UNIVERSITY OF CAPE COAST

ANALYSIS OF HOUSEHOLD ENERGY CONSUMPTION IN GHANA

BY

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DECLARATION

Candidate's Declaration

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

Candidate's Signature: ………………………….. Date…………………

Name: Christian Kyeremeh

Supervisors' Declaration

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

Principal Supervisor's Signature……………… Date……………………

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ABSTRACT

Household energy consumption and its related issues have received considerable attention in recent times. However, the bulk of research has focused on macro perspective using times series data and methods. Empirical research using micro level data is limited. This study therefore examines household energy consumption using household level data. The study used data from the sixth round of the Ghana Living Standards Survey to examine enegy consumption, choice and crowding-out effects of energy expenditure. The econometric approaches used in this study were the Tobit, ordinary least square (OLS), conditional mixed process, and multinomial logit regression techniques. The results of the study showed that there is a significant positive relationship between income and energy consumption. It was also observed that stock of electrical appliances has a significant influence on energy consumption. Finally, expenditure on energy was established to crowd-out allocation to food, alcohol, clothing, communication, housing and furnishing while crowding in spending on health, education, transport, recreation, hotel and miscellaneous. It is recommended that households should be encouraged to adopt energy-efficient electrical appliances. In addition, an intensive sensitisation campaign to educate households about energy conservation practices is strongly advocated.

KEYWORDS

Appliances

Crowding-out

Energy consumption

Energy ladder theory

Households

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DEDICATION

To my family and the late Love K. B. T. Quarshiegah

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LIST OF ACRONYMS

CDF	Cumulative Distribution Function
ESMAP	Energy Sector Management Assistant Program
GDP	Gross Domestic Product
GEC	Ghana Energy Commission
GLSS	Ghana Living Standards Survey
GSS	Ghana Statistical Service
LPG	Liquefied Petroleum Gas
MNL	Multinomial Logit
OLS	Ordinary Least Squares
UNDP	United Nations Development Program
VIF	Variance Inflation Factor
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

Access to modern energy is recognised as an important precondition for sustainable development and the surest means through which the living standards of households in developing countries can be improved upon while achieving environmental sustainability. This means that increasing the adoption of modern fuels for domestic use has the potential to contribute more meaningfully to welfare. Moreover, it has been widely noted that while increasing energy supply is important to guaranteeing availability and consumption, a better understanding of demand by households is critical to provide insights for forecasting future demand. There is the need, therefore, to fully understand the determinants of household energy consumption.

The role of this thesis is to contribute to the literature regarding the effects of income, education and other factors on household energy choice and consumption. Using a nationally representative household level data, the study also investigates the crowding out effects of energy expenditure on other household goods. This first chapter provides the background to the study, statement of the problem, objectives, significance of the study, scope of the study as well as the organisation of the study.

Background to the Study

Energy is vital to the survival of every modern economy. As a result, most societies have become increasingly dependent on it. Access to modern energy is associated with socioeconomic development. The important role of energy in the overall socioeconomic and human development process is well recognised and documented in literature.

For instance, Ki-Moon (2012:5) states that energy is the "golden thread that connects economic growth, increased social equity and an environment that allows the world to thrive". Energy is essential for improving the living standards of people and greatly contributes to economic growth and development (Adaramola, Angelin-Chaab, & Paul, 2014; Barnes, Khandker, & Samad, 2011; Davidson & Sokona, 2002; Ekholm, Krey, Pachauri, & Riahi, 2010; Ghana Energy Commission [GEC], 2012; Johansson & Goldemberg, 2002; Kemausour & Ackom, 2017).

Further, access to modern energy is essential for reducing poverty, improving health and education, saving time, using modern technologies and machinery, increasing productivity, enhancing competitiveness, and promoting economic growth (Cabraal, Barnes, & Agarwal, 2005; Karekezi, McDade, Boardman, & Kimani, 2012; Kaygusuz, 2012; Leach, 1992; Mainali, Pachauri, Rao, & Silveira, 2014; Rehfuess, Mehta, & Pruss-Ustun, 2005; Thiam, 2011). More importantly, the provision of clean and affordable energy is considered as a key to sustainable development and central to socio-economic emancipation (Nussbaumer, Bazilian, Modi, & Yumkella, 2011; Nussbaumer, Nerini, Onyeji, & Howells, 2013). Energy provides services to meet many basic human needs such as cooking, heating and lighting. It is also associated with the provision of facilities required for the sustenance of human life such as food, shelter, clothing and health services (Rahut, Behera, & Ali, 2016a; Saghir, 2005). Energy makes it possible for households to use daily appliances for cooking, laundry, entertainment, preservation and cleaning (Dilaver, 2012; Winkler, Simoes, La Rovere, Rahman, & Mwakasonda, 2011).

The residential sector is an important energy consumption sector in both developed and developing countries. In developing countries, it accounts for inordinately large share of gross national energy consumption (Santamouris *et al*., 2007; Zhou & Yang, 2016). This can be attributed to weakness in industrial demand for energy and low efficiencies in the household use of energy (Hosier & Kipondya, 1993). The sector is also largely dependent on biomass fuels for most of its energy needs (Murphy, 2001; van der Kroon, Brouwer, & van Beukering, 2014; World Bank, 2011).

In Ghana, the household sector is undoubtedly the largest energy consuming sector of the economy. It is estimated that household energy consumption accounts for over 40 percent of total final energy consumption (GEC, 2015). Moreover, household energy mix is dominated by biomass in the form of firewood, charcoal and crop residue. Evidence shows that biomass energy consumption constitutes about 70 percent of household energy consumption in the country (Akpalu, Dasmani, & Aglobitse, 2011; Arranz-Piera, Kemausour, Addo, & Velo, 2017; GEC, 2012; Kemausour, Bolwig, & Miller, 2016). In terms of spatial differences, biomass accounts for over 80 percent of energy consumption of rural households compared to 58 percent of households in urban areas (Ghana Statistical Service [GSS], 2014; Kemausour, Nygaard, & Mackenzie, 2015).

The extensive consumption of biomass energy has implications that extend across a range of social and environmental issues. Biomass energy consumption is associated with health, economic and environmental problems. The environmental effects of biomass energy consumption are enormous including environmental change associated with both greenhouse gas emission and the depletion of the local forest and wood land. The felling of life trees for firewood puts enormous pressure on Ghana's forest cover which negatively impacts the ecosystem as a whole (Duku, Gu, & Hagan, 2011; GEC, 2012; Kemausour *et al.*, 2016).

The production of charcoal degrades the forest and contributes to emissions of greenhouse gases (Muller & Yan, 2018). This stems from the fact that charcoal is produced in simple earth-mound kilns with carbonisation efficiency below 20 percent, implying that large volumes of wood are consumed to make little charcoal (GEC, 2012). It is also recognised that deforestation rate in Ghana is among the highest in Africa as the rate of biomass consumption exceeds natural forest growth. Empirical evidence shows that consumption of biomass resulted in a net increase in forest degradation in Ghana averaging 115,000 hectares per annum during the period 2000-2005 (Kemausour *et al.*, 2016). It is also found that heavy dependence on biomass by households contributes significantly to the rapid depletion of the country's forest cover; estimated at about 2 percent loss per annum (Mensah, Marbuah, & Adu, 2016).

Furthermore, the health effects of using solid fuels cannot be overemphasised. The use of traditional fuels for cooking and heating has serious adverse effects on people's health, especially women and children (Holdren *et al.*, 2000; Parikh, 2011; Smith, 2010; World Health Organization [WHO], 2007). The indoor air pollution, caused by cooking fires, poses many health problems for households such as lower respiratory tract infections, cardiovascular and ocular diseases (Akpalu *et al.*, 2011; Chen, Hong, Pandey, & Smith, 1990; Ellegard, 1996; Ezzati & Kammen, 2001; Ezzati & Kammen, 2002; International Energy Agency [IEA], 2014; Smith, Samet, Romieu, & Bruce, 2000).

Available data reveal that indoor air pollution from the burning of solid fuel is responsible for more than 1.5 million deaths annually worldwide, particularly among children and women (Mandelli, Barbieri, Mattarolo, & Colombo, 2014; WHO, 2007). The deaths caused by the combustion of traditional fuels are more than those of malaria estimated at 1.2 million per annum (Mwaura, Okoboi, & Ahaibwe, 2014). A sizeable number of these deaths occur in Africa alone where nearly 600,000 premature deaths occur each year due to household air pollution linked to the use of solid fuels (WHO, 2007).

In Ghana, exposure to smoke from cooking with traditional fuel accounts for about 16,600 deaths per year (IEA, 2014). Moreover, dependence on traditional fuels can have serious adverse effects on incomes of people (Gaye, 2007; Guta, 2014; Osei, 1996; Sagar, 2005). Poor health resulting from indoor air pollution undermines productivity leading to loss of income and exacerbates poverty among households. Also, the time spent by women and children to collect wood wastes valuable time, which could otherwise be allocated to more productive activities (Gupta & Köhlin, 2006; WHO, 2016).

Recognising the need to improve global energy challenges, the United Nations General Assembly declared 2012 as the International Year of Sustainable Energy for All. Two key objectives of this declaration are: ensuring universal access to modern energy services and doubling the rate of improvements in energy efficiency. Furthermore, the Sustainable Development Goal 7 stresses the commitment to ensure access to affordable, reliable and sustainable household energy that minimises local pollution and health impacts and mitigates global warming by 2030 (Mensah & Adu, 2015; Qian-Qian, Man, & Xiao-Lin, 2015). As a way of achieving this goal, the United Nations advocates that governments and policy makers in member countries, particularly those in developing countries, would adopt programmes and interventions to enhance access and use of modern energy as well as improve energy efficiency and conservation. Even before this laudable global initiative was introduced, Ghana had implemented various programmes and policies in the energy sector aimed at encouraging the use of LPG and reducing the use of biomass for cooking among households in the country. In 1990, the Government of Ghana, with support from the United Nations Development Programme (UNDP), launched a National LPG Programme as a way of promoting the use of LPG in the residential sector (Kemausour, Obeng, Brew - Hammond, & Duker, 2011). The promotion targeted households, public catering facitilities, and small – scale food sellers. Following this programme, the use of LPG for cooking and heating purposes by households progressed from less than 2 percent to 6 percent in 2004 (Kemausour *et al.*, 2011). Also, between 2005 and 2013, the percentage of households in Ghana using LPG as the main cooking fuel rose from 9.9 to 22.3 (Figure 1).

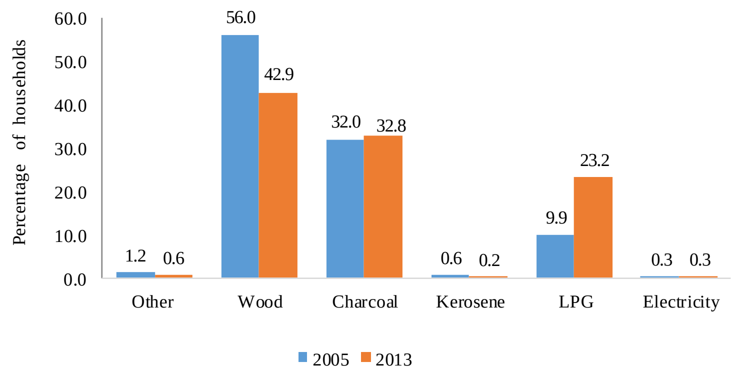

Figure 1: Type of Cooking Fuel used by Households in Ghana

Source: Author (2018).

Despite the improvement in the use of LPG, biomass represents a major source of cooking fuel for a large proportion of households in the country. This demonstrates that effort from the government to reduce household dependence on biomass has not achieved much. Beside biomass, electricity and petroleum products are important energy sources for households in Ghana. Households use electricity predominantly for lighting and powering electrical appliances while petroleum products are used for cooking and transport. Household electricity consumption accounts for a significant share of total electricity generated in the country (GEC, 2012; GEC, 2015; Gyamfi, Modjinou, & Djordjevic, 2015; Taale & Kyeremeh, 2016). For example, the household sector was responsible for 51.2 percent of total final electricity consumption in 2016, making it the largest electricity-consuming sector in the country in that year (GEC, 2017). Electricity consumption by this sector has witnessed an upward trend over the years. Between 2000 and 2014, residential electricity consumption increased by over 96 percent (Figure 2). The rising electricity consumption is driven largely by population growth, urbanization, increase in household income, changing lifestyle and increasing appliance ownership (Gyamfi *et al*, 2015).

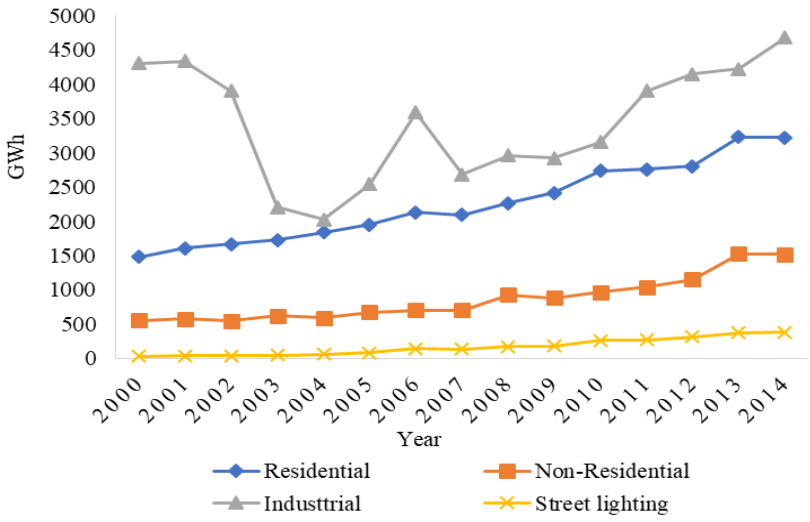

Figure 2: Electricity Consumption by Customer Class (2000-2014)

Source: Author (2018).

The rising electricity consumption associated with the household sector is presenting serious energy security challenges for the country. Unfortunately, the country's power supply does not meet demand, creating a huge energy deficit. It is estimated that the annual growth of national electricity demand is 13.9 percent, with residential demand averaging 6.3 percent. The growth in energy demand far exceeds the growth in energy supply (Ghana Grid Company Limited, 2015). Although several factors account for the power deficit including expanding economy and lack of investment in the power sector largely due to financial constraints, the contribution from the residential sector cannot be overemphasised. The rising consumption for electricity has led to energy crisis with intermittent load shedding of power across the country over the decades and more intense in recent years (GEC, 2012; Mensah *et al*., 2016).

As part of efforts to mitigate the huge energy deficit in the country, policy makers in the energy sector have adopted several interventions including power rationing for residential and other users and more importantly removed subsidies on petroleum products in an attempt to make consumers pay realistic prices (Coady & Newhouse, 2006; Cooke, Hague, Tiberti, Cockburn, & El Lahga, 2016). The fuel subsidy reform has resulted in significant price increases of energy sources for households.

Energy is widely recognised as a necessity as it is indispensable to human life. In the light of this, removal of fuel subsidies; causing increase in prices, negatively affects household welfare with differentiated effects on different social groups such as the rich and the poor or rural and urban households. Obviously, the poor and the socially disadvantaged people are affected most. It is generally expected that as conventional fuels become expensive, households might need to compromise on other essential consumption such as food, health, education and other goods in order to meet their energy needs. Evidence in the literature suggests that low-income households tend to adopt poor coping strategies such as withdrawing children from school, sending them to work early, or reducing health care use and diet variety (Cooke *et al.*, 2016). It is established that households in developing countries spend relatively high proportion of their disposable income on energy (Barnes *et al.*, 2011; Johansson & Goldemberg, 2002; Winkler *et al.*, 2011).

To this end, tackling energy problems in the country necessitates not just short-term measures but a comprehensive energy policy that covers both supply and demand-management issues. That is, not only must generation increase but also efficiency in demand must be pursued. This can be achieved only when the factors shaping energy consumption especially in the household sector are identified and well understood. Understanding such factors will help in predicting future consumption needs and directing policy measures to achieve improved efficiency in consumption.

The literature on the factors driving energy consumption is at least not exhaustive as the world becomes environmentally conscious. Among other factors, level of education and income have been identified as plausible determinants of energy consumption. With respect to income, the argument stems from the observation that higher-income households tend to use energy-intensive appliances and therefore consume more energy than lower-income households. At the same time, higher-income households are observed to adopt energy-saving measures such as solar panels, insulation and energy-efficient light bulbs, all of which contribute to decrease energy consumption (Abrahamse & Steg, 2011). In addition, Sardianou (2007) argues that higher-income households may be more willing and/or able to conserve energy because they can afford the financial costs of energy-saving investments, such as purchasing new efficient technology.

With respect to level of education and energy consumption, it is generally believed that education tends to be associated with increased knowledge, awareness and concern regarding environmental issues such as energy efficiency. This in turn leads to greater efficiency in engery consumption as people become more environmentally concerned. However, there is also the argument that higher levels of education do not translate directly to judicious energy consumption - an argument that leans itself to the Dally's impossibility theorem. Instead, there may often be a knowledge gap in that increasing knowledge and awareness does not routinely translate into congruent behavioural change, possibly due to the effect of several controlling factors that may constrain or facilitate energy-related behaviour (Courtenay-Hall & Rogers, 2002)

Statement of the Problem

Energy contributes to economic growth and development. It is also essential for improving the standard of living of people. Nonetheless, there are two pressing issues regarding energy. These are insecurity in supply and the choice of energy use with respect to the sustainability of the environment. In order to avoid wastage due to excess supply and shortage due to excess demand, there is the need to match energy demand with supply. There is also the need for proper household energy mix to ensure environmental sustainability.

Household energy consumption and its related issues have received considerable attention in recent times. However, most of the empirical studies on energy consumption have focused on macro perspective using aggregate data without covering the behavioural dynamics of households (Adom, Bekoe, & Akoena, 2012; Dergiades & Tsoulfidis, 2008; Richmond & Kaufmann, 2006). Studies using macro data suffer from loss of information since they are unable to account for specific individual level factors which affect energy consumption. It is also recognised that the actual determinants of household energy consumption are established at the household level (Gundimeda & Köhlin, 2008; Ngui, Mutua, Osiolo, & Aligula, 2011). Research on energy consumption in Ghana using household level data is limited. Even the few studies have been largely descriptive (Constantine *et al*., 1999; Van Buskirk, Hagan, Ahenkorah, & McNeil, 2007).

Income and education have been regarded as significant determinants of household energy choice and consumption. However, there is lack of consensus in the literature regarding the exact nature of this relationship. Among other issues, the effects of income and education on household energy consumption in Ghana based on micro-level data are not well known due to the limited nature of empirical studies in this area. This thesis therefore contributes to the literature regarding the effects of income and education on household energy choice and consumption. Using a nationally representative household level data, the study also investigates the extent to which expenditure on energy crowds out spending on other household goods.

Objectives of the Study

The main objective of this study was to investigate household energy econsumption, choice and the extent to which energy expenditure crowds-out other household expenditure in Ghana. Specifically, the study sought to:

1. examine the effect of income on household energy consumption.
2. determine the effect of education on household energy choice.
3. investigate the crowding-out effects of energy expenditure on other household goods.

Hypotheses of the Study

The following three hypotheses are formulated for this study:

1. H_0: Income does not affect household energy consumption.

   H_A: Income affects household energy consumption.

2. $H_{0:}$ Education level of household head does not affect energy choice.

   H_A: Education level of household head affects energy choice.

3. $H_{0:}$ Energy expenditure does not crowd out spending on other household goods.

   $H_{A:}$ Energy expenditure crowds out spending on other household goods.

Significance of the Study

Among the various sectors of the economy, the household sector constitutes the largest energy consumer in Ghana (GEC, 2012). With rapid growth in population, urbanisation, changing lifestyle and increasing income levels, household energy consumption is likely to continue to grow which may lead to serious pressure on energy security and environmental protection. In addition, biomass energy consumption is a major cause of indoor air pollution, greenhouse gas emission and global warming (Salari & Javid, 2017). Reducing household energy consumption is an important part of the transition to a low carbon economy and targeting household sector is widely considered to be the most effective strategy for speeding up the process (Dietz, Gardner, Gilligan, Stern, & Vanderbergh, 2009; Steg, Perlaviciute, & Van der Werff, 2015).

Moreover, Ghana's energy policy aims at reducing energy contribution to climate change, enhancing energy efficiency and conservation measures, and increasing the use of LPG for domestic use (GEC, 2012). The government has set a target to have 50 percent of households in the country use LPG as the main cooking energy by 2020 compared to the current level of 23 percent (GEC, 2012). Identifying the factors that affect energy use in the household sector is important in achieving this goal.

Further, energy is seen as essential to the socioeconomic and human development of every society. Access to sustained and reliable energy services enables households to improve their quality of living. For the energy sector to play its role in the socioeconomic development process of the country, appropriate policies need to be formulated and implemented. Policies makers must therefore know the dynamics of energy consumption by households in order to formulate appropriate policies for the energy sector. As this study investigates the factors explaining household energy consumption and drivers of switching to cleaner energy, it would provide useful findings that can be considered in designing effective strategies to boost the use of clean and efficient energy sources by households in Ghana.

The study will contribute to literature on energy consumption by providing a comprehensive analysis of household energy consumption in Ghana. Research into energy consumption in the household sector in Ghana is scanty and even the few studies have been more macro-based (Adom *et al.*, 2012; Mensah *et al.*, 2016). This the first study to investigate the determinants of energy expenditures among households in Ghana. No study has been carried out using large nationally-representative data set, much more analyse the crowding-out effects of household energy cost.

Delimitations of the Study

The study focuses on energy consumption in the household sector in Ghana. It examines the relationship between household energy use and income and other socioeconomic characteristics of the household. It also investigates the determinants of household energy choice with focus on education and income. The study also evaluates the effects of energy spending on household consumption patterns. The study uses data from the sixth round of the Ghana Living Standard Survey to achieve its objectives.

Organisation of the Study

The study is organised into eight chapters. Chapter one covers the introduction to the study and includes the background to the study, statement of the problem, purpose of the study, hypotheses to be tested, significance of the study, scope of the study and organisation of the study. The second chapter provides an overview of the energy sector in Ghana with a specific focus on the main sources of energy supply as well as the energy demand situation in the country. Chapter three presents review of related literature. This chapter discusses the various theoretical perspectives on household energy consumption and choice of fuels. A survey of empirical literature relevant to the study is also provided.

The fourth chapter details the methods used for the study. It presents the research philosophy underpinning the study and describes the research design. The source of data used for the study is also highlighted in the chapter. The chapter also presents the theoretical frameworks and the econometric models used for estimations. The measurements of the variables and descriptive statistics are also provided in the chapter. Chapter five presents and discusses the empirical results of the effects of income and other socioeconomic factors on household energy consumption. The results on the determinants of household energy choice are presented and discussed in the sixth chapter. This is followed by the results of the empirical analysis of the effect of energy expenditure on household spending on other goods in chapter seven. Chapter eight concludes with the summary, conclusions and recommendations. The chapter also outlines the limitations to the study and suggests areas for future studies.

Chapter Summary

This chapter provided the introduction to the study. It covered background to the study, problem statement purpose of the study, hypotheses and significance of the study. It also presented the scope of the study. The chapter which follows presents an overview of the energy sector in Ghana.

CHAPTER TWO

OVERVIEW OF THE ENERGY SECTOR IN GHANA

Introduction

This chapter provides an overview of the energy sector in Ghana. It is organised into two sections. The first section discusses the various sources of energy supply in the country whiles the second section looks at the energy consumption situation including household energy use.

Sources of Energy Supply in Ghana

Ghana has a total land area of 238,533 km^2 and an estimated population of 27 million people. The country has an annual population growth rate of 2.4 percent compared to the 1.6 percent average for lower-middle income countries (Alagidede, Baah-Boateng, & Nketia-Amponsah, 2013; GEC, 2015). Like other countries, the economy of Ghana is divided into three broad sectors. One of these broad sectors is the service which includes energy services. The energy subsector, consisting of electricity, petroleum products, biomass, and other renewables, is an integral component of the services sector. This section discusses the various energy resources used in the country including the ones upon which the study is based. It gives the general background and current situation.

Electricity

Electricity is an important component of the energy supply mix in Ghana. Currently, electricity is generated from two main sources: hydro and thermal. Ghana has a hydropower potential of about 2000 megawatts (MW), of which nearly 1200 MW corresponds to large hydro dams and the rest in the form of small and medium power projects (Ackah & Asomani, 2015). The generation of electricity from hydro sources started in the 1960s, brought in part by the need to provide a more reliable and effective power to drive industrialization and the construction of the country's first hydroelectric dam at Akosombo in the Eastern Region. Before this period, the country relied on diesel generators alongside detached supply system for the supply of power. Over the years, hydropower generation has remained a major source of electricity supply. Since the first hydropower dam was constructed in 1961, two additional dams have been constructed bringing the total number of hydroelectric dams in the country to three with a combined capacity of about 1500 MW (GEC, 2016).

While the generation of power from hydro sources has contributed enormously to economic growth and development of Ghana, it is apparent that the country cannot continue to depend solely on power from this source, particularly in light of the rising demand for electricity fuelled by increase in per capita income and population growth. For example, the share of hydro generation in the total power generation has reduced over the years from 92 percent in 2000 to 69 percent in 2010. During the energy crisis in 2007 when the water level in the Akosombo dam dropped drastically, electricity generation from hydro took a further dip and reached 53 percent (GEC, 2012). Meanwhile, it was very clear as far back as 1997 that the country could no longer depend on hydro sources to meet its electricity needs. This has increased the need for a shift to other sources. Poor rainfall in recent times and the deterioration of equipment at the country's main hydro sites has rekindled the need for alternatives to hydro. This has contributed to the rise in the number of thermal plants for electricity generation in the country.

Petroleum Products

Petroleum products are also important energy sources in Ghana and are used in various sectors of the economy. Ghana is endowed with oil deposits and produces crude oil in commercial quantities. Even though the country produces oil in commercial quantities, it is a net oil importer (Wesseh Jr., Lin, & Atsagli, 2016; Wesseh, Jr. & Lin, 2017). The country has an oil refinery with the capacity to process 45,000 barrels of oil per day. However, much of the domestic requirements of the refined petroleum products are imported.

Biomass

Without any doubts, biomass is the most common form of energy widely used in Ghana today. It is the country's main energy resource in terms of endowment and consumption (Ackah & Asomani, 2015; GEC, 2017). According to Ackah and Asomani, biomass resources cover about 20.8 million hectares of the over 23.8 million hectare land mass of Ghana, and supplies about 60 percent of the total energy used in the country. In many homes in Ghana, large volumes of biomass fuels in the form of firewood, charcoal and agricultural residue are used for a broad of activities including cooking, heating, and lighting. Presently, more than 50 percent of biomass use in the country is through burning in open fires and stoves.

The main mechanism through which most households in the rural areas of Ghana obtain biomass energy resources is through harvesting from their farms, neighbourhood and communal woodlots. However, the production and supply of biomass energy to households in the urban areas is a relatively brisk economic activity undertaken by private individuals and actors along the biomass energy value chain, though improved cook-stoves are promoted by some governmental and non-governmental organisations. As noted by GEC (2012), nearly 90 percent of biomass is obtained directly from the natural forest with the remaining 10 percent from wood waste such as logging and sawmill residue, crop residue and planted forests.

Other Renewable Energy in Ghana

Ghana is well endowed with enormous renewable energy resources which can be harnessed for the economic growth and development. Besides biomass, other forms of renewable energy such as solar, wind and waste-to-energy resources are recognised as being better positioned to help the country achieve this goal (Ackah & Asomani, 2015; Kemausuor *et al*., 2011). By virtue of being located in the tropics, Ghana is blessed with great potential for the development of solar energy. For example, it has been widely documented that the amount of radiation reaching from the sun to all areas across all the administrative regions of Ghana is good enough to power solar photovoltaic systems to generate energy for use by households and essential social services like hospitals and schools. The total installed capacity of solar plants as at the end of 2015 was 22.5 MW (GEC, 2016).

Moreover, available evidence shows that the coastal belt of Ghana is endowed with good wind potential due to its close alignment to the Atlantic Ocean. In fact, while the use of waste-to-energy resources has the potential to act as a significant part of the national sanitation programme, the development of solar and wind power can contribute to the goal of increasing the share of renewables in the country's energy mix to 10 percent by 2020.

Energy Consumption in Ghana

Energy consumption in Ghana is connected to a large number of diverse activities undertaken by different sectors which can be divided into five: agriculture and fisheries, commercial, industrial, residential and transport sectors. Generally, there has been an increase in the demand for energy in almost every sector of the country especially in the transport and residential sectors. According to GEC (2015), total final energy consumption by all sectors in 2014 was 6,983.4 kilo tonnes of oil equivalent (ktoe) of which 3,271.9 ktoe was from petroleum, 2,791.7 ktoe from biomass and 919.8 ktoe from electricity (GEC, 2015). With respect to the individual fuels, demand for firewood and charcoal has been growing by 3 percent per annum, with demand for electricity increasing annually by about 6 percent and consumption of petroleum products doing so by 5 percent (GEC, 2010).

Evidence shows that transport and industrial sectors are the major consumers of diesel and gasoline in Ghana whereas the household sector dominates with respect to the consumption of LPG and kerosene (GEC, 2015). Specifically, the transport sector accounts for more than 90 percent of gasoline use in the economy, with the remaining 10 percent going into industries for general solvent use. Meanwhile, almost 85 percent of diesel consumption in the country goes to the transport sector, with the rest for the other sectors (ibid).

Figure 3 shows that energy demand has changed over the last decade with consumption shifting gradually away from biomass to modern energy forms like electricity and petroleum products. Between 2005 and 2014, while consumption of biomass energy declined for most periods, the consumption of petroleum products and electricity rather mostly witnessed upward trends.

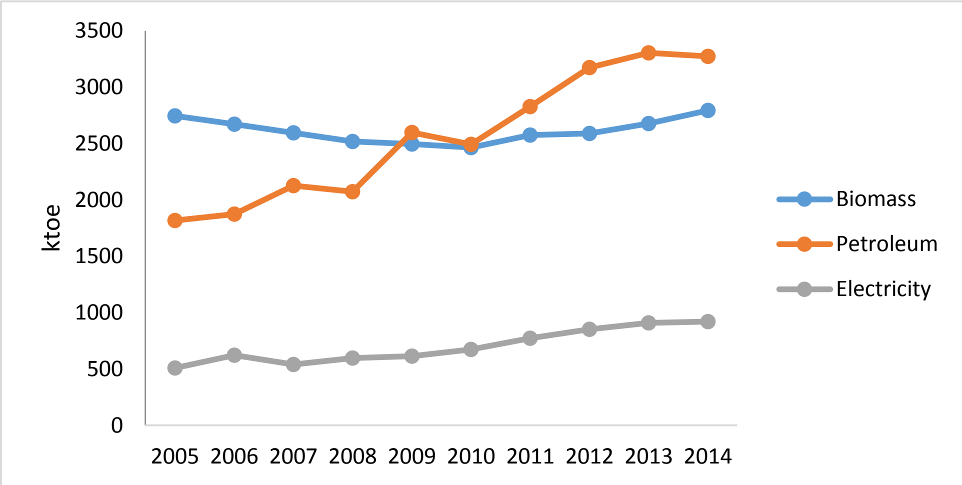

Figure 3: Trends of Final Energy Consumption in Ghana (2005-2014)

Source: Author (2018).

Household Energy Use in Ghana

The household sector consumes the largest share of total energy supply in Ghana. This sector accounts for 40 percent of total final energy consumption and about 47 percent of all electricity consumed in the country (GEC, 2015). The electricity consumption by the residential sector has been rising with consumption growing at an average of 6.3 percent over the last decade (Eshun & Amoako-Tuffour, 2016; Gyamfi *et al.*, 2015) and surpasses consumption growth by other sectors. Gyamfi *et al.* identified four factors accounting for the rise in residential electricity consumption in Ghana. These are increasing grid connections, rising per capita income, penetration of appliances in high-income households and no apparent incentives for more efficient utilisation of energy.

According to Kemausour *et al.* (2011), the increased electricity consumption of households is due to significant increase in electricity access in the country. For instance, electricity access increased from 28% in 1988 to 32% in 1992 and by the close of 2000 it had jumped to 43.7% (Ministry of Energy, 2006; GSS, 2008). Electricity access was estimated to be 54% in 2007 and 55% in 2008. As of 2012, the national coverage of electricity connection was about 71 percent (Gyamfi *et al.*, 2015). Even though access to electricity has increased overtime, there are still disparities in access to electricity between urban and rural areas. GSS (2014) reports that over 80 percent of households in urban areas have access to electricity compared to less than 50 percent of households in rural areas. Households use electricity for lighting and powering domestic appliances. However, the use of electricity for cooking by household is negligible, estimated at less than one percent (0.3%).

Despite the growing importance of electricity in household energy mix, biomass (firewood and charcoal) continues to dominate household energy consumption in Ghana. A survey conducted by GEC (2010) on household energy use patterns in Ghana showed that about 40 percent of households used firewood for cooking and heating. The proportion of households using firewood in rural areas was much higher (62.1%) than in urban areas (25.8%). Furthermore, about 78.8 percent in the country used charcoal for cooking. Charcoal use was found to be higher in urban centres than in rural areas. In urban areas, 80.1 percent of households used charcoal for cooking compared to 76.1 percent of household used charcoal in rural area. The relative affordability of solid fuels and low accessibility of LPG are often cited as the reasons for the high reliance of household on biomass for cooking. However, the use of biomass has dire implications for health and the environment. Unventilated biomass use facilitates indoor air pollution which causes respiratory diseases and other health problems for households particularly women and children.

Chapter Summary

This chapter provided an overview of the energy sector in Ghana. It looked at the various sources of energy supply and considered energy consumption situation in the country. The review of energy sources showed that biomass, electricity and petroleum products are the main components of energy supply. The survey also showed that energy demand in the country has changed over the last decade with consumption shifting gradually away from biomass to electricity and petroleum products. However, household energy use has not changed much as biomass dominates household energy mix. This calls for more policy interventions to facilitate household energy transition from biomass to clean energy sources such as LPG. A research which identifies the factors that affect household energy consumption is important in this regard. The next chapter provides the literature review.

CHAPTER THREE

LITERATURE REVIEW

Introduction

This chapter is dedicated to review of related literature for the study. It is organised into two sections. The first section looks at the various theoretical perspectives on household energy consumption and choice of energy. The second section covers empirical studies on energy consumption, choice and crowding-out effect of energy expenditure.

Review of Theoretical Literature

This section is devoted to review of the related theoretical literature for the study. It covers four main theoretical perspectives: household production theory, two-stage budgeting theory, energy ladder hypothesis and energy stacking theory.

Household Production Theory

The household production theory was developed by Becker (1965) and extended by Lancaster (1966) and Muth (1966). According to this theory, households purchase goods on the market which serve as inputs that are used in production processes to generate commodities which appear as arguments in the household's utility function (Filippini & Pachauri, 2004). As outlined by Eakins (2013), household production theory emphasises the fact that market goods and services do not have direct influence on a household's utility but rather indirectly through other goods and services produced by households using market goods and services as inputs. Besides market goods and services, Becker introduced time as an input in the production of goods and services that directly yield utility to households.

Energy is among the goods that are consistent with the type of household behaviour that is postulated by the household production theory. As noted by Filippini and Pachauri (2004), household demand for energy is derived from the demand for lighting, cooking and heating. Thus, energy in its various forms such as electricity, LPG, kerosene, charcoal, and firewood is treated as an input in the production of other services that households need. It can, therefore, be argued that energy in itself does not generate utility but it is used as an input in the household production process that in turn creates utility.

The household production theory has been extensively applied in the context of household energy consumption. The theory was first applied by Archibald and Gillingham (1980) to study gasoline demand in the United States. Following this study, several other studies on household energy demand have also applied the household production model (Akpalu *et al.*, 2011; Filippini & Hunt, 2012; Linderhof, 2001; Sardianou, 2008).

Two-Stage Budgeting Theory

Household energy consumption has also been conceptualised using two-stage budgeting framework proposed by Strotz (1957) and extended by Gorman (1959). This theory postulates that households engage in a two-stage process in their consumption decisions. In the first stage, households allocate income to broad categories of goods such as food, clothing and energy and then at second stage, given the expenditure constraint in the first stage, they maximise utility within each subcategory (Eakins, 2013).

Chambwera and Folmer (2007) argued that households implement a two-stage budgeting process to decide how much of their energy budgets to allocate to different energy types. First, they choose how much of their total incomes to allocate to energy and other consumption goods. Then at the second stage, they decide how much of their total energy budget to allocate to individual energy types. Eakins (2013) argued that at the first stage only information on the household's total budget and prices for the broad categories is required while at the second stage only information on the household budget allocated to energy types and prices of the different kinds of energy is required.

Following Deaton and Muellbauer (1980) as well as Chambwera and Folmer (2007), the two-stage budgeting theory is presented as a utility tree reflecting a utility function with branch utilities contingent on the quantities of different consumption goods as shown in Figure 4.

The key assumption of the two-stage budgeting approach is the separability of preferences (Chambwera, 2004; Chambwera & Folmer, 2007; Deaton & Muellbauer, 1980; Eakins, 2013; Elsner, 2001). Household goods can be divided into groups such that preferences within the same groups can be described independently of those in other groups. For example, if energy is a group, the consumer can rank different energy bundles in a well-defined ordering system independent of the consumption other goods such as foods and clothing. By so doing, there can be a subutility function for each individual item in the group and the subutilities can be summed up to give total utility for the group.

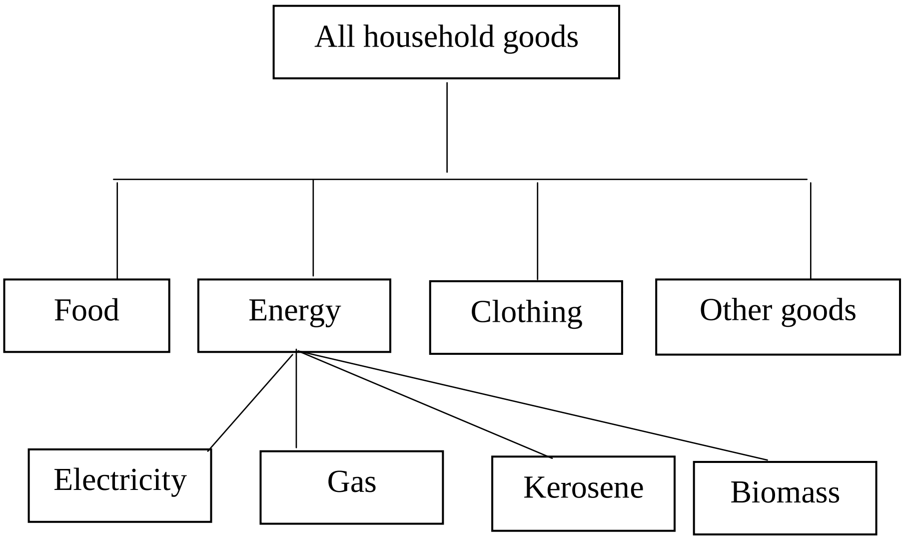

Figure 4: Utility Tree and Two-Stage Budgeting

Source: Author (2018).

A common feature of the two-stage budgeting process is that each stage can be analysed separately. This suggests that decision made at each stage can be considered as corresponding to a utility maximization problem of its own. This permits the development of a systems model where individual goods can be analysed within a broad category (Eakins, 2013). A model commonly used in the context of the two-stage budgeting is the Almost Ideal Demand Systems. The two-stage budgeting theory has been applied in the empirical analysis of household energy demand by Baker, Blundell and Micklewright (1989), Nicol (2003), Chambwera (2004), Chambwera and Folmer (2007) and Ngui *et al.* (2011).

The Energy Ladder Theory

The energy ladder theory is the commonly used model for analysing household energy use in developing countries (Hosier & Dowd, 1987; IEA, 2012; Treiber, Grimsby, & Aune, 2015). This theory conceptualises household energy choice as ascension along a hierarchical order, that corresponds to increases in income, from unclean and inefficient energy sources to transitory energy sources and ultimately to more efficient and clean energy sources (Guta, 2014). The concept predicts a positive linear relationship between household's socio-economic status and the use of energy sources.

It perceives a continuous monotonic fuel substitution process of energy dictated by income growth. This suggests that households move away from traditional to modern energy sources as countries develop and incomes increase, signifying that biomass fuel such as firewood becomes less preferable as income increases. In that sense, the energy ladder concept constitutes an extension of the typical income effect of consumer economic theory that talks about how consumers shift from inferior goods to necessary and luxury goods as their income rises (Muller & Yan, 2018).

The energy ladder is described as a three-stage fuel switching process (Energy Sector Management Assistant Program [ESMAP], 2003). The first stage involves reliance on traditional fuels such as firewood animal dung and, agricultural residue. In the second stage, households gradually switch from traditional fuels to transitional or intermediate energy sources such as charcoal and kerosene as a response to higher incomes and low availability of firewood due to factors such as deforestation and urbanisation. The final stage is where households adopt and use modern energy sources like gas and electricity which are considered superior because of their high efficiency, cleanliness and convenience of storage and usage.

The energy ladder theory argues that households have preference for fuel types based on physical characteristics such as cleanliness, convenience, costs and other considerations (Hosier & Kipondya, 1993; Treiber *et al.*, 2015). It also assumes that households completely switch away from traditional energy to modern fuels and this process is affected by factors such as household income, fuel and equipment cost, availability and fuel availability and accessibility.

Essentially, the energy ladder concept is based on the microeconomic theory of rational choice. It assumes that all sources of energy are available, that there is a universal set of fuel preferences, and that households will choose to move up the ladder as soon as they can afford to do so. The major strength of this theory is its ability to describe the strong influence of income on the energy choice of households, particularly households in urban areas (Kowsari & Zerrifi, 2011).

Several empirical studies support the energy ladder hypothesis for developing countries (ESMAP, 2003, Gregory & Stern, 2014; Hosier & Dowd, 1987; Leach, 1992; Lee, 2013; Reddy & Reddy, 1994). These studies confirm the significant role of income in the energy transition of households from traditional to modern fuels. For instance, ESMAP show that households use energy sources that are higher on the ladder as income increases. Nonetheless, the assumption of the energy ladder model that fuel choice is determined purely by economic factors has been questioned by other researchers. Critics argue that the energy ladder theory is overly simplistic because it suggests that movement along the ladder means a complete switch away from traditional energy to cleaner alternatives subject to rising income (Mensah & Adu, 2015).

Contrary to the energy ladder hypothesis, empirical studies show that households in developing countries often do not completely move away from using traditional fuels to modern fuels as their socio-economic status rise but rather use a combination of fuel (Akpalu *et al.*, 2011; Heltberg, 2004; Leach, 1992; Masera, Saatkamp, & Kammen, 2000; Pachauri & Spreng, 2004; van der Kroon *et al.*, 2014). For example, Akpalu *et al.* demonstrate that households may not progress from the use of less-efficient energy like biomass to transitional fuel such as kerosene and ultimately to more efficient fuel like LPG and electricity as their living conditions improve because they may have preference for specific types which tend to make them stick to the use of these types of energy, regardless of the size of their income.

According to Masera *et al.* (2000), household fuel switching is not unidirectional but can follow a bidirectional process where households can switch back to traditional energy sources after moving up the ladder and adopting modern fuel types. It is also possible that instead of completely switching from one fuel type to another, households can choose a combination of energy sources based on budget preferences and different situations needs (Alem, Beyene, Köhlin, & Mekonnen, 2016; Heltberg, 2004; Pachauri & Spreng, 2004). This gives rise to the energy-stacking hypothesis.

The Energy Stacking Theory

Masera *et al.* (2000) critiqued the energy ladder theory on the grounds that it does not adequately describe the dynamics of household energy use in developing countries and proposed an alternative called the energy stacking theory. This theory postulates that households choose a combination of energy from the lower and upper levels of the ladder. This theory counters the energy ladder hypothesis that with rising income household switch completely from traditional energy types to modern energy types.

In addition, Masera *et al. (*2000*)* established that households adopt a multiple energy use pattern where traditional and modern energy are used together. It is also recognised that modern fuels serve as partial instead of perfect substitute to traditional fuels (Muller & Yan, 2018). Several reasons have been cited for the multiple energy use patterns by households, particularly in developing countries. These include occasional shortages of modern energy types, fluctuations of prices of modern fuels as well as taste and preferences for energy types such that households do not completely move away from traditional to modern fuels (Akpalu *et al.*, 2011; Kowsari & Zerriffi, 2011). The substitutability of energy types depends on their attributes and the various characteristics of the households. Thus, the energy-stacking model suggests that households adopt mixed energy systems and consider various factors affecting the energy portfolio.

Even though there are fundamental differences between the energy ladder hypothesis and the fuel-stacking concept regarding the nature of fuel switching decisions of households, Mensah and Adu (2015) maintain that both theories are based on the assumption of universal hierarchy of fuels and energy services. According to these authors, this hierarchy is based on the respective attributes of the various fuel types and thus energy switching or transition is merely a move away from the least preferred to the most preferred available alternative.

Additionally, Kowsari and Zerriffi (2011) assert that energy stacking theory, like the energy ladder hypothesis, considers income as a significant factor that determines household fuel choice. This means that household use more of efficient and clean modern energy sources as their economic status improves, a conclusion akin to the energy ladder hypothesis. Furthermore, both theories rely on the microeconomic theory of rational choice and provide plausible explanations of household fuel use in developing countries. In what follows empirical literature on energy choice are reviewed. This is done with the view of identifying the important influencing factors of household energy transition.

Empirical Literature on Household Energy Consumption

There are two strands of empirical literature on residential energy consumption. One part of the literature consists of studies that use aggregate data and the other covers studies that use micro- level data. Mostly, studies using aggregate data, usually over time, tend to focus on studying the broad macro factors affecting residential energy demand. These studies established that factors such as urbanisation, real gross domestic product and population determine household energy consumption but they suffer from loss of information because they fail to account for specific, individual level determinants of energy consumption (Adom *et al.*, 2012; Dergiades & Tsoulfidis; 2008; Kamerschen & Porter, 2004; Mensah *et al.*, 2016; Richmond & Kaufmann, 2006; Son & Kim, 2017; Zhang, Song, Li, & Li, 2016).

Another limitation of macro studies is that they do not address how households adjust their consumption patterns with respects to changes in socio-economic and demographic characteristics, which are useful for policy formulation in the energy sector and for developing measures essential for the management of energy consumption. On the other hand, studies based on micro-level data garnered from households are able to reveal the actual determinants of residential energy consumption and thus overcome most of the limitations of the aggregate studies. Moreover, the use of micro data allows for the study of consumer behaviour to changes in price and income which are very useful for tax and welfare policies. In addition, the effects of factors other than income on household energy consumption and related issues can be explored using household level data.

This thesis examines household energy expenditures using micro level data. As a result, the review of the empirical literature on household energy consumption focuses more on the studies that used household-level data to analyse the factors affecting energy consumption.

Factors Affecting Household Energy Consumption

Previous studies have established that several factors affect household energy consumption (Alberini, Gans, & Velez- Lopez, 2011; Baker *et al.*, 1989; Cayla, Maiza, & Marchand, 2011; Hasan & Mozumder, 2017; Leahy & Lyons; 2010; Meier & Rehdanz, 2010; Poyer & Williams, 1993; Salari & Javid, 2017). For the purpose of this study, the factors are divided into five categories namely, socio-demographic, economic, location, building or dwelling characteristics and appliance factors. The socio-demographic characteristics comprise household size and composition, education, age, gender and employment type of the head of household. The economic factors are income and energy prices. The dwelling characteristics include number of rooms and size of dwelling. The appliance factors are used to explore the effects of categories of appliances on household energy consumption such as entertainment appliances, extra-ventilation appliances, and preservation appliances.

Literature shows that income is a significant determinant of household energy consumption. In fact, several studies examining the relationship between income and household energy consumption in developed and developing countries have established that income has a strong influence on household energy demand (Bacon, Bhattacharya, & Kojima, 2010; Bedir, Hasselaar, & Itard, 2013; Black, Stern, & Elsworth, 1985; Cayla, *et al.*, 2011; Dillman, Rosa, & Dillman, 1983; Jones & Lomas, 2015; Rodriguez-Oreggia & Yepez-Garcia, 2014).

D'Agostino, Urpelainen, and Xu (2015) examined the socio-economic factors affecting household charcoal expenditure in Tanzania. Using nationally representative panel data, their analysis showed that income significantly and positively affects household expenditure on charcoal. More specifically, the study found that an increase in household income by 10 percent raises charcoal expenditure by 4 percent. Similarly, Alberini *et al.* (2011) investigated the effect of income on household gas and electricity consumption in the United States. The study used household level data from 50 largest metropolitan areas in United States and found a statistically significant positive relationship between income and energy consumption. It was also observed that as income increases, households tend to show preference for less energy intentive appliances and homes. This moderates energy consumption of higher income households.

Poyer and Williams (1993) studied the effects of price and income on residential energy demand with a specific focus on minority household type in the United States. The results of the ordinary least squares regression analysis based on data from National Residential Eenergy Consumption Survey showed that income has a significant positive effect on household energy consumption. This impies that an increase in income leads to higher energy consumption. This can be attribtured to the fact that income facilitates access to secure and reliable energy services (Taale & Kyeremeh, 2016). Income also aids in the operation of energy-dependent gadgets such as computers and televisions (Jones & Lomas, 2015). This suggests that large disposable income enables households to purchase more energy-consuming appliances hence intensifying the demand for energy (Michaelis & Lorek, 2004).

Salari and Javid (2017) modeled household energy expenditure in the United States. The study used household-level data collected from more than 560,000 households and estimated multivariate regression models to identify the impacts of income and other factors on household energy expenditure. Resutls of the study revealed significant positive relationship between income and expenditure on gas and electricity, indicating that when household income increases, they tend to spend more on both gas and electricity. Age of household head was also found to be positively related to household expenditure on gas and electricity.

Wei, Zhu and Glomsrød (2014) examined the effects of household characteristics on energy spending of floating population in Shanghai, China. The results of fractional logit regression analysis based on data from survey of 1504 floating households showed that income has a significant positive effect on spending on total energy, gas, electricy and oil. In particular, the study notes that a one percent increase in income results in 0.128 percent increase in total energy spending. Again, the study found a statistically positive relationship between household size and energy expenditure. Specifically, it was observed that an additional member of household increases energy spending by 8.6 percent.

Santamouris *et al.* (2007) investigated the relationship between annual electricity cost and income among households in Greece. A descriptive analysis based on data collected from 1110 households revealed a positive relationship between household income and electricity expenditure. Specifically, the study observed that wealthy households spent almost 38 percent extra on electricity per floor area than their low-income counterparts. In a related study, Yohanis, Mondol, Wright, and Norton (2008) investigated domestic energy use in Northern Ireland and found that households with income over £30,000 per annum use nearly three times of electricity compared to households on less than £10,000 per annum.

Jones and Lomas (2015) employed the odds ratio analysis to examine the effects of socioeconomic and dwelling factors on the proablity of being a high energy consumer in the United Kingdom. Using data collected from 305 households, the results showed that households with more occupants, children and teenagers and higher annual household incomes were significantly more likely to be high energy consumers. It was observed that higher household income increases the probability of being a higher energy consumer. This may be due to an increased ownership and use of energy-using appliances and an ability to easily pay energy expenses. Households with a higher income may also purchase new and high end appliances. The analysis also indicated that homes with three or more occupants are more likely to consume more energy than homes with one or two occupants. According to the study, households headed by people over 65 years old or retired persons were significantly less likely to have high energy demand.

Jamasb and Meier (2010) studied the socio-economic determinants of household energy spending in the United Kingdom. Using data from a survey of 77,000 households, the study estimated fixed effects econometric models to understand the effects of socio-economic factors suchs as income, energy prices, household type and number of children on energy spending. Energy spending was disaggregated into three types namely gas, electricity and overall energy spending. The study established a significant positive relationship between energy spending and number of children and energy price. Inome was also found to be significant and positively related to spending on gas, electricy and overall energy and this was attributed to the increasing ownership and usage of appliances. An income increases leads to buying of additional appliances or more frequent usage of existing ones, which leads to higher energy spending.

Khandker, Barnes and Samad (2012) examined the link between income and household energy consumption in India. They found a significant positive relationship between income and energy consumption, reflecting that growth in income leads to growth in household energy consumption. Similarly, Eakins (2016) studied the determinants of household petrol and diesel expenditures in Ireland. The study used micro data set and applied the double-hurdle model to identify the impacts of income and other factors on household energy expenditures. Results of the study showed that households living in urban areas, households that spend money on public transport, and households that do not possess a car spent less on both petrol and diesel. On the contrary, households in possession of higher number of cars and households with more occupants working spent more on petrol and diesel. The study also found a significant positive relationship beween income and household petrol and diesel expenditures.

Chambwera (2004) applied the Almost Ideal Demand System model to examine the factors influencing the variations in energy consumption patterns between electrified and non-electrified households in Zimbabwe. Using household survey data collected from 500 households, the study established that the energy expenditure pattern of electrified households was affected by income, household size, number of rooms and level of education of the head of household.

Rehdanz (2007) conducted a study to examine the determinants of residential space heating expenditures in Germany. Using cross-sectional data collected from 12,000 households in 1998 and 2003, the study found a statistically positive relationship between income and household heating expenditures. In a separate work, Meier and Rehdanz (2010) explored the determinants of residential heating expenditures among households in Britain. The study used household survey data to analyse electricity, gas and overall energy spending. The results showed that income is positively associated with household energy expenditures. Interestingly, the estimated income elasticities were very low with values ranging from 0.01 to 0.04, indicating that energy services are necessities for British households.

Hussain and Asad (2012) studied the determinants of household electricity expenditure in Pakistan. They employed household survey data and multivariate regression analysis. Results showed that household electricity expenditure was explained by family size, number of rooms, region, province and number of electricity consuming appliances. The study also found a strong positive relationship between income and household electricity expenditure. Nonetheless, Alkon, Harish and Urpelainen (2016) reported results showing negative relationship between income and household energy expenditure in India. Similarly, Contraras, Smith, Roth and Fullerton (2009) found a negative effect of income on electricity consumption in United States, suggesting that electricity is an inferior good. Wallis, Nachreiner and Matthies (2016) also identified income as a negative predictor of energy consumption in Germany. Moreover, Sardianou (2007) studied the factors affecting household energy consumption patterns in Greece using cross-sectional data and observed that higher income households are able to afford financial costs of energy-saving investments such as purchasing new efficient appliance that tend to conserve energy leading to reduction in energy consumption.

Contrary to previous studies, a nonlinear effect of income on household energy consumption has been established by Hasan and Mozumder (2017) and Yin, Zhou and Zhu (2016). For instance, Hasan and Mozumder examined the relationship between income and energy use in Bangladesh and found that income has a U-shaped impact on energy use, implying that as income grows household energy expenditure falls slowly up to a point and beyond that point increases in income raises energy expenditures at a faster rate. Yin *et al.* estimated the income and price elasticities of electricity consumption for households in the urban and rural areas of China. Results of the study show that the coefficients for income and its square term are respectively positive and negative and statistically significant, which means that income has an inverted U-shaped impact on electricity consumption.

Kavousian, Rajagopal and Fischer (2013) studied determinants of residential electricity cosnumption in the United States. The study used cross-sectional data based on 1658 households and estimated weighted regression model. Results showed that household electricity consumption is statistically significantly related to location, number of refrigeratiors and entertainment appliance and household size. Unlike other studies, this study found no statistically significant relationship between electricity consumption and income level. The authors explained that the effect of income on electricity consumption is mediated by ownership of appliances; i.e., income of the household impacts electricity consumption through affecting appliance stock. Moreover, Chatterton, Anable, Barnes and Yeboah (2016) argued that household income does not have direct effect on energy consumption. It affects energy consumption through ownership of cars or large detached properties.

The role of household size in explaining energy consumption has been emphasised in the literature (Brounen, Kok, & Quigley, 2012; Kaza, 2010). However, there is a mixed conclusion on the effect of household size on energy consumption. Whereas some studies found positive results (Çetinkaya, Başaran, & Bağdadioğlu, 2015; Leahy & Lyons; 2010; Salari & Javid, 2017; Yohanis *et al.*, 2008; Wei *et al.*, 2014), others reported negative effect of household size on energy consumption (Druckman & Jackson, 2008; Kavousian *et al.*, 2013; Rahut *et al.*, 2016a). However, most studies report that total household energy consumption is positively related to household size indicating that larger households consume more energy than smaller households (Estiri, 2015; Guta, 2014; Huebner *et al.*, 2015; Kelly, 2011).

However, there is empirical evidence that the relationship between household size and energy consumption is not perfectly linear and may differ when energy consumption is measured per capita as opposed to per household (Frederiks, et al, 2015). Most studies have found negative association between household size and per capita energy consumption (Brounen, *et al.*, 2012; Estiri, 2015; Ironmonger, Aitken, & Erbas, 1995; O'Neill & Chen, 2002; Longhi, 2015). There is an economy of scale in energy use (Guta, 2014; Muller & Yan, 2018). People living together tend to consume less energy per capita because they share energy services. They tend to use the same energy consuming appliances for cooking and other activities. The number of appliances in a household may not increase linearly with household size. This makes per capita energy consumption to be lower for households with many members than households with small number of people (Wallis *et al.*, 2016).

O'Neill and Chen (2002) studied the demographic determinants of household energy use in the United States. The study employed cross-sectional data and the impact of population, affluence and technology decompositions approach. Among other factors (income, age of household head, number of adults and number of children) household size was found to be negatively related to per capita energy consumption. In particular, the study notes that households with two-members consume about 17 percent less energy per person for residential activities than one-member households. Unlike other studies, this study did not employ econometric model in the analysis.

Using a nationally representative dataset, Longhi (2015) investitgaed the impacts of household characteristics on per capita energy expenditures of households in the United Kindgom. The study found that hosuehold energy expenditure is related to income, the presence of people of pensionable age and household pro-environmental behaviour. The study also showed that households with children spent between four percent and six percent more per capita on both gas and electricity. Again, study reports that household size has a negative and nonlinear influence on per capita energy expenditures such that moving from a single-member to a two-member household decreased per capita energy expenditures by 47 percent whereas moving from a two-member to a three-member household decreased per capita energy expenditures by about 40 percent.

Ngui *et al.* (2011) employed the Almost Ideal Demand Sytem model to study the determinants of household energy demand in Kenya and reported mixed results for household size. Whereas household size was negatively associated with budget shares of kerosene, fuel wood, petrol and diesel demand, it correlated positively with the expenditure shares on charcoal, electricity and LPG. Similarly, Rahut *et al.* (2016a) determined a statistically significant negative relationship between the amount spent by households on energy and household size, demonstrating the potential of economies of scale associated with a large family size.

Guta (2014) applied the Tobit model to study the socio-economic factors affecting charcoal consumption in rural Ethiopia. Using data on 221 households from four villages in Central and Southern Ethiopia, the study found a significant negative relationship between charcoal consumption and household size in Ethiopia. He argued that when family size increases households spend more on non-energy goods and services resulting in less disposable income available to purchase energy items. D'Agostino *et al.* (2015) showed that when household size increases, charcoal expenditure may not increase at all since a fixed quantity of charcoal is required to cook food on the charcoal stove. Hence the same amount of charcoal will be used on the charcoal stove for cooking regardless of the number of household members. However, their assertion is highly questionable because a household with more members may require the use of a bigger charcoal stove or more cooking frequency which ultimately leads to higher charcoal consumption and hence more expenditure on charcoal.

Household composition has been discussed as a relevant factor that determines energy consumption. A number of previous studies have reported that households with more children and adolescents consume a higher amount of energy (Brounen *et al.*, 2012; Eakins, 2013; Jones, Fuertes, & Lomas, 2015; Jones & Lomas, 2015; Longhi, 2015; Wallis *et al.*, 2016). For instance, the results from an empirical analysis of energy consumption data of households in the United Kingdom by Jones and Lomas (2015) indicated that households with children and teenagers were significantly more likely to consume a greater amount of energy than households without any. They attributed this to the fact that children and adolescents often do not know the financial implications arising from higher energy demand and for that matter are less mindful of the energy they use. Again, households with children and teenagers are obligated to provide more energy to meet the learning and entertainment needs of the younger ones.

Literature advances that the 'life stage' of a household affects its energy consumption intensity and expenditure and different variables reflecting life stage have been employed to investigate energy consumption by residential households. For example, Fell, Li and Paul (2014) researched into household electricity demand in the United States. They used dataset from the Consumer Expenditure Survey for the period 2006-2008 and applied the General Methods of Moments approach. The study provides empirical evidence to show that households tend to use more electricity, and thus pay more in energy bills, as the average age of adult members in the household increases. They argued that households with older indviduals tend to consume more electricity than hosueholds with younger occupants because older individuals spend more time at home due possibly to reduce working hours.

McLoughlin, Duffy and Conlon (2012) reported that energy consumption is highest when household heads are between 26 and 55 years due to the presence of children. Walli *et al.* (2016) assessed the effects of different factors on electricity consumption of German households and observed that electricity consumption increased with the number of adolescents living in a household. A similar finding is reported by Thøgensen and Grønhøj (2010) among households in Denmark. Brounen *et al.* (2012) also analysed residential energy consumption in the Netherlands. The study determined positive effect of the presence of children in the household on energy consumption. In particular, they found that households with children consumed almost one-fifth more electricity than households without children and the effect became stronger when the age of the children increases probably because of the strong preference of these children for energy-consuming appliances such as television, personal computers and gaming devices, all of which have significant effect on energy consumption.

However, there is empirical evidence to suggest that households with children tend to spend less on energy. For example, Rahut *et al.* (2016a) report, in their analysis of household energy expenditure in Bhuttan, that number of children is negatively associated with household expenditure on energy sources, reflecting that households with more children spent less on energy sources such as gas, kersone, fuelwood and electricity.

Some studies have also reported a significant relationship between the presence of elderly or aged people in a household and energy consumption, albeit with mixed results (Romero-Jordán *et al*., 2014; York, 2007; Wang *et al.*, 2015; White, Roberts & Preston, 2010). For instance, Wang *et al.* established that electricity consumption increased with retired persons living in a household. Furthermore, studies by White *et al.* (2010) and York (2007) indicated number of elderly people (65 years old and over) has a significant positive effect on energy consumption of households. The authors reasoned that households with more aged people tend to consume high energy because of the increased demand for space heating and entertainment to keep them active. On the contrary, Romero-Jordán *et al*. showed that energy consumption decreased with the number of older people (> 64 years) living in a household.

The effect of age of the household head on energy consumption is less clear, with some studies establishing negative relationship and others also revealing a positive relationship (Brounen *et al.*, 2012; Hill, 2015; Jones & Lomas, 2015; Lenzen, Dey, & Foran, 2004; Leahy & Lyons, 2010; Salari & Javid, 2017; Xie, Ouyang, & Gao, 2016) while others found no significant link between the two variables (Abrahamse & Steg, 2009; Huebner *et al.*, 2015). Evidence suggests that there is a significant positive relationship between energy consumption and age of the household responsible person and that energy consumption tend to be very high in households in which the responsible economic person is aged roughly between 50 and 65 years (Jones *et al.*, 2015).

Leahy and Lyons (2010) found that households in Ireland with responsible economic persons aged between 45 and 64 years spent more on energy compared to those whose main economic persons were within 35 to 44 years. In addition, Yohanis *et al.* (2008) found that households led by persons aged 50 to 65 years consumed the highest amount of energy while those with heads aged above 65 years consumed the less, and argued that this could be attributed to the fact that the former had higher incomes, bigger houses, and more number of energy appliances compared to the latter. A significant positive relationship between age of household head and energy consumed is also reported by Brounen *et al.* (2012) from their analysis of Dutch households. Contrary to previous studies, Rahut *et al.* (2016a) found an inverted U-shaped relationship between per capita household expenditure on energy and age of household head, suggesting that energy expenditure initially increases with age and later declines.

Kavousian *et al.* (2013) found that households in the United States with responsible economic persons older than 55 years and between 19 to 35 years had lower energy consumption compared to households headed by persons of other age groups. The authors explained that older people tend to be mindful about energy wastage and also tend to use fewer electrical gadgets whereas household members between 19 and 35 years are more likely to be in full-employment and hence tend to spend less time at home while Xie *et al.* (2016) established that age of house responsible person has no significant effect on electricity consumption.

A recent study by Bardazzi and Pazienna (2018) explored the relationship between age and private transport fuel expenditure in Italy. The study used data from the Italian Household Budget Survey and estimated a double hurdle model to understand how age is linked with transport demand and to identify other socio-economic factors affecting household energy expenditure. The results from their analysis showed that age has a significant and negative effect on transport fuel demand, implying that, fuel consumption declines with rising ageing population. Besides age, other socio-economic factors including total household expenditure, gender, dependent children and employment status were directly associated with energy expenditure. The results also showed that having a motorbike reduces transport fuel expenditure. They argued that the negative effect of motorbike on fuel expenditure is due to its greater fuel efficiency and further suggested that increasing accessibility to efficient transport system is a sure way to reduce transport fuel consumption and achieve sustainability.

The importance of education in explaining variation in household energy consumption is emphasised in various studies. A number of studies in developed countries show that education is significant and negatively related to household energy consumption (Gram-Hanssen, Kofod & Petersen, 2004; Salari & Javid, 2017). For example, Salari and Javid found that high educational level of head of household had negative impact on energy expenditure in the United States and suggested that this could be attributed to the fact that higher education induces households to choose more efficient energy sources leading to a reduction in energy expenditure. They added that educated heads of household have more information concerning energy saving than household heads with lower educational level.

In Denmark, Gram-Hanssen *et al.* (2004) established that households with higher education used less amount of electricity compared to households with a lower level of education. Nonetheless, Rahut *et al.* (2016a) found mixed results for influence of education on household energy demand. The results in this study showed that years of education of household head was positively associated per capita expenditure on LPG and electricity, but negatively related to per capita expenditure on firewood among households in Bhutan, suggesting that educated households tend to spend more on cleaner energy but less on others. However, Leahy and Lyons (2010) and Zhou and Teng (2013) indicate that education is significant and positively associated with household energy consumption.

Literature also shows that employment status of household members, particularly the head of household is closely linked with energy consumption. For the most part, employment status of the members of a household may influence energy consumption by affecting the household's socio-economic status and confidence in income security. For instance, Frederiks *et al.* (2015) advanced that households with more members in full-time employment tend to have more disposable income and use energy-intensive appliances resulting in higher energy consumption. Nonetheless, Longhi (2015) observed in the United Kingdom that households with at least one person unemployed spent three to four percent more on electricity compared to households where nobody is unemployed. This may due to the fact that persons that are unemployed tend to spend more hours per day at home and thus use more energy-consuming appliances resulting in high spending on energy. Regarding the type of employment of head of household, Ngui *et al.* (2011) showed in Kenya that being engaged in formal employment is negatively associated with budget shares on electricity, LPG, and charcoal but positively associated budget share on firewood.

With respect to sex of household head, some studies have found that female-headed households consumed more energy and hence incur higher cost on energy services than male-headed households (Klausner, 1979) whereas other also show that female-headed households consume less compared to male-headed household (Estiri, 2015; Permana, Aziz & Siong, 2015; Räty & Carlsson-Kanyama, 2010). For example, Klausner advanced that sex of household head influences the level of social order in the household, and thus energy consumption and associated expenditure. He also maintained that within patriarchal cultural systems male-headed households tend to consume less energy compared to female-headed households, other things being equal.

Klausner (1979) posits that households headed by males are more ordered and disciplined thus making relatively efficient use of energy in comparison to those headed by females. Employing data on a total of 209 families on public assistance in the Camden, New Jersey, the author estimated that families with the adult male person as head spent a slightly smaller proportion of their household budget on energy than households with female heads. In contrast, other studies indicate that men tend to be less cautious about household expenditures and energy consumption compared to women. For instance, Permana *et al.* (2015) observed, from their analysis of residential dwellings in Indonesia, that when the decisions about energy and control of energy consumption in the household were solely made by a woman, energy consumption tended to be the lowest. When wives were the dominant decision makers, energy consumption was reduced by 630MJ, compared to men.

An investigation of both direct and indirect energy use among single women and single men in four European countries revealed that total energy use was higher among men than women in each country, with men consuming on average between 6 to 39 percent more energy than women (Räty & Carlsson-Kanyama, 2010). Similarly, Bardazzi and Pazienza (2018) observed, from their analysis of Italian households, that households with a female head spent less on personal transport fuel than households with a male head. They attributed this to the few income resources for female-headed households because of more discontinuous jobs, a gender wage gap and lower pensions.

Similarly, Alkon *et al.* (2016) found that households under the leadership of females spent less on energy than households headed by men. Other studies have also found similar results and suggested that this could be explained by increased environmental consciousness among women (Carlsson-Kanyama & Linden, 2007; Lee, Park & Han, 2013; Luchs & Moordian, 2012; Van der Werff & Steg, 2014). Lee *et al.* (2013) stated that women are more willing to pay a higher price for energy-efficient light sources and are more likely to engage in energy saving practices than men. A study by Carlsson-Kanyama and Linden (2007) on energy demand reduction in Sweden showed that more women than men reported adopting 'low-tech' saving strategies, such as using slow cookers and ironing during the day.

Literature shows that women are often more willing to make changes in their own behaviours to reduce ecological problems while men tend to down play such issues. Women also express more interest in reducing energy consumption for environmental reasons than men (MacGregor, 2016). Wang (2016) reports that women are motivated to engage in energy conservation behaviours both to reduce energy bills and carbon dioxide emission. Carlsson-Kanyama and Linden (2007) established that men consumed between 14 and 21 percent more of electricity than women. In their view, men tend to have more disposable income, spend more time engaged in leisure pursuits, eat more meat and own and use more electronic appliances than women.

According to Steg (2005), women tend to be less dependent on cars as a prestige symbol and generally show greater concern about air quality leading to lower expenditure on personal transport fuel. Nevertheless, Nazer (2016) found that households headed by men consumed less energy than those headed by female. Similarly, Rahut *et al.* (2016a) established that female-headed households spent more on energy compared to those with male heads, thus contrasting the widely held notion that female-headed households tend to consume less energy because of the general conserving attitudes of women (Permana *et al.* 2015). However, Seebauer and Wolf (2017) showed that the sex of household head does not significantly affect variations in energy consumption. Similarly, DeFronzo and Warkov (1979) observed that sex of household head had no statistically significant effects on energy consumption. Likewise, Blocker and Eckberg (1997) found no evidence that women are more likely to engage in environmentally responsible behaviours than men, although women tend to show greater concern for the environment.

According to Corraliza and Berenguer (2000), people tend to engage in environmentally responsible behaviours out of a sense of moral obligation only when their environmental attitudes do not conflict with other favourable situations. Moreover, Lee *et al.* (2013) showed that women's preference for incandescent lighting and their lack of confidence about the quality of energy-efficient lighting negatively affects the actual purchase of energy-efficient home lighting regardless of their ecological value orientation. A positive and significant link has also been established between the female-male ratio and energy consumption, with households and zip codes with higher female-male ratios reporting higher levels of energy consumption than their counterparts (Elnakat, Gomez, & Booth, 2016).

Location has long been identified as a significant determinant of household energy consumption. Empirical studies show that households living in urban locations consume more energy than those resident in rural areas (Azevedo, Chapman, & Muller, 2016; Bousquet, Cremel, & Loper, 2014; Carcedo & Otero, 2005; Hussain & Asad, 2012; Kaza, 2010; Lenzen *et al.*, 2004; Lin & Ouyang, 2014). More importantly, urban areas are noted to be warmer than rural surroundings, and this increases the demand for energy for cooling and extra ventilation, and hence the amount that households dwelling in such places tend to spend on energy services (Lam, 1998; Salari & Javid, 2017; Wangpattarapong, Maneewan, Ketjoy, & Rakwichian, 2008).

Moreover, urban households are noted to own and use more extra ventilation appliances as a response to heat island effect linked to urban places compared to their counterparts in peri-urban and rural areas. Because energy, especially electricity is constantly required to operate these appliances, urban households tend to consume more electricity and incur higher cost on it than rural households (Kaza, 2010). D'Agostino *et al.* (2015) reported that households in urban areas spent more amount on charcoal than households located in rural areas and argued that an increase in urbanisation fosters charcoal consumption in many developing countries and hence raises the share of charcoal spending in total energy expenditure of households.

A significant positive relationship between household energy consumption and dwelling-related factors such as number of rooms and size of floor area has been reported by a number of empirical studies. For example, Çetinkaya *et al.* (2015) reported a positive and significant relationship between the size of dwelling in square meters and household electricity use and argued that households living in larger dwelling units tend to have higher energy requirements compared to households in smaller units. Salari and Javid (2017) and Yin *et al.* (2016) established that number of rooms had a significant positive effect on electricity expenditure among American and Chinese households respectively.

According to Leahy and Lyons (2010), Irish households with only one or two rooms paid significantly less for electricity than those with five or more rooms. Likewise, McLoughlin *et al.* (2012) showed that each additional bedroom causes 15.4 percent increase in total electricity consumption in the Irish household sector. Bedir *et al.* (2013) established a significant positive relationship between number of study/hobby rooms and electricity consumption. Moreover, Tiwari (2000) found that each additional room leads to 11 percent more electricity expenditure by Indian households.

Yohanis *et al.* (2008) found that the peak electricity demand of households with five bedrooms was over three times more than that of households with two bedrooms, and argued that households with more bedrooms have more appliances and thus greater demand for heating, cooling, and lighting. Besides number of rooms, Yohanis *et al.* also found a strong correlation between size of floor and average annual electricity consumption. Contrarily, some studies have found no significant relationship between electricity consumption and number of rooms (Bedir *et al.*, 2013; Wiesmann, Azevedo, Ferrão, & Fernández, 2011) whereas others also indicate that electricity consumption decreases with increase in number of rooms (Brounen *et al.*, 2012).

Bedir *et al.* (2013) examined the determinants of electricity consumption in the Netherlands and found a significant inverse relationship between number of bedrooms and electricity consumption by Dutch households, and attributed it to the fact that bedrooms are normally used intensively not only in the evening and at night but also do not usually contain a lot of electrical appliances compared to other types of rooms. Among dwelling characteristics, studies have shown that occupants of detached houses tend to consume more electricity compared to others, and thus allocate a significant proportion of their budget to energy costs , both when accounting for other variables and when not (Brounen *et al.*, 2012; Huebner *et al.*, 2015; Huebner *et al.*, 2016; Yohanis *et al.*, 2008).

The role of specific category of appliances on energy consumption has also been a subject of extensive research. The effect of preservation and cooling appliances in increasing electricity consumption has been widely documented. For example, Zhou and Teng (2013) found that Chinese households with a refrigerator consumed 22.2 extra electricity than households that do not have refrigerators. Similarly, findings have also been reported for German households (Wallis *et al.*, 2016), where number of IT appliances, number of refrigerating appliances, number of washing and drying appliances as well as the hours of use of IT appliances are found to significantly and positively affect electricity consumption.

Çetinkaya *et al.* (2015) established a significant relationship between ownership of air conditioners, television, washing machines, and refrigerators and total household electricity consumption in Turkey, reflecting that households with more of these gadgets tend to spend more on electricity than their counterparts. Apart from merely owning a refrigerator, Genjo *et al.* (2005) also found that the size of refrigerator has a significant positive effect on electricity consumption by households in Japan. Larsen and Nesbakken (2004) reported that the electricity consumption of households who owned a sauna was significantly higher than households without sauna in Norway.

Xie *et al.* (2016) estimated that each additional split air conditioner was associated with about 10.8 percent increase in total household electricity consumption. Moreover, Leahy and Lyons (2010) showed that households who owned vacuum cleaners consumed 6.2 percent more electricity than households without such appliances while Kavousian *et al.* (2013) found similar results for households with swimming pool pump compared to those without. Nevertheless, Leahy and Lyons (2010) indicate that ownership of refrigerators has no significant effect on electricity consumption.

Previous studies have also found varying degrees of relationship between electricity consumption and other categories of electrical appliances including entertainment devices, and cooking appliances. Apart from Kavousian *et al.* (2013) who did not find any significant relationship between washing appliances and expenditure on electricity, most studies which included this variable found a significant positive relationship between increased electricity consumption and ownership of washing appliances. For example, McLoughlin *et al.* (2012) observed that households with dishwashers were the largest consumers of electricity. In addition, Leahy and Lyons (2010) indicate that having a dishwasher increases the weekly demand for electricity by over 10.5 percent and hence the bills that dishwasher using households pay for electricity. Moreover, Larsen and Nesbakken (2004) found that households who owned a dishwasher used 2015 kilowatts hours of electricity per annum more than households without dishwashers.

Jones and Lomas (2015) reported that households owing more than thirty appliances have an increased probability of having a high electrical energy demand and energy bills compared to households with fewer appliances. Specifically, households more likely to be high electricity consumers owned four or more IT equipment; more than five entertainment items, an electric oven; two or more preservation and cooling appliances; and three or more laundry appliances. Pothitou, Hanna, and Chalvatzis (2017) also found a significant positive relationship between domestic energy consumption and stock of entertainment appliances. Godoy-Shimizu, Palmer and Terry (2014) found a significant positive relationship between electricity consumption and ownership of laundry appliances. Constantine *et al.* (1999) posit that refrigerators, room air conditioners and lighting account for the substantial part of residential energy use in Ghana.

Income Elasticity of Energy Demand

There is limited literature investigating income elasticities of household energy demand in developing countries. Even with the few studies, attention has been more on energy for domestic use such as firewood, charcoal and kerosene. This may be due to the over reliance of households on solid fuels for cooking and the limited availability of electricity in many developing countries particularly in Africa. Shittu, Idowo, Otunaiya and Ishmail (2004) estimated income elasticities of demand for fuels in the Ogun State of Nigeria and found negative income elasticity for wood, suggesting that wood is inferior to all households regardless of their wealth status and further implying that rise in household income will decrease demand for wood. The estimated income elasticities for electricity and kerosene were positive, with varying values across household segments. While elasticity coefficients for electricity were positive but less than one for poor and average households, they were greater than unity for wealthy households, indicating that electricity is a necessity to average and poor households and a luxury to wealthy households.

Without doubt, the study by Shittu *et al*. (2004) has advanced knowledge on the income elasticity of household energy demand. Unfortunately, the sample used for the estimation was very limited and hence does not allow for drawing conclusions to the entire population. Moreover, this study did not investigate the moderating effect of number of household appliances, thus further limiting its applicability.

Akpalu *et al.* (2011) studied demand for cooking fuels in Ghana using dataset from the fourth round of the Ghana Living Standard Survey. The results showed that income, prices and location significantly influence household demand for cooking fuels. The estimated income elasticities were positive with values of 0.54, 0.70 and 0.38 for charcoal, LPG and kerosene respectively, indicating that each fuel is a necessity to households. This implies that increase in household income will result in less than proportionate increase in the demand for charcoal, LPG and kerosene.

Though the sample used by Akpalu *et al*. (2011) was large and covered the entire country, the data set is slightly dated and therefore the evidence may not reflect current dynamics of energy demand among households. Moreover, they did not estimate income elasticity of demand for other types of energy such as electricity and transport fuels which are used by households to satisfy their needs for personal transport, lighting and entertainment all of which are welfare enhancing. Like Shittu *et al.* (2004), Akpalu *et al.* (2011) did not evaluate the effect of appliances on demand for energy though ownership of appliances is seen as a prerequisite for transitioning from traditional fuels to clean and modern sources (Pachauri & Spreng, 2004).

Arthur, Bond and Willson (2012) estimated elasticities for domestic fuels in Mozambique using household survey data. The study focused on five energy sources namely firewood, charcoal, candles, kerosene and electricity. Applying the econometric approach proposed by Deaton (1990), they found positive income elasticities for all the energy sources with magnitudes less than one. Even though the income elasticities were less than one, biomass energy sources were found to be less income inelastic (0.45 for firewood and 0.32 for charcoal) than other energy sources (with values of 0.93, 0.84 and 0.69 for candles, kerosene and electricity respectively). Moreover, they found that electricity was well valued by Mozambican households as lighting energy source. This study did not estimate income elasticity of demand for gas, transport fuel and total energy consumption, making it different from the present study.

In a related study, Guta (2012) applied an Almost Ideal Demand System model to estimate expenditure elasticities of household energy demand in Ethiopia. Contrary to similar studies that calculated elasticity for specific energy types, this study estimated income elasticity for energy groups. They separated fuels into two groups: traditional and modern. The traditional fuels composed of firewood, charcoal, leaves and animal dung while modern fuels comprised biogas and electricity. They found that expenditure elasticity for traditional fuel group was inelastic with a value of 0.72 in 2000 and 0.76 in 2004. Conversely, the expenditure elasticity for modern energy group was elastic with a value of 1.14 in 2000 and 1.15 in 2004. The results indicated that transitional fuel is a necessity whiles modern fuel is a luxury to households. This study covered more energy types but did not estimated income elasticities for kerosene, transport fuels and overall energy used consumed by households.

Ngui *et al.* (2011) investigated energy demand in Kenya using household level data and estimated income elasticities for firewood, charcoal, kerosene, LPG, electricity, petrol and diesel. They found positive income elasticities ranging from 0.205 to 0.937 for various energy types, indicating that these fuels are necessities to households. Surprisingly, kerosene was elastic with a value of 1.06, implying that a proportionate increase in expenditure on kerosene will be more than the proportionate increase in the total energy expenditures. They attributed the higher elasticity of kerosene to the fact that kerosene has multiple uses and it is easily available and affordable in smaller quantities compared to the other fuels. The problem with this study is that appliance stock was not included as an explanatory variable in the electricity model and therefore the indirect effect of electricity- using appliances on electricity consumption was not evaluated which limits the applicability of the finding.

Sun and Ouyang (2016) estimated income elasticities of household energy demand in China. The study used data from the China's Residential Energy Consumption Services covering three energy types: natural gas, refined oil and electricity. Expenditure elasticities of the three energy types were positive signifying that households demand for refined oil, electricity and natural gas will increase with improvement in income level. The expenditure elasticity of transport fuel was the highest (1.235) signaling that expenditure on refined oil could increase by about 12 percent if household consumption expenditure increases by 10 percent. The study further suggests that household income improvement would have the largest effect on the consumption of transport energy. The income elasticity of electricity ranked second to that of transport fuel. The estimate for electricity showed that electricity expenditure will increase by 8 percent for every 10 percent increase in consumption expenditure. Income elasticity for natural gas was the lowest. In addition, Sun and Ouyang observed that energy expenditure of high-income households takes greater share of their total consumption expenditure. However, with a further increase in income, household spending on energy consumption makes up a relatively small percentage of disposable income.

Burney and Akhtar (1990) studied household energy demand in Pakistan using data from the Pakistan Household Income and Expenditure Survey 1984/1985. The Extended Linear Expenditure system was used to estimate income elasticities. They found that kerosene, natural gas and electricity had positive expenditure elasticities but not firewood. Similarly, Gundimeda and Köhlin (2008) found positive expenditure elasticities of firewood, kerosene and LPG for low, medium and high income groups.

Salari and Javid (2017) examined household energy expenditures in the United States of America using household level data. They estimated income elasticities for gas and electricity consumption and found that the fuels were more income inelastic with values of 0.02 for gas and 0.42, implying that gas and electricity are necessity goods to households. Their results show income growth for households results in a lesser increase in gas and electricity consumption. However, this study was limited to only two energy types namely; gas and electricity and did not estimate income elasticity for other energy types such as transport fuels, kerosene and biomass.

Shi, Zheng and Song (2012) used household level data to estimate elasticity for residential electricity demand in China. The authors found a higher income elasticity for rural households (0.063) than for urban ones (0.023). Although the differential effect was small, the results suggested that the increase in the income of rural households will lead to more household electricity demand in the rural areas than in the urban areas. In a related study, Harold, Cullinan and Lyons (2017) estimated the income elasticity of energy demand among households in Ireland and found that income elasticity of household energy consumption varies across income deciles and cross-section. The analysis by Harold et al. shows that the income elasticity of energy for households in Ireland ranges between 0. 16 and 0.79. This study also shows that the energy demand of low-energy consumption households is more sensitive to rise in income compared to the energy demand of high-energy consumption households.

Empirical Literature on Household Energy Choice

This section is devoted to review of energy studies conducted at the household level in developing countries, focusing on rigorous studies on energy choice. The limited but growing rigorous empirical literature on energy choice provides limited information on the variables that affect the fuel choice and fuel switching behaviour of households.

Factors Affecting Household Energy Choice

The extant literature shows that economic and non-economic factors are important in explaining household energy choice. Among the numerous factors hypothesised to influence energy use, income, education, household size, dwelling location, prices and accessibility of fuels are recognised as most important. For example, the energy ladder theory posits that there is a significant positive relationship between household socio-economic status and the use of more efficient and convenient modern energy sources. It maintains that lower-income households use less-efficient traditional fuels such as firewood, crop residue and animal dung and move on to relative efficient transitional fuels such as kerosene with a rise in income and finally transcend to more efficient modern fuels such as LPG or electricity with a further rise in income (Gupta & Köhlin, 2006).

Many studies have concluded that household income or wealth is an important factor determining the choice of energy sources (Abebaw, 2007; Démurger & Fournier, 2011; ESMAP, 2003; Farsi, Filippini, & Pachauri, 2007; Gregory & Stern 2014; Gupta & Köhlin, 2006; Pandey & Chaubal, 2011; Tang & Liao, 2014). The income of household determines its fuel affordability (Hou, Liao & Huang, 2018). Mottaleb, Rahut and Ali (2017) indicate that higher-income households have relatively higher purchasing power which enables them to afford more efficient and modern fuels such as electricity or gas for domestic activities. Consequently, with an increase in income households gradually switch from the use of dirty and unclean fuels to more clean and efficient energy sources.

Gregory and Stern (2014) maintain that higher-quality fuels provide more economic value to households and that as income increases, households gradually ascend on energy ladder by consuming higher-quality fuels. With limited income, lower-income households have no option than to consume lower-quality fuels, which are less efficient and produce more pollution. Beyond affordability, higher income level increases the opportunity cost of collecting and using solid fuels such as firewood, crop residue and animal dung. For instance, Mottaleb *et al.* (2017) established that an economically-affluent farm households in Bangladesh considered it more rewarding to allocate more time to crop production and animal husbandry than to spend time collecting solid fuel, such as firewood or crop residue.

Reddy (1995) investigated energy choices of households for cooking and heating in Bangalore of India and applied a series of binomial logit models to evaluate the choice between energy pairs. The study determined that households ascend an energy ladder and that income significantly affects energy choice. At higher income levels, there is positive tendency for households to use gas and electricity which are considered superior due to their high efficient and cleanliness whiles at a lower income levels, there is greater probability for households to use firewood and charcoal. The results show that, apart from income, other socio-demographic factors including household size and occupation of household head are important determinants of energy choices.

In a related study, Rao and Reddy (2007) investigated the factors affecting choice of cooking fuels of households in India. The study used cross-sectional data and estimated multinomial logit model for urban and rural households. The results showed that household expenditure, household size and education are important determinants of cooking fuel choices in rural and urban areas. Moreover, having a female heading a household increases the probability of choosing modern fuels in both rural and urban locations. Wage and salary earners were also found to be more likely to choose LPG as main fuel for cooking.

Farsi *et al.* (2007) applied an ordered probit model to cooking fuel choice in urban Indian households. Their results indicated that a lack of sufficient income is one of the main factors constraining households from using cleaner and higher-quality fuels which provide more economic values because they are converted more efficiently and are convenient to use.

Additionally, other social and demographic factors such as education and sex of the household head were also found to be important in determining household energy choice. A major policy conclusion from this study is that promotion of higher level of education, greater empowerment of women and promotion of general economic development could increase the use of modern energy sources by households resulting in less adverse environmental, social and health impacts on households in particularly and society in general.

Looking at how income constraint can impede the adoption of modern fuel by households, Edwards and Langpap (2005) analysed start-up cost and the decision to switch from firewood to gas in Guatemala. Using probit estimation technique, they found that access to credit plays a relevant role in determining firewood consumption levels of households. Their finding also revealed that indeed high start-up cost was a major barrier to the adoption of LPG as an alternative fuel to fuelwood by households in Guatemala. They suggested that subsidising the cost of stove was a more promising policy measure for reducing fuelwood consumption.

Moreover, Gupta and Köhlin (2006) studied the socio-economic factors affecting household choice of domestic fuels in India. Using primary data collected from 500 households in Kolkata in India and applying series of probit models, the study found that income is the single most important factor that affects energy choices. They observed that there is a transition in fuel use away from firewood and kerosene, regarded as inferior by households, to LPG as household income increases. The study also found a significant positive relationship between LPG use and education and age of household head, household size and number of women working outside household. They concluded that an increase in women participation in the labour market could increase the use of modern fuels.

Duan *et al.* (2014) investigated household fuel use for cooking and heating in China. Unlike previous studies that applied rigorous econometric methods, this study was more descriptive. The results of the study indicate that income significantly affects household energy use. The proportion of gas users was found to be positively related to income per capita whiles the proportion of households depending on solid fuels was negatively related with the economic level. Another study by Tang and Liao (2014) determined that low-income households used more of solid fuels while households with relatively high incomes used modern and clean fuels mainly gas and electricity for cooking in rural China.

Hou *et al.* (2018) studied the effect of income poverty on household fuel choice in China. Using nationally representative household survey data and multinomial logit regression, the study found that economic poverty exerts a significant influence on household energy transition from less-efficient traditional fuels to clean modern fuels. Specifically, their results showed that when household income increases by 10 percent, the probability of a household choosing modern fuel also increases by 0.002. They observed that rural households prefer gas to electricity when their economic levels improve, indicating that preference also matter for household energy choice. Additionally, access to public infrastructure, employment, age and gender of the household were found to be significant determinants of energy choice. Household size was however insignificant. They concluded that policies targeted at increasing wealth accumulation, improving infrastructure level and raising employment rate could speed up household energy transition from dirty fuels to clean modern fuels.

A study by Démurger and Fournier (2011) tested the poverty-environment hypothesis in China. Using data on 273 households in 10 villages across Beijing municipality of China, their results confirmed the poverty-environment hypothesis that firewood consumption decreases with increasing income, reflecting that firewood is an inferior fuel for rural households in China. However, they were quick to recognise that the small size of the sample used for the study could limit drawing conclusion from the study to the entire population. Özcan, Gülayand Üçdoğruk (2013) conducted a study to identify the economic and demographic determinants of household energy choice in Turkey. Using multinomial logit regression analysis based on cross-sectional data, the study found that household total monthly income and age of household head were statistically significant and positively related to the choice of modern energy system.

Pandey and Chaubal (2011) examined household cooking fuel choice in rural India. Using data set from 61st round of the National Sample Survey, they estimated series of logistic regression models to understand the determinants of clean cooking fuel use. The study showed that educated females between 10 and 50 years of age, average household education index, regular salary and monthly per capital consumption expenditure positively affected the probability of using clean cooking fuels while family size was negatively associated with the use of clean cooking fuels.

Ouedraogo (2006) applied the multinomial logit model to cooking fuel choice in urban households in Burkina. The results of the multinomial logit analysis based on the survey data from households in Ouagadougou indicated that urban households were more likely to move away from firewood to cleaner fuels as their income increased. In a related study, Gebreegziabher, Alem, Kassie and Köhlin (2012) investigated energy transition of urban households in Ethiopia. A probit regression analysis based on data set from 350 households, revealed that transition from other fuels to electricity was influenced by household expenditure, family, age and education of the household head. A statistically positive relationship was found between choice of electricity and income and education, indicating that improvement in income and education increases the likelihood that a household will use electricity.

Baiyegunhi and Hassan (2014) investigated the determinants of rural household fuel transition in Nigeria. Using a cross-sectional data collected from 120 households and a multinomial logistic regression, the study found that household fuel transition from fuelwood to kerosene, natural gas and electricity occurred along with rising income. The results showed that household's age, educational attainment, household size, income, type of dwelling unit and price of fuel were significant factors influencing household choice of cooking fuel.

In addition, Baiyegunhi and Hassan (2014) found that higher educational attainment increased the probability of using modern fuels and elucidated that this could be due to the fact that increased level of education improves household income, taste, knowledge of fuel attributes and preferences for modern fuels. In a related study, Pundo and Fraser (2006) applied the multinomial logit model to identify the factors influencing household cooking fuel choice between firewood, charcoal and kerosene in rural Kenya. Results from the study showed that educational level of wife and husband, type of food mostly cooked and ownership of dwelling unit were important determinants of household cooking fuel choice.

Mekonnen and Köhlin (2008) studied the determinants of household fuel choice in major cities in Ethiopia. They found that urban households diversify or increase the number of fuels they use and also spend more on the fuels they consume including charcoal but not wood as their income (total expenditure) rises and that even fuel types such as wood are not necessarily inferior goods as is often thought. Therefore, they emphasize the need for a broader approach in understanding and explaining urban household fuel choice as well as drawing appropriate policy recommendations to address issues associated with wood fuel and other urban household energy use.

Using cross sectional data from Ethiopia, Malawi and Tanzania, Rahut, Behera and Ali (2016b) analysed household energy use patterns and observed that a significant number of households used solid fuels for cooking and only a small fraction of households used clean fuels such as electricity, liquid petroleum gas. Results from an econometric analysis showed that female-headed households, household heads with a higher level of education, urban and wealthy households were more likely to use modern energy sources such as electricity and liquid petroleum gas (LPG) but less likely to use solid fuels. More specifically, the study found that, less wealthy households, male-headed households, households located in rural areas and located away from market were more likely to use traditional and solid fuels (so called dirty fuels) for cooking, while richer households, households with a higher level of education, female-headed households, and urban households are more likely to use clean sources of energy such as electricity, LPG and kerosene for cooking.

Using similar methodology, Rahut *et al.* (2016a) investigated the determinants of household energy choice in Bhutan. The results showed that household energy choice was affected by income level and household wealth, age, gender and education of the household head, access to electricity, and location. The results further showed that education and income had a differential role in the choice of modern and traditional fuels. Wealthier and more educated households were found to prefer modern energy sources such as electricity and LPG while poorer and less educated households used traditional fuels like firewood. Even though this study advanced knowledge on the influencing factors of household energy choice, it did not show which of the factors affected choice of energy for cooking and those that influence choice of energy for lighting. It assumed that the factors affecting energy for lighting were the same factors influencing cooking energy choice. However, sources of energy for lighting are not the same as those used for cooking.

Education is an important factor affecting energy choice of a household. Farsi *et al.* (2007) argue that education improves household's awareness of the various environmental and health impacts of the use of different fuels and promotes the need for efficient and cleaner fuels. More education translates into higher awareness of the negative health effects of traditional fuels, and enhanced knowledge about the modern fuels, which are efficient, clean and convenient to use. Likewise, higher education may increase household income and hence strengthen the affordability of various clean and efficient fuels (Hou *et al.*, 2018; Leach, 1992). Higher education also increases the opportunity cost of time for wood collection, which leads to less use of wood fuel and promotes the use of clean fuels.

According to Rahut, Das, de Groote and Behera (2014), education positively affects the use of modern energy because it improves income and hence affordability and also increases knowledge which affects cultural and consumer preference. Therefore, households with more educated members tend to choose modern and clean fuels because of convenience of use, health benefits and the opportunity cost of time. Israel (2002) stated that education erases the negative perceptions about modern fuels and improves household decision-makers understanding of the costs and benefits of modern energy sources particularly their health benefits. In the light of this, higher education is associated with a positive tendency to use modern fuels and lower probability of using traditional fuel. Peng, Hisham and Pan (2010) noted that opportunity cost of wood collection time increases with higher educational level of women and this induces them to move away from wood-based fuels to modern fuels.

In their study of energy choice among households in Bhutan, Rahut *et al.* (2014) found that more educated households have higher preference for cleaner fuel and that they are more likely to choose LPG for cooking but are less likely to choose dirty fuels such as fuelwood, kerosene oil or dung cake for similar domestic work. In Ethiopia, Gebreegziabher *et al.* (2012) found a statistically negative relationship between level of education and wood consumption but a positive relationship between electricity use and level of education of household head. Specifically, their results revealed that a unit increase in the level of education of the household head on average reduced the probability of using firewood by 16.5 percent. In addition, Gupta and Köhlin (2006) found that higher educated women had a lower probability of using wood and kerosene in India

Lee (2003) examined household energy use in Uganda using a nationally representative household survey data. He separated fuels into three categories: solid fuel, non-solid fuels and mixed fuel and estimated multinomial logit model to identify the factors affecting household fuel switch from solid fuel to non-solid fuels. He argued that a full fuel switch occurs when households use only non-solid fuels whereas no switching happens when they use only solid fuel. The results from the study revealed that education was positively related to the choice of non-solid fuels by households. Moreover, income and public infrastructure provision were found to influence household switching from solid fuel to non-solid fuel.

D'Agostino *et al.* (2015) indicate that access to information in the household is an important factor that affects energy use. A study by Crosby and Taylor (1981) examined the twin effects of education and information on the purchasing choices made by consumers. They showed that the higher the level of acquired education, regarding how to judge a product’s performance, the greater the number of salient factors that are considered when purchasing decisions are being made. Information was found to influence consumers’ expectations of a product’s performance and, hence, their preferences.

Joshi and Bohara (2017) investigated household preferences for cooking fuels in Nepal. Using cross-sectional data and multinomial logit model, they found a significant positive relationship between household size and use of modern fuels. The authors explained that households with large members are likely to use modern fuels for cooking because they can have different earning means which can enable them to afford these fuels. In contrast, Barnes, Krutilla and Hyde (2010) indicate that larger urban households tend to select traditional fuels to a greater extent whereas smaller households tend to choose relatively modern fuels. Generally, larger households choose traditional (often less efficient) fuels in greater proportion but their per capita energy consumption tend to be smaller consumed less total energy per household member than smaller households.

Again, Démurger and Fournier (2011) found a significant positive relationship between firewood consumption and household size in China and explained that this is because of increased demand for energy and an increased labour supply for wood collection as household size increases. Moreover, larger household sizes may mean larger labour input, which is needed in firewood collection. Larger households are more likely to have extra labour (for example children’s labour) that can be used to freely collect firewood from public fields (Pundo & Frazer, 2006).

According to Pandey and Chaubal (2011), males and females conceive energy consumption differently and have differential tolerances or reasonable exposure to smoke (Burke & Dundas, 2015; Hou *et al.*, 2018). In many developing countries, women tend to be mainly responsible for cooking and fuel collection particularly in rural areas. For this reason, a higher number of women in the household increases available labour for the collection of wood and for cooking and this decreases the likelihood of the household choosing alternative fuels. However, if there are few women in the household, labour available for collection of wood decreases and this increases the likelihood of the household moving to less-intensive fuels (Rahut *et al.*, 2014). In similar vein, Gupta & Köhlin (2006) maintain that if female head works outside the household and there is shortage of other female household members, then there is the likelihood of the household choosing less time intensive fuels like gas.

Moreover, Burke and Dundas (2015) argue that increased participation of women in the workforce raises the opportunity cost of biomass collection time and that might encourage household to adopt alternative energy sources including gas. A higher participation of females in the labour force is also likely to reduce quantity of energy consumed in the household as fewer people are left at home. However, Gupta and Köhlin (2006) found no evidence to suggest that women participation in labour force reduces household energy demand or increases the likelihood of choosing more efficient clean fuel in India.

Guta (2012) submits that the influence of age of household head on the energy use is determined by custom and familiarity with a particular fuel type. He argued that older household heads have a long history of using traditional fuels like firewood and crop residue and therefore may lack the flexibility to abandon those fuels and to switch to available alternatives. Démurger and Fournier (2011) also argue that older people use more of firewood because they tend to perpetuate traditional heating and cooking habits as compared to younger persons who easily adapt to changing lifestyles. Nonetheless, younger people may also use more traditional fuel because they may prefer to collect firewood from a forest to reduce expenditures on modern fuels, which are often relatively expensive in many developing countries.

Karimu (2015) examined household preference for cooking fuels in Ghana. Using household level data and multinomial probit regression, the study established that income, household size, education, availability of fuels and urban dwelling significantly determine household choice of cooking fuel. With respect to income, the study found that higher income increases the probability of choosing modern fuels relative to traditional fuel.

Similarly, Kwakwa, Wiafe and Alhassan (2013) investigated the determinants of household energy choice in Ghana. A logistic regression analysis based on primary data collected from 507 households in the forest and savannah zones revealed that income, education, family size and employment were significant determinants of household energy choice. Their results contradict the finding of Karimu who report that higher education and income improve the use of modern energy. The study found that choice of electricity was influenced positively by employment but negatively by income and education. Even though Karimu (2015) and Kwakwa *et al.* (2013) studies advanced knowledge on household energy use in developing countries, they did not consider the factors affecting household energy consumption and the extent to which spending on energy affects household expenditure on other goods. These issued are the focus of the present study.

Empirical Literature on Crowding-Out Effects of Energy Expenditure

Research examining the crowding-out effects of energy expenditure on other household expenditures is scarce. Even with the few studies, the focus has largely been on developed countries (Ferdous, Pinjari, Bhat & Pendyala, 2010; Gicheva, Hastings & Villas-Boas, 2007; Murray, 2012) with little known empirically about how household energy expenditure affects spending on other goods and services in developing countries. For example, Ferdous *et al.* studied the relationship between transport expenditure and other categories of household expenditures in United States and found that transport expenditure contributes significantly to reduction in saving rates, food consumption and vehicle purchases. More specifically, the study showed that households adjust savings rates, food consumption and vehicle purchases in response to higher energy expenditure occasioned by rising fuel prices. In addition, household socio-economic and demographic characteristics were found to influence the percent of income or budgets allocated various categories of expenditure and savings.

Gicheva *et al.* (2007) explored the relationship between fuel prices, fuel-related expenditures and grocery purchases by households in United States. Using detailed scanner data from large grocery chain and data from Consumer Expenditure Survey, they estimated series of econometric models to determine the extent to which rising fuel prices, translating to higher fuel expenditure, affect food purchasing and expenditures. They established that household fuel expenditure increases directly with rising fuel prices and that households reduce food consumption in order to compensate for increases in fuel cost. More specifically, they found that a 100 percent increase in fuel price reduces food-away-from-home by about 45 to 50 percent. However, the reduction on eating out is partially offset by increased grocery purchases for eating in-home. Within grocery purchases, it was found that consumers substitute regular shelf-priced products with special promotional items to take advantage of savings.

Another study in United States by Choo, Lee and Mokhtarian (2007) examined transportation expenditure in relation to telecommunication expenditure. The study used the consumer expenditure survey data from 1984 to 2002 and computed elasticities to determine whether transport and communication are substitutes or complements. The estimated income elasticities were positive, indicating that transportation and communication are normal goods and that an increase in income increases demand for transportation and communication.

Sanchez, Makarewicz, Hasa and Dawkins (2006) examined fuel expenditure and other transport related expenditures in relation to housing expenditures. Using a cluster analysis technique, they found existence of a trade-off between spending on fuel and housing expenditure, indicating that higher spending fuel decreases household housing expenditure. According to this study, transport and housing costs are a great burden for low income households which compound their financial challenges. They argued that higher transport cost reduces the ability of low-income households to pay for other needs as well as removing them from the possibility of home ownership and wealth accumulation. This study showed that energy expenditure has impact on other categories of household expenditures.

Nord and Kantor (2006) investigated the link between household food insecurity and heating and cooling costs in the United States. Using data on food insecurity and economic and demographic they estimated series of logistic regression models to understand the extent to which households face trade-offs between heating and cooling costs and other basic needs particular food security. They established that households residing in areas that require high cooling or heating cost were more food insecure compared to household livings in other areas. According to this study, households make decisions between food and fuel cost most of the time, signalling that higher energy costs exert a significant influence on household food consumption.

Murray (2012) conducted a study to determine the relationship between energy expenditure and food expenditure in United States. He used expenditure data from the Consumer Expenditure Survey and employed the Quadratic Almost Ideal Demand System model to estimate energy and food expenditures. His results demonstrated that poor households tend to be more vulnerable to energy price shocks. More specifically, the study found that an energy price shock of 10 percent can lead to reductions in food at home expenditures up to 5 percent. This study emphasised the trade-offs between energy and food expenditure and did not evaluate how energy expenditure affects expenditures on different variety of goods and services household consume. Moreover, the study was carried out in developed country and the findings cannot be extrapolated to developing countries.

Alkon *et al*. (2016) estimated the energy cost burden to households in India. This study measured energy cost burden as the share of total household budget allocated to energy services. While the authors have added to the limited literature on extent to which spending on energy competes with other household goods and services, they failed to provide empirical estimates on how energy expenditure crowds in or crowds out expenditure on other goods; which is the focus of this thesis. Hernández and Bird (2010) used a qualitative approach to ascertain the extent of energy burden of low-income households in United States. This study measured energy burden in terms of financial resources allocated to energy expenditure. They found that low-income households allocated a higher proportion of their income to energy purchases and this affected the amount of money allocated to other goods and services. This study also did not provide empirical estimates of the effect of energy expenditure on household consumption patterns.

It is clear from the review in this section that previous studies have emphasised energy expenditure in relation to expenditure on another commodity or selected commodities while research examining the relationship between energy spending and expenditures on wide range of goods and services consumed by households is virtually non-existent. Additionally, almost all the studies analysing energy expenditure in relation to other expenditures are from developed countries. However, it is unclear if the findings from these economically advanced countries apply to developing countries especially in Africa.

Chapter Summary

This chapter surveyed the existing related literature for the study. The literature review was conducted in two parts. The first part discussed the theoretical perspectives on household energy use and expenditure behaviour and the second part looked at the empirical studies on the three issues of interest in the study. Two main theoretical perspectives were identified as important in explaining household behaviour regarding purchases of energy good. These are the household production theory initially developed by Becker (1965) and later popularised by Lancaster (1966) and Muth (1966) and the two-stage budgeting theory proposed by Strotz (1957) and later extended by Gorman (1959). The household production theory settles down to the fact that energy per se does not generate utility to households but rather the energy services such as cooking, lighting and powering appliances do. Households maximise utility from energy services produced from energy items while the two-stage budgeting theory reveals the two-levels involved in energy purchasing with first being the participation decision that households make and second, the spending.

The theoretical frameworks for explaining household energy choice are the energy ladder concept proposed by Hosier and Dowd (1987) and the energy stacking theory introduced by Masera *et al.* (2000). The energy ladder theory highlights the traditional income effect on household energy transition whiles the energy stacking theory recognises the complex web of interrelated factors that affect household fuel transition. Notwithstanding, the two theories rely on the microeconomic theory of consumer and they provide important explanations for household energy transition in developing countries.

The review of the relevant empirical literature reveals a number of important issues. Firstly, energy use and expenditure are affected by a number of factors including socio-economic characteristics of household. However, the effects of these factors on energy consumption differ widely across countries. Also, the relationship between energy consumption and income and other variables is influenced by a number of issues such as type of data used, the econometric technique applied and the level of development as well as the stage of economic cycle reached of the country under consideration.

Secondly, most previous studies focused on aggregate energy consumption using time series data and method and little research looked as residential energy consumption using micro-level data and techniques.

However, studies based on aggregate data suffer from loss of information because they are not able to reveal the individual specific factors that affect energy consumption. Of the few studies using primary data, the focus has been largely on developed countries and also developing countries in Asia and Latin America while there is severe lack of research investing household energy expenditure in Africa, particularly Ghana. Little is therefore known about the influencing factors affecting household behaviour regarding purchases of energy goods. Therefore, the current research that assesses the impact of dwelling, appliances, income and other household-level factors on household energy consumption is important for energy policy formulation and for contributing to literature income affects energy consumption of households employing micro-level data and methods is necessary to augment literature on household energy use in developing countries.

Thirdly, while studies have looked at the relationship between income and energy consumption with mixed results, the crowding-out effects of energy expenditure on household budget allocation to other goods is understudied. This motivates the current study to look at the extent to which household spending on energy affects other categories of expenditure. Fourthly, empirical studies on energy choice use different approaches (qualitative, descriptive and econometric approaches) and reached different conclusions regarding the factors that affect households' choice of cooking fuels. Rigorous empirical studies on household energy choice in Africa are limited and more studies are required to better understand the energy choice behaviour of households on the continent. The research methods employed for the study are presented next.

CHAPTER FOUR

RESEARCH METHODS

Introduction

This chapter discusses the research methods used for the study. It is organised into four sections. The first section discusses the philosophical stance of the work and provides the research design. The various strengths and weakness of the positivist philosophy are highlighted and a justification for its choice as underlying research philosophy is provided in this section. This is followed by the description of the data source in the second section. The analytical models for the various objectives are covered in the third section. The fourth section deals with the measurement of variables and discusses the descriptive statistics of the variables used for the study.

Research Philosophy

A research philosophy is generally defined as the school of thought that underpins the development of knowledge and the nature of that knowledge in relation to research (Saunders, Lewis, & Thornhill, 2012). Relating to research philosophy is a research paradigm. Generally, research paradigm is the belief system or the theoretical framework that guides research in a field (Willis, Jost & Nilakanta, 2007).There are several paradigms that govern the practice of research. However, four paradigms are widely followed in social science inquiry: positivism, post-positivism, constructivism and critical theory (Denzin & Lincoln, 2011; Gratton & Jones, 2010; Myers & Avison, 2002; Ruben & Babbie, 2010). Positivism is recognized as the first and the traditional paradigm developed for social inquiring and the others are viewed as extension of it (Clark, 1998; Proctor, 1998; Ruben & Babbie, 2010). According to Clark, only positivism and post-positivism need to be explored and understood before any decision on a sound research method can be made. Galliers (1992) advanced that positivism and post-positivism are the two principal philosophical dimensions in the tradition of science.

This study adopted the positivist philosophy within the tenets of liberal economics. Positivism is based on the rationalistic and empiricist philosophy that originated with the classical writings of August Comte and Emile Durkheim, and measures a deterministic philosophy in which causes determine effects and outcomes (Creswell, 2003). As outlined by Aliyu, Bello, Kasim and Martin (2014), positivism is a research strategy and approach that is rooted on the ontological principle and doctrine that truth and reality are free from the viewer or observer.

The positivist paradigm posits that social behaviour can be studied empirically by applying the methods of natural science. In other words, the social world can be studied in the same objective way as the natural world. Thus, the positivist paradigm shares the assumption that in social sciences as in natural sciences, the observer or researcher can be separated from the object of his or her research. This paradigm relies on quantitative approach for testing objective theories by examining the relationship among measurable variables (Creswell, 2003). Positivists assume that patterns (trends), generalisations, methods, procedures, cause-and-effect issues are also applicable to the social sciences. They maintain that the objects of the social sciences, namely people, are suitable for the implementation of scientific methods.

Although positivist philosophy continues to influence social science researches especially economic inquiries, its central assumptions as well as its applicability to studying human subjects have been challenged by a number of writers. One major criticism raised against positivism is the lack of subjectivity in interpreting social reality. Critics argue that objectivity needs to be replaced by subjectivity in the process of social inquiry. Babbie (2012) in particular points out that everybody acts, thinks and interprets subjectively to certain extent. According to Babbie (2010), this subjectivity is unique to any individual; and the endeavour for objectivity could best be obtained through the discovery of intersubjective interests between individuals.

Critics have also challenged the claim that studies based on the positivist research philosophy are more robust and value free. For instance, Kuhn (1962) argues that there is a thin line between dogma and reasoned belief and it is not always as clear as the traditional philosophy of science assumed by social science researchers. As Kuhn points out, it is sometimes difficult to assess when it is reasonable to maintain faith in an unconfirmed hypothesis and when to abandon it. This shows that man's comprehension of science and of the world can never rely solely on objectivity alone, but must account for subjective perspectives as well since all objective conclusions are ultimately founded upon subjective conditioning. Besides, Nagel (1961) remarks that the scientific method itself is not against dogma, that if dogma is applied with integrity it can minimise the maintenance of unwanted beliefs based on logically sound and statistically appealing theories that are no less precise than dogmas in their attempts to explain and predict reality.

Though the criticisms raised against positivist research philosophy are sound and valid, it is imperative to note that the other research philosophies have equally been criticised. There is no research philosophy that is criticism free. All the research philosophies have their strengths and weaknesses. Thus, what matters is the suitability of a research philosophy to the type and purpose of the research.

The choice of the positivist philosophy for the study was informed by the fact that positivist approach favours quantitative research design and therefore advances the mathematical rigour of the study which could provide more useful findings and explanations. Furthermore, positivism allows researchers to move away from unobservable beliefs and desires and to focus on objective facts. As Friedman (1953) states, the design of positivism and the quantitative approach to research is to provide a system of generalisation that can be used to make correct predictions about the consequences of events.

Research Design

A research design describes the detailed plan of how a research study is to be completed (Thyer, 2010). It provides the overall structure and orientation of investigation as well as a framework within which data can be collected, analysed and interpreted (Bryman & Bell, 2007; Bryman, 2008). This study is biult on the positivist and empiricists' philosophy which emphasis quantification of objective knowledge. This paradigm relies on quantitative approach for testing objective theories by examining the relationship among measurable variables (Creswell, 2007). Underlying the positivist ideology is the quantitative research which purports to describe, compare and detect causal relationships between variables (Borg & Gall, 1989; Stainback & Stainback, 1988). It employs the deductive approach and rests on testing theory based on data measured with figures, which are analysed using objective and reproducible statistical techniques.

Considering the objectives to be addressed, the study employed the quantitative research design, which involves the application of econometric procedures to testing and verifying relationships between quantitatively measured variables or parameters. These features were employed for the analysis in this study. Specifically, since the main focus of the study is to analyse energy choice, expenditure and household consumption patterns, the explanatory research design under the quantitative approach was employed.

Data and Source of Data

This study deviates from earlier works relying on macro data. The use of macro data does not give the researcher the room to look at the specific individual-level determinants of household energy consumption. The use of macro data thus makes policy recommendations from such studies generic – generally focusing on aggregate energy consumption. The study employed micro-level data from the sixth round of the Ghana Living Standards Survey conducted by the Ghana Statistical Service from October 2012 to October 2013. As described by GSS (2014), the households who participated in the survey were selected using a two-stage stratified random sampling technique in which 1200 enumeration areas were randomly selected at the first stage of sampling. In the second stage of sampling, 15 households per enumeration area were considered. Combining both stages of sampling resulted in a final sample of 18000 households covering the ten administrative regions in the country. However, 16772 households were successfully interviewed leading to a response rate of 93.2 percent.

Though this survey was not solely dedicated to household energy issues, it collected information on the main fuel used for cooking as well as expenditure on electricity, transport fuel, LPG, kerosene, and biomass. It also collected information on household characteristics such as employment, dwelling location, income, and access to electricity. There is also information on the sex, age, education, and marital status of household heads and other household members.

Undeniably, like previous surveys, the sixth round of the Ghana Living Standards Survey contains important information on household expenses and energy use. But, the GLSS dataset does not come in a ready-to-use format for purposes beyond those for which it was conducted. In order to negotiate this problem, this study employed unique household identifications to determine its own sample by merging all variables of interest. It is crucial to indicate that information on choice of energy for cooking was missing for 35 households, so they were dropped. Additionally, households with zero total expenditure were dropped. The same strategy was applied to respondents with zero gross household income and those without information on any variable considered important for the analysis. Thus, the final sample used for the present study was 16508. This sample represents 98.43% of the original sample, and thus deemed fit for the analysis.

Model for Household Energy Consumption

In examining the effect of income and other factors on household energy consumption, this thesis dwells heavily on the two-stage budgeting theory. Proposed first by Strotz (1957) and extended by other researchers including Gorman (1959) and Chambwera and Folmer (2007), this theory maintains that households engage in a two-stage process in their consumption decisions. In the first stage, households allocate income to various categories of goods such as food, clothing, energy, and others. In the second stage, with constraints imposed by income and other predisposing factors, households maximise utility with each category (Eakins, 2013). By so doing, the household decision process is made easy since one broad cost allocation method can be considered at a time.

Like other countries, energy consumption among households in Ghana follows the two-stage budgeting process in the sense that residential energy consumers in the country constantly have to take economic decisions to allocate their family budget between both segments of energy and non-energy goods, without necessarily being conscious of this theoretical process. Therefore, this thesis relies on the two-stage budgeting model as advanced by Baker *et al*. (1989) who indicate that disaggregate fuel expenditures depend on relative fuel prices and other household level factors as well as weakly separable preferences between fuel and non-fuel goods. Unlike Baker *et al.*, income and other household factors were however used due to the absence of reliable information on fuel prices.

The study relies on the theoretical proposition that household energy consumption is driven by household income, socioeconomic characteristics and energy-consuming devices. Taking cues from Salari and Javid (2017), Curtis and Pentecost (2015) and Eakins (2013), the following general functional form and empirical equations were specified and estimated for the various categories of fuels considered by this study:

$$E_i = f(Y_i, H_i, A_i) \tag{1}$$

Where E is annual energy consumed by the i^{th} household, Y is household income, H is socio-economic characteristics of the household while A represents the stock of energy-consuming devices.

Considering the different forms of energy purchased and used by the households being investigated in this study, the following six empirical models were specified and estimated:

$$\begin{aligned} HEB_i = {} & \alpha_0 + \alpha_1 \ln hinc_i + \alpha_2 hsize_i + \alpha_3 \text{agey}_i + \alpha_4 male_i + \alpha_4 educ_i + \alpha_6 \text{married}_i + \alpha_7 empstat_i \\ & + \alpha_8 urban_i + \alpha_9 elec_i + \alpha_{10} ownh_i + \alpha_{11} \text{child}_i + \alpha_{12} agedpers_i + \varepsilon_i \end{aligned} \quad (2)$$

$$\begin{aligned} HEK_i = {} & \delta_0 + \delta_1 \ln hinc_i + \delta_2 hsize_i + \delta_3 \text{agey}_i + \delta_4 male_i + \delta_5 educ_i + \delta_6 \text{married}_i + \delta_7 empstat_i \\ & + \delta_8 urban_i + \delta_9 elec_i + \delta_{10} ownh_i + \delta_{11} \text{child}_i + \beta_{12} agedpers_i + \varepsilon_i \end{aligned} \quad (3)$$

$$\begin{aligned} HEG_i = {} & \chi_0 + \chi_1 \ln hinc_i + \chi_2 hsize_i + \chi_3 \text{agey}_i + \chi_4 male_i + \chi_5 educ_i + \chi_6 \text{married}_i \\ & + \chi_7 empstat_i + \chi_8 urban_i + \chi_9 elec_i + \chi_{10} ownh_i + \chi_{11} \text{child}_i \\ & + \chi_{12} agedpers_i + \varepsilon_i \end{aligned} \quad (4)$$

$$\begin{aligned} HEE_i = {} & \beta_0 + \beta_1 \ln hinc_i + \beta_2 hsize_i + \beta_3 \text{agey}_i + \beta_4 male_i + \beta_5 educ_i + \beta_6 \text{married}_i + \beta_7 empstat_i \\ & + \beta_9 appliances_i + \beta_{10} rooms_i + \beta_{11} urban_i + \beta_{12} ownh_i + \beta_{12} \text{workers}_i + \beta_{13} \text{child}_i \\ & + \beta_{14} agedpers_i + \varepsilon_i \end{aligned} \quad (5)$$

$$\begin{aligned} HET_i = {} & \lambda_0 + \lambda_1 \ln hinc_i + \lambda_2 hsize_i + \lambda_3 \text{agey}_i + \lambda_4 male_i + \lambda_5 educ_i + \lambda_6 \text{married}_i \\ & + \lambda_7 empstat_i + \lambda_8 urban_i + \lambda_9 ownh_i + \lambda_{10} \text{child}_i + \lambda_{11} agedpers_i \\ & + \lambda_{12} pubtransp_i + \lambda_{13} \text{workers}_i + \lambda_{14} cars_i + \lambda_{15} motorcys_i + \varepsilon_i \end{aligned} \quad (6)$$

$$\begin{aligned} HETT_i = {} & \gamma_0 + \gamma_1 \ln hinc_i + \gamma_2 hsize_i + \gamma_3 \text{agey}_i + \gamma_4 male_i + \gamma_5 educ_i + \gamma_6 \text{married}_i + \gamma_7 empstat_i \\ & + \gamma_8 appliances_i + \gamma_9 urban_i + \gamma_{10} rooms + \gamma_{11} elec + \gamma_{12} ownh_i + \gamma_{13} \text{child}_i \\ & + \gamma_{14} agedpers_i + \gamma_{15} pubtransp_i + \gamma_{16} \text{workers}_i + \gamma_{17} cars_i + \gamma_{18} motorcys_i + \varepsilon_i \end{aligned} \quad (7)$$

Where *HEB, HEK, HEG, HEE, HET and HETT* are the annual expenditures on biomass, kerosene, gas, electricity, transport fuel and total energy respectively; *lnhinc* is the natural logarithm of household income; *hsize* is the number of household members; *agey* is the age of household head, *male* is a dummy variable for sex of household head; *educ* is the education of the household head; *marstat* is the marital status of household head; *empstat* is the employment status of household head; *appliances* is the number of electricity-using appliances; *urban* is the area of residence of the household; *tenstat* is a dummy variable indicating whether the household lived in own house or not; *room* is the number of rooms occupied by the household; *child* is a dummy variable indicating presence of children; *pubtransp* is public transport spending; *agedpers* is number of aged person; *workers* is number of workers; *cars* is the number of cars; and *motorcys* is number of motorcycles. The expectations of the variables used for the analysis are reported in Table 1.

Table 1: Signs of Variables Used in the Energy Consumption Models

Variable	HEB	HEK	HEG	HET	HEE	HETT
Log (income)	-	-	+	+	+	+
Household size	+	+	-	+	+	+
Age	-	+	-	-	+	+
Number of aged	+	-	-	-	+	+
Male	+	+	+	+	+	+
Education	-	-	+	+	+	+
Married	-	-	+	+	+	+
Employment status	-	-	+	+	+	+
Urban	-	-	+	+	+	+
Access to electricity	-	-	+			+
Owner of home	-	-	+	+	+	+
Presence of children	+	+	-	+	+	+
Appliances					+	+
Number of rooms					+	+
Number of workers				+	+	+
Number of cars				+		+
Number of motorcycles				+		+
Public transport spend				-		-

Source: Author (2018).

Estimation Technique

The empirical estimation technique for analysing household energy consumption behaviour depends on the structure of the available data as well as the aim of the researcher (Eakins, 2013; Greene, 2003). As common with household surveys, the data employed for this study included a non-negligible proportion of households with zero energy expenditure. Naturally, all such households could be eliminated without recourse to the reason which led to the occurrence of the zero. However, this would lead to other statistical issues that would be very difficult to soundly defend. Moreover, it has been widely reported that energy expenditure data tend to include numerous zero observations (Curtis & Pentecost, 2015). The presence of zero expenditure on energy item indicates that the data is censored and modelling technique that ignores the censoring nature of the data stand the risk of generating biased estimates. A standard econometric technique for analysing censored data of the type considered in this thesis is the Tobit regression model (Tobin, 1958). As noted by Long (1997), the Tobit model is used to estimate linear relationships between variables when there is either left or right censoring in the dependent variable. Censoring to the right occurs when cases with values at or above a threshold take on a value of that threshold whereas left censoring is when values at or below some threshold assume the value of that threshold. The data used for the analysis was left censored. Consequently, the Tobit regression technique was employed to cater for the censored nature of the data. The main strength of the Tobit model is that it produces estimates that are unbiased and consistent even with the many zero observations in the dependent variable.

The Tobit model is estimated using the maximum likelihood estimator. Unlike OLS, the coefficients of the explanatory variables from the maximum likelihood estimation do not have direct interpretation. The marginal effects are used to evaluate the effects of the independent variables on the dependent variable. The marginal effects are estimated using the approach proposed by Long and Freese (2001).

Model for Household Energy Choice

The model for analysing household energy choice is based on the random utility theory proposed by McFadden (1980). This theory considers the choice of energy type as a behaviour in which households choose a particular type of energy to maximise utility (Hou *et al.*, 2018; Joshi & Bohara, 2017). Suppose households derive utility from the consumption of energy and other goods. The utility function can be expressed as:

$$U=u\ (C_E, C_{X:}\ H^a) \quad (8)$$

Where C_E is bundle of energy goods, C_X represents other goods and H^a stands for household characteristics. The maximization of the utility function subject to the budget constraints gives the energy demand equation in which energy demand is a function of prices, income and the socio-demographic characteristics of the household as:

$$Q_E=q\ (P_{E,}\ P_X, Y, H) \quad (9)$$

The indirect utility function of the household derived from the energy demand function can be expressed as:

$$V= v\ (P_{E,}\ P_X, Y, H) \quad (10)$$

Considering that the household selects from bundle of energy goods, j= 1, 2,…,k. By choosing energy type j, the associated indirect utility function is V_{ij}.

The indirect utility function depends on observable and unobservable factors. Therefore, it is assumed that V_{ij} is the sum of observed component ϑ_{ij} and an unobserved component, $\eta_{ij.}$ The indirect utility function is expressed as:

$$V_{ij} = \vartheta_{ij} + \eta_{ij} \tag{11}$$

Where ϑ_{ij} depends on a set of explanatory variables, X_i, and the vector of the parameters, $\beta_{j.}$ That is:

$$\vartheta_{ij} = f\,(X_{i,}\,\beta j_{,}) = \beta_j X_i \tag{12}$$

The unobserved part, $\eta_{ij,}$ denotes the error term, which is assumed to be normally distributed. Therefore, given a set of alternative energy types, household i chooses energy j over alternatives k if $V_{ij} > V_{ik}$ $\forall\, j \neq k$. Therefore, the probabilistic choice (p) of the j^{th} alternative by the i^{th} household is expressed as:

$$p_i\left(j \middle| X_i\right) = p\left(V_{ij} > V_{ik}\right), \forall j \neq k$$

$$= p\left(U_{ij} > U_{ik}\right) = p(\vartheta_{ij} - \vartheta_{ij} > \eta_{ij} - \eta_{ij}) \tag{13}$$

For the purpose of this study, energy types were divided into three categories namely traditional, transitional and modern. Thus, the household chooses from three alternative energy types (j=1 or traditional fuel; j=2 or transitional fuel and j=3 or modern fuel). Therefore, the probability associated with the choice of one type of fuel category over another is stated as:

$$P_{ij} = \frac{e^{(\beta x_{ij})}}{\sum_{j=1}^{3} e^{(\beta x_{ij})}} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \ldots + \beta_n x_{ni} \tag{14}$$

Expanding equation (14) to include economic and non-economic factors affecting household choice of energy for cooking, the full econometric model is specified as:

$$HEC_i = \beta_0 + \beta_1 hhinc_i + \beta_2 agey_i + \beta_3 hhsize_i + + \beta_4 male_i + \beta_5 educ_i + \beta_6 urban_i + \beta_8 ownhouse_i + \beta_9 agland_i + \beta_{10} elect_i + \beta_{11} livestock_i + \beta_{12} radio_i + \ \beta_{13} ecozone_i + \varepsilon_i \qquad (15)$$

Equation (15) shows that household energy choice is affected by household income (*hhinc*), age of household head (*agey*), household size (*hhsize*), sex of household head (*male*), location of household (*urban*), ownership of dwelling unit (*ownhouse*), education of household head (*educ*), ownership of land for agricultural purpose (*agricland*), access to electricity (*elect*), ownership of livestock (*livestock*) and ownership of radio (*radio*) and ecological zone (*ecozone*).

The empirical estimation is executed using multinomial logit (MNL) model with traditional fuel as the based category. The MNL model is estimated using the maximum likelihood estimation technique. The coefficients of the explanatory variables from maximum likelihood estimation cannot be interpreted directly and therefore there is the need to estimate the marginal effects. The marginal effects are estimated using the approach proposed by Long and Freese (2001). The expected signs of the explanatory variables used in this section are presented in Table 2.

Table 2: Signs of the Variables in the Energy Choice Model

Variable	Definition	Expected sign
hhinc	Household income	+
agey	Age of household head	-
hhsize	Number of people in the household	-
male	Sex of household head	+
educ	Education of household head	+
agricland	Ownership of agricultural land	-
elect	Electricity access	+
urban	Location of household	+
ownhouse	Ownership of dwelling unit	-
livestock	Ownership of livestock	-
radio	Ownership of radio	+
ecozone	Ecological zone	+

Source: Author (2018).

Model for Crowding-Out Effects of Energy Expenditure

The theoretical model for assessing the crowding- out effects of energy spending on other household expenditures can be derived from the classical economic idea of utility maximisation. In the classical utility theory, rational economic agents maximise utility from their consumption of goods and services subject to the constraints imposed on them by income and other predisposing socioeconomic and demographic factors. The theory further assumes that the total demand of each agent is too small to influence the determination and structure of market prices. This is equivalent to saying that all participants in the market are prices takers. Moreover, the concept of weak separability or multistage budgeting in which consumers first allocate a part of their budget to specific categories of goods is assumed within this theory (Deaton & Muellbauer, 1980; John, 2008; Murray, 2012).

Taking cues from John (2008), it can be assumed that the utility function, which characterises the maximisation problem discussed above, can simply be stated as:

$$U = U(x_1....x_n;\mathbf{a}) \tag{16}$$

Where x_i represents the household consumption of the i^{th} good and $\mathbf{a}$ stands for the set of predisposing socioeconomic and demographic factors with which the household is constraint. Letting $P = \{p_i...p_n\}$ represent the vector of market prices of the various goods on which the household allocate its income, the full maximisation problem confronting the household becomes:

$$\text{Max } U = U(x_1....x_n;\mathbf{a}) \text{ subject to } \sum_{i=1}^{n} p_i x_i = Y \tag{17}$$

Where Y denotes total household expenditure. The solution to the maximisation problem specified in equation (17) yields the normal unconditional demand function for each good dependent on Y and the vector of market prices given household socioeconomic and demographic characteristics. This is written as:

$$x_i = h^i(p_1,..., p_n, Y;\mathbf{a}) = h^i(P,Y;\mathbf{a}) \qquad \text{for } i = 1,...,n \tag{18}$$

Following Pollak (1969), it is assumed that each household's expenditure on energy has already been determined ex ante. In other words, the household has already decided how much of its total budget is dedicated to energy and a certain amount denoted by the constant $K = p_e q_e$, where p_e is the price of energy, q_e is the quantity energy purchased has been pre-allocated to energy. This implies that the household now has to optimise its utility for the rest of the other goods subject to the expenditure in excess of K. If energy is the n^{th} good, then this implies that this good is available to the household at price p_e and the total expenditure for the rest of the goods for which the household has control is given by M (i. e. $M = Y - K = Y - p_e q_e$). Accounting for the fact that the household has already committed a certain amount of its financial resources to energy, the utility maximisation problem becomes:

$$\text{Max } U = U(x_1....x_n;\mathbf{a}) \text{ subject to } \sum_{i=1}^{(n-1)} p_i x_i = M \qquad (19)$$

with the additional constraint that x_e represents the household's equilibrium quantity of energy purchased. The solution to equation (19) gives the representative demand curve for the i^{th} good purchased conditional on the consumption of energy as:

$$x_i = g^{i,n}(p_1,..., p_{n-1}, M, x_e;\mathbf{a}) \text{ for every } i \neq n \qquad (20)$$

Following the above theoretical proposition, an emipirical model is specified to examine whether or not expenditure on energy crowds out other household expenditures. It was imperative therefore to specify conditional Engel curves instead of the actual demand functions as specified in equation (18). The general form of the conditional Engel curve is expressed as follows:

$$W_i = f_i(K, M, \mathbf{a}) \qquad i=1,...,12 \qquad (21)$$

Where W is the share of expenditure allocated to each good, K is the expenditure on energy, M is household income on other goods and **a** is a vector of household-specific socioeconomic and demographic characteristics. The type of functional form of the conditional Engel curve varies greatly in the literature. Generally, the specification that best fits the data depends on the issues under investigation and the available data. Acar, Günalp and Cilasun (2016) enumerated over four functional forms. Nonetheless, the most widely used forms are linear and non-linear specification. In this study, the linear form is used in line with Acar *et al*. and Yaméogo (2014). More specifically, conditional Engel curves were estimated for 12 goods with each Engel curve assuming the following form:

$$W_{ij} = \alpha_0 + \alpha_{1i} K_j + \alpha_{2i} \ln M_j + \alpha_{3i} age_j + \alpha_{4i} hsize_j + \alpha_{5i} married_j + \alpha_{6i} educ_j + \\ + \alpha_{7i} empstat_j + \alpha_{8i} Urban_j + \eta_1 + v_i \quad (22)$$

$$K_i = \beta_0 + \beta_1 \ln M_i + \beta_2 age_i + \beta_3 hsize_i + \beta_4 married_i + \beta_5 educ_i + \\ + \alpha_6 empstat_i + \alpha_7 Urban_i + \eta_2 + \varepsilon_i \quad (23)$$

Where W_{ij} is the share of expenditure allocated to the good i by household j after provisions are made for energy, K is expenditure on energy, $\ln M$ is the natural logarithm of household income on other goods, *age* is age of the household head, *hhsize* is household size, *married* is the marital status of household head, *educ* represents the level of educational attainment of the household head, *emp* is the employment type of household head while *urban* is a dummy variable for the household place of residence being in an urban area. η_1 and η_2 are the terms capturing unobserved heterogeneity assumed to be unrelated to the explanatory variables in each equation whereas v_i and ε_i are the stochastic terms assumed to be normally distributed.

From equation (22), energy expenditure, K is suspected to be endogenous. Intuitively, having expenditure on one product from a basket of goods to a consumer as a covariate in the equation on the budget share of other products in the same basket can create problems of endogeneity. If this is true, it would cause the error term in the final regression to be biased, such that $E(X, \mu) \neq 0$ In view of this, a regression approach that helps to solve this endogeneity problem must be used. If household income and all the other explanatory factors assumed to affect energy expenditure are uncorrelated with the error term, and the dependent variables were continuous, then an OLS regression of equation (22) will produce reliable estimates among which the coefficient of K will be the true effect of energy expenditure on spending on other household goods, thus confirming the crowding out or crowding in effect. Unfortunately, the decision of how much to allocate to energy is potentially endogenous and refusal to account for this endogeneity has the potential to produce inconsistent and unreliable coefficients. This error will cause the actual effect of energy expenditure to be overstated in a regression model of the kind indicated in equation (22).

To solve endogeneity, the standard method used by many researchers is to use instrumental variables. As advanced by Chelwa and van Walbeek (2014) and Yaméogo (2014), instrumental variables should be significantly correlated with the endogenous variable but uncorrelated with the error term of the regression. Because of the endogeneity associated with K and the fact that the dependent variables being modelled are not continuous, there is the need to employ a regression technique which is capable of addressing this hurdle.

The conditional mixed process (CMP) model developed by Roodman (2011; 2018) has been identified as the most appropriate technique for such situation and has been used by Makate, Wang, Makate and Mango (2016). According to Makate *et al.*, the joint estimation within the conditional mixed process framework enables researchers to obtain selection-bias revised estimates for fractional response models with endogenous regressors. In addition, Makate *et al.* maintained that different set of instrumental variables are not required before the conditional mixed process model can be implemented, and that joint estimations using the CMP model helps to avoid the problem associated with poor or weak instruments. Taking cues from this, the conditional mixed process model was implemented by jointly estimating equations (22) and (23).

Estimation Technique

The dependent variable used for the estimation in this section is the share of household budget allocated to each good after provision has been made for energy. Because the dependent variable falls between zero and one and the fact that energy expenditure is considered endogenous the CMP estimation technique was employed for the estimation. The CMP approach was considered appropriate for the estimation compared to other classes of estimations such as the OLS.

Measurement of Variables

The variables used for the study comprised dependent and independent variables. The dependent variables were the energy expenditures, main cooking fuel and budget shares for other goods and services consumed by household. Energy consumption was measured as the amount spent on energy by households. While energy consumption could be measured in quantities, the measurement of consumption quantities in household survey is difficult and unreliable (D'Agostino *et al.*, 2015). Moreover, the GLSS does not provide information on the quantities of the various energy types consumed by households. Therefore, the dependent variables for the first analysis were annual household expenditures on biomass, kerosene, gas, electricity and transport fuel. The analysis also included overall household energy expenditure. This was the sum of expenses on biomass, electricity, gas, kerosene and transport fuel. Since aggregate expenditure measures overall energy used by household, the analysis was meant to provide results of direct relevance to energy policy formulation in Ghana.

The dependent variable for energy choice model was the main fuel used for cooking. Two levels of analysis were conducted with respect to choice of cooking fuels. Based on the energy ladder hypothesis and similar studies, the reported main fuels for cooking among households were grouped into three categories, which served as the dependent variables for the first analysis. The three categories considered for this stage were traditional, transitional and modern fuels. Traditional fuel consisted of firewood and other solid fuel; transitional fuel was made up of kerosene and charcoal and modern fuel comprised electricity and LPG. The second analysis focused on the specific energy types used by households. Four energy types were considered in the second estimation, namely fuelwood, charcoal, LPG and other fuels. The other fuels included crop residue, kerosene and electricity. These fuels were less dominant and hence were kept together to constitute one category.

The third analysis sought to estimate the effect of energy expenditure on the budget shares allocated to other household goods. The budget shares devoted to household goods and services served as the dependent variables. Budget shares were created for 12 categories of total household expenditure: food, alcohol and tobacco, clothing and footwear, communication, recreation, health care, education, housing, furnishing, public transport, hotel, and miscellaneous. The budget share for each of these goods was measured as the expenditure allocated to that particular good divided by total household expenditure less energy expenditure.

The explanatory variables were grouped into four categories, namely socio-demographic characteristics of the household head, household level characteristics; appliance factors and dwelling characteristics. The socio-economic characteristics of the household head comprised age, sex, marital status, education and employment type whereas the household level characteristics included household income, household size, possession of radio, electricity access, ownership of livestock, ownership of agricultural land, ownership of dwelling unit, location, public transport spend, number of workers, number of aged persons, presence of children, number of cars and number of motorcycles. The dwelling characteristics were ownership type of the dwelling and the number of rooms occupied by households. The explanatory variables were selected based on theory and empirical studies.

Household income was measured as gross annual income. A number of studies including Alkon *et al.* (2016), D'Agostino *et al.* (2015), Eakins (2016), Hasan and Mozumder (2017) and Ngui *et al.* (2011) have used either total expenditure or non-energy expenditure as a measure of income. However, the use of total expenditure as an explanatory variable in energy expenditure equation is considered problematic (Curtis & Pentecost, 2015). This is because energy expenditure is a fraction of total expenditure and thus using total expenditure to explain variations in energy expenditure generates endogeneity issues. This problem is avoided when actual household income is used. The inclusion of this variable is borne out of the fact that income is important economic factor and affects purchasing ability of households. We expect a significant relationship between income and energy consumption.

Age of household was measured in completed years. The variable was included in the analysis to assess the influence of age on household energy consumption. It is recognised that households under the leadership of relatively young persons tend to adapt to changing lifestyle and practices more easily than those headed by older people. Alkon *et al.* (2016) have argued that older household heads are more likely to hang on to traditional practice of energy use than younger household head. Age is expected to have varying impact on energy consumption and choice of energy category.

Gender was measured as a dichotomous variable taking a value of 1 if the household head was male and 0, if the household head was female. Klausner (1979) has hypothesised that household headed by a female is less ordered and disciplined which makes relatively less efficient energy use than a household headed by a male. Therefore, the inclusion of this variable in the analysis was meant to evaluate the effect of sex on household energy use both in terms of expenditure and choice on energy. Marital status was measured as a dummy variable taking a value of 1 if the head of household was married and 0, if the household was unmarried.

To examine the effect of education of household heads on energy consumption and use, three dummies were created for level of education of the household head: basic education (1), secondary education (2) and tertiary education (3). No education served as the reference category. Longhi (2015) have argued that educated people may be more aware of environmental problems and thus tend to adopt more environmentally friendly behaviours including energy savings. Also, education may be a signal of increased awareness of energy efficiency concerns and that people with relatively higher level of education would consume less energy compared to those with relatively lower level of education (Harold, Lyons, & Cullinan, 2015).

Household size was measured as the number of persons in a household. It has been theoretically suggested and empirically verified that household size is an important determinant of energy demand in both developed and developing countries. Directly, family size affects household energy consumption by influencing the requirements for energy and indirectly by changing income and resources availability (Jones *et al*., 2015; Kowsari & Zerriffi, 2011; Rahut *et al*., 2016a). Larger household size can have different earning members, enabling the household to afford energy items (Joshi & Bohara, 2017).

The analysis also included number of aged persons in the household and a dummy for the presence of children aged 17 years and below. Aged was measured as the number of persons older than 64 years of age. These variables examined the effects of size and composition of household on energy consumption. Previous studies established significant positive relationship between these two variables and energy consumption (Brounen *et al.*, 2012; Louw, Conradie, Howells, & Dekenah, 2008; Wallis *et al.*, 2016; Wang *et al.*, 2015; White *et al.*, 2010; York, 2007), and suggested that there is always intense demand for energy in such household in order to satisfy learning and leisure needs of their younger ones and heating and cooling needs of older members.

Agricultural land and livestock were measured as categorical variables. They were included in the analyses to account for possible agricultural specialization of the household. Households specializing in agricultural production are expected to use more often the traditional fuels because they can take advantage of their crop residues. Also, as noted by Joshi and Bohara (2017), households who own livestock may make rational decisions to collect fuelwood when they collect folder for their livestock or when they send their livestock out for grazing.

Radio was used as proxy for access to information. It was created as dummy variable taking value of 1 if household owned radio and 0, otherwise. Ownership of these gadgets is expected to increase household access to information about negative effects about the use of biomass energy on health and on the environment associated with the harvesting of biomass energy resources (D'Agostino *et al.*, 2015; Muller & Yan, 2018; Rahut, *et al.*, 2016). For instance, D'Agostino *et al.* argued that negative stories of energy-caused illnesses or household experiencing dangerous episodes with unclean energy will likely impact usage habits among recipients of this information. Therefore, ownership of radio is expected to reduce the probability of using biomass energy and the amount household spend on biomass energy.

Access to electricity was used as a proxy for access to modern infrastructure. A household is defined as having access to electricity if electricity is connected to the residence of the household. Access to electricity is expected to decrease the consumption of traditional and transitional fuels but increase the consumption of modern ones. As argued by Joshi and Bohara (2017), household using electricity source of lighting may have more opportunities to use modern fuel for cooking and other applications. Access to electricity may also facilitate access to infrastructural requirement for access to modern cooking energy sources such as LPG. Also, Helberg (2004) and Barnes *et al.* (2010) point to the higher propensity for electrified households to switch cooking fuels from traditional to modern types such as LPG.

The study used two variables to capture dwelling characteristics. These were tenancy status and number of rooms. Tenancy status was divided into two categories namely owning and non-owning of dwelling unit with the latter serving as the reference group. Appliances were grouped into six categories namely: entertainment, preservation, extra ventilation, cooking, IT, and laundry appliances. Under each category, the number of items owned and used by households were counted and included in the analysis.

Descriptive Statistics of Variables used for the Study

The descriptive statistics for the variables used for the analyses are presented in Table 3. As can be seen in Table 3, the mean annual household total expenditure amounted to GH¢8100.24 compared to the gross household income of GH¢8142.56. On an annual basis, the average household covered by the study spent GH¢383.71 on energy, comprising GH¢144.99 on personal transport fuel; GH¢140.21 on electricity; GH¢71.49 on biomass (firewood, charcoal and other solid fuels); GH¢19.15 on gas and GH¢7.88 on kerosene. With respect to expenditure on non-energy items, most households included in the study spent more on food (GH¢4066.35) followed by housing (GH¢721.68) and education (GH¢710.64) with expenditure on health (GH¢76.60) and hotels and restaurants (GH¢2.24) being the least.

Table 3: Descriptive Statistics of Variables used in the Study

Variable	Mean	SD	Minimum	Maximum
Total household expenditure	8100.24	7594.86	31.20	146345.40
Non-energy expenditure	7716.53	7131.43	31.20	145683.60
Gross Household income	8142.56	23252.29	0.05	1233201
Electricity Expenditure	140.21	562.61	0	25028.57
Gas Expenditure	19.15	79.59	0	3844
Kerosene expenditure	7.88	36.84	0	2288.60
Biomass expenditure	71.49	183.41	0	15330
Personal transport fuel exp.	144.99	777.17	0	22630
Total energy expenditure	383.71	1035.21	0	25028.57
Food expenditure	4066.35	3884.46	14.6	135233
Expenditure on alcohol & tobacco	103.56	310.67	0	12410
Expenditure on clothing & footwear	501.36	642.13	0	20107
Expenditure on housing	721.68	1695.47	1	73205.55
Expenditure on furnishing	365.50	417.06	0	10392
Expenditure on healthcare	76.60	206.05	0	5461.80
Expenditure on communication	310.93	515.17	0	15755.40
Expenditure on recreation	250.11	546.31	0	14241.75
Expenditure on hotels & restaurants	2.24	80.81	0	7200
Expenditure on education	710.64	1643.12	0	60160
Expenditure on public transport & airfares	276.46	705.39	0	43800
Expenditure on other miscellaneous	431.12	1199.87	0	102302
Number of livestock*	3.95	26.33	0	3126
Number of rooms	1.89	1.29	1	17
Household size	4.29	2.79	1	29
Age of household head	45.97	15.88	15	98
Number of children	2.02	2.02	0	20
Number of aged persons	0.22	0.49	0	5
Number of workers	1.51	0.88	0	14
Number of cars	0.05	0.26	0	3
Number of motorcycles	0.12	0.36	0	3
Cooking appliances	0.52	1.10	0	12
Entertainment appliances	1.66	1.38	0	11
Extra Ventilation appliances	0.51	0.71	0	6
Preservation appliances	0.36	0.60	0	6
Laundry appliances	0.55	0.66	0	6
IT appliances	1.42	1.24	0	15
Aggregate appliances**	5.02	4.40	0	43

Table 3, continued

Variable	Frequency	Percent
Sex		
Female	4654	28.19
Male	11854	71.81
Marital status		
Unmarried	6706	40.62
Married	9802	59.38
Education		
None	4737	28.70
Basic	8818	53.42
Secondary	1327	8.04
Tertiary	1626	9.85
Employment		
Employee	3775	22.87
Self-employed	11633	70.47
Unemployed	1100	6.66
Tenancy		
Owner	7426	44.98
Non-owner	9082	55.02
Residence		
Rural	9269	56.15
Urban	7239	43.85
Radio ownership		
Owner	10638	64.44
Non-owner	5870	35.56
Agricultural land		
Owner	1659	10.05
Non-owner	14849	89.95
Access to electricity		
Yes	10084	61.09
No	6424	38.91
Ecological zone		
Coastal	3891	23.57
Forest	6894	41.76
Savannah	5723	34.67
Main cooking fuel		
Traditional	9270	56.15
Transitional	4472	27.09
Modern	2766	16.76
N	16508	

*sum of large and medium livestock, **sum of all appliances

Source: Author (2018).

The low spending on healthcare can be attributed to a lot of factors. One plausible explanation could be the fact that most households were active subscribers of the state-wide National Health Insurance Scheme and thus did not have to incur any major out-of-pocket payments to assess healthcare services. It could also be attributed to the fact that they resorted to non-expensive avenues of solving their health problems.

The average number of electrical appliances owned by households was 5.02. At the disaggregated level, it was observed that households had more number of entertainment appliances (1.66) and IT appliances (1.42) than they had extra ventilation appliances (0.51) and preservation appliances (0.36). The mean number of livestock owned by the respondents is 3.95, a result which corroborates the findings of existing studies that households in Ghana own one type of livestock or the other. Most households had about two rooms for sleeping (1.89). The mean household size was 4.29, which compares well with similar figures reported in the 2010 population and housing census. The ages of household heads ranged between 15 and 98 years, resulting in a mean age of about 46 years. The sample was dominated by households headed by males (71.81%) compared to those headed by females (28.19%). A slightly higher proportion of households were headed by married people (59.38%) compared to those headed by the unmarried (40.62%). Generally, most household heads had attained some level of formal education, with the majority (71.31%) having basic education or more.

The distribution of the households on the basis of the employment status of the household heads was as follows: unemployed (6.66%), employed (22.87%) and self-employed (70.47%). In terms of tenancy status, it was observed that 55.02 percent of the households lived in rented homes followed by those in owner-occupied dwellings (44.98%). Households residing in rural areas accounted for 56.15 percent of the sample with the remaining being those in urban areas. The sample was dominated by households who own a radio than compared to those who did not. More than 60 percent of the households had access to electricity. According to Table 3, traditional energy is the main source of cooking fuel for most households (56.15%) followed by transitional energy (27.09%) and modern energy (16.76%). This evidence is very similar to the results of other past studies which indicate that traditional fuels are the common energy sources for cooking among households in developing countries (Giri & Goswami, 2018; Pandey & Chaubal, 2011; Rao & Reddy, 2007; Swarup & Rao, 2015).

Chapter Summary

This chapter discussed the research methods used for the study. It described the positivist philosophy underpinning the study, highlighted its various strengths and weaknesses and provided a justification for the choice of the positivist philosophy. The chapter also presented the theoretical frameworks and the empirical models used for the study and described the various dependent and independents variables used for the empirical analysis of the study. It also provided the descriptive statistics of the various variables included the models. The type of data used for study and the procedures used for sampling and data collection were also discussed. Results of the empirical estimation of the effect of income on household energy consumption are covered in the chapter which follows.

CHAPTER FIVE

INCOME AND HOUSEHOLD ENERGY CONSUMPTION

Introduction

This chapter presents and discusses empirical results on the relationship between income and other characteristics and household energy consumption. The study tests the hypothesis that there is no statistically significant relationship between income and household energy consumption. The chapter is organised into three sections. The first section presents the estimated results while the second provides estimated income elasticities. The third section concludes the chapter and highlights the main findings.

Results of Regression Analysis

Results of the econometric estimation of household energy consumption are presented and discussed in this section. It has to be mentioned that all discussions in this and all other sections in the chapter focused on the significant variables and their interpretations and summarised the results across the different energy types rather than looking at them separately. Furthermore, each model was estimated separately instead of estimating it in a system and as a result the interpretation across the equations is made on a tentative basis. As highlighted in the introduction to the chapter, the estimation in this section included all households, regardless of their annual expenditure on energy.

Before performing the multivariate regression analysis, bivariate analyses were conducted between the various energy sources and all the independent variables including income. Results of this process are reported in Table 4.

Table 4: Bivariate Analysis of Factors Affecting Energy Consumption

Variables	HEB	HEK	HEG	HET	HEE	HETT
Log (income)	1.4462[a]	0.1960[a]	2.0740[a]	15.6300[a]	3.2500[a]	6.8920[a]
	(0.1940)	(0.0270)	(0.1450)	(0.9290)	(0.2260)	(0.264)
Age	-0.0006	0.0110[a]	-0.0264[a]	-0.0264[a]	-0.0317[a]	-0.0380[a]
	(0.0018)	(0.0013)	(0.0027)	(0.00268)	(0.0054)	(0.0059)
Household size	0.0545[a]	0.0213[a]	-0.1450[a]	2.1890[a]	-0.1980[a]	0.1690[a]
	(0.0150)	(0.0057)	(0.0156)	(0.1450)	(0.0271)	(0.0385)
Number of aged	-0.2218[a]	0.1580[a]	-0.9130[a]	-3.8480[a]	-1.0400[a]	-1.4500[a]
	(0.0585)	(0.0368)	(0.1110)	(0.8460)	(0.1690)	(0.2130)
Male	-0.7913[a]	-0.3620[a]	-0.0515	24.7600[a]	-0.5920[a]	0.6630[a]
	(0.1180)	(0.0505)	(0.0704)	(1.6120)	(0.1360)	(0.1800)
Married	0.1190[b]	-0.0712[b]	0.2050[a]	16.7500[a]	-0.2300[b]	1.2790[a]
	(0.0558)	(0.0352)	(0.0670)	(1.0520)	(0.1170)	(0.1900)
Basic	1.1190[a]	-0.0572	2.3710[a]	-3.3390[a]	3.8770[a]	3.9210[a]
	(0.2020)	(0.0391)	(0.2150)	(0.7760)	(0.3830)	(0.2620)
Secondary	1.2260[a]	-0.3040[a]	3.9040[a]	6.7820[a]	6.4270[a]	7.5700[a]
	(0.2120)	(0.0737)	(0.3080)	(1.3240)	(0.5560)	(0.4630)
Tertiary	0.9860[a]	-0.4070[a]	4.9520[a]	18.7600[a]	7.5460[a]	12.0400[a]
	(0.1840)	(0.0745)	(0.3570)	(1.3390)	(0.5960)	(0.5360)
Employee	0.6667[a]	0.0191	1.2880[a]	10.6305[a]	2.4149[a]	4.0721[a]
	(0.1276)	(0.0702)	(0.1508)	(1.7991)	(0.3446)	(0.4191)
Self-employed	-0.1640	0.1330[b]	-0.8695[a]	4.2918[a]	-1.3563[a]	-1.5034[a]
	(0.1101)	(0.0656)	(0.1502)	(1.6355)	(0.2694)	(0.3571)
Urban	2.2370[a]	-0.0492	2.9230[a]	1.9030[a]	6.0680[a]	7.6090[a]
	(0.3300)	(0.0333)	(0.2100)	(0.7230)	(0.4650)	(0.3060)
Children	0.7570[a]	0.1870[a]	-0.4400[a]	6.7270[a]	-0.8150[a]	0.2490
	(0.1040)	(0.0411)	(0.0711)	(0.8980)	(0.1410)	(0.2110)
Owner of home	-0.9670	0.1350[a]	-1.4700[a]	2.8820[a]	-2.8280[a]	-3.0510[a]
	(0.1370)	(0.0359)	(0.1190)	(0.7280)	(0.2590)	(0.2290)
Workers				5.4734[a]	0.6190[a]	1.8250[a]
				(0.4509)	(0.1000)	(0.1560)
Rooms					-0.2080[a]	0.7550[a]
					(0.0649)	(0.1050)
Ent. appl.					2.0670[a]	3.1340[a]
					(0.1740)	(0.1340)
Pres. appl.					4.7970[a]	7.4680[a]
					(0.3630)	(0.3070)
Vent. appl.					4.4790[a]	6.8040[a]
					(0.3600)	(0.2880)
Cooking appl.					2.1010[a]	4.0030[a]
					(0.1370)	(0.1660)
IT appl.					1.7920[a]	3.579[a]
					(0.1460)	(0.1520)
Laundry appl.					3.9150[a]	6.028[a]
					(0.3080)	(0.2650)
Number of cars				30.7535[a]		17.3700[a]
				(1.6716)		(1.0100)
Motorcycles				34.1180[a]		6.2950[a]
				(1.7116)		(0.4150)
Public transport				-8.9009[a]		2.8190[a]
				(0.8298)		(0.2410)
Elect. access	1.9900[a]	-0.3010[a]	3.8980[a]			10.66[a]
	(0.2960)	(0.0428)	(0.2920)			(0.4330)
N	16508	16508	16508	16508	16508	16508

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

Source: Author (2018).

The results showed that age of household head, self-employed and ownership of dwelling unit do not significantly explain variations in biomass consumption. However, income, household size, number of aged persons, male household headship, married household head, educational level of household head, presensence of children in the household, being employed household head, electricicty access and urban household are statistically significant determinants of biomass consumption. More specifically, biomass consumption is positively influenced by income, household size, electricity access, presence of children in the household, educational level of household head and married household head while it is negatively affected by number of aged persons and male household headship.

It can be observed from the results that being located in an urban area, employed household head and basic educational level had no significant effect on kersosene consumption. Meanwhile, there were positive associations between kersonse consumption and income, age of household head, household head, number of aged persons, number of children, ownership of dwelling unit and the self-employed household head whereas married household head, male household headship, educational level of household head and electricity access exerted statistically significant and negative influence on kerosene consumption. Of all the variables relating to kerosene consumption, presence of childern in the household had the highest effect while age of household head exerted the least impact.

With respect to gas consumption, the results showed that all the independent variables considered in the analysis except male household headship were statistically significant in explaining the variations in gas consumption. In particular, age of household, household size, number of aged persons, self-employed, presence of children in the household and ownership of dwelling unit affected gas consumption negatively while income, married household head, educational level of household head, employed household head and electricity access had positive influence on gas consumption.

Interestingly, Table 4 shows that all the factors considered for the estimation of transport fuel consumption were statistically significant. It is also evident from Table 4 that income, househoold size, male household headship, married household head, secondary and tertiary levels of education, employment status of household head, urban household, presence of children in the household, ownership of dwelling unit, number of workers, number of cars, number of motorcycles and owning a house were positively associated with transport fuel consumption whereas public transport spend, age of household head, number of aged persons and basic educational level of household head affected transported fuel consumption negatively. This suggests that transport fuel consumption would be lower in households either headed by older persons or with higher number of aged persons.

For the total energy consumption, the results showed that the factors that explain variations in consumption of the individual fuel types are also significant factors in predicting variations in total energy consumption. The important role of income in total energy consumption is evident in Table 4. The results showed that growth in income leads to growth in household total energy consumption. Moreover, all the three categories of education included in the analysis are significant predictors of total energy consumption. This suggests that household total energy consumption is affected by educaitonal level of household head. Another interesting observation from the results is that total energy consumption is positively associated with appliance stock in the household. This implies that total energy consumption will rise when households acquire more electrical appliances.

In relation to electricity consumption, Table 4 shows that all independent variables considered in the analysis are significant in explaining variations in electricity consumption. In particular, the results showed that income, educational level of household head, employee status of household head, number of electrical appliances and urban location of household had positive influence on electricity consumption. In contrast, household size, number of aged persons, presence of children in the household, ownership of dwelling unit, male household headship and married household head are nagetively associated with electricity consumption. It can also be observed that for the appliance-related factors, number of preservation appliances had the highest effect on electricity consumption. This is followed by number of extra-ventilation appliances and number of laundry appliances, with the least being number of IT appliances. But, would the same results emerge if the estimation is done within the framework of multivariate analysis? This question is answered in the next section.

The estimation which follows extends the bivariate regression by modeling the relationship between all the independent variables and energy consumption within a multivariate framework. The results of this analysis are important because they help to determine whether or not the results reported in Table 4 will hold in a multivariate framework. Given the censored nature of the dataset, Tobit regression technique was employed for the empirical estimation (Tobin, 1958).

Similarly, in line with standard econometric practice (Pallant, 2007; Cameron & Trivedi, 2010), multicollinearity test was conducted using the Variance Inflation Factor (VIF) values of the explanatory variables. In particular, Pallant argues that, for the absence of multicollinearity among independent variables, the value of variance inflation factor for each independent variable must not exceed 10.00 in order to fulfil the absence of multicollinearity. Lack of multicollinearity also requires that the tolerance of each independent factor, obtained by taking the inverse of the VIF value, should not be less than 0.10. Appendix A shows that the study data met these conditions, signifying that multicollinearity among the explanatory variables is not a problem. Meanwhile, the results of the link test show that the models were correctly specified and statistically stable.

Table 5 shows the estimated marginal effects of the various independent variables. With respect to the estimated coefficients, positive and statistically significant coefficients of independent variables imply that household energy consumption will increase as this independent variable increases in the case of continuous factors or change from the base category to the used category in the case of categorical dependent factors whereas negative coefficients imply otherwise.

Table 5: Marginal Effects of Factors Affecting Energy Consumption

Variables	HEB	HEK	HEG	HET	HEE	HETT
Log (income)	1.1110[a]	0.3650[a]	1.6860[a]	10.0000[a]	0.7830[a]	3.1460[a]
	(0.1390)	(0.0446)	(0.1360)	(0.8880)	(0.1180)	(0.2410)
Age	0.0072[a]	0.0109[a]	-0.0045	-0.1780[a]	0.0036	0.0009
	(0.0024)	(0.0015)	(0.0028)	(0.0300)	(0.0066)	(0.0078)
Household size	-0.0146	-0.0261[a]	-0.1910[a]	0.1150	-0.1360[a]	-0.1330[b]
	(0.0179)	(0.0089)	(0.0281)	(0.129)	(0.0414)	(0.0544)
Number of aged	0.1850	-0.0341	0.1990	-0.1260	0.5980[b]	0.1750
	(0.1170)	(0.0434)	(0.1210)	(0.7850)	(0.2440)	(0.2560)
Male	-0.8860[a]	-0.3970[a]	-0.4790[a]	9.5940[a]	-1.3470[a]	-0.9080[a]
	(0.1510)	(0.0570)	(0.0749)	(1.3610)	(0.2090)	(0.2260)
Married	0.2870[a]	-0.0073	0.3830[a]	1.8360[c]	0.0111	-0.1480
	(0.0728)	(0.0419)	(0.0809)	(0.9820)	(0.1470)	(0.2290)
Basic	0.3930[a]	0.0309	1.2900[a]	-3.6310[a]	1.6720[a]	0.4300[b]
	(0.1330)	(0.0407)	(0.1640)	(0.7110)	(0.2420)	(0.1830)
Secondary	-0.1010	-0.1170	1.8220[a]	-0.8110	2.1480[a]	0.1180
	(0.1130)	(0.0749)	(0.1950)	(1.3080)	(0.3240)	(0.3900)
Tertiary	-0.8860[a]	-0.4060[a]	2.2260[a]	4.3930[a]	1.6760[a]	0.4150
	(0.1460)	(0.0843)	(0.2050)	(1.1980)	(0.3130)	(0.4210)
Employee	0.0961	0.2270[a]	-0.0450	-3.5560[b]	-0.2610	-1.1400[a]
	(0.1100)	(0.0758)	(0.1400)	(1.5630)	(0.3110)	(0.3800)
Self-employed	-0.1980[c]	0.0482	-0.4600[a]	-1.6580	-0.7250[b]	-1.8350[a]
	(0.1070)	(0.0643)	(0.1470)	(1.4690)	(0.3030)	(0.3590)
Urban	1.4010[a]	0.0098	1.1220[a]	-1.8730[b]	2.9150[a]	1.7670[a]
	(0.2370)	(0.0399)	(0.1180)	(0.7350)	(0.2730)	(0.2000)
Children	0.5980[a]	0.1260[b]	0.0419	-1.7980[c]	0.0264	0.0054
	(0.0823)	(0.0496)	(0.0887)	(1.0380)	(0.1700)	(0.2560)
Owner of home	-0.3960[a]	0.0261	-0.3010[a]	0.5990	-0.6340[a]	-0.5730[a]
	(0.0761)	(0.0396)	(0.0825)	(0.7310)	(0.1720)	(0.2150)
Number of workers				0.3600	0.3450[a]	0.5890[a]
				(0.3830)	(0.1100)	(0.1450)
Number of rooms					-0.0274	0.3150[a]
					(0.0803)	(0.1100)
Entertainment appl.					0.6420[a]	-0.0446
					(0.1040)	(0.0979)
Preservation appl.					1.3000[a]	0.3300
					(0.1660)	(0.2250)

Table 5, continued

Variables	HEB	HEK	HEG	HET	HEE	HETT
Extra -ventilation appl.					1.6530[a]	0.5650[b]
					(0.2270)	(0.2630)
Cooking appl.					-0.3250[a]	0.4650[a]
					(0.1240)	(0.1670)
IT appl.					0.1150	0.3390[a]
					(0.0720)	(0.1250)
Laundry appl.					0.4820[a]	0.0983
					(0.1190)	(0.2120)
Number of cars				20.2400[a]		10.8900[a]
				(1.5050)		(0.9500)
Number of motorcycles				23.0400[a]		4.8200[a]
				(1.3700)		(0.3960)
Public transport				-7.7030[a]		-0.8150[a]
				(0.8330)		(0.2250)
Electricity access	0.7740[a]	-0.4570[a]	1.7490[a]			5.7240[a]
	(0.1440)	(0.0563)	(0.1860)			(0.3380)
Log likelihood	-22010.090	-7624.01	-8005.80	-11725.88	-35021.51	-48746.79
F Stats.	10.35[a]	7.17[a]	12.03[a]	22.35[a]	13.89[a]	39.09[a]
Pseudo R^2	0.0615	0.0365	0.2326	0.1654	0.0557	0.0643
_hat	0.9059	1.1581	0.8925	0.8923	0.9344	0.9741
	(0.0280)	(0.2239)	(0.0347)	(0.0202)	(0.0172)	(0.0158)
_hatsq	0.1092	0.0757	0.0084	0.0493	0.0316	0.0696
	(0.5098)	(0.0546)	(0.0325)	(0.8016)	(0.5297)	0.1691)
Mean VIF	2.01	2.01	2.01	1.95	2.14	2.05
N	16,508	16,508	16,508	16,508	16,508	16,508

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

Source: Author (2018).

Household income has a significant effect on the dependent variables in all the models. The positive coefficient of household income means that household energy consumption rises with income. The finding with respect to household income contradicts expectation and also invalidates the energy ladder theory which posits a significant inverse relationship between household wealth and the consumption of biomass energy sources. According to the energy ladder thesis, wealthy households should generally spend less on solid fuels since their improved social status makes it easier for them to be able to afford improved energy services (Hosier & Dowd, 1987; Ngui et al., 2011).

The energy ladder theory illustrates the general point of upward shift of households' preferences for more convenient and clean sources of energy as income expands. A number of empirical studies have also found significant positive relationship between household wealth and biomass consumption (Akpalu *et al*., 2011; D'Agostino *et al*., 2015). Additionally, the energy ladder thesis has been a subject of intense criticism in recent times due to its inability to adequately predict household energy consumption in low-income countries (van der Kroon *et al*., 2014).

The strong positive relationship between household income and electricity consumption is unsurprising because income is one of the most important factors when it comes to demand for most modern energy sources including electricity. Moreover, it has been widely reported that income is a significant positive determinant of electricity consumption. For example, Salari and Javid (2017) as well as Wei *et al*. (2014) found strong positive relationship between income and electricity consumption, and observed that whenever household income increases, the consumption of gas and electricity also tend to rise. The same holds for transport fuel consumption, with Eakins (2016) and Eakins (2013) establishing a significant positive effect of household income. In addition, Ferdous *et al*. (2010) posit that wealthy households are more likely to allocate a greater share of their income to transportation than other goods. Similarly, Golley and Meng (2012) found that richer households in China consume more energy compared to their poor counterparts, both directly and indirectly through consuming energy intensive goods and services.

Age of the household head also affects the consumption of biomass, kerosene, and transport fuel, only that it has positive sign in the models for biomass and kerosene while being negative for transport fuel. The positive and significant coefficients of age in the models for biomass and kerosene means that if all other factors are held constant, an increase in the age of household head will increase the consumption of biomass and kerosene by less than one percent whereas the negative effects for transport fuel implies that transport fuel consumption will decline with increasing age of the household head.

The negative effect of age of household head on transport fuel consumption could be attributed to the fact that households headed by older people may have fewer needs for personal transport and hence lower demand for transport fuel. In line with this study, it has been reported that households headed by older people are less probable to report car ownership and higher transport fuel consumption due to their low requirements for motorised travel (Eakins, 2016). Moreover, households headed by extremely older people tend to be poor, reflecting the lack of purchasing power and inability to maintain personal cars. This is expected to decrease their demand for transport fuel (Bardazzi & Pazienza, 2018; Ferdous *et al*., 2010).

Household size is one of the independent variables included in the estimation. According to Table 5, significant effects are found for household size in the models for kerosene, gas, electricity as well as the total energy consumption. The negative coefficient of household size implies a reduction in energy use as the number of persons in the household rises. A plausible explanation for the negative relationship between household size and energy consumption is that higher household size is associated with more cost of providing for basic needs and as such allocating more resources to energy consumption may not be an immediate priority.

In many developing countries including Ghana, the need to meet the basic requirements for life sustenance such as food and housing for dependents has been recognised as a huge burden for many households (Taale & Kyeremeh, 2016). Faced with rising cost of living and fewer earning opportunities, household heads with many dependents may not have the necessary financial resources to allow them to increase their demand for energy services.

The negative effect of household size on energy consumption in this study is in contrast to Wei *et al.* (2014) who found a positive relationship between household size and demand for electricity. However, the finding is in line with Rahut *et al*. (2016a), Eakins (2013), Kavousian *et al*. (2013) as well as Druckman and Jackson (2008) who attributed the inverse relationship between household size and energy demand to economies of scale of a large household size. The implication of the finding is that reducing household size will ease the burden on household heads and allow them the economic space to increase their consumption of improved energy services.

A priori, the more the number of aged people in the houses the more is spent on electricity. While no explanation for this finding is exhaustive, it can be attributed to more time spent in the house by older people. Because these people are not available for active work due to their strength and health conditions, they tend to spend more time indoors, thus increasing the demand for electricity for lighting and entertainment purposes. Eakins (2013) also found that the number of aged people in a household had a strong positive effect on electricity consumption among households in Ireland.

Table 5 also shows significant effect for the sex of household head for all fuels as well as total energy consumption. The estimated results reveal that if all other factors are held constant, the consumption of biomass, kerosene, gas, electricity and overall energy are likely to decrease if the household is headed by a male compared to the situation in which the household head is a female. The coefficient of this variable is significant at the one percent level of probability, implying that sex of the household head can be used as an important entry point to curtail the consumption of solid fuels in aid of reduction the rate of deforestation and other environmental changes linked to the consumption of biomass energy.

This result is consistent with the theoretical proposition by Klausner (1979) who found that households headed by males are more ordered and disciplined and hence makes relatively efficient use of energy in comparison to those headed by females. It also coincides with Nazer (2016) who reported that households headed by males tend to incur lower expenditure on unclean fuels. Thus, it can convincingly be argued that the consumption of biomass, kerosene, gas, and electricity has the potential to decline as more males take interest in the decisions regarding household energy demand. But the positive and significant effect of sex of household head in the model for transport fuel implies that transport fuel consumption in households headed by males was higher than those headed by females. Several factors can account for this result. First, the ownership of private cars could be more prevalent among households headed by males compared to those headed by females. Similarly, households headed by females may undertake more trips by public transport than those headed by males, thus leading to lower demand for transport fuel for private use. This complements the negative and significant coefficient of the variable for public transport expenditure.

Relative to households headed by unmarried people, those headed by people who are married are associated with more biomass, gas and transport fuel consumption. In contrast to the expectations of the study, the sign of marital status is positive suggesting that being married increases the demand for biomass. It was expected that households headed by married people would benefit from the exchange of information about the environmental effects of biomass fuels and the necessary financial resources needed for the transition to more efficient energy sources facilitated by the pooling of earnings. Unfortunately, the results rather show that unmarried are better qualified and consumed less biomass energy. While the result with respect to households headed by the married contradicts expectation, it is not strange at all. Bardazzi and Pazienza (2018) also found significant relationship between being married and energy consumption.

Differences in energy consumption attributed to the educational level of household heads are also evident from the study. According to the results, respondents with tertiary education spent less on biomass and kerosene compared to those with no education. Furthermore, Table 5 shows that households headed by people with tertiary education spent more on gas, transport fuel and electricity. Though, not consistently significant, a similar pattern of higher level of educational attainment overall energy consumption is also noted. Akin to number of aged people, secondary education does not display many significant coefficients except in the model for gas and electricity consumption. Several reasons can account for these results. First, people with tertiary education tend to prefer cleaner sources of energy to dirty ones as a result of the high opportunity cost associated with the collection of firewood and the ease of using modern fuels such as gas and electricity (Piddock *et al.*, 2014; Rahut *et al*., 2016a; Salari & Javid, 2017).

In Ghana, as in many developing countries, households in which the responsible person has more years of education are likely to have more economic power to afford the cost associated with modern fuels such as gas and electricity. The findings with respect to level of educational attainment are important for the economy of Ghana in the sense that household transition to electricity and gas has the potential to reduce biomass extraction, which could increase the protection of forest and natural reserves. Moreover, the negative relationship between higher level of educational attainment and kerosene consumption implies that improvement in eduacational attainment would cause a decrease in kerosene consumption. Therefore, there will be less dependence on imported paraffin, and hence savings of the country’s limited reserves of convertible currencies.

Although employment status was not significant for all fuels, a pattern emerged worth commenting on. Employement status was captured by three dummies with unemployed as the reference category. As evident in Table 5, households headed by self-employed spent less on biomass, gas and electricity compared to those headed by unemployed and employed. This established variation in spending could be explained by taste and preferences as well as the time available to perform household tasks. Past studies indicate that employment status can affect household energy consumption by influencing the amount of time spent at home (Jones *et al*., 2015). Given that the earnings of people in self-employment is directly proportional to the amount of time invested in their businesses, households in this category may not have the luxury of time associated with inefficient sources of energy services for their activities. Consequently, households headed by self-employed have to depend on transitional sources of energy such as kerosene for their cooking and lighting needs. The results of this study question the widely held view that people in self-employment cannot be relied upon for the transition towards cleaner fuels in aid of global environmental change. Thus, it is worthwhile for policy makers in the energy sector of Ghana to target those in self-employment in order to decrease the consumption of biomass fuels.

Being located in an urban area affects the consumption of biomass, gas, electricity and total energy in a positive sense and negative for transport fuel consumption. The positive and significant effect of the dummy variable included for residing in an urban area in the model for biomass consumption is counterintuitive. It was expected that the identification of a household's place of residence as urban compared to rural will substantially reduce the consumption of biomass and kerosene while increasing the consumption of the other fuels.

Literature (Toole, 2015; van der Kroon *et al.*, 2014) suggests that households in urban areas are more likely to utilise higher, costly, and more efficient fuels compared to their counterparts in rural areas. Even within the rural areas, it has been argued that households living in places of fuelwood scarcity would be associated with lower biomass consumption and higher consumption of other fuels (Toole, 2015). Although the results with respect to location are counterintuitive, particularly for biomass consumption, they are not completely out of place given the shipment of large consignment of biomass fuels such as firewood and charcoal from rural areas to urban areas and the availability of infrastructure for gas and electricity in these areas. However, D'Agostino *et al*. (2015) also found that the demand for charcoal was greater among households in urban areas of Tanzania than their counterparts in rural areas. The significant inverse relationship between urban residence and transport fuel consumption can be attributed to easy access to public transport services in such places. This is further confirmed by the negative relationship between spending on public transport and transport fuel consumption.

While no significant effect is observed in the models for gas, electricity and overall energy, the presence of children less than 17 years of age has a statistically significant and positive effect on biomass and kerosene consumption while it is negatively related to transport fuel consumption. Except kerosene and transport fuel consumption, the results show that home ownership status negatively affects the consumption of other fuels. The significant and negative sign of home ownership implies that home owners are associated with lower consumption of biomass, gas, electricity and overall energy compared to their counterparts in rented or rent-free dwellings.

This finding contradicts the results of other studies that home owners tend to be associated with more energy consumption compared to renters and occupants of social housing (Ferdous *et al*., 2010; Labandeira, Labeaga, & Rodríguez, 2006; Vaage, 2000). Nonetheless, it confirms the studies by Bousquet *et al.* (2014) and Rehdanz (2007) which found that households in rented accommodation had higher energy consumption than owner-occupied households. According to Rehdanz, homeowners are more likely to invest in energy-efficient systems whereas renters may have no incentive to undertake such investments as a result of the inclusion of charges for energy as part of rent. Moreover, Bousquet *et al.* estimated home owners' savings on electricity to be 13.2 percent of the total electricity cost of renters and attributed it to higher willingness by home owners to invest on energy-efficient appliances and heating systems.

With respect to the effect of transport equipment on energy demand, the results show that both the number of cars and number of motorcycles owned by households had significant and positive effect on transport fuel and overall energy consumption. The positive coefficients of the number of cars and number of motorcycles owned by the households coupled with the significant negative sign of the dummy indicator for spending on public transport imply that reducing the number of automotive owned by the households and encouraging them to use shared or public transportation systems has the potential to reduce household energy consumption.

The analysis shows that number of workers is positively associated with electricity and total energy consumption. This supports the economic intuition that households with more number of workers have higher levels of electricity and total energy consumption compared to those with fewer or no workers. It is very possible that households with more of their members in active employment will have higher energy requirement than those with fewer or no workers because of the possession of electrical and other technological gadgets that require energy to be successfully operated. Such households may also occupy big dwellings as a result of their social status.

A significant positive relationship between total energy consumption and number of rooms and number of IT appliances is also evident. In addition, number of entertainment appliances, number of preservation appliances, number of extra-ventilation appliances, and number of laundry appliances all have positive and statistically significant effect on electricity consumption. Interestingly, number of cooking appliances is negatively associated with electricity consumption, and positively associated with total energy use. While households with more cooking appliances may tend to use electricity wisely in order to reduce cost without sacrificing the health benefits and convenience associated with clean energy sources, having more cooking appliances may increase total energy consumption via increased frequency of cooking or heating. These findings underlie the importance of seeing to it that any policy aimed at influencing the amount of energy use by households in Ghana should target the number of electrical appliances owned by households.

It can also be observed that the indicator included for access to electricity is positively associated with household consumption of biomass, gas and overall energy and negatively associated with kerosene consumption. This means that households which are connected to grid power tend to use biomass, gas, and overall energy more and less of kerosene compared to those not connected to grid power.

The results showed that number of aged exerted significant and positive effect on electricity consumption. This implies that households with older individuals consume more electricity than households with younger occupants. This result may be due to the fact that older individuals spend more time at home leading to higher electricity consumption. This finding is consistent with the results reported by Longhi (2015) that household electricity consumption is positively associated with the number of aged persons in the household.

As it is evident from Table 5, model fit statistics associated with the results, such as the Log likelihood and pseudo R-squared indicate that the regression models as a whole fitted the dataset better than models without independent variables. Also, the F-statistics associated with the results are statistically significant at one percent level of probability, reflecting that the covariates included in the models contributed significantly as a group to the variations in household energy consumption and that their coefficients are statistically different from zero. Furthermore, the results of the link test revealed that the models are correctly specified and within the thresholds of fitted models (Cameron & Trivedi, 2010).

Table 6 shows the results of the OLS regression of the data excluding zero responses in energy expenditures. The dependent variables in each column of Table 6 are the natural logarithm of reported expenditure. This means that the coefficients of logged independent variables can be directly interpreted as elasticities. The importance of the results in Table 6 is to examine how the independent variables will perform in a sub-sample of only households which reported non-zero energy expenditures. It is not meant to be directly compared to the results of the Tobit regression technique. Moreover, it has been widely noted in the literature that due to differences in axiomatic conditions, results of the Tobit and OLS regression are not directly comparable. For instance, Eakins (2013) obtained similar results for households in Ireland and argued that a direct comparison between the Tobit and OLS regression is difficult for a number of reasons.

Table 6: Results of OLS Regression of Energy Consumption

Variables	HEB	HEK	HEG	HET	HEE	HETT
Log (income)	0.4430[a]	0.2890[a]	0.3150[a]	0.6300[a]	0.2340[a]	0.5400[a]
	(0.0216)	(0.0380)	(0.0306)	(0.0419)	(0.0179)	(0.0183)
Age of head	0.0033[a]	0.0036[c]	0.0029[c]	-0.0035[c]	0.0000	-0.0021[b]
	(0.00107)	(0.0019)	(0.0016)	(0.0020)	(0.0008)	(0.0008)
Household size	0.0189[a]	-0.0114	0.0136	-0.0030	-0.0116[c]	-0.0241[a]
	(0.0072)	(0.0112)	(0.0120)	(0.0071)	(0.0066)	(0.0059)
Number of aged	-0.0141	0.0088	0.1310[b]	0.0225	0.0176	0.0295
	(0.0352)	(0.0499)	(0.0584)	(0.0487)	(0.0279)	(0.0256)
Male	-0.1430[a]	-0.1650[a]	-0.1280[a]	0.1730[c]	0.0194	-0.1280[a]
	(0.0316)	(0.0548)	(0.0397)	(0.0981)	(0.0237)	(0.0229)
Married	0.0826[a]	0.0161	0.1570[a]	0.0590	0.0210	0.1370[a]
	(0.0306)	(0.0517)	(0.0404)	(0.0697)	(0.0228)	(0.0223)
Basic	-0.1700[a]	-0.0945[c]	0.2490[a]	0.1180[b]	0.0836[a]	-0.0336
	(0.0315)	(0.0498)	(0.0822)	(0.0496)	(0.0275)	(0.0248)
Secondary	-0.2260[a]	-0.1360	0.2350[a]	0.1000	0.1410[a]	-0.0023
	(0.0499)	(0.0957)	(0.0880)	(0.0799)	(0.0378)	(0.0368)
Tertiary	-0.4100[a]	-0.4400[a]	0.2980[a]	0.2180[a]	0.1540[a]	0.0762[b]
	(0.0514)	(0.102)	(0.0840)	(0.0789)	(0.0374)	(0.0368)
Employee	0.1550[a]	0.2040[b]	0.0580	0.1070	0.00685	0.0184
	(0.0547)	(0.0959)	(0.0708)	(0.111)	(0.0429)	(0.0399)
Self-employed	0.1800[a]	0.1700[b]	0.0435	0.0303	-0.0830[b]	-0.0280
	(0.0500)	(0.0821)	(0.0699)	(0.102)	(0.0414)	(0.0377)
Urban	0.2810[a]	-0.0913[c]	0.0794[c]	0.1750[a]	0.3930[a]	0.4730[a]
	(0.0281)	(0.0482)	(0.0439)	(0.0488)	(0.0213)	(0.0212)
Children	0.1410[a]	-0.0076	0.1640[a]	-0.178[a]	0.0224	0.0673[a]
	(0.0354)	(0.0610)	(0.0444)	(0.0625)	(0.0264)	(0.0254)
Owner of home	-0.0292	0.0100	0.0017	-0.0093	0.0674[a]	-0.0204
	(0.0268)	(0.0463)	(0.0376)	(0.0488)	(0.0213)	(0.0203)
Number of workers				-0.0370[c]	0.0174	0.0428[a]
				(0.0215)	(0.0150)	(0.0137)
Number of rooms					0.0922a	0.0687a
					(0.0116)	(0.0105)
Entertainment appl.					0.0138	0.0018
					(0.0088)	(0.0088)
Preservation appl.					0.2380a	0.1590a
					(0.0172)	(0.0177)
Extra -ventilation appl.					0.1500a	0.1080a
					(0.0158)	(0.0167)

Table 6, continued

Variables	HEB	HEK	HEG	HET	HEE	HETT
Cooking appl.					0.0582a	0.0413a
					(0.0094)	(0.0096)
IT appl.					-0.0029	0.0059
					(0.0092)	(0.0094)
Laundry appl.					-0.0121	-0.0127
					(0.0165)	(0.0172)
Number of cars				0.5730a		0.3930a
				(0.0564)		(0.0446)
Number of motorcycles				0.2080[a]		0.7840[a]
				(0.0395)		(0.0299)
Public transport				-0.1060[a]		-0.0662[a]
				(0.0399)		(0.0219)
Electricity access	0.1330[a]	-0.5310[a]	0.2030[b]			0.2090[a]
	(0.0311)	(0.0493)	(0.0962)			(0.0266)
Constant	0.1820	1.2040[a]	0.6700[b]	0.2990	1.9110[a]	-0.0756
	(0.1810)	(0.3170)	(0.2830)	(0.3730)	(0.1480)	(0.1480)
Log likelihood	-9786.41	-3200.74	-2929.66	-2794.28	-11868.71	-17285.13
F Stats.	77.43[a]	16.03[a]	30.73[a]	63.38[a]	157.25[a]	279.67[a]
Adjusted R^2	0.1450	0.0900	0.1460	0.4020	0.2970	0.4220
AIC	19604.82	6433.49	5891.32	5634.56	23791.43	34632.26
_hat	1.9816	0.4226	0.4448	2.4523	1.8865	1.8072
	(0.4423)	(0.0902)	(0.1684)	(0.3083)	(0.1830)	(0.0848)
_hatsq	0.0479	0.2022	0.1636	0.0231	0.0183	0.0074
	(0.1066)	(0.1547)	(0.1121)	(0.1094)	(0.0891)	(0.0710)
N	6,860	2,268	2,529	2,136	9,368	12,476

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

Source: Author (2018).

Table 6 indicates that income is statistically significant and positive in all models, signifying that income is an important factor that affects household energy consumption. Specifically, Table 6 shows that the income elasticities of all the individual fuels as well as overall energy are positive and less than one. This implies that all the fuels are necessities to households. Hence once other independent factors considered in the study are held constant, the variations in household energy consumption for a one percent change in household income will be greater for transport fuel consumption followed by biomass, gas, kerosene, and electricity.

Although the income elasticities reported in this study are lower than those obtained by Akpalu *et al.* (2011), they are within the thresholds of estimated income elasticities of household energy consumption in empirical studies on other countries. For instance, Eakins (2013) found the income elasticity of electricity consumption among households in Ireland to be 0.100 with the income elasticity of LPG being 0.196. Guta (2012) observed that expenditure elasticity for traditional fuel consumption by households in Ethiopia was inelastic with a value of 0.72 in 2000 and 0.76 in 2004. Similarly, Salari and Javid (2017) estimated income elasticities for household gas and electricity consumption among households in the United States of America to be 0.02 and 0.42 respectively.

Except electricity consumption, the result in Table 6 also indicates that age of household head significantly predict household energy consumption. Specifically, the results show that there is a significant positive relationship between age of household head and household consumption of biomass, kerosene and gas while there is a significant negative relationship between age and demand for transportation fuel and overall energy consumption. A significant household size effect is also found in the model for biomass, electricity and overall energy consumption. But the increase in biomass consumption is only about 1.9 percent per every additional household member whereas every additional household memebers contributes to about 1.2 perecent and 2.4 percent reduction in electricity and overall energy consumption respectively.

With the exception of electricity consumption, it also can be observed from Table 6 that sex of the household head had a significant effect in explaining variations in household energy consumption. The estimated coefficient of the variable for sex shows that having a household head who is a male reduces spenínding on biomass, kerosene, gas, and overall energy whereas it increases the consumption of transportation fuel. Largely, the results with respect to sex contradicts the widely held view that female-headed households are associated with lower energy consumption due to consciousness about the environmental cost of higher energy generation (Alkon et al., 2016; Permana *et al.*, 2015). However, they confirm the Klausner's hypothesis which shows that families with adult males present as head tend to spend a small proportion of their household budget on energy than households with females as heads (Klausner, 1979).

Klausner (1979) argued that sex of household head infleunces the level of order in the household and thus energy consumption and that male-headed households will tend to consume less energy than female-headed households, other things held constant since male headship creates a sense of social order within the household and helps to reduce random behaviour and maintains disciplined control over energy consuming behaviour. Nonetheless, Seebauer and Wolf (2017) as well as DeFronzo and Warkov (1979) found that sex of household head does not significantly affect variations in household energy consumption, signalling that the relationship between household electricity consumption and the sex of household head is still an open contest.

Differences in energy consumption attributed to the level of education completed by the household head also evident from the study (Table 6). Although not of the same magnitude or sign, level of education had significant influence on most of the fuels studied. Households headed by people with basic, secondary and tertiary education spent less on biomass energy compared to those headed by people with no formal education. Also, households headed by people with basic and tertiary education consumed less kerosene compared to those headed with people without formal education. Though not statiscally significant, a similar pattern of decreasing kerosene consumption with secondary education attaintment is also evident from the results. Generally, Table 6 shows that household consumption of gas, transport fuel and electricity increases with educational attainment.

The coefficient of the dummy included for residing in an urban area is is statistically significant in all models. This suggests that dwelling location is a critical factor which influences household energy consumption. Morever, it can be observed that, with the exception of kerosene, the coefficient of residing in an urban area is positive in the model for all other fuels, which means households dwelling in urban areas are associated with more consumption of these fuels compared to those in rural areas.

While no satisfactory explanation can be found for the link between dwelling location and household energy consumption, much of the research on the topic tend to rely on the urban heat island effect as the theoretical basis for the differences in energy consumption between households in different geographical locations. For example, Gupta and Gregg (2018) as well as Kandya and Mohan (2018) observed that excessive heat associated with the urban heat island effect creates thermal discomfort for households living in heavy build-up environments and increases the requirement for energy for cooling purposes. Households dwelling in urban areas are also found to use high amount of transportation fuel to travel the same or similar distance which could be covered with lower amount of fuel in less-densely populated areas.

Chapter Summary

This chapter analysed the effect of income and other characteristics on household energy consumption. In addition to total household energy consumption, five individual fuels were also modeled namely; biomass, kerosene, gas, transport fuel, and electricity. The hypothesis tested was whether or not there is a significant positive relationship between income and energy consumption. Using the household production theory and multi-stage budgeting as the theoretical underpinnings and the Tobit estimation technique, it was established that the null hypotheses that income is not a significant positive determinant of total household energy consumption should be rejected. The same conclusion was also reached for the individual fuels.

Other significant findings of the study include the positive relationship between electrical appliances and electricity consumption. The study provides statistical evidence that age of household head, presence of children less than 17 years of age, number of workers, number of cars, number of rooms, number of motorcycles, locality, sex of household head and spending on public transport affect household energy consumption. Moreover, the study provides evidence to inform policymakers that households headed by people with tertiary education are associated with less biomass and kerosene consumption. Estimates of the income elasticities, which are relevant for policy and projections, were also undertaken. In particular, the findings show that all fuels are necessities but transport fuel has the highest income elasticity.

CHAPTER SIX

EDUCATION AND HOUSEHOLD ENERGY CHOICE

Introduction

This chapter provides results on the effects of education and other covariates on the choice of main fuel for cooking among households in Ghana. The main hypothesis tested in this analysis was whether or not the level of education of household head affects the choice of main fuel for cooking. The chapter is divided into three sections. The first section presents descriptive analysis on choice of main fuel for cooking and education, standard of living, and locality while the second section covers the estimated econometric results. The third section provides the summary to the chapter.

Education and Energy Choice

The relationship between level of education of household head and energy use as shown in Figure 5 indicates that education is positively related to modern fuel use but negatively associated with the use of traditional fuels. Also, level of education of household head is non-linearly related to transitional energy use. As educational level of household heads changes from none to tertiary, the proportion of households that use transitional fuel rises and later declines. Results show that traditional fuel use was highest for households headed by people with no formal education (80.4%) and lowest for those headed by people with tertiary education (17.3%). The reverse holds for modern fuel use. The proportion of households using modern fuels was highest for households headed by people with tertiary level of education and lowest for households headed by people with no formal education.

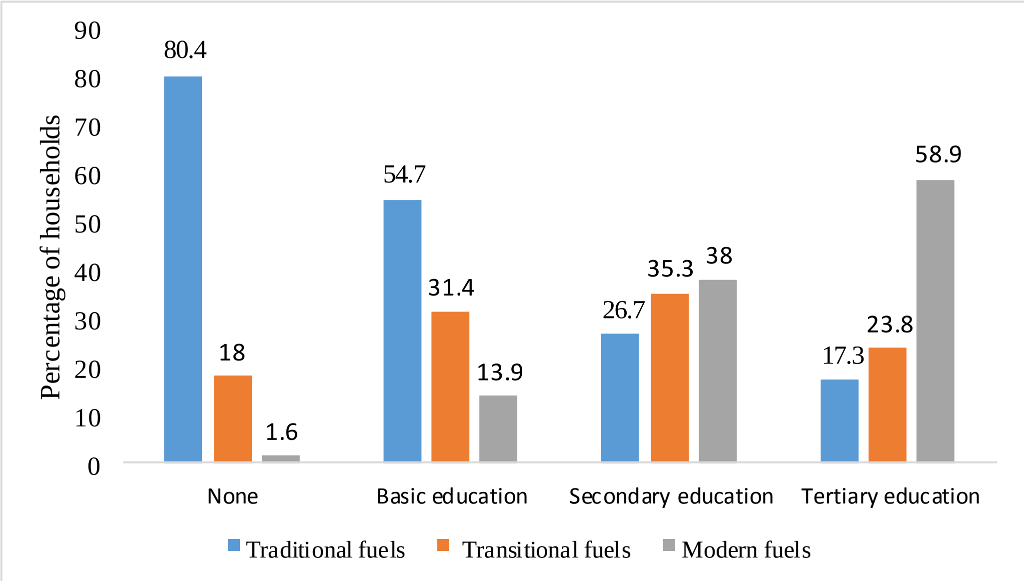

Figure 5: Type of Cooking Fuel by Level of Education

Source: Author (2018).

Figure 5 also shows that the proportion of households using transitional fuels was high among households headed by people with secondary level of education (35.3%), followed by households headed by people with basic education (31.4%), households with heads who had completed tertiary education (23.8%) and households headed by people with no education (18%). The results show that households headed by people with basic and secondary education dominate in terms of trasitional fuel while the use of traditional is more common among households headed by people without formal education.

According to Figure 5, the use of modern fuels rises progressively with increase in educational level of household heads. A possible reason is that higher level of education improves household income which can be used to purchase relatively expensive fuels. Also, education can increase the opportunity cost of fuelwood collection. As argued by Baiyegunhi and Hassan (2014), a woman with higher level of education is likely to lack time to collect fuelwood because of the opportunity cost of her time dedicated to such roles and would rather purchase fuelwood alternatives which are cleaner but expensive. Moreover, education increases awareness about the health hazards of cooking with unclean fuels. Holding all other factors constant, better education translates into higher awareness of the negative health impacts of dirty fuels, and enhanced knowledge about efficiency and convenience of modern fuels (Muller & Yan, 2018).

Standard of Living and Energy Choice

Figure 6 shows the relationship between standard of living and energy use. A household standard of living as measured by the income quintiles shows that dependency on traditional fuels declines progressively with rising standard of living.

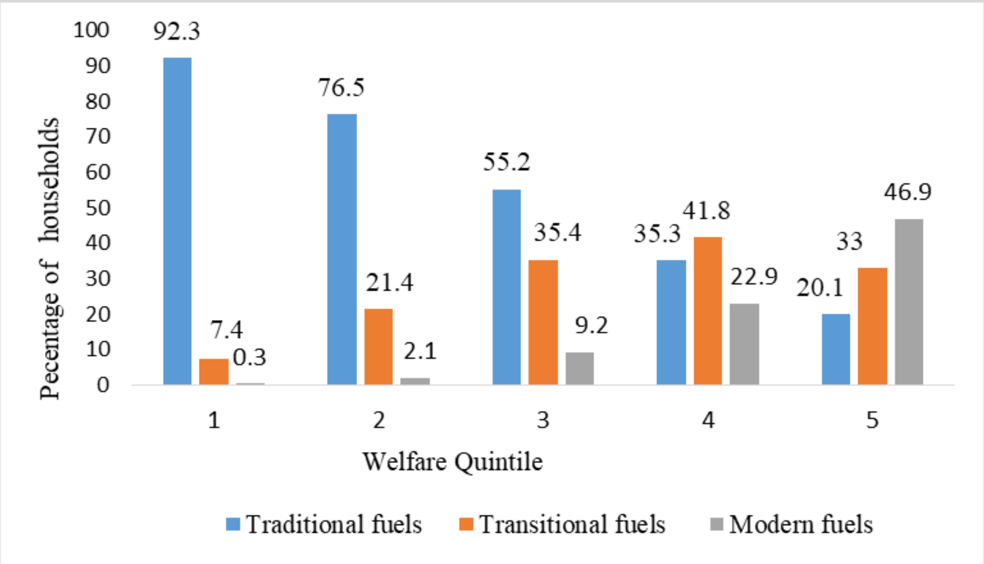

Figure 6: Type of Cooking Fuel by Standard Of Living

Source: Author (2018).

The results show that 92.3 percent of households in the lowest quintile used traditional fuels while 20.1 percent of households in the highest quintile used traditional fuels. A reverse trend was observed for the modern fuels as only 0.3 percent of households in the lowest quintile used modern fuel while

46.9 percent of households in the highest quintile used modern fuel. This demonstrates that modern fuels are least accessible to the poor households. The result indicates that providing opportunities for poor households to raise more incomes can facilitate the uptake of modern fuels.

Locality and Energy Choice

Figure 7 shows type of cooking fuel by locality of households. The differences in the choice of cooking fuels between rural and urban household is more visible. While traditional fuels are predominantly used by households in rural areas as main cooking fuels, transitional and modern fuels are prevalent among households in urban areas. The use of modern fuels is more prevalent among households in urban areas compared to households in rural areas.

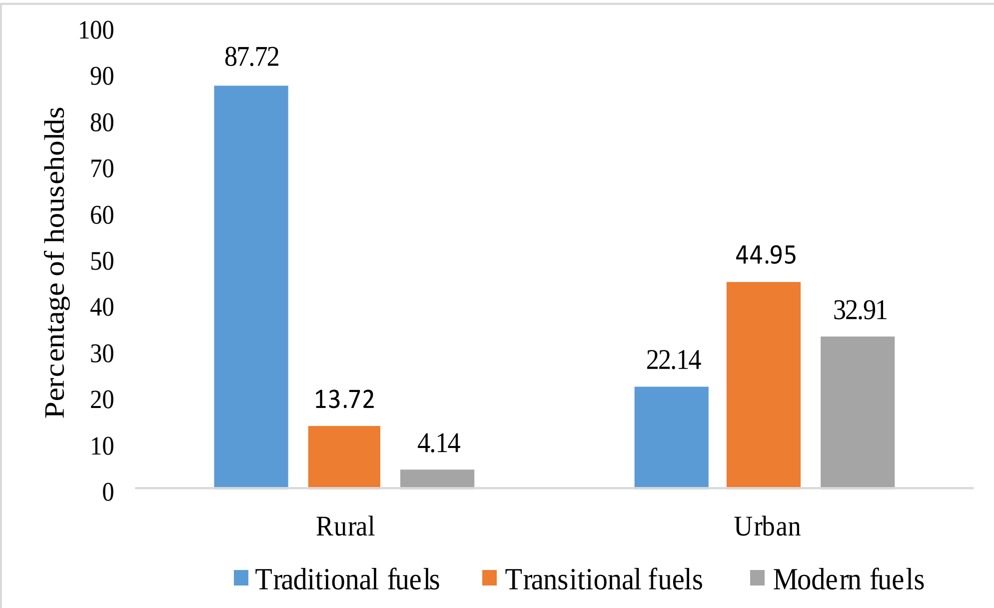

Figure 7: Type of Cooking Fuel by Locality

Source: Author (2018).

The percentage of urban households using modern fuels is approximately 33 percent as compared to 4.14 percent of households in rural areas. Approximately 88 percent of households in rural areas used traditional fuels compared to 22.14 percent for those in urban areas. Generally, Figure 7 shows that households in urban areas tend to adopt transitional and modern fuels for cooking. Nonetheless, the fact that more than 20 percent of households in urban areas use traditional fuels is still an important area of concern with respect to decreasing the use of traditional fuels.

The multinomial logit model was used to analyse the factors affecting household energy choice. Two empirical estimations were conducted. The model was first estimated to determine the factors affecting household choice of energy categories namely; traditional, transitional and modern fuels. The classification of energy types into the three categories was based on the energy ladder theory. This was done in order to identify the drivers of household energy transition. The model was also estimated again to assess household energy choices for specific energy types. Four energy types were considered in the second estimation namely; fuelwood, charcoal, LPG and other fuels. The other fuels included crop residue, kerosene and electricity. These fuels were less dominant that made us to combine them. Regression results for the first estimation are presented and discussed followed by the results of the second estimation.

Effect of Education on Choice of Main Cooking Fuel

Table 7 reports the marginal effects of education, locality and other factors on household choice of traditional, transitional and modern fuels. As in models for multi-discrete variables, the parameter estimates cannot be interpreted directly as the effects of the explanatory variables on the dependent variable. However, the marginal effects give the impact of the independent variables on the probability of choosing a given fuel. For the marginal effects, a positive value means an increase in the explanatory variable or a change relative to the based group for a factor variable will increase the probability of choosing an energy type whereas a negative value shows the opposite effect. The estimated parameters from the model are listed in appendix B.

Table 7: Marginal Effects for Choice of Main Cooking Fuel

Variable	Traditional fuels	Transitional fuels	Modern fuels
Log (income)	-0.0950[a]	-0.0101[b]	0.1050[a]
	(0.0044)	(0.0051)	(0.0039)
Age of head	0.0004[b]	0.0009[a]	-0.0013[a]
	(0.0002)	(0.0002)	(0.0002)
Household size	0.0154[a]	0.0033[b]	-0.0187[a]
	(0.0013)	(0.0015)	(0.0013)
Male	0.0668[a]	-0.0502[a]	-0.0166[a]
	(0.0064)	(0.0073)	(0.0052)
Basic	-0.0758[a]	-0.0013	0.0771[a]
	(0.0079)	(0.0093)	(0.0069)
Secondary	-0.1370[a]	-0.0032	0.1410[a]
	(0.0131)	(0.0145)	(0.0099)
Tertiary	-0.1690[a]	-0.0645[a]	0.2330[a]
	(0.0129)	(0.0138)	(0.0102)
Urban	-0.2540[a]	0.1850[a]	0.0697[a]
	(0.0079)	(0.0083)	(0.0055)
Owner occupied	0.0608[a]	-0.0421[a]	-0.0186[a]
	(0.0062)	(0.0070)	(0.0051)
Radio	-0.0136[b]	-0.0053	0.0189[a]
	(0.0058)	(0.0067)	(0.0049)
Agricland	0.0827[a]	-0.0479[a]	-0.0348[a]
	(0.0097)	(0.0123)	(0.0104)
Livestock	0.1050[a]	-0.0529[a]	-0.0524[a]
	(0.0078)	(0.0095)	(0.0078)
Electricity access	-0.1650[a]	0.0547[a]	0.1100[a]
	(0.0076)	(0.0088)	(0.0067)
Coastal zone	-0.1230[a]	0.0184[c]	0.1050[a]
	(0.0089)	(0.0102)	(0.0070)
Forest zone	-0.0161[b]	-0.0437[a]	0.0598[a]
	(0.0074)	(0.0087)	(0.0060)
N	16,508		
Log pseudo likelihood	-9714.05		
Wald (χ^2)	5338.70[a]		
Pseudo R^2	0.3978		

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

Source: Author (2018).

Table 7 shows that education has a significant positive impact on the choice of modern fuel. The effect of education on the probability of modern fuels uptake is highest for tertiary education (23.3%) followed by secondary education (14.1%) and basic education (7.7%). The study thus provides statistical evidence to demonstrate that education is the most important factor influencing choice of modern fuels by households. However, this study establishes that basic and secondary educations do not significantly influence the choice of transitional fuels. On the contrary, tertiary education has a significant negative impact the use of transition fuel. The marginal effects indicate that having a household who has completed tertiary education reduces the likelihood of using traditional fuels by about 6.5%. This leads to the acceptance of the hypothesis that tertiary education affects choice of fuel for cooking.

A plausible explanation for the positive effect of education on the modern fuel use is that education enhances awareness about the positive effects of modern fuel use. As Démurger and Fournier (2011) pointed out that more educated people tend to value the use of modern energy sources and may be less reluctant to changes in cooking and heating habits. In the same vein, Baiyegunhi and Hassan (2014) indicate that education generally improves household income, taste and knowledge of fuel attributes and preference for modern clean fuels. The results relating to this variable are in line with other studies conducted in developing countries such as Abebaw (2007) in Ethiopia; Heltberg (2005) in Guatemala and Pandey and Chaubal (2011) in India. For instance, Pandey and Chaubal investigated household energy use in India and found that education had positive and statistically significant effect on the choice of clean fuels.

The results reveal that income has a significant effect on household energy choice decisions. The marginal effects suggest that a high income increases the probability of choosing modern fuel while a low level of income leads to the choice of traditional and transitional fuels. More specifically, a one percent increase in household income increases the probability of choosing modern fuel by approximately 11 percent while the same margin of increase in household income decreases the probability of using traditional and transitional fuels by 9.5 percent and one percent respectively. The results show that modern fuels are normal goods while traditional and transitional fuels are inferior goods. This means that an increase in household income is likely to increase transition from traditional fuels to modern fuels.

Income facilitates affordability, which improves the transition from other fuels to modern fuels. Also, as household income increases they may shift to the use of clean and efficient modern fuel because of the prestige associated with the use of these fuels. Compared to other fuels, modern fuels provide more economic value to households because of their high combustion intensity and efficiency. Therefore, as income increases households will gradually shift from less efficient traditional fuels to clean and efficient modern fuels. The positive income effect for modern fuels is consistent with the energy ladder theory which maintains that households will consume more modern fuels when their income increases. This finding is consistent with the result of Baiyegunhi and Hassan (2014) who found evidence of household transition from traditional fuels to modern fuels in response to higher income

Age of household head is a significant determinant of household choice of cooking fuel. Table 7 indicates that households headed by older people are less likely to choose modern fuels as their main cooking fuels compared to households headed by younger people. Also, households headed by older people are more likely to choose traditional and transitional fuels. The marginal effects indicate that a year's increase in the age of the household head decreases the probability of using modern fuel by 0.13% whiles increasing the probability of choosing traditional and transitional fuels by 0.04% and 0.09% respectively. This could be attributed to the fact that older people do not easily adapt to changing lifestyles as compared to younger people. They tend to perpetuate traditional practices of cooking and heating and this affects their preference for traditional fuels. The results on age confirm the findings of Gebreegziabher *et al.* (2012), Démurger and Fournier (2011) and Rahut *et al.* (2014) who found that age of household head is positively associated with use of traditional fuels while negatively related to the choice of modern ones.

The results show that household size has a significant positive effect on the choice of traditional and transitional fuels while the effect is negative for the choice of modern fuels. This suggests that a larger household is less likely to choose modern fuel as the main cooking fuel while smaller households are more likely to use modern fuel. The marginal effects show that an additional household member decreases the probability of transition from traditional fuel to modern fuel by 1.9 percent. Also, an increase in household size increases the probability of using traditional fuel by 1.5 percent and of choosing transitional fuel by 0.03 percent.

These results are consistent with expectation given the fact that households with many members need more energy and the relatively higher cost of modern fuels does not allow them to choose modern fuels. Also, household size is often larger in poorer households that cannot afford modern fuels. Furthermore, larger households may have free or cheap labour for the collection of fuelwood. This finding confirms the results reported by Quedraogo (2006), Rao and Reddy (2007), Pandey and Chaubal (2011) as well as Baiyegunhi and Hassan (2014) which maintain that larger household prefer traditional fuels. However, it contradicts the finding of Gupta and Köhlin (2006) who found that household with larger member are more likely to choose modern fuels because they may have more economic power to pay for these fuels.

Table 7 shows also that sex of household head has a significant effect on the choice of main fuel for cooking. Indeed, the estimated coefficients of the dummy variable included for the sex of household head are all statistically different from zero but their signs differ across energy types. The coefficients are negative under both transitional and modern fuel but positive for the choice of traditional fuel. This implies that households headed by males are less likely to use transitional and modern fuels relative to female-headed households. As evident from the marginal effects, male household headship decreases the probability of moving from traditional fuels to transitional and modern fuels by 5 percent and approximately 2 percent respectively. The result is consistent with the social realities in developing countries. In most households in developing countries men are not often responsible for cooking and thus are not affected by the smoke associated with the burning of dirty fuels. Moreover, because men are mostly responsible for the payment for household energy, they may be motivated to choose traditional fuels which are relatively cheap. The finding in this study confirms the evidence provided by Hou *et al.* (2018) that male-headed household prefers traditional fuels to other alternative fuels. However, it contradicts the results of Alem *et al.* (2016) who reported that sex of the household head does not significantly affect choice of fuel for cooking.

The estimated coefficients for variable for location (urban) are positive and significant for transitional and modern fuels but negative and significant for traditional fuels. This implies that households living in urban areas are more likely to switch from traditional fuels to transitional and modern fuels compared to those in rural areas. The results indicate that for households living in urban areas the probability of choosing transitional and modern fuels increase by 18.5 percent and approximately 7 percent respectively while the likelihood of using traditional fuels deceases by 25.4 percent.

The positive relationship between urban residence and transitional and modern fuel use is largely due to the increased accessibility of these fuels in urban areas. Households living in urban areas tend to have more access to transitional and modern fuels relative to their counterparts in rural areas. For instance, even though charcoal is produced mainly in the rural areas, the bulk of it is transported from the production centres in the rural areas for sale in urban areas. Modern fuels such are electricity and gas are also available more in the urban areas than rural areas. Besides, there are more economic opportunities in urban areas than rural centres. For this reason, households in urban areas have relatively higher incomes which can enable them to purchase modern fuels. This suggests that increasing energy access and providing economic opportunities for people can facilitate household transition to modern fuels. A number of past studies have found similar results (Joshi & Bohara, 2017; Mottaleb *et al*., 2017; Rahut *et al*. 2016a). For example, Rahut *et al*. analysed household energy use pattern and their determinants in Ethiopia, Malawi and Tanzania and found that household living in urban areas were more likely to use modern energy sources like electricity and gas while households residing in rural centres were less likely to use modern fuel but more likely to use solid fuels such as firewood and crop residue.

Another interesting finding is that ownership of house is negatively and significantly related to choice of transitional and modern fuels. The marginal effects indicate that for households living in their own houses the probability of choosing transitional and modern fuels decreases by 4.2% and 1.9% respectively. This implies that owner-occupied households are less likely to choose transitional and modern fuel compared to households living in rented houses. The reason may be that households living in their own households are able to collect traditional fuels such as firewood and crop residue from their surroundings. Another reason can be that if the dwelling unit is owned, the household is free to use any type of fuel for cooking. However, if the dwelling unit is rented there can be restrictions on the type of fuel the household can use. One disadvantage of traditional fuel is that it produces smoke that can stain the walls and roofs. This makes traditional fuel a less preferred option for households living in rented houses. However, the results are at odds with the finding reported by Arthur, Zahran, and Bucini (2010) that households living in their own houses are more likely adopt clean fuels.

A positive relationship was expected between ownership of radio and choice of modern fuels. Generally, households that listen to radio regularly get informed about the adverse effects of traditional fuels on human health and the environment and their influence their choice of fuels. Consistent with expectation, the results show that possession of radio is positively related to household choice of modern fuels. The marginal effects indicate that owning a radio by a household increases the probability of choosing modern fuels by 1.9%. The result is similar to Joshi and Bohara (2017) who found a positive relationship between choice of modern fuels and television.

Table 7 demonstrates that access to electricity exerts a significant effect on household energy choice. The estimated coefficient is positive and significant under transitional and modern fuels but it is negative and significant under the traditional fuels. This implies that households with access to electricity are more likely to choose transitional and modern fuels while less likely to use traditional fuels. The marginal effects show that for household having access to electricity the probability of choosing transitional and modern fuels increases by 5.5 percent and 11 percent respectively while the likelihood of using traditional fuels reduces by 16.5 percent.

The reason why access to electricity has a positive effect on modern fuel use is that households connected to electricity may have more opportunities to use modern cooking fuels. Evidence from other empirical studies shows that in areas where electricity is available, barriers that restrict other modern fuels are minimal. Also, availability of lighting and other appliances motivates people to a greater acceptance of modernity and modern fuels. The result is similar to Heltberg (2004) who observed that access to electricity induced households to adopt modern fuels in India and Brazil.

Ownership of livestock and agricultural land were included to account for agriculture specialisation. As evident from Table 8, the coefficients of these variables are statistically significant and have the expected signs. The negative coefficients of the variables under transitional and modern fuels show that households owning livestock and agricultural land are less likely to use transitional and modern fuels for cooking. More specifically, for households owning livestock the probability of choosing transitional and modern fuels decreases by 5.3 percent and 5.2 percent respectively. Similarly, for households having land for agricultural activities, the likelihood of using transitional and modern fuels decreases by 4.8 percent and 3.5 percent respectively. The results can be attributed to the fact that households engaged in farming and other agricultural related activities find it easy to get firewood and crop residue for use as cooking fuels. Also, households who own livestock make rational decision to collect firewood also when they collect folder for the livestock feed (Joshi & Bohara, 2017).

The coefficients for the two ecological zone variables are statistically significantly different from zero, implying that there are differences in the behaviour of households living in different ecological zones as far as energy use is concerned. Households in coastal zones prefer transitional and modern fuels while their counterparts in the forest zone prefer modern fuels.

The result of Wald test statistics of the estimated model is statistically significant at one percent level of probability value, suggesting that the MNL model has a strong explanatory power. It also indicates that the independent variables in the model are important in explaining household energy choice behaviour. In line with standard econometric practice, multicollinearity test was performed using the variance inflation factors (VIFs) and the results are reported in appendix C. The VIFs for all the variables included in the models were less than 10 indicating the absence of multicollinearity. The marginal effects show that many of the variables influencing the probability of choosing transition or modern energy as the main cooking fuel are statistically significant at different levels. The standard errors were estimated using robust command in Stata to help address the problem of heteroscedasticity.

As mentioned before, the multinomial logit model was re-estimated to assess the factors affecting household choice of individual fuels within the fuel categories. The fuel categories were broken down into the specific fuels used by households for cooking. The specific fuels were firewood, charcoal, gas, electricity, kerosene and crop residue/sawdust. It was realised from the data used for the study that out of the 6 alternatives, three were the major fuels used by households for cooking namely; firewood (54.6%), charcoal (27%) and LPG (14.3%). The rest constituted 4.1 percent of the households in the study sample. Because kerosene, electricity and crop residue/sawdust were less used, they were combined to form the 'other fuel' category. The second estimation was conducted with other fuels as the reference category. The reason for the disaggregated analysis was to determine if the factors affecting the fuel categories also influence the individual fuels. The marginal effects of the independent variables included in the model are reported in Table 8 while the estimated parameters are in appendix D.

Table 8: Marginal Effects for Fuelwood, Charcoal, LPG and Other Fuels

Variable	Fuelwood	Charcoal	LPG	Other fuels
Log (income)	-0.0787[a]	-0.0126[b]	0.1030[a]	-0.0117[a]
	(0.0043)	(0.0051)	(0.0040)	(0.0026)
Age of head	0.0008[a]	0.0008[a]	-0.0013[a]	-0.0002[b]
	(0.0002)	(0.0002)	(0.0002)	(0.0001)
Hhsize	0.0279[a]	0.0065[a]	-0.0169[a]	-0.0175[a]
	(0.0014)	(0.0016)	(0.0013)	(0.0015)
Male	0.0163[a]	-0.0464[a]	-0.0180[a]	0.0480[a]
	(0.0062)	(0.0071)	(0.0051)	(0.0031)
Basic	-0.0485[a]	0.0016	0.0765[a]	-0.0296[a]
	(0.0074)	(0.0090)	(0.0068)	(0.0053)
Secondary	-0.1330[a]	0.0067	0.1410[a]	-0.0149[b]
	(0.0128)	(0.0143)	(0.0097)	(0.0076)
Tertiary	-0.164[a]	-0.0583[a]	0.2330[a]	-0.0111
	(0.0135)	(0.0142)	(0.0102)	(0.0083)
Urban	-0.2920[a]	0.1880[a]	0.0678[a]	0.0368[a]
	(0.0082)	(0.0085)	(0.0055)	(0.0043)
Owner occupied	0.0566[a]	-0.0422[a]	-0.0178[a]	0.0034
	(0.0060)	(0.0070)	(0.0051)	(0.0031)
Own radio	-0.0031	-0.0058	0.0190[a]	-0.0102[a]
	(0.0056)	(0.0065)	(0.0049)	(0.0034)
Own agricland	0.0881[a]	-0.0429[a]	-0.0308[a]	-0.0144[b]
	(0.0096)	(0.0122)	(0.0104)	(0.0056)
Own livestock	0.0842[a]	-0.0531[a]	-0.0560[a]	0.0250[a]
	(0.0074)	(0.0093)	(0.0077)	(0.0051)
Electricity access	-0.151[a]	0.0578[a]	0.108[a]	-0.0143[a]
	(0.0073)	(0.0087)	(0.0067)	(0.0044)
Coastal zone	-0.1200[a]	0.0223[b]	0.1040[a]	-0.0061
	(0.0089)	(0.0102)	(0.0069)	(0.0048)
Forest zone	0.0013	-0.0413[a]	0.0573[a]	-0.0172[a]
	(0.0072)	(0.0086)	(0.0063)	(0.0040)
N	16,508			
Log pseudo likelihood	-11445.92			
Wald (χ^2)	6471.08			
Pseudo R^2	0.3872			

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

Source: Author (2018).

Education is found to positively influence the choice of LPG as the main cooking fuel. Table 8 shows that the probability of using LPG increases with the level of education while the probability of using fuelwood decreases progressively. The result once again confirms the differential role of education of the household head in the energy choice. As the result demonstrates age of household head is positive and significantly related to household use of fuelwood and charcoal while it is negative and significantly related to household's use of LPG, implying that older household heads are less likely to use LPG but are more likely to use fuelwood or charcoal. Similarly, the probability of using fuelwood and charcoal increases with an increase in household size while the probability of using LPG decreases with an increase in household size, suggesting that larger households are more likely to use fuelwood and charcoal but are less likely to use LPG for cooking.

It can be observed that the coefficient of the variable for location (urban) is negative and significantly associated with a choice of fuelwood indicating that compared to households in rural areas, households in urban places are less likely to use fuelwood for cooking. Also, the coefficient of the urban variable is positive and significant for charcoal and LPG, implying that urban households are more likely to use charcoal and LPG for cooking compared to rural households, probably because of the availability and easy access to these fuels in urban areas. Access to electricity is negative and significantly associated with a household's use of fuelwood while it is positive and significantly related to a household's use of charcoal and LPG. Access to electricity has a differential role on a household's choice of energy for cooking in that households connected to electricity are more likely to use charcoal and LPG while households without access to electricity are more likely to use fuelwood.

Table 8 shows that access to information, radio, is positive and significantly related to the use of LPG while it is negative and insignificant for a household use of fuelwood and charcoal, indicating that while access to information is important determinant of LPG it does not significantly affect household choice of fuelwood and charcoal. The results also show that livestock and agricland have differential role in household choice of cooking energy. The coefficients of the variables are significant and negative for a household choice of charcoal and LPG while they are positive and significant for fuelwood, indicating that households having livestock and agricland are more likely to use fuelwood while less likely to use charcoal and LPG.

Chapter Summary

This chapter presented the empirical analysis of the determinants of household choice of cooking fuels. The main hypotheses examined in this chapter were educational attainment positively affects choice of modern fuels and also urban household are more likely to use modern sources of energy for cooking. Using the energy ladder theory as the theoretical underpinning and the multinomial regression technique, it was found that there is a positive and statistically significant relationship between educational level and household choice of modern fuels. It was also established that urban households were more likely to use modern fuels relative to rural households. Additionally, the study identified access to electricity and income as important factors determining the choice of cooking fuel in the sense that high-income households and households with access to modern fuels tended to choose modern fuels such as LPG over alternative fuels such as firewood.

CHAPTER SEVEN

CROWDING-OUT EFFECTS OF ENERGY EXPENDITURE

Introduction

This chapter provides an empirical analysis of the effects of energy spending on other household expenditures. The chapter begins with the budgets shares for energy and non-energy goods and services. The results of the t-test for the differences in budget shares between households that spent on energy and households without energy expenditures are then analysed. The CMP model was used to estimate the relationship between energy expenditure and spending on 12 other categories while controlling for socio-economic and demographic characteristics of the household. The estimated results are presented and discussed followed by the summary of the chapter.

Descriptive Analysis of Household Expenditure Patterns

Table 9 shows the summary statistics of the expenditures employed for the analysis in this section. It also highlights the shares of individual energy expenditures in total household energy budget as well as the shares of different categories of expenditure in total non-energy budget. The results indicate that the average household spent 5.01 percent of its total budget on energy and the rest was spent on other goods and services. With respect to the total energy budget, 45.72 percent was devoted to electricity, followed by biomass (29.26%) and transport fuels (13.10 %) with budget share for LPG being the least (5.17%). Food, housing, and education dominated the non-energy budget of the households. According to Table 9, households spent most of non-energy budget on food (53.68) followed by housing (7.98%) and education (7.68%) with spending on hotel (0.14%) being the least.

Table 9: Percentage Shares of Household Expenditures

Item	Mean
Overall energy	**5.01**
Biomass	29.26
Kerosene	6.76
LPG	5.17
Transport fuel	13.10
Electricity	45.72
Non-energy expenditure	**94.99**
Food	53.78
Alcohol & tobacco	1.32
Clothing	6.81
Health	1.04
Education	7.68
Communication	4.27
Housing	7.98
Furnishing	5.15
Public transport	3.65
Recreation	3.06
Hotel	0.14
Miscellaneous	5.14

Source: Author (2018).

The results of the t-test for differences in the average shares of total budget allocated to different commodities by energy consuming and non-consuming households are presented in Table 10. Statistically significant differences in the budget shares are observed between the two groups of households for all the commodities except health.

Table 10: Differences in Household Expenditure Mean Shares

Commodity	Consuming households	Non-consuming households	Diff.	T stats.
Food	0.5312	0.6249	-0.0937	-45.16
Alcohol	0.0129	0.0268	-0.0139	-27.92
Clothing	0.0656	0.0711	-0.0055	-6.84
Furnishing	0.0488	0.0498	-0.0010	-1.68
Health	0.0101	0.0082	0.0019	1.30
Communication	0.0403	0.0224	0.0179	25.48
Recreation	0.0351	0.0267	0.0084	2.33
Education	0.0742	0.0339	0.0403	16.53
Hotel	0.0011	0.0001	0.0010	2.10
Housing	0.0949	0.0841	0.0108	4.98
Transportation	0.0345	0.0201	0.0144	6.33
Other	0.0512	0.0321	0.0191	18.45
N	12,476	4,032		

Source: Author (2018).

Table 10 shows that the largest share of total budget is allocated to food by both households. This share is incomparable with the share for the rest of the commodities. Obviously, the share allocated to food was higher for non-spending households than spending households. This is the same for three other commodities: alcohol, clothing and furnishing. However, a reverse is observed when it comes to budget shares for the rest of the commodities. For these commodities, the budget shares are higher for spending households than non-spending households. Thus, there is an indication that expenditure on energy crowds outs spending on some categories of goods while it crowds in others.

Results of the Crowding-Out Effects of Energy Expenditure

The role of this section was to examine the extent to which energy consumption crowds out or crowds in household expenditures on other goods and services. As a result, the main independent variable of interest in all the models is energy expenditure. Hence, the estimated parameters of the other independent variables are not interpreted. Moreover, because information on prices was not available for all goods of interest, a conditional Engel curves were estimated to examine the relationship between energy expenditure and shares of the remaining budget allocated to the other goods. Results for overall energy consumption are reported in Table 11, followed by results of the effects of biomass and electricity expenditure on the same set of household goods and services in appendix E and F respectively. The estimation on biomass expenditure and electricity expenditure are necessary because together they account for nearly three quarters of energy budget. In addition, these fuels are at the extreme and opposite ends of the energy ladder.

According to Table 11, an increase in the total amount of household budget allocated to energy led to a decrease in the budget share allocated to food. Specifically, the estimated marginal effect of -0.0453 means that a one percent increase in overall energy expenditure will result in 4.53 percent reduction in the budget share allocated to food, all things being equal. The negative and statistically significant coefficient of overall energy expenditure in the model for alcohol shows that budget share on alcohol reduces with increase in spending on energy. On average, the proportion of household budget allocated to alcohol falls by 0.62 percent for every one percent increase in expenditure on energy.

The coefficient of overall energy expenditure is negative and significant in the models for clothing, communication, housing, and furnishing. The estimated marginal effects reported in Table 11 demonstrate that a one percent increase in spending on energy will translate to about 2.19 percent reduction in the budget share allocated to clothing whereas similar variations will lead to 0.31, 6.0, and 1.3 percent reduction in the budget shares allocated to communication, housing and furnishing respectively. Other interesting findings are the positive and significant relationship between overall energy consumption and the budget shares allocated to education, public transport, recreation, hotel, and miscellaneous. Nonetheless, it can be deduced from Table 11 that the budget share dedicated to education is more sensitive to overall energy consumption than the rest of the goods which are positively related to overall energy consumption.

Table 11: Marginal Effects of Conditional Mixed Process of Crowding Out Effects of Energy Expenditure

.	Food	Alcohol	Clothing	Health	Educ.	Comm.	Hous.
Overallenergy	-0.0453[a]	-0.0062[a]	-0.0219[a]	0.0024[a]	0.0246[a]	-0.0031[a]	-0.0604[a]
	(0.0042)	(0.0012)	(0.0015)	(0.0005)	(0.0022)	(0.0011)	(0.0035)
lnM	-0.0200[a]	-0.0467[a]	-0.0092[a]	-0.0061	0.0112[b]	0.0249[a]	-0.0324[a]
	(0.0025)	(0.0059)	(0.0026)	(0.0051)	(0.0044)	(0.0032)	(0.0038)
hhsize	-0.0135[a]	-0.0092[a]	0.0049[a]	-0.0073[b]	0.0828[a]	-0.0172[a]	0.0097[a]
	(0.0014)	(0.0030)	(0.0013)	(0.0030)	(0.0025)	(0.0018)	(0.0025)
Age	0.0005[b]	0.0014[a]	-0.0030[a]	0.0034[a]	0.0027[a]	-0.0037[a]	0.0035[a]
	(0.0002)	(0.0005)	(0.0002)	(0.0004)	(0.0004)	(0.0003)	(0.0003)
Basic educ.	-0.1700[a]	-0.1120[a]	0.0047	0.0485[a]	0.2400[a]	0.1550[a]	-0.0445[a]
	(0.0078)	(0.0175)	(0.0080)	(0.0164)	(0.0153)	(0.0102)	(0.0111)
Secondary educ.	-0.2690[a]	-0.1580[a]	-0.0019	-0.0105	0.3800[a]	0.2270[a]	-0.0285
	(0.0134)	(0.0368)	(0.0132)	(0.0287)	(0.0256)	(0.0166)	(0.0198)
Tertiary educ.	-0.4040[a]	-0.2290[a]	0.0244[c]	0.0174	0.4450[a]	0.2150[a]	0.0002
	(0.0134)	(0.0344)	(0.0134)	(0.0304)	(0.0246)	(0.0159)	(0.0201)
Employee	-0.0527[a]	0.139[a]	0.0414[b]	-0.1220[a]	-0.0335	0.0678[a]	-0.0680[a]
	(0.0150)	(0.0397)	(0.0161)	(0.0322)	(0.0302)	(0.0178)	(0.0207)
Self-employed	0.0190	0.0608[c]	0.0131	-0.0645[b]	-0.0417	-0.0058	-0.1140[a]
	(0.0138)	(0.0346)	(0.0157)	(0.0295)	(0.0280)	(0.0167)	(0.0185)
Urban	-0.1700[a]	-0.3890[a]	-0.0268[a]	-0.0631[a]	0.2810[a]	0.1290[a]	0.2720[a]
	(0.0069)	(0.0181)	(0.0067)	(0.0148)	(0.0132)	(0.0083)	(0.0010)
Married	-0.0013	0.0579[a]	0.0432[a]	-0.0411[a]	-0.0591[a]	-0.0109	-0.0357[a]
	(0.0070)	(0.0168)	(0.0072)	(0.0146)	(0.0137)	(0.0083)	(0.0105)
Log pseudolikelihood	-61814.79	-5221.902	-54886.955	-51689.74	-54708.902	-53360.583	-55876.934
Wald (χ^2)	6516.18[a]	4087.19[a]	3756.52[a]	3529.77[a]	5675.66[a]	5418.31[a]	4747.20[a]
N	16,508	16,508	16,508	16,508	16,508	16,508	16,508

Table 11, continued

Variables	Furn.	Transp.	Recreation	Hotel	Miscellaneous	Overall energy
Overall energy	-0.0130[a]	0.0046[a]	0.0041[a]	0.0002[a]	0.0073[a]	
	(0.0009)	(0.0013)	(0.0011)	(0.0000)	(0.0013)	
lnM	-0.0155[a]	0.0243[a]	0.0265[a]	0.0939[b]	0.0407[a]	0.5330[a]
	(0.0020)	(0.0046)	(0.0040)	(0.0422)	(0.0032)	(0.0408)
hhsize	-0.0117[a]	-0.0251[a]	-0.0052[b]	-0.0611[a]	-0.0246[a]	0.1860[a]
	(0.0010)	(0.0023)	(0.0023)	(0.0204)	(0.0019)	(0.0179)
Age	-0.0015[a]	-0.0001	0.0022[a]	-0.0059[c]	-0.0006[b]	0.00755[a]
	(0.0002)	(0.0003)	(0.0004)	(0.0030)	(0.0003)	(0.0024)
Basic educ.	-0.0010	0.1610[a]	0.1010[a]	0.2890[b]	0.1350[a]	0.5590[a]
	(0.0063)	(0.0140)	(0.0140)	(0.1240)	(0.0098)	(0.0701)
Secondary educ.	0.0030	0.2330[a]	0.1190[a]	0.2600[c]	0.1450[a]	1.8690[a]
	(0.0107)	(0.0215)	(0.0216)	(0.1470)	(0.0172)	(0.1980)
Tertiary educ.	0.0461[a]	0.2090[a]	0.2440[a]	0.6170[a]	0.2710[a]	4.1180[a]
	(0.0108)	(0.0240)	(0.0210)	(0.154)	(0.0174)	(0.2830)
Employee	-0.0011	0.0985[a]	0.0015	0.0045	0.0513[a]	0.0860
	(0.0129)	(0.0254)	(0.0230)	(0.1630)	(0.0183)	(0.1850)
Self-employed	-0.0203[c]	0.0445[c]	0.0118	-0.1230	-0.0278	-0.2910[c]
	(0.0122)	(0.0236)	(0.0217)	(0.1590)	(0.0171)	(0.1540)
Urban	-0.0277[a]	0.1100[a]	-0.0957[a]	0.1130	0.0578[a]	2.4750[a]
	(0.0055)	(0.0111)	(0.0112)	(0.1080)	(0.0093)	(0.0953)
Married	0.00158	-0.0579[a]	0.0389[a]	-0.0425	-0.0250[a]	0.6470[a]
	(0.0056)	(0.0116)	(0.0121)	(0.1010)	(0.0090)	(0.0852)
Log pseudolikelihood	-54081.151	-53147.302	-52957.397	-50774.34	-53917.464	
Wald (χ^2)	3927.68[a]	4581.17[a]	3686.49[a]	3428.64[a]	4681.72[a]	
N	16,508	16,508	16,508	16,508	16,508	

Robust standard errors in brackets, [a] p<0.01, [b] p<0.05, [c] p<0.1

Source: Author (2018).

Appendix E shows that biomass expenditure is statistically significant and negatively related to the budget shares allocated to alcohol, clothing, communication, housing and furnishing but significant and positive in the models for food, health, education, transport, recreation, hotel, and miscellaneous. Moreover, appendix F shows that expenditure on electricity crowds out spending on food, alcohol, clothing, housing, and furnishing while crowding-in allocations to education, transport, recreation, hotel and miscellaneous.

The significant positive relationship between expenditure on biomass and the share of household budget dedicated to healthcare expenditure can be attributed to the negative health effects associated with the use of biomass fuels. Undeniably, households who use biomass as their main fuel are more likely to face direct and indirect negative effects on their health due to the high quantities of smoke and particulates associated with this kind of energy. Holding all other factors unchanged, the reliance on biomass has the potential to increase how much households spend in dealing with ailments resulting from this process, such as respiratory tract diseases from the indoor air pollution linked to the incomplete combustion of solid fuels. Biomass fuels are usually burned in open fires leading to the emission of very high levels of noxious fumes and chemicals that have the potential to kill or maim their users. For instance, Irfan, Cameron and Hassan (2018) reported that nearly 1.6 million people around the world die prematurely each year due to indoor air pollution whereas several others suffer from serious diseases closely linked to solid fuels.

Meanwhile, the positive relationship between electricity expenditure and the budget share on education implies that electricity expenditures crowds in expenditure on education. This can be explained via a number of channels. First, access to electricity can improve the academic performance of household members attending school by making it possible for them to study at night, thus forcing households to spend more on education. It also provides opportunities to participate in private after-school tuition. Electricity consumption can also improve the wealth status of households and hence increase the value and importance they attach the education of their members. Unlike overall energy, expenditure on biomass has no effect on the budget share allocated to recreation whereas electricity expenditure is found to have no significant impact on the budget shares allocated to communication. Thus, the consumers of such products can be targeted for electricity tariff hikes.

The results reported in this study are consistent with a number of past studies including Murray (2012), Rahut *et al*. (2017), Ferdous *et al*. (2010), Choo *et al*. (2007) as well as Sanchez *et al*. (2006). For instance, Choo *et al.* examined whether expenditure on transport fuel and communication tend to be substitutes, complements or neither. Employing dataset from the 1984-2002 Consumer Expenditure Survey in the United States of America, they found positive income elasticity for both goods, reflecting that demand for transportation and communication increases with increasing income.

Similarly, Sanchez *et al*. (2006) studied the effect of fuel expenditure on housing expenditures. Observing that housing and transport fuel constitute the two largest shares of total household budget, they argued that there is potential trade-off between them. Rahut *et al*. (2017) also found significant crowding in effects of biomass fuels on healthcare expenditure, and attributed it to the negative hazards related to the use of unclean fuels. Moreover, Murray (2012) shows that high energy cost compels many households to sacrifice spending on food and other household essentials.

Chapter Summary

This chapter presented results on the crowding out effects of energy expenditure on the budget shares allocated to other goods, using household micro data to examine its impact in Ghana. It adds to the wide body of knowledge on energy by examining the effect energy expenditure on budget shares of other household goods. Given that the dependent variables are the fraction of non-energy budget allocate to the remaining goods and the fact that energy expenditure is endogenous, the conditional mixed process framework by Roodman (2011) was employed for the estimation. Consistent with expectation and existing studies, it was observed that households with higher energy expenditures allocated smaller shares of their budgets to food, clothing, housing, furnishing, and communication. Further analysis using the budgetary allocation to biomass and electricity also showed significant crowding out effects for some goods. Meanwhile, it was found that biomass consumption has no impact on spending on recreation whereas electricity consumption also showed no significant influence on the budget shares allocated to communication. The next chapter summarises and concludes the study.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

Access to energy is essential to improving the living standards of people. Households require energy for cooking, lighting and other domestic endeavours as well for private transport. The use of energy by household has been increasing at a very fast rate. The rising consumption of energy by the household sector is not only posing challenges for energy security but also the country's forest resources. In light of these, this study examined the factors affecting energy choice, expenditures and household consumption patterns in Ghana using data from the sixth round of the Ghana Living Standards Survey.

The previous chapters presented and discussed the empirical results on energy choice, expenditures and household consumption patterns. This chapter presents the summary of the entire thesis, provides the main conclusions of the study and offer policy recommendations based on the conclusions. The chapter is divided into three main sections. The first section provides the summary of the entire research. This is followed by the conclusions derived from the results of the study in the second section. The third section provides policy recommendations, the limitations of the study as well as areas for future research.

Summary

Three empirical chapters were covered in this thesis. The first empirical chapter presented and discussed results on expenditures on energy and verified whether income had a significant positive impact in explaining variations in energy consumption among the households studied. This hypothesis was formulated and examined to add the trending literature on household wealth and demand for energy. In addition, the chapter provided insights into the extent to which income affects various forms of energy consumed by households such as gas, electricity, transport fuel and biomass.

It also estimated and presented the income elasticities of these forms of energy to increase policy options. Given the censored nature of the dataset employed for the analysis, two forms of estimation procedures were employed for the analysis in this chapter. First, we employed the Tobit regression technique which enabled us to include zero observations. The second estimation was done with the ordinary least square technique employing the data of only households with non-zero energy expenditure. Meanwhile, bivariate analysis between the dependent variable(s) and all the independent variables was conducted prior to the multivariate analysis in order to gauge the statistical performance of the regressors in standalone situations.

The second empirical chapter provided results and discussions on the main fuel used for cooking by households in Ghana. Two hypotheses were formulated in the chapter. These were: (1) there is a significant positive relationship between the level of education of household head and choice of modern fuels for cooking, and (2) there is a significant positive relationship between being resident in an urban area and the choice of modern fuels for cooking. These hypotheses were investigated to contribute to divergent views on the significance of education and dwelling location in helping households to choose fuels at higher levels of the energy ladder.

Akin to the first empirical chapter, two levels of analysis were undertaken in this chapter, although the multinomial regression technique was employed in both analyses. First, a multinomial regression model with traditional fuel as the reference category was estimated to examine the impact of education and locality on household choice of cooking fuel. After examining the effect of education and locality on choice of cooking fuel at the aggregated level the study moved to the second level of analysis by examining the impact of education and dwelling location on specific forms of fuels used for cooking among households in the country.

Finally, the third empirical chapter probed the crowding-out effects of expenditure on energy by households on the budget shares allocated to other household essentials. Since the dependent variables considered for the analysis in this chapter were the percentage of the residual household expenditure allocated to the other items after provisions are made for energy, which were bounded between zero and one inclusive, and the fact that expenditure on energy was suspected to be endogenous, conditional mixed process framework was employed for the estimations. In all, twelve household items were modeled and the findings revealed that energy consumption crowds out some household goods while crowding in others.

Conclusions

Employing different econometric techniques, this study analysed energy consumption, choice and crowding out effects of energy expenditure. The empirical estimation of the relationship between the amount spent by household, income and other household characteristics showed that income had positive effect on energy consumption. The results of the estimated income elasticities showed that all the fuels analysed are necessities but transport fuel has the highest income elasticity, reflecting that increase in household income will drive demand for transport fuels more than the other types of energy.

Additionally, the stock of energy-using appliances was established to exert a significant positive effect on household energy consumption but variations in electricity consumption is more sensitive to changes in stock of extra ventilation appliances and preservation appliances compared to other types. This outcome implies that extra ventilation and perseveration appliances are important variables to consider by policy makers in order to influence household energy consumption. The study also discovered that spending on public transport reduces household expenditure on personal transport fuels. This indicates that improving the quality of public transport services and encouraging the utilisation could reduce use of private cars.

The results regarding the choice of main fuel for cooking show that dwelling location and education play an important role in the adoption of modern fuels. Other factors such as income, access to information, and access to electricity have positive effects on modern fuel use. Though it was discovered that the use of modern use was common among households in urban areas, the proportion of households using traditional and transitional fuels is still high. This means that more effort is required to achieve a complete shift away from traditional fuels by households in these areas.

It was also found that expenditure on energy crowds out the shares of household budget allocated to foods, alcohol, clothing, communication, housing and furnishing while crowding in health, education, recreation, transportation and miscellaneous. This underscores the need for making energy affordable and accessible to households Ghana. From the findings of this study, it is concluded that all the hypotheses formulated and tested by the study were supported. In the first place, the hypothesis that there is positive relationship between income and energy consumption was confirmed. Also, the hypothesis that dwelling location and education significantly affect the household choice of modern fuel for cooking was supported. The crowding out and crowding in effects of expenditure on energy on the budget shares allocated to other household goods also came out.

Policy Recommendations

Based on the findings from the study, the following recommendations are made:

Good Management and Utilisation of Electrical Appliances

The study found significant positive relationship between the number of electrical appliances owned by households and overall energy consumption as well as electricity demand. Thus, there is the need for the Ministry of Energy and Ministry of Trade to extend the current policy of ensuring that refrigerators, air conditioners and light bulbs equipment imported into the country meet approved energy standards should be extended to all electrical appliances. Moreover, measures should be put in place to outlaw the importation of sub-standard as well as second hand appliances into the country.

Investment into Education

The study found a significant link between the level of education of household head and the adoption of modern fuels, government must make a deliberate effort to invest more in the education sector. This makes the free

SHS policy of the current government a very laudable initiative. More resources and efforts should be directed towards removing all barriers militating against its implementation. Households can also play a complementary role by making sure their members avail themselves for any opportunities under the policy. Moreover, the government through the Ghana Eduation Trust Fund should provide more educational infrastructure to increase access to education at all levels.

Availability of Income Generating Opportunities

The study established a significant positive relationship between income and consumption of LPG, reflecting that improvement in income would enable households to use more LPG. There is the need for the Ministry of Local Government and Rural Development to ensure that income generating opportunities are available to households. This can be done through skills training by the district assemblies and provision of financial assistance by the Microfinance and Small Loan Centre. The skills and the financial resources acquired by households would enable them to start new businesses or expand existing ones to generate more income. This will help them to use clean energy sources to enhance not only their welfare but also minimize the negative environmental effects of biomass consumption.

Protection of Forest Cover

The study established that 56.15 percent of the households included in the sample adopted traditional energy as their main fuel for cooking. Although traditional fuels in the form of firewood, saw dust and agricultural residues would remain important fuels for many households in Ghana for a very long time to come, there is the need for a key policy priority aimed at ensuring the long-term health of the remaining forest resources in the country. There is the need, therefore, for agencies like the Environmental Protection Agency to develop and implement pragmatic forest management programmes that will overcome the problem of deforestation and other environmental change linked to the extraction of traditional fuels.

Furthermore, the Ministry of Environment, Science and Technology and the Ministry of Land and Natural Resources should give attention to the amount of depleted natural resources and rate of rapid deforestation to lessen the environmental impact of overexploitation of these resources. To combat deforestation, it is important to control and restrict the flow of wood fuels into urban areas and to take immediate actions over the illegal harvesting of forest resources. Urgent actions should be taken in this area by designing appropriate patrolling mechanisms and deploying adequately resourced forest guards to secure the forest from radical loss. There is also the need to design and implement or strengthen existing economic instruments, if any, to regulate the supply of fuelwood and charcoal as well as educate the public about the sustainable production and supply of clean biomass fuels.

Expansion of Electricity Coverage

Considering the significant link between electricity consumption and the budget share allocated to education, there is the need to expand connectivity to electricity to cover all households in Ghana. Even though the rural-urban dichotomy with respect to household access to electricity in Ghana has generally reduced in comparison to the period immediately after independence, universal access to electricity for all households in the country can be achieved. In this regard, there is still the need for the Minsirty of Energy and Ministry of Local Governement and Rural Development to develop pragmatic programmes and actions that will help to remove all barriers to connection to electricity as well as to allocate more resources to electricity production and provision. This will not only ensure that there is more electricity for households and other users, but also will create the enabling environment for improved access and reduction in power shortages. There is also need to put in place deliberate measures to improve the share of renewables in the country's energy mix in order to limit the environmental effects of electricity consumption.

Availability and Affordability of LPG

In order to encourage the use and penetration of LPG, there is the need to design and implement incentives to both users and suppliers. In this regard, it is strongly advised that the Ministry of Energy should come out with tangible economic instruments which will reduce the cost of LPG for households as well as make it easier for households to acquire and use LPG equipment. One possible way of reducing the cost of LPG is for the government to decrease taxes on LPG in the country. Again, as a matter of urgency, the distribution of subsidised LPG cylinders should be revamped or replaced with a more vibrant alternative. In addition, the distribution of LPG cylinders should come with an incentive for the beneficiary households to fill the cylinders a maximum of two times every quarter. This should be integrated into the Livelihood Empowerment against Poverty Programme providing a real time alternative to the use of firewood and charcoal as energy sources.

Contributions to Knowledge

This study had three broad objectives. The first objective provided insights on the effect of income and other socio-economic characteristics of the household on the amount spent on energy by the household whereas the second probed the effect of education and dwelling location on the main fuel adopted for cooking. Finally, the study examined the crowding out and crowding in effects of energy consumption on the budget shares dedicated to other household essentials.

While evidence on the determinants of energy choice represents an update of the existing literature, there is no doubt about the originality of the third. Additionally, no study has investigated the determinants of energy expenditure in Ghana, and much more for different energy types as covered in this study. This study provides a new direction by investigating all three issues together at the aggregated and disaggregated level of energy profile. Moreover, the combination of different estimation methods for the analysis permits me to confidently claim that the findings are unique and interesting since no previous study has examined the crowding out effects of energy cost to households. Empirical evidence on the crowding out effects of energy cost on other household goods is timely and important for policy formulations in the country's energy sector to enable us obtain the maximum benefits regarding tariff priming and effective management of the various energy resources available in the country.

Limitations of the Study

The results of the study provide insight into household energy use in Ghana. However, the analysis of energy consumption at the household level was without energy prices. This was because of the absence of reliable information on prices in the dataset. This constrained investigation into the effect that price has on the decision of household to purchase energy. Also, the study relied on the cross-sectional data to examine the determinants of household energy consumption. Given that energy consumption is a dynamic process, studying it using cross-sectional data is an obvious limitation. Nevertheless, these limitations do not affect the outcome of this study.

Areas for Further Studies

The study could not exhaust the issues that can be examined as far as energy use at the household level is concern. Future studies can advance the arguments raised in the study by utilising panel data and including others independent variables not captured by the present study as a result of the absence of information on such variables in the original dataset. Some of these variables are energy prices, duration and intensity of use of appliances as well as energy conservation attitudes of household members.

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APPENDICES

A: Variance Inflation Factor Scores of the Independent Variables in the Energy Consumption Model

Variables	HEB	HEK	HEG	HET	HEE	HETT
Income	1.59	1.59	1.59	1.82	1.94	2.12
Age of head	2.28	2.28	2.28	2.31	2.32	2.35
Household size	2.12	2.12	2.12	2.33	3.00	3.02
Number of aged	1.73	1.73	1.73	1.74	1.76	1.76
Male	1.73	1.73	1.73	1.76	1.77	1.8
Married	2.36	2.36	2.36	2.38	2.38	2.39
Basic education	1.63	1.63	1.63	1.62	1.65	1.69
Secondary education	1.48	1.48	1.48	1.46	1.51	1.53
Tertiary education	1.70	1.70	1.70	1.70	1.87	1.88
Employee	3.75	3.75	3.75	4.27	4.28	4.28
Self-employed	3.62	3.62	3.62	4.14	4.16	4.16
Urban residence	1.52	1.52	1.52	1.39	1.52	1.60
Presence of children	1.77	1.77	1.77	1.78	1.82	1.82
Owner of home	1.35	1.35	1.35	1.34	1.39	1.40
Number of workers				1.51	1.53	1.53
Number of rooms					1.94	1.98
Entertainment appliances					2.48	2.57
Preservation appliances					2.02	2.04
Extra -ventilation appl.					2.24	2.32
Cooking appliances					2.02	2.09
IT appliances					1.80	1.82
Laundry appliances					1.70	1.71
Number of cars				1.14		1.23
Number of motorcycles				1.11		1.14
Public transport expenditure				1.24		1.26
Access to electricity	1.46	1.46	1.46			1.70

B: Estimated Parameters for Transitional and Modern Fuels from the Multinomial Logit Model

Variable	Transitional fuels	Modern fuels
Log (income)	0.617[a]	1.735[a]
	(0.0414)	(0.0629)
Age of head	-0.000436	-0.0167[a]
	(0.00163)	(0.00250)
Household size	-0.0958[a]	-0.299[a]
	(0.0115)	(0.0179)
Male	-0.563[a]	-0.619[a]
	(0.0546)	(0.0740)
Basic education	0.458[a]	1.477[a]
	(0.0606)	(0.136)
Secondary education	0.848[a]	2.425[a]
	(0.109)	(0.166)
Tertiary education	0.896[a]	3.284[a]
	(0.119)	(0.168)
Urban	1.673[a]	1.946[a]
	(0.0500)	(0.0775)
Owner occupied	-0.491[a]	-0.583[a]
	(0.0515)	(0.0722)
Own radio	0.0787	0.290[a]
	(0.0515)	(0.0725)
Own agricland	-0.664[a]	-0.918[a]
	(0.0877)	(0.151)
Own livestock	-0.776[a]	-1.228[a]
	(0.0634)	(0.116)
Connected to electricity	1.050[a]	2.311[a]
	(0.0537)	(0.130)
Coastal zone	0.823[a]	1.928[a]
	(0.0713)	(0.111)
Forest zone	-0.0111	0.815[a]
	(0.0615)	(0.105)
Constant	-6.691[a]	-19.37[a]
	(0.332)	(0.548)
N	16,508	

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

C: Estimated Variance Inflation Factors for the Variables Used In the Choice of Cooking Fuels

Variable	VIF	1/VIF
Log income	1.62	0.6180
Age of household head	1.23	0.8137
Household size	1.55	0.6465
Basic education	1.75	0.5713
Secondary education	1.48	0.6779
Tertiary education	1.60	0.6263
Urban	1.58	0.6344
Owner occupied	1.38	0.7424
Radio	1.11	0.9031
Agricland	1.06	0.9429
Livestock	1.48	0.6758
Connected to electricity	1.47	0.6782
Coastal zone	1.84	0.5439
Forest zone	1.75	0.5679

Mean VIF=1.47

D: Estimated Parameters for Fuelwood, Charcoal, and LPG from the Multinomial Logit Model

Variable	Fuelwood	Charcoal	LPG
Log (income)	-0.241[a]	0.361[a]	1.467[a]
	(0.0728)	(0.0737)	(0.0877)
Age of head	0.0109[a]	0.00733[b]	-0.00826[b]
	(0.00297)	(0.00292)	(0.00343)
Household size	0.567[a]	0.412[a]	0.201[a]
	(0.0414)	(0.0397)	(0.0411)
Male	-1.325[a]	-1.668[a]	-1.712[a]
	(0.131)	(0.125)	(0.133)
Basic education	0.287[a]	0.693[a]	1.696[a]
	(0.105)	(0.106)	(0.159)
Secondary education	-0.522[a]	0.476[a]	2.048[a]
	(0.155)	(0.150)	(0.195)
Tertiary education	-0.826[a]	0.232	2.624[a]
	(0.168)	(0.160)	(0.199)
Urban	-1.804[a]	0.147[c]	0.443[a]
	(0.0878)	(0.0872)	(0.103)
Owner occupied	0.224[a]	-0.298[a]	-0.381[a]
	(0.0798)	(0.0806)	(0.0939)
Own radio	0.194[b]	0.229[a]	0.435[a]
	(0.0872)	(0.0864)	(0.0991)
Own agricland	0.856[a]	0.125	-0.118
	(0.192)	(0.194)	(0.224)
Own livestock	-0.0124	-0.789[a]	-1.271[a]
	(0.0981)	(0.103)	(0.141)
Connected to electricity	-0.511[a]	0.625[a]	1.860[a]
	(0.0876)	(0.0904)	(0.147)
Coastal zone	-0.590[a]	0.342[a]	1.431[a]
	(0.110)	(0.107)	(0.133)
Forest zone	0.323[a]	0.248[b]	1.029[a]
	(0.0984)	(0.0990)	(0.127)
Constant	3.521[a]	-2.728[a]	-15.25[a]
	(0.579)	(0.587)	(0.732)
N	16,508		

Robust standard errors in brackets, [a] p<0.01, [b] p<0.05, [c] p<0.1

E: Marginal Effects of Conditional Mixed Process of Crowding Out Effects of Biomass Energy Expenditure

Variables	Food	Alcohol	Clothing	Health	Educ.	Comm.	Hous.
Biomass Exp.	0.0310[a]	-0.0101[a]	-0.0475[a]	0.0054[a]	0.0460[a]	-0.0135[a]	-0.1040[a]
	(0.0080)	(0.0021)	(0.0025)	(0.0008)	(0.0041)	(0.0019)	(0.0073)
lnM	-0.0192[a]	-0.0461[a]	-0.0092[a]	-0.0052	0.0113[b]	0.0248[a]	-0.0325[a]
	(0.0027)	(0.0059)	(0.0026)	(0.0052)	(0.0044)	(0.0032)	(0.0038)
hhsize	-0.0088[c]	-0.0086[b]	0.0055[a]	-0.0036	0.0829[a]	-0.0181[a]	0.0093[a]
	(0.0047)	(0.0038)	(0.0015)	(0.0049)	(0.0030)	(0.0022)	(0.00276)
Age	0.0008[b]	0.0015[a]	-0.0029[a]	0.0036[a]	0.0027[a]	-0.0037[a]	0.0035[a]
	(0.0004)	(0.0005)	(0.0002)	(0.0005)	(0.0004)	(0.0003)	(0.0003)
Basic educ.	-0.1550[a]	-0.1060[a]	0.0064	0.0588[a]	0.2400[a]	0.1530[a]	-0.0456[a]
	(0.0178)	(0.0187)	(0.0083)	(0.0197)	(0.0159)	(0.0110)	(0.0117)
Secondary educ.	-0.2640[a]	-0.1540[a]	-0.001201	-0.0058	0.3800[a]	0.2250[a]	-0.0282
	(0.0183)	(0.0369)	(0.0132)	(0.0294)	(0.0256)	(0.0166)	(0.0199)
Tertiary educ.	-0.4190[a]	-0.2260[a]	0.0231[c]	0.0092	0.4440[a]	0.2160[a]	0.0033
	(0.0140)	(0.0345)	(0.0132)	(0.0301)	(0.0241)	(0.0154)	(0.0199)
Employee	-0.0393[c]	0.1440[a]	0.0432[a]	-0.1100[a]	-0.0330	0.0646[a]	-0.0694[a]
	(0.0218)	(0.0400)	(0.0163)	(0.0349)	(0.0304)	(0.0184)	(0.0210)
Self-employed	0.0298[c]	0.0598[c]	0.0144	-0.0555[c]	-0.0412	-0.0081	-0.1150[a]
	(0.0174)	(0.0348)	(0.0158)	(0.0311)	(0.0281)	(0.0172)	(0.0187)
Urban	-0.1120[c]	-0.3670[a]	-0.0197[c]	-0.0165	0.2830[a]	0.1180[a]	0.2670[a]
	(0.0604)	(0.0333)	(0.0118)	(0.0529)	(0.0221)	(0.0173)	(0.0179)
Married	0.0007	0.0602[a]	0.0437[a]	-0.0378[b]	-0.0590[a]	-0.0108	-0.0353[a]
	(0.0086)	(0.0169)	(0.0072)	(0.0153)	(0.0137)	(0.0084)	(0.0106)
Log pseudolikelihood	-43875.47	-34258.465	-36934.938	-33737.625	-36757.158	-35410.222	-37924.763
Wald (χ^2)	6738.68[a]	1914.17[a]	1506.95[a]	1518.91[a]	3474.79[a]	3506.45[a]	2632.24[a]
N	16,508	16,508	16,508	16,508	16,508	16,508	16,508

Appendix E, continued

Variables	Furn.	Transp.	Recreation	Hotel	Miscellan.	Biomass exp.
Biomass Exp.	-0.0305[a]	0.0138[a]	0.0029	0.0004[b]	0.0147[a]	
	(0.0016)	(0.0026)	(0.0019)	(0.0002)	(0.0026)	
lnM	-0.0155[a]	0.0259[a]	0.0266[a]	0.1010[b]	0.0408[a]	0.0232
	(0.00197)	(0.00473)	(0.00406)	(0.0440)	(0.00319)	(0.0182)
hhsize	-0.0116[a]	-0.0157[c]	-0.00569[b]	-0.0610[a]	-0.0238[a]	0.0636[a]
	(0.00122)	(0.00903)	(0.00271)	(0.0187)	(0.00216)	(0.0068)
Age	-0.00151[a]	0.000403	0.00221[a]	-0.00601[b]	-0.000583[b]	0.0037[a]
	(0.000188)	(0.000620)	(0.000390)	(0.00302)	(0.000284)	(0.0007)
Basic educ.	-0.000673	0.180[a]	0.0999[a]	0.271[b]	0.137[a]	0.1810[a]
	(0.00656)	(0.0209)	(0.0147)	(0.125)	(0.0102)	(0.0247)
Secondary educ.	0.00284	0.233[a]	0.120[a]	0.251[c]	0.144[a]	0.0770
	(0.0107)	(0.0219)	(0.0217)	(0.146)	(0.0173)	(0.0529)
Tertiary educ.	0.0450[a]	0.177[a]	0.248[a]	0.623[a]	0.265[a]	-0.1207
	(0.0106)	(0.0295)	(0.0208)	(0.136)	(0.0172)	(0.0817)
Employee	-0.000765	0.118[a]	0.000540	-0.0141	0.0537[a]	0.1650[a]
	(0.0130)	(0.0324)	(0.0234)	(0.162)	(0.0185)	(0.0517)
Self-employed	-0.0200	0.0618[b]	0.0105	-0.133	-0.0257	0.1310[a]
	(0.0123)	(0.0282)	(0.0219)	(0.160)	(0.0172)	(0.0388)
Urban	-0.0264[a]	0.214[b]	-0.101[a]	0.0443	0.0677[a]	0.7850[a]
	(0.00961)	(0.0947)	(0.0202)	(0.120)	(0.0160)	(0.0281)
Married	0.00161	-0.0513[a]	0.0389[a]	-0.0388	-0.0246[a]	0.0441
	(0.0056)	(0.0159)	(0.0121)	(0.0986)	(0.0091)	(0.0280)
Log pseudolikelihood	-36129.616	-35196.718	-35005.314	-32822.909	-35966.221	
Wald (χ^2)	1676.34[a]	2386.47[a]	1529.48[a]	1311.82[a]	2563.54[a]	
N	16,508	16,508	16,508	16,508	16,508	

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

F: Marginal effects of conditional mixed process of crowding out effects of electricity expenditure

Variables	Food	Alcohol	Clothing	Health	Educ.	Comm.	Hous.
Electricity Exp.	-0.0905[a]	-0.0132[a]	-0.0294[a]	-0.0042[a]	0.0615[a]	0.0013	-0.1040[a]
	(0.0081)	(0.0024)	(0.0030)	(0.0011)	(0.0045)	(0.0022)	(0.0071)
lnM	-0.0204[a]	-0.0458[a]	-0.00921[a]	-0.00614	0.0113[b]	0.0250[a]	-0.0322[a]
	(0.0026)	(0.0058)	(0.0026)	(0.0051)	(0.0044)	(0.0032)	(0.0038)
hhsize	-0.0138[a]	-0.0091[a]	0.0049[a]	-0.0074[b]	0.0828[a]	-0.0171[a]	0.0098[a]
	(0.0014)	(0.0030)	(0.0013)	(0.0030)	(0.0025)	(0.0018)	(0.0025)
Age	0.0005[b]	0.0014[a]	-0.0030[a]	0.0034[a]	0.0027[a]	-0.0037[a]	0.0035[a]
	(0.0002)	(0.0005)	(0.0002)	(0.0004)	(0.0004)	(0.0003)	(0.0003)
Basic educ.	-0.1690[a]	-0.1120[a]	0.0048	0.0491[a]	0.2400[a]	0.1550[a]	-0.0443[a]
	(0.0078)	(0.0176)	(0.0080)	(0.0164)	(0.0153)	(0.0103)	(0.0111)
Secondary educ.	-0.2680[a]	-0.1570[a]	-0.0016	-0.0096	0.3810[a]	0.2260[a]	-0.0277
	(0.0136)	(0.0370)	(0.0132)	(0.0287)	(0.0256)	(0.0165)	(0.0198)
Tertiary educ.	-0.4070[a]	-0.2270[a]	0.0244[c]	0.0174	0.4460[a]	0.2140[a]	0.0025
	(0.0136)	(0.0349)	(0.0133)	(0.0303)	(0.0243)	(0.0156)	(0.0200)
Employee	-0.0526[a]	0.1380[a]	0.0414[b]	-0.1210[a]	-0.0335	0.0670[a]	-0.0684[a]
	(0.0151)	(0.0397)	(0.0161)	(0.0322)	(0.0302)	(0.0179)	(0.0207)
Self-employed	0.0188	0.0608[c]	0.0130	-0.0646[b]	-0.0415	-0.0060	-0.1150[a]
	(0.0139)	(0.0346)	(0.0157)	(0.0295)	(0.0280)	(0.0168)	(0.0185)
Urban	-0.1680[a]	-0.3870[a]	-0.0265[a]	-0.0619[a]	0.2820[a]	0.1280[a]	0.2740[a]
	(0.0074)	(0.0186)	(0.0070)	(0.0150)	(0.0133)	(0.0083)	(0.0098)
Married	-0.0019	0.0592[a]	0.0432[a]	-0.0412[a]	-0.0591[a]	-0.0104	-0.0354[a]
	(0.0070)	(0.0168)	(0.0072)	(0.0146)	(0.0137)	(0.0083)	(0.0105)
Log pseudolikelihood	-59456.703	-49843.146	-52516.919	-49319.68	-52337.919	-50991.786	-53504.96
Wald (χ^2)	4912.22[a]	1514.39[a]	1124.43[a]	973.70[a]	2932.29[a]	2963.58[a]	2150.64[a]
N	16,508	16,508	16,508	16,508	16,508	16,508	16,508

Appendix F, continued

Variables	Furn.	Transp.	Recreation	Hotel	Miscellan.	Electricity exp.
Electricity Exp.	-0.0163[a]	0.0173[a]	0.0130[a]	0.0005[a]	0.0150[a]	
	(0.0018)	(0.0028)	(0.0021)	(0.0002)	(0.0027)	
lnM	-0.0155[a]	0.0255[a]	0.0268[a]	0.1040[b]	0.0406[a]	0.1250[a]
	(0.0020)	(0.0047)	(0.0040)	(0.0449)	(0.0032)	(0.0367)
hhsize	-0.0117[a]	-0.0254[a]	-0.0051[b]	-0.0575[a]	-0.0246[a]	0.0120
	(0.0010)	(0.0024)	(0.0023)	(0.0196)	(0.0019)	(0.0154)
Age	-0.0015[a]	-0.0000	0.0022[a]	-0.0058[c]	-0.0006[b]	0.0075[a]
	(0.000183)	(0.0003)	(0.0004)	(0.0030)	(0.0003)	(0.0021)
Basic educ.	-0.0009	0.1660[a]	0.1010[a]	0.2850[b]	0.1350[a]	0.4410[a]
	(0.0063)	(0.0143)	(0.0141)	(0.1250)	(0.0098)	(0.0574)
Secondary educ.	0.0029	0.2440[a]	0.1190[a]	0.2530[c]	0.1440[a]	0.9200[a]
	(0.0107)	(0.0226)	(0.0216)	(0.1470)	(0.0172)	(0.1790)
Tertiary educ.	0.0456[a]	0.2190[a]	0.2450[a]	0.6130[a]	0.2680[a]	0.9200[a]
	(0.0107)	(0.0257)	(0.0209)	(0.1380)	(0.0173)	(0.2220)
Employee	-0.0010	0.0975[a]	0.0013	-0.0009	0.0513[a]	0.0330
	(0.0129)	(0.0256)	(0.0230)	(0.1630)	(0.0183)	(0.1760)
Self-employed	-0.0202[c]	0.0416[c]	0.0115	-0.1240	-0.0278	-0.1530
	(0.0122)	(0.0238)	(0.0217)	(0.1610)	(0.0171)	(0.155)
Urban	-0.0277[a]	0.1240[a]	-0.0957[a]	0.1010	0.0569[a]	1.2440[a]
	(0.0055)	(0.0139)	(0.0112)	(0.1010)	(0.0094)	(0.0856)
Married	0.0016	-0.0565[a]	0.0390[a]	-0.0369	-0.0251[a]	0.1490[c]
	(0.0056)	(0.0117)	(0.0121)	(0.1000)	(0.0090)	(0.0790)
Log pseudolikelihood	-51711.23	-50777.266	-50587.431	-48404.536	-51548.011	
Wald (χ^2)	1294.77[a]	1735.68[a]	1172.51[a]	954.04[a]	224.91[a]	
N	16,508	16,508	16,508	16,508	16,508	

Robust standard errors in brackets, [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$