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BY
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DECLARATION

I declare that this thesis submitted herein is an original work I have personally undertaken under supervision except where due acknowledgement has been made in the text.

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DEDICATION

To Mavis, Nhyira and Nana

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TO GOD BE THE GLORY

Paul Kwakwa Adjei

ABSTRACT

This thesis addressed three empirical questions in environmental and energy economics in three chapters. The destruction of the environment through carbon emission has gained the attention of policy makers and environmentalists. The African continent is low emitter of CO_2, contributing comparatively little to climate change. However, it is widely accepted that the continent is very vulnerable to the effects of climate change. As a result although the share of Sub-Saharan Africa in global emission of CO_2 is historically low, the rising trend in its share of global emissions calls for a concern. In particular, the trend of CO_2 emission on the continent has been increasing with the rate of economic growth, trade openness and energy consumption.

The first empirical chapter (Chapter Three) thus analyses the effects of income, energy consumption and trade openness on carbon emission in Sub-Saharan Africa (SSA). Empirical estimations from the fully modifies ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) confirmed the existence of the Environmental Kuznets Curve Hypothesis for the SSA region with an estimated (income per capita) turning point values ranging from US$ 1,142.85 to US$ 5,687.09. Furthermore, the paper established a nonlinear relationship between trade and emission and concludes that both income and non-income factors account for carbon emission in SSA. However, income and energy consumption have the greatest effect. The results of the chapter imply among other things, the need to promote economic growth and development as a means of reducing carbon emission. Also opening up the sub region for international trade will in the long run help reduce emission. Again it is imperative for countries in the region to embrace more energy conservation policies in order to reduce emissions.

The second empirical chapter (Chapter Four) investigates the determinants of the rising fossil fuel consumption for three Sub-Saharan African countries - Ghana, Kenya and South Africa - to help manage the rising consumption fossil fuel consumption. The data for Ghana revealed income, trade and urbanization increases fossil fuel consumption while efficiency of the industrial and service sectors reduce its consumption. The Kenyan results however, showed income, industrial efficiency and urbanization contribute

positively to fossil fuel consumption but trade, efficiency of the service sector and price reduce fossil fuel consumption. The consumption of fossil fuel in South Africa is found to be influenced by income, urbanization, industrial efficiency, efficiency of the service sector and trade. Among other things, the results of the study suggest efforts should be geared towards strengthening the energy efficiency system in each of these countries to help reduce fossil fuel consumption. In addition, adequate measures should be put in place to decentralize growth and other lucrative activities in the countries under study to reduce the population pressure in the urban centers so as to curb the high level of fossil fuel consumption in such urbanized areas. Also, it is necessary that tariff and non-tariff barriers on products that do not promote energy efficiency are raised and vice versa.

The third empirical chapter (Chapter Five) probes into the electricity conservation behaviour for rural and urban households in the Ashanti region of Ghana. Based on a cross-sectional data, it was observed that although both urban and rural households engage in electricity conservation practices, rural households have the stronger behaviour. Through an analysis of conservation behaviour towards the usage of four households' appliances, it was noted that the effects of demographic features, dwelling characteristics, information, environmental concern, subjective norms and perceived benefits is somehow dependent on the location of households and the appliance in question. The outcome of the study calls for the need to create more awareness by having more campaigns on conservation for the households in the study area. Also, it tells that influential family members and role models in these areas should be involved in the conservation campaign. Also, the results highlight the need to have different conservation measures tailored towards the usage of different appliance in the study area.

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CHAPTER ONE INTRODUCTION

1.1 Background

The emission of green house gases (GHG) particularly carbon dioxide (CO_2), is the number one cause of global warming and climate change (United Nations Framework Convention on Climate Change 2006). A number of empirical studies have concluded that recent emissions of carbon dioxide have greatly affected the environment, human health and poverty (Arku 2013; United Nations Framework Convention on Climate Change 2006; Tol 2009; Chestin *et al* 2008). Records indicate that the CO_2 emissions from the top four emitters: China, the United States, the European Union and India, account for about 61% of the global emissions. Out of this figure, China's contribution constitutes 30%, the United States contributes 15%, the European Union's (EU-28) share is 10% and India 6.5% (Olivier et al., 2015).

The devastating effects of such emissions have called for global consensus to tackling this problem. Key among this consensus is the Kyoto protocol adopted in Kyoto, Japan, in December, 1997 and which came into force in February, 2005. At the core of the protocol is its aim to control emissions of major GHG taking into consideration differences in GHG emissions of countries, wealth and capacity to even reduce emission. The success of this protocol requires the preparation of policies and measures for reducing GHG emissions. Accordingly, policy makers, researchers and environmentalists have taken keen interest in identifying the drivers of emission for countries and regions.

However, these investigations have mainly focused on developed countries and developing Asia probably because of their relatively high contribution to the emission of GHG with little evidence from Sub-Saharan Africa (SSA) that has the lowest GHG emission levels in the world (Nakhooda et al., 2013; Hogath et al., 2015). Unfortunately, the SSA sub region has been predicted to bear the lion's share of the anticipated negative effects of climate change resulting from accumulated global emissions.

One main factor responsible for the rising trend of GHG emission is the consumption of fossil fuel. In 2014, the consumption of all fuel types except nuclear power, reached record levels with emerging economies accounting for all of the net growth in energy consumption (BP Statistical Review of World Energy, 2015). However, fossil fuel continues to form a greater share of primary energy consumption in the world offering about 85% of primary energy consumption (Gonzalez and Lucky, 2013; Global Opportunity Report, 2014). But the rising trend in fossil fuel consumption which raises global concern, owing to the GHG emissions associated with its combustion, has drawn the attention of the world researchers and policy makers. In addition, many developing countries especially SSA countries are unable able to meet demand requirement for fossil energy.

As a means of ensuring energy sustainability, demand side management of energy, especially conservation, has been touted as one of the surest means to achieve this (PSEC and GRIDCo 2010; African Development Bank 2010). Energy conservation is crucial now even as the world currently has over 1.3 billion people not having access to electricity and about 2.6 billion lacking clean cooking facilities. This situation is worse among Sub-Saharan African (SSA) and developing Asia countries accommodating over 95% of the world's energy poor (IEA 2015). Notwithstanding this situation, many countries in SSA, including, Ghana have a high level of inefficiency in their energy usage, especially, electricity usage. As a result of these concerns, many governments in the region have aimed at promoting electricity conservation measures in their respective countries (see PSEC and GRIDCo, 2010; African Development Bank, 2010; Kitio, 2013).

1.2 Problem Statement and Motivation of the study

Although the African continent is low emitter of CO_2, contributing comparatively small to climate change, it is widely appreciated that the continent, especially the Sub-Saharan region, is very vulnerable to the effects of climate change (Nakhooda et al., 2013; Hogath et al., 2015). The CO_2 emission from the African continent more than quadrupled between 1950 and 2008. This raises a lot of concern about the future implications of such emissions on the continent especially the SSA sub region. The observation is that, the trend of CO_2 emission on the continent has been increasing with the rate of economic growth, trade openness and energy consumption which raises a concern in relation to the environmental impact of these variables.

Even though quite a number of studies have investigated the drivers of carbon emission for the sub region (for example Akpan and Akpan, 2012; Aka 2008; Kohler, 2013), these studies to the best of the author's knowledge, do not control for the income, trade and energy consumption in a single regression. This situation is likely to affect the estimated coefficient of income since the potential positive effect of trade on income, on the one hand and energy consumption as well as a possible feedback from income to energy consumption is well documented in the literature (Go´mez et al., 2011; Solarin and

Shahbaz, 2013). In addition, studies on the subject matter for SSA have mainly relied on time series data which suffers from the problem heterogeneity among other limitations. Accordingly, the first empirical chapter in this thesis examines the individual effects of income, trade, and energy consumption on carbon emissions for selected SSA countries in a panel certain.

The role of energy (the power obtained from physical or chemical resources to aid in the operation and work of machines (Bhattacharyya, 2011) in the growth and developmental process of an economy cannot be over emphasized. However, the reliance on non renewable source of energy particularly fossil fuel has become a concern to many countries owing to the environmental impact of such energy source. In some Sub-Saharan African countries (Ghana, Kenya and South Africa to be precise), the consumption of fossil fuel has been rising amidst inadequate supply (WDI 2015). To curtail the rising demand for fossil fuel and the associated environmental effect in SSA, it becomes crucial to identify the driving forces behind the rising level of fossil fuel consumption.

However, at the macro level, little is known about the factors that influence fossil fuel consumption for the sub region. In cases where such studies exist, the focus has been on the effects of price and income on fossil energy consumption (Sultan, 2010; Ziramba, 2010) leaving out the potential effects of other energy consumption driven variables. Hence, in an attempt to analyse the driving forces behind the rising level of fossil fuel consumption for Ghana, Kenya and South Africa, the second empirical chapter of this thesis incorporates the effects of trade, urbanization, efficiency of the industrial and service sectors in addition to price and income.

Some developing countries such as Ghana are bedeviled with the problem of inadequate power supply to meet the needs of households and industries. In the Ghanaian economy for instance, the functioning electricity generation facilities in the country is unable to meet the demand for electricity. This problem is compounded by the 30% of electricity supplied to consumers which is wasted as a result of inefficient electrical equipment, poor attitude towards energy conservation and theft (Ministry of Energy, 2010). This disturbing situation has prompted the government to target a 10% savings in electricity consumption through the implementation of comprehensive electrical power efficiency and conservation measures.

To this end, it becomes necessary to identify the electricity conservation behavior of households and the associated determinants for the country. With limited knowledge on households' electricity conservation in the country, the third empirical thesis examines and compares the electricity conservation behavior between rural and urban households in the Ashanti Region of Ghana. The importance of energy conservation is two fold. First, it reduces energy demand and secondly, it reduces the emission effect of energy consumption. A revelation of the electricity conservation behaviour in Ghana is necessary to help formulate and direct policy guidelines in this regard for the country whose electricity demand currently exceeds supply and to reduce the environmental impact of energy usage in the country. Further, in order to contribute to the literature, a rural and urban comparison on the factors that influence households' electricity conservation on the usage of four electrical appliances is assessed in the third empirical chapter.

1.3 Objectives of the Study

The main objective of this study is to identify the factors that influence energy consumption, energy conservation and carbon dioxide emission for selected Sub-Saharan African countries. Specifically, the study seeks to:

i. Investigate the individual effects of income, energy consumption and trade on emission of CO_2 in Sub-Saharan Africa.
ii. Explore the drivers of fossil fuel consumption for Ghana, Kenya and South Africa.
iii. Examine the electricity conservation behaviour for rural and urban households in the Ashanti Region of Ghana.

1.4 Hypotheses of the study

Following from the research problem and the objectives, the study seeks to test and validate the following empirical hypothesis:

1. H_0: The Environmental Kuznets Curve Hypothesis does not hold for SSA.

   H_1: The Environmental Kuznets Curve Hypothesis holds for SSA.

2. H_0: The service sector does not influence fossil energy consumption.

   H_1: The service sector influences fossil energy consumption

3. H_0: The Theory of Planned Behaviour variables do not influence electricity conservation in Ghana.

   H_1: The Theory of Planned Behaviour variables do influence electricity conservation in Ghana.

1.5 Organization of the Study

This thesis is organized into six chapters. The rest of the study is structured as follows. Chapter Two reviews the theoretical and empirical literature on carbon emissions, energy consumption, and energy conservation. Chapters Three, Four, and Five present three selfcontained papers. Chapter Three investigates the effects of income, energy consumption and trade openness on carbon emission in Sub-Saharan Africa. Chapter Four does a time series analysis of the drivers of fossil fuel consumption in SSA by focusing on Ghana, Kenya and South Africa. Chapter Five examines households' electricity conservation behavior in Ghana providing evidence from rural and urban households in the Ashanti Region of the country. Chapter Six concludes the study with summary of findings from the three independent articles presented in Chapters 3 to 5 and policy implications/recommendations thereof.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Many ill effects have been attributed to environmental degradation. Climate change for instance, is said to be a major cause of human migration which often leads to pressure on the limited available resources at the places migrants settle. This pressure then degenerates into conflicts. In the tropics, resource conflicts have led to the loss of properties and human life (Hellstrom, 2001; Niemella et al., 2005). Another related effect of degraded environment is the issue of environmental refugees. Authors like Jacobson (1988) and Homer-Dixon (1991) have written on how many people have become refugees due to environmental degradation with its attended problems.

Again, environmental degradation is known to be the cause of many diseases especially those in the tropics. By 2100, global warming can cause between 50-80 million malaria cases per year while other diseases such rabies, cholera, influenza, hanta-virus, schistosomiasis and hookworm are expected to undergo resurgence (Donohoe, 2003). These and many effects such as increased poverty (Duraiappah, 1998), gender inequality (Irish Aid, 2006), hunger and extinction of some spices (Donohoe, 2003) call for the need to curb the problem of environmental degradation.

Energy, the power obtained from physical or chemical resources to aid in the operation and work of machines (Bhattacharyya, 2011), has a closer relation with the environment. And because energy has become a very useful commodity, a shortage of its supply has serious implications on human lives as well. Lack of cleaner energy has been linked to global under-five mortality through diarrhoea and pneumonia. The reason is, energy is needed to pump water from a clean source and it is also needed to boil water for treatment (Sarbu and Valea, 2015). Therefore, the absence of reliable energy forces many households to rely on untreated source of water which adversely affects their lives. Reliable power supply helps in the empowerment of women who are often marginalized in society. The empowerment of women in developing countries has been retarded due to lack of access to reliable and cleaner energy. The reason is that women are forced to go and search for traditional fuels which take their time and have effect on their developmental capabilities. School girls also have to go to class late or miss it entirely in search of energy. Other opportunities in the area of employment and self development elude them (Boiling Point, 2015).

Many lives are trapped in poverty owing to lack of access to modern energy. During periods of lower supply of energy, many economic activities in the various sectors particularly the industrial and even agricultural sectors become malfunctioned thereby reducing the income earnings (ECOSOC, 2014) of the workers in these sectors of the economy. Lack of energy is also associated with environmental degradation (World Energy Outlook, 2002), food insecurity (Mary Robinson Foundation, 2012) and poor economic performance (ISSER, 2008).

The foregoing problems require conscious efforts on the part of government and policy makers in ensuring sustainable environment and energy for development. The first point of call to deal with the problem therefore, is to identify the causes. Consequently, the next section of this chapter looks at the theoretical arguments and empirical evidences on the causes of environmental degradation. Again, the underlying factors of energy consumption and conservation would be looked at.

2.2 Environmental degradation: the theoretical arguments and empirics of the causes

Three main concepts have been developed to explain the relationship between human activities and the sustainability of the environment. These concepts are the Environmental Kuznets curve (EKC) hypothesis, the Environmental Impact Population Affluence and Technology (IPAT) equation, and the Pollution Haven Hypothesis (PHH). In the subsections below, a careful review of these concepts is expounded.

2.2.1 Environmental Kuznets curve hypothesis

The environmental Kuznets curve as a concept has its root from the Kuznets inverted curve hypothesis. In his work Kuznets (1955) argues that as economies begin to grow there is a high level of income inequality but after growth and development has reached a point income inequality reduces. This indicates there is an inverted U shaped relationship between income and inequality. Based on this original idea, Grossman and Krueger (1993; 1995) also hypothesized an inverted U shaped relationship between income and environment. Thus, as an economy develops the quality of the environment would deteriorate but after a certain level of economic development, the quality of the environment improves.

The above then indicates the relationship between income and the environment is not monotonic but rather quadratic implying economic growth and development can eventually improve the quality of the environment. The curvilinear relationship is similar to the original income and income inequality theory developed by Kuznets (1955) hence the name Environmental Kuznets Curve. Many authors have cited reasons to underscore the existence of the EKC. For instance, Grossman and Krueger (1995) and Panayotou (1997) attribute it to what they call the scale effects, the composition effects and the technique effects. The scale effect on the environment is that as the economy expands in its economic activities the usage of energy resources to facilitate production activities also increases thereby increasing pollution than previously. This conflicting goal between development and the quality of environment has been the traditional view of many economists (Stern 2003).

The composition effect of income on the environment is that countries have their output composition change as they grow and develop. From an agrarian economy to industrialized one, economic activities increase in diversity with pollution owing to the increasing physical capital intensive activities (UNCTAD 2012). However, as the structure of the economy develops further from an industrial based to services and information based, the growth in income tends to be associated with relatively low level of pollution. There are cases where the economy even moves from a heavy industrial sector to lighter manufacturing sector which also has a lower rate of pollution (Stern, 2003). The technique effect which others refer to it as the abatement effect, says at a high level of income because citizens perceive environmental quality as a normal good, and thus get concern for the environment, pollution reduction measures are put in place there by resulting in an eventual fall in the emission of pollutants that destroy the environment.

However, the idea that the rich are more concerned about the environment than the poor remains contentious in the literature. Carefully looked at, the technique effect is classified by Stern (2004) into changes in input mix and improvement in the state of technology. This indicates that a growing economy initially witnesses the negative scale effect but it is later outweighed by the positive composition and the technique effects (Aslandis, 2009) generally. Nonetheless, Bouvier (2004) has opined that a growing economy in the course of time has the three effects occurring. Thus the effect of an increase in income will depend on the magnitude of these changes. A higher scale effect than the composition and/or technique effect will increase pollution as the economy grows and vice versa.

Copeland and Taylor (2004) also attribute the existence of the EKC hypothesis to the source of economic growth. An economy whose initial growth is powered by capital accumulation but has human capital acquisition as the source of its advanced growth will witness this inverted U relationship between income and environment. Again, it is explained that as income rises, the citizens who become more educated tend to have less children. As a result of this there will be lower population growth and a reduction in the pressure on the environmental resources (UNCTAD, 2012). This explanation is however not accepted by all as some downplay the degradation effect of population (Alstine and Neumayer, 2012). Another explanation is that externalities have everything to do with pollution. For the causative agents of these pollutants to internalize those externalities would require some relatively advanced and effective institutions for collective decisionmaking. Such institutions and the policies may respectively be available and implementable in high income economies (Andreoni and Levinson, 2001).

Arguments through theoretical models by many authors also offer support for the

EKC. These models are usually under certain assumptions about the economy (Stern, 2003). For instance, the summary of arguments proposed by Stokey (1998), Jaeger (1998) and John and Pecchenino (1994) is that as economies see higher incomes some binding constraints they witnessed at the lower income do not prevail again and thus can take measures to reduce pollution. In her static model with a choice of production technologies with varying degrees of pollution, Stokey (1998) under the assumption that only the dirtiest technology can be used when economic activity is below a certain threshold advanced an inverse-V-shaped relationship between income and the environment. Jaeger (1998) who proposed a similar relationship as Stokey (1998) also relied on the assumption that consumers' taste for clean air is satiated, and that the marginal benefit of additional environmental quality is zero at low levels of pollution.

An overlapping generation model was used by John and Pecchenino (1994) to explain the EKC. Given a stock of environmental resources whose quality degrades over time unless maintained by investment in the environment as the economy starts off from the corner solution of zero, environmental investment will see its environmental quality decline with time and with economic growth until the point at which positive environmental investment is desired, when environmental quality will begin improving with economic growth. John *et al*. (1995) and McConnell (1997) developed similar overlapping generation models under the assumption that pollution is generated by consumption rather than by production activities. Also, Lopez (1994) and Selden and Song (1995) developed their models assuming that individuals live infinitely, there is exogenous technological change and that pollution is generated by production and not by consumption (Stern, 2003).

Since its origin in the 1990s, many researchers have empirically tested the EKC hypothesis. In an effort to do so several estimation techniques, various measurement of environmental degradation with other variables have been used to test the EKC hypothesis for many countries and regions. Owing to the different dimensions of environmental quality, various proxies have been used in empirical studies that seek to test the EKC hypothesis. Notable among these proxies for the quality of the environment is CO_2 emissions (see Selden and Song, 1994; Yavuz, 2014; Jebli et al., 2013; Jayanthakumaran et al., 2012; Jalil and Mahmud, 2009; Farhani et al., 2013; Iwata et al., 2010; Halicioglu, 2009; Shahbaz et al., 2013; Cho et al., 2014; Shahbaz et al. 2014; Al-Mulali et al. 2015a, 2015b; Jebli et al. 2016, Apergis and Ozturk, 2015, Ozturk and AlMulali, 2015 among others).

Another means of measuring environmental quality has been the emission of SO_2 (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Taguchi, 2014; Yaguchi et al., 2007; Shafik, 1994; Sayed and Sek, 2013; Selden and Song, 1994; Cole, 2003; Common and Stern, 2001; Cole *et al*.,1997, De Bruyn et al., 1998, Kaufmann *et al*., 1998; Panayotou, 1993; 1995; 1997, Shafik, 1994; Stern et al., 1998, Llorca and Menuie, 2009; Hackenbuchner, 2012; Ismail *et al*., 2014, among others). Also water pollution (Grossman and Krueger, 1995; Lee et al., 2010, Thompson, 2012; Sekar et al., 2009, Paudel and Pandit, 2015; Paudel et al., 2014, Farzin and Grogan, 2013 among others); carbon monoxide (Grossman and Krueger, 1995; Plassmann and Khanna, 2006; Selden and Song, 1994) and Deforestation (Ehrhardt-Martinez et al., 2002; Oliveira and Almeida, 2010; Shipley, 2014; Bhattarai and Hammig, 2002 etc) have been researched on.

Many researchers including Stern (2003) have raised some econometrics shortfall associated with earlier empirical studies on the EKC. They argue some of these studies paid little attention to the statistical properties of the data used, model adequacy and that the EKC does not exist when diagnostic statistics and specification tests are taken into consideration. However, seven main observations from the survey of the recent empirical studies can be made:

1. Researchers have focused more on variables that affect the quality of the air especially carbon dioxide probably because of its significant effect on climate change and global warming than any other measures of environmental quality;
2. Group of countries or panel studies have become more popular. This could be attributed to the limitations associated with time series data which are used for country specific studies;
3. There are conflicting results as some confirm the hypothesis and others do not;
4. Majority of these studies however have confirmed the EKC hypothesis;
5. Those that did not confirm the EKC hypothesis are mainly studies on developing countries. Alstine and Neumayer (2010) have argued, it would not be in the interest of LDCs to follow the EKC due to its many ramifications
6. Evidence from Sub-Saharan Africa is limited.
7. Few earlier studies like Torras and Boyce (1998), Panayotou (1997) and Suri and Chapman (1998) included other explanatory variables in addition to income. Many of the post millennium researchers on the subject matter tend to add other explanatory variables in addition to income and income square to the EKC model. Mention can be made of variables like urbanization, energy, industrialization and

trade (see Al-Mulali *et al*. 2015a and b). This approach is a sure way of dealing with the econometric problem of omitted variables that might be associated with previous studies. As such recent studies capture cointegration and other statistics that inform about omitted variables which were missing in earlier studies.

2.2.2 The Pollution haven hypothesis

Another concept that explains the effect of human activity on the environment is the pollution haven hypothesis. The main thrust of the hypothesis is that trade liberalization leads to relocation of pollution intensive firms from high income countries to low income countries. As a result of the weak environmental regulations in the developing countries they finally become safe havens for polluting industries after they have gained comparative advantage in pollution-intensive industries. The genesis of this debate is traced to the negotiations over the North American Free Trade Agreement (NAFTA), the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) negotiations, and the formation of the World Trade Organization (WTO). However, it became more prominent thanks to the Kyoto and Montreal Protocols and discussions on the impact of greenhouse gas emissions on global warming and climate change (Temurshoev, 2006). It is worth noting that the relationship between trade and environmental quality was first debated by Copeland and Taylor (1994).

Based on a two country static general equilibrium model of international trade with a continuum of goods differentiated by their pollution intensity, Copeland and Taylor (1994) under certain assumptions a) only one primary factor of production; b) countries only differ in their endowment of this factor; and c) pollution is a joint product to goods produce; show that trade liberalization causes the transfer of the production of dirty goods found in high income and strict environmental regulated country to low income and lax environmental regulated country. The ultimate effect is the rise in pollution for the latter country and the world as a whole. Furthermore, Temurshoev (2006) reveals three reasons why low income countries tend to have weak environmental regulations. The first factor is that developing countries incur a higher cost to monitor and exert pollution standard because of a number of challenges such as the scarcity of trained personnel, difficulty in obtaining modern equipment and corruption. The opposite is the case of higher income countries. Second, low income countries pay little attention to the environment and their health when considering issues that will generate extra jobs and earnings. Third, when developing countries experience growth it is associated with a transition from agriculture to manufacturing which ultimately leads to urbanization and pollution unlike the developed economies where growth implies a transition from manufacturing to service sector associated with less emission.

During the NAFTA debate, critics of the agreement used the PHH to support the possibility of environmental destruction in Mexico that is poorly and laxly regulated (Taylor, 2015). Aliyu (2005) also offers three dimensions to the PHH. The first is relocation factor mentioned already. Second, developed countries through trade openness tend to dump hazardous waste generated in developing countries and thirdly multinational corporations who find themselves in developing but naturally resourced countries usually extract natural resources especially non renewable resources at an uncontrollable rate and neglect the use of strict environmental standards that they have to comply in economically advanced countries.

Although a solid theoretical argument has been made by Copeland and Taylor (1994) and other researchers for the PHH, same cannot be said of the empirical studies as they have generated mixed results. See for instance, Dean et al. (2005), Asghari (2013), Neelankanta et al. (2013), Elmarzougui (2013), Eskeland and Harrison (2003), Ederington et al., (2005), Frankel and Rose (2005), Smarzynska-Javorcik and Wei (2005), Leitão (2011), Drukker et al. (2007), Timmins (2004), List et al. (2003) and Rezza (2011).

Aside the conflicting results, other observations from the previous studies are majority of these study have focused on outside the African continent; the use of panel data study is prominent and substantial number of the studies control for other variables. The relationship between quality of the environment and foreign direct investment (FDI) is also bourgeoning in the literature.

2.2.3 The IPAT equation

This is perhaps the longest held view among the three concepts presented in this study pertaining to factors that influence the environment although the EKC hypothesis has been used widely. This equation is attributed to Ehrlich and Holdren (1971) and Commoner (1972). The basic idea of the equation is that the multiplicative effect of levels of population (P), affluence (A) and technology (T) determines environmental impact. Thus, environmental impact (I) depends on the levels of population (P), level of affluence (A) and technology (T). Mathematically, the equation actually indicates that:

Environmental impact = Population x Affluence x Technology.

This implies all the three variables together are responsible for environmental impact (York et al., 2003). A look at the individual components of the IPAT equation would suggest three things (UNCTAD, 2012) a) growing population rates would lead to larger pressures on the environment; b) a higher levels of affluence would increase demand for natural resources and energy, as well as a rising generation of wastes and pollution; and c) the level of technology (the different ways in which societies use their productive resources), can have a significant effect on the degree of environmental impact, either reducing it or enlarging it. However, the multiplicative relationship implies that should any two of the variables remain constant a change in the other one will not have any environmental impact. IPAT's main strengths are that it is a parsimonious specification of key driving forces behind environmental change and, further, it identifies precisely the relationship between those driving forces and impacts (York et al., 2003).

As a springboard, the IPAT equation has been modified my many authors. Schulze (2002) for instance, introduces another variable called behavioral choices (B) to the IPAT and thus modifies it to I=PBAT. This modification throws more light on drivers of impact and thus reveals the need to modify behavior in order to reduce impact (Giambona et al., 2010). However, failure to indicate how B is measured has made the applicability of IPBAT less satisfactory (York et al. 2003) and less appealing. Waggoner and Ausubel (2002) have also developed the ImPACT model based on the IPAT. The authors disaggregated the T into consumption per unit of GDP (C) and impact per unit of consumption (T) to arrive at I = PACT (ImPACT). What the ImPACT model seeks to achieve is to recognize the environmental impact factors that can be manipulated to help reduce impacts and their associated influential factors.

Confronted with the limitation of the IPAT and ImPACT equations to allow for non-monotonic or non-proportional effects from the driving forces, a stochastic form of the IPAT equation that allows for random errors in the estimation of parameters has been proposed by Dietz and Rosa (1994). This, the authors refer to it as the Stochastic Impacts on Population, Affluence and Technology (STIRPAT). The STIRPAT equation is given below:

$I = aP^b A^c T^d e$ where *a*, *b*, *c* and *d* are parameters, and *e* is an error term. The strength of the STIRPAT model unlike the IPAT and ImPACT models is its ability to test hypothesis empirically. The stochastic model, STIRPAT is thus useful for two purposes at least (Wei, 2011). It is useful for the prediction of the impact certain key variables have on the environment.

Again, the estimation of the coefficient of the log of these variables that appear in the STIRPAT model could be interpreted as ecological elasticities (York et al. 2003). York et al. (2003) again proposed a refined version of the STIRPAT by arguing that the T variable in the original IPAT equation stands for any other factor. This implies, it is possible to add other factors to the model which can be likened to a disaggregation of the T and CT in the IPAT and ImPACT equations respectively. Such adjustment and improvement of the model renders STIRPAT to have stronger applicability (Dai et al., 2015). However, it has the potential to create the problem of multicollinearity (Wei, 2011).

Empirically, quite a number of studies have examined the antecedents of environmental degradation within the IPAT (STIRPAT) framework. They include Fan et al. (2006), Wang et al. (2013), DeHart and Soulé (2000), Liddle (2011), Youngho and Quah (2012), Zhuang et al. (2011), Dai and Liu (2011), Holm and Englund (2009), Poumanyvong and Kaneko (2010), Uddin et al. (2016), York and Rosa (2012),Wang et al. (2015), de Mattos and Filippi (2013), Shi (2003), Zhou et al. (2015) and Zhang and Lin (2012). A general observation from the empirical literature on the IPAT and its modifications suggest the following:

1. Population variable has the biggest impact on environment (Wang et al. 2013; Liddle 2011; Uddin 2016; Sztukowski 2010, York et al. 2003, Youngho and Quah 2012, Dietz et al 2007, Cole and Neumayer 2004, Martínez-Zarzoso 2008, Razak et al. 2015 Behera and Vishnu 2011);
2. Panel studies are more frequent than country specific studies (see Sadorsky 2014, Liddle 2011; 2013 and 2014; Youngho and Quah 2012; Martínez-Zarzoso 2008; Cole and Neumayer 2004 and Liddle 2014);
3. There are conflicting results on the effect of PAT on I; and
4. Many of studies do not regard T as an error term but find proxies for it (Zhou et al., 2015, Dietz et al., 2007, Razak et al., 2015, Shi, 2003, Giambona et al., 2005)

2.3 Review on energy consumption and conservation

As an essential commodity, the use of energy is crucial for the growth and development of an economy. As argued by Garg and Halsnaes (2008) and other researchers, energy is a pre requisite for attaining better education, health, agriculture, environmental sustainability and alleviating poverty. However, the supply and availability of this commodity to meet the above outcomes is limited in many developing economies. At the same time as seen through the EKC hypothesis and the PHH, the use of energy could have detrimental effect on the environment. To find remedy to these challenges at the macro level especially, the underlying factors of high energy consumption has been sought for by policy makers, economists and environmental scientists.

Various arguments have been made to suggest what influences energy consumption. These factors argued include price, income, economic structure, economic policy and financial development. Others are trade openness, population and urbanization. The structure of the economy has to do with which sector dominates the economy - is it the agricultural sector, industrial or the service sector? As an economy transits from an agrarian to industrial sector that uses many heavy duty machines that rely a lot on energy, the country's energy consumption increases (Shahbaz and Lean, 2013; Sardosky, 2013). When the economy is service dominated, energy consumption is lower compared with the industrial since the former sector is not associated with much energy consumption. If the industrial sector is characterized by efficiency in its energy usage, energy usage will be low (Adom and Bekoe, 2013).

The effect of trade openness on energy has been argued strongly by Sardosky (2011). The author indicates that energy is used for the production and transportation of the exported goods. Again, energy is used for the distribution of imported goods to other parts of the country and trade opens the floodgate for other goods that use energy to be brought into the country. All these therefore increase energy consumption of an economy. On the other hand, it can be argued that, when trade openness allows energy efficient goods to be brought into the economy, energy consumption reduces. Jones (1989) and Madlener (2011) have expounded the positive effect urbanization has on fuel consumption. They argue urbanization is characterized by manufacturing firms that rely on energy, heavy vehicular traffic in and out of those centers and increase in private consumption.

Also, financial development is argued to influence energy consumption although there are two opposing sides of the argument. Proponents of the idea that financial development increases consumption (Kakar et al., 2012; Mahalik and Mallick, 2014) are of the view that once an economy's financial sector is developed, it helps in the facilitation of trade, growth, entrepreneurship and industrialization through which energy consumption increases. In addition, individuals are able to acquire loans for consumption purposes (Chang, 2015). Those who oppose this argument contend financial development rather enables firms and individuals to acquire energy efficient gadgets thereby reducing energy usage (Alfaro et al., 2004 and Hermes and Lensink 2003). Price is argued to have a negative effect on the consumption of energy. A higher energy price reduces the purchasing power of consumers. As a result, consumers reduce their quantity of energy consumed when price rises and vice versa. As a normal commodity, energy consumption is also positively influenced by income. Once consumers' income rises they demand more of energy.

Empirically various studies have been conducted on the factors that influence energy consumption. Some of these studies have analysed the aggregate energy consumption of an economy (see De Vital *et al.,* 2006; Adom, 2015) while others have paid attention to electricity consumption (see Adom and Bekoe, 2013), gasoline (see

Ramanathan, 1999; Hughes et al., 2008) and crude oil (Tsirimokos, 2011; Altinay, 2007). A careful look at these empirical studies gives a clear indication that variables such as income, price, urbanization, population, trade openness and industrialization among others have been used in modeling the driving force of aggregate energy consumption and electricity consumption. However, when it comes to gasoline and other fossil fuels, the price and income elasticities have been the focused and such studies have emanated from the developed world and developing Asia with little evidence from Africa. An aggregate study on the determinants of fossil fuel is also rarely available. In addition, little evidence is known about the role of the efficiency of the service sector towards energy consumption.

Since there is the possibility of feedback effect from energy consumption to any of its explanatory variable, the causality tests have featured in the literature (Farhani et al., 2013, Hossain, 2011 and Ang, 2007). Four causal relationships have been identified in the literature namely;

1. Unidirectional causality from energy to the explanatory variables, meaning that energy consumption has effect on those variables and thus a conservation of energy will negatively affect those variables;
2. Unidirectional causality from the variables to energy, where an expansion in the variables increases energy consumption;
3. Bilateral causality between energy and the variables meaning the variables influenceenergy consumption and the latter also influences the former; and
4. Independence in that case there is no causality between energy and the variables

To help in the management of energy, the conservation side of its usage at the household level has also gained attention. Energy conservation simply means households exhibiting efficiency and curtailment behaviors (Gardner and Stern, 2002) towards the usage of energy. These behaviours are known to be influenced by certain factors explained through the theory of planned behavior due Ajzen (1991). These factors are the subjective norm, perceived behavior control, information and attitude. Studies such as Sardianou (2007), Castaldi and Zoli (2012), Abrahamse and Steg (2011) and Hori et al. (2013) relied on this theory to examine the factors of households' energy conservation. Their results however have not been conclusive with little known about SSA.

CHAPTER THREE

EFFECTS OF INCOME, ENERGY CONSUMPTION AND TRADE OPENNESS ON CARBON EMISSION IN SUB-SAHARAN AFRICA

3.1 Introduction

The attention of environmentalists and policy makers to climate change and global warming in recent times has increased due to their perceived threatening effects. The estimated effects of climate change and global warming are numerous and diverse ranging from the deterioration of the environment to the health implications for human population (Fernandez-Amador *et al*., 2013). However, the effects of climate change and global warming are found not to be the same for all regions in the world as some countries especially those in Sub-Saharan Africa are considered to be greatly at risk by these events (United Nations, 2006). A major contributor to climate change and global warming is carbon dioxide (CO_2) emission (Sharma 2011; UNEP 2013).

The concentration of CO_2 in the atmosphere as observed by climate scientists has been increasing significantly over the past century. For the past few decades alone, global carbon dioxide emission increased from 5,612.9 million tonnes in 1975 to 8537.8 million tonnes in 1995. By 2005, CO_2 emission stood at 11,335.5 million tonnes and it jumped to 13,773.1 million tonnes in 2011(OECD/IEA 2013). Globally, the current high trend of carbon emission can be said to be associated with a high level of economic growth, energy consumption and international trade (OECD/IEA 2013; Sharma 2011; UNEP 2013; WTO/UNEP 2009).

Although the contribution of Africa to carbon emission is very low compared with some countries, especially the Organization for Economic Cooperation and Development (OECD) member countries as well as emerging economies like China, there has been a twelve-fold increment from 1950 to 2008 with a current emission of 311 million metric tonnes. For Sub-Saharan Africa (SSA) region alone, the emission of CO_2 has increased gradually from 302.9 million tonnes in 1975, to 669.7 million tonnes in 1995 and then to 1058.3 million tonnes in 2011 (Boden *et al.* 2011). The spate of carbon emission from the African continent suggests a serious future implication especially for the SSA because of its effect on climate change and global warming for which the continent is very vulnerable to. This is because many people in the SSA sub region rely on agriculture that is dependent on rain for their sustenance.

Available data from the Word Development Indicator (2014) suggests that the rise in carbon dioxide emission in the SSA is found to follow a similar trend with the sub region's growth in income, level of trade openness and energy consumption from 1971 to 2011 (see Figure 3.1 below). For instance, the sub region's per capita income increased from US$ 217 in 1971, to US$ 694 in 1981 and then to US$ 1661 in 2011. This development could be attributed to the impressive growth performance the region has experienced over the years as it has grown at more than 5 percent on the entire continent and 5.6 percent for the SSA since 2000 (African Development Report, 2012). Energy, the power obtained from physical or chemical resources to aid in the operation and work of machines (Bhattacharyya, 2011) demand or consumption has also been increasing with carbon emission in the sub region from about 16,948 kt of oil equivalent in 1971 to 312,946 kt of oil equivalent in 1991 and then to 511,879 kt of oil equivalent in 2011. The high expenses on energy by some countries in the sub region also suggest that energy demand has increased in the sub region (Stambuli, 2013; Institute of Economic Affairs, 2013).

Regarding trade openness, Figure 3.1 shows that the sum of import and export as a share of GDP has increased from about 44% in 1971 to about 74% in 2010 but reduced marginally to 62% in 2011. Over the period, the share of export (import) in GDP increased from about 21 (24) % in 1971 to 27 (28) % in 1996 and then to 30 (31) % in 2011 although the share of import is higher than that of export. This increase in the trend of export and import can be attributed to the trade liberalization policies associated with the structural adjustment programmes (SAP) and economic recovery programme (ERP) by the IMF/World Bank that many SSA countries adopted in the 1980s and 1990s as a remedy for the abysmal economic performance they were experiencing in the 1970s.

Following that, between 2002 and 2009, the average nominal export growth of SSA is reported to have exceeded the world's average of 9.7% by 5.4%. It also outpaced those of developing countries in Asia (13.7%) and Latin America (9.9%). Importation to the sub region also increased with an average annual growth rate of 16.9% exceeding that of developing Asia and America which stood at 9.7% at the same period (Chea, 2012).

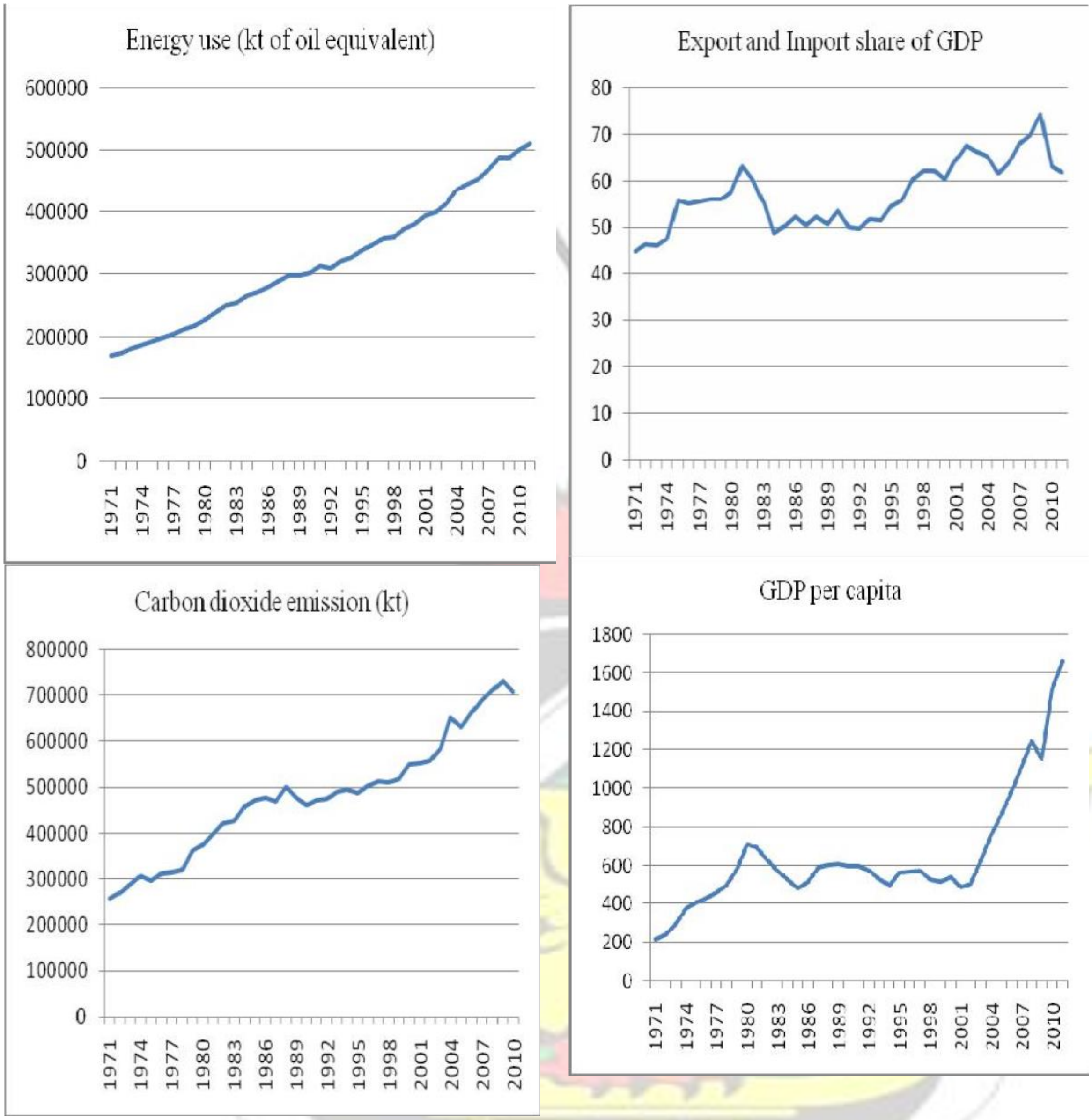

Figure 3.1: Trend of carbon dioxide emission, GDP per capita, export and import and energy consumption

The above facts and Figure 3.1 suggest that the path of carbon dioxide emissions in the SSA is influenced by changes in income, trade openness and energy consumption. This paper then examines the effects of income, energy consumption and trade openness on CO_2 emissions in SSA using panel cointegration techniques. The paper makes important contributions to the literature on the determinants of carbon emissions in general and particularly for the Sub-Saharan Africa region on four grounds. First, from the review of the available literature, we identified a dearth of research on Sub-Saharan Africa that controls for income, trade and energy consumption in a single regression.

The potential positive effect of trade on income, on the one hand and energy consumption on growth, and hence income per person as well as a possible feedback from income to energy consumption is well documented in the literature (Gomez *et al.*, 2011; Nayaran *et al.*, 2007; Kwakwa 2012; Yoo 2006; Solarin and Shahbaz 2013). Thus omitting one of these closely related variables from the emissions equation can result in upwards bias of the estimated effect of income on emissions. However, the existent literature on the subject for the SSA commonly suffers from this defect as Kohler (2013) appears to be the only study that examines the emission effect of energy consumption, trade and income on the sub region. Some earlier studies on the sub region account for the effect of either income or energy consumption (Akpan and Akpan 2012; Kwakwa *et al*,. 2010)or the effects of income and trade (Aka, 2008) on carbon emission.

Second, most of these previous studies on SSA including Kohler (2013) are mainly country case studies that employ time series approaches which have some limitations associated with their estimations including the problem of relatively short data span (Balgati, 2005). This means that panel data study which deals with the shortfalls associated with time series studies (Apergis and Payne, 2010a) should be embarked upon. In addition to the above, findings from previous studies on the subject matter have not yielded a conclusive results which calls for further studies.

More so, to the best of the authors' knowledge, many studies on the subject matter such as Aka (2008), Akpan and Akpan (2012), Apergis and Payne (2009), Arouri (2014), Grossman and Krueger (1991), Grossman and Krueger (1995), Holtz-Eakin and Selden (1995), Iwata et al. (2011), Jayanthakumaran *et al.* (2012), Jebli *et al*. (2013) and Kohler (2013) have tested for an inverted U shape relationship between income and emission but none has been established for trade. In this paper we confront the theoretical argument of the potential nonlinearities in the relationship between trade and emissions with SSA data by including a quadratic trade term in our specification.

The paper finds that emission of CO_2 in SSA is explained by income, energy consumption, trade openness, urbanization and industrialization. In particular, it confirms an inverted U shaped relationship exists between income and carbon emission implying that promoting economic development will reduce carbon emission. The paper which again established a nonlinear relationship between trade and emission concludes that both income and non income factors account for carbon emission in SSA however, income and energy consumption have the greatest effects.

The rest of the paper is organized as follows: Section 3.2 provides a review of the literature on the core drivers of carbon emissions. Section 3.3 specifies the empirical model and econometric strategies towards the identification (estimation) of model parameters. We also provide a description of data sources and sample as well as descriptive analysis of the data. Section 3.4 presents and discusses the results while Section 3.5 concludes the paper with summary of findings and policy implications thereof.

3.2 Literature review

Theoretically, the relationship between income and emission is explained by the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis stems from Kuznets' (1955) argument that economic development initially increases income inequality but it gets to its peak and then income inequality is reduced. This relationship between economic development and income inequality is seen as an inverted U shaped curve. Similarly, the EKC hypothesis which was first hypothesized by Grossman and Krueger (1991) postulates an inverted U shaped relationship between income and environmental degradation. That is, an initial level of growth in income will harm the environment until income reaches a level where the quality of the environment improves with income.

According to Grossman and Krueger (1991) and Panayotou (1997), three factors explain the inverted U shape relationship between income and the quality of the environment (Mohapatra and Giri, 2009). These are the scale effect, the composition effect and the technique effect. The scale effect explains that growth in income occurs with an increase in the scale of economic activities. Thus, there will be more consumption and production which will increase the level of environmental pollution than before. The second explanation known as the composition effect is that the output composition of countries changes drastically as they grow from a more agrarian economy to an industrialized one that increases pollution initially. Later on, the composition shifts from industry to services which then decrease pollution. The third factor is the technique effect and the explanation is that at high level of income, pollution reduction measures are put in place since individuals and policy makers become more environmentally conscious. Given the inverted U shaped relationship between income and emission, the rising portion of the curve indicates the scale effect while the falling part is the composition and the technical effects.

The reality however is that as an economy grows and people demand and produce more goods, both the composition of production and the technique of production changes and thus the effect of an increase in income will depend on direction of these changes. A higher scale effect than the composition and/or technique effect will increase pollution as the economy grows (Bouveir 2004). Also, although it is clear and easy to identify the location of all the effects on the curve, economists and researchers have debated on the level of income at which the turning point takes place. For instance, Grossman and Krueger (1995) suggest a per capita income of $8000; whiles Holtz-Eakin and Selden (1995) indicate $35,418. Neumayer (2004), gives a range between $55,000 and $90,000; Cole (2004) proposes $62,700 and $25,100; and Aka (2008) suggests a value of $825.

The environmentally damaging effect of trade on one hand can be explained by the Pollution Haven Hypothesis (PHH) which argues that trade puts pressure on host countries especially poor ones, to reduce the environmental standards in order to protect the hosted foreign firms, or entice other firms to come and operate, in their countries. When environmental laws are relaxed, negative externality effects to the society in general increases since they are not borne by the producers (Neumayer, 2004). As a result, trade will benefit the developed countries than the developing ones.

Another argument to support the negative effect of trade on the environment is that it encourages countries to extract more of resource that does not have a well defined property right. In the process, according to Chichilnisky (1994), there is a lower marginal cost of extraction compared with the true value of the resources (Aklin, 2011). On the other hand, the effect of trade on the pollution can be linked to the EKC hypothesis. Thus, since trade can promote growth, an increase in trading activities which leads to growth in income will lead to a higher consumption and production level associated with high pollution. This is the scale effect of trade. However, trade may cause an economy to move from agricultural sector to the industrial and then lastly to the service sector where pollution is relatively low. This is the composition effect of trade. Finally, there is the technique effect when trade enables countries to export more and invest in newer and low pollution production technique (Erickson *et al.,* 2013).

Energy plays important role in the growth and development of economies. However, energy usage is also argued to harm the environment through emission (Bozkurt and Akan, 2014). The environmental impact of energy is explained by the fact that the combustion of fossil fuels such as gasoline, coal and diesel for usage, releases emissions like nitrogen oxides, sulfur dioxide and carbon dioxide. As a result inefficient usage of energy increases the rate of emissions (OECD/IEA 2013; Sharma, 2011; UNEP, 2013). It is in this light that energy efficient technologies and clean energy sources are encouraged to help reduce carbon emission globally (OECD/IEA, 2012). Thus, energy consumption will increase carbon dioxide emission if it is more of the unclean type and less of energy saving technologies are used while the use of clean energy and efficient energy technologies can help reduce carbon dioxide emission.

These arguments put forth indicate clearly that the effect of income, energy consumption and trade is inconclusive. To test these arguments, empirical studies have been carried out using different data sets, region and methodological approach with mixed results. For instance, the pioneering work of Grossman and Krueger (1991) which assessed the relationship between income growth and emission for 42 countries covering the period of 1977-1984 confirmed the EKC hypothesis for two out of three emissions substances. Holtz-Eakin and Selden (1995) also examined the relationship between per capita income and carbon dioxide emissions for 130 countries over the period 1951-1986 and their findings confirmed the EKC hypothesis. Selden and Song (1994) used a cross sectional panel data and found an inverted U shaped relationship between emissions and income.

Later, Grossman and Krueger (1995) estimated the effect of growth on environmental pollution and confirmed the EKC hypothesis for the United States of America. A study by Aka (2008) employed the Autoregressive distributed lag (ARDL) model to analyze both the short and long-run impacts of trade and growth on carbon emissions on Sub-Saharan Africa using data covering the period 1961-2003. The author found that in the short run a 1% increase in economic growth leads to 1.04% increase in carbon emission but in the long run a 1% increase in *GDP* per capita reduces emission by 1.8%. Again, a 1% increase in trade intensity reduced carbon emission by 0.15% in the short run and 0.57% in the long run. Recently, Arouri (2014) also modeled carbon emission in Thailand as a function of income, square of income, energy consumption, trade and urbanization. Employing the Autoregressive Distributive Lag (ARDL**)** bounds test for annual data from 1971-2010, a long run relationship was established among the variables. The estimation showed that energy consumption increase emission while trade reduces emission. In addition, the EKC hypothesis was confirmed in the study.

Iwata et al. (2011) also examined the determinants of carbon emissions in 11 OECD countries by employing the ARDL to cointegration approach. The authors modeled carbon emission as a function of trade, electricity production from nuclear, energy consumption, income and square of income. The results show insignificant effect of trade on emission, positive effect of energy consumption on emissions, emission reducing effect of nuclear energy and a confirmation of the EKC hypothesis for some of the selected countries. Halicioglu (2008) studied the causal relationships between carbon emissions, energy consumption, income, and foreign trade in the case of Turkey using the time series data for the period 1960-2005. A positive and significant effect of energy consumption, growth and trade on carbon emission was found. In terms of magnitude it was found that income was the most significant variable followed by energy consumption and foreign trade.

Akpan and Akpan (2012) applied a multivariate Vector Error Correction model (VECM) to examine the long run and causal relationship between electricity consumption, carbon emissions and economic growth in Nigeria for the period 1970 to 2008. The results showed that an increase in economic growth increases carbon emissions although there was no support for the EKC hypothesis. Also, a negative relationship was found between electricity consumption and carbon emission which the authors attributed to the large deficit in the supply and surplus demand of electricity that existed in Nigeria. A Granger causality test showed a unidirectional causality from income to emission and no causality between energy and emission.

Apergis and Payne (2009) studied the causal relationship between carbon emissions, energy consumption, and GDP within a panel VECM for 6 Central American countries over the period of 1971-2004. The long run results confirmed the EKC hypothesis and a positive effect of energy consumption on emission. A Granger causality test results from the authors showed a short run unidirectional causality from energy consumption and real output to emission but a long-run bidirectional causality between energy consumption and emissions. In another study, Apergis and Payne (2010) used VECM to study the carbon dioxide emissions effect of energy consumption and real output for eleven countries of the Commonwealth of Independent States over the period 1992–2004. The authors found energy consumption has a positive effect on carbon dioxide emissions and a confirmation of the EKC hypothesis.

Jayanthakumaran *et al.* (2012) examined the emission effect of income, energy consumption and trade openness for China and India. The bounds testing approach to cointegration indicated a long run relationship among the variables in both countries. In the long run, the EKC hypothesis was established for both countries. In addition, an insignificant effect of trade on emission and a positive effect of energy consumption on emission in both countries were observed. Baek and Kim (2013) in their study on the interrelationships between trade, income, energy consumption and carbon emissions for Group of 20 economies employed the cointegrated vector autoregression (CVAR) for their estimation. Using data for the period 1960-2006, it was found that in the long run income and trade have negative relationship with emissions for the developed G-20 members. For the developing countries, trade and income were found to have positive effect on emissions. Again for most of the countries, energy consumption was found to positively contribute to emissions. Jebli *et al.* (2013) in their study employed the panel cointegration techniques to investigate the causal relationship between carbon emissions, energy consumption and trade openness for twenty-five OECD countries over the period 1980-2009. Estimations from FMOLS and DOLS confirmed the EKC hypothesis;

emission reduction effect of renewable energy, export and import; and a positive effect of non renewable energy on emission. Granger causality test revealed both the square of income and non-renewable energy granger cause emission. Chebbi *et al*. (2009) modeled carbon emissions as a function of trade and growth in Tunisia for the period 1961-2004. A co-integration technique employed showed that in the long run there is a positive linkage between trade openness and per capita emissions and a negative linkage between economic growth and per capita pollution emissions. In the short run a positive effect of trade on emissions was established while growth was found to have a negative effect on emission. Granger causality test found bidirectional relationship between emissions and output growth in the long-run.

Also, Farhani et al. (2013) examined the effects of GDP, energy consumption, trade openness and urbanization on carbon emissions for MENA countries over the period 1980-2009. The results from FMOLS and DOLS show that income, trade openness and energy consumption positively affect carbon emissions while squared income and urbanization have negative effect on emission. Short run causality from GDP and energy consumption to emissions was established. In the long run unidirectional causality from trade, GDP and energy consumption was obtained. In his study, Al-mulali (2012) examined the effect of energy consumption, foreign direct investment GDP and total trade on carbon emission for 12 Middle Eastern countries. Using data set for the period 1990–2009, it was established that all the variables have positive effect on carbon emission.

Amin *et al*. (2012) relied on time series data from 1976-2007 to examine the causal relationship among energy use, growth and carbon emissions in Bangladesh. A Johansen cointegration test confirmed a long run relationship among all the variables and granger causality test found a one-way causality from energy use to emission. Gu et al. (2013) also examined the effects of trade on carbon emissions in China. The authors used annual data from 1981 to 2010 and the Johansen Co-integration test showed there is a long-term equilibrium among carbon emissions, foreign trade dependency and FDI dependency. The estimation revealed that an increase in foreign trade dependency and FDI dependency will increase emissions. Lim et al. (2014) studied the causality issues among oil consumption, carbon emissions, and economic growth in the Philippines. The authors relied on annual time series data for the period 1965–2012 and by employing the granger causality test, a bi-directional causality between oil consumption and carbon emissions, and uni-directional causality running from carbon emissions to economic growth were detected.

Rahman and Porna (2014) used data span of 1970-2008 to investigate the relationship between environmental parameters and economic growth in six South Asian countries and found a long run relationship between growth and emission, and a one-way granger causality from carbon dioxide to growth. Sharma (2011) examined the effect of energy, economic growth, urbanization and trade on emission for 69 countries. The results from the GMM estimator for three separate panels generally indicated a positive effect of income and energy consumption on emission. A study by Ang (2007) looked at the relationship between emissions, energy consumption, and output for France. The author employed the VECM for data covering the period 1960-2000 and found that GDP granger caused emission. Ozturk and Uddin (2012) examined causality relationship between energy consumption, carbon dioxide emission and economic growth in India over the period 1971-2007. Granger causality test showed a casual flow from energy consumption to carbon emission.

Liu (2006) examined the causal relationship between growth and carbon emission among others using annual data for the period 1973-2003. The test results indicate a unidirectional causal relationship exist between GDP and air emissions. Adom et al. (2012) investigated causal relationships among carbon emissions, economic growth, technical efficiency, and industrial structure for Ghana, Senegal, and Morocco. Using Bounds cointegration approach for data covering the period of 1971 to 2007, a long run long-run equilibrium was established for two countries whiles the Toda and Yomamoto Granger causality test showed a blend of unidirectional, bidirectional, and neutral relationships for all countries.

The general conclusion from the above review is that just as there are diverse opinions on the effect of income, energy consumption and trade on CO_2 emissions, so has the empirics confirmed. Thus there is no consensus yet on how these factors affect the environment through carbon emission and this may be due to the differences in the estimation techniques, data sources and time period used for the various studies. Again very few studies have incorporated all three variables energy consumption, income and trade in the estimation process. These then call for further studies to deepen the understanding on the subject matter.

3.3 Empirical Strategy and Data

3.3.1 Theoretical and empirical specification

Theoretically, it is argued through the EKC hypothesis that income has a quadratic relationship with carbon emission; energy has a linear relationship with emission and there exists a non linear relationship between trade and emission through the EKC hypothesis. Based on this we model the emission effects of income, trade openness and energy consumption as follows:

$CPC_{it} = \alpha + \beta X_{it} + \lambda Z_{it} + \xi_{it}$ -- *(1)* where *CPC* is carbon emission, *i* represents countries used in the study, *t* represents time and ξ is made of the country specific effect and an error term assumed to be identically and independently distributed with zero mean and constant variance. *X* represents vector of explanatory variables namely income, square of income, energy consumption, trade openness and square of trade openness. *Z* consists of control variables, namely, urbanization and industrialization added to the model to ensure full and adequate specification. The inclusion of these two variables was based on the fact that they are known to affect carbon emission (Wang et al., 2011a; Sharma, 2011).

In the estimation, six separate models are proposed where two of them serve as baseline models which examine the emission effects of energy consumption, income and square of income as well as the emission effect of income, square of income and trade openness. Other two models also with income or energy consumption test for the nonlinearity relationship between trade and emission. The rest of the models add the control variables for estimations. The natural logarithmic form of all these variables is used for estimation which gives us the opportunity to interpret the coefficients, βs and λs as elasticities. If an inverted U shaped relationship is found between income and emission (i.e a positive sign for β_1 and negative β_2) the turning point *(K)* will be estimated as:

$$k = \exp\left[-\beta_1 / 2\beta_2\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where β_1 is the coefficient of the non squared income whiles respectively β_2 is the coefficient of square of income. The formula for the turning point is explained as follows. The establishment of the EKC hypothesis denotes a quadratic (concave) relationship between income and carbon emission (environmental deterioration). The turning point (k) is arrived at by partially differentiating regression equation with respect to income per capita. This produces the marginal effect/elasticity effect of income per capita on environmental degradation. This equation is then set to zero and k, the value of income that will set that equation to zero is solved for. The EKC produces ranges of values between positive and negative. By setting the equation to zero and solving for k, we show where the range of these positive values (where environmental deterioration increases with income) will end and where values begin to decline (where environmental quality increases with income). So when the value of k solved for is θ, it means that for values of income between 0 and θ, environmental quality deteriorates. However, for all values beyond θ, environmental quality improves.

3.3.2 Empirical Strategy

3.3.2.1 Testing for unit root of the variables

In estimating the Equation (1) above, the following steps are taken into consideration. First of all the stationarity test for the variables is conducted. Stationarity occurs when the mean value, variance and autocorrelation structure of the series remain constant over time. If the variables are stationary it also means they contain no unit root. If the variables are non-stationary, (i.e. they have unit root) then it is inappropriate to use classical methods of estimation such as Ordinary Least Square in the regression since it could lead to spurious regression. Spurious regression simply means the result we get from running a regression on time series variables is nonsensical (Gujarati and Sangeetha, 2007). Thus, the results are rendered meaningless. In that case the t-statistics and overall measures of fit become misleadingly "significant". The panel unit root test in the paper was conducted using

Levin–Lin–Chu (LLC), Breitung and Im, Pesaran and Shin (IPS) tests. The LLC test by Levin et al. (2002) is seen as a panel extension of the augmented Dickey-Fuller (ADF) test and it is based on the following equation:

$$\Delta x_{iy} = \alpha_i + \rho x_{it-1} + \sum_{j=1}^{\rho_i} \beta_{ij} \Delta x_{it-1} + \mu_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where i= 1,…I denotes the country and t=1,…,T is the time period and x_{it} represents the series for country i over the time period t. The number of lags represented by ρ_i and μ_{it} is the stationary error term. In carrying out this test Levin et al. (2002) suggest three-step procedure of (i) carrying out separate ADF regressions for each individual and generate two orthogonalised residuals; (ii) estimating the ratio of long-run to short-run innovation standard deviation for each individual; and (iii) computing the pooled t-statistics, with the average number of observations per individual and average lag length. The LLC works with a null hypothesis H_o: $\beta = \rho - 1 = 0$ and an alternate hypothesis of $H_1 = \beta < 0$.

An extended version of the LLC test is the IPS test developed by Im et al. (2003). The IPS test allows for heterogeneity on the autoregressive (AR) coefficient, β for all the panel unit, a feature that makes IPS superior to the LLC. As a result the null hypothesis according to the IPS is stated as H_o: $\beta_i = 0$ $\forall_i$ while the alternate is $\beta_i < 0$ $\forall_I$. Breitung (2000) establishes that the LLC and IPS tests suffer from a dramatic loss of power based on how the deterministic components are specified and consequently proposed a test statistic to overcome this difficulty. Breitung's test statistic assumes a common unit root process and is also shown to be asymptotically distributed as a standard normal (Kareem 2009; Martins 2011).

3.3.2.2 Testing for cointegration

Next, the panel cointegration is tested to determine if there is a long run relationship among the variables. This test is essential because although the variables of interest may not be stationary at levels, a certain linear combination of these variables will be stationary. In such case, the variables are said to be cointegrated and a long run relationship exists among them. The implication is that the independent variables can be said to be the driving forces behind the trend of the dependent variable in the long run. The Pedroni (1999; 2004) conintegration test is used in the study. Pedroni's test is an extended version of the Engle-Granger (1987) cointegration test which explains that there is a valid cointegration relationship among $I(1)$ series if the residual from their spurious regression is found to be $I(0)$ (Kareem, 2009). By extending this approach, Pedroni (1999; 2004) developed a test that takes into consideration the individual heterogeneous and fixed-effect cointegrated panels by proposing seven test statistics for testing panel cointegration. The seven tests are grouped into two; a) those that test for heterogeneous cointegration based on the within dimension technique and b) those that are based on the between means techniques. The former group consists of the Panel Phillips-Perron (PP), Panel Augmented Dickey-Fuller (ADF), Panel v and Panel rho statistics whiles the latter consist of the Group PP, Group ADF and Group rho statistics.

The Pedroni (1999; 2004) conitegration test is based on the regression:

$$y_{it} = x_{it}\beta_i + \alpha_i + \delta_i t + e_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4)$$

Examining the existence of cointegration requires the test to be done on the residual from the static long-run regression term expressed as :

$$e_{it} = \rho_i e_{it-1} + u_{it} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (5)$$

with the null hypothesis of no cointegration $\rho_I = 1$.

3.3.3 Estimations technique

Having tested for cointegration the final step is to estimate the effects of energy consumption, trade openness, income, industrialization and urbanization on carbon emission in equation (1) by using the extended version of Phillip and Hansen (1990) fully modified ordinary least squares (FMOLS) estimator for time series data as proposed by Pedroni (2000) for heterogeneous panel data. The choice of FMOLS estimator over other estimators is determined by the fact that it is appropriate for estimating equation with *I*(1) variables and endogenous regressors.

In this study, the income and energy consumption variables are likely to be endogenous. The reason is that our model excludes tourism development which is known to influence carbon emission, energy and income (Solarin, 2014). An increase in tourism activities has the potential of increasing energy consumption due to transportation (vehicular movement of people) involved and ultimately influences carbon emission. The monetary payment to visit tourist centers as well as the expenditures on food and accommodation also give rise to GDP of an economy (Kuo et al., 2012). Tourism development was excluded due to lack of data availability. Another advantage of this estimator is that it does not require testing for the order of cointegration rank. It is found also to be robust to both non-stationary and endogenous variables (Adu and Marbuah 2011). The panel FMOLS estimator is generally given by:

$$\hat{\beta}_{fmol} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}(x_{it}-\bar{x}_i)(x_{it}-\bar{x}_i)'\right]^{-1}\left[\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(x_{it}-\bar{x}_i)\hat{y}^{+}_{it}-T\hat{\Delta}^{+}_{\varepsilon\mu}\right)\right] \text{..........................(6)}$$

where $\hat{\Delta}^{+}_{\varepsilon\mu}$ is the serial correlation correction term and $\hat{y}^{+}_{it}$ is the transformed variable of y_{it} to achieve the endogeneity correction. Again the panel extension of Stock and Watson's dynamic ordinary least squares (DOLS) is estimated to check for the robustness of the results. The estimated coefficient of DOLS is given by:

$$\hat{\beta}_{dol} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}z_{it}z_{it}'\right)^{-1}\left(\sum_{t=1}^{T}z_{it}\hat{y}^{+}_{it}\right) \text{... (7)}$$

where $z_{it} = \left(x_{it}-\bar{x}_i, \Delta x_{i,t-q}, \ldots, \Delta x_{i,t+q}\right)$ is 2 (q + 1) x 1 vector of regressors.

3.3.4 The Data: sources and descriptive analysis

The study used an unbalanced cross-country panel data for 19 SSA countries[1] for the period 1977-2012. The initial plan of using all the SSA countries did not materialize due to the fact that a number of the countries had quite a number of missing data for the variables of interest. We were finally left with 19 countries that had most of the data available for the 1977-2012. The use of the panel model is also informed by the fact that countries differ in many respects and that, it is important to control for such heterogeneity to avoid misspecification of the results. Again, panel data are known to be more informative, more variability, less collinearity, have more degrees of freedom and their estimates are more efficient (Klevmarken 1989). All variables were from the 2014 version of the World Development Indicator published by the World Bank.

The dependent variable *CPC,* is measured by carbon dioxide emission in metric tonnes per capita. Also income *(Y)* is measured by the per capita GDP and Y^2 is the square of income. With the pace of economic growth and development in the sub region, the EKC hypothesis is expected to hold for SSA and as such income is expected to have a positive coefficient and negative for income square. Our trade openness *(TO)* variable is measured as sum of exports and imports as a percentage of GDP. It is also expected to have a positive effect on emission since the region under study is a developing one and the PHH is likely to hold in the region. We introduce in our estimation, the square of trade openness (TO^2) based on the ground that the literature has established the emission effect of trade through the EKC hypothesis. This implies trade may also have an inverted U shape relationship with emission and consequently this study tests for such relationship. The square of trade openness is therefore expected to have a negative effect on emission. *EC,* energy consumption per capita is also expected to have a positive coefficient. Urbanization, *UB* measured as the total urban population is expected to

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[1] Benin, Botswana, Burkina Faso, Cameroon, Congo Democratic Republic, Congo Republic of Brazzaville, Cote D'lvoire, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, Sudan, South Africa, Tanzania, Togo, Zambia and Zimbabwe

positively increase emission; and *INV* is the level of industrialization measured by the industrial value added as a share of GDP and it is expected to increase carbon emission.

The summary statistics of carbon emission, income, industrialization, energy consumption, trade and urbanization are shown in Table 3.1 below. The mean for income is US$1481.696 and this is low compared with the developed and other developing Asian countries. The value of the standard deviation tells there is little variation in the level of income across countries and time. Trade as a share of income has a mean of 0.695 which suggests that within the period of study, trade share of real GDP for the average country in the sample is in excess of 60%. This indicates that on the average, the sub region over the period that we study was modestly open to international trade. The minimum and maximum values of 0.109 and 2.153 are recorded respectively for trade. The mean energy consumption is 639.511 kg of oil equivalent per capita; and compared with the minimum and maximum values it is clear that there is not much variability in the energy consumption across countries and time. Carbon emission in terms of metric tonnes per capita varies greatly across space and time as the standard deviation, mean, minimum and maximum values suggest.

Table 3.1: Summary of descriptive statistics

Variable	***Mean***	***Median***	***Maximum***	***Minimum***	***Standard Dev.***

CPC	1.1947	0.3192	10.918	0.0311	2.3895
Y	1481.69	643.97	10647.12	111.88	1975.96
Y_2	6092981.2	414711.5	1.13E+08	12518.43	14035977
TO	0.6952	0.6461	2.1528	0.1093	0.3629
TO^2	0.6149	0.4174	4.6348	0.0119	0.6397
EC	639.5113	412.4260	2961.354	207.7592	557.0525
UB	4.3051	4.1070	15.3413	1.12100	1.71773
INV	29.420	25.212	77.413	7.179	14.413

As a precursor to preview the relationship between carbon dioxide emission and the variables of interest, the study employed scatter plots for the variables in their natural logarithmic form. Figure 3.2 is a plot of the income per capita against carbon dioxide emission and the line of best fit indicates a positive relationship suggesting that GDP per capita increases with carbon emission. In Figure 3.3, where the square of income is plotted against carbon dioxide, the line of best fit also depicts a positive relationship between the two variables. Figure 3.4 is a plot of carbon dioxide emission and energy consumption, and a positive relationship is seen although it is concentrated between 5.5 and 6.5kg per capita of energy consumption. In Figure 3.5, a positive relationship is seen between trade and emission. However, Figure 3.6 indicates a negative relationship between square of trade and emission of carbon dioxide. The relationship between emission and urbanization as well as that of emission and industrialization as shown in

Figures 3.7 and 3.8 respectively, also denotes negative and positive relationship respectively. Thus, all the variables from the scatter plots are expected to harm the environment except square of trade and urbanization.

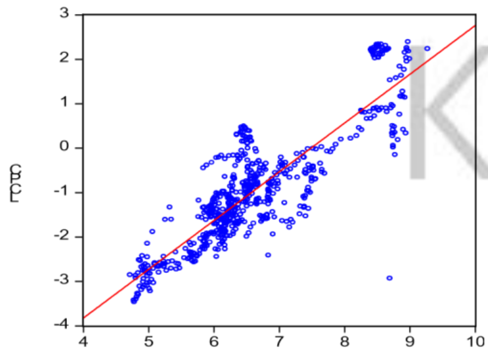


Figure 3.2: Plot of CO_2 emission and income

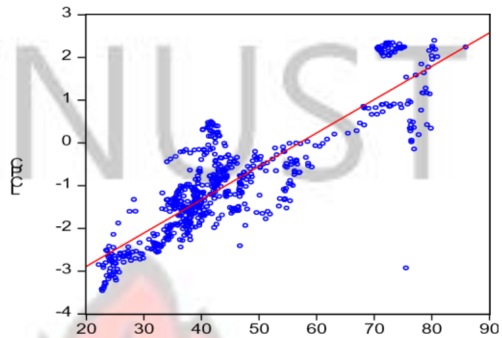


Figure 3.3: Plot of CO_2 emission and square of income

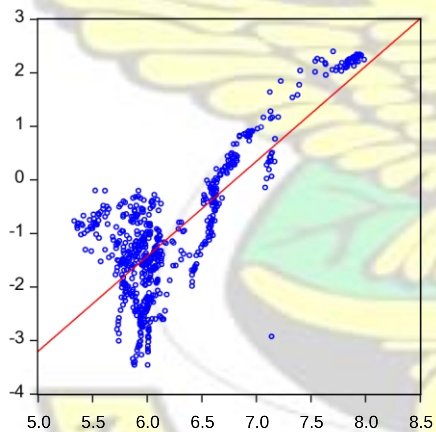


Figure 3.4: Plot of CO_2 emission and energy consumption

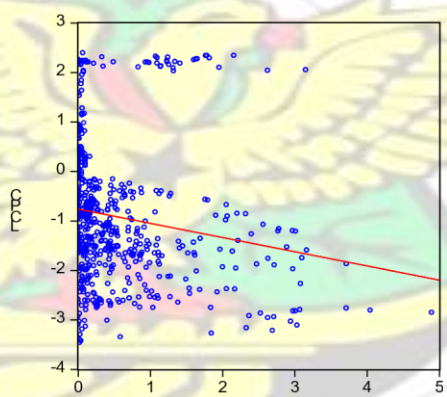
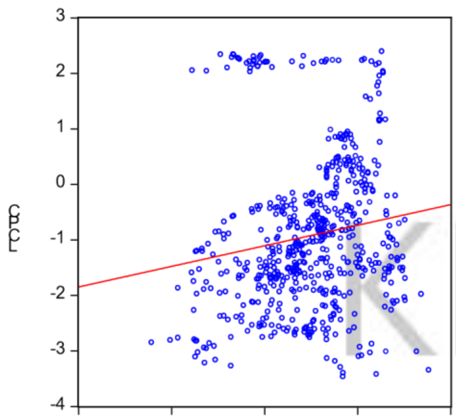
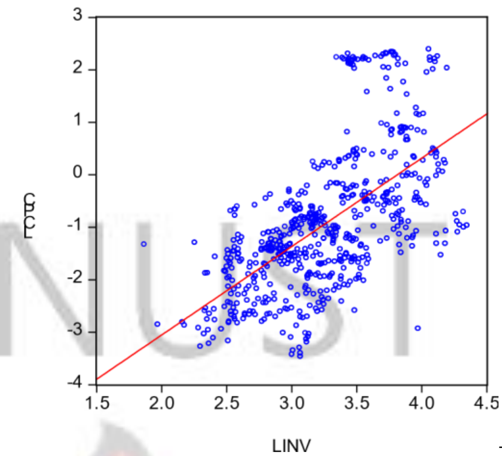


Figure 3.6: Plot of CO_2 emission and square of trade





-3 -2 -

1 0 1

LTOT

Figure 3.8: Plot of CO_2 emission and industrialization

Figure 3.5: Plot of CO_2 emission and trade

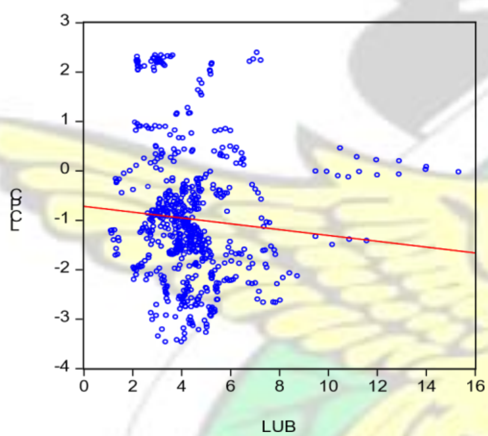


Figure 3.7: Plot of carbon emission and urbanization

3.4 Results and Discussion

This section presents and discusses the results of econometric techniques employed to establish the long-run effect of income, trade, energy consumption, urbanization and level of industrialization on the rate of carbon dioxide emission in the SSA. The analysis presented in this section follows three sequential steps. First, panel unit root test is conducted on the individual series in the sample. Second, panel cointegration test is performed to ascertain the existence of long-run equilibrium relationships among the variables in the specified equation. Third, different specifications of the model are estimated using both panel FMOLS and DOLS.

3.4.1 Unit root test

The results of the panel unit root tests for the series, income, trade openness, energy consumption, carbon emission, urbanization and industrialization are reported in Table 3.2. The study relied on the LLC, Breitung and IPS tests to examine stationarity of the series in their levels and the results show all the tests could not reject the presence of unit root for the variables with the exception of the Breitung test that rejects the presence of unit root for industrialization. Based on the first differences of the variables, all three tests reject the presence of unit root at one percent level of significance. Thus, the variables become stationary using their first differences and in the light of this we can then conclude that all variables are integrated of order one, *I(1)*. With the individual series integrated of order one and are thus nonstationarity, we proceed to the panel cointegration test.

Table 3.2: Panel Unit Root Tests Results

Variables	**LLC t-star**	**Breitung t-stat**	**IPS t-stat**
		Variables in levels	
LCPC	-0.83494	-1.22857	-2.46357
LY	-0.59705	4.932	1.90421
LY^2	-0.31516	5.2455	2.16500
LEC	-0.34409	3.08483	2.02852
LTO	0.7375	1.09151	1.82711
LTO^2	0.93388	2.73855	3.40005
LUB	3.51416	8.16508	1.9093
LINV	1.03045	-2.9399*	-1.21681

Variables at first difference			
DLCPC	-22.4471***	-12.7463***	-16.1760***
DLY	-7.0980***	-7.3512***	-10.0329***
DLY^2	-7.21943***	-7.15923***	-10.1161***
DLEC	-6.22989***	-3.7970***	-11.5805***
DLTO	-11.0145***	-7.3780***	-12.3626***
$DLTO^2$	-7.4612***	-1.84265**	-2.20304**
DLUB	-5.15967***	-8.13839***	-6.7774***
DLINV	-11.419***	-12.5671***	-12.9091***

Note: ***, **, and * indicate rejection of null hypothesis at 1%, 5% and 10% respectively

3.4.2 Test for long run equilibrium

The study employs the Pedroni (1999; 2004) test to check for cointegration among the series, and the results are presented in Table 3.3. The results for each group of series show some test accepting the null hypothesis of no conintegration while others reject that. Thus, mixed results are provided from the cointegration tests for each group of series. Notwithstanding this, the conclusion that there is a stable long-run relationship among the variables for each group can be established on two grounds. Firstly, we have the PPstatistics which Gao and Zhang (2014) have noted to be more powerful than rho-statistics confirming the presence of long run relationships for each group of series. Secondly, majority of the statistics indicates the presence of cointegration, among the variables.

Table 3.3: Panel Cointegration tests results

	LCPC, LEC, LTO, LTO^2, LY, LINV & LUB	*LCPC, LTO, LY & LY^2*	*LCPC, LEC, LY & LY^2*

Test statistic	Statistic	Statistic	Statistics
Panel v-statistc	1.5162*	-1.3228	-1.0900
Panel rho-statistic	-1.0742	-3.1609***	-4.0797***
Panel pp-statistic	-9.3082***	-5.3478***	-6.9340***
ADF statistic	-2.4289***	-1.5714*	-1.6470**
Group rho-statistic	2.6012	0.1548	-0.2620
Group pp-statistic	-7.6105***	-2.9981**	-4.6563***
Group ADF-statistic	-2.1594**	-0.6547	-2.4549***
	LCPC, LEC, LTO, LINV, LUB, LY & LY^2	*LCPC, LEC, LTO & LTO^2*	*LTO, LTO^2 & LY*

Test statistic	Statistic	Statistic	Statistic
Panel v-statistc	0.5406	-0.4681	1.1286
Panel rho-statistic	-1.1853	-2.1791**	-3.3258***
Panel pp-statistic	-9.2670***	-5.1011***	-5.5323***
ADF statistic	-1.9426**	-0.0728	-1.3147**
Group rho-statistic	2.7943	-0.0652	2.3910
Group pp-statistic	-10.5969***	-3.7308***	-2.8827***
Group ADF-statistic	-2.7243***	-2.1154**	-1.3114*

*Note: ***, **, and * to indicate rejection of null hypothesis at 1%, 5% and 10% respectively*

3.4.3 Long run analysis

Having tested and confirmed that the variables are co integrated, the fully modified OLS (FMOLS) developed by Pedroni (2000) and an extension of Stock and Watson (1993) DOLS estimation techniques for heterogeneous cointegrated panels are estimated. The results are reported in Tables 3.4. As it can be seen, the results from both FMOLS and DOLS estimations under the six models yield similar results. A general conclusion from the result is that all the variables have a positive and significant effect on CO_2 emissions except the square of income and square of trade with negative coefficients.

The result for energy consumption is found to positively contribute to CO_2 emission in the sub region with a coefficient ranging from of 0.96 to 1.99. The interpretation is a 1% increase in energy consumption will lead to about 0.96% to 1.99% increase in the sub region's carbon emission. Thus, over time higher energy consumption in the sub region gives rise to more carbon emissions. The reason why energy consumption increases emission can be explained by the fact that the sub region is mainly rural where a high number of the population rely on unclean energy, which emits more carbon, for their cooking and other domestic activities (International Energy Agency, 2014). Even in the urban areas, scarcity of cleaner energy may compel many to use unclean energy which increases the carbon emission in the sub region. The findings here are consistent with those reported by Gao and Zhang (2014) who report a coefficient of 0.27, Apergis and Payne (2010) with a coefficient of 0.42, Hossain (2014) with a coefficient of 1.09 and Farhani et al. (2013) with a coefficient lying between 0.82 and 0.92.

The income elasticity of carbon emission is positive and generally elastic but negative and generally inelastic for the square of income. Specifically, a 1% increase in real per capita GDP leads to about 0.3% to 4.1% increase in the emission of carbon but a 1% increase in the square of income will reduce carbon emission by almost 0.03% to 0.29%. The positive sign for income and the negative sign for income squared in models 1 (FMOLS and DOLS), 2 (DOLS) and 3 (FMOLS and DOLS) support the EKC hypothesis that pollution emissions initially increase with income and then later increases at a decreasing rate after income reaches a certain level. From the results it can be said that the reduction impact of growth in income from the composition and techniques effects outweighs the negative scale effect of income growth. This implies that economic growth and development in the region will improve environmental quality since the rate of carbon emission will increase at a decreasing rate. The outcome in this study collaborates Farhani et al. (2013) and Gao and Zhang (2014).

From the results we estimated the turning point $k = \exp\left(-\beta_1/2\beta_2\right)$ of the EKC and found it to be between about US$ 1,142.85 to US$ 5,687.09 which higher than Aka's (2008) value US$ 824 for the SSA. However, they are lower than Grossman and Krueger's (1995) value of $8000; Holtz-Eakin and Selden's (1995) value of $35,418 and Neumayer's (2004) values of $55,000-$90,000. The variances in the values of the turning points clearly indicate why although it is clear and easy to identify the location of all the three effects on the EKC, economists and researchers have debated on the level of income at which the turning point occurs.

The effect of trade openness is found to be positive and generally inelastic meaning that a 1% increase in the trade openness will increase carbon emission by a rate less than 1%. On the other hand, the square of trade openness is negative and significant. Specifically, 1% increase in the square of trade openness will reduce carbon emission by about 0.08% to 0.19%. Thus, the results strongly confirm nonlinearity in the relationship between trade and emissions with SSA data. This tells that the composition and the technique effects of trade exceed the scale effect of trade for the sub region. As a result, the Pollution Haven

Hypothesis (PHH) can be concluded to be relatively a short run phenomenon for SSA sub region since in the long run trade will reduce carbon emission despite the fact that the sub region seems to have a weaker environmental laws for the multinational firms from the advanced countries that contributes to emission in the region (see Shinsato, 2005; Aghalino and Eyinla, 2009).

The concave nature of the relationships between income and carbon emission, and carbon emission and trade, can be explained by the scale effect, composition effect and the technique effect explained earlier. Thus, promoting economic development and trade openness in the SSA region led to initial deterioration of the environment via carbon emission. However, after attaining a higher level of income, mechanisms have been put in place to have more of a quality environment (which is seen as a normal good) by ensuring that carbon emission in the region increases at a reducing rate. Attaining a good environment is crucial for reducing the risk of related health problems, reducing resources related conflict and also ensuring food and water security (Donhoe, 2003; Hellstrom, 2001). It is this regard that citizens, civil organizations, policy makers and governments would promote the attainment of good environment.

With respect to urbanization, it is found that a 1% increase in the urban population will cause carbon emission to grow by 0.05% - 0.06%. The positive coefficient of urbanization can be explained by the fact that urban towns in the sub region receive the best services from utility companies that has led to the fast rate of industrialization that requires dirty energy such as gasoline to operate well. Again, heavy vehicular traffic congestion is a common thing to see in many urban towns the effect of which is more fuel usage most of which is regarded as unclean energy thereby leading to an increase in carbon emission in the sub region. The finding here confirms the results of Sharma (2011). Industrialization is found to positively affect the emission of carbon dioxide. The estimated industrialization coefficient implies that for every 1% increase in the industrial share of the GDP of the sub region, carbon emission will increase by between 0.13% - 0.32% and vice versa. Thus, as the economy of the SSA region becomes more industrialized, there is the associated negative effect of carbon emission from the machines used.

Table 3.4: Long run estimation for CO_2 emission in Sub-Saharan Africa, 1977–2012

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
FMOLS						
LEC	1.1151*** (3.6519)		1.2087*** (4.7523)		0.9633*** (3.4601)	1.1201*** (5.5142)
LTO		0.0642* (1.6466)	0.0238 (1.4161)	0.0636** (1.9820)	0.2245*** (3.2146)	-0.0566 (-1.2012)
LTO^2				-0.0832** (-2.2104)	-0.1113*** (-4.5641)	-0.1851*** (3.3058)
LY	1.2321*** (3.8542)	1.0064*** (2.7324)	1.3745*** (2.8170)	0.8892*** (3.7891)		0.2714*** (6.2310)
LY^2	-0.0729** (-1.9741)	-0.0384 (-1.1521)	-0.0975** (-1.9312)			
LINV			0.1374*** (4.1243)			0.1365*** (7.5142)
LUB			0.0598*** (3.6015)			0.0679* (1.6782)
DOLS						
LEC	1.4257*** (2.9851)		1.9864*** (3.6438)		1.2504*** (2.8742)	1.5560*** (3.8452)
LTO		-0.0964 (1.3510)	0.0716*** (2.9915)	-0.1608 (-1.0210)	2.1565** (1.9741)	-0.1170 (1.2103)
LTO^2				-0.1092* (-1.6543)	0.0107 (1.4010)	-0.1915*** (-3.4927)
LY	2.3680*** (2.5891)	2.9500** (2.1120)	4.0938*** (3.2104)	1.248*** (2.6841)		0.8524*** (2.7230)
LY^2	-0.1656*** (-3.2022)	-0.1706** (-1.9601)	-0.2907*** (-2.7165)			
LINV			0.3207*** (3.0054)			0.1574** (2.3901)
LUB			0.0300* (1.7621)			0.0260*** (4.0214)

Note: *, **, and *** represent statistical significance level at 10, 5, and 1% levels; t-statistic in parenthesis

3.4.4 Diagnostic test

To ensure reliability of the results, the estimated FMOLS and DOLS models are tested against correlation problems because of the way some of the variables are measured in this study. The Variance Inflation Factor (VIF) was used in this study to test for multicollinearity. The literature suggests a VIF value of 1 means there is no correlation among a predictor and the other remaining predictor variables whiles a VIF exceeding 4 warrant further investigations. However, if the VIF exceeds 10 then there are clear signs of serious multicollinearity that will require correction. The result of the test is shown in Table 3.5 for FMOLS models 3, 4, 5 and 6. It is seen that there is no problem of collinearity among the variables as they all have VIF value of less than 1.07. It is to be noted that similar results were obtained for all the other models though not reported here. Test for serial correlation was not much concern since the main estimator FMOLS caters for that.

Table 3.5: VIF Multicollinearity test results

	FMOLS Model 3		FMOLS Model 6		FMOLS Model 5		FMOLS Model 4	
	Coefficient variance	Uncentered VIF	Coefficient variance	Uncentered VIF	Coefficient variance	Uncentered VIF	Coefficient variance	Uncentered VIF
LTO	0.001284	1.021551	0.000998	1.036232	0.000804	1.004857	0.003174	1.016380
LTO^2			0.000687	1.055739	0.001211	1.004244	0.000724	1.016380
LY	0.000281	1.014262	0.001161	1.006565			0.001427	1.01879
LY^2	0.000714	1.056409						
LEC	0.001121	1.048953	0.000297	1.028194	0.000659	1.005372		
LUB	0.000653	1.013261	0.001147	1.010850				
LINV	0.000281	1.014262	0.001081	1.006889				

3.5 Conclusions and Policy Implications

The paper was motivated by four reasons. First of all studies on the determinants of carbon dioxide emission have not yielded conclusive results. Secondly, there are limited studies on the carbon dioxide emission that account for the effects of income, energy consumption and trade openness for the Sub-Saharan Africa in a single regression equation despite the fact that there is the possibility of trade openness positively affecting income, on the one hand and energy consumption affecting growth, and hence income per person, as well as a possible feedback from income to energy consumption.

This suggests that omitting one of these closely related variables from the emissions equation can result in upwards bias of the estimated effect of income on emissions for the sub region. Also most existing studies on the subject for the SSA region have employed time series techniques for individual countries with little evidence from panel data. The last motivation for the paper stemmed from the fact that studies that examine the non linearity in the relationship between income and emission abound but to the best of the authors' knowledge no study exists that tests for such relationship between trade and emission (since trade is argued, can affect emission through the EKC hypothesis). Consequently, this paper sought to examine the effects of trade openness, income and energy consumption on carbon dioxide emission for 19 Sub Sahara African countries using data covering the period 1977-2012.

The study employed the FMOLS model which is found to be more robust to deal with the problem of endogeneity and serial correlations more or less very prevalent in panel data. The DOLS estimation was also employed to check for the robustness of the results. Unit root tests using the LLC, Breitung and IPS test statistics indicated all variables to be integrated of the order one, *I(1)* except the Breitung test that showed industrialization as an *I(0)* variable. However since the other two tests showed industrialization as *I*(1) variable all the variables were considered to be integrated of the order one. Pedroni's heterogeneous panel cointegration test reveals a long run relationship among trade openness, income, energy consumption, carbon emission, industrialization and urbanization variables.

The FMOLS and DOLS estimations confirmed the EKC hypothesis holds for the sub region with an estimated turning point values between US$ 1,142.85 to US$ 5,687.09 that is lower middle to upper middle income status based on the World Bank classification. The study also confirms a nonlinear relationship between trade and emission for the sub region. The results actually suggest an inverted U shape relationship between trade and emission.

These findings suggest that economic expansion as predicted by the EKC will eventually reduce carbon dioxide emission in Sub-Saharan Africa. Thus as the economy in the sub region grows and develops carbon emission will reduce. This implies the need to promote economic growth and development as a means of reducing carbon emission. Consequently, any growth and development impediment in the sub region needs to be addressed.

It is inferred from the results again that opening up the sub region for international trade is not detrimental to the environment. Also, an increase in the level of energy consumption is expected to increase the level of emission in the sub region. The implication of this is that since energy has been recognized as a necessity for growth and development in the sub region by previous studies and that a reduction may be harmful to the economy, policies like investment grants that will ensure the availability of cleaner energy for economic activities will help reduce emission. It also implies that it is imperative for countries in the region to embrace more energy conservation policies such as pricing, education and training policies in order to reduce emissions.

In addition, putting measures in place to decentralize growth in the country can help reduce pressures in the urban areas and hence reduce urbanization and eventually, carbon emission. A possible way to achieve this is for governments in the sub region to promote rural development. Moreover, given the rapid rate of urbanization in the region, the "greening" of the urban areas by creating national parks is recommended. Lastly, the results suggest the promotion of low carbon emission or green energy technologies at the industrial level to help reduce emission. Generally, the results from the study conclude that both income and non income variables explain carbon emission in SSA although income and energy consumption have a greater effect.

CHAPTER FOUR

A TIME SERIES ANALYSIS OF FOSSIL FUEL CONSUMPTION IN SUBSAHARAN AFRICA: EVIDENCE FROM GHANA, KENYA AND SOUTH AFRICA

4.1 Introduction

Energy, the power obtained from physical or chemical resources to aid in the operation and work of machines (Bhattacharyya, 2011) has become the engine that turns the wheels of economic activities in every country, because it is a key factor of production like capital and labour. It also has a direct effect on the wellbeing of humans since it plays important role in a country's transportation, industry, agriculture, communications, commercial and public services and other sustainability issues like education, health and alleviation of poverty (OECD/IEA, 2010; Garg and Halsnaes, 2008). A plethora of empirical studies have also underscored the important contribution of energy to economic growth (Kraft and Kraft, 1975; Khan and Ahmad, 2008; Adom, 2011; Chandran and Tang, 2013; Bloch et al., 2012; Nasiru 2012; Li and Leung 2012; Jinke and Li 2011, Satti et al., 2013).

Owing to its importance, inadequate supply of energy does negatively affect the economic and social developments of countries. To avoid such situation, empirical investigations are carried out among other efforts to predict and regulate energy consumption in many countries. The evidence from such investigations indicate varied factors influence energy consumption for specific countries. This chapter thus investigates into the drivers of fossil energy consumption for three Sub-Saharan African countries – Ghana, Kenya and South Africa. This is to help bridge the gap between the rising fossil energy consumption and the inadequate supply in these selected countries.

The share of fossil fuel in the total energy consumption for Ghana, Kenya and South Africa has been increasing over the years. For instance, available data shows the share of fossil fuel in the total energy consumption in South Africa has exceeded 84% for more than four decades. In the case of Ghana, it has more than doubled from 16.5% in 1991 to 37.4% in 2011 and for Kenya it has increased from 16.9% in 1991 to 19.7% in 2011 (WDI, 2015). However, the above mentioned countries are unable to meet their fossil energy demand requirement (see Section 4.2 for stylized facts on energy situation for each of the three countries)[1] which has dire consequences on households, firms and the entire economy. It has been suggested that failure to predict future energy demand has been a major factor for the inadequate energy supply in Sub-Saharan African countries (Davidson et al., 2007; Botchwey, 2016). Predicting future energy demand requires the need to identify the forces of energy demand and thus to avoid a worsening energy security situation in the future, this chapter seeks to identify the factors behind the increasing trend of fossil fuel consumption in Ghana, Kenya and South Africa.

Countries that do not meet their domestic fossil energy supply import from other counties. The challenge however is that importation of fossil energy entails considerable fiscal planning since it is dependent on the price at which the energy is sold on the world market. The implication is fluctuations of fossil energy price on the international market do have serious macroeconomic impact on the importing countries. It is imperative therefore, for countries that import fossil energy to reduce their consumption of fossil energy in order to reduce their exposure to international price shock (Sinha, 2015). Global energy price shocks have had significant effects on macroeconomic variables such as inflation, gross domestic product, balance of payments and budget stances for the

[1] The stylized fact is on the three major energy sources in Ghana, Kenya and South Africa. Although a high proportion of the population in each country relies on wood fuels, the study focuses on fossil fuels consumption owing to the high rising trend in its consumption for the three countries amidst inadequate supply, environmental effects and macroeconomic implications. For instance, the BP Statistical Review of Energy (2015) and Global Opportunity Report (2014) have indicated that the combustion and usage of fossil fuels is a major contributory factor of the global greenhouse gases emissions. The WDI (2015) of the World Bank has also revealed that carbon dioxide emission in these countries is mainly from fossil fuels usage. Also, Cantah and Asmah, 2015; Kambou, 2015 among others have highlighted the macroeconomic effects of fossil fuel prices on the economies of Ghana, Kenya and South Africa.

economies of Ghana (see Cantah and Asmah, 2015; Wiafe et al., 2014; Etornam, 2015; Marbuah, 2014), Kenya (see Kambou, 2015; Kennedy, 2013; Kiptui 2009) and South Africa (see Balcilar et al., 2014; Kambou, 2015; Wakeford 2006).

Moreover, the increasing level of fossil fuel consumption raises environmental concerns. This is due to the fact that the combustion of fossil fuel for energy releases greenhouse gases (GHG) that contribute to global warming and climate change whose effects Sub-Saharan African countries are vulnerable to (Ackah and Adu 2014, Africa Development Report 2012). This development has led many organizations, environmentalists and policy makers to campaign aggressively for countries to reduce the pollution effects of fossil fuel production and consumption.

According to the WDI (2015), solid fossil fuel consumption has accounted for about 79%-91% of carbon dioxide emission in South Africa while liquid fossil fuel constitutes between 70%-90% and 77% -91% of carbon dioxide emission in Ghana and Kenya respectively. Because the solution to the problem of GHG requires concerted efforts from all countries, Ghana, Kenya and South Africa equally have a role to play (at least by reducing their fossil energy consumption). To this end, knowledge of the determinants of fossil energy consumption is crucial for Ghana, Kenya and South Africa. This chapter thus models the drivers of fossil fuel consumption for the three countries.

Although some studies exist on the consumption of fossil fuel for the countries under study, (for example Onuonga et al., 2011; Boshoff 2012; Ziramba, 2010; Ackah and Adu, 2014) there is still room for further investigations since these previous studies have relied on cross sectional or short span time series data. Such studies only offer estimates for the short term which renders policy consequences inappropriate for long term measures. Cross sectional studies again are susceptible to subject bias, observer error, observer bias, low response and inability to measure long term change and development (Saunders et al., 2009). The study addresses these weaknesses associated with previous studies by using a relatively long annual time series data spanning from 1975-2013 which is free from the biases associated with cross sectional data and also has the capacity to offer estimates that has long term implications. We employ long run cointegrating estimation techniques - the Fully Modified OLS (FMOLS) by Phillip and Hansen (1999) and Canonical cointegration regression (CCR) by Park (1992) - to estimate the determinants of fossil energy consumption for each of the three countries. To ensure roboustness of the results, a random effects panel estimation is also run in addition.

This current study also differs from other studies that have examined the long run determinants of fossil energy consumption (see Ramanathan, 1999; Lim, 2012; Sultan, 2010; Tsirimokos 2011; Dahl and Sterner 1991; Cooper 2003; Cheung and Thomson 2004; Eltony and Al-Mutairi, 1995) in one unique way. This stems from the fact that such previous studies have focused on mainly the price and income effects on fossil fuel consumption. However, since energy is consumed by both residential and non residential sectors of the economy, it is important to consider other variables in addition to price and income when it comes to identifying the determinants of fossil fuel consumption. Accordingly, the present study examines the effects of price, income, trade, urbanization, industrial efficiency and efficiency of the service sector on fossil fuel consumption for Ghana, Kenya and South Africa. The inclusion of the service sector to the explanatory variables contributes to the energy consumption literature, since to the best of the author's knowledge; previous studies on the drivers of energy have ignored the potential role of the service sector to energy consumption.

Findings from the current study show that income has a positive effect on fossil fuel consumption for all the three countries; industrial efficiency reduces consumption of fossil fuel for Ghana but increases fossil fuel consumption for South Africa and Kenya; trade increases consumption of fossil fuel for Ghana but reduces for South Africa and Kenya; price reduces fossil fuel consumption for Kenya while efficiency of the service sector reduces fossil fuel consumption for all the three countries. Again, urbanization was found to increase fossil fuel consumption for all the three countries.

The rest of the chapter is organized as follows. Section 4.2 presents stylized facts about the energy situation for each of the three countries. Section 4.3 reviews literature on previous studies examining the demand determinants of fossil fuel consumption. Section 4.4 deals with the data type and source and the method employed in the analysis. Section 4.5 discusses the empirical results and Section 4.6 concludes the chapter with summary and policy recommendations.

4.2 Stylized facts on energy situation for Ghana, Kenya and South Africa

In this section of the chapter, we present and discuss core stylized facts about each of the selected countries to provide further motivation for their selection and some background information on these countries as far as their fossil fuel consumption profile is concerned.

4.2.1 Ghana

The country has a number of energy resources such as biomass, hydrocarbons, hydropower, solar and wind. However, the primary sources of energy consumption over the years are wood fuels, fossils fuels and hydropower.

4.2.1.1 Wood fuels

Records indicate that majority of Ghana's supply of total primary energy had come from wood fuels (charcoal and firewood) until 2010. According to the Energy Commission (2014), the supply of wood fuel has grown at a rate of 2.13% between 2000 and 2013. In the years 2000, 2006 and 2013, the supply of wood fuel constituted 61.6%, 48.5% and 41.5% respectively of the total energy supply in Ghana. About 90% of wood fuels in Ghana come from the natural forest with the remaining 10% coming from planted forest and the residues of logging and sawmill. However, the country's rate of deforestation at 3% per annum according to the UN food and agricultural programme, together with unsustainable practices in the production and marketing of wood has led to a faster depletion of the wood fuels resources (Energy Commission, 2012). The two main wood fuels of charcoal and fuel wood are normally produced in the rural areas and transported to urban centres with some few exported to Europe.

Annual consumption of wood fuel has increased tremendously from 10.7 million tonnes of wood in 1985 (Obeng *et al.*, 2009) to 18 million tonnes of wood in 2000 rising again to 20 million tonnes of wood in 2011 (Energy Commission 2012). This situation is as a result of the over 70% Ghana households that utilize wood fuels for their domestic activities of cooking and water heating and the hundreds of institutions, and the thousands of industries and commercial units that rely on wood fuels for their operations. Since 2008, there has been an average annual growth of 1.2% in the demand for charcoal while firewood has been reducing by 7%. The latter experience is as a result of the high level of GDP the country has experienced over the years leading to an increase in demand for cleaner fuels. Notwithstanding, Ghana's Energy Commission has estimated by 2020, the nation's consumption of wood fuel is likely to exceed 25 million tonnes of wood fuel (Energy Commission 2012).

4.2.1.2 Fossil fuel

Fossil fuel forms a significant part of the primary energy consumption in Ghana it was next to wood fuels until 2010 when it became the major source of energy consumption in Ghana (Energy Commission 2012). Data from the Energy Commission indicates a general upward trend in the consumption of fossil fuels. For instance, between 2000 and 2010, the consumption of Liquefied Petroleum Gas (LPG) increased steadily from 45,000 tonnes to 178,400 tonnes; gasoline increased from 524, 400 tonnes to 737,800 tonnes; and gas oil increased from 665,800 tonnes to 1,271,900 tonnes (Energy Commission 2012). Between 2000 and 2013 petroleum consumption increased from 1535.3 ktoe to 3300.1 ktoe (Energy Commission 2014).

Many factors can be assigned to explain the rising levels of the fossil fuels in Ghana. One of these reasons is the government of Ghana through the Energy Ministry in 1989, promoted the use of LPG in order to reduce the overdependence on wood fuels. To achieve this, activities including distribution of free gas cylinders and door to door distribution of gas cylinders, were embarked upon which helped increase demand for

LPG by an annual growth rate of 40% between 2000 and 2010 (Energy Commission, 2012). Additionally, the subsidization of petroleum products by the government to enhance the living conditions of rural Ghanaians, the falling share of the agricultural sector in the real sector and the use of gas in power production can be mentioned as some of the reasons behind the surge in fossil fuel consumption in Ghana.

As high as the consumptions level are, fossil fuels production capacity of the country has been inadequate and the situation got worse when the only refinery the country has, the Tema Oil Refinery, was shut down somewhere 2010. The situation has called for intense importation of fossil fuels to meet the demand of the nation and this has also been increasing with the consumption level. For instance, from 2000 to 2013, imported LPG increased from 35,400 tonnes to 203,900 tonnes; imported gasoline jumped from 387,000 tonnes to over 1,017,000 tonnes, gas oil also increased from a little over 363,000 tonnes to over 1,600,000 tonnes while crude oil increased from 1,284,900 tonnes to 1,302,300 tonnes (Energy Commission 2000-2013). In the CIA World Fact book 2015, it is recorded that Ghana is the third African country that imports large quantity of natural gas. The country also occupies the 6th position in Africa with regard to the importation of crude oil (http://www.photius.com/rankings/2015/).

Notwithstanding this, there have been cases where the country has exported some amounts of these fuels (see Energy Commission 2012). However, the discovery of the Jubilee Oil in 2007 and subsequent commercial production of oil in Ghana which expanded Ghana's energy sector as production of oil increased from 7,000 barrels per day (bbl/d) in 2009 to 108,000 bbl/d in 2015 has helped reduce the importation of crude oil in the country (EIA, 2015a). A further reduction of crude oil and natural gas should be expected when the Jubilee Oil's offshore Tweneboa, Enyenra, and Ntomm (TEN) project is brought online in 2016 with expected peaked crude oil output of 80,000 bbl/d and 50 million cubic feet per day (MMcf/d) of natural gas, as well as the commencement of commercial production of the potential 150 MMcf/d of natural gas associated with oil production at the Jubilee field (Energy Information Administration (EIA, 2015a).

Fossil fuel is used for both residential and non-residential purposes. The nonresidential dependence on the various fossil fuels is not uniform. CEPA (2002) reports that with the exception of LPG that is used virtually by all productive sectors of the economy, diesel is largely used by the industrial sector for operating excavators, forklifts and dump trucks and equipment of machinery for drilling, crushing, hoisting, loading and transfer to haulage trucks. The service sector follows with a negligible usage in the agricultural sector. Gasoline is also predominantly used in the services sector, particularly in the transport and haulage sub-sector while residual fuel oil is mostly used in production processes of the manufacturing sub-sector of the industry.

4.2.1.3 Electricity

Electricity's role in Ghana's growth and development cannot be overemphasized. As a crucial commodity to households and industries, electricity demand in Ghana has been increasing steadily from a 1.4% annual growth in peak power demand of 1,258 MW in 2000 to 1,423 MW in 2009 and cumulative growth from 7,539 GWh in 2000 to 10,116 GWh in 2009 at 3.3% growth annually (PSEC and GRIDCo., 2010). The rising trend in electricity demand exceeds what the country is able to supply for domestic sale. For instance, between 2000 and 2013, electricity purchases grew by about 3% from 6367GWh in 2000 to 9355 GWh in 2013. (Energy Commission 2000-2014). Ghana's electricity supply comes mainly from hydro power and thermal plants with the former supplying more than half of the total electricity generated in the country. Currently Ghana has three hydro power plants namely Akosombo power plants, Kpong power plants and Bui power plants.

The Akosombo Dam built on the Volta river is the first among the three to be constructed in 1966 by Ghana's first President and it remained the largest source of electricity with an installed capacity of 1,020 MW of power. The Kpong hydro plant which became functional in 1982 is also built on the Volta River with an installed capacity of 160 MW. A rise in tail water elevation, however, limits the dam's output of the generation to about 148 MW. These two hydro plants had been the only source of hydro power until the Bui Dam was commissioned in 2013 to generate a maximum 400MW of power.

The country also has the following six thermal plants with their varied generation capacity; Takoradi Thermal Plant Company (330MW), Takoradi International Company (220MW), Tema thermal 1 Power Project (110MW), Tema thermal 2 Power Project (50 MW), Sunon Asogli power plants (200) and Mines Reserve Plant (80 MW) (Energy Commission 2014). The inability of these electricity generating resources together with imported power to meet the growing demand of electricity for Ghana has plunged the country into long periods of power rationing characterized by frequent power outages with its consequential effects on households and firms.

4.2.2 *Kenya*

Kenya's energy requirement for a very long period has been met by wood fuels, petroleum and electricity. And like many developing economies, wood fuels dominate the supply of energy requirement in Kenya.

4.2.2.1 Wood fuels

Wood fuels (firewood and charcoal) account for about 69% of the total primary energy consumption in Kenya. As high as 55% of wood fuels in Kenya come from woody biomass and crop residue from farmlands with the rest coming from the forests (Ministry of Energy and Petroleum 2015). Wood fuels by providing about 90% and 85% of the energy needs of rural and urban households respectively have implications on the nation's sustainable development (Ngigi 2008). Out of the 47% of all households in

Kenya that use charcoal mainly from rangelands in the Rift Valley province, 82% is urban and the remaining 34% rural (Ngigi 2008). According to Mutimba (2005), an estimated 1.6 million tonnes of charcoal is produced annually and about 350-600kg is consumed by households annually (Bizzarri et al 2010).

In addition to the majority Kenyan households that rely on firewood for their various domestic and business activities, fire wood is also used by learning and correctional institutions (prisons), industries and small and medium enterprises (Bizzarri et al 2010). Mugo (2001) has indicated that households consume about 6.5 tonnes per household per year. According to the Ministry of Energy (2002) the cottage industries including brick making, tobacco curing, fish smoking, jaggaries and bakeries follow as the highest consumers of wood fuels by spending an average 20-30% of their operational cost on wood energy (Githiomi and Oduor 2012). Also, the tea industries rely a lot on wood fuels. Although most of these industries have boilers that can use oil and wood for curing tea, they prefer to use wood in order to save about 60% of their fuel cost (Githiomi and Oduor 2012).

4.2.2.2 Fossil fuel

Fossil fuel-based domestic energy dominated by petroleum fuel plays an important role in Kenya. Petroleum used for the transport, commercial and industrial sectors of the Kenyan economy alone accounted for 22 percent of total primary energy consumed in 2014 while coal used by the cement manufacturers formed one percent of the energy used for the same period (Ministry of Energy and Petroleum 2015). Evidence from the Economic Survey (2015) indicates oil consumption by agriculture, rail transport, power generation, retail pump outlets and road transport and government sectors increased between 2010 and 2014. The following were some of the level of increment reported by the survey: Agriculture 27.7%, retail pump outlet and road transport 9.8%, rail transport 9.9%, government 29.2% and fuel for power consumption over 50% (KNBS 2015). At the households level kerosene and LPG are widely used in Kenyan homes for cooking and lighting.

Without any commercial production of crude oil or natural gas, petroleum fuel is imported to meet the needs of the population and industries. Imported oil has been relatively constant over the years in Kenya. It was when the 1998-2000 power crises started that the country imported a record 2157.7 tonnes of crude petroleum and 1387.8 tonnes of petroleum fuels to meet the energy needs of the country but by 2002 it had declined to

1493.4 and 1023.5 tonnes respectively (Ministry for Planning and National Development, 2006). Per its location, the country's Mombasa port that hosts a 35,000-bbl/d refinery is also busy as it serves as a transit point for other neighbouring East African countries that depend on imported crude oil and refined products. Importation of crude oil is mainly from Abu Dhabi and other Middle-East countries. While the nation's imported crude oil once again dropped from 20 thousand barrel per day in 2012 to about an average of 12 thousand barrels per day by November 2013; her imported refined oil products in 2012 was 10 thousand bbl/d more than the previous year (EIA 2014).

Petroleum consumption, increased from year 2002 amount of 76.2 kg (Minister for Planning and National Development, 2006) to 88 kg in 2006, a figure which is low even by the standards of developing countries (Ngigi 2008).

However, the KIPPRA has projected that the industrial demand for petroleum products would rise by 3.1% on average per annum from 2009 to 2030 (Ministry of Energy and Petroleum). On the other hand, consumption of LPG seems to be on the increase as the KNBS (2015) Economic Survey indicates consumption between the year 2010 and 2014 rose by 61.1% while motor gasoline also increased by 16.7%. However, there was 4.0% reduction for jet fuel as well as 11.6% reduction for fuel oil declined.

There are brighter chances that in the near future the country will produce oil at the backdrop of oil exploration and discoveries. With the development and other exploratory activities on going at the South Lokichar basin, the 2013 annual report by Tullow, the company that has been leading exploratory activities in the basin reveals the basin has about 600 million barrels of oil with the capacity to produce over 100,000 barrels per day (bbl/d) of oil (EIA 2014). The Kenyan economy relies on certain amount of coal for the production process of the cement manufacturers. The share of coal consumed in the total primary energy consumed in Kenya is less than 1%. However, all the quantities of coal consumed in Kenya are all imported with an annual average of 172,000 metric tonnes between 2006 and 2014 (Ministry of Energy and Petroleum 2015).

4.2.2.3 Electricity

Electricity provides about 9% of the total energy requirement of Kenya. Electricity consumption in Kenya has had commercial and domestic household users as the major consumers (Onyango et al. 2009). About 60% of Kenya's urban population has access to electricity; while about 7% of those in the rural areas have access to electricity (OECD/IEA, 2012). Data from the WDI (2015) shows electricity consumption has increased from about 113kWh per capita in 2000 to 148 kWh per capita in 2007 and jumped to 157 kWh per capita in 2012. However, compared with other developing countries, the country's electricity consumption is low amounting to 121 kilowatt-hours (KWH) per capita and national access rate of about 15%. Kenya has a current peak demand of 1,055 megawatts and is projected to rise by 14% per annum to 2,100 MW in 2016/17 (Onyango et. al. 2009) to 15,000MW by 2030 (Norton Rose Fulbright 2013).

The country has a total installed generating capacity of 1,429MW (Norton Rose Fulbright 2013). About 69% of the total electricity generated in the country comes from renewable energy sources especially water as at the end of 2014. At the end of the same period larger and smaller hydropower potential was estimated at 6,000MW. The country's larger hydropower generated 821MW of electricity representing 38% of total installed capacity of larger hydros. The five major drainage basins in Kenya namely Lake Victoria, Rift Valley, Athi River, Tana River and Ewaso Ng'iro North River have their respective potential capacity of 295MW, 345MW, 84MW, 800MW and 146MW untapped. While the average energy production from these potential projects is estimated to be at least 5,605 GWh per annum, a total of about 1,249MW from the above untapped capacity has been earmarked for projects that require more than 10MW.

Again small hydro dams in Kenya have an estimated 3000MW potential capacity of which not more than 25MW has been developed following both governmental schemes (15MW) and private investors (10MW) (Minister for Planning and National Development, 2006). This means the country has got brighter potential for meeting her electricity demand if these potentials are generated. Kenya is currently the largest producer of geothermal power in Africa followed by Algeria. There are unexploited geothermal resources estimated to be between 7,000MW and 10,000MW in the Rift Valley province alone. Geothermal energy is known to account for 13.2 per cent (approximately 180MW) of Kenya's total installed capacity. The country already has installed geothermal capacity of about 250 MW while a further 280 MW is under development (EIA 2014).Government of Kenya plans to increase the supply of energy from geothermal resource to 5,000MW by 2030 so as to reduce the dependence on fossil fuels and also hydropower (Norton Rose Fulbright 2013).

4.2.3 South Africa

The country's energy supply has also been from fossil fuel, electricity and wood fuel although fossil fuel dominates.

4.2.3.1Wood fuel

Despite the fact that South Africa is a well developed country in the sub region, with an increased number of the population having access to electricity (Davidson and Mwakasonda 2004; Winkler et al. 2011; Dinkelman 2011), wood fuel remains the main source of energy for about 54% of the rural households (Serwadda-Luwaga and Shabalala 2002, Madubansi and Shackleton 2006); 80% -95% of rural households connected to electricity (Matsika 2013; Petrie & Macqueen, 2013) and over 30% of urban households (Shackelton et al. 2007). The use of wood fuel mainly for the purpose of cooking, heating of water and heating space purpose (Damm and Triebel 2008) is found predominantly in poorer and largely rural populated Limpopo, KwaZulu Natal, Eastern Cape, and North West provinces. Studies have shown annually between 4.5 to 6.5 million tonnes of fuelwood is used by rural households in South Africa (Shackleton and Shackleton 2004), a situation which can be attributed to the high costs of acquiring a stove, cost of additional electricity (Wessels et al. 2013) and affordability of wood fuel (Damm and Triebel 2008). The country's wood fuel supply comes from the natural

woodlands (60%), trees outside forests (13%), commercial plantations (9%), processed waste (9%), indigenous forests (2%), woodlots (4%) and clearing of alien invasive species (3%) (Damm and Triebel 2008).

4.2.3.2 Fossil fuel

South Africa has reserves of oil, natural gas and coal. However, the dominant component of fossil fuel and primary energy source in South Africa is coal. The dominance of coal as the major energy supply in the country dates back as far as the 19^{th} Century when the diamonds fields of Kimberley received coal from the Vereeniging area and followed by gold discovery in Witwatersrand and the growing rail infrastructure. At the moment, the Southern African economy holds about 4% of world coal reserves and about 95% of coal reserves in Africa. Coal as a major source of energy supply in South Africa has 53% used for electricity generation, 33% for petrochemical industries (Sasol), 12% for metallurgical industries (Arcelor-Mittal) and 2% for domestic heating and cooking.

On the international market, South Africa is a net exporter of coal as available records from the EIA shows more than 25% of the total coal production in South Africa is exported to Europe, India, China, other part of Asia and Oceania, Middle East, Africa, North America and South America and the Caribbean. In 2014 alone the country exported majority of her 78 million metric tonnes (or 86 million short tonnes) of coal produced to Asia (with India being the major recipient) followed by Europe, Africa, the Middle East, and the Americas (EIA 2015b).

In addition to coal, South Africa also consumes large amounts of natural gas and oil. Most of the domestically produced natural gas comes from the maturing F-A gas field and South Coast Complex fields. The production level of natural gas for many years was equal to the amount consumed until 2006, where production level started falling as against rising consumption level. Consequently, the country began the importation of natural gas from Mozambique in order to sustain domestic consumption. Since then importation has increased steadily. For instance, figures from EIA indicates consumption increased from an amount of 4.2 billion cubic metres (BCM) in 2006 to 4.9 BCM in 2013 against falling production levels from 2.9BCM in 2006 to 1.2BCM in 2013, meaning the differences in the production and consumption would have to be catered for by imported natural gas.

South Africa plans to reduce her reliance of coal for electricity generation which is possible when there is a sustained gas supply. In this regard, PetroSA is developing the F-O field for gas production and together with production from the lbhubesi fields as wells as imports from Mozambique. Also there are potential imports from Namibia in the future is likely to make this become a reality (EIA 2015b).

On petroleum and other oil consumption, South Africa is the second largest consumer of oil in Africa next to Egypt. Data from the EIA shows over two decades now, the amount of oil consumed has been consistently increasing from near 400 thousand barrels per day in 1990 to 655 thousand barrels per day in 2014 while production has not reached 250 thousand per barrels over the same period. This implies the country imports oil in order to meet the growing demand of the energy needs of the population and industries. The domestic production of petroleum is from the limited proved crude oil reserves according to the Oil and Gas Journal which has a capacity of 15 million barrels. Importation of oil comes mainly from OPEC countries in the Middle East and West Africa which are later refined at a capacity of 503 thousand barrels per day making it the second largest crude oil distillation in Africa according to the January 2015 estimates from the Oil and Gas Journal (EIA 2015b).

4.2.3.3 Electricity

South Africa is the largest producer of electricity in Africa, supplying two-thirds of the continent's power. The country's electricity generation is dominated by state-owned power company Eskom, which produces over 96.7% of the power used in the country. The company has a nominal installed capacity of 44,175MW and it is expected that the country will need over 40,000 MW new generation capacity by 2025 in order to meet the growing demand. South Africa is one of the four countries in the world that produces electricity cheaply (Department of Energy 2015). Notwithstanding their level of development and the implementation of free basic electricity entitlements to a maximum limit of 50kW hours per month which has helped many poor households access electricity, South Africa has 20% of households in the urban and rural areas without access to electricity (Petrie and Macqueen 2013).

The nation's electricity production come from the huge abundance of coal generating over 80% of the total electricity capacity for the country with the hydroelectric plants supplying 10%, nuclear power plant 4% and 1% from non-hydro renewable energy (EIA, 2015). South Africa electricity per capita consumption is very high exceeding the 2011 world average by 60% (4,500 kWh compared with the world average of 2,800 kWh in 2011). The electricity consumption distribution is such that the industrial sector consumes about 40.9%, the residential sectors 36.8%., transport sector 2.7%, commercial 11.4% and other sectors 8.1% (Adom 2015).

While demand for electricity continues to increase in South Africa, the power generation has for some time now been unfavorable leading to a power outbreak in 2008 with its attendant problems (Adom 2015). The energy problem increased in 2014 when the coal storage silo collapsed at one of the largest coal power plants, Majuba (4,110 MW installed capacity). Even though the problem was attended to and remedy provided, the EIA has noted the situation is an indication that the South Africa's electricity system is fragile because majority of the current coal power plants are not only outdated, but also poorly maintained, and are pushed to their maximum working capacity. Efforts by Eskom to bring online almost 12,000 MW of new electricity installed capacity has been delayed by cost overruns, construction delays, and labor strikes, exacerbating South Africa's power problems (EIA 2015).

4.3 Literature Review

Although the Millennium Development Goals were silent on energy, the role of energy to achieving these goals was highlighted by some authors and institutions/organizations. For instance, the effects of energy on developmental issues like education, health, agriculture, environmental sustainability and alleviating poverty has been noted by Garg and Halsnaes (2008) and Mensah and Adu (2013; 2015). The United Nations (2005) has also shown how energy services such as lighting, heating, cooking, etc are essential for socioeconomic development. It is no wonder energy has been captured in the newly developed Sustainable Development Goals (SDGs) of the United Nations. Earlier, the International Chamber of Commerce (ICC) (undated) had argued that one necessary and enabling condition for achieving sustainable development is for people to have easy access to energy. In this regard, the ICC opined that prudent energy policies and research can play an important role in steering both industrialized and developing countries onto more sustainable energy development paths.

Accordingly, studies have been examined in many countries and regions to identify factors that determine the consumption and choice of energy both at the micro and macro levels. However, the results from these studies have been inconclusive. Such phenomenon in the literature can be attributed to the differences in methodological related issues like estimation techniques, country or characteristics of study area, data source and time periods. It is as a result of this situation that further studies are unavoidable. At the micro level, the review of studies on fossil energy demand show a number of variables such as gender, age, family size, the number of children in the household, marital status, education, place of residence, employment, income level and distance do have some influence on the demand for LPG, gasoline and Kerosene oil energy consumption (see Blundell et al. 2012; Heltberg 2003; Tchereni 2013; Adepoju et al. 2012; Pundo and Fraser 2006; Nnaji et al. 2012; Njong & Johannes 2011; Ouedraogo 2006; Suliman 2010; Mekonnen & Köhlin 2008; Kwakwa et al. 2013; Mensah & Adu 2013, 2015; Manyo-Plange 2011; Abebaw 2012)

At the macro level, which is the focus of the current research, studies on fossil energy demand especially crude oil, gasoline and natural gas also abound but with no unanimous conclusion. For instance, in their study, Khan and Ahmad (2008) analysis centered on coal and natural gas demand for Pakistan using annual data from 1972-2007. Their error correction model (ECM) estimation shows there is a positive relationship between real income per capita and demand for natural gas but a negative one between natural gas and price level. For coal, the authors found that its demand in the short run is influenced by real income and domestic price level. Though the sum of the short-run elasticities of coal demand with respect to real income is positive and elastic they found that its impact on coal consumption takes place after one and two years. This outcome confirms the argument by Johansson and Schipper (1997) as pointed out by GonzálezMarrero et al. (2012) that changes in the explanatory variables of fuel demand do not lead to simultaneous changes in energy usage because fuel demand by nature is dynamic and thus fuel consumption would lag behind changes in their determining factors. Hughes et al. (2008) estimated the price and income elasticities of gasoline demand in two periods of similarly high prices that is 1975 to 1980 and 2001 to 2006 for the US economy. The finding indicated a considerable difference in the short-run price elasticities spanning from -0.034 to -0.077 during 2001 to 2006, and -0.21 to -0.34 for 1975 to 1980. For income, elasiticty range of 0.21 to 0.75 did not differ that much in the two periods. In another study, Lim et al. (2012) investigated the demand for diesel in Korea over the period 1986–2011. The co-integration and error-correction model were employed to find the short-run and long-run elasticities of diesel demand with respect to price and income. The short-run and long-run price elasticities were estimated to be −0.357 and −0.547 respectively, and the short-run and long-run income elasticities were computed to be 1.589 and 1.478 respectively.

Sultan (2010) studied the gasoline demand by the transport sector in Mauritius. The results indicated that gasoline demand, per capita income and real price of gasoline are integrated of the order 1 and a long-run income and price elasticities of gasoline demand value of 0.77 and -0.44 respectively were recorded. In the short-run, income elasticity estimate was 0.37 and -0.21 for price elasticity. Dahl and Sterner (1991) reported a price and income elasticities of -0.26 and 0.48 respectively. Ramanathan (1999) estimated elasticities of demand for gasoline for India. Using the ECM approach, the author concluded that a relatively high long and short run elasticities of income that is 1.12 and 2.68 respectively existed. The price elasticities were estimated to be -0.32 for the short run and -0.21 for the long run. Cooper (2003) also examined the short-run and the long-run price elasticities for 23 countries over the period 1979-2000. The author used a multiple regression model and found that short-run price elasticity of demand for crude oil ranged from -0.023 to -0.109 implying that oil demand is price inelastic. On the other hand, price elasticity in the long-run ranged from -0.038 to -0.568.

Tsirimokos (2011) analysed demand for crude oil for ten IEA countries. Using a time period of 1980 to 2009, estimations indicated that oil consumption in both short run and long run is highly price inelastic. Income elasticities were observed to be more elastic than price elasticities in the long-run. The estimation of elasticities of demand for crude oil in Turkey for the time-span 1980-2005 by Altinay (2007) showed a short run values for price and income elasticities to be -0.10 and 0.64 respectively while their respective long run values were -0.18 and 0.61. The author employed the autoregressive distributed lag bounds testing approach. Dees et al. (2007) used the dynamic ordinary least-squares method and error correction method to analyze the short and long run world oil market. Their findings revealed long-run income elasticities in the range of 0.17 to 0.98 while in the short-run those elasticities ranged from 0.0001 to 0.82. The short-run price elasticities were found to be very close to zero. For the South African economy, Ziramba (2010) examined the long-run and the short-run price and income elasticities of crude oil demand for the period 1980-2006. The author employed the Johansen cointegration multivariate analysis and estimated a significant long-run price elasticity to be equal to 0.147. The long-run income elasticity was also statistically significant and estimated to be equal to 0.429. Ackah and Adu (2014) estimated the demand for gasoline and found among others, the long run price and income elasticities for gasoline demand to be -0.065 and 5.129

respectively in Ghana. Also productivity is found to have an inverse relationship with gasoline consumption.

The general observation from the literature reviewed on fossil energy consumption is that the empirical studies have generally sought to examine the price and income elasticities. The effect of price has been found to be negative while income is found to exert positive effect on fossil fuel consumption. Again, this effect in short run is more inelastic than the long run effect. In addition, little to no attention has been paid to the potential effect of other macroeconomic variables such trade, industrialization and demographical variables such urbanization. Again, although there is large number of studies on the factors influencing fossil fuel consumption, the evidence from the African continent is rare.

4.4 Empirical Strategy and Data

4.4.1 Theoretical and empirical specification

Demand for fossil fuel at the national level has been modeled as a function of price and income in the literature (see Ziramba 2010; Tsirimokos 2011). Mathematically, this can be expressed as:

$$F_t = \alpha + \beta_1 P_t + \beta_2 Y_t + \varepsilon_t \qquad (1)$$

where F is the amount of fossil energy consumed at time t, α is the drift term, P is price of fuel, Y is income, β_i is the matrix of coefficient of each explanatory variable and ε_t is the error term. However, because both residential and non-residential sectors use energy, it is important to take into consideration other variables in addition to price and income that may have influence on fossil fuel consumption at the national level. One of such variables is trade openness. The effect of trade on fossil fuel consumption can be positive or negative. Trade openness can increase fuel consumption in three main ways as argued by Sardosky (2011).

First, energy including fossil fuel is involved in the production of manufactured export goods and the transportation of both manufactured goods and raw materials for export. Second, after imported goods have arrived at the port, the transport system which relies on (fossil) energy would have to distribute the goods to the various parts of the country, and thirdly importation brings into the country goods such as automobiles and other manufacturing machines that use fossil fuel. However, trade openness can reduce (fossil) fuel consumption when high efficient equipments that consume less energy are made available to individuals and firms.

Another variable worth considering is urbanization. Urbanization is argued to increase energy consumption in diverse ways. For instance, urban centres are associated with the concentration of manufacturing firms that depend on energy especially fossil fuel. Such centres also experience heavy vehicular traffic and vehicular movements in and out of the centres which increase fuel consumption. Again, urbanization increases the demand for infrastructure which relies on energy for construction; and lastly, urbanization does impact energy demand through private consumption patterns since individuals become wealthier in such centres and do acquire energy intensive machines (Jones 1989, 1991; Madlener 2011; Madlener and Sunak 2011; Parikh and Shukla, 1995).

We also include industrial efficiency to our explanatory variables. Because the level of industrialization thrives on energy, it is argued to positively affect fossil energy consumption. This is because, a key feature of industrialization is the use of machines that rely on fossil fuel to run. Consequently, as industries expand in their production activities more fuel would be needed to power these machines (Shahbaz and Lean 2013) than does traditional agriculture or basic manufacturing (Sardosky 2013). However, since firms do change their technological characteristics in the long run to become efficient with their energy consumption (Adom and Bekoe 2013) industrial efficiency does reduce fossil fuel consumption.

The economies of Ghana, Kenya and South Africa have seen an expansion in the service sectors contributing greatly to their respective economic growth. This sector also relies on fossil fuel for operation and an expansion in its size suggests more fossil fuel would be consumed. Like the industrial sector, firms in the service sector are expected to change their technological characteristics in the long run to become efficient with their energy consumption thereby reducing energy consumption.

Another variable that could affect the consumption of energy is the price of its substitutes. A higher price of fossil fuels' substitute would lead to a higher consumption of fossil fuels and vice versa. However, owing to lack of data availability or appropriate proxy, the price of substitute energy for fossil fuels is not included in the final estimation. Consequently, we model the demand for fossil fuel consumption for each of the three countries as a function of price of fossil energy, income, trade, urbanization, industrial energy efficiency and efficiency of the service sector. Equation (1) is thus modified to take into account the several other factors described earlier and it is expressed in Equation 2:

$$F_{it} = \alpha + \beta_1 P_{it} + \beta_2 Y_{it} + \beta_5 U_{it} + \beta_6 T_{it} + \beta_7 N_{it} + \beta_8 S_{it} + \varepsilon_{it} \qquad (2)$$

Where *F, α, P, Y* and ε remain the same as explained earlier, *U* is the degree of urbanization, *T* is trade openness, *N* is industrial efficiency and *S* is the efficiency of the service sector. The natural log of each variable in Equation (2) is used for our final estimation to interpret the coefficients as elasticities.

4.4.2 Estimation Strategy

We begin our investigation into the determinants of fossil energy consumption for Ghana, Kenya and South Africa by testing for the stationarity of the series. Stationarity occurs when the mean value, variance and autocorrelation structure of the series remain constant over time. If the variables are stationary it also means they contain no unit root. If the variables are non-stationary, (i.e. they have unit root) then it is inappropriate to use classical methods of estimation such as Ordinary Least Square in the regression since it could lead to spurious regression. Spurious regression simply means the result we get from running a regression on time series variables is nonsensical (Gujarati and Sangeetha, 2007). Thus, the results are rendered meaningless. In that case the tstatistics and overall measures of fit become misleadingly "significant". We used the Augmented Dickey-Fuller (ADF) and the Phillips-Perron tests respectively developed by Dickey and Fuller (1979) and Phillips and Perron (1988) for the stationarity test. The ADF test is a widely used test for unit root; it uses parametric autoregression to deal with the problem of serial correlation and heteroskedasticity in the residuals.

However, the ADF test has been criticized over the problem associated with selection of the appropriate lag length to tackle the issue of serial correlation and heteroskedasticity. Using few lags implies there may still be the problem of autocorrelation and size distortion while using many lags generally affects the power of the test. These challenges are dealt with by the PP test which uses non-parametric methods to correct for any serial correlation and endogeneity of regressors. This then prevents loss of power implied by the ADF test. The PP test in addition is still robust to general forms of heteroskedasticity in the error term. The ADF and PP tests for stationarity are undertaken with the null hypothesis that the series is not stationary or it contains unit root and the alternative is the series is stationary or does not contain unit root.

It is argued, the ADF and PP approaches can be biased in the presence of structural breaks in the time series. In the light of this, a test developed by Zivot and Andrews (1992) is employed to complement the results of ADF and PP tests. The Zivot and Andrews (ZA) test which allows for unknown breaks provides three models to test for a unit root. The models are structural break in the intercept, the slope and both the intercept and slope. The working null hypothesis for the ZA test is that there is unit root with structural break against the alternative hypothesis of unit root with no structural break.

Next, is to examine the long run relationship among the variables for each country. To do so, the cointegrating estimators namely, the Phillip and Hansen's (1991) Fully Modified OLS (FMOLS) and Park's (1992) Canonical Cointegrating Regression (CCR) models are employed. These models are chosen over others like the more commonly used ARDL (Pesaran and Pesaran 1997, Pesaran and Shin 1999, Pesaran et al., 2001) cointegration technique and the maximum likelihood based approach (Johansen 1998;

1991) because they are more robust to the problems of serial correlation and endogeneity. Also these models are robust to both non-stationarity and endogenous regressors. The Fully Modified OLS estimator is given as in the equation below:

$$\hat{\theta}_{FME} = \left(\sum_{t=1}^{T} Z_t Z_t'\right)^{-1}\left(\sum_{t=1}^{T} Z_t y_t^{+} - T\hat{J}^{+}\right) \quad (4)$$

where $y_t^{+} = y_t - \hat{\omega}_{ox}\hat{\Omega}_{xx}^{-1}\Delta x_t$ is the correction term for endogeneity, and $\hat{\omega}_{ox}$ and $\hat{\Omega}_{xx}$ are the kernel estimates of the long-run covariances, $\hat{J}^{+} = \hat{\lambda}_{ox} - \hat{\omega}_{ox}\hat{\Omega}_{xx}^{-1}\hat{\Lambda}_{xx}$ is the correction term for serial correlation, and $\hat{\lambda}_{ox}$ and $\hat{\Lambda}_{xx}$ are the kernel estimates of the one-sided long-run covariances.

The approach by Park (1992), that is the canonical cointegration regression, is similar to the FMOLS. The point of departure, however, is that while the FMOLS uses the transformations of both the data and estimates, the CCR uses only the data transformation and selects a canonical regression among the class of models representing the same cointegrating relationship (Park 1992). The CCR estimator is shown below:

$$\hat{\theta}_{CCR} = \left(\sum_{t=1}^{T} Z_t^{*} Z_t^{*\prime}\right)^{-1}\sum_{t=1}^{T} Z_t^{*} Y_t^{*} \quad (5)$$

where $Y_t^{*} = (X_t^{*\prime}, D_t')'$, $X_t^{*} = X_t - (\hat{\Sigma}^{-1}\hat{\Lambda}_2)'\hat{u}_t$ and $Y^{*}_t = Y_t$ -

$\hat{\ }_{\square 1}\hat{\ }_{2}\hat{\Gamma}\ [\hat{\Gamma}_{22}^{\square 1}\hat{\Gamma}_{21}]'\hat{\Gamma}_t$ denotes the transformed data, $\hat{\Gamma}$ is an estimate of the cointegrating equation coefficients, $\hat{\ }_{2}$ is the second column of $\hat{\ }$ and $\hat{\ }$ denotes estimated contemporaneous covariance matrix of the residual. Stock and Watson (1993) DOLS and a random effect panel estimations are run to check for robustness of the results.

4.4.3 Data source and description

The study used annual times series data for all the variables namely, fossil fuel consumption, income, price, efficiency of the industrial sector, urbanization, trade openness and efficiency of the service sector for each of the three countries. The period of study span from 1975-2013 and it is because of availability of data for the countries under consideration. All the data were sourced from the World Development Indicators of the World Bank except price which was from Energy Information Administration. The dependent variable, fossil fuel consumption is measured as the fossil energy consumption as percentage of total energy consumption (this is the available proxy from the WDI). The study uses price of crude oil as a proxy for the price of fossil fuel (to capture how citizens react to fossil fuel consumption following changes in its price).

From the literature, price is expected to negatively affect fossil fuel consumption. The income variable is measured by real annual per capita income. Income is expected to have a positive effect on consumption of the fossil fuel. Trade is measured as the sum of import and export as share of GDP and its effect is uncertain based on the literature. Urbanization is expected to increase fossil fuel consumption and in this study it is measured as the annual population in the largest city. Both efficiencies of the industrial and service sectors are expected to reduce fossil energy consumption. Industrial efficiency is measured as the ratio of the valued added to GDP by the industrial sector to fossil fuel consumption. Similarly, the efficiency of the service sector is measured as the ratio of the value added to GDP by the service sector to fossil fuel consumption.

4.5 Empirical results and discussion

This section discusses the results of the study under sub sections of unit root test of series, cointegration test and long-run determinants of demand for fossil fuel.

4.5.1 Unit root test

The study employed the Phillip-Perron (PP), Augmented Dickey-Fuller (ADF) and the Zivot Andrews (ZA) tests to ascertain the stationarity of the variables fossil fuel consumption, income, price, urbanization, trade openness, industrial efficiency and efficiency of the service sector. The results have been reported in Table 4.1 and Table 4.2 below. Working with the null hypothesis of nonstationarity of the variables in levels, the ADF and PP tests yield similar results for all the variables. Thus from the ADF and PP tests results, all variables are non stationary at their levels. However, based on the first difference, all variables become stationary rendering the variables as integrated of the order one or I(1) for each country under study.

Conversely, at least one of the models of the ZA test indicates that the variables are I(0) variables. The unit root test results imply that regression analysis to establish the relationship between the fossil energy consumption and its regressors chosen for this study could be embarked upon without generating any spurious results.

Table 4.1: ADF and PP Unit root test of variables for Ghana, Kenya and South Africa

Variable	Ghana		Kenya		South Africa	
	PP-test	ADF- test	PP-test	ADF- test	PP-test	ADF- test
			Variables in levels			
lnF	-0.9582	0.1897	-2.1366	-2.0495	-1.4712	-1.4781
lnP	-1.2739	-1.1550	-1.2739	-1.1550	-1.2739	-1.1550
lnY	-0.9568	-1.3469	0.2884	0.2878	-1.7679	-1.7929
lnT	-1.0514	-1.2924	-2.3810	-2.2345	-2.3486	-1.7928
lnU	-1.3371	-1.0398	0.0476	0.0179	-1.7985	-1.7970
lnN	0.9801	14.6951	1.4363	-1.8177	-1.3768	-2.0975
lnS	0.67995	0.5034	-0.9782	-1.4895	-0.5824	-1.7712
			Variables at first differences			
DlnF	-9.7586***	-7.2557***	-5.4686***	-5.4429***	-6.7816***	-6.8096***
DlnP	-6.0697***	-6.0645***	-6.0697***	-6.0645***	-6.0697***	-6.0645***
DlnY	-4.2812**	-4.8110***	-8.1775***	-7.9888***	-6.3778***	-6.1204***
DlnT	-4.0884***	-4.1322***	-5.9587***	-5.9620***	-5.2747***	-5.1715***
DlnU	-6.1548***	-5.6214	-1.8889	-4.1894**	-0.9354***	-1.4298
DlnN	-9.4488***	-9.1160***	-5.6403***	-5.6401***	-9.1333***	-7.1354***
DlnS	-2.0940	-9.0084***	-3.8223**	-3.6968***	-3.8845**	-4.0869**

Note: ***, **, * respectively represents 1%, 5% and 10% level of significance

5.2 Cointegration test

The cointegration test is carried out to determine whether long-term relationships exist among the variables. The study used the Engel-Granger and Phillip-Ouliaris tests which allow a single cointegrating relationship to be estimated. The results of the cointegrating tests for Ghana, Kenya and South Africa reported in Table 4.3 indicate there is a long run relationship between the fossil fuel consumption and the explanatory variables for each country. This implies a long run relationship exists among the variables and thus offers evidence that price, income, efficiency of industrial sector, efficiency of service sector, trade and urbanization are the long run forcing variables explaining fossil energy consumption in Ghana, Kenya and South Africa.

Table 4.2: ZA unit root test for Ghana, Kenya and South Africa

	Ghana			Kenya			South Africa		
Variable	Break in mean	Break in trend	Break in both	Break in mean	Break in trend	Break in both	Break in mean	Break in trend	Break in both
lnF	-3.2240*** (1984)	-3.4485** (1993)	-3.9218*** (1984)	-3.6988** (2007)	-3.6900** (2005)	-3.7276 (2004)	-3.5088*** (2004)	-2.8977*** (1999)	-3.5704** (1987)
lnP	-3.8997*** (1986)	-4.0621*** (1999)	-3.8087 (1999)	-3.8997*** (1986)	-4.0621*** (1999)	-3.8087 (1999)	-3.8997*** (1986)	-4.0621*** (1999)	-3.8087 (1999)
lnY	-3.8619* (1982)	-3.0187** (1985)	-4.4670** (1984)	-4.0289*** (1993)	-2.2947** (1992)	-4.1984** (1997)	-2.0276** (1986)	-5.1025*** (1995)	-4.7444** (1992)
lnT	-3.5871*** (2007)	-3.4841 (2002)	-3.6261 (1984)	-4.4773** (1994)	-3.8648 (1987)	-4.1984*** (1997)	-3.1685** (1983)	-3.6103*** (1994)	-4.0121** (1990)
lnU	-4.081* (2003)	-4.0945 (1999)	-3.9954 (1995)	-1.8779 (1985)	-3.8648 (1987)	-4.4014* (1994)	-6.0195*** (1993)	-5.0650*** (1990)	-4.4513 (1988)
lnN	-2.4865*** (1992)	-1.1465*** (1995)	-3.9954 (1995)	-3.6470* (2003)	-3.5427 (2008)	-4.4877*** (2004)	-4.3204*** (1992)	-2.7232* (2001)	-4.0909*** (1992)
lnS	-3.1744** (1999)	-4.0945 (1999)	-3.0203* (1999)	-3.2651** (2007)	-3.8713*** (2005)	-3.8779 (2003)	-3.7843*** (2006)	-4.1631*** (2000)	-4.5620*** (1991)

Table 4.3: Cointegration results of series for Ghana, Kenya and south Africa

Series		Ghana		Kenya		South Africa	
	Test	tau-stat.	z-stat.	tau-stat.	z-stat.	tau-stat.	z-stat.
lnF, lnP, lnN, lnS, lnU,lnY & lnT	Engelgranger	-6.206**	-101.533***	-4.500**	-65.506***	-4.635*	-133.48
	Phillips-Ouliaris	-5.461**	-26.321	-6.144**	-29.566	-5.451	-59.235

Note: ****, **, * respectively represents 1%, 5% and 10% levels of significance*

4.5.3 Long run determinants of fossil energy consumption

Having tested and confirmed that the variables are cointegrated, the long run impact of price, income, trade openness, urbanization, industrial efficiency and efficiency of the service sector on fossil fuel demand are analysed for Ghana, Kenya and South Africa using the Fully Modified OLS and Canonical cointegration regression methods. The results are presented in Table 4.4.

Price was expected to significantly have a negative relationship with fossil energy consumption for each country. However, we obtained a negative and significant effect of price on fossil consumption for the Kenyan economy but insignificant effect for Ghana and South Africa. In the case of Kenya, a one percent increase in the price of fossil fuel will reduce fossil fuel consumption by 0.0236-0.0346 percent. This suggests that a higher price displaces consumption, making the rich to invest more in efficient energy appliance and the poor cutting down on their energy use (Adom 2015) in Kenya. The inelastic price effect we found for Kenya corroborates those established in earlier studies in the literature. For instance, Tsirimokos (2011) found a negative and inelastic price effect for ten IEA countries, Altinay (2007) also established an inelastic price effect on demand for crude oil in Turkey and Zarimba (2010) found similar effect for the South African economy.

The outcome that price has not significantly influenced fossil fuel consumption in South Africa over the period of study contradicts earlier paper on fossil energy consumption in South Africa by Ziramba (2010) which recorded a significant negative effect. The current result may differ from Ziramba (2010) due to the differences in the time span and the different estimation techniques of the two studies. Ziramba (2010) employed the Johansen Cointegration approach for data that covered 1980–2006 period which is quite shorter than the period this study employs. The additional explanatory variables added to price and income in this study could also be a contributory factor to the differences in the price effects for the South African economy. The insignificant effect we obtain for Ghana is in line with observation in that it appears demand for energy no more depends on price because energy is also becoming a necessity in the country and irrespective of the level of the price, households and industries still demand energy, although amidst complaints.

The effect of real per capita income is found to be positive and statistically significant for all the three countries consistent with a priori expectations. The results meet our expectation. We record that for the Ghanaian economy there will be about 0.0842-0.1205% increment in the consumption level of fossil fuel following a 1% increment in the income level. For the economy of South Africa, a 1% increase in income level will cause fossil fuel consumption to also increase by about 0.0397-0.0441% while a 1% increase in income level will cause fossil fuel consumption to also increase by about 0.1075-0.2072% in Kenya. From these estimations, fossil fuel can be classified as a normal good in Ghana, Kenya and South Africa. In other words, an increase in the level of income results in a corresponding increase in fossil energy consumption although by less magnitude.

The positive effect of income on fossil fuel consumption suggests that as per capita income increases in these countries, citizens and firms are able to afford appliances that rely on fossil fuel to operate thereby increasing the consumption of fossil energy. For instance, from the abysmal performance in the late 1970s and early 1980s Ghana's economy grew from a rate of 4.8% (in 1987) to 15% (in 2011) suggesting an increase in the overall wellbeing of citizens over the last three decades. This in a way has contributed to the country's ability to reduce by half the people living in poverty. With such increase in income and reduction of poverty, individuals demand for items that thrives on energy has also increased contributing to the rising level of fossil fuel consumption. According to the Driver and Vehicle Licensing Authority (DVLA) of Ghana, there was about 50% increment in the number of registered vehicles between 2000 and 2010 alone. The effect of such development is the rising trend of fossil fuel consumption.

Kenya has also recorded important strides in its economic growth. From a negative 2.01% rate of per capita income in 1984, the country registered a 5.7% growth in per capita income for year 2013. Such development has increased the demand for fossil fuel in the country. Similarly, the South African economy has performed impressively well in the sub region over the years and has thus received the reputation for being among the richest economies in Africa. The economic performance in terms of growth in per capita income has increased from US$ 5053.1 in 1972 to 6090.4 in 2013 on the back of a thriving mining sector hence an increase in the demand for fossil fuel consumption over the period. Studies abound on the income elasticity effect on fossil fuel (coal, gasoline and natural gas) consumption.

A review of such studies indicates that generally, income has a long run inelastic effect on fossil consumption. The current study then lends support to the inelastic effect of income on fossil fuel consumption that the literature suggests. The results of Altinay's (2007) estimation of elasticities of demand for crude oil in Turkey show a positive and an inelastic long run income effect. Also, Ackah and Adu (2014) established an inelastic income effect of gasoline demand in Ghana. Ziramba (2010) also found the long run effect of income on crude oil to be inelastic and positive for the South African economy.

Hughes et al., (2008) had positive inelastic income effect for coal demand in the US. Lim (2012) had positive and inelastic demand for diesel in Korea and Sultan's (2010) study on demand for gasoline in Mauritius found inelastic and positive effect of income. The few studies that had elastic income effect include Tsirimokos (2011) research on demand for crude oil for ten IEA countries and Ramanathan (1999) paper on demand for gasoline in India.

The technological characteristic of the industrial sector (industrial efficiency) is found to have a negative effect on fossil fuel consumption in Ghana but the opposite rather holds for South Africa and Kenya. This variable happens to be the one with the greatest impact on the consumption of fossil energy in South Africa but the second most significant variable in Ghana and Kenya. For the Ghanaian economy, a one percent increase in the efficiency of the industrial sector will reduce fossil fuel consumption by 0.4781-0.5370 percent. However, a one percent increase in the efficiency level of the industrial sector will increase fossil fuel consumption by 0.1711-0.3031 percent and 0.0152 and 0.0564 percent respectively for the South African and Kenyan economies.

This means that industrial efficiency has an inelastic effect on fossil fuel consumption in all the three countries. The results suggest that over the period of study, Ghana's industrial sector has invested in efficient technologies for their operations which have reduced the amount of fossil energy consume to produce an output.

The positive effect of the industrial efficiency on fossil in South Africa and Kenya implies that as industrial firms become more efficient in their operations, they tend to use more energy than before. Such a situation in the literature is known as the backfire rebound effect, commonly known as the Jevons paradox. A review of the literature on the industrial efficiency elasticity revealed that the focus of such studies has been on electricity consumption. Authors like Lin (2003) found a significant and negative inelastic effect of industrial efficiency for Chinese electricity consumption. Zuresh and Peter (2007) also had similar results for electricity consumption in Kazakhstan. Findings by Adom and Bekoe (2012, 2013) on electricity consumption in Ghana were also negative and inelastic. However, Keho (2016) recorded a positive impact of the industrial sector on energy consumption in South Africa.

A significant negative relationship is established between the technical characteristics of the service sector and consumption of fossil fuel for Ghana, South Africa and Kenya. From the results, a one percent increase in the efficiency of the service sector will decrease fossil fuel consumption by 0.1479-0.3110% in the Ghanaian economy; 0.0961-0.1382% in the economy of South Africa and 0.7907-1.2502% in the Kenyan economy. The service sector for many decades has particularly been the backbone of the Kenyan and South African economies offering the greatest contribution to the GDP of the two countries (see WDI 2015). In the case of Ghana, the sector became prominent following the commercial production of oil in 2011. It is now the second largest contributor to the country's GDP next to the industrial sector. The negative effect of the service sector efficiency recorded for the three countries suggests that as the sector invests in efficient technology for production, their usage of fossil fuel decreases than before. It also implies that the negative effect the financial sub sector has on the consumption of fossil energy (see Alfaro et al., 2004; 2006, Sadorsky 2010, Islam et al., 2013, and Hermes and Lensink 2003) outweighs the potential positive effects from the other components of the sub sector.

This argument is premised on the fact that the service sector in Ghana, Kenya and South Africa consisting of sub sectors such as hotels and restaurants, transport and storage, financial and insurance activities, education and health has the financial services as the leading sub sector for the Kenyan and South African service sector while it occupies the third position in Ghana's service sector. The relative dominance of the financial activities affords firms and individuals the opportunity to access credit to acquire more energy efficient equipments reducing the use of energy per output of service produced. This therefore reinforces the idea that the technological feature of the service sector plays a major role in managing the rising level of fossil fuel consumption.

The level of urbanization is shown to have an elastic and positive effect on fossil fuel consumption for the countries under study. A 1% increase in the rate of urban population will increase consumption of fossil energy by about 1.0248-1.0378% in the Ghanaian economy; and 0.3206-2.590% increase for the Kenyan economy and 0.07170.1071% in the economy of South Africa. This outcome is not surprising in the sense that over the period under study, urban population for the three countries has increased massively. For instance, Ghana's urban population has seen a tremendous increase from

2,575,314 in 1971 to 13,660,790 people in 2013. This thus has partly accounted for the positive effect on the consumption of fossil fuel. The reason is urban towns in Ghana are characterized by heavy vehicular traffic and movement of vehicles that rely on fossil energy. Ghana's urban centres have also witnessed rapid infrastructural development made possible by using fossil fuel in the process of construction and other activities. These have contributed to the positive effect urbanization has on the consumption of fossil energy in the country.

Like Ghana's experience, urban population in Kenya increased from 1,256,443 people in 1971 to 3,926,810 people in 1990 and then to 10,990,845 people in 2013. Urban centres in the country have also been associated with vehicular traffic and rapid infrastructural development there by contributing to energy consumption. The urban population for the South African economy grew from 10,819,530 people in 1971 to 33,908,100 people in 2013. In addition, records indicate that over 80% of South Africa's GDP come from the cities and large towns.

Again, it is reported that 75% of all net jobs created in South Africa between 1996 and 2012 were from the urban centres. Thus, the urban centres in South Africa have become the hub of industries that rely on fossil fuel and also the destination of many people in search of jobs (http://www.southafrica.info/about/government/iudf70515.htm#.Vyc_HuSRrK8#ixzz47UyOgioY). The positive effect of urbanization on fossil fuel consumption obtained in this study gives support to earlier arguments by Jones (1989, 1991); Madlener (2011); Madlener and Sunak (2011) and Parikh and Shukla (1995). Other studies on the demand for electricity by Adom et al. (2012) had similar positive results for the urbanization. Also Kwakwa and Aboagye (2014) had similar results for aggregate energy consumption. Holtedahl and Joutz (2004) found the effect of urbanization to be elastic for electricity consumption in Taiwan and for the Chinese economy.

The effect of trade is found to be positive for Ghana but negative for Kenya and South Africa. This indicates that the energy content of the trading activities under the period of study for Kenya and South Africa is less intensive than it is for Ghana. This also implies that trade openness has enhanced efficiency in the usage of fossil fuel in Kenya and South Africa. In the light of the argument by Sardosky (211), one can contend that access to energy efficient equipments by households and firms in Kenya and South Africa has been relatively easier through international trade. This has helped to reduce the rate of fossil fuels consumption. On the other hand, the positive effect of trade openness on fossil fuel consumption for Ghana indicates opening up to trade has increased the consumption of fossil fuel for the country. Previous studies including Sadorsky (2011) and Cole (2006) reported positive effect of trade on energy consumption.

Table 4.4: Long run estimates for Ghana, Kenya and South Africa

	Ghana			**South Africa**			**Kenya**		
Variable	FMOLS	CCR	DOLS	FMOLS	CCR	DOLS	FMOLS	CCR	DOLS
ln P	0.0253	0.0263	-0.0680	0.0011	-0.0025	0.0565	-0.0236*	-0.0262***	-0.0349*
	(0.0431)	(0.0454)	(0.0530)	(0.0047)	(0.0058)	(0.0106)	(0.0055)	(0.0024)	(0.0169)
ln Y	0.0921*	0.0842*	0.1205*	0.0397***	0.0407***	0.0441***	0.1176***	0.1075***	0.2072***
	(0.0475)	(0.0449)	(0.0629)	(0.0070)	(0.0093)	(0.0071)	(0.0056)	(0.0053)	(0.0376)
ln N	-0.5370***	-0.50269***	-0.4781***	0.2945***	0.3031***	0.1711**	0.0152**	0.0564***	0.4403**
	(0.0706)	(0.0629)	(0.1021)	(0.0567)	(0.0605)	(0.0715)	(0.0147)	(0.0183)	(0.1737)
ln S	-0.2944***	-0.3110***	-0.1479***	-0.0961*	-0.1382**	0.0057	-0.7907***	-0.8072***	-1.2502***
	(0.0863)	(0.0753)	(0.1365)	(0.0471)	(0.0527)	(0.0943)	(0.0127)	(0.0013)	(0.1657)
ln T	0.2318***	0.2079***	0.3041***	-0.0448***	-0.0464**	-0.0474**	-0.04511***	-0.0335***	0.0406
	(0.0547)	(0.0548)	(0.0889)	(0.0146)	(0.0149)	(0.0474)	(0.0065)	(0.0082)	(0.0537)
ln U	1.0378**	1.0248***	-0.3220	0.0717**	0.1071***	0.0523	0.3443***	0.3206***	2.5920***
	(6.8453)	(0.4719)	(1.1505)	(0.0312)	(0.0349)	(0.0491)	(0.0140)	(0.0128)	(0.6853)
Constant	-12.8673*	-12.5472*	4.7313	-0.6543	-0.4724	-0.0577	-1.3471***	-1.0101***	-31.399***
	(6.8453)	(6.7258)	(15.9381)	(0.8382)	(1.2185)	(0.0349)	(0.2193)	(0.2116)	(9.1690)

Note: ***, **, * respectively represents 1%, 5% and 10% level of significance; Standard errors in parenthesis

Table 4.5 Random Effects Panel estimation

Variable	Coefficient	Std. Err.	t	P>t
Ln P	0.103117	0.027477	3.75	0.000
Ln Y	0.008335	0.018921	0.44	0.660
Ln N	0.018803	0.005941	3.16	0.002
Ln S	0.025626	0.005456	4.7	0.000
Ln T	0.092046	0.035383	2.6	0.010
Ln U	-0.34656	0.071655	-4.84	0.000
Dummy				
Ghana=2	0.656142	0.069071	9.5	0.000
S. Africa= 3	0.976398	0.150859	6.47	0.000
Constant	5.194808	1.089163	4.77	0.000

The results of the panel estimation are reported in Table 4.5. One can see some differences in the panel estimation and the time series estimations. This may be due to methodological differences. The panel results reveal that price, industrial efficiency, service sector efficiency, trade and urbanization affects fossil fuel consumption is the SSA sub region. While the individual country time series estimation showed fossil price to significantly reduce fossil fuel consumption for Kenya, the panel results show price has a positive effect on the consumption of fossil fuel in the region. As puzzling as this contradiction may seem, one can assign policy issues to explain the outcome. The price variable captured here is represented by the world fossil fuel price instead of domestic fuel price (due to lack of appropriate data). Countries in the sub region do have different policies that regulate the prices of fossil fuels. The success or otherwise of these policies may be the reason why in the case of Kenya we had a significant and negative effect but insignificant for Ghana and Kenya.

However, the overall effect of price on fossil fuel consumption being positive can be attributed to panic buying behaviour of consumers. An increase in the price of world fossil fuel price does have direct bearing on the price of fossil fuel in SSA. As a result such an increment sometimes causes consumers of fossil fuel to rush and buy more fossil fuel in anticipation that domestic price of fossil fuel will be increased in some days to come.

Another puzzling result is the negative effect of urbanization on fossil fuel consumption obtained in the panel estimation for the sub region. Most previous studies reviewed earlier have established a positive relationship between urbanization and energy consumption. However, Li and Lin (2015) have argued that highly urbanized societies do improve their effective use of infrastructure and also have less demand for per capita road transport energy use thereby reducing energy consumption in the urban centers. This could mean that overall, urban centers in the sub region are experiencing the argument put forward by Li and Lin (2015).

The effect of trade is found to be positive for the panel estimation. This suggests that opening up to trade has increased the consumption of fossil fuel for the region. This is in line with Sardosky's (2011) contention that trade increases energy use for production of goods and transportation of goods for export and imported goods for distribution in a country. Significant and positive effects are obtained for the efficiencies of the industrial and service sectors in the panel estimation. This implies that as these sectors in the sub region become more energy efficient in their operations, they tend to use more energy than before. Such a situation in the literature is known as the backfire rebound effect, commonly known as the Jevons paradox.

As expected, real income per capita was expected to have a positive effect on the consumption of fossil fuel in the region. Although it is not statistically significant, the positive coefficient signals the variable's potential effect of increasing the overall fossil consumption in the region.

4.6 Conclusion and policy implications

Concerned about the high emission of carbon from fossil fuel consumption that contribute to climate change and global warming, as well as the rising levels in the consumption of fossil fuel but inadequate supply and future energy security, the study investigated the determinants of fossil fuel consumption for three Sub-Saharan African countries namely Ghana, Kenya and South Africa using annual time series data over the period of 1975-2013. The demand for fossil consumption for each of the countries was modelled as a function of price, income, trade, urbanization and the technical efficiency characteristics of the industrial and service sectors. The ADF and PP tests for stationarity indicate all the variables are integrated of the order one while the ZA test suggest the variables are I(0) variables. The Engel-Granger and Phillip-Ouliaris cointegration tests also confirmed a long run relationship among the variables. The long run relationship between fossil fuel consumption and the other variables was examined using Phillip and Hansen (1990) FMOLS and Park (1992) CCR supported by the DOLS.

Results from the three estimations revealed income, urbanization, trade, efficiency of the service and industrial sectors are the long run drivers of fossil fuel consumption for Ghana and South Africa. In the case of the Kenyan economy, price in addition to the variables mentioned earlier for Ghana and South Africa were found to influence fossil fuel consumption. On the direction of impact, Ghana's fossil fuel consumption was determined positively by income, trade and urbanization; and negatively by industrial efficiency and efficiency of the service sector. For Kenya, fossil fuel consumption was positively affected by income, industrial efficiency and urbanization; but negatively affected by trade, price and efficiency of the service sector. Lastly, for the South African economy, our results showed urbanization, industrial efficiency and income increase fuel consumption while price and trade reduce fossil fuel consumption.

Since economic development translate into higher income, it is important for policy makers and governments to factor the fossil fuels consumption effect into such (growth and development) agenda and design appropriate policies to reduce fossil fuel demand. One of such measures is to develop, make available and promote the usage of cleaner forms of energy. Achieving higher economic growth and development in the years ahead has been the concern for many countries including Ghana, Kenya and South Africa. For instance, Kenya plans to achieve 10% annual economic growth in order to eliminate absolute poverty by 2030. Ghana has also set for herself 40 year development plan and South Africa has the vision 2030. The major goal of such growth and development agenda among other things is to reduce poverty of the citizens. Without such appropriate measures, future rise in per capita income would lead to higher level of fossil fuels consumption.

The negative effect of price suggests Kenya may be vulnerable to fossil energy price shocks. This is on the premises that an increase in the price of fossil fuels on the world market would translate into a higher domestic price. At the micro level, households may therefore have to spend extra share of their budgets on fossil fuels leaving them with less to spend on other goods and services. For firms, such a higher price will make it more expensive to produce. At the macro level, an increment in the price of fossil fuels is known to increase inflation, create balance of payment problems and also reduce economic growth (Cantah and Asmah, 2015; Balcilar et al., 2014; Kambou, 2015). Thus, appropriate measures including fast tracking the development of its geothermal energy should be put in place to handle any future fossil energy price shock. Because the effect of price changes on fossil fuel consumption is inelastic it is possible for authorities in the economy to reduce the subsidies on fossil energy. Since it has the least effect for the Kenyan economy it is essential that other policies apart from price related policies are given attention.

The results of the study imply that an adoption of advanced technological energy efficient equipment will ensure lower amount of fossil fuels is consumed for their activities in Ghana. In this regard, it is important for the government of Ghana to help reduce the obstacles or impediments that hamper industrial firms' ability to adopt energy efficient technologies in their operations. This would require the government follows national policy frameworks geared towards equipping industries to be energy efficient. Regarding the South African and Kenyan economies, more efforts are needed in order to make the industrial sector reduce consumption of fossil fuel. Intensive education on energy savings may come at handy for the economy in this regard. Similar recommendation stems from the panel estimation results.

Also, it is important to intensify efforts to decentralize growth and other lucrative activities in Ghana, South Africa and Kenya to reduce the population pressure in the urban centres. As it stands now the urban centres in Ghana, South Africa and Kenya have received relatively more attention in terms of resources from governments and corporate bodies when it comes to developmental issues more than rural areas. The rural areas need greater attention. In addition to the above point, attention needs to be given to educating the urban dwellers on efficient energy consumption to reduce the demand. This is because, urbanization, whether good or bad, has come to stay. We may not prevent its growth but have to find a way to live with it. Based on Li and Lin (2015) justification for the negative effects of urbanization on energy consumption, urban centres in the sub region needs to promote efficient usage of infrastructure that relies on fossil fuel and also reduce per capita road transport energy use.

Trading in less fossil energy intensive products and energy efficient technologies is recommended to help reduce fossil fuel consumption. It is essential that tariff and nontariff barriers on products that do not promote energy efficiency is raised and vice versa.

Looking at the contradictory results found between the time series and panel estimations especially for price and urbanization, it is important that further studies are carried out to ascertain the effects these variables have on fossil fuel consumption. Data and methodological issues such as the use of different proxies for price and urbanization should be taken into consideration in future studies for the SSA sub region and other regions.

CHAPTER FIVE

HOUSEHOLDS' ELECTRICITY CONSERVATION BEHAVIOUR IN GHANA: A RURAL AND URBAN COMPARISON FROM THE ASHANTI REGION

5.3 Introduction

Energy conservation has emerged as one of the surest ways of ensuring reliable and sustainable power supply (Ahn and Graczyk, 2012; Oyedepo, 2012; 2013, Williams, 2012) as well as reducing carbon emission (Worrell et al., 1999; Wang et al., 2013b; Hasanbeigi et al., 2013, Zhang, 2012; Zaid et al., 2014). Both theoretical arguments and empirical investigations show energy conservation factors are many and have varied effects. The outcomes of empirical studies on energy conservation have proven conservational factors are country or regional specific. This places emphasis on the need to recognize the determinants of energy conservation in a given country or region for effective conservation policy. Thus, this chapter has the objective of establishing the determinants of electricity conservation among households in the Ashanti region of Ghana. The rationale is to help offer guidelines for a better and effective electricity conservation policy geared towards the attainment of the 10% electricity savings target set by the government of Ghana.

Like most countries, electricity constitutes an important source of energy to both households and industries in Ghana. A look at the electricity supply before and after the global energy shock of 1973/1974 shows a clear opposite situation in the country. Prior to the energy shock, Ghana's electricity sector was characterised by excess supply.

Therefore, to avoid a collapse of the energy network, both residential and non residential electricity users were motivated to consume energy so that equilibrium is maintained in the system (Ofosu-Ahenkorah, 2007). The contrast is happening today where electricity supply is deficient. This has created an uncomfortable situation for the citizens and entire economy, through the frequent power rationing and outages. The country has experienced about five major electricity power crises since the 1980s with various reasons assigned to them. The first crises took place in 1983/84, followed by the second and third respectively in 1998 and 2002. The fourth one was in 2006/2007 and the recent one started from late 2012 and till date, solution to the problem has eluded managers of the energy sector.

The effects of such power crises on an economy are enormous. For instance, in Sri Lanka, Wijayatunga and Jayalath (2004) estimated the economic loss from a 300 hour of power interruption to be 0.4% - 0.9% of the country's gross domestic product (GDP)

(Pokharel, 2010). According to Tsehaye *et al.,* (2010), power outages in Ethiopia from 2009-2010 cost the country an estimated GDP loss of 1.5%. The Statistics Canada (2003) also revealed that the Canadian economy saw a decline in its GDP by 0.7% in August 2003 alone in the aftermath of a blackout in Ontario. Ghana has not been spared from such effects. The 2006-2007 electricity power rationing in Ghana cost the manufacturing sector a negative growth rate of 2.3% (ISSER, 2008). A further 13,000 decline in employment has been attributed to the 2012 to 2016 energy crises by the Association of Ghana Industries.

As a measure towards regular power supply, the government of Ghana in 2010 announced a target of 10% electricity savings through the implementation of comprehensive electrical power efficiency and conservation measures. This followed a revelation by the Ministry of Energy (2010) that about 30% of electricity supplied to consumers is wasted as a result of inefficient electrical equipment, poor attitude towards energy conservation and theft. Since the government's announcement, many analysts including Arko, (2013), UNDP, (2015) and Yeboah, (2014) have emphasized that electricity conservation will help cushion the limited electricity supply. However, inefficiency in the usage of electricity is still considered high in the country especially among households (Yeboah 2014, Arko 2013) who form about 70% of the total electricity consumers in Ghana (World Bank 2013). This situation calls for an investigation into the conservation behaviour of households in Ghana. It is in this regard that the current chapter investigates the rural and urban households' electricity conservation behaviour in the country.

Such a study is necessary since the demand side management (energy conservation) is key to solving Ghana's frequent power crises over the last three decades in addition to ensuring an efficient and reliable power system. Energy conservation also reduces demand for new generation and transmission capacity of electricity (PSEC and GRIDCO, 2010). According to the World Bank (2013), Ghana will need an additional 1,560 MW of dependable generation capacity from new projects to respond swiftly to the projected demand for electricity by 2023. This caution from the World Bank comes at a period the government of Ghana aims at ensuring availability of and universal access to energy services by 2020 (Ministry of Energy, 2010). However, without curtailing power usage, any investment made to provide the additional 1,560 MW may still be inadequate to meet the energy requirement of Ghanaians.

PSEC and GRIDCo (2010) have hinted, the implementation of electricity conservation programme will be challenging and that is true especially without adequate support from research studies. In countries and regions like the USA, European Union, China and other Asian countries where conservation programmes have been implemented with positive results, information and education based on research could not be left out (see Abrahamse et al. 2009, Sardianou 2007 and Gatersleben et al., 2002). Thus, using a conservation measure to help solve the persistent and recurring power crises and also ensure reliable power supply in Ghana may be ineffective without the necessary information on the electricity conservation behaviour on the part of households who form a substantial part of electricity consumers. Owing to the dearth of studies on the subject matter in Ghana, this study is carried out to help identify the determinants of households' electricity conservation behaviour in Ghana using a survey that solicited information from heads of households in the Ashanti Region. By so doing, the study helps to offer guidelines for a better and effective electricity conservation policy in the country.

With the appreciated role energy plays in the Ghanaian economy, researchers in recent times have developed interest in energy matters and empirical studies with varied focus, especially on energy demand (Dramani and Tewari, 2014; Adom *et al*., 2012, Mensah and Adu, 2013; 2015, Adom and Bekoe, 2012), energy-growth nexus (Adom, 2011; Kwakwa, 2012, Dramani *et al.*, 2012; Wolde-Rufael, 2008 and Akinlo, 2008) and hydro electricity generation (Kwakwa, 2015) have been carried out. Notwithstanding the fact that some attention has been given to the demand side of energy by previous studies on Ghana, little consideration has been paid to energy conservation practices. Consequently, this study is embarked upon to bridge this gap in the literature.

The paper adds to the literature on energy conservation behaviour in a number of ways. First, it is acknowledged that numerous studies have been conducted on household energy conservation behaviour. However, there is a scarcity of recent knowledge on rural and urban household comparisons as Castaldi and Zoli (2012) have noted such studies are not always explored. There is also an undeniable fact about the differences in rural and urban everyday life which needs to be considered in the formulation of energy conservation policy. Studies including Blakely (1976), Morrison (1977), Semenik *et al*., (1982), Milstein (1977; 1978), Fujii and Mak (1984) and Beaulieu and Miller (1984) are among the pre 21st century studies that compared rural and urban households while Hori et al. (2013) is a recent work on rural-urban comparisons. Aside Hori et al. (2013), most of the previous papers only provide evidence of the general tendency for rural or urban households to conserve energy without capturing the predictors that matter in these areas.

This study, thus, adds to the literature by providing evidence of the conservation factors from rural and urban households. Second, since electricity conservation behaviour as pointed out by Lutzenhiser (1993) differs among households when it comes to the use of electrical appliances, it is useful to identify what factors drives households' conservation behaviour regarding the use of specific appliances. Failure on the part of the previous studies including Hori et al (2013) to bring out such crucial information offers further ground to embark on this study. Third, almost all previous studies on energy conservation have been conducted outside the African continent hence a study from Ghana would help provide evidence from the region where little is known. This study thus enriches the literature on the subject matter as it provides evidence from rural and urban households in Ghana.

Foretelling the main results, this research work brings to bear that although both rural and urban households in the region have an encouraging level of electricity conservation behaviour; rural households have stronger conservation behaviour than urban households. Again, we found the conservation behaviour is influenced by households' demographic features, dwelling characteristics, information, environmental concern, subjective norms and perceived benefits. However, the effects of these variables are not uniform considering location and appliance.

The rest of the chapter is organized as follows. Section 5.2 reviews the relevant literature on the subject matter; Section 5.3 focuses on the methodology; Section 5.4

presents and discusses the results while Section 5.5 concludes the chapter with summary of findings and policy implications that follow from the findings.

5.2 Literature Review

Gardner and Stern (2002) have categorized household energy conservational behaviour into two namely, efficiency and curtailment behaviours. Abrahamse et al., (2005, p. 274) explain efficiency behaviours as "one-shot behaviours and entail the purchase of energy efficient equipment, such as insulation. Curtailment behaviours involve repetitive efforts to reduce energy use, such as lowering thermostat settings". Since households globally are increasingly using more electrical appliances due to its availability (Abrahamse and Steg, 2009), economic growth and development, and globalization, among other reasons, it counteracts the effects of energy efficiency behaviour. The implication is that the world cannot rely only on technological innovations to conserve energy (Abrahamse and Steg, 2009). Again the slow rate, at which such technological innovations have penetrated society (Jaffe and Stavins, 1994; Reddy, 1990), has impeded efforts to achieve energy efficiency. With this insight, it is erroneous to conclude energy efficiency alone is equivalent to energy conservation. Thus Costanzo et al. (1986) long ago clearly stated:

"*Achieving energy conservation is a two-fold challenge, partly technical and partly human.The development of energy-conserving technologies is a necessary but insufficient step toward reduced energy consumption. Unless adopted by a significant segment of consumers, the impact of technical innovations will be negligible. Indeed, several studies have shown that energy users have failed to adopt currently available energy-conserving technologies even when adoption is highly cost effective" (p. 521).*

Meanwhile, to account for the determining factors of electricity conservation behaviour, recent studies including Wang et al. (2011b), Abrahamse and Steg (2011) and Hori et al. (2013) have relied on the theory of planned behaviour (TPB) due Ajzen (1991). The TPB explains that any behaviour exhibited by an individual is influenced by the intention, which is the motivational factors influencing a behaviour. Usually a stronger intention to perform behaviour is associated with a higher chance of its performance and vice versa. The intention is in turn, a function of three key things attitude towards the behaviour, subjective norm, and perceived behaviour control. The attitude toward a behaviour is how the individual sees that behaviour in his/her own evaluation as to whether it is favourable or unfavourable, positive or negative or good or bad based on awareness and "pro" concern. This implies that attitude has got more to do with information and pro environmental concern.

The role of information in electricity conservation has been mentioned in Ek and Söderholm (2010), Chong and Dubois (2010), Steg and Vlek (2009), and Vassileva et al. (2012) among others. According to Chong and Dubois (2010) information is a necessary condition for households to adopt energy saving behaviour since its provision does increase household's awareness of energy consumption and conservation issues. The information carried out could be on the benefits of conserving energy to the household and the environment, energy efficiency equipment and energy-related problems. Various avenues are available for conveying conservation information to households (Chong and Dubois 2010) but they should be in the right form (He and Kua, 2012) to capture attention and be understood before it can become effective. Ek and Söderholm (2010), Mizobuchi and Takeuchi (2012), Abrahemse and Steg (2009) and Castaldi and Zoli (2012) have all confirmed the positive effect of information on energy conservation in their research. It is in this vein that Wang et al (2012b) have incorporated awareness into the "attitude" factor of theory of planned behaviour. Similarly, the concern people have for the environment makes them exhibit behaviour that will protect the environment (Wang et al. 2012b). Thus, households would invest in conservation practices like purchasing compact fluorescent lamp bulbs because they hope it can affect the environment. Mills and Schleich (2012), and Ek and Soderholm (2010) identified a significant effect of respondents concern for the environment on energy saving. Ma et al. (2013) in their study concluded that Chinese need to change their attitude and behaviour in other to constrain energy intensity.

The perceived behaviour control focuses on the economic motive for engaging in an action. In relation to energy conservation, the decision to conserve or not to, would be based on cost-benefit analysis of such action taken by the individual (Oikonomou et al., 2009). In situations where conservation behaviours come with disutility such as reduction in comfort Chong and Dubois (2010), the willingness to reduce energy conservation will be reduced. Ma et al. (2013) found that their respondents were willing to save energy as long as it did not reduce their comfort and convenience. Wang et al., (2011b) and Banfi et al., (2008) had similar results showing that individuals' willingness to embark conservation practices was influenced by the associated benefits.

Subjective norm is the influential pressure to perform an action or otherwise. It explains that individuals take into consideration how others perceive the action they are engaging in. Usually the perception that close ties, opinion leaders and other important people may approve or disapprove an action determines the final decision of individuals.

If those people who matter to the individual are perceived to be in support of the action, then it becomes easier for individuals to engage in that certain behaviour. The implication is the more influential members approve energy conservation practices, the more it would be for individuals to conserve energy and vice versa (Ek and Söderholm 2010, Abrahemse and Steg 2009). Wang et al (2011b) confirmed a significant effect of subjective norms on the electricity conservation behaviour of Chinese.

A critical look at the literature also shows studies on energy conservation behaviour among households have been carried out based on concepts from economics, psychology and sociology (Brohmann et al. 2009). From these concepts, the determining factors influencing energy saving behaviour activities can be classified into the characteristics of the household (education, income, family size, age, income), characteristics of the residence (age of the building, size or number of rooms, renter or owner), economic factors (energy prices), availability and quality of information and attitudes. The relationship between income and conservation has been closely linked with the Environmental Kuznets Curve (EKC) hypothesis by Grossman and Krueger (1991) that stems from Kuznets' (1955) economic growth and income inequality argument.

According to Kuznets, at low level of income, a country's environmental degradation is high but as income increases, environmental degradation falls giving an inverted U shape relationship between income and environmental degradation. Following this Grossman and Krueger (1991) have argued that there is an inverted U shaped curve or bell shaped curve between income and environmental degradation. The reason is as income increases individuals become conscious of the environment and begin to demand for goods that will not harm the environment. Another reason to buttress the positive relationship between income and energy conservation behaviour is that the energy efficient equipments that are manufactured are expensive that the relatively richer people in society are able to afford (Costanzo et al. 1986).

Although the EKC hypothesis has been criticized that it only serves as a point of comparison for theoretical and empirical research, and is as such no longer the accepted relationship between income and environmental degradation (Bachus and Ootegem 2011), some empirical studies have confirmed it. At the household level, Brohmann et al. (2009) argue richer households are less likely to face income or credit constraints for investments in energy efficiency and thus will have stronger conservation behaviour. For instance, the study by Scott (1997) of 1200 households in Ireland confirmed that when access to credit is restricted, households are prohibited from conservation actions. In their study Poortinga *et al*. (2003) established that respondents with high income were more likely to accept technical improvements as an acceptable means of conserving energy than behavioural means in Holland. Sardianou (2007) found in Greece that consumers with a higher private income are more willing to conserve energy. However, among British households, Castaldi and Zoli (2012) showed that lower and middle classes are more likely to see energy saving behaviour crucial since it is a characteristic of their lifestyle as influenced by the economic context they find themselves. However, Chong and Dubois (2010) found no significant relationship between income and energy conservation.

Educated people are more likely to exhibit pro environmental behaviour (Gatersleben et al. 2002) since they are assumed to be in a better position to know the dangers facing the environment, become concerned and take the necessary action available to protect it. Empirically, Castaldi and Zoli (2012) established a positive correlation between high education levels (University degree) and energy saving among households. Also, Brechling and Smith (1994) and Scott (1997) found positive effect of education on energy saving activity. On the other hand, Poortinga *et al*. (2003) found behavioural measures were relatively more acceptable for respondents with a low level of education than for respondents with an average or high level of education while Sardianou (2007)**,** Chong and Dubois (2010) found no significant relationship between education and practices that conserve energy.

Age has also been identified to significantly affect energy conservation behaviour. Some have argued that older people are less likely to adopt energy efficient technology because of lower expected rate of return (Mills and Schleich 2012) and also, they are not much aware of environmental problems (O'Neill and Chen, 2002; Lenzen et al., 2006). Moreover their monotonous way of doing things may reduce their willingness to adopt energy efficient technology. Others like Wang et al. (2011b) argue older people have a greater desire to conserve electricity because they might have had more experience of electricity shocks and its associated effects. In their study Ma et al. (2013) observed that younger individuals were more likely to agree that they should change their behaviours towards energy conservation; Hori et al. (2013) showed a weak positive effect of age on energy saving behaviour in five Asian cities while the work of Ek and Soderholm (2010) had insignificant effect of age on electricity savings.

Another factor, household size has been found to affect energy savings. Evidence provided by Poortinga et al. (2003) informs that couples and families consider technical improvements more acceptable than singles. Lee and Emmel (2008) also found multifamily households made greater efforts to save energy than single family, although, the former were less likely to make any inquiry about energy saving than the latter. The positive relationship between household size and electricity conservation is explained by the fact that members may talk about issues concerning energy and cooperate with each other on the action to take. Moreover, they may be more conscious of the savings, given their relatively high electricity bills (Mizobuchi and Takeuchi, 2012). Castaldi and Zoli (2012), on the other hand, found a negative relationship between large household size and conservation.

Whether the occupant of a house is the owner or renter is another determining factor of energy saving behaviour. Sardianou (2007) contends that owners of houses are likely to use efficiency measures whereas curtailment may be the only option for renters. Findings from Curtis *et al*. (1984), Black *et al*. (1985) and Mills & Schleich (2009) support that assertion. Studies have also shown that characteristics of building such as age of building, number of rooms (Brounen et al., 2012), residence type (Sardianou, 2007), tenure characteristics (Castaldi & Zoli 2012, O'Doherty et al 2007) and type of apartment (O'Doherty et al 2007) equally play a role in the level of energy conservation.

The above studies and recent ones on energy conservation such as Amelia and Brandt (2015), Hara et al. (2015), Frederiks et al. (2015) and McClaren (2015), have all failed to clearly analyzed the effect rural – urban dynamics and appliance specific on energy conservation.

5.3 Methodology

5.3.1 The survey

A survey was carried out in the Ashanti region of Ghana through the use of questionnaire technique. The questionnaire approach was chosen over other methods of survey such as the in-depth interview or observation since it is considered the most appropriate means of soliciting the needed information (on electricity conservation practices) from a large number of respondents. The reason is that, collection of data of this nature by the use of questionnaires is less time consuming and cost effective than the other methods. Again, it is easier to quantify the results of the questionnaires through the use of a software package. Also, the choice of the Ashanti Region for the study is premised on the grounds that it is the most populated region in the country according to the 2010 National Population Census. From the census, the Ashanti region has a population of 4,780,380 people, which offers great opportunity to get a larger sample size for the study. Again, the region especially the capital, hosts many corporate organizations and this has drawn people from other regions and different socio-economic background. This thus affords us the opportunity to have responses from people of different backgrounds.

Based on the Morgan and Krejcie (1970) sample selection formula suggested and a 5% we established a minimum optimal sample size of 400 households for the survey. In order to arrive at this, 560 households were targeted out of which 477 households (85% response rate) agreed to part take in the exercise or/and answered the majority of the questions appropriately. Out of this figure, 238 were rural and 239 were urban households.

The process in the selection of households involved a combination of several sampling techniques. First, the regional capital Kumasi was chosen on purpose to represent urban households because it is the second largest city in the country after the nation's capital, Accra. The populace in the Kumasi Metropolis also consists of people from different socio-economic backgrounds from all over the country. A simple random sampling technique to select four sub metros in Kumasi, where 70 households were systematically sampled from each of the sub metros (Kwadaso, Asokwa, Tafo and Bantama sub Metros). Rural households were chosen from four simple randomly selected districts (Efigya-Sekyere, Ejisu-Juaben, Atwima Nwabiagya and Atwima Kwanwuma Districts) in the Ashanti region. In each of these districts, 70 households were sampled systematically.

Guided by previous studies, arguments reviewed earlier in the literature and energy conservation campaigns by the Energy Commission of Ghana and other state agencies, a questionnaire was designed to cover areas of respondents demographic and dwelling characteristics; energy-saving behaviour; attitudes towards electricity saving (environmental concern and information); subjective norms and perceived behaviour.

5.3.2 Modelling and estimating electricity conservation behaviour

Estimating electricity conservation in this study is inspired by the theory of planned behaviour (TPB) due Azjen (1991) which has been explained already in the previous section. In the literature, accounting for pro-environmental behaviour such energy consumption, recycling and water conservation has relied extensively on the TPB (see Alias et al., 2015; Lam, 1999; Fielding et al., 2012; Finlinson 2005; Armitage and Conner 2001, Abrahamse and Steg, 2009; Martiskainen, 2007; Tonglet et al, 2004; Park and Ha, 2014). Thus, we argue electricity conservation behaviour is determined by attitude (information and environmental concern), subjective norms and perceived benefits. In addition, based on previous studies, other explanatory variables of conservation behaviour namely demographic features (age, age square, gender, years of education, household size, income and expenses on electricity) and dwellings characteristics (occupancy type, number of rooms, age of apartment and presence of business that rely on electricity) are employed to embark upon this empirical analysis for the Ghanaian economy.

Studies like Ek and Soderholm (2010) and Wang et al. (2011b) used households' willingness to conserve energy for their estimation and analysis. The problem that is likely to arise from such measurement is that, one may give a positive response to willingness to conserve but in practical life will do otherwise. As a result, this study sought from respondents, the actual behaviour they do/(have) exhibit/(ed) towards electricity conservation on lighting, radio-TV, ironing and refrigeration. To achieve this, a seven point Likert scale (from 1 completely not true/not involved to 7 completely true/involved) which according to Foddy (1994) meets the minimum categories to ensure scale validity and reliability was developed. Three electricity conservation practices for lighting, three for radio-TV, four for refrigeration and three for ironing were developed to explore households' conservation behaviour. Constructing energy conservation behaviour among households would require electrical gadgets that are often used by households'

members and/or have high consumption rate. It is for these reasons that we considered these four appliances (light, radio-TV, refrigerator and iron) which have become part and parcel of most Ghanaian households today and commonly mentioned during campaigns to conserve electricity. Owing to the fact that the responses for conservation behaviour in this study are not continuous, it renders the ordinary least squares regression estimation technique not appropriate because it can produce spurious probabilities (greater than unity or less than zero) and negative variance estimates (Greene, 2003). Due to this, the ordered probit model was used for estimating the drivers of electricity conservation.

Following Greene (2003), the ordered probit model can be expressed as:

$$q_i^* = x_i\beta + \mu_i \qquad (5.1)$$

where q_i^* is a latent variable representing the electricity conservation behaviour (for lighting, radio and television, refrigeration, ironing and the total of all the four) associated with household *i*, x_i is a vector of explanatory variables and β is the vector of regression coefficients to be estimated and μ is the random error term assumed to be standard normally distributed. Because q_i^* is latent, we observe discrete responses of the variable q_i as below:

$q_i = 1$ if $q_i^* \le \theta_1$, (5.2a) $q_i = 2$ if $\theta_1 < q_i^* \le \theta_2$, (5.2b) $q_i = 3$ if $\theta_2 < q_i^* \le \theta_3$, (5.2c) $q_i = 4$ if $\theta_3 < q_i^* \le \theta_4$, (5.2d) $q_i = 5$ if $\theta_4 < q_i^* \le \theta_5$, (5.2e) $q_i = 6$ if $\theta_5 < q_i^* \le \theta_6$, (5.2f) $q_i = 7$ if $\theta_6 \le q_i^*$ (5.2g) The θ_j are the unknown threshold parameters to be estimated simultaneously with the other coefficients β. The probability that the ordered dependent variable q takes different possible value is:

$$\Pr(q_i = 1|x) = 1 - \lambda[\beta' x_i - \theta_1] \qquad (5.3a)$$

$$\Pr(q_i = 2|x) = \lambda[\beta' x_i - \theta_1] - \lambda[\beta' x_i - \theta_2] \qquad (5.3b)$$

$$\Pr(q_i = 3|x) = \lambda[\beta' x_i - \theta_2] - \lambda[\beta' x_i - \theta_3] \qquad (5.3c)$$

$$\Pr(q_i = 4|x) = \lambda[\beta' x_i - \theta_2] - \lambda[\beta' x_i - \theta_4] \qquad (5.3d)$$

$$\Pr(q_i = 5|x) = \lambda[\beta' x_i - \theta_4] - \lambda[\beta' x_i - \theta_5] \qquad (5.3e)$$

$$\Pr(q_i = 6|x) = \lambda[\beta' x_i - \theta_5] - \lambda[\beta' x_i - \theta_6] \qquad (5.3f)$$

$$\Pr(q_i = 7|x) = \lambda[\beta' x_i - \theta_6] \qquad (5.3g)$$

where λ indicates a cumulative normal distribution and the cut-points θ_j, divide the categories of the dependent variable. The parameter of the ordered probit model is estimated by the maximum likelihood method. However, since we are not only concerned about the direction of the impact of the explanatory variables but also the magnitudes of their impacts, the marginal effects are also estimated:

$$\frac{\partial \Pr(q_i = 1 \mid x)}{\partial x} = -\phi(\theta_1 - \beta' x_i)\beta \qquad (5.4a)$$

$$\frac{\partial \Pr(q_i = 2 \mid x)}{\partial x} = [\phi(\theta_1 - \beta' x_i) - \phi(\theta_2 - \beta' x_i)]\beta \qquad (5.4b)$$

$$\frac{\partial \Pr(q_i = 3 \mid x)}{\partial x} = [\phi(\theta_2 - \beta' x_i) - \phi(\theta_3 - \beta' x_i)]\beta \qquad (5.4c)$$

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$$\frac{\partial \Pr(q_i = 7 \mid x)}{\partial x} = \phi(\theta_6 - \beta' x_i)\beta \qquad (5.4d)$$

The measurement of the explanatory variables and their priori expectations are presented in Table 5.1 below. These expectations are guided not only by the literature but also the prevailing situation in the country. For instance, because many households in Ghana are male headed, sex is expected to reduce electricity conservation. This is because the literature argues that women are more concern about the environment and so would exhibit behaviour that would protect the environment.

It is also expected that age will reduce electricity conservation behaviour since the aged are more resistant to change they would be less likely to change their pattern of behaviour in order to conserve electricity. Also, there has been an increasing demand for higher education in the country over the years. The educated person is likely to be aware of the electricity challenges the country is facing and would like to take measures that will help reduce this challenge. Education is therefore expected to increase electricity conservation in the study area. Electricity bill is likely to increase electricity conservation in the study area since there is always a public outcry when electricity tariff is increased in the country and as such, consumers would conserve electricity in order to pay less electricity bill.

Information on electricity conservation is expected to have a positive effect on electricity conservation because there has been increased campaign on electricity conservation and that is expected to enable individuals to know the need to conserve electricity.

Table 5.1: Description, measurement and priori expectations of explanatory variables

Explanatory variables	Description	A priori expectations
Gender	Gender of household head (1 if male, 0 otherwise)	-
Age	Age of respondent in years	-
Years of Education	Total number of years respondent has spent in schooling	+
Household size	Number of people in the household	-/+
Income	Average monthly income of Average household	+
Electricity bill	Household expenditure	+
Electricity business	Presence of business that rely on electricity (1 if yes, 0 otherwise)	+

Occupancy type	Whether the occupant is the owner or a renter of the building (1 if yes, 0 otherwise)	-/+
Age of apartment	Years of the apartment has been existence	+/-
Information	Respondent level of information and awareness on electricity conservation	+
Subjective norm	Respondent level of subjective norm	+/-
Environmental concern	Respondent level of environmental concern	+
Perceived benefit	Respondent level of perceived benefit	+
Location	1 if respondent resides in a rural area and 0 if otherwise	+/-

The effect of subjective norm is uncertain. In the event that subjective norm supports electricity conservation its effect will be positive and vice versa. The effect of income is expected to be positive since from economic theory higher income earners are more likely to purchase energy efficient gadgets. Concern for the environment among Ghanaians has increased in recent times as a result, environmental concern is expected to increase electricity conservation. Rural residents are less likely to conserve energy because they may not be exposed much to the effects of electricity shortage as well as the environmental impact of energy consumption that their counterparts in the urban areas do.

5.4 Results and Discussion

We start off by looking briefly at the distribution of the responses for the electricity conservation behaviour as well as the theory of planned behaviour (TPB) variables (environmental concern, information, perceived benefit and subjective norms).

5.4.1 Electricity conservation practices by respondents

The results for households lighting conservational practices in Table 5.2 indicate households in the study area have stronger electricity conservation behaviour for lighting activities. Majority 72.4% are observed to be above the neutral point of 4 for total lighting conservation. Compared with urban households' value of 69.87%, rural households recorded a 75.5% as those whose actions exceed the neutral level. Concerning the lighting sub components, rural households tend to have the stronger conservation for all except preference for using CFL/LED bulb which saw more urban than rural households showing the stronger behaviour. From Table 5.3, the total radio-TV conservation behaviour is stronger among all households given that close to 70% are above the neutral point.

Rural households are found to even have a higher percentage of respondents (74.11%) above the neutral point. Regarding the specific sub components for radio-TV, a greater portion of households both urban and rural are above the neutral point (although rural households have the higher percentage) of conservation. The exceptional case is switching off the main power sub component which has less than 50% of households below the neutral level on the scale. Refrigeration results reported in Table 5.4 show that a majority of the households having a stronger behaviour for conserving electricity.

A look at the refrigeration sub components discloses majority do not switch off refrigerator in the night to conserve energy unlike the other sub components where the opposite is the case. The conservation behaviour in total ironing is found to be weaker as over 50% the households, both urban and rural, are in the range of neutral to completely not true. The same case holds for the sub components of avoiding piecemeal ironing and avoiding wrinkling clothes before ironing. However, majority of the households revealed they have stronger conservation behaviour for avoiding ironing of wet clothes (Table 5.5).

The above distribution portrays generally, households in the study area have an encouraging electricity conservation behaviour. However, rural households reported stronger electricity conservation behaviour than their urban counterparts. This difference could be due to the differences in households' lifestyle. In comparison to studies that have evaluated households' electricity usage and conservation, our findings to some extent give credence to those that reported stronger conservation practices among rural households. For instance, McKenna and Nixon (1979) reported a larger proportion of rural households spend money to conserve energy than urban households. Muratori (2013) also observed rural households are generally more energy efficient per square foot than urban households.

Regarding electricity conservation related information, 65.11% of urban households are much informed compared with 45.49% of rural households. The entire study area registered 55.43% of households to be well informed about electricity conservation issues. Having more urban households informed on electricity conservation matters than rural households is not surprising in the sense that households in such areas have access to modern means of accessing information. In addition, electricity conservation campaign in the region and the entire country seems a bit biased towards urban households. Also, this observation could be attributed to the fact that urban households are more likely to have higher levels of education and knowledge about the environment.

Majority 74.19% of all households, 70% rural and 77.28% urban, also indicate a stronger perceived benefit for conserving electricity. This suggests households' conservation behaviour is related to the benefits households perceive to receive including paying low electricity bills and electrical appliances lasting longer. Also 45.43% of rural households, 41.41% of urban households and 43.28% of all households indicate subjective norms do have significant influence on their electricity conservation activities. It is not strange to see more rural than urban households indicating that their conservation behaviour is influenced by subjective norms. Rural areas are often characterized by communal living which is simpler and more of mechanic solidarity than urban areas noted for their individualistic, complex and organic solidarity way of living. Thus, the role of family members, friends and opinion leaders with regard to electricity conservation is prevalent in rural areas.

Table 5.6 reports that a higher percentage of rural households (51.28%) and 43.47% of urban households have their concern for the environment exceeding the neutral point. This implies rural households have a stronger concern for the environment than urban households. The percentage of rural households even exceeds that of the entire study area (47.29%) whose concern for the environment is above the neutral point of 4. The differences in the distribution of responses could be due mainly to the reliance on the environment for their economic livelihoods in rural areas.

Table 5.2: Households lighting conservation behaviour

Level	Rural	Urban	Total
	Turn off light when not needed		
1 (completely not true)	4.62%	7.95%	6.29%
2	5.46%	5.86%	5.66%
3	3.36%	2.09%	2.73%
4	2.94%	8.79%	5.87%
5	5.04%	18.83%	11.95%
6	6.89%	10.46%	18.66%
7 (completely true)	51.68%	46.03%	48.85%
	Prefer to use fluorescent bulb		
1 (completely not true)	27.73%	26.78%	27.5%
2	5.88%	5.02%	5.45%
3	4.62%	3.77%	4.19%
4 (Cannot tell)	2.10%	7.95%	5.03%
5	5.46%	9.62%	7.55%
6	26.05%	14.64%	20.34%
7 (completely true)	28.15%	32.22%	30.19%
	Use one large bulb cover large area		
1 (completely not true)	15.02%	15.06%	15.04%
2	19.74%	12.55%	16.10%
3	6.44%	15.90%	11.23%
4 (Cannot tell)	5.15%	6.69%	5.93%
5	10.30%	10.88%	10.59%
6	17.17%	10.04%	13.56%
7 (completely true)	26.18%	28.87%	27.54%
	Total for lighting		
1 (completely not true)	2.15%	2.09%	2.12%
2	4.73%	2.1%	3.39%
3	10.31%	15.49%	12.92%
4 (Cannot tell)	7.31%	19.45%	8.90%
5	36.05%	31.8%	33.60%
6	17.56%	24.26%	20.97%
7 (completely true)	21.89%	13.81%	17.80%
Total Number	**238**	**239**	**477**

Table 5.3: Households' Radio-TV conservation behaviour

Level	Rural	Urban	Total
	Off radio and TV when no one watching or listening		
1 (completely not true)	4.33%	6.69%	5.53%
2	4.76%	2.51%	3.62%
3	2.16%	5.86%	4.04%
4 (Cannot tell)	5.63%	7.53%	6.60%

5	10.82%	15.48%	13.19%
6	32.90%	12.97%	22.77%
7 (completely true)	39.39%	48.95%	44.26%
	Family prefers to watch one TV and listen to one radio with family		
1 (completely not true)	7.02%	20.08%	13.70%
2	11.84%	11.72%	11.78%
3	3.07%	6.28%	4.71%
4 (Cannot tell)	3.95%	6.28%	5.14%
5	8.77%	11.72%	10.28%
6	32.02%	10.46%	20.99%
7 (completely true)	33.33%	33.47%	33.40%
	Always switches the main power off		
1 (completely not true)	23.04%	31.38%	27.29%
2	13.91%	12.55%	13.22%
3	7.39%	8.79%	8.10%
4 (Cannot tell)	7.83%	12.97%	10.45%
5	8.70%	10.46%	9.59%
6	20.43%	4.60%	12.37%
7 (completely true)	18.70%	19.25%	18.98%
	Total for Radio-TV		
1 (completely not true)	1.34%	1.26%	1.30%
2	2.23%	3.74%	3.02%
3	8.93%	16.32%	12.74%
4 (Cannot tell)	13.39%	16.32%	14.90%
5	29.02%	35.57%	32.40%
6	22.32%	16.32%	19.22%
7 (completely true)	22.77%	10.47%	16.42%
Total Number	**233**	**239**	**472**

Table 5.4: Households' Refrigeration conservation behaviour

Level	Rural	Urban	Total
	Adjust the regulator to suit the temperature of the day		
1 (completely not true)	36.06%	41.84%	39.15%
2	25.48%	25.10%	25.28%
3	3.37%	5.86%	4.70%
4 (Cannot tell)	6.25%	7.11%	6.71%
5	10.58%	9.62%	10.07%
6	9.62%	5.86%	7.61%
7 (completely true)	8.65%	4.60%	6.49%
	Always wait for hot food to cool before putting it in the fridge		

1 (completely not true)	4.37%	8.37%	6.51%
2	7.28%	5.44%	6.29%
3	5.34%	6.28%	5.84%
4 (Cannot tell)	5.34%	7.95%	6.74%
5	9.71%	13.81%	11.91%
6	38.83%	17.57%	27.42%
7 (completely true)	29.13%	40.59%	35.28%
	Conscious of not leaving the fridge door open ajar		
1 (completely not true)	5.24%	10.46%	8.02%
2	3.33%	2.93%	3.12%
3	3.81%	5.44%	4.68%
4 (Cannot tell)	5.24%	5.86%	5.57%
5	11.43%	11.30%	11.36%
6	26.19%	15.90%	20.71%
7 (completely true)	44.76%	48.12%	46.55%
	Switch off refrigerator in the night		
1 (completely not true)	30.77%	43.28%	37.44%
2	30.77%	23.95%	27.13%
3	4.81%	6.30%	5.61%
4 (Cannot tell)	4.81%	7.98%	6.50%
5	4.33%	6.72%	5.61%
6	8.65%	4.62%	6.50%
7 (completely true)	15.87%	7.14%	11.21%
	Total for refrigeration		
1 (completely not true)	5.48%	3.78%	12.76%
2	10.46 %	3.78%	2.74%
3	4.47%	14.28%	3.42%
4 (Cannot tell)	8.96 %	10.92%	11.84%
5	12.44 %	41.17%	11.62%
6	41.80 %	15.99%	41.44%
7 (completely true)	16.39 %	10.08%	16.18%
Total Number	**201**	**238**	**439**

Table 5.5: Households' ironing conservation behaviour

Level	Rural	Urban	Total
	Avoid piecemeal ironing		
1 (completely not true)	20.36%	25.10%	22.83%
2	25.34%	13.39%	19.13%
3	5.43%	10.04%	7.83%
4 (Cannot tell)	5.43%	10.04%	7.83%

5	15.38%	13.39%	14.35%
6	17.19%	7.53%	12.17%
7 (completely true)	10.86%	20.50%	15.87%
	Avoid wrinkling of clothes before ironing		
1 (completely not true)	14.75%	24.27%	19.74%
2	23.04%	17.57%	20.18%
3	10.60%	12.97%	11.84%
4 (Cannot tell)	11.52%	12.97%	12.28%
5	10.60%	14.23%	12.50%
6	23.04%	7.95%	15.13%
7 (completely true)	6.45%	10.04%	8.33%
	Avoid ironing wet clothes		
1 (completely not true)	6.39%	12.55%	9.83%
2	2.74%	3.35%	3.06%
3	5.02%	2.51%	3.71%
4 (Cannot tell)	5.48%	9.21%	7.42%
5	11.42%	9.62%	10.48%
6	35.62%	16.32%	25.33%
7 (completely true)	33.33%	46.44%	40.17%
	Total for ironing		
1 (completely not true)	2.43%	4.20%	3.31%
2	4.65%	2.93%	3.75%
3	15.89%	20.92%	18.54%
4 (Cannot tell)	24.27%	23.85%	24.06%
5	19.58%	21.75%	20.75%
6	27.10%	16.31%	21.43%
7 (completely true)	6.08%	10.04%	8.16%
Total Number	**214**	**239**	**453**

Table 5.6: Theory of planned behaviour variables

Level	Rural (%)	Urban (%)	Total(%)
	Environmental concern		
1 (completely not true)	12.28	18.99	15.7
2	14.92	6.76	10.76
3	12.72	16.88	14.84
4	8.80	13.90	11.41
5	21.03	21.52	21.20

6	14.03	12.66	13.39
7 (completely true)	16.22	9.29	12.70
Respondents	**228**	**237**	**465**
	Information		
1 (completely not true)	6.87	2.10	4.46
2	7.73	2.94	5.3
3	17.59	13.87	15.71
4 (Cannot tell)	22.32	15.98	19.1
5	17.59	33.19	25.48
6	21.03	20.16	20.59
7 (completely true)	6.87	11.76	9.36
Respondents	**233**	**238**	**471**
	Perceived benefits		
1 (completely not true)	1.68	3.77	2.73
2	2.93	2.22	2.52
3	3.36	5.44	4.41
4 (Cannot tell)	21.1	11.29	16.15
5	13.86	17.21	15.73
6	32.7	22.63	27.64
7 (completely true)	24.37	37.44	30.82
Respondents	**238**	**239**	**477**
	Subjective norm		
1 (completely not true)	10.14	15.9	13.23
2	11.11	5.03	7.84
3	17.38	23.43	20.63
4 (Cannot tell)	15.94	14.23	15.02
5	17.39	27.2	22.65
6	14.98	9.2	11.88
7 (completely true)	13.06	5.01	8.75
Respondents	**207**	**239**	**446**

5.4.2 Predictors of energy conservation

The drivers of the electricity saving behaviour are identified through the ordered probit model. Four separate estimations were done. These are,

a) estimation to identify electricity saving factors separately, for activities relating to lighting, refrigeration, ironing and radio-TV for rural and urban households;

b) estimation to identify the total electricity saving factors separately for rural and urban households;

c) estimation to identify the overall energy saving factors separately for lighting, refrigeration, ironing and Radio-TV in the study area; and

d) estimation to identify overall energy saving factors in the study area.

This was done to allow for comparison regarding the factors critical for each centre. Because conservation behaviour is not the same for all appliances, separate estimation is also crucial to ascertain the underlying factors that affect electricity conservation for each appliance. The estimated results are presented in Table 5.7 to Table 5.9. Once the models were estimated, the marginal effects showing the likelihood of completely adopting a conservation behaviour were also calculated and reported alongside the coefficients of the ordered probit estimations.

Various studies have reported different effects of demographical features (*household characteristics)* on energy saving behaviour of households (Hori et al., 2013; Beaulieu and Miller, 1984; Ek and Sorderholm, 2010 and Castaldi and Zoli, 2012). In this study we include age, income, electricity bill, education, gender of the head of household and household size to examine their respective impacts on electricity conservation behaviour. Results from the estimations indicate a male headed household increases the probability of conserving electricity in general for rural households by about 9% and their lighting activities 16% but not with ironing, refrigeration and radio-TV. Regarding urban households, a male headed household reduces the probability of conserving electricity through radio-TV activities by 5%.

Compared with previous works, Sardianou (2007), Hori et al. (2013), Ek and Sorderholm (2010) did not establish a significant effect for gender. It is said individuals' ways of thinking and acting are influenced by their gender owing to the biological differences and social experiences. Thus men and women generally do not have the same values, attitudes and behaviours (do Paço, 2015). Some have argued women are more concerned about social justice, harmony with nature and environmental protection (Fukukawa et al., 2007, Schwartz and Rubel, 2005). Also, because they are the worse victims of environmental destruction (Arku, 2013) due to their defined social roles and income status, women would conserve more energy than men.

The results on sex in this study suggest that men may equally have concern for what women care for, particularly environmental destruction and hence their decision to conserve electricity. The result is more striking for the rural households than the urban households as the former do not just conserve electricity for lighting activities but their total conservation behaviour. This is not surprising as the distribution of responses show a greater percentage of rural households, than urban households, conserve more energy.

On the age effect, we find that aging exerts a negative impact on the probability of conserving electricity among rural households. Paying attention to specific appliances, it s found that as one gets older the probability of conserving electricity associated with the use of fridge and iron reduces by 3% for rural households. Regarding urban households aging increases conservation with the use of light by about 2%. This suggests that younger people tend to embark on conservation activities in rural areas while the opposite holds in the urban areas. At the entire study area, aging has no effect on conservation actions. Scholars including Olsen (1983), Berry and Brown, (1988), Tonn and Brown (1988), Poortinga *et al*., (2003) and Sardianou (2007) have shown that the elderly have low energy conservation effect since among other things they have fewer years of formal education and also lack energy know-how. The evidence from rural households in this study offers support to the position held by these authors while that of the urban households contradicts their arguments.

The effect of increased household income is that it reduces the probability of general electricity conservation behaviour as well as actions regarding the usage of fridge in the study area. In the urban area, income has no significant effect on any of the dependent variables while in the rural areas, it reduces chances of conserving energy when households use refrigerator by 3% and radio-TV by 0.09%. According to Castaldi and Zoli (2012), people with low income tend to be more concerned about saving money from energy hence a negative relationship should be expected between income and households' actions to conserve energy. Such a situation can be the case for households in the study area when it comes to their total energy conservation; their usage of refrigerator and radio-TV; and rural households' energy savings through refrigeration and radio-TV activities. For urban households, no significant effect was recorded for income. In previous studies, Beaulieu and Miller (1984) observed negative effect of income for households in Florida while Hori et al. (2013) had a contrary evidence for Ho Chi Minh.

The high expenses made for using electricity also tends to increase electricity conservation behaviour for households in the urban and the entire study area. Paying more for using electricity makes one sensitive and energy conscious hence the positive effect it has on conservation. Our findings then contradict the findings of Sardianou (2007) for the Greek households. The insignificant effect electricity bill has on energy conservation for the rural households may be attributed to the subsidization policy by the government of

Ghana. The aim of the subsidization policy (which offers lower charges for electricity usage to rural households) has been to reducing wood fuel dependence among rural households. From an economic perspective, a high price level for goods and services leads to a low demand. Accordingly, because urban households pay more for electricity they will have a higher probability to conserve electricity by 13% for ironing, 3% for radio-TV and 16% for their general electricity conservation behaviour.

Castaldi and Zoli (2012) have posited that highly educated people are more likely to have better knowledge on conservation. Conversely, our results from the field show slight variations. The study observed that, additional year of education increases the probability of rural conservation practices when households use lights and iron respectively by 3% and 0.08%. On the other hand, additional year of education decreases the probability of electricity conservation behaviour among urban households regarding their radio-TV activities by 0.6%. It also decreases the conservation probability for using radio-TV by 5% in the entire study area. Thus, educated people in the rural areas conserve more electricity than educated urban households. It is quite surprising that the more educated urban households and those in the entire area become, the less electricity they conserve. Intuitively, one can assign the relatively low environmental concern recorded for urban households and lack of commitment to explain this outcome.

Consequently, an educated person with a low commitment and environmental concern on his part may not contribute positively to electricity conservation. On the other hand, owing to the high concern for the environment, educated rural households would be more committed to conserve electricity. The positive effect of education on electricity saving among rural households throws light on the position of Castaldi and Zoli (2012) that educated people most especially those with university degrees (Bachus and van Ootegem, 2011) are associated with having much concern for the environment. On the flip side, previous studies including Poortinga et al. (2003) have revealed relatively low educated people embrace behavioural measures capable of reducing energy usage more than highly educated people. The negative effect of education on the urban electricity conservation then gives support to such evidences recorded in previous studies.

Newer dwellings usually use less energy (Santin *et al*., 2009) and also have efficient energy installed wiring system. They are thus expected to help increase energy conservation. In this study we rather find older apartments increase the probability of rural households' conservation behaviour towards the usage of iron, radio-TV and their general conservation behaviour by 2%, 06% and 0.8% respectively. When it comes to the usage of radio-TV, older apartments increase conservation probability in the entire study area by 0.8%. The plausible explanation to support this finding lies in the fact that buildings per se cannot conserve electricity. It is rather the behaviour of the occupants of such buildings which matters most. Therefore, occupants of older households knowing that their apartments may lack efficient energy installed wiring system and for that matter may consume more energy to affect the environment or even pay for more electricity, would be more careful about the manner they use their electrical appliances. This may be the reason why older rural apartments increases conservation behaviour and the entire study area.

Again rural households with business that rely on electricity tend to lower the probability of energy saving behaviour towards lighting and ironing by 2% and 3% respectively while households in the urban centre with such business increases their probability for conserving electricity when using iron by 33%. Operating an electricitysupported business in the house has a higher chance of increasing the cost of using energy. This is a situation households may want to avert by conserving energy. The contradictory results between the urban and rural households could be explained in the following way. Rural households tend to have more subsidies for the utility bills which may make them conserve less energy when they have a business that relies on electricity in the house. On the other hand, urban households that have business which runs on electricity tend to conserve electricity at least when it comes to their usage of iron. This perhaps is to avoid payment of high electricity bills.

The more rooms available to households in both urban and rural areas increases their electricity saving through lighting activities and refrigeration and ironing for rural households. For rural households, having more rooms increases electricity conservation chance by 5% with the use of light and 1% with the use of refrigerator. It also increases the overall electricity saving probability through actions related to lighting by 6% and ironing by 2%. The reason for this is linked to the idea of conserving energy in order to pay less for energy. Thus the more rooms in an apartment, the greater the chances of paying more for using more energy. To reduce this, occupants of such apartments would tend to conserve electricity usage to pay less relatively by using energy efficient gadgets (Ritchie *et al.*, 1981; Walsh, 1989).

The more concern people have for the environment the more likely they will embark on practices that would be less harmful to the environment (Wang et. al., 2011b; Ek et al., 2010). Such actions include reducing energy consumption among other things through the use of energy efficient gadgets or intentionally using energy wisely. Environmental concern increases the probability for households in the study area conserve electricity when they use iron by 0.04%. Similar result is reported for urban households. This shows concern for the environment's effect is quite limited to ironing

activities although it increases the total electricity conservation in the study area and among urban households. One would have expected such a concern to positively affect conservation behaviour for majority of the appliances.

The fact that this paper did not register any significant effect of environmental concern for rural households falls in line with some previous empirical papers. For instance, Wang et. al., (2011b) did not find any significant effect of environmental concern on electricity conservation for households in Beijing, China. Poortinga et al. (2003: p. 61) obtained a counter intuitive results when they observed "…people with a high environmental concern evaluated measures with small energy savings as being relatively more acceptable than measures with a large amount of energy savings. The opposite applied to respondents with a low environmental concern ..." Other earlier studies including Sardianou (2007), Gadenne et al. (2011), Hori et al. (2013), Viklund (2004), Ek and Soderholm (2010) recorded significant effect of environmental concern on energy saving.

Also, we find that the probability of increasing electricity conservation increases with information. From the analysis, apart from increasing the overall tendency to conserve electricity, getting information on electricity conservation also positively influences energy saving activities for refrigeration by 0.3%, ironing by 1% and radio-TV by 7% in the study area. The role of information in the urban centre is also positive for the general conservation behaviour and all the appliances. Electricity conservation tendencies associated with refrigeration, ironing and radio-TV increases by 1%, 8% and 2% respectively when urban households' information on electricity conservation

increases. For the rural households information increases the tendency to conserve electricity associated with refrigeration by 0.09% and radio-TV by 32% and over all electricity conservation by 2%.

By having access to information on issues concerning energy saving, households' awareness of energy consumption and conservation issues get increased which then translates into higher energy conservation behaviour. The fact that information does not have a significant impact on the overall lighting in the study area suggests educational programmes and campaigns on energy conservation such as "the Efficient Lighting Project", "save a watt" and "the lamb project" by state agencies have not yielded results

for saving energy through ironing and lighting. According to He and Kua (2012) information put into the public domain which is not in the right form to capture attention and understanding may not yield the needed outcome.

That may be the case for households in the study area. Again being positive and significant for refrigeration and radio-TV activities in the study area and urban areas is not strange since campaigns to conserve energy in the country have focused on these appliances in recent times. Particularly, the current policy of exchanging old refrigerators and TV for a more energy efficient ones seems to have yielded positive results on energy conservation. As the results show, information significantly affects conservation behaviour for the entire four appliances in urban areas but only refrigeration and radioTV for rural households. It stands to reason therefore that the role of information has been more effective in the urban areas than rural areas. This situation could be as a result of the fact that urban dwellers may be much informed on conservation issues and more educated than rural dwellers. The positive effect of information on electricity saving behaviour compares favourably with previous studies (see Luyben, 1980; Sardianou, 2007; Wang et al., 2011b; Ek and Soderholm, 2010). Our findings however contradict the evidence by Castaldi and Zoli's (2012) of a negative effect of access to internet on energy conservation behaviour.

The effect of subjective norm is mixed in this study. It increases the probability of electricity conservation for overall refrigeration by 0.3%, ironing by 1% and radio-TV by 7% in the study area. Among rural households, subjective norm increases the likelihood of electricity saving behaviour towards lighting by 2%, ironing by 1% and refrigeration by 0.6% but reduce conservation likelihood with the use of radio-TV by 2%. On the other hand, subjective norm increases the probability of conserving electricity through lighting activities among urban households by 35%. The evidence that subjective norm generally has a positive effect on the energy conservation in this study corroborates the findings by Wang et al. (2011b). The authors however recorded no significant effect of social relations on conservation; a situation the authors attributed to the difficulties in observing other people's energy conservation behaviour. They again argued this outcome could be as a result of weaker interactions among people in recent times. For subjective norm to reduce conservation through radio-TV is quite odd and contradicts expectation.

Compared with other studies, Hori et al. (2013) recorded positive effect of this variable for rural households but the opposite for urban households. Generally, having a significant effect of subjective norm among rural households and no effect for urban households could be due to the communal living and mechanical solidarity that characterize rural areas contrary to the individualistic, complex and organic solidarity way of living at urban areas in the country. In a typical rural community where mechanical solidarity prevails, the sociologist Durkheim (1933) pinpoints there are common values and beliefs that on the inside of members make them corporative. The opposite is the case for urban areas where the bond among members is generally loose.

Expected benefit from electricity conservation causes rural households to reduce the chance of electricity conservation associated with refrigeration by 1% and ironing by 8%. In the case of urban households, perceived benefit increases the chance of electricity conservation associated with ironing by 2% and 6% for radio-TV activities in the entire study area. The negative effect perceived benefit has on conserving energy through refrigeration can be attributed to the fact that individuals hoping to pay less electricity bill thereby getting more money could have less concern about energy conservation.

In the nutshell, we find that being a resident in rural area generally increases the probability of electricity conservation regarding the usage of fridge, iron and radio-TV by 2%, 5%, and 74% respectively. The probability of increasing the overall electricity conservation increases by 2% for rural households. This situation could be as a result of the fact that rural households may be much concerned about the environmental effect of excessive energy use as well as their low level of income which tends to make them conserve energy in order to save money.

Table 5.7 Ordered Probit estimation for rural households

Variable	Lighting		Refrigeration		Ironing		Radio-TV		Total	
	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects
Male Head HH	0.4169* (0.2146)	0.1575* (0.0879)	0.3122 (0.2294)	0.0341 (0.0679)	-0.0951 (0.2196)	0.0042 (0.7219)	0.0495 (0.2147)	0.0648 (0.0639)	0.4498** (0.2287)	0.0949* (0.0547)
Age	-0.0090 (0.0098)	0.0059 (0.0059)	-0.1108* (0.0614)	0.0103 (0.0178)	-0.1909*** (0.05838)	-0.0334** (0.0144)	-0.0038 (0.0101)	-0.0112 (0.0222)	-0.0271** (0.0114)	-0.0238 (0.0222)
Household size	-0.0052 (0.0270)	-0.0097 (0.0069)	-0.0406 (0.0432)	-0.0103 (0.0087)	-0.0383 (0.0270)	-0.0117 (0.0098)	0.0262 (0.0281)	-0.0004 (0.0065)	-0.0240 (0.0427)	0.0032 (0.0044)
Years of education	0.0802*** (0.0309)	0.0309** (0.0135)	-0.0017 (0.0342)	-0.0084 (0.0099)	0.0616* (0.0325)	0.0089 (0.0106)	-0.0230 (0.0306)	-0.0088 (0.0097)	0.0470 (0.0352)	-0.0056 (0.0077)
Income	-0.0988 (0.1297)	0.00113 (0.0393)	-0.3100** (0.1450)	-0.0290* (0.0143)	-0.1632 (0.1340)	0.0178 (0.0517)	-0.2231* (0.1314)	0.00964 (0.0502)	-0.1789 (0.1460)	0.0722 (0.0684)
Electricity bill	-0.1540 (0.1235)	-0.0588 (0.0401)	0.0620 (0.1348)	-0.0075 (0.0444)	0.1408 (0.1286)	0.0071 (0.0468)	0.0523 (0.1257)	-0.0075 (0.0432)	0.0322 (0.1350)	-0.0729 (0.0543)
Occupancy type	0.1391 (0.2315)	0.0050 (0.0733)	-0.4039 (0.2531)	-0.1199 (0.0836)	-0.3835 (0.2419)	0.0830 (0.0061)	-0.1303 (0.2321)	-0.0212 (0.0779)	-0.2573 (0.2532)	-0.1371 (0.1072)
Log likelihood	-265.96		-217.29		-245.56		-270.06		-285.86	
Chi square	43.05		42.30		49.53		31.08		56.28	

Note: For marginal effects, Prob ($q_i = 7$), ***, **, * respectively represents 1%, 5% and 10% level of significance; standard error in parenthesis

Table 5.7 Continued: Ordered Probit estimation for rural households

Variable	Lighting	Refrigeration	Ironing	Radio-TV	Total

	Coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects
Number of rooms	0.1322*** (0.0491)	0.0504** (0.0234)	0.1136* (0.0610)	0.0107* (0.0078)	0.0910* (0.0510)	0.0174 (0.0199)	-0.0176 (0.0485)	0.0171 (0.0148)	0.1403** (0.0622)	0.0127 (0.0176)
Apartment age	0.0010 (0.0050)	0.0015 (0.0017)	-0.0021 (0.0084)	0.0026 (0.0023)	0.0129* (0.0054)	0.0228* (0.0012)	0.0128** (0.0059)	0.0066** (0.0135)	0.0276*** (0.0084)	0.0081* (0.0047)
Electricity business	- 0.4603** (0.2155)	-0.0186* (0.0909)	-0.2143 (0.2334)	0.0262 (0.0646)	-0.4593** (0.2202)	-0.0265* (0.0109)	-0.1957 (0.2160)	0.01220 (0.0653)	-0.3887* (0.2340)	-0.0993* (0.0566)
Environmental concern	-0.0287 (0.0225)	-0.0229 (0.0207)	-0.0359 (0.0265)	-0.0085 (0.0.226)	0.0109 (0.0235)	-0.0081 (0.0241)	-0.0278 (0.0229)	-0.0027 (0.0214)	-0.0315 (0.0262)	-0.0043 (0.0059)
Information awareness	0.0138 (0.029)	0.0068 (0.0235)	0.0752** (0.0377)	0.0090* (0.0051)	0.0051 (0.0339)	0.0079 (0.0324)	0.0993*** (0.0310)	0.3212** (0.0178)	0.0644* (0.0384)	0.0189* (0.0107)
Benefit	-0.0419 (0.0423)	0.0068 (0.0234)	-0.1064** (0.0466)	-0.0135* (0.0072)	-0.0508 (0.0426)	-0.0795* (0.0480)	0.0409 (0.0416)	0.0138 (0.0264)	-0.0451 (0.0465)	0.0132 (0.0105)
Subjective norm	0.0488** (0.0231)	0.0186* (0.0096)	0.0580** (0.0251)	0.0060* (0.0022)	0.0410*** (0.0242)	0.0114 (0.0232)	-0.0576** (0.0240)	-0.0186* (0.0096)	0.0615** (0.0264)	0.0095 (0.0071)
Log likelihood	-265.96		-217.29		-245.56		-270.06		-285.86	
Chi square	43.05		42.30		49.53		31.08		56.28	

Note: For marginal effects, Prob (q_i = 7), ***, **, * respectively represents 1%, 5% and 10% level of significance; standard error in parenthesis

Table 5.8 Ordered Probit estimation for urban households

Variable	Lighting	Fridge	Ironing	Radio-TV	Total

	coefficient	Marginal	coefficient	Marginal	coefficient	Marginal	coefficient	Marginal	coefficient	Marginal
		coefficient		Marginal effects	effects	effects	effects	effects		
Male Head HH	-0.1549 (0.1777)	-0.3133 (0.0650)	0.0900 (0.1774)	-0.0366 (0.7361)	0.1487 (0.1782)	0.047 (0.7045)	-0.3685** (0.1786)	-0.0509** (0.0264)	-0.08825 (0.1769)	-0.0350 (0.0566)
Age	0.0829* (0.0471)	0.0168** (0.0102)	0.0017 (0.0088)	0.0068 (0.0185)	0.0093 (0.0087)	-0.0048 (0.01838)	-0.0104 (0.0088)	0.0053 (0.0181)	0.0800* (0.0461)	0.0227* (0.0126)
Household size	0.0261 (0.0455)	-0.0226 (0.0161)	0.0556 (0.0454)	-0.0033 (0.0189)	-0.0697 (0.0461)	0.0261 (0.0455)	-0.0194 (0.0454)	0.0126 (0.0190)	0.0035 (0.0452)	0.0027 (0.0151)
Years of education	0.0028 (0.0257)	0.0084 (0.0089)	0.0057 (0.0259)	-0.0044 (0.0109)	0.0333 (0.0257)	0.0053 (0.0098)	-0.0531** (0.0260)	-0.0067* (0.0038)	-0.0039 (0.2555)	-0.0019 (0.0083)
Income	-0.0864 (0.1258)	-0.0338 (0.0424)	-0.0846 (0.1259)	-0.0753 (0.0512)	-0.0162 (0.1248)	-0.0421 (0.0508)	-0.0895 (0.1255)	-0.0288 (0.0479)	-0.1585 (0.1250)	-0.0829 (0.0371)
Electricity bill	0.0991 (0.1207)	0.0482 (0.0986)	0.0764 (0.1202)	0.0458 (0.0871)	0.1788 (0.1204)	0.1259** (0.5139)	0.2487** (0.1209)	0.0349* (0.0175)	0.2895** (0.1213)	0.1615*** (0.0408)
Occupancy type	-0.0922 (0.0982)	-0.0600 (0.0943)	-0.0741 (0.0974)	-0.0411 (0.0390)	-0.0601 (0.0975)	0.0082 (0.5218)	0.0305 (0.0975)	0.1860* (0.0800)	-0.0899 (0.0972)	-0.0580* (0.0305)
Log likelihood	-352.49		-363.63		-356.36		-366.96		-363.05	
Chi square	33.20		21.75		59.12		31.75		21.75	

Note: For marginal effects, Prob ($q_i = 7$), ***, **, * respectively represents 1%, 5% and 10% level of significance; standard error in parenthesis

Table 5.8 Continued: Ordered Probit estimation for urban households

Variable	Lighting		Fridge		Ironing		Radio-TV		Total	
	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects

Number of rooms	0.0442* (0.0242)	0.0129** (0.0069)	0.0194 (0.0239)	0.0115 (0.0348)	0.0145 (0.0241)	0.0187 (0.0144)	-0.0370 (0.0241)	-0.0010 (0.0107)	0.0279 (0.0240)	0.0045 (0.0100)
Apartment age	0.0081 (0.0103)	0.0703 (0.0041)	-0.0015 (0.0125)	0.0034 (0.0040)	-0.0043 (0.0103)	0.00017 (0.0040)	-0.0041 (0.0104)	-0.0021 (0.0039)	0.0013 (0.0102)	0.0026 (0.0036)
Electricity business	0.1399 (0.1355)	0.1055 (0.0795)	-0.0295 (0.1352)	-00578 (0.0625)	0.3372** (0.1449)	0.3300** (0.1452)	-0.0564 (0.1349)	-0.0821 (0.0525)	0.1645 (0.1350)	0.0229 (0.0812)
Enviro nmental concern	0.0269 (0.0182)	0.0075 (0.0191)	0.0051 (0.0182)	0.0216 (0.0227)	0.0521*** (0.0184)	0.0595*** (0.0210)	0.0077 (0.0182)	0.0084 (0.0210)	0.0435** (0.0184)	-0.0006 (0.0057)
Information awareness	0.0470* (0.0275)	0.0156 (0.0093)	0.0524* (0.0275)	0.0100** (0.0031)	0.0839*** (0.0277)	0.0817*** (0.0337)	0.0510* (0.0273)	0.0231* (0.0123)	0.1044*** (0.0278)	0.0257*** (0.0094)
Benefit	0.0382 (0.0303)	0.0274 (0.0195)	0.0161 (0.0300)	0.0225 (0.0442)	-8.4E-05 (0.0302)	0.0060 (0.0236)	0.1081* (0.0308)	0.0157* (0.0052)	0.4576 (0.0205)	0.0032 (0.0087)
Subjective norm	0.0217 (0.0207)	0.3521* (0.0210)	0.0207 (0.0207)	-0.0111 (0.0258)	-0.0233 (0.0207)	-0.0166 (0.0249)	-0.0068 (0.0206)	-0.0017 (0.0244)	0.1255 (0.0556)	-0.0027 (0.0067)
Log likelihood	-352.49		-363.63		-356.36		-366.96		-363.05	
Chi square	33.20		21.75		59.12		31.75		21.75	

Note: For marginal effects, Prob ($q_i = 7$), ***, **, * respectively represents 1%, 5% and 10% level of significance; standard error in parenthesis

Table 5.9 Ordered Probit estimation for the entire study area

Variable	Lighting		Fridge		Ironing		Radio-TV		Total	
	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects

Male Head HH	0.0878 (0.1310)	0.0361 (0.0478)	0.1629 (0.1342)	-0.0205 (0.0522)	0.0861 (0.1319)	0.0410 (0.0528)	-0.2221* (0.1331)	-0.0298 (0.0499)	0.1108 (0.1343)	0.0215 (0.0388)
Age	-0.0016 (0.0062)	0.00299 (0.0105)	0.0020 (0.0063)	0.0052 (0.0112)	0.0055 (0.0062)	-0.0084 (0.0138)	0.0008 (0.0062)	0.0012 (0.0117)	0.0016 (0.0063)	0.0140 (0.0079)
Household size	-0.0013 (0.0220)	-0.0034 (0.0221)	0.0201 (0.0276)	-0.0105 (0.0075)	-0.0404* (0.0220)	-0.0040* (0.0023)	0.0178 (0.0226)	0.0021 (0.0087)	0.0035 (0.0276)	-0.0032 (0.0071)
Years of education	0.0214 (0.0187)	0.0062 (0.0066)	-0.0041 (0.0193)	-0.0037 (0.0087)	0.0171 (0.0190)	0.0110 (0.0096)	-0.0535*** (0.0190)	-0.0531** (0.0191)	-0.0032 (0.019)	-0.0044 (0.0057)
Income	-0.0253 (0.0839)	0.0360 (0.0303)	-0.1560* (0.0889)	-0.0076 (0.0053)	-0.0826 (0.0848)	-0.0325 (0.0350)	-0.1337 (0.0846)	-0.0219 (0.0851)	-0.1946** (0.087)	-0.0465* (0.0273)
Electricity bill	-0.0381 (0.0800)	0.0032 (0.0272)	0.0824 (0.0820)	0.048 (0.0313)	0.1822** (0.0817)	0.0817** (0.0008)	0.2142*** (0.0811)	0.2149*** (0.0812)	0.2151*** (0.0822)	0.0774** (0.0254)
Occupancy type	-0.0537 (0.0846)	-0.0338 (0.0269)	-0.1595* (0.0860)	-0.0481 (0.0312)	-0.0978 (0.0848)	-0.0115 (0.0419)	-0.0038 (0.0843)	0.0720 (0.0545)	-0.1108 (0.0857)	-0.0579** (0.0232)
Log likelihood	-641.51		-606.32		-645.45		-663.61		-13.33	
Chi square	50.40		50.03		62.29		44.09		25.85	

Note: For marginal effects, Prob ($q_i = 7$), ***, **, * respectively represents 1%, 5% and 10% level of significance; standard error in parenthesis

Table 5.9 Continued: Ordered Probit estimation for the entire study area

Variable	Lighting		Fridge		Ironing		Radio-TV		Total	
	Coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	coefficient	Marginal effects	Coefficient	Marginal effects

Number of rooms	0.0577*** (0.0207)	0.0231** (0.0098)	0.0386* (0.0215)	0.0021 (0.0013)	0.0471** (0.0208)	0.0234** (0.0112)	-0.0377* (0.0207)	-0.0375* (0.0207)	0.0474** (0.0217)	0.0085 (0.0079)
Apartment age	0.0012 (0.0043)	0.0010 (0.0015)	-0.0062 (0.0059)	-0.0003 (0.0004)	0.0083* (0.0035)	0.0079* (0.0020)	0.0078*** (0.0046)	0.0079* (0.0086)	0.0111* (0.0061)	0.0004 (0.0014)
Electricity business	-0.0898 (0.1070)	-0.0234 (0.0370)	-0.0627 (0.1092)	-0.0271 (0.0413)	0.1233 (0.1100)	0.0109 (0.0111)	-0.0233 (0.1072)	-0.0761 (0.0385)	0.0030 (0.1089)	0.0795 (0.0434)
Environmental concern	0.0116 (0.0137)	-0.0010 (0.0145)	-0.0089 (0.0143)	0.0144 (0.0161)	0.0398*** (0.0140)	0.0042** (0.0016)	0.0003 (0.0138)	0.0082 (0.0149)	0.0626 (0.0433)	0.0008 (0.0040)
Information awareness	0.0207 (0.0195)	-0.0027 (0.0202)	0.0542*** (0.0209)	0.0036*** (0.0018)	0.0399** (0.0202)	0.0129** (0.0066)	0.0677*** (0.0198)	0.0680** (0.0198)	0.0724*** (0.0211)	0.0173** (0.00600)
Benefit	0.0091 (0.0236)	0.0257 (0.0156)	-0.0194 (0.0245)	0.0142 (0.0178)	-0.0024 (0.0239)	-0.0087 (0.0176)	0.0579** (0.0236)	0.0576** (0.0237)	0.0272 (0.0245)	0.0053 (0.0063)
Subjective norm	0.0463*** (0.0146)	0.0378** (0.0150)	0.0426*** (0.0150)	0.0062** (0.0031)	0.0143 (0.0147)	0.0019 (0.0188)	-0.0810** (0.0148)	-0.0184* (0.0062)	0.0390** (0.0151)	0.0033* (0.0019)
Location (1 for rural 0 for urban)	0.1812 (0.1495)	0.0206 (0.0171)	0.2919* (0.1537)	0.0153 (0.0152)	0.4610*** (0.1506)	0.0461*** (0.0176)	0.4661*** (0.1482)	0.7435*** (0.1574)	0.52008*** (0.1547)	0.0170** (0.0077)
Log likelihood	-641.51		-606.32		-645.45		-663.61		-13.33	
Chi square	50.40		50.03		62.29		44.09		25.85	

Note: For marginal effects, Prob ($q_i = 7$), ***, **, * respectively represents 1%, 5% and 10% level of significance; standard error in parenthesis

5.5 Conclusion and policy implications

This chapter has examined the determinants of electricity conservation behaviour for urban and rural households in the Ashanti region of Ghana. The study was partly motivated by the fact that despite the electricity crises facing the Ghanaian economy, available records indicate a high level of inefficient usage of power. This could imply past efforts to ensure energy conservation has not yielded better results for the country. Moreover, previous studies on energy conservation have not captured enough on the differences in the drivers of energy conservation among rural and urban households. An analysis of the data sampled shows rural households tend to have stronger conservation behaviour than their urban counterparts. Our estimation results from the ordered probit model show energy conservation is a complex issue in modern society.

It was found some elements of demographical features, dwelling characteristics, environmental concern, information, subjective norms and perceived benefit play different vital roles in the electricity conservation outcome of the respondents towards the use of different appliances among rural and urban households. For instance, income was identified to reduce conservation of electricity among rural households when they use refrigerator. Income was found to also reduce conservation behaviour for the entire study area but with the urban households no significant effect was recorded. On education, we also found it increases lighting and ironing conservation for rural households but reduces urban households' conservation when they use radio-TV. However, information increased conservation for both rural and urban households.

While environmental concern did not significantly affect conservation among rural households it significantly affected urban conservation through ironing. Our study also showed that the effect of subjective norm was more prevalent in the rural areas than urban areas. Perceived benefit was found to reduce the tendency for rural households to conserve energy when using refrigerator but increased conservation practices for the entire study area towards the usage of radio-TV.

The findings in the paper offer some policy implications. Specifically the paper implies increasing the educational level of rural households in the study area to enhance energy conservation. It also suggests the need to create more awareness by having more educational campaigns on conservation for the households in the study area. In recent times such campaigns have increased. However, in doing so, the information put out in the public should be clearer, understandable, convincing enough and appliance specific. The appliance specific aspect of the energy conservation campaigns needs more emphasis.

Influential family members and role models in these areas should be involved in the conservation campaign to help increase electricity conservation. In addition, weight should be placed on social interactions in the study area to ensure high conservation behaviour. Also the results highlight the need to have different conservation measures tailored towards the usage of different appliance in the study area. More so, it is important that the high income earners in the study area are educated more on the electricity conservation.

In conclusion, since energy conservation is a complex phenomenon, the results in the study have captured the need to have policies or measures that take into account the location characteristics of households. Also such policies should be tailored for specific electrical appliance. Although the paper is limited to households in the Ashanti Region of Ghana, regions that shares similar features with it, can equally rely on the outcome of the study.

CHAPTER SIX

SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

6.1 Introduction

This chapter presents a summary, conclusion and policy implications of the thesis. In all, the thesis has sought to examine the determinants of energy consumption, energy conservation and carbon emission in selected countries of SSA. Owing to the fact that the worrying rising trend of CO_2 is seen to be relating directly with income growth, trade and energy consumption in the sub region, the thesis investigated into the effects of income, trade and energy consumption on CO_2 in SSA. Moreover, the study analyzed the drivers of fossil fuel consumption for Ghana, Kenya and South Africa on the backdrop that consumption of fossil fuel in these countries has been increasing with associated challenges.

Further, because Ghana's electricity supply is currently not sufficient to meet the rising demand amidst inefficient usage, the thesis also ascertained the determinants of households' electricity conservation behavior for rural and urban households in the Ashanti Region of the country. The summary, findings and policy implication of each of the three component studies are presented in the subsequent sections of this chapter.

6.2 Effect of Income, Trade, and Energy consumption on Carbon emissions In Chapter three, we examined the emission effects of income, trade and energy consumption on carbon emission in Sub-Saharan Africa. This is as a result of the fact that the rising trend in the emission of green house gases (GHG) especially carbon dioxide from the SSA sub region in recent times suggest a serious future implication because of its effect on climate change which the region is vulnerable to. The trend of carbon emission on the continent has been rising with income, trade and energy consumption. To this end, it becomes necessary to empirically examine the effects of income, energy consumption and trade on carbon dioxide emissions on SSA. The study used crosscountry panel data for 19 SSA countries (Benin, Botswana, Burkina Faso, Cameroon, Congo Democratic Republic, Congo Republic of Brazzaville, Cote D'lvoire, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, Sudan, South Africa, Tanzania, Togo, Zambia and Zimbabwe) for the period 1977-2012. The data were analysed using the panel cointegration fully modified OLS (FMOLS) developed by Pedroni (2000) and an extension of Stock and Watson (1993) DOLS.

The results showed that energy consumption, urbanization and industrialization were found to positively contribute to CO_2 emission. The EKC hypothesis was confirmed with a turning point income level of about US$ 1,142.85 to US$ 5,687.09 for the region. Further, a potential non linear relationship was established between trade openness and emission of carbon dioxide. This chapter makes some contributions to the literature. First of all, majority of the previous studies of carbon emission in the region have relied mainly on time series with short data span nature which tend to impair results for individual country studies. A panel data estimation procedure as used in this study is more useful. More so, most of the extant studies on emission do not control for income, trade and energy consumption in a single regression. However, since the potential effect of trade, income and energy are closely related and a possible feedback among them is well documented in the literature, an omission of one of these variables from the emissions equation can result in an upwards bias of the estimated effect of income on emissions. The chapter caters for this gap in the literature.

Also, the non linear relationship between income and emission has been widely tested empirically but not for emission and trade. This study utilizes the theoretical argument of the potential nonlinearities in the relationship between trade and emissions. Policy implications of the results include the need to increase the region's income level and trade openness so as to help reduce emission in the sub region in the long run. Also, energy efficient measures need to be put in place help reduce carbon emission in the region.

6.3 Drivers of Fossil Fuel Consumption in Ghana, Kenya and South Africa In Chapter four, the thesis investigates the driving force of fossil fuel consumption in three Sub-Saharan Africa countries, namely Ghana, Kenya and South Africa. The chapter argues that Ghana, Kenya and South Africa are among the SSA countries whose consumption of fossil fuel is high and/or is rising. However, these countries are unable to meet their fossil energy demand requirement. In addition, the rising trend in fossil fuel consumption contributes to the greenhouse gases (GHG) that affect global warming and climate change whose effect Sub-Saharan African countries are vulnerable to. In order to address these challenging issues, there is a need to have knowledge of the determinants of fossil energy consumption so as to provide information to the public and policy makers to improve their demand management. As a result, the study modelled the drivers of fossil fuel consumption for the three countries.

At the macro level, this study differs from previous ones that looked only at the income and price elasticities of fossil fuel consumption. Because both residential and non residential sectors of the economy use energy, the study argues the need to include other explanatory variables in the fossil fuel consumption model. The role of the service sector towards energy consumption which has been ignored in the energy consumption literature was factored in this study.

Results from the ADF and PP tests indicated that all variables were non stationary at their levels, however, all become stationary based on their first difference rendering the variables as integrated of the order one or I(1) for all three countries under study. The ZA test on the other hand, established all the variables as I(0). In addition, the EngelGranger and Phillip-Ouliaris tests confirmed the existence of a long run relationship among the variables for each country. Findings from the FMOLS and CCR estimations indicate that industrial efficiency, income, trade, efficiency of the service sector and urbanization significantly affect fossil energy consumption in Ghana with the efficiency of the industrial and service sectors having the negative coefficients. For Kenya trade, service efficiency and price were found to reduce consumption while urbanization, industrial efficiency and income were found to increase consumption of fossil fuel. The South Africa's fossil fuel consumption was found to increase with increasing income, urbanization and industrial efficiency but reduced by trade and service efficiency.

Findings from a panel estimation however showed that price, industrial efficiency, service sector efficiency, trade and urbanization affects fossil fuel consumption is the SSA sub region with price having a positive effect and urbanization a negative effect. The policy implications from this study suggest efforts should be geared towards strengthening the energy efficiency system in each of these countries as income has significant effect on fossil consumption. Also adequate measures should be put in place to decentralize economic related activities and growth to reduce the population pressure in the urban centers so as to manage the high level of fossil fuel consumption in such urbanized areas. In addition, the urban populace needs to be educated on energy efficiency. The impact of trade suggests each country needs to factor the effect trade openness has on fossil fuel consumption in their trade liberalization discussions. Specifically, it is essential that tariff and non-tariff barriers on products that do not promote energy efficiency are raised and vice versa. At the industrial level, energy efficiency needs to be promoted in Ghana to help reduce the amount of fossil fuel consumed for production activities. Again, in the case of South Africa and Kenya, more education is needed in order to make the industrial sector reduce the consumption of fossil fuel as their efficiency increases. The contradictory results found between the time series and panel estimations especially for price and urbanization calls for future studies to use different proxies for price and urbanization.

6.4 Electricity Conservation Behavior

Chapter five focuses on households' electricity conservation behavior in rural and urban Ghana. The case of the chapter is that the country has experienced about several major electricity power crises since the 1980s with various reasons assigned to them. The first crises took place in 1983/1984, followed by the second and third respectively in 1998 and 2002. The forth one was in 2006/2007 and the recent one started from late 2012 to 2016.

The World Bank has indicated that the nation will not be able to meet its peak demand for electricity with the current existing and committed plants and thus suggests in the next ten years, Ghana needs an additional 1,560 MW of dependable generation capacity from new projects to respond swiftly to the projected demand for electricity.

Notwithstanding this challenge, energy is not put to efficient. The Ministry of Energy (2010) indicates that about 30% of electricity supplied to consumers is wasted as a result of inefficient electrical equipment, poor attitude towards energy conservation and theft. The government of Ghana has since then targets a 10% savings in electricity consumption through the implementation of comprehensive electrical power efficiency and conservation measures. Using such public campaigns as a form of energy-saving measure can be more effectively undertaken if the determinants of the conservation behaviour are known. Owing to lack of empirical study on the subject matter, the paper investigated households' electricity conservation behavior.

A survey was carried out in Ashanti region of Ghana. The analysis of the survey data shows that rural households tend to have a stronger conservation behavior than their urban counterparts. Also, estimation results from the ordered probit model show some elements of demographical features, dwelling characteristics, environmental concern, information awareness, subjective norm and perceived benefit play different vital roles in the electricity conservation outcome of the respondents towards the use of different appliances. This chapter also contributes to energy conservation literature as it provides evidence from both rural and urban households regarding the determining factors of their electricity conservation for using certain electrical appliances. The findings in the paper offer some policy implications. These include the need to increase educational levels of householders in the study area; the need to have more educational campaigns on conservation for the households in the study area; and the need to involve family members and role models in the conservation campaigns. Also the results highlight the need to have different conservation measures tailored towards the usage of different appliance in the study area. Policy measures also need to take into account the location characteristics of households.

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Appendix 1: Multicollinearity tests for Ghana

Eigenvalues	0.035973	0.000233	0.000186	5.14E-05	1.05E-05	1.48E-06	6.22E-09
Condition	1.73E-07	2.67E-05	3.35E-05	0.000121	0.000593	0.004211	1.000000
Variance Decomposition Proportions				*Associated Eigenvalue*			
Variable	1	2	3	4	5	6	7
lnF	0.464281	0.000553	0.294717	0.055673	0.179784	0.004966	2.59E-05
lnP	0.000408	0.430910	0.306157	0.248377	0.014120	2.66E-05	1.72E-06
lnY	0.278597	0.002559	0.647016	0.070967	0.000662	0.000198	8.42E-07
lnT	0.469351	0.294024	0.106546	0.114828	0.014236	0.000965	4.98E-05
lnU	0.520549	0.020683	0.345562	0.035929	0.019996	0.057245	3.56E-05
lnN	0.477009	0.497768	0.016689	0.005626	0.002853	5.28E-05	1.96E-06
lnF	0.021727	-0.009317	0.240751	-0.199087	0.791422	-0.350629	0.390584
lnP	-0.001067	-0.430586	0.406356	-0.696378	-0.367299	0.042512	0.166766
lnY	0.038550	0.045895	-0.817048	-0.514841	0.109998	0.160315	0.161176
lnT	0.030423	-0.299103	-0.201589	0.398176	-0.310142	-0.215224	0.753605
lnU	-0.017179	0.042535	0.194659	0.119423	0.197084	0.888961	0.341538
lnN	0.066811	0.847778	0.173803	-0.191998	-0.302467	-0.109697	0.325912
C	-0.998304	-0.043625	0.009690	-0.020753	0.007676	0.005402	-0.029540

C	0.999980	1.57E-05	3.17E-06	9.95E-07	3.72E-08	3.91E-08	5.00E-10

Eigenvectors

Associated Eigenvalue

Variable	1	2	3	4	5	6	7
lnF	-0.013068	0.054999	0.031639	-0.140263	0.612933	-0.719101	-0.288681
lnP	-0.018598	0.041490	0.228089	0.959915	0.057298	-0.074693	-0.124938
lnY	0.088183	0.097115	-0.937477	0.208933	0.201353	0.122820	-0.068177
lnT	-0.069701	0.195638	-0.161559	-0.025102	-0.719432	-0.396268	-0.505496
lnU	-0.151006	0.862141	0.155859	-0.090847	0.186137	0.341667	-0.223566

lnN	0.135300	-0.406663	0.099338	-0.079371	0.159277	0.430309	-0.767865
C	-0.972492	-0.197197	-0.088597	0.007336	0.053747	0.057445	-0.035800

Variable 1 2 3 4 5 6 7

Appendix 2: Multicollinearity tests for Kenya

Eigenvalues	0.025261	0.003680	0.000746	7.74E-05	1.62E-05	3.63E-06	6.33E-10
Condition	2.51E-08	1.72E-07	8.48E-07	8.18E-06	3.92E-05	0.000174	1.000000

Variance Decomposition Proportions

Associated Eigenvalue

Variable	1	2	3	4	5	6	7
lnF	0.168098	0.433818	0.029099	0.059338	0.236518	0.073126	2.05E-06
lnP	0.069745	0.050574	0.309790	0.569306	0.000423	0.000162	7.88E-08
lnY	0.220506	0.038965	0.735940	0.003793	0.000735	6.15E-05	3.30E-09
lnT	0.420229	0.482347	0.066672	0.000167	0.028633	0.001951	5.54E-07
lnU	0.172908	0.821165	0.005440	0.000192	0.000168	0.000127	9.49E-09
lnN	0.428174	0.563557	0.006816	0.000451	0.000379	0.000622	3.45E-07
C	0.993800	0.005954	0.000244	1.73E-07	1.94E-06	4.98E-07	3.37E-11

Eigenvectors

Associated Eigenvalue

Appendix 3: Multicollinearity tests for South Africa

Eigenvalues	6.559776	0.025092	0.001603	9.85E-05	2.81E-05	7.97E-06	1.50E-09
Condition	2.29E-10	5.98E-08	9.36E-07	1.52E-05	5.34E-05	0.000188	1.000000
Variance Decomposition Proportions							
			Associated Eigenvalue				
Variable	1	2	3	4	5	6	7
lnF	0.096513	0.438271	0.463043	0.001481	0.000621	7.15E-05	4.85E-08
lnP	0.995087	0.004905	7.84E-06	2.98E-08	1.84E-07	2.81E-12	1.22E-12
lnY	0.044363	0.076870	0.465290	0.404916	0.007078	0.001484	3.11E-07
lnT	0.082670	0.010577	0.077735	0.480467	0.063963	0.284580	7.58E-06
lnU	0.659763	0.137302	0.186843	0.003076	0.009919	0.003094	1.87E-06
lnN	0.000571	0.624364	0.335321	0.005346	0.034187	0.000210	5.12E-07
C	0.997390	0.002605	4.64E-06	1.74E-08	9.47E-08	8.17E-11	9.81E-13
Eigenvectors							
			Associated Eigenvalue				
Variable	1	2	3	4	5	6	7
lnF	0.006184	0.213070	0.866493	0.197685	-0.239636	0.152710	0.289703

lnP	0.649384	-0.737139	0.116579	0.029003	-0.135006	0.000990	0.047616
lnY	0.001157	-0.024628	0.239730	-0.902291	0.223280	-0.192006	0.202664
lnT	-0.000513	-0.002964	0.031795	0.318923	0.217801	-0.862872	0.324472
lnU	0.006850	-0.050523	-0.233182	0.120709	0.405729	0.425643	0.763327
lnN	-0.000216	0.115285	-0.334262	-0.170283	-0.805999	-0.118543	0.426961
C	-0.760403	-0.628307	0.104943	0.025924	-0.113168	0.006245	0.049865

APPENDIX 4: Questionnaire

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF ECONOMICS

QUESTIONNAIRE FOR A SURVEY ON HOUSEHOLDS ENERGY CONSERVATION BEHAVIOR IN GHANA

This research instrument is designed to study household energy conservation behaviour in Ghana. Your response would serve as an input for research purposes. Therefore it is requested that you answer the following questions as candidly as possible. The information you provide will be treated with the strictest confidentiality. Thank you.

A. Demographical and dwelling apartment features

1. Gender of respondent a) Male b) Female
2. Age of respondent ……………………….
3. Occupation ……………………………………………………..
4. What is the household size ………………………………..
5. What is the level of education.

a) No formal Education b) Primary c) JHS/Middle sch d) SHS d) Tertiary

6. What is the total number of years you have spent on schooling? ....

7. What is the average monthly income (GH¢) for the family

a) 0-100 b) 101 –300 c)301- 600 d) 601- 1200
e)1201 – 2000 f) 2001-3000 g) above 3000

8. What is the average household expenditure for the month in GH¢?

a) 0-100 b) 101 –300 c)301- 600 d) 601- 1200
e)1201 – 2000 f) 2001-3000 g) above 3000

7. You occupy the apartment as a/an a) Tenant b) Owner 8. How many rooms do you have in your apartment? …………………

9. How old is the building apartment? …………………………..

10. Do you have any business in the house that rely on electricity a) Yes b) No

11.How much on the average have you paid as electricity bill for the past three months?

B. Conservation behavior

For each of the following activities rank from 1 (not completely true) to 4 (cannot tell) to 7 (completely true) about you.

Behaviour	**Rank**
LIGHTING	
13. Usually turn off light when not needed or no one is in the room	
14. Prefer to buy and use compact fluorescent bulbs	
15. Use one large bulb to serve an area instead of many	
TELEVISION AND RADIO	
16. Dislike allowing TV and radio on when no one is watching or listening	
17. Prefer to watch one TV and listen to one radio with family	
18. Always switch off the main power off	
FRIDGE/REFRIGERATOR	

19.Do adjust the regulator to suit the temperature of the day	
20.Always wait for hot foods to cool before putting it in the fridge	
21.Conscious of not leaving the fridge door open ajar	
22.Switching off refrigerator in the nite	
IRONING	
23.Avoid piecemeal ironing	
24.Avoid wrinkling of clothes before ironing	
25.Avoid ironing wet clothes	

C. Influential factors and energy conservation

For each of the following activities indicate from 1 (not completely true) to 4 (cannot tell) to 7 (completely true) about you towards energy saving

Attitude 1: environmental concern	
28. You are worried about climate change:	
You worried about global warming	
30.Believe energy usage affect the atmosphere	
Attitude 2: Information awareness	
You are informed about methods of electricity saving	
32. You have information on energy saving policy	
You have understanding of energy efficiency labels	
Perceived benefit	
34. You save energy because it can lead to low electricity bill	

You save energy because it can make appliance last longer	
Subjective norms	
36. Family members behaviour influence you to save energy	
Friends behavior influence you to conserve energy	
38. Opinion leaders influence you to conserve energy	