

<table>
<thead>
<tr>
<th>S/N</th>
<th>RESEARCH LAYERS</th>
<th>RESEARCH COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Philosophy</td>
<td>Positivism, Realism, Interpretivism and Pragmatism</td>
</tr>
<tr>
<td>2</td>
<td>Approach</td>
<td>Deduction, Abduction and induction</td>
</tr>
<tr>
<td>3</td>
<td>Methodological Choice</td>
<td>Primary, Secondary and mixed-method</td>
</tr>
<tr>
<td>4</td>
<td>Research Strategies</td>
<td>Experiment, survey, archival research, case study, ethnography, action research, grounded theory, narrative inquiry.</td>
</tr>
<tr>
<td>5</td>
<td>Time Horizon</td>
<td>Cross- sectional and Longitudinal</td>
</tr>
<tr>
<td>6</td>
<td>Techniques and Procedures</td>
<td>Data collection and data analysis</td>
</tr>
</tbody>
</table>
trinity of research should be dealt with before other such as data sources are considered (Hay, 2002).

### 3.2.1 Ontology
Ontology is the researcher’s perception of the world. It is the assumption the researcher make about the specific features of the society under consideration (Blaikie, 2002). According to Saunders et al. (2007), Ontology can be categorised into three different viewpoints. The first is positivism which has an objective view of society. The second category of ontology is interpretivism which has a subjective view of society. The final category is pragmatism, which can be positivism or interpretivism depending on the aim of the research. Grix (2002) further highlights the distinction can be made based on whether a phenomenon exist independently of social actors (objectivism) or are been fashioned by social actors (constructionism). In a nutshell, ontology seeks to provide two choices: rationalism and empiricism. A researcher can adopt any or both based on the aims and how he perceives society and social actors. Ontology therefore answers the question: *what is out there to know?*

<table>
<thead>
<tr>
<th>Table 3.2 Comparison of Research Philosophies</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONTOLOGY</td>
</tr>
<tr>
<td>Researcher’s view of reality</td>
</tr>
<tr>
<td>Positivism</td>
</tr>
<tr>
<td>External, objective and independent of social actors</td>
</tr>
<tr>
<td>Interpretivism</td>
</tr>
<tr>
<td>Socially constructed, subjective</td>
</tr>
<tr>
<td>Pragmatism</td>
</tr>
<tr>
<td>View chosen to best answer research question</td>
</tr>
<tr>
<td>EPISTEMOLOGY</td>
</tr>
<tr>
<td>Researcher’s view of what constitutes acceptable knowledge</td>
</tr>
<tr>
<td>Positivism</td>
</tr>
<tr>
<td>Only observable phenomena / facts</td>
</tr>
<tr>
<td>Interpretivism</td>
</tr>
<tr>
<td>Subjective meanings and social phenomena</td>
</tr>
<tr>
<td>Pragmatism</td>
</tr>
<tr>
<td>Both observable phenomena and subjective meanings</td>
</tr>
<tr>
<td>AXIOLOGY</td>
</tr>
<tr>
<td>Researcher’s view of the role of values in research</td>
</tr>
<tr>
<td>Positivism</td>
</tr>
<tr>
<td>Value-free or researcher is independent of process</td>
</tr>
<tr>
<td>Interpretivism</td>
</tr>
<tr>
<td>Value-bound / researcher is part of process</td>
</tr>
<tr>
<td>Pragmatism</td>
</tr>
<tr>
<td>Values may play a role in interpretation</td>
</tr>
</tbody>
</table>
3.2.2 Epistemology
Blaikie (2002) posits that epistemology deals with the question of ‘how can we learn about what is assumed to exist out there?’ Therefore epistemology involves gathering information about a phenomenon. Using Table 3.2, epistemology can also be classified under positivism, interpretivism and pragmatism. Positivism highlights the need for social sciences to adopt the methods of the natural sciences in order to test theories and hypothesis to develop relative laws (Bryman, 2012). Saunders et al (2012) emphasis that positivism relies on facts and seek to investigate causes and effects. Positivism is therefore a description of human behaviour. For instance, when condition B occurs, an employee Y respond by reporting to work early. Interpretivism on the other hand emphasis the understanding of human behaviour and seek answers to why people do what they do. According to Taylor (1975), the main theoretical underpinning of epistemology is phenomenology which views human behaviour as a product of how they interpret the world and uses such interpretation to understand human actions. For instance, interpretivism seeks answers to ‘why will employee Y report to work early when condition B occurs?’

3.2.3 Methodology
According to Grix (2002), a researcher’s methodology should reflect his ontology and epistemology arguments. That is, the choice of methodology should be based not only on the aim but also how the researcher perceive society and social actors. Taking these into consideration, Blaikie (2002) defines methodology as the procedures and processes researchers
employ to identity, collect and analyse data. According to Bryman (2002), choosing a methodology is synonymous to selecting a research strategy and identified two main types of research strategies: quantitative research strategy and qualitative research strategy.

**Qualitative research strategy** method is a data collection method which is unstructured in nature. An example of this method is focus groups and interviews to collect data (Saunders et. al 2009). Bryman (2002) posits that this method is an exploratory form of non-statistical research that is used to basically understand opinions and thoughts and underlying reasons for motivations. **Quantitative research strategy** on the other hand investigates the relationship between variables that are measured scientifically and numerically (Saunders et al 2012). Westerman (2006) posits that quantitative research is interpretive, constructionist and is based on inductive reasoning. It has been argued however that, either quantitative or qualitative, all experiments involve some form of studying the relationship between a dependent variable and independent variable (Bryman, 2012). Further, Collis and Hussey (2003) suggest that, researchers should be mindful of the reliability and validity of the framework they employ, whether quantitative or qualitative. Reliability deals with the consistency of the findings whereas validity explains the integrity of the findings (that is whether generalisation can be made out of the finding). Bryman highlights four main features of the quantitative method: (i) it follows objectivist path, (ii) it concentrates on quantification in terms of data collection and analysis (iii) it subscribes to the positivists view and (iv) it emphasis on testing theories and hypothesis.

**3.4. Adopted Philosophy**

This study employs a quantitative research strategy and adopts econometric methods under the positivism philosophy for the empirical analysis in the thesis. This is because econometric models help to model the relationships between variables. To begin with, econometric analysis helps to ascertain whether the independent variables explain a significant variation in the dependent variable. Moreover, it can determine how much of the variation in the dependent variable can be explained by the independent variables and lag dependent variable. Finally, it controls for other independent variables when evaluating the contributions of a specific variable.
or set of variables. According to Engelhard (2014), econometric methods are able to match the data to the model as closely as possible. Since the thesis aims at ascertaining the determinants of natural gas, energy efficiency and renewable energy, and study the relationship between oil resources and economic growth, the econometric model will be most suitable. The sections below discuss the evolution of econometric approach in energy demand studies.

3.4.1 Econometric models in energy demand
Three separate events or factors seem to have contributed to the increased in energy demand over the 50 years. The first is the oil price shocks in 1973, 1979, 2003 and 2008. The impact on oil price shocks on the economy is usually adverse. For instance, Roubini, and Setser, (2004) find that the 1973 oil price shock caused the 1974-1975 recession whilst the recession of 1980-1981 recession was caused by the oil price spike in 1979. When oil prices increase drastically, it leads to the consumption of alternatives such as renewables and natural gas. On the other hand, a drastic fall in oil prices increase the consumption of oil. The second factor is global warming. The impact of energy consumption on climate change has been studied by various researchers such as Nordhaus (1991), Holland and Mansur (2008) and Isaac and Vuuren (2009). The general findings from these studies is that, energy is a major contributor to global warming. For instance, Raupach et al., (2007) estimates that carbon emissions from fossil fuel burning and industrial usage of energy has been growing at more than 1% between 1990 and 1999 and more than 3% between 2000 and 2004. The final factor is energy security. There have been concerns about inconsistent energy supply especially in Africa. Eberhard et al, (2008) estimate that at 68 Gigawatts, the entire electricity supply of Sub-Saharan Africa is less than that of Spain. According to Ryan and Plourde (2009), the availability of data, advances in computing and modelling software and the training of energy analyst and researchers have made the increased in energy demand studies possible.

Urban et al, (2007) find that previous energy demand models assume that developing countries have the same features as the developed ones and therefore do not mostly consider them in energy demand estimations. However, sustained economic growth in South Africa, Egypt, Ghana, Nigeria and other African economies makes them important to be considered in global energy debates. In addition, access to clean and reliable source of energy in these countries is
still a development challenge despite their growth. Urban et al, (2007) identify energy characteristics of developing countries that can have energy demand consequences. These are poor performance of the power sector, transition from traditional-rural form of energy to modern-urban form and structural deficiencies in energy systems which have led to inadequate investments in the energy sector and misdirected energy price subsidies. In addition to these, traditional lifestyle, rural-urban migration, economic, institutional and social obstacles to investment in the energy sector and challenges to technology diffusion have an impact of energy demand (Pandey, 2002; Bhattacharyya and Timilsina, 2009).

Due to lack of data, energy demand estimations for developing countries have mostly relied on log-linear models (Pindyck 1979). Worrel et al, (2004) supports Pindyck (1979)’s assertion and further identify data quality and the inability to capture technological progress and productivity as a major modelling challenge in developing countries. Since the service energy provides is enjoyed through appliances and capital stock, the technology and productivity of the appliance influence the amount of energy demanded (Hunt et al, 2003, Bhattacharyya and Timilsina, 2009). In addition to these, the frequency of use which is informed by the energy usage behaviour influences energy demand. It is therefore important to incorporate the efficiency of the capital stock and behavioural trends in models when estimating energy demand.

Energy demand is therefore influenced by economic factors such as energy prices, consumer income, productivity growth and non-economic factors such as lifestyle, energy regulations and energy efficiency education. The main challenge has been unavailability of data to capture some of these factors such as consumer lifestyle.
3.5 Factoring technological progress in energy demand models

Ever since the pioneering work on technical progress and productivity by Timmergen (1942) and Solow (1957), four main hypotheses have emerged in this area. These are the Schur hypothesis, the Jorgenson hypothesis, deterministic hypothesis and the Hunt’s UEDT hypothesis.

3.5.1 The Schur (1982) hypothesis - disembodied and embodied technology

Schur (1982) propounds that the electrification of the US industry in the early 20th century contributed significantly to productivity growth. Schur posits that some forms of energy especially electricity and liquids have the distinct qualities of both embodied and disembodied technology. For instance, some types of capital have been innovated because of the availability of a type of energy. Again, the abundance and flexibility of electricity and liquid fuels inspired the design on industrial floors devoid of shafts and belts which are characteristics of solid fuel usage. This led to a systematic and logical arrangement of industrial to enhance free movement of people and goods. This means that, energy (electricity and liquids) enhances productivity, promote workplace efficiency and saves time. These forms of energy therefore promote growth.

3.5.2 The Jorgenson hypothesis - biased technical change hypothesis: disembodied technical progress

Jorgenson and Fraumeni (1983) and Jorgenson (1984, 1988) recognize the importance of disembodied technology to energy demand. Jorgenson used ‘time’ as a proxy to capture disembodied technological progress and finds that the estimated parameter of the ‘time’ variable in the cost share demand equation is positive. This means that technical progress is energy using. The implication of these findings is that an increase in the price of energy results in lower rate of multifactor productivity growth. When technical progress occurs; the same output can be produced using fewer total inputs. The proportional savings on some inputs may be larger than for other inputs (Berndt, 1990). Technical progress is said to be energy using if the proportional savings on energy is less than average proportional savings on all inputs. However, technical progress is said to be input saving if the proportional savings on energy is more than the average proportional savings over all inputs. For instance, Welsch and Ochsen (2005) examine the determinants of energy use in West Germany from 1976 to 1994 and find that technological change is energy saving.
It can also be neutral if the technology effect on energy is equal to the overall effect on all inputs. According to Jorgenson (1988), technical change is biased and energy using. This implies that the cost of energy increases overtime and therefore lower energy prices tend to accelerate productivity and vice versa (Stern, 2003).

3.5.3 Beenstock and Willcocks’ deterministic trend hypothesis
Beenstock and Willcocks (1981) use a deterministic time trend to capture energy productivity improvements in a study on OECD countries. They argue that though the linear deterministic trend was not ideal, it is better than not capturing the productivity improvements at all. They further argue that, without any measure to capture the productivity improvements, the estimated price and income elasticities will be underestimated. Using OECD aggregated energy data from 1950 to 1978, they find the estimated coefficient on the linear time trend to be -0.036, indicating autonomous technical progress occurs at 3.6% p.a., with estimated long-run price and income elasticities of -0.06 and 1.78 respectively. Whereas the exclusion of the proxy for technical progress (the linear time trend) results in estimates of -0.13 and 0.88 for the price and income elasticities respectively.

This method of capturing energy efficiency by a linear deterministic trend has been criticized by Kouris (1983). He posits that several factors affect energy consumption apart from income and energy price, all of which cannot be captured with a simple linear deterministic trend. According to Kouris (1983), factors such as the economic structure, inter-factor substitutability and fuel switching affect energy demand. He argues that some part of energy efficiency improvements is induced by price changes and agrees that the non-economic factors should be captured to get reliable elasticities but not with linear trend. He suggests that until a robust measure of non-economic factors is found, energy demand models should be estimated without the deterministic trend.

In a study that seeks to answer Kouris’ criticisms in 1983, Beenstock and Wilcox (1983) indicate that though the linear deterministic trend may not be a good proxy for the technical efficiency, it is better than not capturing it at all. To buttress the arguments raised by Beenstock and Wilcox, Welsch (1989) applied a model selection to energy consumption in eight industrialized countries and finds high differences among countries relating to the appropriateness of including a time
trend. This assertion is supported by Jones (1994) who found that including a time trend improves a model’s fit and also makes run price elasticities more credible.

### 3.5.4 Harvey and Hunt: The STSM and UEDT hypothesis

Harvey (1989) developed the STSM and formulated a dependent variable as a function of a time trend and a set of seasonal dummies. He decomposes a time series into different components that have direct interpretations. Harvey and Shephard (1993) extended the initial model by adding observable explanatory variables. Hunt et al (2003) becomes the first attempt to use the STSM for UK demand and coined the term ‘UEDT’. It is suggested that the STSM is superior for energy demand modelling since it allows for stochastically changing unobservable trend. According to Hunt and Ninomiya (2005), energy demand is determined by both the observable factors such as price and income and the unobservable factors such as improvement in technology, efficiency and changes in ‘taste’. ‘Taste’ is explained as non-economic and social factors that influence consumer behavior like energy regulations, family size, culture and lifestyle.

Hunt et al, (2003) therefore argue that such factors cannot be ignored or simply be captured with a deterministic linear trend. This is because; technical progress can take many forms and arise from different sources. It can be embodied, disembodied, endogenous or exogenous and cannot be simply captured with a deterministic linear trend. Again, a change in ‘taste’ shifts the demand curve to the right or left and should be estimated when modelling energy demand. According to Weber and Perrels (2000), lifestyle and taste can be used to identify the expenditure patterns of time and money. Hunt et al (2003) therefore suggest an inclusion of a stochastic trend instead when modelling energy demand function and referred to this trend as the Underlying Energy Demand (UEDT) which captures efficiency, technological progress and other non-economic factors.

Hunt and Ninomiya (2003) examine the long run relationship between energy demand, GNP and real energy price in Japan from 1887 to 2001. They find that income has much effect on energy demand than price. The study reported a price elasticity of -0.2 and found that UEDT has a concave shape. These findings suppose that Japan is very energy intensive from 1887 to the 1950’s. After the 1950’s, the country becomes energy efficient. Al-Rabbaie and Hunt (2006) estimate energy demand functions for 17 OECD countries with data from 1960 to 2003 using a
Structural Time Series Model. The findings suggest that long run price elasticity ranges from -0.1 to -0.4 whilst long run income elasticity range from 0.5 to 1.5. The estimated UEDT varies across countries reflecting different rates of technological progress, energy efficiency and different socio-economic factors that impact energy demand in respective countries.

Technology and lifestyle are included in an energy demand function by Kratena et al, (2009) to directly capture their impact on energy demand in Austria from 1990 to 2006. Population density and building features which are obtained in a cross section survey are used as proxies for lifestyle and technology respectively. They find that technology and lifestyle changes have important effect on energy demand in the residential sector. Filippini and Hunt (2011) estimates a panel frontier of aggregate energy demand function for 29 countries over the period 1978 to 2006 using a stochastic frontier analysis. Energy efficiency of each country is estimated together with energy prices, climate, share of industrial value added, share of service value added and the UEDT. They find that the variables have significant effect on energy demand and that energy intensity is not a good proxy for energy efficiency for all countries. Broadstock and Hunt (2010) estimate energy efficiency separately from the UEDT. Their study examines the impact of exogenous non-economic factors on the UK transport oil demand from 1960 to 2007. The structural time series is employed and energy demand is modelled as a function of real price of oil, income, and fuel car efficiency. The study found an income elasticity of 0.6, price elasticity of -0.1 and efficiency elasticity of -0.3. They conclude that non-economic factors have major impact as compared to price and efficiency. Therefore, taxes and energy efficiency measures may not have the same impact as income and other non-economic factors on transport oil demand in UK.

In this thesis, the structural time series model together with panel data analysis and spatial effects model are employed.

3.6 Panel data analysis
Panel data analysis are quickly displacing cross-sectional methods in social science studies (Halaby, 2004). Panel data analysis contains repeated observation over the same country for several time periods. It can be classified as a short or long panel depending on the number of countries and the time period. If it contains a small number of countries but long time period, it is a long panel. However, if it contains large number of countries but short time period, it is
considered a short panel. When all the countries are observed at every time period it is classified at a balanced panel. Panel data analysis have a number of advantages over other forms of estimation. Panel data analysis is used in these thesis for three reasons. First, according to Hsiao (2003), panel data models take into account greater degree of heterogeneity that characterizes the different countries over time. This quality overcome the bias of results often produce by time series and cross-sectional studies (Baltagi, 2005). Second, by combining time series and cross-sectional data, panel data increase the number of observations significantly. Finally, according to Wooldridge (2002), panel data analysis under certain conditions can be used to obtain consistent results even in the face of omitted variables.

In this thesis, three main types of panel data analysis are used. They are:

i. Spatial panel data analysis

ii. Dynamic panel generalized methods of moments

iii. Panel random effects model

3.7 Types of energy demand models

According to Ryan and Plourde (2009), several factors including computing power, data availability and data education have led to the development of energy demand models. Hartman (1979) summarizes energy demand decision of the consumer into three steps. First, the consumer decides whether to buy an energy-using appliance. Second, the consumer decides the efficiency and technological level of the appliance to be bought such as the fuel type it will use and whether the appliance is new or old. Finally, the consumer’s intensity and frequency of use of the appliance will also influence the amount of energy demanded. Bhattacharya and Timilsina (2009), argue that energy demand models should be able to incorporate all or most of the consumer energy decision-making process. This can be done by taking into account the characteristics of the energy user, technological progress of the appliance and frequency of use. Since the outcome of energy demand models inform policy recommendations, regulations and policies which influence energy demand should also be incorporated in models (Hartman, 1979).
Despite these recommendations, it has been suggested that there is no ‘perfect’ model to estimate energy demand (Ryan and Plourde, 2009). The type of a model is informed by data availability, geographical factors and objective of the study. Following the work of Dilaver (2012), three types of energy demand models are reviewed in this section. These are (a) end-use models, input-output models and econometric models.

The end-use modelling approach identifies the contribution of each end-user to the aggregate consumption. According to Dilaver (2012), the end-use modelling approach technically relates the output with the amount of energy use in each sector or industry. Timilsina and Bhattacharya (2009) summarizes the process of using end-use model into five basic steps. First, aggregate demand is divided into homogenous end use sectors. Second, the evaluation of determinants of interrelationships and the grouping of these determinants in a hierarchical order. Third, the mathematical formulation of the hierarchy and the interrelationships identified in step two. Fourth, different scenarios are then designed based on the determinants and variety of assumptions. Finally, forecasting can then be undertaken based on the determinants, assumptions and the interrelationships. On the advantages of the end-use modelling approach, Timilsina and Bhattacharya (2009) suggest that the model relies on recent structural and technological relationships and changes instead of history. However, the end-use modelling approach faces the challenge of data limitation since the level of disaggregation is often not supported by available data (Pesaran and Smith, 1998). In addition, the model may not be able to detect price induced effects on energy demand (Timilsina and Bhattacharya, 2009).

With regards to the input-output models, it quantifies complex relationships under fully general equilibrium condition (Arbex and Perobelli, 2010). Dilaver (2012) stipulates that the input-output model analyse the process by which input of one sector is converted to output or into another industry’s input. The input-output model helps to estimate both direct and indirect energy demand by studying inter-industry transactions and relationships (Timilsina and Bhattacharya, 2009). Further, the model assumes time-invariant input-output ratio which fails to account for the effects of technological progress on energy demand (Timilsina and Bhattacharya, 2009).

Finally, econometrics models quantifies statistical relationship between a dependent variable such as energy consumption and independent variables such as income, prices of energy and
technological progress. According to Dilaver (2012), it can be used to analysis the past or predict the future and is usually based on economic theory. A major advantage of the econometrics approach is the fact that it takes its roots from economic theory. Over the past 20 years, different econometric techniques have been applied to energy demand studies. Prominent among them are cointegration techniques and the structural time series model which is use to estimate the relationship between energy demand and its determinants. These determinants can be categorized into four. The first are economic factors such as the price of the type of energy and the prices of substitutes and complements and income. The second determinants are the demographic and consumer characteristics which include population, the frequency and intensity of use and consumer choice of energy using appliance. The third and fourth determinants are the environmental and technological factors such as average weather conditions, the efficiency of the energy using appliance, productivity of the appliance, environmental laws and regulations. This thesis employs econometric analysis for three main reasons. To begin with, econometric analysis helps to ascertain whether the independent variables explain a significant variation in the dependent variable. Moreover, it can determine how much of the variation in the dependent variable can be explained by the independent variables and lag dependent variable. Finally, it controls for other independent variables when evaluating the contributions of a specific variable or set of variables.

3.8 Adopted Methods
This thesis applies both the time series and the panel methods. In chapter 4, three panel methods namely, GMM, panel fixed effect and panel random effects, are applied to the study of renewable energy demand. Chapter 5 employs the GUM, which is a time series method and two panel methods, GMM and panel two stage least squares are used to study the predictors of natural gas demand. In chapter 6, a PGD is employed to study energy efficiency. Finally, a spatial panel method considering communication, cultural and economic spillover effects is employed in chapter 7 to study the relationship between oil resources and economic growth. The justification for the selection of each method and the details of the methods are explained in each chapter.
After analysis the types of methods in Chapter 3, Chapter 4 looks at the practical application of these methods. Specifically, Chapter four examines the determinants of renewable energy demand in oil producing African countries. This chapter is motivated by the fact that renewable energy is carbon neutral and abundant in Africa. Three models, a panel GMM, a two-way fixed effects and a random effects model are applied to examine the effect of GDP, price, energy resource depletion, and energy related carbon emissions on renewable energy demand.
CHAPTER 4: RENEWABLE ENERGY DEMAND

4.1 Introduction

Economic growth has long been considered a solution to unemployment, poverty and equity issues (Boqiang, 2003) making growth the ultimate goal of every economy. This is because economic growth enhances the standard of living and aids the development of human capital. It has further been established that energy is a key determinant of economic growth (Stern and Cleveland, 2004). According to Stern and Cleveland (2004), energy is the pivot on which the wheels of society turn. Energy facilitates heating, lighting, transport, and the transformation of inputs into outputs. Thus, energy is a key factor for economic development. This means that energy challenges such as the oil price crises in 1973 and 1979 and 2008, climate change and potential depletion of fossil energy sources, present an opportunity to the World to reflect and consider energy issues since they could be a limiting factor to economic growth.

Coupled with these factors, energy access has been a critical challenge to economic development in Africa. Access to modern form of energy is necessary, and a requirement for development since energy has been found to be a key factor of production. However, in Sub-Saharan Africa (SSA), just 31% of the population have access to modern energy, such as electricity (IEA, 2010). Out of about 1.4 billion people without access to energy globally, 15% are in SSA. Out of the 587 million people without access to electricity in Africa, 585 million are in SSA. Can one imagine London or New York without electricity for one hour? That will be disaster! Many businesses will come to halt and many will become inefficient without energy. This makes the use of energy indispensable. These statistics therefore threaten sustainable development, may hinder development and prevent many countries from achieving the Millennium Development Goals. The World Bank (2001) finds a strong correlation between electricity access and reduction in poverty. The study also indicates that efficiency and clean energy is crucial to the reduction of poverty and essential for economic growth, particularly in rural areas. For instance, business activities, including opening of cold store to sell fish, selling chilled water and drinks, night-time sewing and hair dressing can be undertaken in rural areas when there is access to electricity. These activities increase employment, income and overall development of the area.

This notwithstanding, energy use has negative environmental consequences. The World Resource Institute estimates that 61.4% of global greenhouse emissions emanate from energy
consumption. Thus, any solution that reduces the negative effect of energy consumption should include investment in cleaner and reliable sources of energy to allow energy to play its role in the economy without endangering the environment. Hence, two key forms of energy—energy efficiency and renewable energy consumption—stand out.

Renewable energy such as wind, solar, geothermal, wave and waste have the advantage of being carbon-neutral and non-depletable (Sadorsky, 2011). Renewable energy therefore becomes the solution to the recent concerns of energy security, sustainable development and climate change for three reasons. First, renewable energy sources abound in Africa and can continually supply energy over a long term if developed. Second, renewable energy can aid the provision of modern energy to rural areas and other places that are difficult to be reached by the electricity grid. Third, renewable energy can help to offset the proportion of foreign exchange that is used to import oil. In order to enhance sustainable energy supply, there is the need to invest in renewables whilst curbing the use of fossil fuel. This calls for a forced choice between fossil fuel and renewable energy. However, this choice can have environmental, investment and growth consequences.

Global investment in new renewable capacity increased to USD 120 billion in 2008 (REN21 2009). Annual percentage gains for 2008 also show significant achievements in all types of renewable energy, especially the grid connected solar photovoltaic capacity, which grew by 70%. In addition, wind power grew by 29%, solar hot water increased by 15%, and small hydro expanded by 8% (El-Ashry, 2009). Notably, such investments usually take place in developed economies, such as the European Union. By contrast, the major forms of renewable energy consumption in Africa are biofuels and waste (IEA, 2010). These traditional and typically unprocessed renewable forms of energy consumption comprise wood fuel, charcoal, animal waste and agricultural residues (Karekezi, 2002). They trigger both health and environmental effects, such as respiratory diseases, degradation and deforestation (Kantai, 2002). There is the need to harness the modern forms of renewable energy to curb these problems. According to Deichmann et al. (2011), Africa has a renewable energy potential in the form of abundant sunshine all year round for solar energy, river and water bodies for hydroelectric dams and wind energy potential. Karekezi et al. (2003) find that only 7% of Africa’s hydro potential is harnessed. Since renewable energy investments require huge capital outlay, the drivers of renewable energy need to be examined to guide policy design.
Africa features 1.1 Gigawatts hydropower capacity, 900 Megawatts of geothermal potential, abundance wind and solar potential (Karekezi and Ranja, 1997). To transform these potential energy resources into energy supply, there is a need for both private and public investment in the sector. This calls for studies that aid renewable energy policy designs and help to make investment decisions in the sector. Unfortunately, few studies have been conducted on renewable energy in Africa. For instance, Bugaje (2006) reviews renewable energy policies of Egypt, Mali, Nigeria and South Africa and finds that (i) the use of fuel wood can create environmental damages, and (ii) Africa has the potential of harnessing the renewable energy potential given the right investment and human capital. Karekezi and Kithyoma (2002) suggest that for Africa to harness its renewable energy potential there is the need for long term planning and financing.

This chapter contributes to the literature on energy in three main ways: First, we attempt to fill both the literature and policy gap by investigating the impact of energy resource depletion on renewable energy consumption in oil-producing African countries. The inclusion of the energy resource depletion is to test whether the potential depletion of fossil fuels has effect on the amount of renewable energy consumed. Second, the effect of energy-related carbon emissions on renewable energy demand is estimated. That is, since carbon emissions in Africa can be attributed to several factors such as bush burning, farming activities and energy consumption, it is prudent to distinguish the effect of energy related emissions on renewable energy consumption. Third, by means of a dynamic panel generalized methods of moments, the effects of past values of renewable energy demand on current consumption are assessed. The study further employs a one-way and two-way fixed effect models to estimation.

This chapter is organized as follows. The second section provides a review of the existing literature on the determinants of renewable energy demand and looks at the relation between renewable energy and sustainable development in Africa. The third section presents the methodology and the sources of data and model specification. The fourth section presents the results and discussion. The fifth section concludes and provides policy recommendations.

4.2 Literature Review

Africa’s population will be 2 billion by 2050 with 40% living in rural areas according to a report by the United Nations Human Settlements Programme (2010). In addition, the report states that
655 million Africans will have no access to electricity by 2030. It is necessary to invest in renewable energy sources such as geothermal, solar, hydro, wind and biofuels that are abundant in Africa. This is because renewable energy technologies are considered to be one of the cheapest solution to off-grid and mini-grid electrification in rural areas. Further, the need to control the environmental effects of energy consumption and enhance energy security has led to the design of renewable energy policies. An example is the 20-20-20 policy of the European Union, which seeks (i) to reduce greenhouse emissions by 20% (relative to the 1990 level), (ii) 20% improvement in energy efficiency and (iii) increase the share of renewable energy in the energy mix to 20% by 2020. Due to such policies, there has been a gradual increase in studies on the factors that influence renewable energy in Europe in particular and in the developed countries in general. The data envelope analysis is applied to 45 economies by Chien and Hu (2008) to analyse the effects of renewable energy on the technical efficiency of 45 economies over the period 2001-2002. They find that an increase in the use of renewable energy improves an economy’s technical efficiency while an increase in the use of traditional energy (fossil fuel) decreases technical efficiency.

Sadorsky (2009a) studies renewable energy consumption for the emerging countries in a panel cointegration. He shows that in the long run, increases in real GDP per capita and CO2 per capita are found to be major drivers behind per capita renewable energy consumption. Oil price increases have a smaller albeit negative impact on renewable energy consumption. Specifically, in the long run, a 1% increase in real income per capita increases consumption of renewable energy per capita in emerging economies by approximately 3.5%. Long-run renewable energy per capita consumption price elasticity estimates are approximately equal to -0.70. These results are robust across two different panel cointegration estimators.

Sadorsky (2009b) employs a panel-cointegrated FMOLS model to investigate the relation between renewable energy consumption and economic growth in G7 countries. He shows that a 1% increase in real GDP per person increases per capita renewable energy consumption by 8.44%, while a 1% increase in carbon dioxide emissions per person increases per capita renewable energy consumption by 5.23%.

Bowden and Payne (2010) study the causality between residential consumption of renewable energy and economic growth in the US from 1946 to 2006 and find a unidirectional causal relation from residential renewable energy consumption to growth. Apergis and Payne (2010)
find bidirectional causality in both the short and long-run between renewable energy consumption and economic growth.

Marques et al. (2010) use panel regression techniques to investigate the relationship between renewable energy consumption, political factors, socioeconomic factors, and country specific factors for a panel of 24 European counties covering the period 1990-2006. They find that lobby efforts from the fossil fuel sector, and CO2 emissions reduce renewable energy consumption, while reducing energy self-sufficiency promotes renewable energy consumption. Menyah and Wolde-Rufael (2010) use vector auto-regression techniques to study the relationship between carbon dioxide emissions, renewable energy consumption, nuclear consumption and real GDP for the US over the period 1960-2007. They find causality running from nuclear energy consumption to CO2 emissions but no causality running from renewable energy consumption to CO2 emissions. There is evidence of causality running from GDP to renewable energy. Apergis and Payne (2011) use panel cointegration techniques to examine the relationship between renewable energy consumption and economic growth for a panel of 6 Central American countries over the period 1980-2006. Results from a panel error correction model indicate bidirectional causality between renewable energy consumption and economic growth in both the short- and long-run.

The literature review reveals two major trends. First, most of the studies on renewable energy concentrate on Europe, Asia, America or developed and emerging countries. In addition, most of these studies test the causal relation between renewable energy and economic growth in a multivariate framework. Studies on renewable energy are important because of the growing concerns over energy security and global warming (Sadorsky, 2009a). According to the IEA (2006), renewable energy is projected to be the fastest growing energy source between 2010 and 2030. Again, though renewable energy consumption-economic growth causality has been extensively investigated, factors that influence renewable energy demand has received less attention especially in the context of Africa. This study contributes to the renewable energy demand literature by studying these factors. Since there is lack of econometric study on renewable energy demand in Africa, this study seeks to fill this gap.
4.2.1 Renewable Energy and Sustainable Growth in Africa
Africa has been growing in terms of population and development over the last two decades. According to the International Renewable Energy Agency (IRENA, 2012), Africa’s population will be 2 billion by 2050 with 40% living in rural areas. The accelerated population growth will put pressure on energy resources. The IEA (2012) estimates that 57% of Africa’s population had no access to electricity in 2010. This implies that there is the need to provide modern energy to the present generation and make plans to cater for the future ones. Apart from population, economic growth has also been a vital reason for African economies to develop energy infrastructure. IRENA (2012) posits that 7 out the 10 fastest-growing economies in the world over the last decade are in Africa and projects Africa’s growth to seven-fold by 2050. In order to provide sustainable energy that meets both growing population and economy, there is the need to invest in renewable energy.

To begin with, renewable energy sources are indigenous and help to promote self-sufficiency in energy supply. This helps to reduce the impact of price and supply vitality of fossil fuel on the economy. The dependence on renewable energy helps African economies to save the money that would be used to import crude oil. For instance, African economies spent USD 18 billion in 2010 to import crude oil (IRENA, 2012). This amount exceeds the foreign income Africa received in the same period. Adding the cost of oil imports to that of oil subsidies, Africa stands to gain more if there is investment in renewable energy to reduce dependence on oil.

Secondly, renewable energy offers technologically viable alternative to connect rural areas to electricity in the form of off grid or mini grid systems. This will help businesses in remote areas and improve healthcare and education. Thirdly, because renewable energy sources are locally based, they help create jobs in terms of construction, operations and maintenance for the indigenes and the economy as a whole. These advantages together with the fact that renewable energy is carbon-neutral and non-depletable make it the ideal source of energy for sustainable growth in Africa. Since agriculture in Africa is mostly rain-fed, curbing the impact of energy on the climate will help boost productivity.

Karekezi (2002) identifies three main reasons for the growth in renewable energy in Africa. The first reason is the petroleum price increases especially between 1998 and 2011, which induced an increase in import expenditure of African countries. The second reason is the quest of many countries to boost electricity supply and reduce power outages. For instance, countries such as
Ghana and Nigeria embarked on power rationing in the past, which had adverse effects on their economic performance. The third reason is the commitment of international bodies to curb global emissions. Though efforts have been made to switch from traditional sources of renewable energy to modern sources, the challenge has been the huge upfront investment required for such energy transition. Due to the huge investments required, estimates of the factors that influence renewable energy demand can serve as a guide to predict potential demand and returns on investment. Specifically, this chapter seeks to test

1. Whether energy resource depletion and increase in income influence renewable energy demand in oil producing African countries
2. Whether energy-related carbon emissions enhances renewable energy consumption

4.3 Methodology

4.3.1 Data
There are two main forms of energy which are non-renewable energy and renewable energy. The non-renewable energy comprises of natural gas, gasoline, coal etc. whilst the renewable energy sources include solar, biomass, hydro, wind, geothermal, fuel wood etc.

Figure 4.1: Renewable and non-renewable energy consumption in oil producing African countries
Figure 4.1 presents renewable and non-renewable energy demand trend in oil producing African countries. Renewable energy, including mainly woodfuel, hydroelectric sources, solar, wind and biofuels are used for power generation (wind, hydro, solar) and cooking (woodfuel). On the other hand, the non-renewable energy (gasoline, natural gas, coal and diesel) are mostly used for power generation, manufacturing and transportation.

Annual data from 1985 to 2010 on renewable energy in metric tonnes of oil equivalent is obtained from the International Energy Agency. Non-renewable energy which include natural gas, diesel and gasoline are mostly used for power generation and transportation. The renewable energy data captures the sum of hydro, geothermal, wind, solar, industrial waste, municipal waste, biomass, biofuels and charcoal measured in Kilotonne of oil equivalent (ktoe). GDP in current US dollars serves a proxy for economic growth. Consumer price index (CPI) represents changes in energy prices. Both GDP and CPI are obtained from the World Bank Development indicators. The choice for consumer price index as a proxy for the energy price variable was informed by two reasons. First, there is unavailability of consistent data on energy prices on the countries under consideration. Second, studies, such as Mahadevan and Asafu-Adjaye (2007) and Tang et al (2013), use consumer price index as a proxy for energy price when they carried out similar studies on Africa. Renewable energy consumption made up of biomass, hydro, waste, solar and wind grew at 0.4% annually in the countries under study from 1985 to 2010 (IEA, 2013). Our sample includes Algeria, Angola, Cameroon, Congo, Cote D’ivoire, Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia. Data on Libya and Equatorial Guinea were not complete. Since renewable energy in Africa is mainly used for cooking or residential purposes and power generation, the study further uses data on carbon emissions that are generated as a result of electricity production. According to Bhattacharya (2011), global warming is highly associated with emissions from energy consumption and production. Moreover, as developing countries move from agrarian to manufacturing economies, they produce more energy and hence emit more carbon. This requires the effect of energy-related carbon emissions to be estimated separately.
Table 4.1 Summary statistics

<table>
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<th>Variables</th>
<th>Mean</th>
<th>Median</th>
<th>Max</th>
<th>Min</th>
<th>Std</th>
<th>Skew</th>
<th>Kurt</th>
<th>JB</th>
<th>Prob</th>
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<td>0.397184</td>
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<td>15597.28</td>
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<tr>
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<td>11463.16</td>
<td>4.339659</td>
<td>949.6882</td>
<td>5.397326</td>
<td>48.23722</td>
<td>46052.39</td>
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</tr>
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<td>1.131005</td>
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</table>
Notes: Table 4.1 summarizes descriptive statistics (sample mean, median, maximum, minimum, standard deviation, skewness, kurtosis, the Jarque-Bera test statistic, and the p-value associated to the Jarque-Bera test statistic) of renewable energy consumption (REN, in kg of oil equivalent per capita), gross domestic product (Y, in real 2005 US dollars per capita), capital (K, in real 2005 US dollars per capita), labour (L, in millions of persons), human capital, a proxy for government expenditure on education (H, in real 2005 US dollars per capita), energy depletion (D, in real 2005 US dollars per capita), CO2 emissions (in tonnes per capita) and the price level (consumer price index). The sample period runs from 1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d’Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Data on human capital are unavailable for Gabon. Therefore, Gabon has been excluded from the sample of country-years used to estimate our panel data models.
Table 4.1 summarizes descriptive statistics of the variables used in our study. All variables are expressed in real per capita terms. Gross domestic product per capita (Y), capital per capita (K), human capital per capita (H) and energy depletion (D) per capita are expressed in real 2005 US Dollars (USD). Renewable energy consumption (REN) is measured in tonnes per capita of oil equivalent. Population (POP) is measured in millions of persons. CO2 emissions (C) are expressed in tonnes per capita.

Over the sample period and across countries, the mean of real GDP is 2,275.90 real USD per capita. Real GDP per capita varies between 104 and 15,597.28 USD per capita. The degree of variability is also witnessed by the standard deviation. Real GDP deviates from its mean on average by 2,235.85 USD per capita. The data for this variable are positively skewed (with the value of the skewness standing at 2.2781) and leptokurtic (with the value of excess kurtosis of 9.6855). The latter suggests that the distribution of real GDP across countries and over time features heavy tails, whereas the former suggests that positive deviations from the mean tend to be more dispersed than negative deviations. Overall, positive skewness and excess kurtosis collectively result in a non-normal distribution, as indicated by the Jarque-Bera test statistic and the associated probability value.

Real capital per capita is measured as a flow variable. It takes on value 618.18 USD on average across countries and over time. Real capital varies dramatically in the sample of country-years, ranging from the value as low as 4.34 USD to as high as 11,463.16 USD per capita. Capital also deviates from the mean on average by 949.69 USD per capita, as indicated by the standard deviation. Large positive skewness (5.3973) and large excess kurtosis (48.2372) lead to the rejection of normality in real capital per capita.

Oil-producing African countries are populated on average by 27.028 million of inhabitants over the sample period. However, this number varies between 0.601 million and 168.834 million with the standard deviation of 29.311 million. Again, the data are positively skewed (with the value of skewness standing at 2.1637) and highly leptokurtic (with the value of excess kurtosis estimated at 8.4489). Overall, the null of normality of the data is decisively rejected by the Jarque-Bera test statistic.

Human capital averages 72.78 USD per capita across countries and over time. The data also feature a considerable degree of volatility, as reflected within the range of 1.13 USD and 362.03 USD per capita, and the standard deviation of 71.09 USD per capita. As in the
case of real GDP per capita, real capital per capita and population, the data are also positively skewed, with the value of skewness of 1.4284, and leptokurtic, with the value of excess kurtosis estimated at 4.6259. Positive skewness and excess kurtosis jointly result in the non-normality of the data, as witnessed by the Jarque-Bera test statistic and its associated probability.

Energy depletion averages 340.83 USD across countries and over time. Again, the data are highly volatile, with the values ranging from 0 to 7,214.05 USD per capita and the ensuing standard deviation estimated at 747.90 USD per capita. Moreover, energy depletion is positively skewed (with the asymmetry coefficient standing at 4.4662) and highly leptokurtic (the value of kurtosis of 28.9407). Overall, the null of normality is decisively rejected by the Jarque-Bera test statistic.

CO2 emissions per capita are estimated at 0.4991 tonnes per capita across countries and over time. The data vary between 0.0014 and 5.1213 tonnes per capita. The range of variation causes the data to deviate from the sample mean by 1.0449 tonnes per capita. Again, we observe positive skewness (with the asymmetry coefficient standing at 2.9529) and large excess kurtosis (with the value of kurtosis standing at 10.5158). In the regression analysis, the t-test is based on the assumption that the random disturbance terms is normally distributed. Under this assumption, the t-statistic then follows a t-Student distribution. If the random disturbance term is not normally distributed the p-value will be wrong. Testing for normality of the dependent variable therefore help ascertain whether the random disturbance term is normally distributed. Indeed, the classical linear regression model implies that the distribution of the dependent variable is determined by the distribution of the random disturbance, since the explanatory variables are non-stochastic with regard to the random disturbance. If they are not, then it is important to find out their distribution.

The price level averages 55.4985 across countries and over time. The price level deviates from its mean by on average 52.3942. The price level is relatively less skewed than the other variables in our study. More specifically, the coefficient of skewness is 0.8933.
Likewise, excess kurtosis (3.5515) is also lower relative to the other variables. Nevertheless, positive skewness and excess kurtosis cause a significant departure from normality in the data, as the probability associated to the Jarque-Beta test statistic is arbitrarily close to zero.

Lastly, renewable energy consumption averages 0.2499 tonnes of oil equivalent per capita. The data range from 0.0004 and 0.8227 tonnes per capita, with the standard deviation estimated at 0.2049 tonnes per capita. It is positively skewed (1.2530) and leptokurtic (4.1765). Therefore, the Jarque-Bera test statistic unambiguously rejects the null of normality in the data (Prob = 0.0000).

**TABLE 4.2 Coefficients of correlation**

<table>
<thead>
<tr>
<th>Variables</th>
<th>REN</th>
<th>Y</th>
<th>K</th>
<th>L</th>
<th>H</th>
<th>D</th>
<th>C</th>
<th>P</th>
</tr>
</thead>
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<td>0.140047</td>
<td>0.085221</td>
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</table>
This table summarizes the Pearson coefficients among renewable energy consumption (REN, in kg of oil equivalent per capita), gross domestic product (Y, in real 2005 US dollars per capita), capital (K, in real 2005 US dollars per capita), labour (L, in millions of persons), human capital (H, in real 2005 US dollars per capita), energy depletion (D, in real 2005 US dollars per capita), CO2 emissions (in tonnes per capita) and the price level (consumer price index). The sample period runs from 1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Data on human capital are unavailable for Gabon. Therefore, Gabon has been excluded from the sample of country-years used to estimate our panel data models.

We begin our analysis by conducting the Im, Pesaran and Shin (2003). The essence of the unit root is to ascertain where the variables are stationary. After checking the form of the empirical function, three models are estimated. These countries include Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Egypt, Gabon, Ghana, Libya, Nigeria, South Africa, Sudan and Tunisia. Renewable energy grew at 4.71% annually from 1985 to 2010, the total of 260 observations.

4.3.2 The Model

In order to examine the determinants of renewable energy demand in oil-producing African countries, we employ a panel-data regression. The use of a panel-data regression in studies of energy demand has been limited (for informative review, see Suganithi and
Specifically, we employ three different panel-data specifications; a random effects model, a period- and cross-sectional random effects model and the Arrellano and Bond (1991) generalized method of moments (GMM) estimator of a dynamic panel-data model. This approach uses instrumental variables that address the problem of endogeneity among the explanatory variables (Omri et al., 2014). Following the work of Omri et al., the lag forms of the dependent variables and predictors are used as instrumental variables. Additionally, it avoids estimation bias that is associated with the correlation between the lagged dependent variable and the error term.

This study seeks to investigate the potential determinants of renewable energy demand in oil-producing African countries. The renewable energy demand is modelled as a function of an array of explanatory variables

\[ REN_{i,t} = F(Y_{i,t}, K_{i,t}, L_{i,t}, H_{i,t}, D_{i,t}, C_{i,t}, P_{i,t}) \]  

Where \( i = 1, \ldots, N \) sub-indexes countries and \( t = 1, \ldots, T \) index time periods. Equation (1) relates renewable energy demand \( (Re_{n_{i,t}}) \), GDP per capita \( (Y_{i,t}) \), capital stock per capita \( (K_{i,t}) \), labour force \( (L_{i,t}) \), human capital \( (H_{i,t}) \), energy depletion \( (D_{i,t}) \), energy-related carbon emissions \( (C_{i,t}) \) and energy price \( (P_{i,t}) \). The relation between renewable energy consumption and economic growth in China is instrumented with labour force and carbon dioxide emissions (Lin and Moubarak, 2014). Following Chakravorty et al. (1997), we include energy price and aggregate income as potential determinants of renewable energy demand. In addition, we argue that labour force, human capital, energy depletion and energy-related carbon emissions can trigger changes in renewable energy demand. The inclusion of labour force (as measured by the total size of a country’s population) can be rationalized in the following ways. First, labour is a key input to energy production (Wei, 2007). Second, increasing labour force (population) in the African economy poses a challenge to sustainable development of energy resources since increased demand without corresponding energy supply will lead to energy shortage, blackouts and brownouts. Third, labour is key production factor in the African economy. Education leads to increase in renewable energy demand through innovation (Isoard and Soria, 2001). This enhances energy efficiency and productivity since a relatively smaller quantity of renewable energy performs the same function. Energy (particular of non-renewable forms of energy)
depletion stimulates the use of alternative forms of energy. Increases in energy-related carbon emissions lead to a reduction in renewable energy consumption through the presence of greenhouses gases in the atmosphere, increased levels of pollutions and, consequently, lower crop harvests that are transformed into biomass. Further, since there is no established technology in the literature that transforms inputs into renewable energy (see also Usha Rao and Kishore, 2010), the linear demand function we propose adheres to the principle of parsimony.

Equation (1) can now be expressed as a linear relation between renewable energy consumption and the explanatory variables. Equation (2) is obtained by writing the resulting equation in a panel form with both cross-sectional and time-specific effects.

\[ REN_{i,t} = \beta_0 + \beta_1 Y_{i,t} + \beta_2 K_{i,t} + \beta_3 L_{i,t} + \beta_4 H_{i,t} + \beta_5 D_{i,t} + \beta_6 C_{i,t} + \beta_7 P_{i,t} + u_{i,t} \]  

(4.2)

### 4.4 Empirical Analysis

We begin our analysis by conducting a unit root test to ascertain whether the variables should enter into the empirical model in growth rate form or in levels. The ADF-Fisher Chi-square, Levin, Lin and Chu, PP-Fisher Chi-square and the Im, Pesaran and Shin-W-stats are used to test for unit root (see Appendix B to E). All the test rejected the null hypothesis of unit root implying that the variables are not stationary in levels and requires differencing. The Arellano Bond GMM is then applied to examine the effect of the regressors on renewable energy demand and use the Sagan test to examine the hypothesis of over-identification. The purpose of the Sagan procedure is to test for over-identification. The Sagan test is distributed as \( X (p-k) \) where \( p \) is the instrumental rank, in this case 58 and \( k \) is the number of estimated coefficients including instrumental variables, in this case 9. Testing for the null that the over-identifying restriction are valid, we compute the p-value of the Sagan test by taking into consideration the value of the J-statistics, the instrumental rank and the number of estimated co-efficient. The findings indicate the Sagan test reject the null of over-identification. Instrumental variables are used to check the problem of endogeneity whilst the Sagan test and the Arellano Bond test for second order
autocorrelation in first differences indicate good statistical performance of the model. According to Arellano and Bond (1991), if the disturbance in the original levels equation is not serially correlated, there should be evidence of significant negative AR (1) and a non-significant AR (2) in the difference equation. Though the results of AR (2) indicates no serial correlation, AR (1) shows partial evidence of serial correlation.

We estimate three panel data models, a one-way random effect model, a two-way random model and a dynamic panel model. The Hausman test finds no evidence against the assumption that the random effects are uncorrelated with the predictors, thus lending support to the random effects model, as opposed to fixed-effects model.¹ The dynamic panel data model is estimated by using the GMM estimation method, proposed by Arellano and Bond (1991). The use of an instrumental variable approach to estimate our panel data models address the endogeneity issue of some of the predictors, notably real income per capita² (see also Fang, 2011). To this end, the predictors are instrumented with the first lag of the explanatory variables (the second lag of renewable energy consumption in the case of the dynamic panel data model). In specifications 1 to 7, predictors of renewable energy consumption enter regressions individually, whereas specification 8 employs the entire set of predictors.
<table>
<thead>
<tr>
<th>Predictor</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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Note: This table reports estimation results for the one-way (cross section) random effects model. Renewable energy consumption (REN, in kg of oil equivalent per capita), gross domestic product (Y, in real 2005 US dollars per capita), capital (K, in real 2005 US dollars per capita), population (l, in millions of persons), human capital (H, in real 2005 US dollars per capita), energy depletion (D, in real 2005 US dollars per capita), CO2 emissions (C, in tonnes per capita) and the price level (P, in index points of consumer price index). The sample period runs from 1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Data on human capital are unavailable for Gabon. Therefore, Gabon has been excluded from the sample of country-years used to estimate our panel data models. The model has
been estimated using the panel two-stage EGLS. In each equation, we use lagged predictors as instruments. Standard errors are reported in parentheses. DW is the Durbin-Watson test statistic for serial correlation of order 1. R2 is the coefficient of determination. The F statistic (F) tests for collective significance of the explanatory variables. The coefficient estimates highlighted in bold are significant at the significance level of 5%.

Table 4.4 estimation results – two way fixed effects model

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71
Note: This table reports estimation results for the one-way fixed effects model. renewable energy consumption (REN, in kg of oil equivalent per capita), gross domestic product (Y, in real 2005 US dollars per capita), capital (K, in real 2005 US dollars per capita), population (l, in millions of persons), human capital (H, in real 2005 US dollars per capita), energy depletion (D, in real 2005 US dollars per capita), CO2 emissions (in tonnes per capita) and the price level (consumer price index). The sample period runs from
1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Data on human capital are unavailable for Gabon. Therefore, Gabon has been excluded from the sample of country-years used to estimate our panel data models. The model has been estimated using the panel two-stage least squares estimation procedure. In each equation, we use lagged predictors as instruments. Standard errors are reported in parentheses. DW is the Durbin-Watson test statistic for serial correlation of order 1. R2 is the coefficient of determination adjusted by the degrees of freedom. The F statistic (F) tests for collective significance of the explanatory variables. The coefficient estimates highlighted in bold are significant at the significance level of 5%.

Table 4.5 estimation results – dynamic panel GMM

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<td>0.42</td>
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Note: This table reports estimation results for the dynamic panel GMM model. Renewable energy consumption (REN, in kg of oil equivalent per capita), gross domestic product (Y, in real 2005 US dollars per capita), capital (K, in real 2005 US dollars per capita), population (l, in millions of persons), human capital (H, in real 2005 US dollars per capita), energy depletion (D, in real 2005 US dollars per capita), CO2 emissions (in tonnes per capita) and the price level (consumer price index). The sample period runs from 1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Data on human capital are unavailable for Gabon. Therefore, Gabon has been excluded from the sample of country-years used to estimate our panel data models. The model has been estimated using the panel two-stage least squares estimation procedure. In each equation, we use lagged predictors as instruments. Standard errors are reported in
parentheses. R2 is the coefficient of determination adjusted by the degrees of freedom. The F statistic (F) tests for collective significance of the explanatory variables. The coefficient estimates highlighted in bold are significant at the significance level of 5%.
Table 4.3 reports the estimation results for the one-way random effect model. Table 4.4 reports the estimation results for the two-way random effects model. Table 4.5 reports the estimation results for the dynamic panel data model. Our main analysis is based on the one-way random effects model. The two-way random effects model and the dynamic panel data model are estimated as a robustness check.

We first find that GDP per capita has positive and significant effect (at the 5% significance level) on renewable energy consumption (Table 4.3). Higher economic growth may lead to increased renewable energy consumption in oil producing Africa countries. For instance, the estimation results of specification (1) imply that a one US dollar increase in GDP per capita will lead to an increase in renewable energy demand in 0.00384 kg of oil equivalent per person. This result is validated by specification (8) that estimates the effects of the explanatory variables collectively. This finding is consistent with Asafu-Adjaye (2000) and Sadorsky (2009) and Shabbaz et al (2013). Since economic growth is vital for renewable energy consumption, it would be policy-prudent to promote the linkage between economic growth and renewable energy consumption. When consumers’ income increases or profits of firms rise, they can switch to alternative sources of energy. Key to the aforementioned linkage is energy policy pursued by governments in countries such as Ghana, Nigeria, Algeria and Angola, which aim at increasing the contribution of renewable energy to 10% in aggregate energy consumption by 2020. This has led to the introduction of subsidies and economic benefits that encourage the deployment and use of solar and mini-hydro dams.

The estimated effect of capital (K) a proxy for investment is significant, albeit not robust in specifications (2) and (8). In the individual effects model, capital exerts a positive and significant influence on renewable energy consumption. The estimated effect of capital in specification (2) indicates that one dollar increase in capital or investments leads to an increase in renewable energy consumption by 0.00914 kg of oil equivalent per capita. Investment in capital promotes renewable energy consumption. This finding agrees with the theory of underlying energy demand, which argues that energy has an indirect demand and the amount of energy consumed is influenced by the type of investment in capital appliances. However, this finding contrasts with the estimated effect of capital in a more general model. When renewable energy demand is regressed against capital and other potential determinants the effect of capital remains significant, but the sign switches from being positive to being negative. This may imply that other factors reduce the impact of capital on renewable energy
consumption. Arguably, the lack of stability in the coefficient sign in specification (8) may also be a statistical artefact that is associated with the existence of multicollinearity among the explanatory variables. If this is the case, then the estimated effect of capital in specification (2) indicates that one dollar increase in capital leads to an increase in renewable energy consumption by 0.00914 kg of oil equivalent per capita. Investment in capital promotes renewable energy consumption. The changes in sign from positive to negative can be influenced by the amount of investment. That, higher investments may gain from economies of scale and lead to lower renewable energy prices which will encourage demand.

The changes in sign from positive to negative can be influenced by the amount of investment. That, higher investments may gain from economies of scale and lead to lower renewable energy prices which will encourage demand.

The use of human capital in our models is based on the notion that more educated people are expected to consume more renewable energy due to the awareness of carbon emissions and environmental consequences of energy consumption. This implies that education influences the taste of consumers for energy consuming products to acquire modern forms of appliances that can have consequences on renewable energy demand. Although in specification (4), the coefficient estimate has the expected positive sign, the effect is not significant.

Further, renewable energy has three principal advantages. It is carbon neutral, available and widely distributed geographically and non-depletable. It is expected the depletion of energy resources will lead to higher renewable energy consumption. Indeed, in an attempt to encourage sustainability, policy makers will encourage renewable energy consumption. The estimated effect of energy depletion lends support to our ex-ante expectation. Specifically, an increase in energy resource depletion in 1 USD per capita is associated with the increase in the renewable energy consumption by 0.00536 kg of oil equivalent per capita.

The role of carbon emissions for renewable energy consumption is underscored by Lund (2007). (Bhattacharya et al., 2014) find that renewable energy is carbon-neutral due to its potential to mitigate the presence of greenhouse gases in the atmosphere. However, the possibility of causal effects running from carbon emissions to renewable energy demand has been ignored in the related literature. In this regard, the coefficient estimate in specification (6) suggests the presence of a negative and significant effect of carbon emissions on renewable energy demand. This finding implies that an increase in carbon emissions by 1 tonne per capita reduces renewable energy consumption by 0.691 kg of oil equivalent per capita. One plausible explanation is that declining carbon emissions may boost crop
yields and consequently biomass output by alleviating the presence of greenhouse gases. Another reason may be due to the higher cost barrier which deter some consumers from switching from no-renewable to renewables.

Consistent with the findings of Mahadevan and Asafu-Adjaye (2007), the consumer price index (energy price) has an adverse effect on renewable energy consumption in models (7) and (8). As the CPI increases, renewable energy consumption reduces. This finding has an important implication for energy production subsidies in Africa. Since the CPI is a vital determinant of renewable energy demand, policy makers should design feed-in tariffs that encourage bulk production for economies of scale and production subsidies that attract investment and reduces price for consumers.

4.5 Conclusion and Recommendation

Renewable energy consumption has been considered one of the major ways through which the challenge of climate change and energy security can solved. This is necessary especially for Africa where renewable energy sources abounds and energy access is a major issue. Although the environmental benefits of renewable energy has been extensively studied, the potential determinants of its demand has received less attention especially in Africa. This has been attributed to lack of data in the past. In this paper, the Arrellano Bond GMM, a two-way random effect model and one-way random effect model are employed to estimate the effect energy resource depletion, energy related carbon emissions, human capital development, capital, income and energy prices on renewable energy demand in oil producing African countries. The dynamic panel GMM model has the advantage of taking instrumental variables to check for endogeneity. Further, Sagan test is employed to check for over identification. In order to check the robustness of the results, three estimation methods are employed in this study.

The study finds the energy resource depletion and the Kaya Identify (energy related carbon emissions) as drivers of renewable energy demand. This is not surprising since renewable energy sources replenishes themselves when successive units are consumed. This makes it important to invest in their production and consumption since fossil fuel are obtained from depletable sources. Again, renewable energy has been considered carbon-neutral and therefore have minimal impact on the environment. The
findings further reveal that income growth has a positive impact on renewable energy consumption. However, in consistent with literature, price has an inverse relations with renewable energy demand. The main policy recommendations arising from the study is as follows. To begin with, since income per capita increases renewable energy consumption, efforts should be made to remove technological barriers that deny consumers from accessing renewable energy. For instance, whilst the growth rate of most African countries has been encouraging over the last two decades, the consumption of commercial sources of renewables outside hydro such as geothermal, solar and biofuels has not been encouraging to attract the needed investment. Policies makers should therefore create the necessary investment climate to promote the availability of commercial forms of renewables.

In addition, renewable energy policies should factor education as a medium to through which renewable energy consumption can be increased. Such educational effort should highlight the potential contribution of renewable energy to sustainable development in the face of energy resource depletion. Further, the environmental attractiveness of renewable energy should be highlighted to encourage the consumption of renewable energy.

Finally, commercial policies such as feed-in tariffs, solar panels for individual homes and the opportunity for firms to sell excess renewable energy generated should be encouraged to promote consumption. This will enhance the choice of renewable as a substitute or complement to non-renewable energy for industries especially since power supply is intermittent in Africa.

We also suggest that, subject to availability of data, future studies should look at the determinants of non-commercial sources of renewables (charcoal, fuel wood) and the commercial sources (solar, geothermal) to promote effective renewable energy demand strategy.
Natural gas is the cleanest form of fossil fuels and abundant in Africa. This means, natural gas is a complement to renewable energy as Africa searches for clean and available sources of energy. With new discoveries in Ghana and Mozambique and investments such as the West Africa Gas Pipeline, natural gas can be the bridge between renewable and non-renewable energy in Africa. The next chapter, (Chapter 5) models the predictors of natural gas demand in oil producing African countries. The chapter also looks at the underlying demand trend of each of the countries under consideration.
CHAPTER 5: NATURAL GAS DEMAND

5.1. Introduction
The global need for clean and affordable sources of energy cannot be overemphasized, since the consumption of energy has been found to be a major determinant of CO2 emissions (Bhattacharya, 2010). Access to a clean, affordable and available source of energy has therefore become a major policy priority for both developed and developing economies. According to BP (2010), coal emits 94.6 ppm CO2 per each unit use. This notwithstanding, natural gas emits 70% less carbon than coal and 40% less than crude oil (BP, 2010). This makes natural gas the preferred fuel of choice for three reasons. First, natural gas is cheaper than petroleum and cleaner than both coal and petroleum (Aras and Aras, 2004). In addition, due to its efficiency and attractive qualities, natural gas is suitable for power generation. This means that, since Africa is a developing continent with a great economic potential, natural gas should be the fuel that drives this growth. However, only 5.4% of Africa’s energy mix can be attributed to natural gas (IEA, 2013). Has Africa been left behind in the natural gas revolution? Second, the discovery of natural gas in Africa has been increasing over the last two decades. Finally, natural gas plays a vital role in reducing capital costs in energy intensive industries since natural gas using appliances like gas fired thermal plants are relatively cheaper to operate (Shahbaz et al., 2013). This is because, natural gas is cheaper and burns faster than oil. Natural gas therefore comes to mind as the preferred choice. Apergis and Payne (2010) note that most economies are using natural gas as a major source of energy and cite reduction in carbon emissions as the reason.

In a report in 2011, the IEA predicts that natural gas demand will grow in the coming decades due to five main factors. First, there is increasing use of natural gas in emerging and developing countries like China, Bangladesh and Turkey. Second, the use of natural gas in the transport sector has been increasing in both developed and developing countries. Thirdly due to the Fukushima Daiichi nuclear disaster, slower growth in nuclear power is anticipated. The fourth factor has been the discovery of conventional natural gas such as Tanzania, Mozambique and Ghana and the productivity of old gas fields. Lastly, there has been rapid expansion of global supply capacity for Liquefied Natural Gas (LNG). For instance, Nigeria, which hitherto flared its gas, became the 4th largest LNG exporter in
2012. Total (2011) estimates that the demand for natural gas will grow at 2.5% annually over the next two decades. This implies that natural gas will become the second most important fossil fuel after oil taking the growth rate of coal at 0.2% and crude oil at 1.1% over the same period. These demand projections require investments in LNG facilities, pipelines and natural gas infrastructure. Since investment in natural gas infrastructure is huge and requires long lead times, knowledge of the determinants of natural gas can guide investment decisions. Again, natural gas is traded regionally in North American, European and Asia-Pacific gas markets. Nevertheless, Africa has no gas market. Given the complexity of the natural gas market, the interplay of factors that influence the market and the interdependence of these factors, a quantitative model representing the demand side of the market needs to be devised to guide energy policy decisions.

Shabbaz et al. (2013) review the literature on natural gas demand and highlight two important gaps. First, the results are not unanimous as some studies report bidirectional, unidirectional or no relation between natural gas demand and economic growth. Second, the estimation methods are less suitable in some studies especially those using a bivariate model which is subject to omitted variable bias. Third, most of the studies on natural gas are outdated and are not able to capture current trends in the energy sector. For instance, the global economic crisis and the recent development in the climate change agenda have drastically changed the fuel mix policy. Therefore, without the inclusion of this time period, results of previous studies may have little relevance for current natural gas policy making. The few studies on natural gas in Africa usually test the causal relation between economic growth and gas demand in a multivariate framework or in a bivariate framework which can potentially omit some relevant variables. According to Hunt and Evans (2011), understanding the factors that influence the demand for energy is vital to design an energy policy framework that deals with issues such as climate change, energy access, energy security and energy investments. To support this point, Bianco et al. (2014) posit that knowledge of natural gas demand helps to predict natural gas consumption with high accuracy, to optimally manage domestic production, manage gas supply contracts and develop local gas infrastructure. The objective of this study is to identify the determinants of natural gas demand in oil producing African countries. The study also seeks to determine the underlying energy demand trend (UEDT) of natural gas demand in oil producing African countries.

This study contributes to the existing literature on natural gas demand in three main ways. First, the study incorporates both heterogeneous and homogenous variance structures by employing a dynamic
panel and a structural time series analysis. Second, contrary to studies on natural gas demand such as (Khan, 2015; Waheed and Martin, 2013), this study employs a multivariate framework that includes GDP, energy resource depletion, CO2, price and a stochastic trend that captures the effect of exogenous unobservable factors on natural gas consumption. Finally, in order to enhance the robustness of the findings and depart from existing time series applications to natural gas demand (see Ackah, 2014; Khan, 2015; Waheed and Martin, 2013), two different panel-data specifications, a dynamic panel two stage least squares model and Arrellano and Bond’s (1991) generalized method of moments (GMM) estimator of a dynamic panel-data model, are employed in this study. The dynamic GMM estimator employs instrumental variables (IV) that address the problem of endogeneity among the explanatory variables and avoids estimation bias that is associated with the correlation between the lagged dependent variable and the error term (Omri et al., 2014). According to Wooldridge (2001), the panel two stage model is the most efficient IV estimator.

The remaining study is structured as follows. In Section 2, we review the related literature. In Section 3, we describe data. In Section 4, we outline the methodology. In Section 5, we analyse the estimation results. Finally, in Section 6 we offer some concluding remarks.

5.2. Literature Review

Natural gas was produced from coal when it was first used in commercial quantities in Britain in 1785 (Soldo, 2012). Soon after, natural gas was obtained by drilling and attracted less attention since associated gas was mostly flared. However in recent times, studies on the demand for natural gas have been proliferating due to climate change concerns, the safety of nuclear energy, increased discovery of gas and associated gas, environmental concerns about natural gas flaring and the need for an affordable source of fuel. In addition, the need to find a suitable complement or substitute for crude oil has also shifted attention to natural gas. Natural gas consumption has been studied extensively, especially within the last 30 years, due to its growing environmental and economic impacts among other consumption goods, with a particular emphasis on price elasticities (Bilgili, 2014). In particular, regional studies on price elasticity include 18 OECD countries (Griffin, 1979)³, West Germany and

³ For instance, Griffin (1979) investigates natural gas demand functions for different sectors of 18 OECD countries including Austria, Belgium, Canada, Denmark, France, West Germany, Greece, Ireland, Italy, Japan, Netherlands,
France (Estrada and Fugleberg, 1989)\textsuperscript{4}, Kuwait (Eltony, 1996)\textsuperscript{5}, 12 European countries (Nilsen et al., 2005)\textsuperscript{6}, and a broader sample of European and OECD countries (Dilaver et al., 2014)\textsuperscript{7}, and Bangladesh (Wadud et al., 2011)\textsuperscript{8}. Table 1 illustrates key characteristics of the existing body of research.

A growing body of literature investigates the relation between natural gas consumption and economic growth, with a particular emphasis on Bangladesh (Das et al., 2013)\textsuperscript{9}, Pakistan (Shabbaz et al., 2013)\textsuperscript{10}, and a panel of eight OECD countries (Bigli, 2014)\textsuperscript{11}. By contrast studies on natural gas demand in Africa are virtually non-existent. The total production of natural gas in sub-Saharan Africa in 2011 was estimated to be 1,690 billion cubic feet (Bcf). Nigeria contributed (66%) of the total gas produced, Equatorial Guinea (14%), Mozambique (8%), Ivory Coast (3%) and South Africa (3%) (EIA, 2013). In contrast, the two largest natural gas producers in the world, the USA and Russia, produced 22,902 Bcf and 21,436 Bcf respectively, and the world total production was 116,230 Bcf (BP, 2013).

\textsuperscript{4} Estrada and Fugleberg (1989) study the price responsiveness of natural gas demand for West Germany and France and found estimated price elasticities varying between -0.75 and -0.82 for West Germany and from -0.61 to -0.76 for France.

\textsuperscript{5} Eltony (1996) models the demand for natural gas in Kuwait and finds that natural gas demand is inelastic to price and income in both the short and long run.

\textsuperscript{6} Nilsen et al. (2005) examine natural gas demand per capita in 12 European countries including Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Switzerland and UK over the period 1978-2002. Their results suggest that the short run and long run price elasticities vary between 0 to -0.3 and 0 to -0.6 respectively, whereas the short and long run income elasticities range from 0.3 to 0.7 and 1.9 to 2.2 correspondingly.

\textsuperscript{7} Dilaver et al. (2014) investigate the impact of income, real natural gas prices and the underlying energy demand trend (UEDT) on OECD-Europe natural gas consumption by applying the structural time series technique to annual data over the period 1978 to 2009. The results suggest that income, the UEDT and natural gas prices all play a major role in driving OECD-Europe natural gas consumption. The estimated long run income and price elasticities are 1.16 and -0.17 respectively.

\textsuperscript{8} Wadud et al. (2011) use the partial adjustment model to natural gas demand in Bangladesh and find a long run income elasticity of 1.5.

\textsuperscript{9} Das et al. (2013) apply the Vector Error Correction Model (VECM) to natural gas demand in Bangladesh and find that there is a unidirectional relation from economic growth to natural gas consumption.

\textsuperscript{10} Shabbaz et al. (2013) examine the relationship between natural gas consumption and economic growth in a multivariate framework that includes capital, labour, and exports. The ARDL bounds testing approach and the findings indicate that natural gas consumption leads to growth in Pakistan.

\textsuperscript{11} Bigli (2014) applies the panel data for eight Organization for Economic Cooperation and Development (OECD) countries to seek responses of per capita natural gas consumption to per capita income and natural gas price from 1979 to 2006.
Figure 5.1 shows Africa produced 4.5 billion cubic metres of natural gas in 1971. This increased to 204 billion cubic tonnes in 2012. The major natural gas suppliers in Africa over this period are Algeria, Angola, Cameroon, Congo, Cote d’Ivoire, Egypt, Equatorial Guinea, Gabon, Libya, Mozambique, Morocco, Nigeria, South Africa, and Tunisia. On the supply side, new natural gas field discoveries such as in Mozambique, technological improvements like hydraulic fracturing, LNG technologies, and new uses of gas in Africa such as for power generation and construction of pipelines to aid transportation have increased production. The demand emanates from (i) the industrial sector that uses natural gas for power generation and (ii) households that use natural gas for cooking and heating. The growing use of natural gas can be seen as a perfect substitute for charcoal. Household income and natural gas subsidies are thought to be the major drivers of demand for natural gas.

It is estimated that gas consumption in Africa has been growing at 6% per annum since 2000 and reached 210 bcm in 2011 (BP, 2012). In terms of consumption, Egypt and Algeria account for more than 70% of total gas consumption in Africa for 2011 (IEA, 2013).
Ackah (2014) investigates the effect of economic (price, income, household final expenditure, industrial output) and non-economic factors (the underlying energy demand trend) on natural gas demand in Ghana at the aggregate and disaggregated levels. To capture the effects of the exogenous non-economic factors, a structural time series model is employed. The findings suggest that both economic and non-economic factors influence natural gas demand. It further reveals that different sectors respond differently to these factors. The study recommends that policies such as natural gas price subsidies should be customized for different sectors to obtain policy objectives.

Over the past 20 years, different econometric techniques such as the modified logit model (Mackay and Probert, 1995), the dynamic log-linear model (Nilsen et al., 2005), the bottom up approach (Honore, 2006), the autoregressive distributed lag model (Bernstein and Madlener, 2011), and the structural time series model (Dilaver et al., 2014) have been applied to energy demand studies.

### TABLE 5.1. SUMMARY OF NATURAL GAS STUDIES

<table>
<thead>
<tr>
<th>Author</th>
<th>Method</th>
<th>Country</th>
<th>Period</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu (1983)</td>
<td>OLS</td>
<td>USA</td>
<td>1960-1978</td>
<td>Price = -0.49, Income = 0.55, Price = -0.75 to -0.82 (West Germany), -0.61 to -0.76 (France)</td>
</tr>
<tr>
<td>Estrada and Fugleberg</td>
<td>Translog functions</td>
<td>West Germany and France</td>
<td></td>
<td>Price = -0.34, Income = 0.82, Price = -0.51</td>
</tr>
<tr>
<td>(1989)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eltony (1996)</td>
<td>PAM, ECM</td>
<td>Kuwait</td>
<td>1975-1993</td>
<td>Price = -0.34, Income = 0.82</td>
</tr>
<tr>
<td>Sunak and Madlener</td>
<td>ARDL</td>
<td>OECD-Europe</td>
<td>1980-2008</td>
<td>Price = ---</td>
</tr>
<tr>
<td>(2011)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dilaver et al. (2014)</td>
<td>Structural time series model</td>
<td>OECD-Europe</td>
<td>1978-2011</td>
<td></td>
</tr>
</tbody>
</table>
Three categories of determinants of natural gas demand can be identified. The first category of determinants comprises economic factors such as the price of the type of energy, the prices of substitutes and complements, and income. The second category comprises demographic and consumer characteristics such as population, the frequency and intensity of use, and consumer choice of energy using appliances. The third category accommodates environmental and technological factors such as average weather conditions, the efficiency of the energy using appliances, productivity of the appliances, environmental laws and regulations.

Specifically, this chapter seeks to:

1. Test whether both economic factors such as GDP and CPI (energy prices) influence natural gas demand
2. The effect of environmental factors such as energy resource depletion and CO₂
3. Examine the underlying energy demand trend for natural gas demand in oil producing African countries.

5.3. Data

The study seeks to identify the determinants of natural gas demand in oil producing African countries. To this end, we build upon Balestra and Nerlove (1966), Estrada and Fugleberg (1989) and Erdogdu (2010), who estimate the effect of price and income on natural gas demand. More specifically, we use a panel-data model that combines a time dimension and a cross section of countries. The time dimension consists of annual data and spans from 1971 to 2012.

The use of income as a key explanatory variable is motivated by Cleveland et al. (2000) and Ayres et al. (2007). The role of price as a driver of demand for natural gas has received considerable attention (Gately and Huntington, 2002, Wadud et al., 2010). The specific countries selected and the timeframe are dictated by data availability. These countries are Algeria, Angola, Egypt, Nigeria and Tunisia which together consume more than 90% of natural gas in Africa (EIA, 2013). These five countries have been selected because they constitute the major consumers of Natural Gas among oil producing countries in Africa. Since these five countries consume more than 90% of the natural gas in Africa, the findings can be generalised for the rest of the oil producing African countries.

Natural gas is principally used for power generation, for fertilizer manufacturing, as a transport fuel, and in households for cooking. The IEA (2011) forecasts that the share of natural gas in global energy
mix will rise from 21% in 2010 to 25% in 2035. This rise is principally driven by increased use of natural gas in transportation, low growth in nuclear energy and discovery of conventional and unconventional (shale) gas. In Africa, a series of major natural gas infrastructure projects have been carried out that have led to higher demand for natural gas. Notable among them are the West African Gas Pipeline that stretches from Nigeria through Benin and Togo to Ghana and huge gas discoveries in Mozambique, Nigeria, Angola and Tanzania. In terms of natural gas reserves, the African Development Bank estimates that Algeria, Egypt, Libya and Nigeria possess about 91% of Africa’s gas reserves. An Ernst and Young 2012 report describes natural gas as a ‘prime mover’ for broader economic development in Africa. According to the BP Statistical Review (2012), natural gas consumption in Africa has been growing at an annual rate of 6% since 2010. BP (2012) estimates that Egypt and Algeria accounted for 70% of Africa’s total gas consumption in 2011.

Data on GDP in current US dollars, our proxy for income, are obtained from the World Bank development indicators. Obtaining data on natural gas prices from reliable sources in the various countries is a daunting task. Therefore, following Mahadevan and Asafu-Adjaye (2007), consumer price index (CPI) of the base year 2000 is used as a proxy for natural gas prices. The choice of CPI as a proxy for the energy price variable was informed by two reasons. First, there is unavailability of consistent data on energy prices on the countries under consideration. Second, studies, such as Mahadevan and Asafu-Adjaye (2007) and Tang et al. (2013) used CPI as a proxy for energy price when they carried out similar studies on Africa. Annual data on natural gas consumption in kilogramme of oil equivalent is obtained from the International Energy Agency. Table 2 shows the descriptive statistics of the data. Five countries are used in this study. These are Algeria, Angola, Egypt, Nigeria, and Tunisia.
Figure 5.2 shows natural gas demand trend and energy related carbon emissions. Apart from Angola, the trend shows that as natural gas consumption increases energy related carbon emissions increase. Angola has been able to reduce carbon emissions through a UN sponsored REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programme that helps to avoid deforestation, increased renewable energy consumption, distribution of compact fluorescent lamps (CFLs) and efficient stoves and reduction in natural gas flaring (Lutken et al., 2013).
FIGURE 5.3: TREND IN NATURAL GAS CONSUMPTION IN THE 5 SELECTED OIL PRODUCING AFRICAN COUNTRIES

GDP in current US dollars serves as a proxy for cumulative economic growth. Consumer price index (CPI) proxies for accumulated changes in energy prices. Both GDP and CPI are obtained from the World Bank Development indicators. Our sample includes Algeria, Angola, Egypt, Nigeria and Tunisia.

TABLE 5.2. DESCRIPTIVE STATISTICS

<table>
<thead>
<tr>
<th>Statistic</th>
<th>G</th>
<th>P</th>
<th>Y</th>
<th>ED</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2076.431</td>
<td>52.51237</td>
<td>5.26E+10</td>
<td>8.39E+09</td>
<td>15.60770</td>
</tr>
<tr>
<td>Median</td>
<td>807.5000</td>
<td>41.16544</td>
<td>3.59E+10</td>
<td>4.66E+09</td>
<td>9.690000</td>
</tr>
<tr>
<td>Maximum</td>
<td>13351.00</td>
<td>211.3093</td>
<td>4.14E+11</td>
<td>4.98E+10</td>
<td>86.73000</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.000000</td>
<td>4.14E-08</td>
<td>4.06E+09</td>
<td>82648876</td>
<td>0.280000</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>2889.033</td>
<td>50.63241</td>
<td>5.86E+10</td>
<td>1.05E+10</td>
<td>17.24766</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.091713</td>
<td>0.769637</td>
<td>3.035148</td>
<td>2.019803</td>
<td>1.965628</td>
</tr>
</tbody>
</table>
Kurtosis | 6.879640 | 2.797838 | 15.44202 | 6.620334 | 7.009050
Jarque-Bera | 236.0068 | 17.47421 | 1389.479 | 213.3329 | 228.5727
Prob | 0.000000 | 0.000161 | 0.000000 | 0.000000 | 0.000000

Notes: This table summarizes descriptive statistics (sample mean, median, maximum, minimum, standard deviation, skewness, kurtosis, the Jarque-Bera test statistic, and the p-value associated to the Jarque-Bera test statistic) of natural gas consumption (G, in kg of oil equivalent per capita), the price level (P, consumer price index), gross domestic product (Y, in real 2005 US dollars per capita), ED for natural resource depletion and CO2 emissions (in tonnes per capita) and. The sample period runs from 1971 to 2012 for five countries (Algeria, Angola, Egypt, Nigeria, and Tunisia).

Over the sample period and across countries, the mean of GDP is 52.6 billion of US Dollars according to Table 5.2. The degree of variability is also witnessed by the standard deviation. The data for this variable are positively skewed and leptokurtic with the value of the skewness at 3.04 and the value of kurtosis at 15.44. The positive value of the kurtosis suggests that the positive deviation across the countries is more dispersed than the negative deviations. The latter suggests that the distribution of real GDP across countries and over time features heavy tails, whereas the former suggests that positive deviations from the mean tend to be more dispersed than negative deviations.

Energy depletion averages 8.39 billion of current US Dollars across countries and over time. Energy depletion varies over time ranging from USD 0.083 billion to USD 49.8 billion. The data are positively skewed with a skewness value of 2.02 and a kurtosis value of 6.62 which result in the rejection of the null of non-normality. CO2 emissions have an estimated mean of 15.61 metric tonnes per capita. Again, we observe negative skewness. The price level averages 52.51 across countries and over time. Finally, natural gas demand averages 2.076 million cubic metres. The positive value of skewness (2.09) and kurtosis (6.880) provide evidence of non-normality in the data. Non-normality may infer inaccuracy of the statistical test. However, this can be due to small nature of the sample size.

<table>
<thead>
<tr>
<th></th>
<th>G</th>
<th>Y</th>
<th>ED</th>
<th>P</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0.61</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 5.3. COEFFICIENTS OF CORRELATION
Table 5.3 summarizes the Pearson coefficients among natural gas consumption, GDP, energy resource depletion, price and carbon emissions. The sample period runs from 1971 to 2012 for five countries (Algeria, Angola, Egypt, Nigeria and Tunisia). The result indicates that natural gas consumption is positively correlated with all the explanatory variables included in this study. With respect to correlation among the explanatory variables, the highest correlation was found between Gross Domestic Product and energy resource depletion (0.77) which is positive followed by a positive correlation between GDP and CO\textsubscript{2} emissions (0.73). Energy price was also found to be positively correlated with CO\textsubscript{2} emissions (0.61) as well as positively correlated with GDP (0.52). Also, energy resource depletion was found to have a weak positive correlation with energy price (0.19) and CO\textsubscript{2} emissions (0.39). It must however be cautioned that correlation only indicates the direction and magnitude of relationship among the variables but does not imply causality.

### 5.4. The Model

The demand for natural gas depends on many factors such as price of natural gas, income and environmental factors (Wadud et al., 2011). Functional forms like linear, log-linear and translog can be used to mathematically express the relations between natural gas demand and the predictors. According to Kaboudan and Liu (2004), log-linear models represent the non-linear nature of the variables better. In addition, the log-linear functions directly provide the elasticities of demand with respect to the predictors.

According to Bruno (2005) the usual panel fixed and random models are inconsistent when the time span of the study is small. In such cases, Anderson and Hsiao (1982) recommend that instrumental variables, or the Arrellano Bond estimator through the generalized method of moments is preferred.
This study seeks to investigate the predictors of natural gas demand in oil producing African countries. Natural gas demand is modelled as a function of an array of explanatory variables and a random disturbance:

\[ G_{i,t} = F(P_{i,t}, Y_{i,t}, ED_{i,t}, CO2_{i,t}, u_{i,t}) \]  \hspace{1cm} (1)

where \( i = 1, ..., N \) sub-indexes countries and \( t = 1, ..., T \) index time periods. Equation (1) relates natural demand \( (G_{i,t}) \), energy price \( (P_{i,t}) \), gross domestic product \( (Y_{i,t}) \), energy depletion \( (ED_{i,t}) \), energy-related carbon emissions \( (CO2_{i,t}) \) and the stochastic disturbance \( (u_{i,t}) \). Energy consumption and GDP are shown to be positively related in the energy economics literature (see also Cleveland, 2000, Ayres et al., 2007, among others). In addition, the inverse relation between price and energy demand has received considerable attention in the literature (Gately and Huntington, 2002, Graham and Glaister, 2002, Wadud et al., 2011). According to Ibrahim and Hurst (1990), due to lack of information, energy demand studies in developing countries often use only price and income as predictors. In this study, we additionally consider energy related carbon emissions (CO2) and energy resource depletion are added as predictors. Indeed, all fossil fuels including natural gas emit CO2 (Marland, 2008). Further, since natural gas is non-renewable, it is presumed that energy resource depletion can influence gas consumption. We assume that the relation between natural gas demand and its potential determinants takes on a parsimonious linear form as follows:

\[ G_{i,t} = \beta_0 + \beta_G G_{i,t-1} + \beta_Y Y_{i,t} + \beta_P P_{i,t} + \beta_{ED} ED_{i,t} + \beta_{CO2} CO2_{i,t} + u_{i,t} \]  \hspace{1cm} (2)

According to Suganthi and Samuel (2012), the use of panel methods in energy demand is limited. In this study, the dynamic panel GMM and the dynamic panel TSLS with instrumental variables are employed to estimate the determinants of natural gas demand. Omri (2014) posits that the inclusion of instrumental variables helps to overcome the endogeneity problem. Following the study of Omri (2014) this study employed the lag values of the dependent and independent variables were used as instruments which were accepted. It also avoids estimation bias that is associated with the correlation between the lagged dependent variable. Equation (2) is estimated with panel GMM and panel TSLS.
However, we recognize that energy does not produce output by itself but works through capital stocks and other mediums to produce a given output, the efficiency of the capital stock influences the amount of energy use in the production process. In addition to the efficiency of the capital stock, price and income change, ‘taste’ has also been found to influence energy consumption. According to Hunt et al., (2003), the addition of technological progress, efficiency of the capital stock and ‘taste’(which captures all non-economic factors that influence natural gas consumption such as lifestyle and energy regulations)) is referred to as the Underlying Energy Demand Trend (UEDT). This study applies an automatic variable selection procedure to identify the predictors of natural gas demand for each country and ascertain the underlying energy demand trend.

Hendry and Krolzig (2005) suggest that model selection is a vital step in empirical research especially where (i) a prior does not predefine a complete and correct generally accepted specification and (ii) there is room for exploratory modelling. Since a large set of factors can potentially influence the demand for natural gas, it is prudent to have an econometric procedure that automatically selects the significant factors based on some predefined criteria. For Africa, Bhattacharya and Timilsina (2009) suggest that due to factors such as the transition from traditional sources of energy to modern commercial ones and the economic structure, the energy demand functional form may depart from the ones that specify energy demand as a function of energy price and income. The automatic variable selection proceeds in a general-to-specific fashion. It works by first specifying a general model based on previous findings, geographic and demographic characteristics, technological and economic trends. Misspecification tests, lag structures, significance levels and the desired information criteria are then set. Such procedure allows valid inference from the selected specification (Hendry and Krolzig, 2005). All insignificant variables are eliminated.

In order to examine the determinants of natural gas demand for specific countries, a general unrestricted model (GUM) consisting of all predictors is specified. Autometrics then uses a tree-search to remove insignificant variables to select the final model (Pellini, 2014). We begin by specifying a GUM error correction model featuring impulse indicator and step dummies.

$$\beta_G(L)G_t = \beta_o + \beta_t t + \beta_p (L) P_t + \beta_y (L) Y_t + \beta_{ED} (L) ED_t + \beta_{CO} (L) CO_{2t} + \sum_{i=1}^{t} \left( \beta_j I_{j,t} + \delta_j S_{j,t} \right) + \mu_t$$
Where $i$ indexes country, $t$ indexes time, $I_{i,t}$ is the impulse indicator dummy and $S_{j,t}$ is a step dummy. For all dummies, $j$ is the indicator index. For instance, $I_{2004,t}$ means the impulse indicator dummy variable for 2004 that takes on the value 1 for 2004 and 0 prior to 2004. $\beta(L)$ denotes a lag polynomial. In order to enhance the robustness of the model, a battery of misspecification tests are used to evaluate it. These tests include the autocorrelation test (Breusch and Godfrey, 1981) where the null hypothesis stipulates no serial correlation in the residuals. Moreover, the ARCH test (Engle, 1982) where the null stipulates no serial correlation in the squared residuals is employed. Other tests include the normality test (Bera and Jarque, 1982) which tests the normality assumption in residuals, the heteroskedasticity test (Breusch and Pagan, 1979) that tests the assumption of constant error variance, and finally, the Reset test (Ramsey, 1974) which tests for linearity in the functional form of the regression.

**5.5. Results and Discussions**

We estimate three models to ascertain the determinants of natural gas demand in oil producing African countries. These are the dynamic panel generalized method of moments, the two stage least squares and general unrestricted model. Table 4 presents the results of the dynamic GMM. According to Fang et al. (2011), the use of instrumental variables in GMM addresses the endogeneity problem. In specifications (1) to (5), the predictors of natural gas demand enter the regression individually whilst specification (6) employs the full set of predictors.

**5.5.1 Results from the Dynamic Panel GMM**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G (-1)$</td>
<td>0.917</td>
<td></td>
<td></td>
<td></td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td></td>
<td></td>
<td></td>
<td>(0.030)</td>
<td></td>
</tr>
<tr>
<td>$P$</td>
<td></td>
<td>-0.032</td>
<td></td>
<td></td>
<td></td>
<td>-0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.011)</td>
<td></td>
<td></td>
<td></td>
<td>(0.017)</td>
</tr>
</tbody>
</table>
Table 5.4 reports the results from the panel dynamic GMM estimation. In tandem with general findings in the energy economics literature (Balestra and Nerlove 1966, Erdogdu 2010, Andersen et al., 2011), GDP has a positive and significant effect on natural gas demand. When income increases, consumers buy natural gas using appliances or increase the frequency of use of existing appliances such as natural gas cylinders leading to increased gas consumption. In addition, increased income leads to increased demand for electricity. Since natural gas is an input into electricity generation, gas consumption increases through additional power generation (Hultman et al., 2011). In both the individual and group specifications, GDP is positive and significant. Specification (3) reports that 1% increase in GDP leads to an increase of 0.032% in natural gas consumption. This is supported by the findings of specification (6) which reports that 1% increase in GDP leads to 0.028% increase in natural gas consumption. The positive and significant relations between natural gas demand and GDP underscores the importance of energy policies that encourage the accessibility and availability of energy demand. Investments in cross-border natural gas infrastructure such as the West African Gas Pipeline that stretches from Nigeria to Ghana, should be taken to enhance regional economic growth. The positive relationship between income and energy demand has been widely documented (Cleveland et al., 2000 and Ayres et al., 2007). In addition, the inverse relationship between price and energy consumption has received considerable attention (Gately and Huntington, 2002, Wadud et al., 2010). It has been suggested however that there are other factors such as technological progress, lifestyle and economic structure that affect the demand for natural gas or energy apart from price and income (Bhattacharya and Timilsina, 2009).

The estimated CPI which proxied for energy price is significant in both specifications (2) and (6). The results show that the CPI has an inverse relationship with natural gas demand. These results vindicate Mahadevan and Asafu-Adjaye (2007) who identify a negative and significant price effect on the CPI.
According to Table 5.4, 1% increase in price reduces natural gas demand by 0.032% in specification (2) and 0.033% in specification (6).

Moreover, natural gas is a non-renewable source of energy. This means as a unit of gas is drawn, the remaining amount reduces. In order to test whether this concept has an impact on demand, a variable for energy resource depletion was introduced into the model. This is to measure whether energy resource depletion has any effect on natural gas demand. Though the effect of natural resource depletion in specification (6) is insignificant at 5%, results from specification (4) 1% increase in energy resource depletion reduces natural gas consumption by 0.441%. This may imply that other energy sources such as renewable energy are used as alternatives for power generation and cooking.

Since non-renewable sources of energy such as coal, oil and natural gas emit carbon dioxide, the study also examines how carbon emissions affect the consumption of natural gas. Table 5.4 reports that though the estimates for carbon dioxide in specifications (5) and (6) are positive, they are not significant.

### 5.5.2 Results from the Dynamic Panel Two Stage Least Square (DP-TSLS)

**TABLE 5.5. ESTIMATION RESULTS – DYNAMIC PANEL TWO STAGE LEAST SQUARES**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G (-1)</td>
<td>0.687</td>
<td></td>
<td></td>
<td>0.952</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td></td>
<td>(0.018)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>-0.035</td>
<td></td>
<td>-0.028</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.013)</td>
<td></td>
<td>(0.010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td></td>
<td>1.154</td>
<td></td>
<td>0.062</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.094)</td>
<td></td>
<td>(0.027)</td>
<td></td>
</tr>
<tr>
<td>ED</td>
<td></td>
<td></td>
<td>-0.418</td>
<td></td>
<td>-0.052</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.092)</td>
<td></td>
<td>(0.032)</td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td></td>
<td></td>
<td></td>
<td>0.004</td>
<td>0.064</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.002)</td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>0.987</td>
<td>0.959</td>
<td>0.957</td>
<td>0.954</td>
<td>0.948</td>
<td>0.969</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>DW</td>
<td>1.680</td>
<td>0.461</td>
<td>0.420</td>
<td>0.431</td>
<td>0.345</td>
<td>1.990</td>
</tr>
</tbody>
</table>

Note: Standard errors are reported in parentheses. The coefficient estimates highlighted in bold are significant at the significance level of 5%.
Table 5.5 presents the results of the dynamic panel two stage least square (DP-2SLS) model for natural gas demand in oil producing African countries. The findings are qualitatively similar to those of the dynamic panel GMM. Consistently, in the GMM estimation of the model, the lagged dependent value of natural gas consumption is positive and significant. This implies that the previous year’s consumption follows a long memory process. According to Table 5.5, an increase in previous year’s consumption of 1% leads to an increase in current consumption of 0.687% (1) and 0.952% (6). This increase may be as a result of improved standard of living, population higher birth rate or increased demand for electricity.

5.5.3 Results from the General Unrestricted Model
This section discusses the results of the general unrestricted model.

TABLE 6. ESTIMATION FROM THE GUM MODEL

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Algeria</th>
<th>Angola</th>
<th>Egypt</th>
<th>Nigeria</th>
<th>Tunisia</th>
</tr>
</thead>
<tbody>
<tr>
<td>G(-1)</td>
<td>0.464</td>
<td>0.303</td>
<td>0.353</td>
<td>0.729</td>
<td>0.700</td>
</tr>
<tr>
<td></td>
<td>(0.135)</td>
<td>(0.155)</td>
<td>(0.084)</td>
<td>(0.025)</td>
<td>-0.156</td>
</tr>
<tr>
<td>P</td>
<td>-1.196</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.327)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>0.134</td>
<td></td>
<td>0.652</td>
<td>0.133</td>
<td>0.631</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td></td>
<td>(0.098)</td>
<td>(0.022)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>ED</td>
<td>0.106</td>
<td></td>
<td>-0.254</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td></td>
<td>(0.020)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2(-1)</td>
<td>0.574</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2(-2)</td>
<td>0.201</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I(1984)</td>
<td></td>
<td></td>
<td></td>
<td>0.180</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>S(2003)</td>
<td>0.219</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S(2004)</td>
<td></td>
<td>-0.366</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.052)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR 1-2</td>
<td>0.253</td>
<td>0.487</td>
<td>1.359</td>
<td>2.700</td>
<td>0.519</td>
</tr>
</tbody>
</table>
Table 5.6 shows the result of the model selected by the general to specific model selection procedure. Consistently with the conventional modelling strategy, five lags to each variable are used (see Hunt et al., 2003, Broadstock and Hunt, 2010). Autometrics selected step dummy (SI) variables for Nigeria in 1977, 1978, 1986, 1987, 1988, 1991, 2008 and 2009. Step dummies take the value of 0 for the year before an event occurs and 1 for the year after the event. The numerous step dummies for Nigeria may represent responses to changes in international oil price shocks in 1977/78, 1986 and 2008/2009. Price increases lead to energy efficiency measures and changes in lifestyle such as the energy efficiency standardization introduced in the early 1990’s. The price variable is only significant for Algeria and Tunisia with Algeria recording the highest short and long run elasticities. The short run price elasticity for Algeria is -1.196 whilst the long run is -2.231. According to Wadud et al. (2011), for developing countries the elasticity estimates are often reported greater than unity. In terms of income, Egypt recorded the highest elasticity value in the short run. The model passed all (with few exceptions highlighted in bold) diagnostic tests and the estimates in Table 6 represent the preferred model.

5.5.4 Underlying Energy Demand Trend
Energy has a derived demand. Therefore, the demand for all forms of energy, including natural gas, is a result of demand for energy services such as power generation, heating and cooling (Dilaver et al., 2014). This implies that the factors that influence the provision of these energy services play a vital role in determining the demand for natural gas. For instance, Dilaver et al. (2014) suggest that the capital stock and the efficiency of the capital through which energy services are provided is a key determinant of natural gas demand. However, Hunt et al. (2000) posit that the efficiency of the capital appliance is not the only exogenous factor that affects the demand for natural gas and cite energy regulations,
consumer lifestyle, consumer values and changes in taste for appliances that could lead to a more or less energy intensive situation, and technological development as some of the other exogenous factors. It is therefore important to consider these exogenous factors when modelling the demand for natural gas (Hunt and Ninomiya, 2005, Doornat et al., 2008, Dilaver and Hunt, 2011). According to Hunt et al. (2000), the collective name for these exogenous factors is the underlying energy demand trend (UEDT).

In summary, the underlying energy demand trend shows the technical efficiency of energy using appliances. Hunt et al. (2003) explain that an upward slope implies that energy savings due to appliance efficiency have been consumed by excessive demand and inefficient behaviour. A downward trend of the UEDT implies energy saving behaviour which could be due to increased efficiency of the appliances used. This means consumers are using less energy to achieve the same results. This could be due to behavioural change as a result of increased energy prices or education, technological improvement or government policies such as the introduction of feed-in-tariff. These efficiency gains can however be short-lived due to the rebound effect. That, consumers may be tempted to consume frequently or more quantity when they experience efficiency gains. Generally, the UEDT of the various countries imply that these countries have to do more to enhance energy efficiency and promote technological innovation in natural gas consumption.

FIGURE 5.3. UEDT ALGERIA
The UEDT of Algeria shows an increasing trend with minor structural breaks in 1980 and 1990. This trend implies that the excessive natural gas consumption offset the efficiency gains of technically efficient appliances over the estimation period. The UEDT is similar to the trend reported by Sa’ad (2011) for the aggregate energy demand in South Korea.

Angola has initiated a number of energy efficiency measures over the last decade according to Lutken et al. (2013). Although these measures are not reflected in the trend since it slopes upwards, there are major structural breaks in 2001, 2004, 2005, 2007 and 2008. There was a downward trend from 2000 to 2001, 2004 to 2005 and 2007 to 2008. From 2009, the trend has been increasing but relatively slower.
The underlying energy demand trend shows an upward slope with a structural break in 2004 which may be due to oil price volatility or recession. The trend implies that inefficiencies associated with natural gas consumption offset efficiency gains through the technical progress of appliances in Egypt.
According to Figure 5.6, Nigeria’s UEDT has been relatively stable and the trend appears to flatten after 1991. This may be as a result of measures such as appliance standardization, efficiency education and other efficiency measures introduced after an energy efficiency study commissioned by the Nigerian Energy Commission and conducted by the Sokoto Energy Research Centre (Sambo, 2005).

The UEDT for Tunisia is similar to the trend reported by Pellini (2014) for France. The trend rises gradually with no major structural breaks signifying ‘natural gas using’ behaviour. This shows the inefficient consumption of natural gas indicating that over the years, households in Tunisia have exhibited an increasing demand of lighting, cooling and heating services that has more than offset the impact of improved technical efficiency of appliances. This may explain a recent World Bank grant of US$8.5 million to Tunisia in 2013 to implement energy efficiency strategies.

5.6. Conclusion and Recommendations
Natural gas is considered a bridge fuel between renewable and non-renewable sources of energy. Apart from this, natural gas is relatively cheaper than oil, cleaner than oil and coal and widely available in oil producing African countries. This makes natural gas very attractive for domestic consumption, industrial usage and power generation in oil producing African countries. In this study, the predictors of natural gas demand in oil producing African countries are examined. In order to ensure the
robustness of the findings, three models are used in this study. First, a dynamic panel generalized method of moments with instrumental variables that is capable of controlling for endogeneity is used. In addition, following the recommendation of Wooldridge (2011) who asserts that the dynamic panel two stage least squares is more efficient with IV, the study employs the panel TSLS as a second model to estimate natural gas demand. Finally, the structural time series model that is capable of modelling the underlying energy demand trend is applied. Five main variables including the lag dependent variable are used in this estimation. They are energy resource depletion, GDP, price and energy related CO₂.

The results are in line with findings in existing literature. The study confirms the importance of all the predictors such as income, price, energy resource depletion and the lagged dependent variable on natural gas consumption in oil producing African countries. This notwithstanding, the model reported conflicting results for energy related CO₂ and energy resource depletion. Moreover, the study finds that the countries under study have not been efficient in terms of natural gas consumption over the estimated period.

Based on the findings, the following recommendations are made. First, the advantages of natural gas consumption such as lower carbon emissions should be highlighted to encourage its consumption. In addition, effort should be made to encourage domestic natural gas consumption through gas availability by discouraging charcoal consumption. Again, effort should be made to encourage efficiency and technological innovation in natural gas consumption. Whilst this chapter made attempts to include all oil producing African countries, unavailability of data made it very challenging. Future research should explore other available datasets to include more countries. Finally, there should be conscious effort to encourage energy efficiency and demand side management to curb emissions and enhance energy conservation.

Natural and Renewable Energy sources are available in Africa. The findings in chapter 4 and 5 indicate that policy makers will have to use both economic strategies such as subsidies and non-economic ones such as education to encourage consumption. Energy efficiency has been found to be clean, affordable and available. It is therefore has some advantages over the traditional sources of energy and can complement natural gas and renewables. In chapter six, the product generational dematerialisation to
study energy efficiency in Ghana. Further, the chapter investigates the barriers to energy efficiency practices among SMEs in Ghana.
CHAPTER 6: ENERGY EFFICIENCY

6. 1. Introduction

SMEs operating in developing countries face the hydra-headed challenges of energy access, power outages, access to finance and access to market. These challenges adversely affect productivity, hinder their competitiveness and stifle growth. Thus, for SMEs to maintain their competitiveness, they need to be energy efficient, insofar as energy efficiency reduces the costs of production through reduced energy bills (Worrell et al., 2003). At the aggregate level, energy efficiency is the cheapest way of reducing energy-related carbon emissions. At the firm level, energy efficiency can be a key means of enhancing productivity growth (Jorgenson, 1984; Thollander et al., 2007). Furthermore, environmental policies that seek to curb carbon emissions have positive health effects due to improved air quality. In this regard, the Johannesburg Plan of Implementation of the United Nations Department of Economic and Social Affairs, (UNDESA, 2002) called on both developed and developing countries to develop policies and measures contributing towards the reduction of carbon emissions. Energy efficiency can lead to improvements in energy security and ensure a firm’s profitability and competitiveness (Gboney, 2009).

A major drawback is that most studies in this field are either carried out in developed economies or at the aggregate level. Furthermore, energy efficiency gains are constrained by the market mechanism and rely upon the extent to which the energy market can be restructured (Jaffe and Stavins, 1994). Indeed, imperfect competition, asymmetric information and incomplete markets, among other inhibitors, can hinder the viability of energy price changes as a major efficiency tool. More generally, economic, behavioural and organizational hindrances to energy efficiency gains have been investigated (Sorrell, 2007). For instance, Sutherland (1991) studies economic impediments to efficiency of energy consumption and identifies the external cost to the consumption of energy as one of the reasons governments should initiate in energy efficiency measures. Indeed, Shirley (2005) classifies barriers into firm profitability, consumer concerns about prices and the preparedness of regulators to restructure energy markets. These different findings call for SME-specific initiatives, behavioural changes and policy intervention in the context a developing country like Ghana.
In 2011, Ghana grew at an astonishing rate of 14.4% and it attained middle-income status (Aiyar et al., 2013). To sustain such growth, various measures have been undertaken by policy makers, businesses and researchers. First, the government recently established a fund (Youth Enterprise Support Fund) to help the country’s youth start businesses. Second, researchers and policy makers are calling on the government to remove energy price subsidies. The removal of such subsidies will increase energy prices. The cheapest way of offsetting the impact of energy prices on a firm’s performance is through energy efficiency (Patterson, 1996). To this end, the Energy Commission of Ghana encourages energy-efficient practices through education and other measures, such as ‘swapping old freezers for new ones’.

Although these policies have been well received, they mostly target household energy consumption. Even at the household level, to the best of our knowledge, no study has yet attempted to evaluate the effects of such energy efficiency policies on energy consumption and productivity in both rural and urban areas. Gboney (2009) is perhaps an exception. He finds that energy efficiency activities undertaken by the Energy Foundation in Ghana within the residential and business sectors have yielded significant monetary savings for consumers. However, Gboney’s (2009) study makes a critical untested assumption that the impact of energy efficiency practices in Accra can be generalized and extended to other regions in Ghana, thus neglecting the potentially important effect of geographical location.

According to Shipley and Elliot (2001), SMEs (i) sometimes face challenges in obtaining the necessary advice on new and existing energy methods and technical innovations and (ii) have inadequate capital and technical know-how to invest in energy-efficient technologies. These difficulties are amplified by the relatively low level of attention directed at non-energy-intensive SMEs in policy (Ramirez et al., 2005). Although an increase in energy prices is necessary for energy efficiency, Bertoldi et al. (2005) suggest that this is not always an effective mechanism. Energy-efficient technologies have many advantages, such as lower maintenance costs, high productivity and safe working environment. Despite these advantages, there is dearth of energy efficiency studies focusing on Ghana. The few attempts that have been made (Van Buskirk et al., 2007; Gboney, 2009; Apeaning and Thollander, 2013) are either sector-specific or focused only on electricity consumption.

This study uses the product generational dematerialization (PGD) indicator to investigate energy efficiency practices in Ghana. The PGD has been applied to dematerialization or decoupling (Recalde et al., 2014), resource use such as that of water (Fiksel et al, 2012) and waste reduction, for example of
food waste (Guidat et al., 2015; Van Ewijk and Stegemann, 2014). The PGD indicator measures a change in population in relation to changes in the energy used by this specific population (Ziolkowska and Ziolkowski, 2010). The PGD therefore measures a decrease or an increase in energy consumption by a given population. When energy consumption decreases, the population is said to save energy or behave efficiently. By contrast, when energy consumption increases, the population is said to exhibit energy-using behaviour. ‘Materialization’ refers to an increased energy consumption relative to a reference year, while ‘dematerialization’ characterizes a lower energy consumption compared to the reference year. This study extends recent boundaries in the application of the PGD indicator by considering the efficiency of current electricity, fossil fuel and total energy consumption by comparing changes in energy consumption and changes in population. In this respect, the PGD indicator has three main advantages. First, it allows a dynamic analysis of energy consumption. Second, it helps create a new interpretation and visualization method. Finally, it provides a model that is easily comprehended by the public, policymakers and investors. The study further applies the subjective evaluation method to examine the energy efficiency practices of SMEs and the barriers to energy efficiency in rural Ghana.

6.2. Literature Review

The literature review analysis the regulatory framework of energy efficiency in Ghana and an overview of empirical studies on energy efficiency, productivity and SMEs. It ends with a summary and identification of gaps in the literature.

6.2.1 Energy efficiency

According to neoclassical economic theory, the production function represents the relationship between the maximum amount of output that can be obtained from a given amount of energy and other inputs (Sorrell, 2007). Energy productivity is essential to the environment and economic growth. First, it is the cheapest way to reduce global emissions of greenhouse gases (McKinsey, 2010). The International Energy Agency (IEA, 2006) finds that an additional dollar spent on more efficient electrical equipment, reduces investment in electricity production by two dollars. Second, energy saved through productivity
measures can channelled to existing and new industries. Energy efficiency has been found to be a major means of minimising the effect of the trade-off between a reduction in energy consumption and economic growth. For instance, Dan (2002) finds that there has been a gradual decline in energy consumption in China since 1978 despite increasing growth and attributed this to energy efficiency.

Post oil price shocks in 1973/74 and 1979/80 witnessed an average productivity in energy use increasing due partly to the replacement of energy-inefficient machines, methods and appliances with efficient means (Berndt, 1990). This efficiency can be embodied in the capital or can be disembodied in the form of experience. Berndt (1990) asserts that as one operates a production process, experience is accumulated through learning, which leads to a decreasing unit cost that is independent of the capital stock. He indicates further that an increase in energy productivity usually follows energy price high but often with time lags. This means changes in energy consumption can happen through learning, in the same way as when capital stock is replaced with more energy-efficient means. The lifestyle of the consumer can also affect their consumption of energy. Hager & Morawicki (2013) reveal that the act of closing a pot with a lid when cooking can reduce energy consumption by more than 8 times. Also people who cook in pots that are full to capacity tends to use lesser energy.

6.2.2 Product generational dematerialization (PGD)

Although there are several sustainable energy consumption indicators, such as the eco-index, the environmental sustainability index and the composite sustainable development index, it has been suggested that they are not sufficient to measure dynamic energy efficiency (Labuschagne et al., 2005). According to the IEA (2006), these indicators measure static efficiency. The PGD on the other hand evaluates simultaneous changes in population and energy consumption (Ziolkowski and Ziolkowska, 2015). The PGD indicator measures a change in population in relation to changes in the energy used by this specific population (Ziolkowska and Ziolkowski, 2010). The indicator can either be used independently or as a complementary instrument in an energy efficiency study. The PGD indicator
reveals two main outcomes: either materialization or dematerialization of energy resource use. According to Sun (2001) dematerialization or materialization is “the real change of energy use in an observation year if that is less/more than the trend based on the levels of a given base year, and if this process occurred throughout the whole observation period”. ‘Materialization’ can be defined as an increased level of energy consumption relative to the reference year, while ‘dematerialization’ depicts a reduced level of energy consumption relative to the reference year. Therefore, materialization occurs when households and industries consume more energy through frequency of use, or excessive use in relation to population growth (Singh et al., 2009). This notwithstanding, energy consumption can be influenced by regulations, lifestyle and environmental concerns. These factors are termed ‘taste’ factors and are captured by the underlying energy demand trend (see figure 7) (Hunt et al, 2003).

6.2.3 Energy Efficiency Regulations in Ghana

According to Gboney (2009), if appropriate energy efficiency policies are initiated and well implemented, it can help countries to meet increased demand for energy at the lowest cost and also minimize the environmental consequences of energy consumption. Based on this assumption, policy makers in the energy sector have a number of strategies and tactics to encourage energy efficiency and demand-side management. In 1997, the Ghana Energy Commission (EC) was established by a law passed by parliament (Act 541). The purpose of the EC is, amongst other things, to enhance the development of renewable energy resources and promote efficiency of energy production and use. In the same year, the Ghana Energy Foundation, a public–private organization, was created with the mandate to develop energy efficiency mechanisms and promote energy efficiency among consumers. Gboney (2009) points out that although the Ghana Energy Foundation has made some progress, most of its activities have been limited to the residential sector.

One key measure introduced by the Ghana Energy Commission was the labelling of appliances. (see Figure 6.1). This initiated is backed by the Legislative Instrument 2005 (LI 1815).
6.2.4 Demand-side management of energy

In 1999, the Ghana Energy Foundation conducted a study on the energy efficiency practices of the Ghana Textile Manufacturing Company and found that the company saved 207,000 KWh in electrical efficiency, translating into 3,519 Ghanaian Cedis (GHC1.6 = US$1).

According to Zhou et al. (2008), DSM helps to reduce electrically related accidents, promotes customer satisfaction and reduces operational costs. With the continuous growth rate in electricity demand in Ghana, it can be deduced that utilities have a lot of work to do in terms of increasing investment and the supply side. Despite this, the government is strongly looking at DSM as a means of checking consumption trends and reducing power consumption. Within a few years, smart metres will be fixed in
households to enable better monitoring of their electricity use and private load control (Gottwalt et al., 2011).

There are various concerns about DSM, which are not new. The concept surfaced in a study in the 1908s when the need for solutions to influence consumers’ use of electricity was raised. DSM was considered even earlier, irrespective of the different kinds of utilities or geographical regions of a country. From a broader perspective, the main DSM techniques which have been implemented are as follows: (i) the use of night time storage heaters and electrical heating (Strabac, 2008); (ii) the adoption of low limiters (activated when demand is above a specific threshold); (iii) reduction in the price base for electricity usage, desirable time slots and curve flattening through the activation of DSM programming (Dincer, 2002); (iv) the inclusion of smart appliances which manage their own operation; (v) smart metering and feedback updates; (vi) the use of frequency regulation to manage generators and loads (Mohsenian-Rad et al., 2010).

One factor which constrains and limits the application of DSM approaches is the existence of stand-alone micro grids. For instance, the demand curve, which shows the match between demand and solar generation over periods of time, must be flattened. The opposite of this strategy must be applied to the normal grid. During wind generation, the local-based and changing nature of wind demands the application of control strategies and efficient load management to allow for the management of fluctuations and intermittence which can create system failures. Another strategy which can be implemented for DSM is load shifting. This has been proposed for the management of micro grids. However, there is lack of proper definition for DSM in relation to stand-alone grids which focus how to manage and optimize power generation (Deindl et al., 2008).

6.2.5 Energy efficiency practices in Ghana

The Ghana Shared Growth and Development Agenda (GSGDA) (2010–2013) confirms the need for reliable supply of high quality energy services for national development. This notwithstanding, Ghana has been experiencing intermittent power supply and load-shedding in the past which has led to reduced productivity and output, decline in GDP and unemployment. According to Braimah and Amponsah (2012), these negative effects are as a result of delays, lack of alternative sources of power, and increased cost of production which makes. The Institute of Statistical, Social and Economic
Research (ISSER, 2013) estimates that the contributions from the electricity sub-sector to economic output in 2011/2012 were at the level of 0.5% and its contribution in industry’s share of GDP in 2012 reduced in total to 1.8%.

According to Gyamfi (2007) and Adom et al. (2012), the solution to Ghana’s electricity challenges is the effective demand side management. Though Adom et al. (2012) and Adom and Bekoe (2012) study electricity demand in Ghana, their studies did not consider aggregate and firm level energy efficiency practices.

The following short-term DSM strategies have been proposed by policy makers to increase energy efficiency in the country (Ofosu-Ahenkora, 2008):

1. The intensification of energy efficiency education.
2. The implementation of mandatory efficiency standards for room air conditioners and CFLs.
3. Supply and injection of 6 million CFLs by the government, expected to reduce peak demand by 200–240 MW – the cost of this option is US$60/MW capacity compared to US$1,000/MW for simple cycle gas turbines (SCGTs).

This study therefore seeks to:
1. Examine energy efficiency practices of SMEs in Ghana.
2. Identify the causes of efficiency (inefficiency) behaviour
3. Ascertain whether Ghana has been efficient with regards to electricity and gasoline consumption.

6.3. Methodology

This study applies the PGD, similar to the work of Ziolkowska and Ziolkowski (2015), but departs from existing literature by applying a dynamic dematerialization model to study energy efficiency in Ghana. Unlike Ziolkowska and Ziolkowski (2015), who focused on the transport sector, this study focuses on the efficiency of the aggregate use of different kinds of energy (fossil fuel, electricity and total energy consumption). The study goes further to identify energy efficiency practices of small- and
medium-scale enterprises in rural Ghana and ascertain the barriers to energy efficiency. To achieve the second objective, 15 industries were selected from 4 regions: Central, Eastern, Greater Accra and Volta. The choice of the industry and regions was dictated by energy consumption rate, energy access rate and the selection of electric utility provider. Based on the classification of the Regional Project on Enterprise Development, the study categorizes small enterprises as those with 5–29 employees and medium-sized enterprises as those with 30–99 employees (Regional Enterprise Development, 2008). The higher response rate may have been due to the Ghana energy crises which had led to general increased interest in energy matters.

Following the work of Ziolkowska and Ziolkowski (2015), a PGD which involves changes in population and changes in electricity and gasoline consumption is used. The data span the period from 1971 to 2013. The PGD is measured as follows:

$$PGDE_i = \Delta POP_t - \Delta EC_t$$

where $PGDE_i$ is the product generational dematerialization of electricity consumption at time $t$ and $POP_t$ is the population of Ghana at time $t$. From this, we derive the following equation for the efficiency of gasoline consumption:

$$PGDG_i = \Delta POP_t - \Delta GC_t$$

where $\Delta GC_t$ represents the dynamic changes in gasoline consumption in Ghana. Other variables (product generational dematerialization and population) are as defined in Equation (1). Equations (1) and (2) can be re-written as:

$$PGDE_i = \left(\frac{POP_t}{POP_{t-1}}\right) * 100\% - \left(\frac{EC_t}{EC_{t-1}}\right) * 100\%$$

$$PGDG_i = \left(\frac{POP_t}{POP_{t-1}}\right) * 100\% - \left(\frac{GC_t}{GC_{t-1}}\right) * 100\%$$

A positive PGD would mean that energy consumption decreased in the years analysed compared to the preceding years given what was expected to happen if all the population consumed energy in the same
way. Conversely, a negative PGD would mean that the energy consumption increased given what was expected to happen if all the population consumed energy in the same way. Both outcomes would deliver policy-relevant information for decision making.

3.1 Description of data

Data for the study were collected from two sources. First, data for the PGD analysis were collected from the World Development Indicators (WDI) of the World Bank. Data on fossil fuel and energy consumption in kilotons of oil equivalent (ktoe) for the period 1971 to 2012 and on electricity in kilowatts per hour (kWh) and population figures from 1971 to 2012 were obtained from the WDI.

The second part of the study made use of data collected from SMEs in rural Ghana through a questionnaire and observation. The essence of using observation is to minimize the impact of social desirability biases, i.e. when respondents report things that may not be the fact on the ground or reflect actual behaviour (Brace, 2004). The sample size for the study is 160 SMEs in rural area as defined by the Ghana Population Census. The coastal zone of Ghana, which comprises the Western, Central, Greater Accra, Volta and Eastern Regions, is generally humid and is home to most energy-intensive SMEs. Four regions were selected: Central, Eastern, Greater Accra and Volta. The questionnaire was pre-tested to ascertain whether the respondents understood the questions asked and whether they were consistent with the objectives set out by the study. The questionnaire contained both close and open-ended questions. Numbers were assigned to the qualitative variables for the purpose of understanding the relationships between the variables. The higher response rate of 80% was as a result of increased interest in energy matters due to the Ghana energy crises. Please refer to page 218 (Appendix O for the questionnaire. Parametric (Bonferroni) and non-parametric tests (Mann–Whitney and chi-squared tests) were used to test for non-response bias between the respondents and the non-respondents. These primary data were compared to data from the Ghana Statistical Service.

6.4. Analysis and Discussion

6.4.1 Product generational dematerialization (PGD)
Figure 6.2. Results of product generational dematerialization

Figure 6.2 shows the PGD of fossil fuel consumption (PGDFFC), total energy consumption (PGDTEU) and electricity consumption (PGDelc) in Ghana from 1971 to 2011. The trends for all three variables show structural breaks and follow a similar pattern. Fossil fuel consumption showed a positive trend of generational dematerialization in 1975, 1981 to 1983, 1988, 1990, 2000, 2003 to 2004 and 2007. These changes in the trend could have been influenced by certain economic and political events that have impact on energy consumption. For instance, Ghana experienced a major drought from 1981 to 1985 which affected the water level of the Akosombo Dam, the main producer of electricity then. In addition, 1981 was associated with the end of the coup d’état that brought Flight Lieutenant Jerry John Rawlings of the Provisional National Defence Council (PNDC) to power and changes resulted in the suspension of the Ghana’s constitution and some state institutions. These led to a decline in economic activities and economic output leading to the implementation of the World Bank sponsored structural adjustment plan and economic recovery programs changing many old economic policies. The structural adjustment programme witnessed a shift from agrarian based economy to gradual movement to industry based economy through divestiture of poorly managed public owned companies and, public-private investments. These structural changes had energy consumption implications. However, the general pattern suggests inefficiency in fossil fuel consumption. Finally, the PGD of total energy
consumption is -0.27%. This implies that there is high efficiency in non-fossil fuel energy consumption such as renewables. As energy efficiency improvements rely on technological progress and behavioural changes, there should be systematic investments in energy efficiency measures and education to save money, save energy and also curb carbon emissions.

Overall, fossil fuel consumption recorded a PGD of -1.51% over the estimated period. This finding is in line with the PGD of Estonia (-1.5%) and Sweden (-1.4%) for non-renewable energy consumption reported by Ziolkowska and Ziolkowski (2015). The negative PGD for fossil fuel implies that energy consumption is growing faster than population growth. With carbon emissions from liquid fuel consumption increasing, there is a need for policy initiatives that will encourage efficiency in fossil fuel consumption.

![Figure 6.3. Carbon emissions of fossil fuel consumption](image)

Figure 6.3 shows carbon emissions from liquid fuel consumption of 2016.85 kt in 1971. As at 2010, this had jumped to 7990.39 kt. Therefore, there is a need to implement measures that will promote investment in technology, reduce the imports of used vehicles and introduce efficient mass transportation systems to reduce the number of cars on the road, as well as educational promotion to target behavioural changes.
In 1997, the Ghana Energy Commission was launched as an agency to promote standards and efficiency in the use of energy. However, it has focused predominantly on the efficiency of electricity consumption at the expense of other fuel sources such as gasoline. For instance, the Ghana Energy Commission has introduced the ‘old fridge for new’ campaign to minimize waste in electricity consumption, coupled with educational campaigns that inform on the need to adopt efficient practices with regard to electricity. The PGD for electricity consumption was -1.11%, which is lower than that for fossil fuels. This means that more has to be done, especially in rural areas where some of these energy campaigns by the Ghana Energy Commission do not reach.

6.4.2 Energy efficiency of SMEs in rural Ghana

The study uses a survey conducted from November 2014 to March, 2015 in 4 out of the 10 regions of Ghana through a questionnaire, which is summarized in Appendix 1. The essence of the study is to identify energy efficiency practices of SMEs in rural Ghana and ascertain whether these practices influence productivity. The reason for the rural emphasis is that few works that have been conducted on energy efficiency are concentrated in the urban areas (see Gboney, 2009). In addition, energy efficiency education is usually carried on televisions, which may not be accessible by the rural population. Finally, since the Ghana Energy Commission is not decentralized, the old fridge for new one policy is clustered in cities. In all, 200 questionnaires were distributed, and 160 were returned completed. The questionnaires were semi-structured with both closed and open-ended questionnaires. The high rate of response may be attributed to the high interest in the public in energy matters at the time of the study as a result of the Ghana power crises. The industries were selected based on their connection to the electricity grid, whether they operate within the rural Ghana and their preparedness to answer the questionnaires. The rationale behind the using rural SMEs is that the work of the Energy Commission including television adverts and energy efficiency promotions is mainly concentrated in the cities. Therefore, the chapter seeks to examine the knowledge of SMEs in rural Ghana on energy efficiency practices and whether they are implementing such practices and also identify their sources of information on energy efficiency. The industry distribution is summarized in Figure 4.
Figure 6.4. Industry distribution for data collection

Figure 6.4 highlights the industry categorization of the respondents. Because hair dressing saloons, barbering shops and dress making shops are predominant in rural areas, the fashion industry provided the highest number of respondents, followed by the catering industry. This was followed by the catering industry which comprises restaurant and traditional food joints. Please refer to page 218, Appendix O for the questionnaire.

The results indicate that approximately 60% of the SMEs studied recorded a reduction in their electricity consumption over the preceding six months. However, 72% of these attributed the reduction in electricity consumption to blackouts (unreliable power supply).
Figure 6.5. Causes of reduction in electricity consumption

According to Figure 6.5, the principal cause of the reduction in electricity consumption over the six months preceding the survey was blackouts according to 72% of those sampled. The study further finds that second most important driver of reduction in electricity consumption was increases in prices (5.7%). This confirms the findings of Adom et al. (2012), who find that price is a major driver of electricity consumption in Ghana. Price therefore leads to allocative efficiency. Finally, only 4.9% indicated that their reduced consumption resulted from energy efficiency. This finding has two important policy implications. First, policy makers can use price as a tool to achieve energy efficiency and climate change measures. Since consumers will have to pay more for a given unit of energy consumed, higher energy tariffs can serve as an incentive for consumers to make improvements in energy efficiency and lower their electricity use by investing in more efficient lighting and heating appliances or by installing higher quality insulation or windows. Second, the Ghana Energy Commission, the main body charged with enhancing energy efficiency should adopt more pro-rural mechanisms and media to target and educate rural SMEs.

In Figure 6.6, the reasons for energy efficiency are identified. This is important for policy makers to use appropriate mechanisms such as price, mass communication and subsidies to encourage energy efficiency behaviour.
In terms of where the respondents first heard about energy efficiency, 53% indicated radio and television, whilst 36.8% reported using their instincts in deciding whether they should adopt energy efficiency or not. Despite the effort of successive governments to encourage Ghanaians to use energy-saving bulbs by distributing 5,000 bulbs in 2007, approximately 54% of the respondents use the incandescent (‗onion’) bulbs, which have been found to be inefficient. The IEA estimates that CFL (energy saving bulbs) uses less than one-third to one-fifth the energy of incandescent bulbs. It is recommended that subsequent distribution of the energy-saving bulbs should consider SMEs in rural areas.

6.4.2.1 Other findings from SMEs survey

According to the findings, 60.5% turn off their appliances when not in use, 11% use fewer appliances to consume less and 8.3% of the respondents avoid the use of old or second-hand electrical appliances. Moreover, the three most important barriers to energy efficiency are lack of information on energy efficiency measures, lack of staff awareness and lack of technical skills. These barriers fall under the institutional and organizational barriers highlighted by Weber (1997). These findings mean that the Energy Commission needs to look at its communication strategy and devise means of training SMEs in energy efficiency measures. Whilst commendable efforts are being made by the Ghana Energy
Commission and Ghana Energy Foundation to promote energy efficiency, most of these efforts seem to be concentrated in urban areas. In addition, the media used by the Energy Commission, such as TV3 and Metro TV, do not have nationwide coverage, depriving rural SMEs of opportunities to learn of energy efficiency measures.

Respondents were asked for their views on how to improve energy efficiency. For instance, 26.4% of the respondents called for public education on energy use and management, whilst 8.4% called on the government to resolve the power crises. Whilst public education on energy efficiency through mass media is ongoing, efforts should be made to include rural areas. In addition, the provision under the Renewable Energy Act (2011) that calls for subsidized solar panels should be operationalized to allow rural SMEs to minimize the impact of the power crises through sales and energy efficiency efforts.

6.4.3 Relationship between energy efficiency and productivity (Autometrics™)

Hendry and Krolzig (2005) post that it is vital to select an appropriate model for empirical research, especially when there are extant arguments over the choice of variables that affect a given phenomenon. As different sets of factors can potentially influence productivity, it is important to have an econometric approach that automatically selects the significant factors based on some predefined criteria. In Africa for instance, Bhattacharya and Timilsina (2009) suggests that due to factors such the transition from traditional sources of energy to modern commercial sources and the economic structure, productivity functions may be the same as those specified for developed countries. Automatic variable selection in three main steps. First, a general model based on previous findings, geographic and demographic characteristics and technological and economic trends are specified. Second, a misspecification test, lagged forms, significance levels and the desired information criteria are then established. Finally insignificant variables are eliminated.

To ascertain the relationship between energy efficiency and productivity, a general unrestricted model (GUM) consisting of all predictors is specified. According to Patterson (1996), energy efficiency (EE) can broadly be defined as the ratio of output (Y) over energy input (E) as follows:

\[ EE = \frac{Y}{E} \]  

(5)
More specifically, energy efficiency at the aggregate level can be obtained by dividing output by energy consumption (Ang, 2006). Therefore the more goods and services a country produces with a given amount of energy, the higher its energy efficiency. This notwithstanding, the structure of the economy can also influence the amount of energy consumed. For instance, movement from agrarian to industry-based economy will lead to higher energy consumption. This is not the case of Ghana though since the service and agriculture sectors contribute more to GDP than industry. With regard to productivity, this study uses total factor productivity (TFP) as a proxy. This is because Zaman et al. (2011) highlight that the strong relationship between energy productivity and capital use indicates that energy efficiency may be augmented by optimizing capital use. Data on observed TFP for the period 1971 to 2010 were collected from the UNIDO global productivity database. TFP is calculated using growth accounting and is obtained by attributing the excess of the sum of labour and capital contribution to economic growth to productivity. For instance, using Hicksian growth accounting, we assume that a change in income (y) is the result of changes in capital (k), labour (l), productivity (a) and other factors (x), such as health, energy and quality of inputs. Thus:

$$\Delta y = \Delta a + \alpha \Delta k + \beta \Delta l + \rho \Delta x$$  \hspace{1cm} (6)

Therefore, productivity becomes:

$$\Delta a = \Delta y - \alpha \Delta k - \beta \Delta l - \rho \Delta x$$  \hspace{1cm} (7)

where A is a Hicksian demand function.

According to Boyd and Pang (2000), improvements in energy efficiency have positive effect on worker productivity and the general productivity of companies through cost saving. In this paper, the Hicksian demand function is applied since it captures the effects of re-allocation of resources by examining the intuitive appeal of the Pareto improvements through the Kaldor-Hicks efficiency (Alston and Larson, 1993). ‘A’ is a Hicksian productivity indicator. We begin by specifying a GUM error correction model which include impulse indicators and step dummies with ‘A’ as the dependent variable:

$$\beta_A(L)A_t = \beta_0 + \beta_1 t + \beta_Y (L)Y_t + \beta_{EE} (L)EE_t + \beta_{EC} (L)EC_t + \beta_{CO2} (L)CO2_t + \sum_{j=1}^{J} (\beta_j \gamma_j,t + \delta_j S_j,t) + u_t$$  \hspace{1cm} (8)
Where \( i \) indexes country, \( t \) indexes time, \( I_{j,t} \) is the impulse indicator dummy and \( S_{j,t} \) is a step dummy. For all dummies, \( j \) is the indicator index. For instance, \( I_{2004,t} \) means the impulse indicator dummy variable for 2004 that takes on the value 1 for 2004 onwards and 0 prior to 2004. \( \beta(L) \) denotes a lag polynomial. Energy consumption (EC) is included in Equation (8) since it has been found that reduction in energy consumption improves productivity (Kander, 2002). Moreover, since one of the goals of productivity is to reduce carbon emissions (CO2), this paper examines how carbon emissions influence productivity (reverse causality). It is expected an inverse relation between carbon emissions and productivity.

To enhance the robustness of the model, a battery of misspecification tests are used for its evaluation. These tests include the autocorrelation test (Breusch and Godfrey, 1981) where the null hypothesis stipulates no serial correlation in the residuals. Moreover, the ARCH test (Engle, 1982) where the null stipulates no serial correlation in the squared residuals is employed. Other tests include the normality test (Bera and Jarque, 1982), which tests the normality assumption in residuals, the heteroskedasticity test of Breusch and Pagan (1979) that tests the assumption of constant error variance, and finally, the Reset test (Ramsey, 1974), which tests for linearity in the functional form of the regression.

The output of the GUM shows that there is a significant relationship between energy efficiency, energy-related carbon emissions and productivity (see Table 1).

**Table 6.1. Estimation results on relationship between energy efficiency and CO\(_2\)**

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Coefficient</th>
<th>Std. Error</th>
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<tbody>
<tr>
<td>A (-1)</td>
<td>0.817***</td>
<td>0.041</td>
</tr>
<tr>
<td>EE</td>
<td>-0.284***</td>
<td>0.065</td>
</tr>
<tr>
<td>CO(_2)</td>
<td>0.049***</td>
<td>0.015</td>
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Diagnostics

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<tr>
<td>Sigma</td>
<td>0.019</td>
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<tr>
<td>AR 1-2 test F(2, 32)</td>
<td>0.999</td>
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<tr>
<td>Normality test Chi 2(2)</td>
<td>2.135</td>
</tr>
<tr>
<td>Hetero test F(6,30)</td>
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<tr>
<td>Observations</td>
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</tbody>
</table>
Energy intensity denotes the amount of energy that is used to obtain a unit of output, usually GDP (IEA, 2007). This means that when energy intensity increases, energy efficiency diminishes. Table 6.1 suggests that a 1% increase in energy intensity leads to a 0.284% reduction in productivity. This confirms the findings of previous studies that show an indirect relationship between energy intensity and productivity (Zhang, 2003). Figure 6.7 depicts variation over time in the energy intensity of Ghana. Ghana’s energy intensity decreased from 1971 to 1983; it increased between 1983 and 1985, then remaining constant until 2001. The increasing trend after 2001 can be attributed to inefficiency in energy consumption, the increased share of heavy industrial manufacturing companies, structural changes and obsolete technology (Ma and Stern, 2008).

Even though Ghana is gradually moving towards a service-based economy, the consumption of energy is increasing. This may be driven by urbanization, economic growth and increased population.

![Figure 6.7. Ghana’s energy intensity from 1971 to 2013](image)

In terms of energy-related carbon emissions, the lagged values have a direct relationship with productivity. This implies that as consumers become aware of previous emissions as a result of energy use, their energy using behaviour change, become greener and minimize their input use. Finally, the lagged dependent variable has a positive relationship with the current value of productivity.
Figure 6.8. Underlying productivity trend

Figure 6.8 shows the underlying productivity trend of Ghana. This is adapted from Hunt et al. (2003), who measured the underlying energy demand trend. According to Dilaver and Hunt (2011), the slope of the line determines the extent to which behaviour is productive. When the line slopes downwards, it shows generally productive behaviour. According to Figure 8, Ghana was not particularly productive until 2006, when the slope began to decline. This may be due to several factors. First, it can be attributed to the general decrease in the contribution of manufacturing to GDP and an increase in the contribution of services. As the service sector uses relatively less input such as energy, the energy to output ratio is low. In addition, the distribution of free energy-saving bulbs to both industry and households in 2007 can also explain the rise in productivity. The government of Ghana distributed six million energy saving incandescent bulbs in 2007 which saved 162.7 GWh annually.

6.5. Conclusion and Recommendations

The purpose of this chapter was to identify the energy efficiency practices of SMEs in rural Ghana and also examine the barriers to implementing energy efficiency practices. Furthermore, the study sought to ascertain the relationship between energy intensity and productivity at both the aggregate and micro (SME) levels. To achieve these objectives, three methods were employed. First, a descriptive analysis was used to examine the barriers and energy efficiency indicators. Second, a two-stage least squares approach was applied to test the relationship between energy efficiency and productivity at the micro
level. Finally, *Autometrics™* was used to examine the relationship between energy efficiency and productivity at the aggregate level.

The chapter finds that the energy consumption of most SMEs in rural Ghana has diminished. However, this reduction is attributed to the power crises and high electricity prices. Energy efficiency came third in the ranking of factors behind the reduction in electricity consumption. Furthermore, the study finds that most SMEs use post-paid meters despite efforts by policy makers to encourage the use of pre-paid meters as post-paid ones are inefficient and could be used as a tool to pay reduced bills. Moreover, 62% of the respondents indicated that energy efficiency leads to profitability through reduced electricity bills. The study also finds that lack of information on energy efficiency practices is the most important impediment to energy efficiency. With regards to the practices employed, methods such as turning off electrical appliances when not in use or when the business is closed, using new electrical appliances and using fewer appliances to achieve the same goal are some of the common approaches adopted by SMEs in rural Ghana. The results of the PGD reveal that the consumption of fossil fuel is relatively inefficient compared to electricity consumption. This may be due to the emphasis of the Ghana Energy Commission on electricity efficiency at the expense of other fuel sources.

The study recommends that the Ghana Energy Commission intensify its energy efficiency education and extend this to rural areas. In addition, associations and organizations such as churches and mosques can be used to train SMEs in rural areas on energy efficiency measures. Furthermore, the ‘old freezer for a new freezer’ programme should be extended to cover common appliances used by SMEs. As price is a vital factor in reducing energy consumption, policy makers should charge realistic prices for electricity to enhance efficiency. Finally, Ghana Energy should educate the public on the need to be efficient in terms of fossil fuel consumption to save energy, save money and curb carbon emissions.
The three previous empirical chapters concentrated on the need to invest in energy sources that are clean, available and affordable. But where will the money come from? In Chapter 7 which follows after this chapter applies a cross sectional, panel and a spatial econometric model to examine the oil resource-economic growth nexus in oil producing African countries. This can provide empirical basis for policy recommendations in investing oil revenues in cleaner energy sources.
CHAPTER 7: OIL RESOURCE MANAGEMENT

7.1 Introduction
The assumption underpinning classic economic reasoning is that natural resource endowments should be the drivers of economic growth, development and poverty reduction. Indeed, natural resources such as crude oil, gold and other primary commodity exports are the major means by which countries in their early stage of development, such as those in Africa, can generate foreign exchange and promote job creation (Auty and Mickell, 1998; Auty, 2001). In addition, revenue from natural resource endowments can be invested in other productive sectors of the economy, such as manufacturing, human capital development and agricultural modernization, which can spur per capita growth in both the short and the long term. Ross (2012) argues that revenues from oil, a key natural resource, have distinctive qualities in terms of scale, stability, source and superiority. These qualities should translate into the growth of the economy by means of job creation in the oil and oil-related industries, access to credit by companies, government and individuals, technological transfer from major foreign oil companies to local partners, training and capacity building and increased government revenue through oil-related taxes and resource rent.

However, this has not been the case in most oil-producing countries, especially in Africa. Sachs and Warner (1995) propose a paradoxical hypothesis that seems to imply that oil abundance puts limits on economic growth. This hypothesis stipulates that resource-endowed countries (e.g. Nigeria, Sudan and Venezuela) are worse performers than less well-endowed countries, such as Japan, Taiwan and Korea (Sachs and Warner, 199, Tiago et al., 2010, Ross, 2012). Based on Sachs and Warner’s (1995) findings, oil resources are therefore a curse rather than a blessing. Moreover Atkinson and Hamilton (2003) posit that the inability of resource-rich countries to translate resource wealth into development may be the source of the curse. This paradoxical hypothesis suggests a shift from the classic conception of the growth-enhancing effect of rich natural resource endowments to a growth-inhibiting effect termed the oil curse.
The purpose of sustainable development is to satisfy the needs of today’s generation whilst taking into consideration the needs of future generations and the environment. To achieve this goal, Baumgartner and Quaas (2009) recommend that natural resources should be used in three ways. First, scarce and non-renewable natural resources can be used in alternative ways to achieve a number of goals. For instance, instead of exclusive reliance on oil resources, the economy should be geared towards both oil and non-oil natural resources (e.g. agriculture) to enhance sustainability. This calls for diversification of the income from natural resources. Second, scarce resources can be used to achieve alternative goals. For instance, natural resource revenues can be invested in power production and distribution to enhance electricity access which can help minimise rural poverty and rural-urban migration. Finally, scarce resources can be used to achieve some other legitimate societal goals such as establishing social or economic mitigation funds.

Cavalcanti et al. (2011) provides a number of reasons for questioning existing models and evidence that are used to test the oil curse hypothesis. These models are usually based on the cross-sectional regression methodology applied by Sachs and Warner (1995). According to Cavalcanti et al. (2011), cross-sectional regression methodology does not take into consideration the time dimension of the data and consequently may suffer from endogeneity bias. Moreover, according to Koedijk et al. (2011), the few studies that build upon panel data methodology featuring fixed or random effects are plagued by a high degree of homogeneity across the countries under study. Koedijk et al. (2011) suggest that homogeneous estimates can exhibit large biases that may provoke wrong inferences and recommend heterogeneous estimation.

Since the 1960s, African countries have mooted the idea of an economic union just like that of the European Union. As a result, international institutions such as the Economic Community of West African States (ECOWAS), the African Union (AU) and the New Partnership for Africa’s Development (NEPAD) have been formed. In addition to the existing trade and cultural relations among African countries, there is an assumption that major developments and policies in one country can affect other countries. This assumption is empirically validated by Ellison and Glaesar (1997) who find that agglomeration or spatial concentration lead to regional socio-economic and technological spill overs.

These effects arising from the spatial agglomeration of countries have not properly been accounted for in previous studies. According to Damette and Seghir (2013), existing studies that have estimated
the oil curse feature two main weaknesses. First, these models assume the same effect of natural resources on economic growth in all countries. As countries have different quantities of reserves, production capacity and reliance on oil revenues, this assumption may lead to unreliable estimates. Second, the constant effect of natural resources is another widely held assumption in existing studies. In practice, due to oil price and production volatility, the amounts of oil revenues differ from period to period. Third, regional studies, especially those that are based on neoclassical thought, assume that the economy is closed (Solow, 1956). However, the use of regional data opens up the possibility that the variables are not independent due to the interconnectedness of contiguous countries (Anselin, 1988). If such interconnections are not factored into the modelling, bias and inefficient estimates may arise (Buccellato, 2007). Indeed, there is evidence of cross-border contagion (Easterly and Levine, 1998).

In particular, the growth of one country and its policy choices affects the growth and policy choices of other countries. While improving policies alone boosts growth substantially, the growth effects are larger if contiguous countries act together in international institutions such as ECOWAS and the AU. As the related literature on the growth–resource abundance nexus has rarely examined these geographic effects, this study seeks to test jointly the spatial effect and the neighbouring effect on the oil curse hypothesis. In this study, these weaknesses are taken into consideration by using a spatial panel data model. The spatial econometric model has three main advantages over traditional econometric methods (Paelinck and Klaassen, 1979; Anselin, 2003): i) the formal specification of spatial effects in an econometric model; ii) the use of diagnostic tests to examine the presence of spatial dependence or heterogeneity; iii) the ability to interpolate or predict spatial effects. The contribution of this study is threefold. First, the study estimates whether there is spatial dependence between the observations by taking into consideration the location of the data measured in space. The second contribution is to ascertain whether there is spatial heterogeneity among the variables and how this affects the oil revenue–economic growth nexus. Finally, cross-country heterogeneity and the time variability of the relationship between oil revenues and economic growth determinants are also major components of the model.

7.2. Literature Review

Oil is different from other natural resources in three main ways. To begin with, oil is a strategic form of energy that makes even advanced countries such as Japan and the US depend on less developed
countries such as Nigeria and Algeria. Second, due to the fact that oil is liquid, it can easily be transported from one place to another unlike natural gas. Finally, according to Amuzegar (2011), the difference between the cost per unit of oil production and the international price of oil is very high, implying huge economic rent. Therefore, the ownership of oil resources brings with it certain advantages that other natural resources may not have. These advantages should therefore translate into growth and increased welfare. However, the findings in the literature concerning the effect of oil abundance and revenues on economic growth have been inconclusive.

The oil curse hypothesis has been investigated from different economic, political and conflict perspectives. Toto-Same (2009) argues that studies of the effect of oil resources on economic growth have produced contradictory results. For instance, whilst Sachs and Warner (1995, 1997, 2001) find a negative effect of oil production on economic growth, Lederman and Maloney (2007) find a positive relation between oil resources and economic growth.

The oil curse occurs when oil production leads to high appreciation of a country’s currency which makes the manufacturing sector uncompetitive (Wijnberger, 1984). For instance, when a windfall such as the finding of oil occurs in an open economy, it leads to current account surplus, which leads to the appreciation of the local currency under a flexible interest rate regime. This makes the non-natural resource sector uncompetitive and leads to high prices (Sachs and Warner, 2001). These high prices for local produce lead to a stagnant export sector, which deprives the economy of the benefits of export-led growth and increases unemployment. Krugman (1987) illustrates that a resource boom causes hysteresis – a permanent loss in an economy’s competitiveness. Indeed, when a country’s manufacturing base is eroded due to a natural resource windfall and a negative effect of the exchange rate, the manufacturing sector cannot restore its competitiveness even if the appreciation in the currency is reversed. The export of manufacturing goods therefore becomes stunted. In a nutshell, a resource boom can crowd out the other productive sectors and the development of human capital in the economy and lead to a decrease in export and productivity (Matsuyama, 1992). Indeed, there is a lack of incentive to invest in the knowledge industry, thus affecting the development of human capital because of over-concentration on the natural resource sector (Gylfason, 2001). All these factors, acting together or separately, slow growth in oil-rich countries (Frankel and Romer, 1999). In explaining how the oil curse occurs, Toto-Same (2009) explains that every economy has three different export sectors: the booming export sector, the lagging export sector (tradable goods) and the non-traded goods sector.
The tradable export sector has the potential to enhance productive growth as it enjoys increasing returns to scale (Matsuyama, 1992). When oil resources are discovered, the tradable sector is crowded out as both capital and labour moves from the manufacturing sector to the resource and non-tradable sectors. This is known as resource movement effects. Moreover, the shift to the non-tradable sector leads to an increase in the demand for goods in this sector, which in turn leads to inflation and currency appreciation (Toto-Same, 2009). The mechanism that leads to currency appreciation is constituted by an inelastic supply in relation to the non-tradable sector (e.g. retail and hospitality in the short term). Therefore, when demand increases, prices go up, leading to exchange rate appreciation. This is known as the spending effect. This notwithstanding, in oil-producing African countries, the manufacturing sector barely exists; where it does exist, it is neither technologically driven nor globally competitive (Toto-Same, 2009). This implies that the resource curse in Africa may be due to spending and resource movement effects.

From the political perspective, Torvik (2002) argues that oil discovery and production generate incentives for rent-seeking behaviour among policy makers. According to Lane and Tornell (1996), the oil curse is also caused by the ‘voracity effect’ in which oil revenue is wasted through corruption, weak governance and excessive rent-seeking among competing interest groups. Corruption, which is a key consequence of rent-seeking behaviour, has been proven to be an anti-growth factor (Bardhan, 1997). One of the determinants of rent-seeking is governmental confusion between wealth creation and wealth extraction (Gylfason, 2001). Economic rent is the excess of revenue derived from a certain activity over the sum of its supply prices of capital, labour and any other related inputs required to undertake the activity (Garnaut and Ross, 1983). Similarly, resource rent is the value added of the natural resource, the difference between the revenues generated from extraction of the resource and the extraction cost and the cost of factors of production and their opportunity cost (Dickson, 1999). This definition is affirmed by Watkins (2001) who posits that economic rent is the value of the resource at the point of production less all prior costs incurred, including expected return on investment. These costs include wages, interest on capital, the profits of entrepreneurs and the reward for land. Although these present a high opportunity for job creation, Torvik (2002) finds that oil production leads to rent-seeking entrepreneurship.

Another perspective on the oil curse concerns conflicts and wars, such as those happening in the Delta State of Nigeria, Sudan, Algeria and Libya. In this regard, Rosser (2006) finds that oil discovery
has a strong relationship with the start and duration of civil wars. Rosser (2006) identifies three main reasons for oil discoveries attracting conflicts. First, large oil resources and production make a country or region a potential target for rebel activities or military invasion. Second, oil discovery in a particular location increases conflict incidents, such as kidnapping, bribery and corruption. Third, oil resources weaken state institutions, breed rent-seeking behaviour and render countries less likely to prevent conflict. Mehlum et al. (2006) classify state institutions as producer friendly and grabber friendly.

This notwithstanding, the resource curse hypothesis has recently been challenged (Rosser, 2006; Conrad, 2009). According to the critics, the mere presence of oil or oil revenues does not lead to a curse. Instead, the oil resource curse can be catalysed by the challenges of oil resource management, including the risk, intensity and duration of conflicts (Ross, 2006). In addition, Salai-Martin and Subramanian (2003) attribute the poor economic performance of oil-rich countries to the negative growth in total factor productivity and waste. To support this assertion, Gylfason (2001) cites Norway and Indonesia as examples of oil-rich countries which have overcome the resource curse. Toto-Same (2009) argues that oil resources raise income and savings, which can further be translated into capital accumulation and economic growth. This argument is confirmed by Hausman and Rigobon (2002) who found that average savings in oil-exporting countries were twice as high as in non-oil-exporting countries in the period 1960 to 1998.

Several methodologies have been developed to test the oil and natural resource curse hypothesis. For instance, Matsuyama (1992) applies the linkage approach to study the natural resource curse. He concludes that factors that push the labour force from the manufacturing sector to the primary sector slow economic growth. This is because the learning-induced positive effects in manufacturing that enhance productivity are reduced. In contrast, Sachs and Warner (1999) argue that such an approach is applicable to primary sectors such as agriculture and not the oil sector. As a remedy for the apparent deficiencies of Matsuyama’s (1992) approach, Sachs and Warner (1995) decompose the linkage into the tradable natural resource sector, the tradable non-natural resource sector and the non-tradable sector. They find that the greater the natural resource endowment, the greater the demand for non-tradable goods and the lesser the capital and labour allocation to the manufacturing sector. This implies that oil endowment slows industrial growth.

Extending the oil curse debate, Collier (2008) argues that the oil curse can be explained by factors other than resource abundancies, such as institutional quality, lack of skilled managers and labourers
for resource governance, geographic location and other regional factors. These make the analyses of spatial effects within the relationship between oil revenues and economic growth relevant in reaching a valid conclusion. Table 7.1 shows a summary of studies on the relationship between oil revenues and economic growth.

Table 7.1. Summary of works on the oil curse hypothesis

<table>
<thead>
<tr>
<th>Author</th>
<th>Methodology</th>
<th>Period</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexeev and Conrad (2009)</td>
<td></td>
<td></td>
<td>Abundance of oil and other natural resources have a positive impact on economic growth</td>
</tr>
<tr>
<td>Mehrara (2009)</td>
<td>Panel fixed effects</td>
<td>1965–2005</td>
<td>Growth rate of oil revenues beyond the 18% threshold has a negative impact on economic growth</td>
</tr>
</tbody>
</table>
A cursory look at the literature on the oil resource-economic growth nexus indicates a lack of consensus on the oil curse hypothesis. First, the findings in the literature are far from conclusive. Whilst a strand of the literature shows that oil resources have a positive effect on growth, other research provides evidence to the contrary. This necessitates the application of a new and rigorous methodology. Second, although Sachs and Warner (1997) suggest that geographical influence may be able partially to explain the oil curse hypothesis, Fan et al. (2012)’s study is perhaps the only one that seeks to evaluate the role of spatial dynamics on the oil curse hypothesis. However, Fan et al. (2012) study centres on China and examines how the distance between cities influences natural resource management. Unlike Fan et al. (2012), this study examines the cross-country effect and the impact of economic distance on how oil resources have contributed to growth in Africa. Agnew and Corbridge (1989) indicate that the concept of spatiality can be taken to imply the effect of geographical entities such as distance, districts, regions and structural and economic concepts (e.g. trade) on economic growth. Furthermore, Herbert-Burns (2012) posits that the concept of space (spatial attributes) is relevant to the study of oil resource management.

In a nutshell, for the purpose of effective testing, measurability and to contribute to literature, 4 hypothesis are proposed:

i. Benign business environment of oil producing countries have spatial spill over effects on neighbouring oil producing countries.

ii. Oil revenues, oil production and oil revenues have positive effect on economic growth in oil producing African countries

iii. The method applied (cross-sectional, panel or spatial panel method) does not alter the findings on relationship between oil resources and economic growth

iv. Quality institutions have significant relationship with economic growth in oil producing African countries
7.3. Methods

7.3.1. Data
This study uses a standard cross-sectional approach, with panel data and spatial econometrics to study the oil resource–economic growth nexus. The time dimension consists of annual data spanning a period of 26 years, from 1985 to 2011. The cross-section of countries is dictated by the International Energy Agency (IEA) in terms of countries that have been producing oil over the sample period. These include Algeria, Angola, Cameroon, Congo, the Cote d’Ivoire, Egypt, Equatorial Guinea, Gabon, Libya, Nigeria and Sudan. According to the IEA (2012), there are 19 oil-producing countries in Africa. In this study, only countries for which oil production data have consistently been recorded from 1985 are considered. Out of these countries, Nigeria, Algeria, Angola and Libya are the major producers. According to the EIA (2013), Africa’s oil reserves have grown by 120% in the last 30 years, from 57 billion in 1980 to USD 124 billion barrels in 2012. In 2010, Africa contributed 12.4% of global crude oil production (KPMG, 2013).

Africa’s growth has been punctuated by social and economic tensions, conflicts, corruption and global economic events (AEO, 2013). Despite these challenges, Africa recorded a growth rate of 6.6% in 2012, dropping to 4.8% in 2013 and projected to be 5.3% in 2014. This growth has principally been driven by high prices of commodities such as oil. Similar to the studies of Sachs and Warner (1995) and Yaduma et al (2013), this research uses vital determinants of economic growth, including trade openness, oil revenues and investment, as well as governance indicators, such as corruption and institutional quality. Institutional quality is proxied by the polity index. It is assumed that the oil curse is more pronounced in countries with poor institutional frameworks than in countries with quality institutions (Boschini et al. 2007). Indeed, investment in productive sectors and rent-seeking activities compete for oil revenues in countries with poor institutions. According to Mehlum et al. (2006), the prudent management of oil revenues in Norway and the US can be attributed to well-defined property rights and good quality and transparent institutions. On the other hand, dysfunctional institutions which promote rent-seeking behaviour have been cited as a key cause of poor management of oil revenues in Nigeria and Venezuela (Lane and Tornell, 1999).

Following the work of Yaduma et al. (2013), the sum of exports and imports as a percentage of GDP is used to measure trade openness. Yaduma et al. (2013) argue that trade opens an economy to the outside world and serves as a channel for technological transfer, which boosts economic growth. Other
variables that are considered in the study include investment, computed as domestic investment as a percentage of GDP. Again, energy consumption, which has been found to be a major driver of industrialization (Stern, 2003) is included as a predictor of growth. Due to lack of complete data, Libya and Equatorial Guinea are excluded from this study.

Table 7.2. Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observation</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>270</td>
<td>3.42e+10</td>
<td>3.42e+10</td>
<td>4.10e+09</td>
<td>1.66e+11</td>
</tr>
<tr>
<td>GDPpc</td>
<td>270</td>
<td>1952.26</td>
<td>1804.753</td>
<td>201.7319</td>
<td>7710.144</td>
</tr>
<tr>
<td>OP</td>
<td>270</td>
<td>4.226834</td>
<td>0.41752</td>
<td>3.017353</td>
<td>5.187351</td>
</tr>
<tr>
<td>Inv</td>
<td>270</td>
<td>19.0248</td>
<td>8.152736</td>
<td>2.1</td>
<td>52.93884</td>
</tr>
<tr>
<td>En</td>
<td>270</td>
<td>639.7167</td>
<td>304.3034</td>
<td>230.2079</td>
<td>1644.835</td>
</tr>
<tr>
<td>Oilrent</td>
<td>270</td>
<td>20.29743</td>
<td>19.78108</td>
<td>0.0673111</td>
<td>75.70786</td>
</tr>
<tr>
<td>Oilrev</td>
<td>270</td>
<td>6.51e+09</td>
<td>1.35e+10</td>
<td>7062706</td>
<td>1.25e+11</td>
</tr>
<tr>
<td>Oilreserv</td>
<td>270</td>
<td>4.635273</td>
<td>7.453701</td>
<td>0</td>
<td>37.2</td>
</tr>
<tr>
<td>GDPpc85</td>
<td>270</td>
<td>2067.11</td>
<td>2000.221</td>
<td>589.869</td>
<td>7710.144</td>
</tr>
<tr>
<td>Polity</td>
<td>270</td>
<td>6.67037</td>
<td>3.80943</td>
<td>1</td>
<td>15</td>
</tr>
</tbody>
</table>

Notes: GDP is real GDP measured in current US dollars, GDPpc is real GDP per capita measure in current US dollars, OP is oil production Kilotonne of oil equivalent, Inv is investment measured in current US dollars, En is energy consumption measured in Kilotonne per oil equivalent, Oilrent is oil rent measure in current US dollars, Oilrev is oil revenues, Oilreserv is oil reserves and Polity is a proxy for institutional quality. The estimation period is 1985 to 2011. The countries used in this study are Algeria, Angola, Cameroon, Congo, the Cote d’Ivoire, Egypt, Equatorial Guinea, Gabon, Libya, Nigeria and Sudan. GDP per capita is measured in current US dollars. Oil producing countries such as Chad, Equatorial Guinea, Libya and Sudan were exempted because there were no continuous data on some of the variables used in this study. Time series plots of oil revenues and GDP are provided in Fig. 7.1. Interestingly, most African countries seem to be diversifying since the relative share of oil revenue in GDP is low in almost all countries except in Angola, Gabon and Nigeria.
Figure 7.1. Time series plot of Oil Revenues and GDP
Time series plots of oil revenues and GDP in oil-producing African countries. Notes: this figure depicts time series plots of renewable energy consumption of 9 oil-producing African countries. The sample period runs from 1985 to 2011 for 9 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte D’ivoire, Egypt, Gabon, Nigeria, and Tunisia). Renewable energy consumption is measured in current US dollars). Please refer to page 223 (Appendix Q) for detailed variable definitions.

Four different measurements of oil abundance are used in this paper. The first is oil production in thousand barrels per day, the second is oil revenues in current US dollars, the third is oil rent in current US dollars and the final indicator is oil reserves in billion barrels. All the oil abundance indicators are
obtained from the Energy Information Administration (EIA). Polity, a proxy for institutional quality, draws on Yaduma et al (2013), who also define institutional quality in a similar manner. According to Lane and Tornell (1999) and Mehlum et al. (2006), the difference between highly performing oil-producing countries, such as Norway, and under-performing oil-producing countries, like Nigeria and Cameroun, can be attributed to institutional quality. Indeed institutions with poor quality enhance rent-seeking and revenue-grabbing behaviour. Polity takes on values ranging from one to ten, with the lowest values indicating countries with institutions of low quality. The data are obtained from the Polity IV project of the Centre for Systemic Peace (http://www.systemicpeace.org/polity/polity4.htm), which is similar to the data used by Wagner (2011) to measure institutional quality. Consistent with the resource abundance–growth nexus literature, other factors include energy use (measured in kilograms per oil equivalent per capita), trade openness (a ratio of export and imports in current US dollars) and investment (in current US dollars). Please see appendix A for the definition of the variables.

7.3.2. Methodology
Spatial econometric methods have gained prominence in economics for two main reasons (Anselin, 2001). The first is the desire to apply theoretical economic models that explicitly account for the interaction between an economic agent and other heterogeneous agents in a system. Indeed, these models consider factors such as neighbourhood effects, social norms, economic groupings and peer group effects and capture how individual interactions can lead to aggregate patterns. For instance, there is spatial correlation when a variable of interest (per capita growth) in location A is determined by the values of the same variable in location B. This chapter therefore seeks to capture spatial spillover of the predictors. The second driver is the need to handle spatial data when there is spatial autocorrelation which cannot be captured by standard econometric methods. This paper investigates the presence of spatial effects by studying the spatial heterogeneity and the spatial correlation between per capita oil revenues and per capita economic growth. The study draws on the augmented Solow growth model suggested by Mankiw et al. (1992) and Easterly and Levine (1998) in a spatial panel analysis. As oil is traded on the international market, oil price shocks and other factors related to oil revenue management in one country can affect the growth of a neighbouring country. An example is given by the oil exploration issues involving Nigeria and Cameroun, where litigation concerning maritime border challenges has affected the oil output of both countries (Frynas and Mellahi, 2003). Another factor may
be the effect of conflicts in one oil-producing country, such as Nigeria, on the growth of another, such as Cameroon. A case in point is the Boko Haram threat in Northern Nigeria which is affecting oil operations in Chad and Cameroon. This makes spatial panel data analysis suitable for this study as it captures the effect of shocks to per capita income growth of one country on the growth of another country.

According to Anselin (2001), the most common form of spatial econometric model is one that relates the value of a random variable in a given location (A) to its values in another location (B). This implies that a random variable is indexed to location j:

\[ \{ y_j, j \in D \} \]  

(1)

where D is a set of discrete locations or a continuous surface. As each random variable is assumed to be influenced by location, the spatial correlation can then be specified as:

\[ \text{cov}\left[y_j, y_i\right] = E\left[y_j, y_i\right] - E\left[y_j\right]E\left[y_i\right] \]  

(2)

where \( j \neq i \); j and i are the individual locations; \( y_j, y_i \) are the values of a random variable at locations j and i. Anselin (2001) suggests that the covariance can be estimated in three fundamental ways. First, a functional form can be estimated based on equation (1) so that the covariance structure can follow. Second, the covariance structure can be estimated directly as a function of selected parameters. Finally, the spatial equation can be modelled non-parametrically by leaving the covariance structure unspecified.

Taking an \( N \times 1 \) vector of random variables, y, observed across space and an \( N \times 1 \) vector of independent and identically distributed (iid) random errors \( \epsilon \), the spatial stochastic model is derived as follows:

\[ [y - \mu] = \rho W[y - \mu] + \epsilon \]  

(3)
where $\mu$ is the mean of $y$, $i$ is an $N \times 1$ vector of ones, whilst $\rho$ is the spatial autoregressive parameter. $W$ is the spatial weight matrix, which depends on the definition of neighbourhood for each observation. The spatial weight matrix can then be defined as:

$$[Wy]_i = \sum_{j=1}^{N} w_{ij} y_j$$

(4)

To estimate the determinants of economic growth in oil-producing African countries, GDP can be expressed as a function of the predictors defined in Table 2. This will allow the estimation of the cross section and the panel methods before the spatial variables are introduced.

The empirical model is specified as:

$$gdp_{it} = \alpha_0 gdp_{i-t} + \alpha_1 oilrent_{i} + \alpha_2 inv_{i} + \alpha_3 en_{i} + \alpha_4 open_{i} + \alpha_5 polity_{i} + \eta_i + \gamma_t + \epsilon_{it}$$

(5)

Oil rent, oil production, oil revenues and oil reserves are entered in turn separately in the equation. In addition, $\eta_i$ is an unobservable country effect, $\gamma_t$ is an unobservable time effect that is common to all countries and $\epsilon_{it}$ is an unobservable component that varies over time and country and is assumed to be uncorrelated. According to Madariaga and Poncent (2007), the introduction of a lagged dependent variable and country-specific effects in Equation (5) may render the OLS estimator biased and inconsistent.

To analyse the stability of the parameter estimates, we also estimate Equation (5) by replacing oil production with oil revenues, oil rent, oil reserves and energy use. In addition, we estimate the cross-sectional equation without an oil abundance variable. The specific indicators of institutional quality are the investment risk profile (the higher the value, the lower the perceived risk of investment) and the corruption index with a higher value indicating higher levels of corruption. Moreover, we estimate the panel data model without the measure of openness to trade. The estimation results for the panel method are summarized in Tables 4 ($O_{lt} = \text{oil production}$), 5 ($O_{lt} = \text{oil revenues}$), 6 ($O_{lt} = \text{oil rent}$) and 7 ($O_{lt} = \text{oil reserves}$).
However, ignoring the spatial effects could also lead to misspecification and invalid inference. The spatial effects equation can be expressed as:

\[ y = \rho Wy + \beta X + \varepsilon \]  \hspace{1cm} (6)

where \( y \) is a vector of observations for the dependent variable, \( \rho \) is a spatial autoregressive that takes the values -1 and 1, \( x \) is an \( n \times k \) matrix of \( k \) exogenous variables, whilst \( \beta \) is the element of vector coefficients and \( \varepsilon \) is an \( n \) element of vector of errors. The Moran-I test (Moran, 1950) is used to detect spatial dependence among the variables. In addition in order to minimise the impact of the Modifiable Area Unit Problem (MAUP), alternative zoning systems were applied during the aggregation of the spatial units. If, for instance, the test shows evidence of spatial dependence for oil rent and income, Equation (7) is augmented to include the spatial dependence variables, as follows:

\[ gdp_t = \alpha_0 gdp_{t-t} + \alpha_1 oilrent_t + \alpha_2 inv_t + \alpha_3 en_t + \alpha_4 open_t + \alpha_5 polity_t + \alpha_6 wgdp_t + \alpha_7 woilrent_t + \eta_t + \gamma_t + \varepsilon_t \]  \hspace{1cm} (7)

### 7.4. Estimation Results

In Section 4.1, the estimation results from a standard cross-sectional model that draws on Sachs and Warner (1995) are analysed. In Section 4.2, the results of a standard panel-data model with cross-sectional and time fixed effects are estimated and discussed. Section 4.3 summarizes and analyses the results of the spatial Durbin model (SDM) and the spatial autoregressive model (SAR).

#### 7.4.1. Cross-sectional estimation

Using a cross-sectional estimation method à la Sachs and Warner (1995), we test the growth effects of oil abundance. The results is presented in table 3.

**Table 7.3.** Cross-sectional estimation, real GDPpc growth as the dependent variable

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Table 7.3 shows the estimates of the cross-sectional model. The effect of economic growth per capita of 1985 (GDPpc85), investments (Inv), oil revenues (Oilrev), oil rents (Oilrent), oil production (OP), oil reserves (Oilreserv) and energy consumption (En) on economic growth in oil-producing African countries from 1985 to 2011 is estimated. The countries used are Algeria, Angola, Cameroon, Congo, the Cote d’Ivoire, Egypt, Equatorial Guinea, Gabon, Libya, Nigeria and Sudan. Table 7.3 indicates that the logarithm of initial real GDP per capita has the expected negative and significant effect on the average growth rate of real GDP per capita. The effect size is also stable across the six equations, except for the equation that features oil rent. Therefore, consistent with classic growth theory, poorer countries show a tendency initially to catch up with richer countries.

The average investment share in GDP has the expected positive and significant effect on the average growth rate of real GDP per capita. The effect magnitude is stable across the six equations. Therefore, higher proportional investment as a share of GDP is associated with greater economic growth. This calls for investments especially in the productive sectors of the economy such as power generation to stimulate economic growth.

Next, the oil abundance variable has a positive and significant effect, except for the equation featuring energy use. This result initially suggests that in oil-exporting African countries the resource blessing prevails. The coefficient of determination $R^2$ ranges from 22% (the equation without an oil abundance variable) to 51% (the equation featuring oil rent as an oil abundance variable).

This notwithstanding, the disadvantages of the cross-sectional method has been highlighted by a number of studies. According to Cavalcanti et al. (2011), the cross-sectional regression methodology does not take into consideration the time dimension of the data and, consequently, may suffer from
endogeneity bias. Further, there is difficulty in making causal inference and the results may be different if another time-frame is used (Bland, 2001). Based on these limitations, a robust method that takes into consideration the time and geographic dimensions is used in this study.

7.4.2. Panel data estimation
We next estimate a panel-data model that features cross-sectional and time-period specific effects to test for the growth effects of oil abundance.
Table 7.4. Panel estimation with country-specific and time-specific fixed effects

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Notes: Table 7.4 presents the results of the panel estimation for oil-producing African countries. Real GDP in current US dollars per capita is the dependent variable. The explanatory variables are the lag value of GDP (gdp), investment share of GDP (inv) in current US dollars, trade openness (open) in current US dollars, oil production (op) in thousands of barrels per day and energy consumption (en) in kilotonnes per oil equivalent. In addition to these, several governance variables were used to proxy for good
governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity, which proxies institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconfl) with values ranging from 1 to 12, external conflicts (extconfl) with values ranging from 1 to 12, religion in politics (relpol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethten) with values ranging from 0 to 6. Ten oil-producing African countries, namely Algeria, Angola, Cameroon, Congo, the Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia, are included in the analysis.
Tables 7.4 to 7.7 present the results of the panel estimations. The choice of panel fixed-effects methods was informed by the results of the Hausman tests. However, Clark and Linzer (2012) argue that the Hausman test is not a sufficient metric for deciding between fixed- and random-effects models. The best metrics are the size of the dataset, the level of correlation between the covariate and unit effects and the extent of within-unit variation between the dependent and the explanatory variables (Clark and Linzer, 2012). In a large dataset with a high number of observations, the fixed-effects model produces unbiased estimates (Gelman and Hill, 2007). Therefore, this paper draws on the Hausman test and the high number of observations to establish the use of the fixed-effects model.

Four different equations are estimated with oil production, oil reserves, oil revenues and oil rents respectively. The results shown in Table 4 indicate that oil production has an inverse relationship with economic growth in all the equations estimated. Although previous studies, such as Barnett and Ossowski (2002), have used oil revenues as a proxy for oil abundance, this finding has potential policy implications. Oil production has both positive and negative effects on economic growth. First, the beginning of commercial production can offer the oil-producing country the opportunity to access the financial market as the country becomes attractive for foreign direct investments (Ross, 2012). However, oil production also has disadvantages. First, Matsuyama (2002) finds that oil production attracts labour from the other sectors of the economy and reduces productivity in these sectors. For instance, universities start introducing petroleum-related courses and radio and television discussions begin to centre on crude oil production. This affects the growth of non-oil sectors, which reduces the overall economic performance of the country. Second, oil production becomes the central focus of every major economic policy to the disadvantage of the other sectors of the economy. For example, the contribution of the agricultural sector to Ghana’s GDP before oil production was 31% in 2008. After three years of oil production, the agricultural sector contributed less than 20%. Nigeria, once a cocoa and coffee producer, has insignificant cocoa trees after more than 50 years of oil production. As the growth rates of other sectors such as agriculture and manufacturing diminish without a corresponding increase in the contribution of oil to growth, the economic performance of the country suffers. The study finds that on average, any 1% increase in oil production reduces economic growth by 0.0021%. This calls for policies that ensure balanced investment in oil production and other sectors such as manufacturing and agriculture to boost economic growth. The results further reveal that the investment profile of an oil-producing country has a positive effect on economic growth. According to the
International Country Risk Guide (ICRG), the investment profile is the sum of all the factors that affect the risk of investments which are not covered by political, economic and financial risk sections. This includes contract viability/expropriation, profit repatriation and payment delays. According to Table 7.4, any 1% increase in the investment profile increases economic growth by 0.0038%. This implies that the promptness with which contracts are paid and the extent to which they are transparent have a positive effect on economic growth. Therefore, oil-producing African countries should encourage disclosure of information on beneficial ownership and contract details and laws on profit repatriation regulations should be published to improve their investment profile.
Table 7.5. Panel estimation with country-specific and time-specific fixed effects

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Notes: Table 7.5 presents the results of the panel estimation for oil-producing African countries. Real GDP in current US dollars per capita is the dependent variable. The explanatory variables are the lagged value of GDP (gdp), the investment share of GDP (inv) in current US dollars, trade openness (openness) in current US dollars, oil revenues (oilrev) in current US dollars and energy consumption (en) in kilotonnes per oil equivalent. In addition to these, several governance variables were used to proxy good governance, benign business climate, transparency and accountability. These variables are used interchangeably. The
governance variables include polity, which proxies institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconf) with values ranging from 1 to 12, external conflicts (extconf) with values ranging from 1 to 12, religion in politics (relpol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, the military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethten) with values ranging from 0 to 6. Ten oil-producing African countries, namely Algeria, Angola, Cameroon, Congo, the Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia, are used in this analysis.
Table 7.5 shows the results for the determinants of economic growth in oil-producing African countries. In this section, the results for the impact of oil revenues, governance variables and energy consumption on economic growth are presented. Consistent with the findings of Sachs and Warner (1995), Gyfalson (2001), Atkinson and Hamilton (2003) and Yaduma et al. (2013), there is an inverse relationship between economic growth and oil revenues in oil-producing African countries. Lane and Tornell (1996) attribute this to excessive rent-seeking behaviour, corruption and weak institutions, which they term ‘voracity effects’. This notwithstanding, two circumstances can explain this finding. First, as oil revenues are seen as ‘given by nature’, citizens’ demand for accountability are not as strong as in the case of tax revenues. This creates incentives for the diversion of funds and rent-seeking behaviour on the part of various interest groups. Second, oil revenues are cyclical due to the volatile nature of oil prices. Therefore, projects that are started using oil revenues when there is a boom are left to decay when there is bust. This leads to waste and inefficiency, both of which affect growth negatively. Furthermore, the results reveal that the investment profile has a significant and positive impact on economic growth.
Table 7.6. Panel estimation with country-specific and time-specific fixed effects

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Notes: Table 7.6 presents the results of the panel estimation for oil-producing African countries. Real GDP in current US dollars per capita is the dependent variable. The explanatory variables are the lagged value of GDP (gdp), investment share of GDP (inv) in current US dollars, trade openness (openness) in current US dollars, oil rent (rsoilrent1) in current US dollars and energy consumption (en) in kilotonnes per oil equivalent. In addition to these, several governance variables were used to proxy good
governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity, which proxies for institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconfl) with values ranging from 1 to 12, external conflicts (extconfl) with values ranging from 1 to 12, religion in politics (relpol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, the military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethten) with values ranging from 0 to 6. Ten oil-producing African countries, namely Algeria, Angola, Cameroon, Congo, the Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia, are used in this analysis.
The oil rent measures the contribution of oil to GDP according to the World Bank Development Indicators. The a priori expectation was that oil rent and economic growth should be inversely related as oil revenues are volatile and suffers from the voracity effect. Consistent with this assumption, oil rent and economic growth are inversely related. However, unlike the other indicators of oil resources, oil rents are not significant at 5% confidence level.
### Table 7.7 Panel estimation with country-specific and time-specific fixed effects (real GDPpc growth as the dependent variable)

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Notes: Table 7.7 presents the results of the panel estimation for oil-producing African countries. Real GDP in current US dollars per capita is the dependent variable. The explanatory variables are the lagged value of GDP (gdp), investment share of GDP (inv) in current US dollars, trade openness (openness) in current US dollars, oil reserves (oilreserv) in billion barrels, and energy consumption (end) in kilotonnes per oil equivalent. In addition to these, several governance variables were used to proxy good governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity, which proxies institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconfl) with values ranging from 1 to 12, external conflicts (extconfl) with values ranging from 1 to 12, religion in politics (repol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, the military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethen) with values ranging from 0 to 6. Ten oil-producing African countries, namely Algeria, Angola, Cameroon, Congo, the Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia, are used in this analysis.
Finally, Table 7.7 presents the results of the ‘oil reserve’ equation. According to Stijns (2005), natural resource reserves have had an inverse relationship with economic growth since the 1970s. As reserves represent a future revenue stream, policy makers may be tempted to spend more today and pay with the production of the reserves tomorrow. Another explanation for the inverse relationship between economic growth and reserves is ‘feeding frenzy’. Lane and Tornell (1996) argue that the discovery of natural resources leads to a fight for control and spending between competing factions, which leads to inefficiency, this being termed a ‘feeding frenzy’. Without any long-term planning or accountability in institutions, such spending can lead to waste and corruption, thereby affecting growth negatively. Table 8 reveals this trend and supports Stijns’ (2005) assertion that reserves generally have a negative impact on growth. Furthermore, and consistent with other findings, the investment profile of the countries has a positive impact on economic growth.

4.3 Spatial model
To examine the effect of geographic and economic proximity on economic growth, a spatial econometric model is employed in the third section of the analysis. The first two sections applied a cross-sectional method and a panel method respectively. The results of these two estimations confirm that oil revenues, oil reserves, oil production and oil rent have an inverse relationship with economic growth. Furthermore, in three out of the four models of the panel estimation, the investment profile is found to have a significant and positive effect on economic growth. In section 7.4.3, the results of the spatial econometrics are discussed.
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Notes: Table 7.8 presents the results of the panel estimation for oil-producing African countries. Real GDP in current US dollars per capita is the dependent variable. The explanatory variables are the lagged value of GDP (growthL1), investment share of GDP (Inv) in current US dollars, trade openness (openness) in current US dollars, oil production (OP) in thousands of barrels per day and energy consumption (en) in kilotonnes per oil equivalent. In addition to these, several governance variables were used to proxy good governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity, which proxies for institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconfl) with values ranging from 1 to 12, external conflicts (extconfl) with values ranging from 1 to 12, religion in politics (relpol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, the military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethten) with values ranging from 0 to 6. Ten oil-producing African countries, namely Algeria, Angola, Cameroon, Congo, the Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia, are used in this analysis. Significant variables are in bold letters.
An attempt is made to examine the spatial dynamics between oil resources (production, reserves, rent and revenues) and economic growth in oil-producing African countries. The results indicate that the parameter ‘rho’ is statistically significant in all equations of the spatial Durbin model (SDM) and the spatial autoregressive (SAR) model. This indicates that if a country grows, it positively affects the growth of its neighbours. Therefore, the spatial autoregressive effect is positive and significant. This finding is relevant to regional bodies such as the African Union and ECOWAS in initiating regional policies that improve economic growth in both regional and individual countries. Regarding the geographical effects on the relationship between oil resources and economic growth, the study finds no evidence that the proximity of countries has an impact on oil revenue management. This finding implies that ‘bad company’ does not necessarily corrupt good character but rather the actions and inactions of individual oil-producing countries affect the economic growth–oil resource management nexus. This finding therefore confirms the assertion by Sachs and Warner (2001) that geographical influence on the resource curse hypothesis may be insignificant.

Furthermore, the spatial effect of trade openness is positive but is significant only in some equations. The effect is not robust across different measures of oil variables and different models. Thus, there is some evidence that if a country is open to international trade, its neighbouring countries are likely to grow faster, but it is rather weak. Yanikkaya (2003) finds that developing economies should benefit from trade among themselves, especially when the trade encourages technical transfer. However, he argues that the impact of trade openness on economic growth is not straightforward and that trade barriers have relatively higher impact on economic growth when the country has a comparative advantage.

Consistent with the oil curse literature, corruption is found to be detrimental to economic growth in some of the models. This is because corruption diverts revenues into personal accounts that would otherwise have been used for development. Mo (2001) argues that one of the main channels in which corruption affects economic growth negatively is political instability.

Finally, the study also finds that lower risk of investment or a better investment environment have a positive and direct effect on economic growth and also a spatial effect. This implies that if the risk of investment deteriorates in a neighbouring country, this is likely to stifle the economic growth of other countries around it.
7.5. Conclusion and Recommendations

The effect of oil revenues and oil abundance on economic growth in oil-producing African countries is examined in this paper by considering the spatial dynamics of this relationship. In particular, the effects on economic growth of oil production, oil resources and oil revenues, together with the quality of democratic institutions, investment and openness to trade, are investigated. The findings are as follows. First, the validity of the spatial Durbin model is vindicated. Second, consistent with the oil curse hypothesis, oil production, resources, rent and revenues have a negative and generally significant effect on economic growth. This result is robust across the panel data, spatial Durbin and spatial autoregressive models and for different measures of spatial proximity between countries. Third, the extent to which the business environment is perceived as benign for investment has a positive, albeit marginal, effect on economic growth. In addition, the economic growth of a country is further stimulated by spatial proximity to a neighbouring country if the neighbouring country has created strong institutions protecting investments. Fourth, openness to international trade has a positive and marginally significant effect on economic growth. However, the significance of the parameter estimate is sensitive to the model that is being considered.

Overall, the findings suggest that oil-producing African economies are cursed by oil discovery, production and revenues, rather than by the spatial proximity to their neighbouring countries. These findings have four main policy implications. First, oil-producing African countries should do more to translate oil production and oil revenues into sustainable economic development. This can be done by adapting any of three practical models. The first is the Norwegian model. Norway invested in domestic infrastructure and human capital development in the initial stages of its oil production. Later, it created a Sovereign Wealth Fund and now spends only the interest accruing to the fund. The second model is Indonesia’s agricultural modernization. Indonesia invested much of its oil revenues in modernizing agriculture to boost food production, reduce food imports and create jobs, especially in rural areas. Finally, Malaysia’s diversification model ensures that oil revenues are invested in small and medium-
scale enterprises and also invests in ways that help to create an enabling business environment. These models call for capital investment at the expense of spending on goods and services.

Second, regional institutions, such as ECOWAS, AU and the African Development Bank, should help member countries to implement strategies and policies that create a benign investment climate. This stems from the finding that a better investment climate has a positive and spatial effect on economic growth. This can be done by enforcing the implementation of treaties such as the Abuja Declaration, which called for high investment in agriculture, and the New Partnership for Africa’s Development, which focuses more on trade, regional integration and human capital development.

Third, international trade has been identified as one of the main drivers of growth in this study. Oil-producing African countries should therefore engage in value-added trade with other African countries and the international community to promote job creation and economic growth.

Fourth, with investment profile as a leading driver of economic growth, countries should create an enabling business environment by minimizing the process of establishing businesses, enforcing contracts and publishing beneficial ownership information, encouraging transparency and accountability in awarding oil production contracts and managing oil revenues.

Finally, the non-oil sector should be given considerable attention. This has three advantages: (i) the non-oil sector will become the anchor of the economy when oil productions peak and start diminishing; (ii) it will minimize the impact of oil price fluctuations on the economy and help build stability to stem volatility; (iii) as the opportunity of creating more jobs in the oil sector is minimal due to the capital-intensive nature of the sector, investing in the non-oil sector can take up labour to reduce unemployment.
Chapter 1 provided the basis for this thesis. In chapter 2, the theories underpinning energy consumption and natural resource management are discussed. Chapter follows with the discussion of methodology and the research approach. In chapters 4, 5 and 6, the determinants of renewable energy, natural gas and energy efficiency are discussed. Chapter 7 looks at oil resources and economic growth. The final chapter (chapter 8) summarises the key findings and discusses the policy recommendations of this thesis. Further, looks at the limitations of this thesis and provides direction for future studies.
CHAPTER 8: CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

Africa faces the challenge of access to modern forms of energy and intermittent energy supply. These challenges have been attributed to lack of investment in energy infrastructure. However, energy investment requires long lead times and huge capital outlay. Due to these, there is the need to estimate the elasticities of demand to serve as guide for decision making and investment. In addition to this, the oil curse has been associated with the African continent for some time. This thesis is motivated by the need to invest in clean and available sources of energy. There is the need to manage oil resources efficiently and create the enabling environment that promotes investments. A glance at the literature reveals that oil revenues or production are estimated as a function of GDP, institutional quality and growth-related variables. However, there is a possibility that apart from growth related variables, geographical and cultural effects can also influence the management of oil revenues. Therefore, the original contribution of the second part of the study is to estimate the effect of spatial variables on the relationship between oil production and revenues and economic growth. In addition, the effect of energy resource depletion, energy related carbon emissions, income and price on renewable and natural gas consumption is also examined. Together, the aim of the study is in threefold. First, the effect of non-economic and exogenous variables are estimated on energy demand. Second, a spatial panel model is used to estimate how geographical and trade associations among oil producing African countries influence the oil curse hypothesis. Finally, the determinants of energy (renewables and natural gas) is estimated.

There are eight chapters in this thesis. The first chapter is an introductory chapter that covers the background, significance, objectives and research questions for the thesis. Chapter one also provides an over of the contribution of the thesis and the organization of the thesis. In chapter 2, literature on energy demand, econometric modelling techniques, the relationship between oil revenues and economic growth, technological progress and energy demand and the historical trends of oil production in Africa is reviewed. This chapter ends with a literature summary and the gaps that have been identified. Empirical findings from chapters 4 to 7 are summarised below.
8.1.1 Linkages among the empirical chapters

This thesis assumes that efficient and effective management of energy resources have a direct relationship with economic growth. In order to test this assumption, the thesis investigates energy efficiency, efficiency of natural gas consumption, renewable energy demand and the relationship between oil resources and economic growth. The thesis is divided into two parts. The first part examines the determinants of natural gas demand, renewable demand and energy efficiency separately in three chapters. Since these types of energy are available in Africa and relatively clean, finding their demand determinants can guide policy decisions such as introduction (or withdrawal) of energy taxes or energy efficiency education. In addition, the knowledge of the determinants can guide investment in the energy sector. Since oil revenues are a major component of government funds in oil-producing countries, the second part of the thesis investigated oil revenue management and examined the relationship between oil resources and economic growth. The objective of the second part of the thesis is to ascertain how oil revenues contribute to economic growth so that recommendations can be made to channel oil proceeds to finance investments in the energy sector. However, departing from previous literature, this thesis’ original contribution is to assess how neighboring countries and trade associations influence how oil revenues affect economic growth.

8.2 Renewable Energy Demand

8.2.1 Empirical findings
Renewable energy consumption offer the opportunity to divert from finite energy sources and reduces the impact of energy consumption on the environment. In addition, renewable energy sources such as rivers for hydro, sunshine for solar, waste and wind abound in Africa. Chapter three therefore focuses on the demand for renewable energy since renewable energy has been considered as the solution to the hydra-headed problems of energy security, energy access and climate change, especially in Africa. In order to provide both policy and investment guide, this study investigates the drivers of renewable energy demand in oil-producing African countries. Specifically, this chapter contributes to the literature on energy in the following ways: first, we attempt to fill both the literature and policy gap by investigating the impact of energy resource depletion on renewable energy consumption in oil-producing African countries. The inclusion of
energy resource depletion helps to assess whether the potential depletion of fossil fuels has effect on the amount of renewable energy consumed. Second, the effect of energy-related carbon emissions on renewable energy demand is evaluated. That is, since carbon emissions in Africa can be attributed to several factors such as bush burning, farming activities and energy consumption, it is prudent to distinguish the effect of energy related emissions on renewable energy consumption. Third, by means of a dynamic panel data model, the effects of past values of renewable energy demand on current consumption are assessed.

Three panel data models – a random effect model, a fixed effects model and a dynamic panel data model are used to estimate renewable energy demand with a comprehensive set of determinants. The determinants include real income per capita, energy related carbon emissions per capita, human capital development, energy resource depletion per capita and capital. The estimation results indicate that the main drivers of renewable energy in oil-producing African countries are real income per capita, energy resource depletion per capita, carbon emissions per capita and energy prices.

8.2.2 Policy Recommendations
The thesis throws more light on the role of energy resource depletion and energy-related carbon emissions on renewable energy demand. This is important since renewable energy has been identified as carbon neutral and is also obtained from a source that replenishes itself. Due to these, it was expected that the depletion of energy resources will encourage renewable energy consumption. The estimated results lends support to the ex-ante expectation and finds energy resource depletion a driver of renewable energy consumption. This finding provides opportunity for communicating the extent of fossil fuel depletion and the need to invest in renewable energy. Since income has been identified as a major driver of renewable energy consumption, incentives that boost consumers’ income such as feed-in-tariffs should be introduced to encourage consumption. Feed-in-tariffs allow consumers to sell excess power generation to the national grid when the use renewable energy sources such as solar. Feed in tariffs is a key feature of the renewable energy ACT (2011) of Ghana and the renewable energy target of South Africa. Consistent with the literature on renewable energy (Mahadevan and Asafu-Adjaye, 2007), price has indirect relationship with renewable energy demand. This calls for price subsidies on
renewable energy products to encourage their demand. Finally, since energy related carbon emissions is important for renewable energy consumption, policy makers should introduce carbon tax to discourage the consumption of fossil fuels and promote renewable energy consumption. Apart from serving as a source additional income, carbon tax will reduce emissions through decreased fossil fuel consumption.

8.3 Natural Gas Demand

8.3.1 Empirical findings
Chapter 5 deals with the demand of natural gas. With less than 50% of the population of Sub-Saharan Africa having access to modern forms of energy and the desire to minimize the impact of energy consumption on the environment, there is the need to invest in energy sources that are affordable, available and environmentally clean. Natural gas is therefore the ultimate choice of energy since it is carbon-neutral and relatively affordable. This chapter employs three methods namely the dynamic generalized methods of moments (GMM), the two stage least squares and the general unrestricted model (GUM). The GUM captures important unobservable factors which helps to identify structural changes in natural gas demand behaviour. The chapter affirmed the importance of income and price as drivers of natural gas demand.

Again since natural gas is a non-renewable energy, a unit drawn reduces the quantity remaining. The study tests this statement by including a variable for energy resource depletion in all three methods. The finding suggests that increase in energy resource depletion reduces natural gas consumption since the state may be looking for alternative energy sources.

Generally, the estimated underlying energy demand trend (UEDT) for each country shows the possibility of inefficient natural gas consumption. Since most African countries are in transition from low to middle income status, the appetite to consume more energy is there. However, this desire can lead to inefficient consumption when appropriate and new energy using appliances are used instead of ‘second hand’ cheap machines. This seems to be the norm especially for imported old thermal plants that uses natural gas for power generation.
8.3.2 Policy Recommendations
Based on the findings, the following recommendations are made. First, the advantages of natural gas consumption such as lower carbon emission should be highlighted to encourage its consumption. This will promote investments in gas-fired thermal plants and encourage domestic use of natural gas for cooking. Other oil producing African countries can adapt Ghana’s policy of distribution of LPG cylinders free to vulnerable households to curb carbon emissions and forest depletion. This will encourage domestic natural gas consumption through gas availability by discouraging charcoal consumption.
Again, effort should be made to encourage efficiency and technological innovation in natural gas consumption especially in power production. There should be policies that encourage the acquisition of new and efficient plants and natural gas-using appliances.

8.4 Energy Efficiency
8.4.1 Empirical findings
Efficiency is the cheapest and cleanest source of fuel. Again, energy efficiency is a major means of curbing carbon emissions. Whereas effort has been made in the advanced countries to promote technology and efficiency, little is known about efficiency in emerging economies in Africa. The purpose of this study is in twofold. First, a Product Generational Dematerialization (PGD) indicator is used to measure aggregate energy efficiency of Ghana. Second, the study seeks to identify the energy efficiency practices of SMEs in rural Ghana and also examine the barriers to energy efficiency practices. The chapter also applies the general unrestricted method to examine the relationship between productivity and energy consumption. The findings suggest Ghana has been inefficient especially with regards to fossil fuel consumption. On the practices, methods such as putting off electrical appliances when not in use or when closed, using new electrical appliances and using less appliances to achieve the same goal are some of the common ones adopted by SMEs in rural Ghana. Findings of the PGD indicates that electricity is relatively efficient than the consumption of fossil fuels. The results of the GUM confirms the PGD finding energy consumption has been inefficient.
8.4.2 Policy Recommendations
All three results indicate that energy consumption has not been efficient. The Ghana Energy Commission and the Ghana Energy Foundation should expand their energy efficiency education to the rural areas. Again, there should be emphasis on ‘energy efficiency’ and not electricity efficiency. That is, effort should be made to educate consumers on saving any type of energy they use, be it gas, gasoline or renewables.

8.5 Geographical effects of oil resource management

8.5.1 Empirical findings
Chapter 7 focuses on the relationship between oil production, oil reserves and oil revenues on one hand and economic growth on the other. This chapter is necessary since a widely held belief before the 1990s – referred to as the oil-blessing hypothesis – was that oil discovery and production should promote economic growth and development, and lead to poverty reduction. However, the so-called ‘oil-curse’ hypothesis, postulated by Sachs and Warner in 1995, challenged this belief, thus provoking a heated debate on the theme. The oil-curse hypothesis has been traditionally tested by means of cross-sectional and panel-data models. We go beyond these traditional methods to test whether the presence of spatial effects can alter the hypothesis in oil-producing African countries. In particular, the effects on economic growth of oil production, oil resources and oil revenues along with the quality of democratic institutions, investment and openness to trade are investigated. Our findings are as follows. First, the validity of the spatial Durbin model is vindicated. Second, consistently with the oil-curse hypothesis, oil production, resources, rent and revenues have a negative and generally significant effect on economic growth. This result is robust for across the panel data, spatial Durbin, and spatial autoregressive models, and for different measures of spatial proximity between countries. Third, we find that the extent to which the business environment is perceived as benign for investment has a positive and marginally effect on economic growth. Additionally, economic growth of a country is further stimulated by a spatial proximity of a neighbouring country, if the neighbouring country has created strong institutions protecting investments. Fourth, openness to international trade has
a positive and marginally significant effect on economic growth. However, the significance of the parameter estimate is sensitive to the model that is being considered. Overall, the findings suggest that oil-producing African economies are cursed by oil discovery, production and revenues rather than by the spatial proximity with their neighbouring countries.

8.5.2 Policy Recommendations
It is recommended that oil producing African countries should share knowledge and expertise and promote inter-country trade. Effort should also be made to strengthen institutional, technical and human capacity relating to oil resource management. Again, due to the regional nature of most of the oil governance challenges, they may require pan-African policies from institutions such as the African Union and the Africa Development Bank to address them.

Second, strong institutions and the conducive business environment should be created to enhance investment in the non-oil economy to promote economic growth. There should be conscious effort to reduce the amount and processes for business registrations, streamline taxes, honour long term contracts and make the general business conducive to boost the tradable and non-tradable sectors of the economy.

Third, oil producing African countries should diversify their economies to reduce the impact of volatile international oil prices. They should therefore invest in other sectors such as the tradable (industry and manufacturing sectors) which has the potential the potential for technological spill over and reducing the ‘oil curse’ phenomenon. This will also help create jobs and enhance the quality of export of these countries.

Fourth, in order to reduce the ‘oil curse phenomenon’, there should be transparency and accountability in the management of oil revenues. For instance, countries should set up oversight regulatory bodies that monitor expenditure from oil revenues. For example, in Ghana, there is the Public Interest Accountability Committee (PIAC), an independent body that monitors oil revenue expenditure. In addition, like Ghana, countries can open three oil revenue accounts: one for budgetary support, one for currency stabilization in times of volatility and the other for future generation and important projects. These steps can help check corruption and rent seeking, two major causes of the oil curse. Moreover, policies on property rights and political bureaucracy
should be streamlined and make them more business friendly. Acemoglu et al (2003) suggest that oil producing countries should enforce property rights so that individuals will have the incentive to invest and take part in economic life, invest in human capital and productive economic activities and put in place laws that constraint the efforts and desires of politicians and elites from expropriating oil revenues and individual investments.

Sixth, oil producing African countries should encourage trade. Toto-Same (2009) highlights that the growth of every economy depends on three factors. These are trade, sound fiscal and monetary policies and quality of institutions. The importance of trade supports the findings of this thesis. Oil producing African countries should open up their economies and reduce bureaucracy and time of clearance at their ports to encourage trade. This can be also done by adapting and adopting new and existing technologies that adds value to primary commodities and meet international standards for export.

8.6 Limitations

Although the sample of the thesis was all oil producing African countries, due to data unavailability, only 10 out of the 18 countries producing oil in Africa were used in the renewable energy study. With regards to the chapter on natural gas demand, 5 countries were used due to data limitations. However, these 5 countries account for more than 90% of the total natural gas consumption in Africa. Second, the chapter on energy efficiency had to be limited only to Ghana due to challenges with funding. This chapter was supported with funding from the United Nations University, but was not enough to cover the entire sample.

Third, chapter 3 would offered well targeted policy recommendations if the various types of renewables such as solar, hydro, geothermal and wind have been used instead. This would have provided indicators as to which of types of renewables that should be invested in. Fourth, a forecast of the different kinds of energy in the study would have made the thesis more robust.

8.7 Direction for further Studies

There are several areas for further studies. First, since chapter 3 finds the importance of the spatial lags for the dependent and predictors in oil resources and in economic growth relationship, future studies on energy (supply and demand) in Africa should consider using the spatial Durbin model. In addition, the oil resources – economic growth study can also be
extended to the whole of Africa to allow for appropriate comparison with studies that used Africa. Moreover, it will be interesting and useful to provide forecast for renewable and natural gas demand for oil producing African countries in future research. Indeed, a more disaggregated study on energy efficiency for Ghana, such as the energy efficiency practices of industry, service and agriculture could be important for energy policy design. Finally, subject to availability of data, future studies should treat the demand for commercial sources of renewables such as wind and solar separately from non-commercial sources such as charcoal and fuelwood.
APPENDICES

APPENDIX A: SUPPLEMENTARY FIGURE FOR CHAPTER 4
The appendix below shows the time series plots of renewable energy demand of the countries used in Chapter 4.
Figure 4.2 Time series plot of renewable energy consumption

Time series plots of renewable energy consumption in oil-producing African countries. Notes: this figure depicts time series plots of renewable energy consumption of 12 oil-producing African countries. The sample period runs from 1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte D’ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Renewable energy consumption is measured in kg of oil equivalent per capita.

Appendix B: Supplementary table for chapter 4

Table 4.5 Tests for panel integration
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<th>PP TEST</th>
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Notes: This table summarizes panel integration and cointegration tests of renewable energy consumption (REN, in kg of oil equivalent per capita), gross domestic product (Y, in real 2005 US dollars per capita), capital (K, in real 2005 US dollars per capita), labour (L, in millions of persons), human capital (H, in real 2005 US dollars per capita), energy depletion (D, in real 2005 US dollars per capita), CO2 emissions (in tonnes per capita) and the price level (consumer price index). The sample period runs from 1971 to 2012 for 12 countries (Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia). Data on human capital are unavailable for Gabon. Therefore, Gabon has been excluded from the sample of country-years used to estimate our panel data models.
Panel A summarizes results of the Levin, Lin and Chu (LLC), Im, Pesaran and Shin (IPS) and Phillips and Perron (PP) panel unit root tests. The LLC test assumes a common unit root, whereas the IPS and the PP tests assume individual unit root processes. The null hypothesis assumes the presence of a unit root in the variable. If the null is rejected then the variable is deemed to be stationary. The test statistics highlighted in bold are significant at the significance level of 5%. Panel B summarizes the Kao test for panel cointegration. The null hypothesis of no cointegration is rejected.

Appendix C Detailed descriptive statistics for chapter 7

Table 7.9 descriptive statistics for chapter 7

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The explanatory variables are the lag value of GDP (growthL1), Investments’ share of GDP (Inv) in current US dollars, trade openness (openness) in current US dollars, oil production (OP) in thousands of barrels per day, and energy consumption (EN) in Kilotonne per oil equivalent. In addition to these, several governance variables were used to proxy for good governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity which proxies for institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstabl) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconf1) with values ranging from 1 to 12, external conflicts (extconf) with values ranging from 1 to 12, religion in politics (relpol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethsen) with values ranging from 0 to 6. Ten oil producing African countries namely Algeria,
Angola, Cameroon, Congo, Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia are used in this study.

**Appendix E: Supplementary tables from chapter 7**

Table: 7.10 Panel estimation with country fixed effects and country specific deterministic trends, Real GDPpc growth as the dependent variable

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Notes: Table 7.9 presents the results of the panel estimation for oil producing African countries.

Real GDP in current US dollar per capita is the dependent variable. The explanatory variables
are the lag value of GDP (growthL1), Investments’ share of GDP (Inv) in current US dollars, trade openness (openness) in current US dollars, oil production (OP) in thousands of barrels per day, and energy consumption (EN) in Kilotonne per oil equivalent. In addition to these, several governance variables were used to proxy for good governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity which proxies for institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconfl) with values ranging from 1 to 12, external conflicts (extconfl) with values ranging from 1 to 12, religion in politics (repol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethten) with values ranging from 0 to 6. Ten oil producing African countries namely Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia are used in this study.

Appendix F: Supplementary table from chapter 7

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Notes: Table 7.9 presents the results of the panel estimation for oil producing African countries. Real GDP in current US dollar per capita is the dependent variable. The explanatory variables are the lag value of GDP (growthL1), Investments’ share of GDP (Inv) in current US dollars, trade openness (openness) in current US dollars, oil production (OP) in thousands of barrels per day, and energy consumption (EN) in Kilotonne per oil equivalent. In addition to these, several governance variables were used to proxy for good governance, benign business climate, transparency and accountability. These variables are used interchangeably. The governance variables include polity which proxies for institutional quality with values ranging from 0 to 10, corruption (corrupt), government stability (govstab) with values ranging from 1 to 10, socioeconomic conditions (soccon) with values ranging from 0 to 10, investment profile (invprof) with values ranging from 0 to 12, internal conflicts (intconfl) with values ranging from 1 to 12, external conflicts (extconfl) with values ranging from 1 to 12, religion in politics (relpol) with values ranging from 0 to 6, law and order (law) with values ranging from 0 to 6, bureaucracy quality (burqua) with values ranging from 0 to 6, military in politics (milpol) with values ranging from 0 to 6 and ethnic tensions (ethten) with values ranging from 0 to 6. Ten oil producing African countries namely Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Egypt, Gabon, Nigeria and Tunisia are used in this study.

**APPENDIX G: RELATIONSHIP BETWEEN GDP PER CAPITA AND OIL RENTS**
Figure 7.1 GDP per capita and oil rents
APPENDIX H: RELATIONSHIP BETWEEN REAL GDP PER CAPITA AND REAL OIL REVENUES PER CAPITA

Figure 7.2 GDP per capita and oil revenues
APPENDIX I: RELATIONSHIP BETWEEN REAL GDP PER CAPITA AND REAL OIL RENTS

Figure 7.3 Real GDP per capita and real oil rents
APPENDIX J: RELATIONSHIP BETWEEN GDP PER CAPITA AND OIL PRODUCTION PER CAPITA

Figure 7.4 GDP per capita and oil production
APPENDIX K: RELATIONSHIP BETWEEN GDP PER CAPITA AND OIL RESERVES PER CAPITA

Figure 7.5 GDP per capita and oil reserves per capita
APPENDIX L: RELATIONSHIP BETWEEN GDP PER CAPITA AND ENERGY CONSUMPTION PER CAPITA

7.6 GDP per capita and energy consumption per capita
APPENDIX M: RELATIONSHIP BETWEEN GDP PER CAPITA AND INVESTMENTS PER CAPITA

Figure 7.7 GDP per capita and investments per capita
APPENDIX N ETHICAL APPROVAL FORM

Ethics Approval Form - Students

This form should be completed by the student and passed to the supervisor prior to a review of the possible ethical implications of the proposed dissertation or project.

**No primary data collection can be undertaken before the supervisor has approved the plan.**

If, following review of this form, amendments to the proposals are agreed to be necessary, the student should provide the supervisor with an amended version for endorsement.

The final signed and dated version of this form must be handed in with the dissertation. The form MUST be signed and dated by both the student AND the supervisor. If the dissertation is submitted without a fully completed, signed and dated ethics form it will be deemed to be a fail. Second attempt assessment may be permitted by the Board of Examiners.

What are the objectives of the dissertation / research project?

a. Examine energy efficiency practices of small and medium scale enterprises in rural Ghana
   b. Investigate the barriers to energy efficiency among SMEs in rural Ghana

Does the research involve **NHS patients, resources or staff?** YES / (NO) (please circle).

If YES, it is likely that full ethical review must be obtained from the NHS process before the research can start.

1. **Does the research involve MoD staff?** YES / (NO) (please circle).

If YES, then ethical review may need to be undertaken by MoD REC. Please discuss your proposal with your Supervisor and/or Course Leader and, if necessary, include a copy of your MoD REC application for quality review.

Do you intend to collect **primary data** from human subjects or data that are identifiable with individuals? (This includes, for example, questionnaires and interviews.) (YES) / NO (please circle)

If you do not intend to collect such primary data then please go to question 15.
If you do intend to collect such primary data then please respond to ALL the questions 5 through 14. If you feel a question does not apply then please respond with n/a (for not applicable).

How will the primary data contribute to the objectives of the dissertation / research project?
It will help to identify energy efficiency practices of Small and Medium Scale Enterprises and the barriers to such practices

What is/are the survey population(s)? 1500 SMEs

How big is the sample for each of the survey populations and how was this sample arrived at?
200 SMEs were selected based on a purposive sampling technique. Only SMEs in that use electricity in the four regions of interest were considered were considered.

How will respondents be selected and recruited?
Respondents were contacted directly.

What steps are proposed to ensure that the requirements of informed consent will be met for those taking part in the research? If an Information Sheet for participants is to be used, please attach it to this form. If not, please explain how you will be able to demonstrate that informed consent has been gained from participants.
A short letter introducing the purpose of the study will be given to respondents for the consent before data collection.

How will data be collected from each of the sample groups?
Data was collected through questionnaires

How will data be stored and what will happen to the data at the end of the research?
A spreadsheet has been created for the data and has been stored on dropbox. The data will be kept for some time for comparative analysis in future studies.
What measures will be taken to prevent unauthorised persons gaining access to the data, and especially to data that may be attributed to identifiable individuals?

The data is not attributed to individuals. However, all effort has been made to prevent the data from reaching third parties. This effort include keeping the data on dropbox with a password.

What steps are proposed to safeguard the anonymity of the respondents?

The identity of the respondents are not going to be disclosed.

Are there any risks (physical or other, including reputational) to respondents that may result from taking part in this research? YES / (NO) (please circle).

If YES, please specify and state what measures are proposed to deal with these risks.

Are there any risks (physical or other, including reputational) to the researcher or to the University that may result from conducting this research? YES / (NO) (please circle).

If YES, please specify and state what measures are proposed to manage these risks.¹²

Will any data be obtained from a company or other organisation. (YES) / NO (please circle) For example, information provided by an employer or its employees.

If NO, then please go to question 19.

What steps are proposed to ensure that the requirements of informed consent will be met for that organisation? How will confidentiality be assured for the organisation?

---

¹² Risk evaluation should take account of the broad liberty of expression provided by the principle of academic freedom. The university’s conduct with respect to academic freedom is set out in section 9.2 of the Articles of Government and its commitment to academic freedom is in section 1.2 of the Strategic Plan 2004-2008.
Does the organisation have its own ethics procedure relating to the research you intend to carry out? YES / NO (please circle).
If YES, the University will require written evidence from the organisation that they have approved the research.

Will the proposed research involve any of the following (please put a √ next to ‘yes’ or ‘no’; consult your supervisor if you are unsure):

- Vulnerable groups (e.g. children)? YES ☑ NO ☐
- Particularly sensitive topics? YES ☑ NO ☐
- Access to respondents via ‘gatekeepers’? YES ☑ NO ☐
- Use of deception? YES ☑ NO ☐
- Access to confidential personal data? YES ☑ NO ☐
- Psychological stress, anxiety etc? YES ☑ NO ☐
- Intrusive interventions? YES ☑ NO ☐

If answers to any of the above are “YES”, how will the associated risks be minimised?

Are there any other ethical issues that may arise from the proposed research? NO
Please print the name of: student
type

I/We grant Ethical Approval

supervisor

Signed:

(student) Ishmael Ackah

Date 09/09/2015

(supervisor) Renatas Kizys

Date 09/09/2015

AMENDMENTS

If you need to make changes please ensure you have permission before the primary data collection. If there are major changes, fill in a new form if that will make it easier for everyone. If there are minor changes then fill in the amendments (next page) and get them signed before the primary data collection begins.
APPENDIX O- QUESTIONNAIRE

QUESTIONNAIRE

PART A: COMPANY PROFILE

1. Name of Company………………………………………………………………………………………………………………

2. Industry……………………………………………………………………………………………………………………………

3. Company location (town and region)…………………………………………………………………………………………

4. Number of employees ……………………………………………………………………………………………………………

5. Monthly turnover (Approximation)…………………………………………………………………………………………

6. The company is owned by (a) male (b) female

PART B: ENERGY CONSUMPTION

7. Please indicate your company’s approximate monthly expenditure on:

Petrol………………………………………………
Electricity…………………………………………

8. Do you use generator? (A) Yes (b) No

If no, kindly go to number 10

9. If yes, how many gallons do you buy in a day?

……………………………………………………………………………………………………………………………………

10. Do you check your energy consumption? (a) Yes (No)

If no, kindly go to 12
11. If yes, how frequent is your energy use generally recorded/checked?  
   (a) Daily  
   (b) Weekly  
   (c) Monthly  
   (d) Yearly  

12. Are consumption records adjusted to energy price change?  
   (a) Yes  
   (b) No  

13. Is a monitoring and targeting scheme employed?  
   (a) Yes  
   (b) No  

14. Do you use post-paid metre or pre-paid?  
   (a) Post-paid  
   (b) Pre-paid  

15. Why?  
   (a) regulation (forced on you by law)  
   (b) economic reasons (lower prices)  
   (c) cannot access pre-paid metre (shortage on market)  
   (d) other, please specify  

16. Who connected your electricity for you?  
   (a) Myself  
   (b) ECG staff  
   (b) private electrician  
   (d) other, please specify  

PART C: ENERGY EFFICIENCY INDICATORS

17. Over the past six months, has your energy changed?  
   (a) Increased  
   (b) decreased  
   (c) the same  

18. What accounted for the change?  
   (a) blackout (dumsor)  
   (b) energy efficiency measures  
   (c) increase in electricity prices  
   (d) acquired new electrical gadgets  
   (e) please specify  

19. Do you have Automatic switch off of pumps, fans, conveyors & other Equipment when not required?  
   (a) Yes  
   (b) No  

20. Do you Purchase of energy efficient computers, photocopiers & other Office equipment?  
   (a) Yes  
   (b) No  

21. Are your electrical gadgets second hand or brand new  
   (a) second hand  
   (b) new  
   (c) home use  

22. Which type of electrical bulbs do you use?
23. Where did you first hear about energy efficiency (a) TV and radio (b) Books (c) Instinct (d) other, please specify

24. Do you turn off your electrical gadgets when you close from work? (a) Yes (b) No

If no, explain

25. If yes why? (a) to save cost (b) protect it from damage in case of power outage (c) because others do it (d) other, please specify

26. What are the barriers to energy efficiency improvement in company?

(a) Lack of information on energy efficiency measures (b) lack of funds (c) I feel its not important (d) Lack of technical skills (e) Lack of staff awareness (f) other, please specify

26. What three things do you do to save energy?
1. 
2. 
3. 

PART D: ENERGY EFFICIENCY AND PRODUCTIVITY GROWTH

27. How has been your profit over the past 6 months? (a) Increased (b) decreased (c) same

If decreased, why

If increased, why………………………………………………………………………………………………………………………………………………………………

………

28. Do you think energy savings enhance profit in your company? (a) Yes (b) No

If yes, explain…………………………………………………………………………………………………………………………………………………………………………………………………………

…
29. What energy efficiency measures are there in your company? (a) Training (b) Reward/punishment (c) other, please specify

30. Do you have any further comments on driving forces for energy efficiency improvement?
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Thank you.

APPENDIX Q – VARIABLE DEFINITIONS FOR CHAPTER 7

Variable definition

Countries:
1. Alg = Algeria
2. Ang = Angola
3. Cam = Cameroon
4. Con = Congo
5. Cot = Cote D'ivoire
6. DRC = Democratic Republic of Congo
7. Egy = Egypt
8. Gab = Gabon
9. Nig = Nigeria
10. Tu = Tunisia

Variable definitions
1. gdp = Gross domestic product per capita (in current USD per capita)
2. op = oil production (in thousands of barrels per day)
3. ex = Exports (in current USD)
4. im = Imports (in current USD)
5. Inv = Standardised investment (Investment/GDP)
6. en = energy use (in kilogramme per oil equivalent per capita)
7. Y = Gross domestic product (in current USD)
8. to = trade openness (export+import)/GDP
9. or = Oil revenues (in current USD)
10. sor = Standardised oil revenues (oil revenues/GDP)
11. K = Investment (in current USD)
12. polity = institutional quality (values ranging from negative to 10)

VARIABLES_ORDERED

1. gdp = natural logarithm of gross domestic product per capita in THOUSANDS of current USD per capita
2. op = oil production (in MILLIONS of barrels per day)
3. Inv = Standardised investment (Investment/GDP)
4. en = energy use (in TONES per oil equivalent per capita)
5. to = trade openness (export+import)/GDP
6. sor = Standardised oil revenues (oil revenues/GDP)
7. polity = institutional quality (values ranging from negative to 10)

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