

KWAME NKRUMAH UNIVERSITY AND SCIENCE TECHNOLOGY
COLLEGE OF HUMANITIES AND SOCIAL SCIENCES
FACULTY OF SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS



AN ECONOMIC ASSESSMENT OF ENERGY CONSUMPTION ON HOUSEHOLD
WELFARE IN GHANA

BY

EDNA ADJEI-BRUCE

(PG1081017)

A DISSERTATION SUBMITTED TO THE KWAME NKRUMAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN ECONOMICS

JUNE, 2019

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgement is made in the thesis.

KNUST

.....
Name and ID of Student Signature Date

Certified by:

.....
Name of Supervisor Signature Date

Certified by:

.....
Name of Head of Signature Date
Department

ABSTRACT

The study assesses the complexities that exist between energy consumption by households and their welfare levels using data from four waves of the Ghana living standard surveys – with datasets spanning over 35,000 households across rural and urban areas. Energy consumption was measured using the multi-tier matrix framework approach.

Repeated cross-section techniques employing multiple regression models were used in assessing the impact of the different determinant factors on welfare. The study finds that fuel choice, income, poverty status are key drivers of improving a household's welfare level. Welfare was an increasing function of higher levels of access as well as income, poverty and other socio-economic determinants identified the study.

Energy consumption rose with income, with changes in income exhibiting unitary elasticity on welfare levels. There is strong evidence that female-led households exhibit a significantly higher welfare than male-headed households. Also, the influence of location on energy use was also assessed with results showing that as households move away from the use of biomass, locational effects of energy on welfare becomes identical for both urban and rural localities.

The existing welfare gap between households using electricity and those using biomass has widened over time. This is as a result of the cumulative productivity effects of electrification to households over time. The general policy recommendation for the study aims at promoting a transitional shift from traditional energy forms to more efficient and modern energy forms.

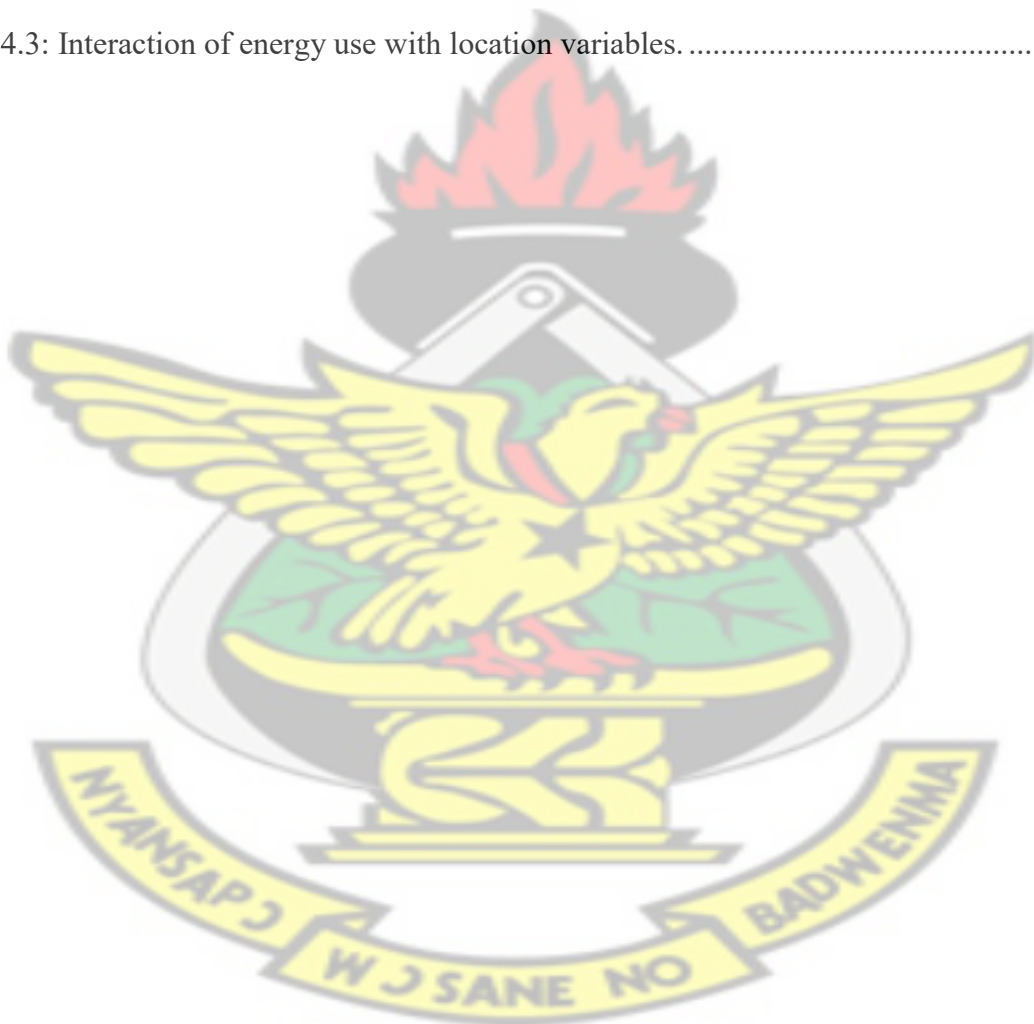
TABLE OF CONTENTS

DECLARATION	I
ABSTRACT	II
LIST OF TABLES.....	V
LIST OF FIGURES.....	VI
CHAPTER ONE.....	1
INTRODUCTION	1
1.1 BACKGROUND OF THE STUDY	1
1.2 PROBLEM STATEMENT.....	4
1.3 OBJECTIVES OF THE STUDY	5
1.4 RESEARCH QUESTIONS.....	6
1.5 RELEVANCE OF THE STUDY.....	6
1.7 ORGANIZATION OF THE STUDY	6
CHAPTER TWO.....	8
LITERATURE REVIEW	8
2.1 DEFINITION OF CONCEPTS	8
2.1.1 <i>Welfare</i>	8
2.1.2 <i>Household energy consumption</i>	8
2.2 THEORETICAL REVIEW	9
2.2.1 <i>Theories of welfare</i>	9
2.2.2 <i>Theories of energy choices</i>	10
2.2.3 <i>Theories of energy use</i>	11
2.2.4 <i>Theories of consumer behaviour</i>	12
2.3 EMPIRICAL REVIEW	13
2.3.1 <i>Energy consumption, the macro-economy and household welfare.</i>	13
2.3.2 <i>Welfare, energy poverty and access to modern energy</i>	15

2.3.3 Household energy consumption impacts in Ghana	16
2.3.4 Summary of findings	17
CHAPTER THREE.....	18
METHODOLOGY	18
3.1 MODEL SPECIFICATION	18
3.2 VARIABLE DEFINITIONS AND MEASUREMENT	20
3.3 ESTIMATION STRATEGY.....	22
3.3.1 Categorizing Energy use using the multi-tier framework.....	22
3.3.2 Running pooled cross-sections	23
3.3.3 Running individual multiple regressions for each survey.	24
3.4 DATA.....	24
CHAPTER FOUR	27
RESULTS AND DISCUSSION	27
4.1 INTRODUCTION.....	27
4.2 RELATIONSHIP BETWEEN WELFARE AND HOUSEHOLD SOCIO-ECONOMIC DETERMINANTS.....	32
4.3 RELATIONSHIP BETWEEN WELFARE AND ENERGY CONSUMPTION.....	34
4.4 LOCATION AND ITS IMPACT ON WELFARE AND ENERGY CONSUMPTION.....	35
CHAPTER FIVE	37
SUMMARY OF RESULTS AND POLICY IMPLICATIONS	37
5.1 INTRODUCTION.....	37
5.2 SUMMARY OF FINDINGS.....	37
5.3 RECOMMENDATIONS.....	39
5.4 SUGGESTED AREAS FOR FURTHER RESEARCH.....	39
5.5 CONCLUSION	40
REFERENCES	41
APPENDIX	52

LIST OF TABLES

Table 3.1: A priori expectations of welfare determinant variables.....	20
Table 3.2: Describing the endogenous and exogenous variables of the model.	21
Table 3.3: Multi-tier matrix for household energy consumption.....	22
Table 4.1: Summary statistics of Household Socio-Economic characteristics.....	27
Table 4.2: Estimated results from multivariate regression model.	30
Table 4.3: Interaction of energy use with location variables.	35



LIST OF FIGURES

Figure 4.1: Change in levels of poverty over four surveys.....29

KNUST



CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The consumption of energy for both productive and household uses has led to the rapid economic development and vast increases in living standards over the past century (Johansson, 2012). In every modern society, economic growth and development are driven by economic processes and transactions in the market economy that involve the production and consumption of goods and services (Solow, 1956). These processes arise as individuals seek to increase and maximize their utility, thereby improving their welfare (Moore, 2007). Fundamental to the undertaking economic process are inputs; with energy inputs, mainly derived from fossil source, playing a critical and enabling role for other production and consumption processes to be undertaking.

The relationship between energy consumption and economic growth has been studied extensively in literature. These studies reveal that there are strong correlations between the level of energy consumed and the level of development in the economy (Cabraal, Barnes and Agarwal, 2005; Pollin, Heintz and Garrett-Peltier, 2009; Nadimi, 2017). Due to the fact that energy plays a vital role in the economy, the level of access and utilization of energy by economic agents determines to a large extent the impact energy consumption can have on the wellbeing of individuals and households. To better understand and capture the welfare effects of energy consumption on individuals in a wider population, this study borrows from neoclassical unitary model assumptions that posit that a household serves as a consumer unit and the household maximises a single set of objectives for all its members (Sen, 1983; Lloyd

et al., 1993; Posel, 1997; Mattila-wiro, 1999). Hence, this study focuses on household energy consumption.

According to Danlami, Islam and Applanaidu (2015), household energy consumption refers to the amount of energy resources that are being used by households on their appliances. Household energy consumption depends to a great degree on the household's energy choices for various uses mainly for cooking, heating, and lighting. Studies on energy choices mainly use the "Energy Ladder" hypothesis to describe household energy decision-making processes, and transitions from across fuel types (Mirza and Kemp, 2009; Swarupk and Rao, 2017).

The energy ladder model states that in response to higher incomes, households would switch to more modern, cleaner and energy-efficient fuels such as LPG and electricity. Some empirical studies on the energy ladder model have found that income change alone does not influence transitions in fuel use due to substitution effects, fuel stacking and other socio-economic factors play a role. However, there is a general consensus on the positive relationship between fuel transition and increase in the economic well-being of households variables (Mekonnen et al., 2009; Hanna and Oliva, 2015; Swarupk and Rao, 2017).

Studies have shown that an increase in access to modern energy reduces energy poverty, has profound impacts on improving the economic opportunities available to households to rise out of absolute poverty (Karimu, Mensah and Adu, 2016). Moreover, access to electricity and LPG, especially in rural areas, has been found to positively impact on health, education and income of households (Bonan, Pareglio and Tavoni, 2014).

Evidence from literature reveals increasing energy consumption over time in developing nations especially in sub-Saharan Africa sub-region For instance, there was a dramatic rise in energy consumption levels from 16.95 million tonne of oil equivalent (Mtoe) in 1971 to 312.95

Mtoe's in 1991 and further to 511.88 Mtoe in 2011, outpacing average rates for developed countries (Nondo, Kahsai and Schaeffer, 2010; Kwakwa and Adu, 2016). These rises are attributable to an increase in economic activities due to trade liberalization and economic reform policies adopted by these countries in the 1980's and 1990's. The economic growth witnessed has further driven increased adoption of modern energy services in sub-Saharan countries, although, energy poverty levels and use of traditional forms of fuel remain relatively high (Pradeep, Alois and Lugmayr, 2016; World Bank, 2016; International Energy Agency, 2017).

In Ghanaian, access to modern energy has steadily risen over time with electricity access increasing 15% in 1989 to 82.5% in 2016 and LPG use rising from 5% in the early 1990's to around 23.1% as at 2015. However, there is still a heavy reliance on biomass (mainly charcoal and fuelwood) as a source of heating and cooking (Karimu, Mensah and Adu, 2016; Kumi, 2017). There is a clear indication that there is a gradual transitioning in fuel use and energy consumption in Ghana. However, empirical evidence suggests that the dynamics of this transition is far more complex than the simplistic predictions of the energy ladder hypothesis (Karimu, Mensah and Adu, 2016). In spite of varying levels of success of policy efforts by Government targeting access to modern energy services, there, however, remain significant challenges in energy supply and household energy choices and fuel stacking that are not clearly understood (Asumadu-Sarkodie and Owusu, 2016; Karimu, Mensah and Adu, 2016).

Also, a key concern as to whether shifts in fuels consumption has a significant impact on the economy, the economic well-being of individuals and the livelihoods of households remains a puzzle. This study, therefore, seeks to investigate how energy consumption influences household levels of welfare in order to provide insight on how access to modern energy services increases wellbeing and facilitates national development.

1.2 Problem Statement

The relationship between energy consumption, economic growth and development has received some considerable attention for reasons including renewed interest in climate change and carbon (CO₂) dioxide emissions and the need for 'clean' energy; increased availability of data and improvement in econometric techniques for analyzing time-series relationships; and the impact of energy price volatilities on economies over the past 3 decades (Guttormsen, 2007; Mahfoudh and Ben Amar, 2015). Literature has established that energy plays a major role in economic growth and to some extent, drives development and economic wellbeing of individuals in countries. However, measuring the effect of energy on the standard of living and welfare are complex because income and economic growth alone cannot explain welfare effects. Especially with households, various non-economic factors such as education, access to healthcare, location, household size etc. affect the welfare of households (Ganga, 2015). This necessitates that the various determinants of household welfare be assessed in order to fully grasp how energy enhances the lives and activities of individuals and households.

Despite the vast literature on energy consumption and economic growth, however, in Ghana, the research on the nexus between energy consumption and economic growth is not expansive. Most studies have explored the nexus between; energy and climate change and carbon emissions; electrification and its socioeconomic impacts; and renewable energy development. (Kwakwa, 2012; Quartey, 2014; Alabi, Ackah and Lartey, 2017; Kumi, 2017).

However, limited literature exists on how energy consumption affects welfare levels, the differences in welfare effects of energy consumption between urban and rural populations and the levels of energy poverty in Ghana (Karimu, Mensah and Adu, 2016; Alabi, Ackah and Lartey, 2017; Kumi, 2017; Adu, Dramani and Oteng-Abayie, 2018). For instance, Adu, Dramani and Oteng-Abayie (2018) examined the causal impact of rural electrification on

household income and welfare finding that electricity has a significant impact on welfare. Aside electricity, other forms of energy were not taken into consideration. Similarly, Mensah, Huchet-Bourdon and Latruffe (2014) and Akpandjar and Kitchens (2017) used electricity as the only source in evaluating the direct effect of energy access on welfare households in Ghana. However, energy studies show that different forms of energy consumed by a household has different effects on their socio-economic wellbeing (Mirza and Kemp, 2009; Bonan, Pareglio and Tavoni, 2014; Hanna and Oliva, 2015).

Therefore, the study seeks to address two main gaps in knowledge identified in energy consumption in Ghana:

- 1) Limited knowledge on the effects of energy consumption on economic well-being and human welfare in Ghana.
- 2) Limited knowledge on the comparative welfare effects of energy consumption in rural and urban areas.

1.3 Objectives of the study

The main objective of the study is to investigate the relationship between energy consumption by households and their welfare levels. Specifically, the study aims at:

1. To determine the extent to which socio-economic characteristics of a household influence the welfare of households.
2. To evaluate the relationship between household energy consumption and welfare of households
3. To compare the welfare implications of energy consumption between rural and urban households;

1.4 Research questions

1. How does the socio-economic characteristics of household influence the welfare of a household?
2. What is the relationship between household energy consumption parameters and welfare of households?
3. What are the differences in welfare implications of energy consumption between rural and urban households?

1.5 Relevance of the study

Findings of the study would provide relevant insights into how energy consumption can be used to impact household welfare levels based on relationships and interactions between various factors that influence household energy choices.

Also, the study would provide knowledge on how rural versus urban household welfare levels respond to energy consumption levels in order to give clear insight on how policies can be structured to boost welfare levels in various regions.

The study provides a significant contribution to existing energy literature by giving insight into the implications of household energy consumption on the standard of living and wellbeing of energy consumers in a developing economy.

1.7 Organization of the study

The study to consist of five chapters with the first chapter providing the background and rationale and objectives of the study. The second chapter reviews findings in literature to identify key concepts and theories underpinning the study as well as debates, empirics and key findings related to the study.

The third chapter describes the methodology that would be used to achieve the research objectives and answer the research questions. The third chapter also outlines the key model for assessing the nexus between energy consumption and household welfare. Data is then modelled and analysed with results and findings presented in chapter four. The concluding part of the study is outlined in the fifth chapter which presents a summary of findings and recommendations for future studies for household energy consumption.

KNUST



CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of concepts

Key working definitions and concepts used in measuring variables in this study are highlighted in this section.

2.1.1 Welfare

The study adopts the definition of welfare given by the Ghana Statistical Service which states that welfare is the “Ghana cedi value of the standard of living measure” (that is the total consumption expenditure per adult equivalent in the constant prices of Accra at a specified time (Ghana Statistical Service, 2014b).

The working definition of welfare for this study is the unit value of standard of living measure for each household at a given point in time as given by consumption expenditure on food and non-food items for an adult.

Food expenditure is given by the universally accepted Recommended Dietary Allowance (10th edition) defining the minimum food basket of 2900 calories per adult equivalent per day (National Research Council et al., 1989). Non-food expenditure is defined by the current non-food basket of goods and service used for national CPI computation.

2.1.2 Household energy consumption

For this study, we adopt the definition of Danlami, Islam and Applanaidu (2015) who define household energy consumption as the amount of energy resources that are used by households

on home appliances. It should be noted that this does not include energy used by households in transportation or direct commercial use.

2.2 Theoretical review

To analyze the nexus between energy consumption and welfare, theoretical literature that relate directly to energy use, welfare and household consumption behaviour are identified. Hypothesis on these concepts is key to understanding the theoretical relationship between household welfare and energy use. The key selected theories are grouped into four categories. That is theories of welfare and development, theories of energy choices, theories of energy use, theories of consumer behaviour.

2.2.1 Theories of welfare

These theories set the theoretical background for welfare comparisons with energy use. A number of theoretical frameworks have been proposed to describe welfare and poverty (Haider, 1982; Ravallion, 2008). The study looks at the 'Relative Deprivation' hypothesis and the 'Life Cycle' hypothesis (LCHO) as the theoretical basis for understanding welfare.

The relative deprivation theorem developed by Peter Townsend (1979) argues that an assessment of individual or group welfare should be done by comparing the individual's lack of certain goods relative to that of the society which they belong to. It is useful in describing inequalities amongst population groups such as differences between rural and urban welfare. This implies that a household's inability to access certain types of energy services should be measured against whether other households use that energy form.

2.2.2 Theories of energy choices

The theories of energy choice provide a basis to understand why and how household choose the fuel types they consume. The theories take a look at the 'Energy ladder' hypothesis and 'Fuel Stacking' models of households. The fuel type chosen by a given household has energy poverty and socioeconomic wellbeing implications.

The energy ladder hypothesis is an energy transition theory that postulates that as household income and socioeconomic status increases, households would substitute traditional fuels such as fuelwood with more modern fuels such as electricity and LPG (Hosier and Dowd, 1987; Leach, 1992). This implies that household incomes and fuel prices have a very significant positive effect on household energy consumption as it enables households to 'move up the ladder' to more modern fuels.

However, proponents of fuel stacking take a contrasting view of the energy ladder theory and rather propose the energy stacking hypothesis which proposes that households consume a portfolio of fuel types at different points on the energy ladder. That is, irrespective of income levels, households still consume a combination of fuels at the same time (Van Der Kroon, Brouwer and Van Beukering, 2013).

A body of growing research has confirmed that the energy ladder hypothesis provides a necessary but not sufficient explanation of household energy use (Mekonnen et al., 2009; Hanna and Oliva, 2015; Choumert, Motel and Le Roux, 2017). Hence, income levels alone cannot be assumed to be the only influencing variable for energy consumption in households. This implies the study would have to look into non-income variables in attempting to explain the welfare effects of energy use.

2.2.3 Theories of energy use

The two main theories of energy consumption are the Putty – Putty and Putty-Clay models of energy use (Atkeson and Kehoe, 1999). These two models look at the short-run and long-run elasticities between energy consumption, capital and energy prices. This is based on the observations made by Berndt and Wood (1975) that in time series data, energy use moves much slower to energy price changes. However, in cross-sectional data, energy use is highly responsive to changes in international energy prices. The two models help us theorize whether energy prices are important in studying household welfare changes over time (Pindyck, 1979).

The Putty -Putty theoretical model of energy use was formulated by Pindyck and Rotemberg (1983) postulates that energy use and capital assets are highly complementary and capital is subject to adjustment costs. They studied the effect of dynamic changes in energy prices on a firm's production function (with factors excluding technology) subject to constraints of its costs function. The findings reveal that energy-cost share (energy price elasticity) over time yield short-run elasticities. The implication of the Putty-Putty model is that in the long run, energy price shocks have little effect on energy use and consumption. This can be extrapolated to imply that household energy use is not affected by energy price changes over time.

The Putty-Clay hypothesis, on the other hand, states that energy and capital are ex-ante substitutes. Struckmeyer (1987) applied the Putty-Clay hypothesis for energy. The model is derived from vintage economic growth model know as putty-clay technology developed by Johansen (1959) (Gilchrist and Williams, 2000).

In Putty-Clay models the firm's production function focuses on its choice of technology rather than the factors of production. The results showed that higher energy prices lead to substitution of energy with more capital intensive techniques (Struckmeyer, 1987). Hence, the models

suggest that in the long run, energy price shocks lead to higher investment in energy efficient capital. This implies that as energy price rises, more energy efficient appliances would be used by households over time.

Comparing the two models, we find that the Putty-Clay and Putty-Putty have similar implications on how energy use is affected by energy prices over time. The main difference between the two models is their cross-sectional implications rather than their time series implications (Atkeson and Kehoe, 1999). This implies that we can safely ignore energy price variables in our time-series model as it has little effect on energy consumption levels in the long run, hence, there would be no misspecification errors.

2.2.4 Theories of consumer behaviour

Understanding the theories of household demand and utility maximization behaviour is central to understanding and prioritizing behavioural factors that may significantly affect energy demand. Behavioural economics enables modelling of household behaviours with regards to energy demand, expenditure and investments (Pollitt and Shaorshadze, 2011). Several existing theories attempt to explain consumer behaviour but the study takes a look at two relevant ones for understanding energy consumption amongst households.

First, the study looks at the neoclassical theory of rational choice which is based on the notion that individuals choose the most beneficial course of action when presented with different choices. This implies that the household would use fuels available to them because those fuels present the most convenient and rational option (Martiskäinen, 2007). This means that households would maximize their utilities by choosing the best available fuel type

Secondly, the study takes a look at the theory of household behaviour developed by Lancaster (1975). It suggests that a household can be considered as a single entity that aggregates

individual preferences when it has a well-behaved household decision function. By well-behaved, it assumes decisions are dictatorial and household members don't take different budget decisions.

For indivisible economic goods like energy, household members are known to take cooperative rational decisions to enable them to maximize household benefits (Woolley, 1990). These decisions are usually taking by the household head, hence, understanding the characteristics of the household head provides a good way to measure household decision variables (Davis, 1976).

2.3 Empirical review

The relationship between energy consumption and its effect on economic growth, poverty and human welfare has been subject to empirical inquiry since the late 1970's. The concept of welfare and energy use is captured mainly through concepts of energy poverty, energy choice, and climate change mitigation. To understand how energy use affects social and economic variables, literature has used vast methodologies and approaches with largely elusive empirical results.

2.3.1 Energy consumption, the macro-economy and household welfare.

For instance, a pioneering study by Kraft and Kraft (1978) to determine "the relationship between energy and GNP" using test for unidirectional causality found that there is a strong relationship between energy and GNP with causality moving from GNP to energy alone and not the other way round. As a result, they found that improving economic activity and output creates more energy use. They challenged the logic that energy conservation policy (restricting energy use without comprising economic growth) options are unacceptable, as energy has very little causal effect on economic output.

Findings by Abosedra and Baghestani (1989) also support the economic growth-energy unidirectional causality relationship and energy conservation, however, these results were contested by Akarca and Veach Long (1979). They argued that the oil price shocks from the oil-crisis affected the sample of Kraft and Kraft's study. They found a unidirectional causality rather flowing from energy to economic growth by using dynamic time series methods.

More recent studies on the issue have found that causality between energy and national output is ambiguous and to a large extent based on a country's economic context and organization of services in an economy. Studies by Lee (2006) in eleven (11) highly industrialized countries using a new granger non-causality test approach developed by Toda and Yamamoto (1995) shows different results in different countries. The results of the study showed a neutral relationship between energy and GDP in the UK, Germany and Sweden. Bi-directional causality was found only in the United States with the remaining 5 countries showing unidirectional causality with reverse relationships in 3 countries. Different methodologies have been used in literature to establish the energy-economic growth nexus with mixed results indicating different causality directions, however, they all established a long-run relationship between the energy consumption and economic growth (Masih and Masih, 1996; Cheng and Lai, 1997; Glasure and Lee, 1998).

The national output in a country affects per-capita incomes and this has trickle-down effects on household incomes especially in low-middle income countries (Diacon and Maha, 2015). Household incomes imply higher energy consumption and household energy use has been shown to enable a vast number of welfare-enhancing services that satisfy a wide range of consumption needs from necessities and basics to recreational and luxury consumption (Jamasp and Meier, 2010).

The link between energy consumption and income is presented by Jamasb and Meier (2010) in their paper, “Household energy expenditure and income groups. Evidence from Great Britain”. The study suggested that there are significant differences among household income levels in particular in their responses to income and energy price changes. Households with lower incomes were seen to be more sensitive to energy price changes than households that earned higher incomes. The study concluded that although the causality of the main energy determinants is in the same direction for all income groups, the magnitude of the impact differs for each of the income groups. The findings implied that it would be useful to analyze the impacts of energy and income on less tangible characteristics of households such as welfare. Results from similar studies support the above findings and even went further to show that poorer households suffer more welfare losses as they are more responsive to energy price shocks (Gassmann, Coady and Klytchnikova, 2005; Zhang, 2015).

Bridge, Adhikari and Fontenla, (2016) also studied the effect of electricity on income by using Three-Stage Least Squares (3SLS) and the Two-Stage Probit Least Squares (2SPLS) models. Their study found bidirectional causality between electricity and income levels. However, they concluded that connection to electricity increases household consumption, hence welfare significantly.

2.3.2 Welfare, energy poverty and access to modern energy

Universal access to modern energy services has become topical in the pursuit of the global agenda to enable sustainable development of countries and individuals. Bonan, Pareglio and Tavoni (2014) reviewed the impact of access to modern energy services and found that modern energy such as electricity enables “reallocation of household time (especially by women) from energy provision” to activities that generate higher incomes and healthcare. They found a strong correlation between development indicators and welfare but they did not establish the

direction of causality. A key result of their study was that due to selectivity biases in infrastructure provision, the probability of being connected to modern services is significantly lower in rural areas.

Cabraal, Barnes and Agarwal (2005) investigated the impact of energy use on household development in rural areas in India and found that applications of modern forms of energy improved human capital by facilitating improvements in health and educational development.

However, the causal link between household welfare and impacts of rural electrification is quite difficult to establish and three main challenges in studying the welfare impacts of modern energy access are identified by van de Walle et al. (2013). The challenges are 1) the potential for electricity acquisition by households to be correlated with omitted variables or jointly determined with outcomes, (2) non-random placement of energy infrastructure is likely to lead to endogeneity and biases in regression, (3) external spillover effects of electrification in communities on individual households who are not connected themselves. The result of their finding, also confirmed by Burlando (2014), found significant spillover effects of electricity to households who are not connected.

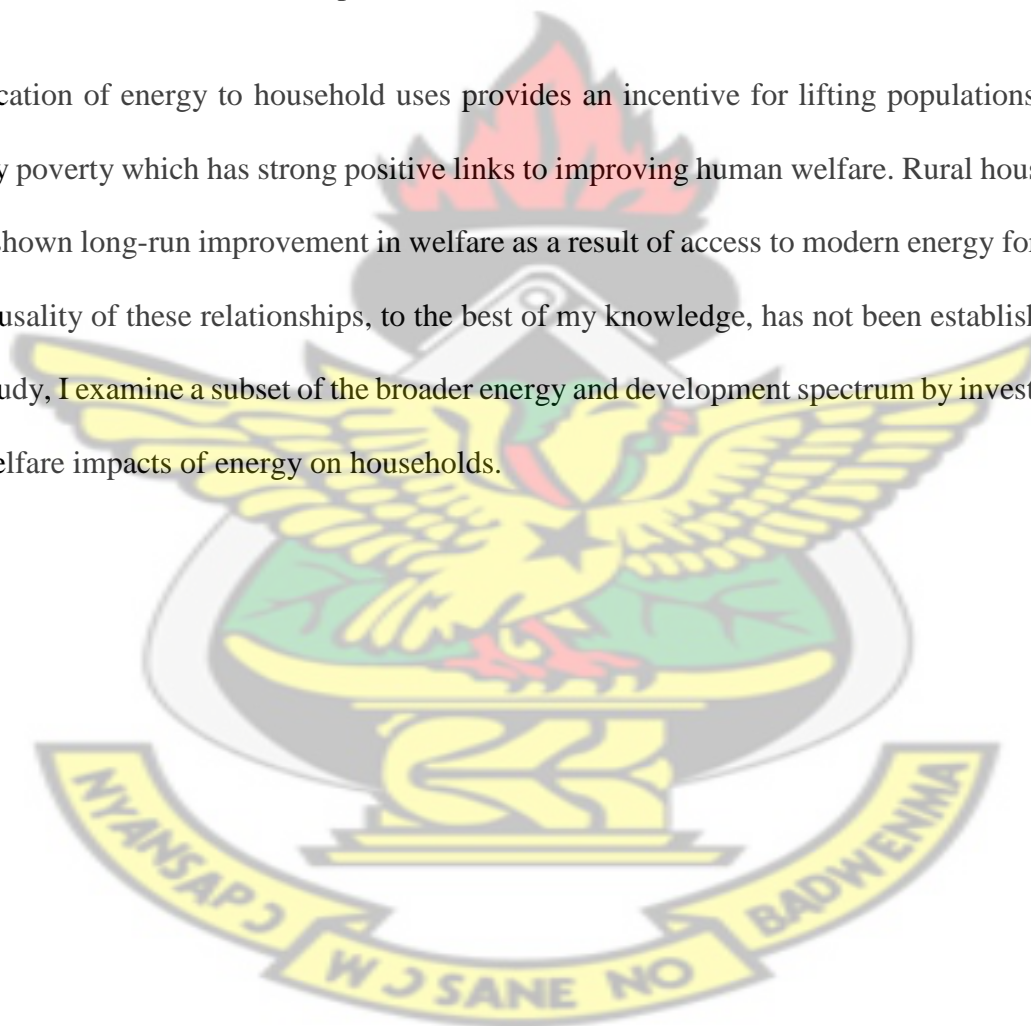
2.3.3 Household energy consumption impacts in Ghana

A limited number of studies in Ghana have looked at the nexus between energy, electricity and economic growth (Kwakwa, 2012; Karimu, Mensah and Adu, 2016; Adu, Dramani and Oteng-Abayie, 2018). A review of empirical literature on energy and development in Ghana done by Kwakwa (2014) showed that studies on energy-growth nexus have yielded inconclusive results due to the difference in data use, estimation techniques and time periods. However, at the micro-level (households), studies have shown a positive correlation between electricity use and improvement in welfare indicators of households (Dramani, Tandoh and Tewari, 2012).

2.3.4 Summary of findings

Strong links between energy consumption, economic development and household welfare are established in literature. However, the direction of causality between energy consumption, economic growth and household welfare has been hotly debated as results from different economies and time periods suggest different directions of causality. This presents a need to further investigate the relationship and causality between energy consumption and economic growth as well as the welfare implications of these results.

Application of energy to household uses provides an incentive for lifting populations out of energy poverty which has strong positive links to improving human welfare. Rural households have shown long-run improvement in welfare as a result of access to modern energy forms but the causality of these relationships, to the best of my knowledge, has not been established. In this study, I examine a subset of the broader energy and development spectrum by investigating the welfare impacts of energy on households.



CHAPTER THREE

METHODOLOGY

3.1 Model Specification

The household is modelled as a single unit taking unitary decisions, hence it aggregates utilities of all household members and maximizes these welfare functions as a single agent. The household welfare function is a real value function given by:

$$y: \mathcal{H}(E, Z) \rightarrow \mathbb{R} \quad (1)$$

Where y is the household welfare level, $\varepsilon \in E$ is a vector of all energy services consumed by households chosen from the consumption set \mathbb{R} . $z \in Z$ represents a vector of household characteristics and $h \in \mathcal{H}$ is a vector of households. Energy and household variables used in this study are discussed in section 3.2.

The model assumes an ordinal level comparability (OLC) with strict monotonic transformations, τ where the transformations depend on z^h but not on h itself. OLC is chosen to enable comparison across all households irrespective of differences in characteristics and income levels (Lind, 2000; Fleurbaey and Hammond, 2004). The model further assumes that each household variable has an identical weight placed on it over time, for instance, the poverty status variable in the 1992 wave is the same as that in the 2013 wave. To run regressions, a specific linear function for welfare is defined for each household i is at time period t as:

$$Y_{it} = \beta E_{it} + \delta_j Z_{it} + \xi_{it} \quad (2)$$

Where ξ_{it} is the error term, representing all unobserved factors affecting the model and it follows a normal distribution $\xi_{it} | x \sim N(0,1)$. The parameters to be estimated are β , the energy

coefficient and δ the coefficient for each household characteristic j . Making equation (2) more explicit to measure the second objective, the energy component parameters are defined categorically as:

$$E_{it} = E_{\text{no energy}} + E_{\text{wood}} + E_{\text{charcoal}} + E_{\text{kerosene}} + E_{\text{lpg}} \quad (3a)$$

Therefore, a more verbose of the equation (2) which highlights clearly the second objective is:

$$Y_{it} = \alpha_1 E_{\text{wood}} + \alpha_2 E_{\text{charcoal}} + \alpha_3 E_{\text{kerosene}} + \alpha_4 E_{\text{lpg}} + \delta_j Z_{it} + \xi_{it} \quad (3b)$$

Where $E_{\text{electricity}}$ has been dropped as the base variable and α_i is the coefficient for each energy parameter.

To measure the third objective which compares welfare in rural and urban areas through energy use, equation (2) is modified by interacting a dummy variable for the location with the energy use parameters with * indicates location has been dropped from the term. This model therefore becomes:

$$Y_{it} = \beta E_{it} + \delta_j Z_{it}^* + \psi_0 \text{urban}_{it} * E_{it} + \xi_{it} \quad (4)$$

The a-priori expectations for this model are based on deterministic assumptions derived from the literature on consumer behaviour and energy-growth-development thesis in both short and long-term (Lind, 2000; Dacuycuy and Dacuycuy, 2018). Welfare trend is expected to increase over time and energy consumption has a positive and quantitatively significant effect on the dependent variable, welfare. Employment and income are also expected to have positive bearings on welfare. A large household size implies higher energy consumption, however, its distributive effects on welfare depend on how adequacy of consumption. The expected magnitude and sign for each independent variables in the model are shown in table 3.1.

Table 3.1: A priori expectations of welfare determinant variables.

Explanatory variable	Sign	Significance (at 95% CI)
Energy use	$\beta > 0$	$p \leq 0.05$
Household size	$\delta_{\text{hsize}} \geq 0$	$p > 0.05$
Log Income	$\delta_{\text{inc}} > 0$	$p \leq 0.05$
Poverty Status (poor)	$\delta_{\text{poor}} < 0$	$p \leq 0.05$
Location (urban)	$\delta_{\text{loc}} > 0$	$p \leq 0.05$
Employment (unemployed)	$\delta_{\text{edu}} < 0$	$p \leq 0.05$
Age of HH	$\delta_{\text{age}} < 0$	$p > 0.05$
Gender of HH	$\delta_{\text{gender}} \geq 0$	$p \leq 0.05$

Source: Authors construct, 2019.

3.2 Variable Definitions and Measurement

The explained variable for the study is the log-transformed version of welfare; defined in the second chapter of this study. The explanatory variables for the study are total energy consumed, income, poverty status, and location. It also includes the following household characteristics: household size, sex of household head (HH), the age of household head and education attainment of the household head. Table 3.2 gives a description of the explanatory variables to be used in the study.

Energy use is measured using the ordered tiers of the multi-tier framework discussed in the previous chapter. The tiers represent the level of energy use in ascending order with electricity representing the highest level of use.

Income variable represents the total household incomes earned comprising income from employment, remittances, farm and non-farm earnings, rent and other sources of income. Income levels are log-transformed to account for skewness in income across the population.

Employment shows whether the household head is actively employed or not. Poverty status indicates the level of poverty of the household based on poverty line measures by the Ghana Statistical service and is measured as poor or non-poor.

Table 3.2: Describing the endogenous and exogenous variables of the model.

Variable	Variable type
Explained variable:	
Log Welfare	Continuous
Explanatory variables:	
Energy use	Categorical (0=no energy; 1=fuelwood use; 2= charcoal use; 3=kerosene use; 4=LPG use; 5=electricity use)
H/H economic characteristics	
Log Income	Continuous
Poverty Status (poor)	Binary (0=not poor; 1=poor 2=very poor)
Spatial	
Location	Binary (0=rural; 1=urban)
H/H social characteristics	
Household size	Continuous
Employment of HH	Categorical (0=unemployed; 1=employed; 2= inactive (retired/other);
Age of HH	Continuous
Gender of HH	Binary (0=female; 1=male)

Source: Authors construct from GLSS data, 2019.

3.3 Estimation Strategy

First, we define the energy-use variable categorically using the ranking system of the multi-tier energy framework. The GLSS does not give one specific energy use variable but rather gives variables for lighting cooking, transportation, etc. For the purposes of this study, the multi-tier framework is used to categories energy use.

Welfare and household variables regressed using repeated cross-sectional techniques by first estimating a regression model for the pooled cross-section that combines the four waves of surveys. Then followed by running multiple regressions for each individual dataset.

3.3.1 Categorizing *Energy use* using the multi-tier framework

The Multi-tier approach uses a matrix to rank energy forms into five hierarchical tiers (categories) and eight attributes of energy. Tiers are defined based on a combination of attributes that reflect the performance of energy supply. More modern energy fuel is assumed to imply higher consumption levels. The framework measures both household access to electricity supply and cooking fuels. Table 3.2 shows the multi-tier framework adapted for this study.

Table 3.3: Multi-tier matrix for household energy consumption

Attributes of Energy Supply	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Availability	No access	Access to fuelwood	Access to charcoal	Access to Kerosene	Access to LPG	Access to Electricity
Quality	-	very low	low	medium	good	very good
Convenience	Not convenient			Convenient		

Source: Adapted from ESMAP (2014); Bhatia and Angelou (2015); Groh, Pachauri and Narasimha (2016)

The attributes chosen for energy supply to households are based on literature and available data are (1) availability of the fuel form to the household, (2) convenience of fuel for use in household activities (3) quality of fuel based on combustion attributes. Other attributes such as (4) reliability of supply of fuel form to households, (5) capacity of fuel, (6) health and safety, (7) affordability and (8) legality are not included in this study due to lack of data (ESMAP, 2014; Energy Commission, 2018).

The framework allows for flexibility of measurement based on data available. It also captures multi-dimensionality of energy access and also provides a basis for measuring levels of consumption which is a step further from the existing binary measures of access (which are generally insufficient to measure inequalities).

3.3.2 Running pooled cross-sections

The various waves of the survey is pooled together (using repeated cross-sections) and run while controlling for a survey year (GLSS 3) to identify the fixed effects.

In repeated cross-sections, structural change across time (which reflects differences in multiple regression models for each wave of the survey datasets used) can manifest which would affect the results of the findings. To test for the structural break, we use the Chow test. The chow statistic is an F-test given by:

$$F = \left(\frac{SSR_{pooled} - SSR_{ur}}{SSR_{ur}} \right) \left(\frac{n - T - Tk}{(T - 1)k} \right)$$

Where, $(T - 1)k$ and $n - T - Tk$ represent the degrees of freedom $T =$ Total time periods/number of survey waves, $k =$ no of explanatory variables, $n =$ total number observations for all waves of the survey. $SSR_{pooled} =$ Sum of squared residuals for the pooled model while SSR_{ur} represents that for the independent models given:

$$SSR_{ur} = SSR_{GLSS3} + SSR_{GLSS4} + SSR_{GLSS5} + SSR_{GLSS6}$$

Before the Chow test is undertaken, however, a heteroskedastic-robust test must to done to ensure the variance of the terms does not vary across time. The White test and the Breush-Pagan test are conducted to rule out heteroscedasticity in the data.

3.3.3 Running individual multiple regressions for each survey.

Multiple regression using ordinary least squares (OLS) is done independently for each survey wave and compared to see trends and changes between variables.

Based on the results of the Chow test for the pooled panel regression, the individual model is chosen for presentation of the results if the pooled model exhibits significant structural breaks.

A p-value of 0.05 or less is considered to indicate statistical significance and the explanatory power of the model is deduced from the R^2 .

3.4 Data

The study utilized data from the last 4 rounds of the Ghana Living Standards Survey (GLSS) which is a nationally representative survey that provides detailed and crosscutting information on Ghanaian households with each round providing snapshots of living conditions at each stage of the development process. The rounds of GLSS used — GLSS 3: 1991/92, GLSS 4:1998/99, GLSS 5:2005/6, GLSS 6: 2012/13 — are chosen because they cover a standardized spectrum

of living standards, welfare and energy use indicators that would enable homogeneity in comparing variables of the different rounds. Populations living in private households in Ghana represent the defined universe for the GLSS surveys. Based on the stratified and proportional allocation of the population in the 10 administrative regions of Ghana, census Enumeration Areas (EAs) are derived to serve as the primary sampling units (PSU's) while households within the individual EAs constituted the secondary sampling units (SSU's). Each PSU is further divided into urban and rural based on the locality of residence.

GLSS 3 used a multi-stage sample design which covered 407 EA's. The sample is self-weighting (except for special cases of expenditure data. In total, 4552 households (out of 4565) were successful interviewed indicating a 99.72% success rate. GLSS 4 used a two-stage sampling design with the first stage selecting 300 EAs using systematic sampling with probability proportional to size method (PPS) – with the size measure defined as the 1984 number of households in the EA. The second stage, 20 households were systematically chosen for each EA giving a total of 6000 households with a response of rate of 99.7% (5998 households). Unlike the GLSS 3, the GLSS 4 was weighted using 1984 population size factors to get the true contribution of each EA (Ghana Statistical Service, 2013b, 2013a).

GLSS 5 adopted a two-stage stratified sampling method with a total of 580 EA's selected in the first stage with 15 households per EA chosen in the second stage bringing the total number of sample households to 8700. The response rate was 99.5% (i.e. 8687 successful interviews). The GLSS 5 did not use a self-weighting sample design in order to prevent disproportionate samples. The GLSS 6 used identical sampling methodology to obtain 1200 EA's and 18,000 SSU's with a response rate of 93.18% (16772 households). The GLSS 6 provides additional cross-sectional information on fuel expenditure which cannot be found in earlier rounds (Ghana Statistical Service, 2008, 2014a).

The GLSS provides information on the type of energy form used by households for lighting and cooking purpose. Amount paid for electricity is also provided but not price of other fuels. However, the exact quantities of fuel used by households is not provided by the GLSS, hence the analysis in this study uses access to specific energy forms as proxies for energy consumption.

KNUST



CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The empirical results for this study are presented in this chapter. The first section gives a brief description of the data used in studying the relationship between welfare and energy consumption. The summary statistic is shown in table 4.1. The test for model fit and other data related test is also discussed in the first chapter. Afterwards, each subsequent section discusses the results for each specific objective, derived from running the econometric model.

Table 4.1: Summary statistics of Household Socio-Economic characteristics.

	GLSS 6		GLSS 5		GLSS 4		GLSS 3	
	Mean/ percent	Std. Dev.	Mean/ percent	Std. Dev.	Mean/ percent	Std. Dev.	Mean/ percent	Std. Dev.
Num. Obs.	16547		8372		5793		4434	
Energy_use	3.50	1.90	2.92	1.95	2.66	1.92	2.27	1.80
no energy	0.58		1.09		0		0	
fuelwood	33.24		44.69		53.63		62.8	
charcoal	4.53		7.71		6.42		6.91	
kerosene	0.09		0.13		0.18		0.44	
LPG	0.49		0.38		0.1		0.13	
electricity	61.07		46		39.66		29.71	
Log Income	6.37	0.36	6.19	0.36	6.11	0.32	6.04	0.31
Poverty Status	1.66	0.65	1.60	0.75	1.47	0.82	1.33	0.87
Very poor	9.82		16.04		21.07		26.66	
Poor	14.11		8.05		10.55		13.20	
Non poor	76.07		75.92		68.37		60.14	
Employment Status	1.05	0.32	0.94	0.23	0.95	0.21	0.96	0.20
unemployed	2.93		5.78		4.52		4	
employed	89.46		94.22		95.48		96	
Location	1.56	0.50	1.58	0.49	1.63	0.48	4.48	2.83
Urban	44.39		41.65		36.66		34.89	

Rural	55.61		58.35		63.34		65.11	
Age	45.84	15.9	45.34	15.64	45.83	15.37	44.28	15.33
HH_size	4.26	2.78	4.20	2.83	4.28	2.56	1.65	0.48
Gender	1.28	0.45	1.28	0.45	1.34	0.47	1.32	0.47
Male	71.8		72.13		66.42		67.85	
Female	28.2		27.87		33.58		32.15	

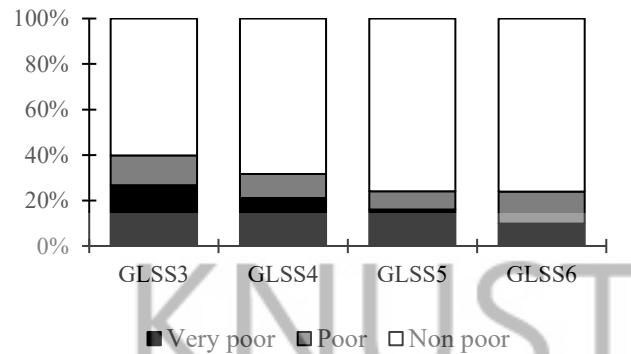
Source: Authors construct from GLSS data, 2019.

Table 4.1 standard deviations and means of variables used in the model. For each categorical variable, the percentage frequency of each category of the variable is shown. This is by no means exhaustive (see appendix B for a more detailed descriptive statistic).

The data shows that over the four waves of the survey, mean energy consumption has increased with households showing a marked shift from traditional energy choices towards more modern energy forms such as electricity and LPG. This increase corresponds to mean increases in income levels and poverty levels over the period. This co-movement of income and energy use, shown in figure 4.1, is in line with the energy ladder hypothesis.

Another key factor variable that changed significantly is poverty status with the ratio of *very poor* households starting at 26.6 in 1992 and falling to 9.8% of surveyed households in 2013, indicating a vast improvement in fortunes of households over the period. This can be attributed to various policy interventions pre and post the HIPC era (Osei-Fosu, 2008). These changes provide a lot of impetus for energy use transitions and improvements in household welfare.

Figure 4.1: Change in levels of poverty over four surveys.



Source: Authors construct from GLSS data, 2019.

Noteworthy variable changes include the shift in populations from rural to urban areas with a 27.2% increase in urban residents from the first survey in 1992 to the last wave in 2013. Several reasons account for these changes but this study would focus on the effects of these changes on energy consumption and welfare levels. Increase in urbanisation increases the probability of a household accessing improved energy forms, thereby increasing energy consumption levels of the household.

Household characteristics such as age and gender of the household head and household size did not vary much across the different survey waves. The survey also indicates that unemployment levels of household heads fell steadily over the period.

The values deviations around the mean for the observed variables showed a fair spread in the sample's distribution with approximately 7 of the 8 variables lying within 3 standard deviations of their mean values.

Table 4.2: Estimated results from multivariate regression model.

Dep.Var: Log Welfare	GLSS 3	Sig.	GLSS 4	Sig.	GLSS 5	Sig.	GLSS 6	Sig.
(Intercept)	5.72 (0.040)	0.00	5.83 (0.037)	0.00	6.63 (0.034)	0.00	6.69 (0.022)	0
Energy_use								
Fuelwood	-0.037 (0.008)	0.000	-0.085 (0.006)	0.000	-0.075 (0.006)	0	-0.075 (0.004)	0
Charcoal	-0.008 (0.011)	0.454	-0.050 (0.011)	0.000	-0.074 (0.009)	0	-0.075 (0.008)	0
Kerosene	-0.081 (0.054)	0.130	-0.014 (0.046)	0.767	0.090 (0.077)	0.24	-0.058 (0.049)	0.24
LPG	0.057 (0.048)	0.237	-0.051 (0.090)	0.569	-0.025 (0.038)	0.508	0.106 (0.027)	0
Poverty Status								
Very Poor	-0.434 (0.006)	0.000	-0.458 (0.006)	0.000	-0.475 (0.006)	0	-0.590 (0.005)	0
Poor	-0.263 (0.000)	0.000	-0.273 (0.005)	0.000	-0.293 (0.006)	0	-0.356 (0.003)	0
Emp (Unemployed)	0.064 (0.018)	0.000	0.033 (0.015)	0.026	0.034 (0.011)	0.003	0.020 (0.009)	0.03
Log Income	0.099 (0.006)	0.000	0.100 (0.006)	0.000	0.136 (0.005)	0	0.092 (0.004)	0
Location (Urban)	0.061 (0.007)	0.000	0.045 (0.006)	0.000	0.093 (0.006)	0	0.084 (0.004)	0
Age	0.000 (0.000)	0.494	-0.001 (0.000)	0.000	0.000 (0.000)	0.001	-0.001 (0.000)	0
HH_size	-0.027 (0.001)	0.000	-0.033 (0.001)	0.000	-0.036 (0.001)	0	-0.032 (0.001)	0
Gender (Male)	-0.015 (0.005)	0.006	-0.011 (0.005)	0.029	-0.019 (0.005)	0	-0.007 (0.004)	0.07
<hr/>								
Num. Obs.	4434		5793		8372		16547	
SSR	115.96		172.63		320.58		709.93	
R-squared	0.72		0.71		0.70		0.67	
Adj. R-squared	0.72		0.71		0.70		0.67	
Heteroskedasticity test								
Breusch Pagan		0.676		0.157		0.001		0.98
White		0.893		0.081		0.029		0.04

Source: Authors construct from GLSS data, 2019.

All variables are measured at a 5% significance level with variables in parenthesis indicating standard errors for its corresponding coefficients. Sig. indicates the p-value of the coefficients of each variable. SSR signifies the sum of squared residuals of the model

The model explains an estimated 70% of the variability in the data for GLSS3-5 and 67% of the variability in the various waves of the data for GLSS 6. This indicates that the model is a good fit for the observations of the survey datasets.

Putting all the surveys together as a longitudinal set (see appendix c for detailed tables), the R-squared was 26.8 percent implying a low model fit. This is a key issue exhibited in repeated cross-sectional data (pooled cross-sections), hence, the model is run for each survey wave and analysed concurrently.

Limited evidence of heteroscedasticity was found in the fitted values of the model with the white test results similar to that of the Breush-Pagan test. As the sample got larger, evidence of heteroskedacity was found in GLSS 5 for both test types. However, GLSS 6 samples exhibit homoskedasticity in the Breush Pagan test but the White test fairly weak evidence of heteroskedacity. Both statistics reveals that p-values are quite large for the GLSS 3 and 4 survey waves (that is $p > 0.05$) implying that we fail to reject the null hypothesis of constant variance, hence the model exhibits a strong evidence of homoskedasticity.

The chow test (see appendix A for computations) reveals that there structural breaks in the different waves of the survey data as the null hypothesis that the model from the pooled regression result is independent and identical. This structural break is possibly explained by the exponential growth in GDP since the turn of the millennium. Hence, caution is exercised in the explaining results as we drop the pooled regression model in favour of the individual regression for each wave of the data.

4.2 Relationship between welfare and household socio-economic determinants.

The results from the intercept-only model show that setting all other factors to zero, the Log (welfare) levels would be 5.72, 5.83, 6.63 and 6.69 in the GLSS 3 to GLSS 6 surveys respectively. The mean welfare levels have been increasing over time and this is attributable to increasing per-capita incomes across the country.

Household size has a statistically significant negative effect on welfare with identical p values across the four waves of the survey (that is $p = 0.01$). Holding other factors constant, an increase in household size by one member leads to an average decrease in welfare 3.2% over the periods of the surveys. This is in tandem with findings by Yalcintas and Kaya (2017) which indicates that large household size lessens the energy consumption per capita leading to reduced welfare benefits for households.

Variation in age household has zero to little effect on a household's welfare in the model, all other things being equal. This can be attributed to the fact that a large proportion of household heads are in the working age and are actively employed.

Households headed by males have proportional lower welfare as compared to female-headed households. The result shows that males headed household were significantly worse off by 15% ($p = 0.01$), 11% ($p = 0.03$), 19% ($p = 0.01$) in 1992, 1998 and 2008. However, this gap reduced in the last round of survey with male-headed households having 7% comparably lower welfare, although, this figure is not statistically significant ($p = 0.07$). This finding is in line with results from Karimu, Mensah and Adu (2016) which shows that a household headed by a male decreases the probability of the household adopting more modern energy forms. Attributions to the preferences and opportunity cost, especially for cooking fuels indicate that female-headed households respond more to the adoption of modern energy forms. Also, the

closing gap in is attributed to households acquiring more modern and efficient cooking and lighting appliances over time increases the odds of the household to improve upon its energy consumption and welfare levels. This finding is consistent with results from Link, Axinn and Ghimire (2012) who find evidence showing households appliances increase over time and there is a positive relationship between electrical appliances owned by a household and energy consumption.

Income, as expected, has a statistically significant effect on welfare levels with identical p values for all survey periods ($p = 0.01$). The results show a 10% increase in income leads to proportional levels of welfare increase across all waves with an average welfare increase of 10.7% (9.9%, 10%, 13.6%, and 9.2% for GLSS3-6 respectively). This implies that holding all factors constant, the point elasticity of income to welfare is almost unitary in line with studies that show that income elasticity is unitary with welfare factors such as energy demand, and household expenditures (King and Weimer, no date; Pinzón, 2016). This is attributable to the fact that energy consumption is a derived demand which is mainly driven by the spending capacity of the household and hence, the lifestyle and welfare of the household.

Similarly, poverty levels decreased over time with significant results ($p < 0.01$). However, the welfare gap between poor and non-poor households widened further over time. It can be seen that the differences in welfare between non-poor households and very poor households started out 43% but rose steadily to 59% by the end of the fourth wave of the survey.

The average non-poor household has 48.93% and 29.64% better welfare than very poor and poor households respectively. These wide variations in welfare levels is possibly explained by income inequalities amongst different regions and households in the country with the Gini coefficient of the country for the country risen from 37 to 41 from 1992 to 2013 (Cooke, Hague and McKay, 2016).

4.3 Relationship between welfare and energy consumption.

The results show that holding all other factors, the effect of energy consumption on welfare is dependent on the form of energy service used by a household. The welfare effects for modern energy services that is LPG and electricity are positive while intermediate and traditional energy forms such as kerosene, wood and charcoal have negative welfare effects.

Electricity provides a statistically significant ($p < 0.01$) higher welfare in comparison to fuelwood over the four survey waves with an average difference of 6.7%. This welfare gap between households using electricity and those using fuelwood has widened over time from 3.7% in 1992 to 7.5% in 2013. This is attributable to cumulative benefits of electrification to households over time.

Similarly, the consumption of charcoal by households shows a welfare gap which is 3.3% less than that of households who consume electricity. Just like the case of fuelwood, the gap has widened over time from 0.8% ($p > 0.05$) in 1992 to 7.5% ($p < 0.01$) in 2013. It should be noted that the negative welfare difference for using charcoal is not statistically significant for the 1992 survey only. This is attributable to a higher use of fuelwood in 1992/3 due to the fact that a larger proportion of survey households lived in rural areas (UNDP, 2014). Use of kerosene and other intermediate energy forms is shown to be statistically insignificant over the survey period.

LPG use is only statistically significant, with a p -value < 0.01 , in the 2013 wave of the GLSS survey. This is possibly explained by the recent development of LPG in many areas of the country which has boosted adoption levels. These results show that welfare effects are 10.6% higher than that of households using electricity only.

4.4 Location and its impact on welfare and energy consumption.

Results for the residential location of a household show that urban households enjoy more welfare benefit than rural households and this evidence is statistically significant ($p = 0.01$). Urban households on average have 7% better welfare than rural households. This gap has been increasing over time with the last wave of surveys (GLSS 6) 2.3% wider than the first wave (GLSS3) of the study.

To fully understand the implications of welfare on energy consumption and welfare, location and energy consumption variables are interacted for each wave of the survey. The base variable for *energy use* is electricity and the base variable for *location* is rural. The results are presented in table 4.3.

Table 4.3: Interaction of energy use with location variables.

	GLSS 3	Sig.	GLSS 4	Sig.	GLSS 5	Sig.	GLSS 6	Sig.
fuelwood*urban	-0.110 (0.018)	0.000	-0.354 (0.018)	0.000	-0.262 (0.018)	0.000	-0.295 (0.015)	0.000
charcoal*urban	-0.024 (0.024)	0.309	-0.171 (0.023)	0.000	-0.161 (0.017)	0.000	-0.192 (0.016)	0.000
Kerosene*urban	-0.131 (0.126)	0.296	0.021 (0.117)	0.858	0.063 (0.154)	0.682	-0.257 (0.156)	0.099
LPG*urban	0.259 (0.198)	0.192	-0.156 (0.203)	0.443	-0.065 (0.062)	0.294	0.066 (0.048)	0.173

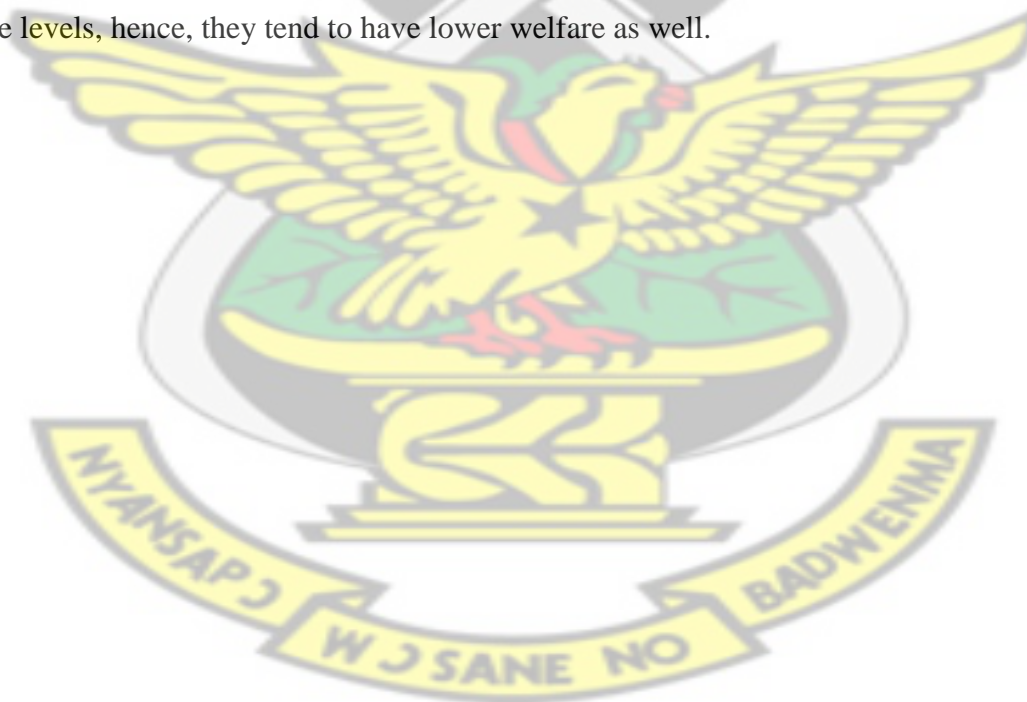
Source: Authors construct from GLSS data, 2019.

The results of the interaction show that the use of fuelwood has a negative effect on the household as compared to electricity. This relationship is statistically significant with $p < 0.1$ for all waves of the survey data. On average, households in urban areas using electricity have 25.53% higher welfare than households in rural areas using fuelwood.

Similarly, the use of charcoal by households in rural areas lead to an average of 13.7% less welfare as compared to their urban counterparts using electricity. This is consistent with various energy poverty and household energy use theories that suggest that the use of traditional biomass means of energy such as fuelwood for light or cooking leads to significantly lower welfare (Pachauri and Spreng, 2003; Kabahuma, 2010; Barnes, Khandker and Samad, 2011).

KNUST

However, as households in rural areas transition to intermediate and modern energy forms, such as kerosene and LPG, the results show that the welfare effect of location becomes statistically insignificant with very large p-values > 0.05 . This signifies that the effect of location is more pronounced with the consumption of biomass. This can be attributable to the low opportunity cost of collecting biomass fuels in poorer households who usually have lower income levels, hence, they tend to have lower welfare as well.



CHAPTER FIVE

SUMMARY OF RESULTS AND POLICY IMPLICATIONS

5.1 Introduction

In this study, the links between household energy consumption and welfare have been analysed and key summary of the results and their policy implications are presented in this chapter. Policy recommendations and areas for further research are also suggested in the chapter.

5.2 Summary of findings.

To better understand the household welfare impacts of energy use, the study looked at how changing household energy consumption choices and other relevant socio-economic factors influenced household energy use over time. The approach used was to distinguish into various levels of energy consumption based on their access to understand the different energy mix patterns that influence the welfare of households.

The study applied repeated cross-sections and panel techniques to four waves of living standards data to analyse its three key objectives – 1) determining how energy consumption and other socio-economic determinants play out in influencing household welfare 2) measuring if different levels of energy access impact household welfare and 3) finding out the influence of the location of a household on welfare through energy consumption.

From the results, the following inferences were derived. Firstly, household welfare has a positive relationship with income, energy use and other household determinants such as employment and poverty status. Change in income exhibits unitary elasticity on household welfare but more elastic for very poor households. Income and energy use co-moves, rising in a linear fashion, however, other determinant factors such as location of the household

influences this change. This finding is consistent with energy ladder theories. A change in demographic factors such as age of household head has negligible impact on welfare but the gender of the household head has significant effects on welfare and energy use, with female-led households adopting more modern energy technologies as well as having more welfare as compared to male headed households; although this difference has reduced over time, it is still quite significant.

Secondly, the study results inferred that using a modern fuel choice such as electricity and LPG has a monotonically increasingly positive effect on household welfare. This welfare gap between households using electricity and those using fuelwood has widened over time. This is as a result of the cumulative productivity effects of electrification to households over time.

Households using LPG for cooking actually exhibit higher welfare than households using other fuel forms mainly because they also have higher mean incomes. These results are consistent across the four survey periods. However, increasing household incomes and shifts in economic structure has seen an increase in the use of more efficient energy forms for lighting and cooking purposes with less reliance on fuelwood and kerosene over time.

Finally, geographical location has a significant effect on household energy consumption and welfare. Urban households as expected have higher welfare levels, however, the study found that despite the falling proportion of the rural population, the welfare gap between for urban households and rural households widening over time.

However, as households in rural areas transition to intermediate, such as kerosene, the results show that the welfare effect of location becomes statistically insignificant. This shows that location results in more pronounced welfare effects when biomass such as charcoal or firewood

is being used by households. Hence, the more efficient the energy form used in a household, the higher the welfare of the household.

5.3 Recommendations

From the energy policy perspective, one main policy implication from the study results shows that in rural communities, the use of poorly-efficient energy forms influences welfare significantly, hence more incentives such as subsidies to enable adoption of appropriate technology such as improved cook stoves is needed. This would enable households to transition from traditional fuels to more efficient energy forms.

Secondly, energy policy should have promote gender inclusion as the results show that females drive the adoption of modern energy forms more than their male counterparts.

5.4 Suggested areas for further research

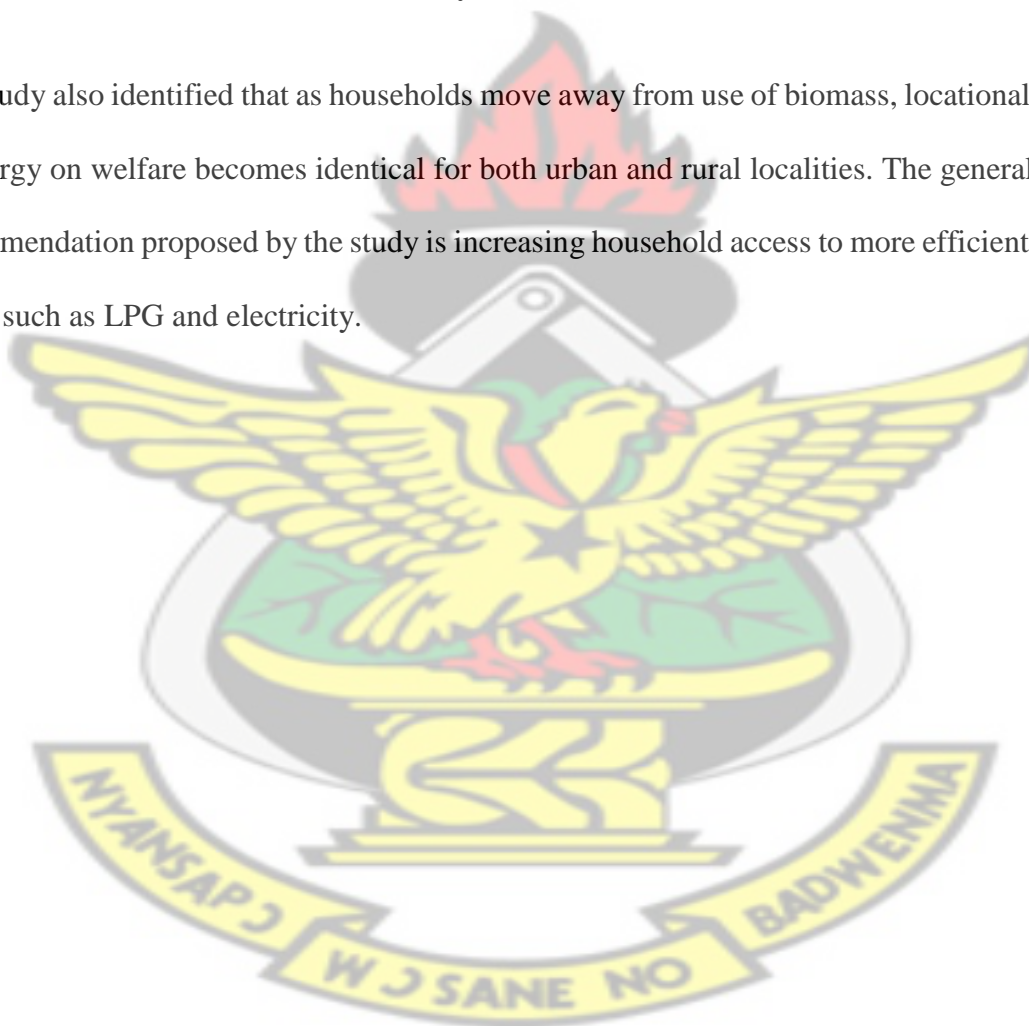
Based on the literature review and findings for the study, I find two areas for future work that would be beneficial to energy policy. First, a study on how adoption and use of 'green' energy, for example, solar technologies, impacts household energy consumption in developing economies to enable policymakers to determine the 'green' technology's direct welfare effect on welfare.

Secondly, research on the effect of energy prices and household appliance efficiencies in Ghana would enable understanding of the stages in the energy demand decision-making process of a household and also help policymakers estimate and forecast end-use energy demand.

5.5 Conclusion

The study assessed the relationship between household welfare levels and energy consumption in Ghana. Energy consumption is measured by ranking household access to energy forms based on the multi-tier framework for measuring energy use. The study found that energy use and income variables co-moved over the survey period from 1992 – 2013. Welfare was an increasing function of higher levels of access as well as income, poverty and other socio-economic determinants identified the study.

The study also identified that as households move away from use of biomass, locational effects of energy on welfare becomes identical for both urban and rural localities. The general policy recommendation proposed by the study is increasing household access to more efficient energy forms such as LPG and electricity.



REFERENCES

- Aboosedra, S. and Baghestani, H. (1989) 'New evidence on the causal relationship between United States energy consumption and gross national product', *The Journal of Energy and Development*. JSTOR, pp. 285–292.
- Adu, G., Dramani, J. and Oteng-Abayie, E. (2018) 'Powering the powerless: Economic impact of rural electrification in Ghana', *IGC*, (February). Available at: <https://www.theigc.org/project/powering-powerless-economic-impact-rural-electrification-ghana/>.
- Akarca, A. and Veach Long, T. (1979) 'Energy and employment: A time series analysis of the causal relationship', *Resources and Energy*, 2, pp. 151–162.
- Akpandjar, G. and Kitchens, C. (2017) 'From Darkness to Light: The Effect of Electrification in Ghana, 2000–2010', *Economic Development and Cultural Change*, 66(1), pp. 31–54. Available at: <https://econpapers.repec.org/RePEc:ucp:ecdecc:doi:10.1086/693707>.
- Alabi, O., Ackah, I. and Lartey, A. (2017) 'Re-visiting the renewable energy–economic growth nexus: Empirical evidence from African OPEC countries', *International Journal of Energy Sector Management*, 11(3), pp. 387–403. doi: 10.1108/IJESM-07-2016-0002.
- Asumadu-Sarkodie, S. and Owusu, P. A. (2016) 'A review of Ghana's energy sector national energy statistics and policy framework', *Cogent Engineering*. Cogent, 3(1). doi: 10.1080/23311916.2016.1155274.
- Atkeson, A. and Kehoe, P. J. (1999) *Models of Energy Use : Putty-Putty versus Putty-Clay Models of Energy Use : Putty-Putty Versus Putty-Clay*.
- Barnes, D. F., Khandker, S. R. and Samad, H. A. (2011) 'Energy poverty in rural Bangladesh', *Energy Policy*. Elsevier, 39(2), pp. 894–904. doi: 10.1016/j.enpol.2010.11.014.

Berndt, E. R. and Wood, D. O. (1975) 'Technology, Prices, and the Derived Demand for Energy', *The Review of Economics and Statistics*, 57(3), p. 259. doi: 10.2307/1923910.

Bhatia, M. and Angelou, N. (2015) *Beyond Connections: Energy Access Redefined*, *The World Bank*. Available at: [http://www.worldbank.org/content/dam/Worldbank/Topics/Energy and Extract/Beyond_Connections_Energy_Access_Redefined_Exec_ESMAP_2015.pdf](http://www.worldbank.org/content/dam/Worldbank/Topics/Energy%20and%20Extract/Beyond_Connections_Energy_Access_Redefined_Exec_ESMAP_2015.pdf) (Accessed: 2 August 2018).

Bonan, J., Pareglio, S. and Tavoni, M. (2014) *Access to Modern Energy: A Review of Impact Evaluations*, *FEEM Working Papers*. doi: 10.2139/ssrn.2527874.

Bridge, B. A., Adhikari, D. and Fontenla, M. (2016) 'Household-level effects of electricity on income', *Energy Economics*. North-Holland, 58, pp. 222–228. doi: 10.1016/j.eneco.2016.06.008.

Burlando, A. (2014) 'Power Outages, Power Externalities, and Baby Booms', *Demography*, 51(4), pp. 1477–1500. doi: 10.1007/s13524-014-0316-7.

Cabraal, R. A., Barnes, D. F. and Agarwal, S. G. (2005) 'Productive Uses of Energy for Rural Development', *Annual Review of Environment and Resources*, 30(1), pp. 117–144. doi: 10.1146/annurev.energy.30.050504.144228.

Cheng, B. S. and Lai, T. W. (1997) 'An investigation of co-integration and causality between energy consumption and economic activity in Taiwan', *Energy Economics*. North-Holland, 19(4), pp. 435–444. doi: 10.1016/S0140-9883(97)01023-2.

Choumert, J., Motel, P. C. and Le Roux, L. (2017) 'Energy Ladder or Energy Stacking: a Panel Data Analysis of Tanzanian Households' Energy Choices', (July), pp. 1–42. Available at: http://faere.fr/pub/Conf2017/FAERE2017_Choumert.pdf.

Cooke, E., Hague, S. and McKay, A. (2016) *The Ghana Poverty and Inequality Report. Using the 6th Ghana Living Standards Survey*. doi: 10.1080/19439342.2015.1064148.

Dacuycuy, C. B. and Dacuycuy, L. B. (2018) 'Urban and Rural Households' Energy Use: Sets, Shocks, and Strategies in the Philippines'. Available at: <https://think-asia.org/bitstream/handle/11540/8068/pidsdps1801.pdf?sequence=1>.

Danlami, A. H., Islam, R. and Applanaidu, S. D. (2015) 'An analysis of the determinants of households' energy choice: A search for conceptual framework', *International Journal of Energy Economics and Policy*, 5(1), pp. 197–205. Available at: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84920982722&partnerID=tZOtx3y1>.

Davis, H. L. (1976) 'Decision Making within the Household', *Journal of Consumer Research*, 2(4), p. 241. doi: 10.1086/208639.

Diacon, P.-E. and Maha, L.-G. (2015) 'The Relationship between Income, Consumption and GDP: A Time Series, Cross-Country Analysis', *Procedia Economics and Finance*. Elsevier, 23, pp. 1535–1543. doi: 10.1016/S2212-5671(15)00374-3.

Dramani, J. B., Tandoh, F. and Tewari, D. D. (2012) 'Structural breaks, electricity consumption and economic growth : Evidence from Ghana', *African Journal of Business Management*, 6(22), pp. 6709–6720. doi: 10.5897/AJBM11.2800.

Energy Commission (2018) *National Energy Statistics 2008 - 2017*. Accra. Available at: [http://energycom.gov.gh/files/Energy Statistics_2015Final_1.pdf](http://energycom.gov.gh/files/Energy%20Statistics_2015Final_1.pdf).

ESMAP (2014) 'A New Multi-Tier Approach to Measuring Energy Access Agenda', *World Bank*. Available at: [http://www.esmap.org/sites/esmap.org/files/DocumentLibrary/Multi-tier BBL_Feb19_Final_no annex.pdf](http://www.esmap.org/sites/esmap.org/files/DocumentLibrary/Multi-tier%20BBL_Feb19_Final_no%20annex.pdf) (Accessed: 2 August 2018).

Fleurbaey, M. and Hammond, P. J. (2004) 'Interpersonally Comparable Utility', in *Handbook of Utility Theory*, pp. 1179–1285. doi: 10.1007/978-1-4020-7964-1_8.

Ganga, S. (2015) 'Concept of Economic Development and Its Measurement', in. Available at: [http://shodhganga.inflibnet.ac.in/bitstream/10603/12950/11/11_chapter 3.pdf](http://shodhganga.inflibnet.ac.in/bitstream/10603/12950/11/11_chapter%203.pdf) (Accessed:

29 July 2018).

Gassmann, F., Coady, D. and Klytchnikova, I. (2005) 'An evaluation of the Welfare impacts of electricity tariff reforms and alternative compensating mechanisms in Tajikistan'. N/A.

Available at: http://collections.unu.edu/view/UNU:959#.W2YtidRbP_U.mendeley

(Accessed: 4 August 2018).

Ghana Statistical Service (2008) *Ghana Living Standard Survey 5 - 2005, National Data Archive (NADA)*. Accra. Available at:

http://www.statsghana.gov.gh/docfiles/glss5_report.pdf.

Ghana Statistical Service (2013a) *Ghana - Ghana Living Standard Survey 4 - 1998, With labour force model*. Accra.

Ghana Statistical Service (2013b) *Ghana Living Standards Survey 3 -1991, Third round, National Data Archive (NADA)*. Accra. Available at:

<http://www.statsghana.gov.gh/nada/index.php/catalog/12>.

Ghana Statistical Service (2014a) *Ghana living standards survey Round 6*. Accra. doi: 10.1007/s13398-014-0173-7.2.

Ghana Statistical Service (2014b) *Ghana Statistical Living Standards Survey 6: Poverty Profile in Ghana 2005-2013*. Accra. doi: 10.1017/CBO9781107415324.004.

Gilchrist, S. and Williams, J. C. (2000) 'Putty-Clay and Investment: A Business Cycle Analysis', *Journal of Political Economy*, 108(5), pp. 928–960. doi: 10.1086/317673.

Glasure, Y. U. and Lee, A.-R. (1998) 'Cointegration, error-correction, and the relationship between GDP and energy:: The case of South Korea and Singapore', *Resource and Energy Economics*. North-Holland, 20(1), pp. 17–25. doi: 10.1016/S0928-7655(96)00016-4.

Groh, S., Pachauri, S. and Narasimha, R. (2016) 'What are we measuring? An empirical analysis of household electricity access metrics in rural Bangladesh', *Energy for Sustainable*

Development. International Energy Initiative, 30(February), pp. 21–31. doi:
10.1016/j.esd.2015.10.007.

Guttormsen, A. G. (2007) ‘Causality between Energy Consumption and Economic Growth :
The Case of Pakistan’, *The Journal of Energy and Development*, 33(1), pp. 1–22.

Haider, O. C. (1982) ‘Measuring Social Welfare : Theory and Practice’, *The Bangladesh
Development Studies*, 10(2), pp. 1–18.

Hanna, R. and Oliva, P. (2015) ‘Moving up the Energy Ladder: The Effect of an Increase in
Economic Well-Being on the Fuel Consumption Choices of the Poor in India’, *American
Economic Review*, 105(5), pp. 242–246. doi: 10.1257/aer.p20151097.

Hosier, R. H. and Dowd, J. (1987) ‘Household fuel choice in Zimbabwe: An empirical test of
the energy ladder hypothesis’, *Resources and Energy*, 9(4), pp. 347–361. Available at:
<https://econpapers.repec.org/RePEc:eee:reseng:v:9:y:1987:i:4:p:347-361>.

International Energy Agency (2017) *WEO-2017 Special Report: Energy Access Outlook*.
Available at:

[http://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_Energy
AccessOutlook.pdf](http://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf) (Accessed: 23 June 2018).

Jamasb, T. and Meier, H. (2010) ‘Household Energy Expenditure and Income Groups :
Evidence from Great Britain’, 49(0), pp. 1–21.

Johansen, L. (1959) ‘Substitution versus Fixed Production Coefficients in the Theory of
Economic Growth: A Synthesis’, *Econometrica*. [Wiley, Econometric Society], 27(2), pp.
157–176. Available at: <http://www.jstor.org/stable/1909440>.

Johansson, T. B. (2012) ‘Global Energy Assessment’, *Gea Iiasa*. Available at:
<http://web.mit.edu/afs.new/athena/course/12/12.000/www/m2018/pdfs/worldbank.pdf>.

Kabahuma, S. (2010) ‘ENABLING EQUITABLE ACCESS TO RURAL

ELECTRIFICATION: CURRENT THINKING AND MAJOR ACTIVITIES IN ENERGY, POVERTY AND GENDER', 86(November), pp. 1984–1991.

Karimu, A., Mensah, J. T. and Adu, G. (2016) 'Who Adopts LPG as the Main Cooking Fuel and Why? Empirical Evidence on Ghana Based on National Survey', *World Development*, 85, pp. 43–57. doi: 10.1016/j.worlddev.2016.05.004.

King, M. K. and Weimer, D. L. (no date) 'Price and income elasticities of demand for energy', *Theory and Practices for Energy Education, Training, Regulation and Standards*. Available at: <http://www.eolss.net/sample-chapters/c08/e3-03-16.pdf> (Accessed: 17 September 2018).

Kraft, J. and Kraft, A. (1978) 'On the Relationship Between Energy and GNP', *The Journal of Energy and Development*. International Research Center for Energy and Economic Development (ICEED), 3(2), pp. 401–403. Available at: <http://www.jstor.org/stable/24806805>.

Van Der Kroon, B., Brouwer, R. and Van Beukering, P. J. H. (2013) 'The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis', *Renewable and Sustainable Energy Reviews*, 20, pp. 504–513. doi: 10.1016/j.rser.2012.11.045.

Kumi, E. N. (2017) 'The Electricity Situation in Ghana: Challenges and Opportunities www.cgdev.org', (September), p. 30. Available at: www.cgdev.org.

Kwakwa, P. A. (2012) 'Disaggregated energy consumption and economic growth in Ghana', *International Journal of Energy Economics and Policy*, 2(1), pp. 34–40. doi: 10.1080/15567249.2017.1286527.

Kwakwa, P. A. (2014) 'Energy-growth nexus and energy demand in Ghana: A review of empirical studies Paul', *MPRA*, (10679).

Kwakwa, P. A. and Adu, G. (2016) 'Effects of Income, Energy Consumption, and Trade

Openness on Carbon Emissions in Sub-Saharan Africa', *The Journal of Energy and Development*, 41(1), pp. 85–117.

Lancaster, K. (1975) 'The Theory of Household Behavior: Some Foundations', *Annals of Economic and Social Measurement, Volume 4, number 1*, 4(1), pp. 5–21. Available at: <http://ideas.repec.org/h/nbr/nberch/10216.html>.

Leach, G. (1992) 'The energy transition', *Energy Policy*, 20(2), pp. 116–123. Available at: <https://econpapers.repec.org/RePEc:eee:enepol:v:20:y:1992:i:2:p:116-123>.

Lee, C.-C. (2006) 'The causality relationship between energy consumption and GDP in G-11 countries revisited', *Energy Policy*, 34(9), pp. 1086–1093. doi: 10.1016/J.ENPOL.2005.04.023.

Lind, J. T. (2000) *The Use of Household Welfare Functions to Estimate Equivalence Scales*. Available at: https://www.ssb.no/a/histstat/doc/doc_200016.pdf (Accessed: 31 July 2018).

Link, C. F., Axinn, W. G. and Ghimire, D. J. (2012) 'Household energy consumption: Community context and the fuelwood transition.', *Social science research*. NIH Public Access, 41(3), pp. 598–611. doi: 10.1016/j.ssresearch.2011.12.007.

Lloyd, B. *et al.* (1993) 'Book Reviews', *Journal of Moral Education*, 19(1), p. 1993. doi: 10.1080/0305724900190107.

Mahfoudh, S. and Ben Amar, M. (2015) 'The Importance of Electricity Consumption in Economic Growth : The Example of African Nations', *The Journal of Energy and Development*. ICEED, 40(1), pp. 99–110.

Martiskäinen, M. (2007) *Affecting consumer behaviour on energy demand*.

Masih, A. M. M. and Masih, R. (1996) 'Empirical tests to discern the dynamic causal chain in macroeconomic activity: new evidence from Thailand and Malaysia based on a multivariate cointegration/vector error-correction modeling approach', *Journal of Policy*

Modeling. North-Holland, 18(5), pp. 531–560. doi: 10.1016/0161-8938(95)00133-6.

Mattila-wiro, P. (1999) ‘Economic Theories of The Household: A Critical Review’, *UNU World Institute for Development Economics Research*, (159).

Mekonnen, A. *et al.* (2009) ‘Income alone doesn’t determine adoption and choice of fuel types’, (2009), p. 5. Available at:

<http://manage.www.efdinitiative.org.zope.sizeit.se/www.efdinitiative.org/research/publications/publications-repository/income-alone-doesn2019t-determine-adoption-and-choice-of-fuel-types-evidence-from-households-in-tigray-and-major-cities-in-ethiopia/file>.

Mensah, E. J., Huchet-Bourdon, M. and Latruffe, L. (2014) ‘Infrastructure access and household welfare in Rural Ghana’, *African Development Review*, 26(3), pp. 508–519. doi: 10.1111/1467-8268.12107.

Mirza, B. and Kemp, R. (2009) ‘Why Rural Rich Remain Energy Poor’, *United Nations University Working Paper Series*, 6(31), pp. 1–28.

Moore, J. C. (2007) *General Equilibrium and Welfare Economics*. Berlin: Springer. doi: 10.1007/978-3-540-32223-8.

Nadimi, R. (2017) ‘Quality of life modelling in terms of energy consumption’, *Meeting the Energy Demands of Emerging Economies, 40th IAEE International Conference*.

National Research Council *et al.* (1989) *Recommended Dietary Allowances: 10th Edition*. National Academies Press (Dietary Reference Intakes). Available at: <https://books.google.com.gh/books?id=l6q-sDEO7CgC>.

Nondo, C., Kahsai, M. S. and Schaeffer, P. V (2010) ‘Energy Consumption and Economic Growth : Evidence from COMESA Countries’, (412), pp. 1–20.

Osei-Fosu, A. K. (2008) ‘the Heavily Indebted Poor Countries (Hipc) Initiative Fund Micro-Credit and Poverty Reduction in Ghana: a Panacea or a Mirage?’, *Journal of Science and*

Technology, 28(3).

Pachauri, S. and Spreng, D. (2003) 'Energy Use and Energy Access in Relation to Poverty', (25), pp. 1–20.

Pindyck, B. R. S. and Rotemberg, J. J. (1983) 'Dynamic Factor Demands and the Effects of Energy Price Shocks', *The American Economic Review*, 73(5), pp. 1066–1079.

Pindyck, R. S. (1979) 'Interfuel substitution and the industrial demand for energy: an international comparison', *The Review of Economics and Statistics*, 61(2), pp. 169–179. doi: 10.2307/1924584.

Pinzón, K. (2016) 'Analysis of Price and Income Elasticities of Energy Demand in Ecuador: A Dynamic OLS Approach'. doi: 10.1016/j.eap.2017.09.004.

Pollin, R., Heintz, J. and Garrett-Peltier, H. (2009) 'The Economic Benefits of Investing in Clean Energy', *Center for American Progress*, (June). Available at: <https://www.americanprogress.org/issues/green/report/2009/06/18/6192/the-economic-benefits-of-investing-in-clean-energy/>.

Pollitt, M. G. and Shaorshadze, I. (2011) *The Role of Behavioural Economics in Energy and Climate Policy*, *Eprg Wp 1130*.

Posel, D. (1997) 'Counting the Poor: Who gets what in which households', *Agenda*, 33(The Poverty Issue), pp. 53–54.

Pradeep, M., Alois, P. M. and Lugmayr, M. (2016) 'Decentralized power in countries of ECOWAS region: A case study', in Guruswamy, L. and Neville, E. (eds) *International Energy and Poverty: The Emerging Contours*. Routledge, pp. 181–191. doi: 10.4324/9781315762203.

Quartey, J. D. (2014) 'Energy poverty and climate change mitigation in Ghana: An economic assessment', *Journal of Economics and Sustainable Development*, 5(8), pp. 72–85. Available

at: <http://iiste.org/Journals/index.php/JEDS/article/view/12608>.

Ravallion, M. (2008) *On the Welfarist Rationale for Relative Poverty Lines*. 4486. doi: 10.1093/acprof:oso/9780199239115.003.0021.

Sen, A. (1983) 'Economics and the Family', *Asian Development Review*, 1.

Solow, R. M. (1956) 'A Contribution to the Theory of Economic Growth', *The Quarterly Journal of Economics*, 70(1), pp. 65–94. Available at: <http://links.jstor.org/sici?sici=0033-5533%28195602%2970%3A1%3C65%3AACTTTO%3E2.0.CO%3B2-M> (Accessed: 25 June 2018).

Struckmeyer, C. S. (1987) 'The Putty-Clay Perspective on the Capital-Energy Complementarity', *The Review of Economics and Statistics*, 69(2), pp. 320–326. doi: 10.2307/1927240.

Swarupk, V. A. and Rao, R. (2017) 'An Econometric Approach to Analysis of Trends and Patterns of Household Fuel Choices in India', *Indian Economic Review*. Department of Economics, Delhi School of Economics, University of Delhi, 50(1), pp. 105–129.

Toda, H. Y. and Yamamoto, T. (1995) 'Statistical inference in vector autoregressions with possibly integrated processes', *Journal of Econometrics*, 66(1–2), pp. 225–250. Available at: <https://econpapers.repec.org/RePEc:eee:econom:v:66:y:1995:i:1-2:p:225-250>.

Townsend, P. (1979) *Poverty in the United Kingdom: A Survey of Household Resources and Standards of Living*. Middlesex: Penguin Books. doi: 10.2307/1962256.

UNDP (2014) *NAMA STUDY FOR A SUSTAINABLE CHARCOAL VALUE CHAIN IN Ghana*. New York. Available at: <http://www.undp.org/content/dam/LECB/docs/pubs-namas/undp-lecb-mdgc-Ghana-Sust-Charcoal-NAMA-Study-2016.pdf> (Accessed: 17 September 2018).

van de Walle, D. et al. (2013) *Long-Term Impacts of Household Electrification in Rural*

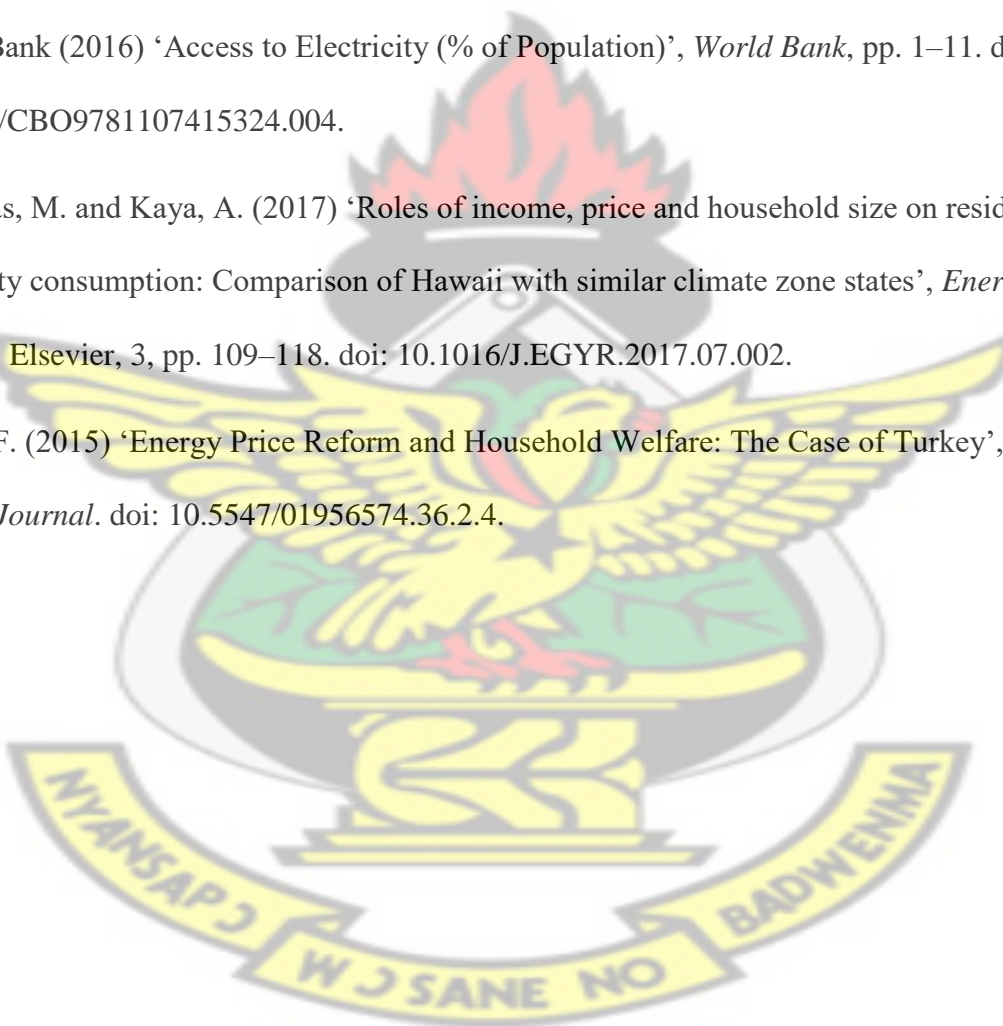
India. 6527. doi: 10.1596/1813-9450-6527.

Woolley, F. R. (1990) *Economic models of family decision-making, with applications to intergenerational justice, PQDT - UK & Ireland*. London School of Economics. Available at: [https://search.proquest.com/docview/301522894?accountid=27468%0Ahttp://sfx.nelliportaal.i.fi/nelli32b?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+%26+theses&sid=ProQ:ProQuest+Dissertations+%26+Theses+Global&atitle=.](https://search.proquest.com/docview/301522894?accountid=27468%0Ahttp://sfx.nelliportaal.i.fi/nelli32b?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+%26+theses&sid=ProQ:ProQuest+Dissertations+%26+Theses+Global&atitle=)

World Bank (2016) 'Access to Electricity (% of Population)', *World Bank*, pp. 1–11. doi: 10.1017/CBO9781107415324.004.

Yalcintas, M. and Kaya, A. (2017) 'Roles of income, price and household size on residential electricity consumption: Comparison of Hawaii with similar climate zone states', *Energy Reports*. Elsevier, 3, pp. 109–118. doi: 10.1016/J.EGYR.2017.07.002.

Zhang, F. (2015) 'Energy Price Reform and Household Welfare: The Case of Turkey', *The Energy Journal*. doi: 10.5547/01956574.36.2.4.



APPENDIX

A. Chow Test

Note: see regression tables for residuals and number of observations

$$T = \text{time periods} = 4$$

$$k = \text{no of explanatory variables} = 8$$

$$n = \text{total number observations} = 35146$$

$$SSR_r = 5953.76$$

$$\begin{aligned} SSR_{ur} &= SSR_{GLSS3} + SSR_{GLSS4} + SSR_{GLSS5} + SSR_{GLSS6} \\ &= 115.96 + 172.63 + 320.58 + 709.93 \\ &= 1319 \end{aligned}$$

$$= \left(\frac{SSR_r - SSR_{ur}}{SSR_{ur}} \right) \left(\frac{n - T - Tk}{(T - 1)k} \right)$$

$$= (3.514)(1462.917)$$

$$F - \text{value} = 5140.69$$

$$df_1 = (T - 1)k = 28$$

$$df_2 = n - T - tk = 35106$$

The F-critical at 95% confidence level = 1.383

$$\therefore F_{\text{value}} > F_{\text{critical}}$$

Hence, we reject the null hypothesis that the model from the pooled result is independent, identically and normally distributed.

B Descriptive statistics tables

KNUST

Table B1: Combined Descriptive statistics table

	GLSS 6			GLSS 5			GLSS 4			GLSS 3		
	Obs	Mean/ percent	Std. Dev.	Obs	Mean/ percent	Std. Dev.	Obs	Mean/ percent	Std. Dev.	Obs	Mean/ percent	Std. Dev.
energy_use	16770	3.50	1.90	8687	2.92	1.95	5998	2.66	1.92	4527	2.27	1.80
no energy	98	0.58		95	1.09		0	0		0	0	
fuelwood	5575	33.24		3882	44.69		3217	53.63		2843	62.8	
charcoal	759	4.53		670	7.71		385	6.42		313	6.91	
kerosene	15	0.09		11	0.13		11	0.18		20	0.44	
LPG	82	0.49		33	0.38		6	0.1		6	0.13	
electricity	10241	61.07		3996	46		2379	39.66		1345	29.71	
Poverty Status	16772	1.66	0.65	8687	1.60	0.75	5998	1.47	0.82	4523	1.33	0.87
Very poor	1647	9.82		1393	16.04		1264	21.07				
Poor	2367	14.11		699	8.05		633	10.55				
Non poor	12758	76.07		6595	75.92		4101	68.37				
Employment Status	16772	1.05	0.32	8687	0.94	0.23	5998	0.95	0.21	4523	0.96	0.20
unemployed	492	2.93		502	5.78		271	4.52		181	4	
employed	15004	89.46		8185	94.22		5727	95.48		4342	96	

Location	16772	1.56	0.50	8687	1.58	0.49	5998	1.63	0.48	4523	4.48	2.83
Urban	7445	44.39		3618	41.65		2199	36.66		1578	34.89	
Rural	9327	55.61		5069	58.35		3799	63.34		2945	65.11	
Age	16772	45.84	15.9	8687	45.34	15.64	5998	45.83	15.37	4523	44.28	15.33
hh_size	16772	4.26	2.78	8687	4.20	2.83	5998	4.28	2.56	4523	1.65	0.48
Gender	16772	1.28	0.45	8687	1.28	0.45	5998	1.34	0.47	4523	1.32	0.47
Male	12043	71.8		6266	72.13		3984	66.42		3069	67.85	
Female	4729	28.2		2421	27.87		2014	33.58		1454	32.15	



C Regression Tables

Table C1: Regression results for pooled panel

Pooled Panel for GLSS 3 - 6						
logwelfare	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Intercept	5.510	0.012	466.350	0.000	5.487	5.533
energy_use						
fuelwood	0.100	0.006	16.310	0.000	0.088	0.113
charcoal	0.097	0.010	9.530	0.000	0.077	0.117
kerosene	0.189	0.059	3.180	0.001	0.072	0.305
LPG	0.020	0.039	0.500	0.620	-0.058	0.097
electricity	0.000	base variable				
location						
Urban	0.147	0.006	25.060	0.000	0.136	0.159
emp						
unemployed	0.074	0.012	6.060	0.000	0.050	0.097
inactive	-0.445	0.013	-33.940	0.000	-0.471	-0.420
pstatus						
Very poor	-0.029	0.009	-3.160	0.002	-0.047	-0.011
Non poor	0.425	0.008	55.370	0.000	0.410	0.440
Gender						
(male)	0.030	0.005	5.630	0.000	0.019	0.040
age	0.000	0.000	-2.310	0.021	-0.001	0.000
hhsiz	-0.030	0.001	-32.080	0.000	-0.032	-0.028

Source	SS	df	MS	Number of obs	35146.000
				F(14, 35131)	1462.930
Model	3470.97	14.00	247.93	Prob > F	0.000
Residual	5953.76	35131.00	0.17	R-squared	0.368
				Adj R-squared	0.368
Total	9424.73	35145.00	0.27	Root MSE	0.412

Table C2: Regression results for GLSS 3

GLSS 3 Multiple regression results						
LogWelfare	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Intercept	5.721	0.040	143.680	0.000	5.643	5.799
energy_use						
fuelwood/other biomass	-0.037	0.008	-4.830	0.000	-0.053	-0.022
charcoal	-0.008	0.011	-0.750	0.454	-0.031	0.014
kerosene/other intermediate	-0.081	0.054	-1.520	0.130	-0.186	0.024
LPG	0.057	0.048	1.180	0.237	-0.038	0.152
pstatus						
very poor	-0.434	0.006	-75.040	0.000	-0.445	-0.422
poor	-0.263	0.005	-54.860	0.000	-0.272	-0.253
emp						
unemployed	0.064	0.018	3.610	0.000	0.029	0.098
logIncome	0.099	0.006	15.380	0.000	0.086	0.112
location						
Urban	0.061	0.007	8.070	0.000	0.046	0.075
age	0.000	0.000	-0.680	0.494	0.000	0.000
hhsize	-0.027	0.001	-21.830	0.000	-0.029	-0.024
Gender (male)	-0.015	0.005	-2.760	0.006	-0.026	-0.004
Source	SS	df	MS	Number of obs	4434.000	
				F(12, 4421)	943.820	
Model	297.06	12.00	24.75	Prob > F	0.000	
Residual	115.96	4421.00	0.03	R-squared	0.719	
				Adj R-squared	0.719	
Total	413.01	4433.00	0.09	Root MSE	0.162	

Table C3: Regression results for GLSS 4

GLSS 4 Multiple regression results						
LogWelfare	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Intercept	5.829	0.037	158.200	0.000	5.756	5.901
energy_use						
fuelwood/other biomass	-0.085	0.006	-13.380	0.000	-0.098	-0.073
charcoal	-0.050	0.011	-4.580	0.000	-0.071	-0.029
kerosene/other intermediate	-0.014	0.046	-0.300	0.767	-0.104	0.077
LPG	-0.051	0.090	-0.570	0.569	-0.227	0.124
pstatus						
very poor	-0.458	0.006	-74.450	0.000	-0.470	-0.446
poor	-0.273	0.005	-54.940	0.000	-0.283	-0.264
emp						
unemployed	0.033	0.015	2.220	0.026	0.004	0.061
logIncome						
Urban	0.100	0.006	16.750	0.000	0.088	0.111
location						
Urban	0.045	0.006	7.200	0.000	0.033	0.057
age						
age	-0.001	0.000	-3.840	0.000	-0.001	0.000
hhsiz						
hhsiz	-0.033	0.001	-27.790	0.000	-0.035	-0.030
Gender (male)						
Gender (male)	-0.011	0.005	-2.180	0.029	-0.021	-0.001

Source	SS	df	MS	Number of obs	5793.00
Model	431.91	12.00	35.99	F(12, 5780)	1205.12
Residual	172.63	5780.00	0.03	Prob > F	0.000
Total	604.54	5792.00	0.10	R-squared	0.714
				Adj R-squared	0.714
				Root MSE	0.173

Table C4: Regression results for GLSS 5

GLSS 5 Multiple regression results						
LogWelfare	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Intercept	5.627	0.034	166.830	0.000	5.561	5.693
energy_use						
no energy	-0.104	0.025	-4.150	0.000	-0.153	-0.055
fuelwood/other biomass	-0.075	0.006	-13.560	0.000	-0.086	-0.064
charcoal	-0.074	0.009	-8.470	0.000	-0.091	-0.057
kerosene/other intermediate	0.090	0.077	1.170	0.240	-0.060	0.241
LPG	-0.025	0.038	-0.660	0.508	-0.100	0.050
pstatus						
very poor	-0.475	0.006	-74.900	0.000	-0.487	-0.463
poor	-0.293	0.006	-52.980	0.000	-0.304	-0.282
emp						
unemployed	0.034	0.011	2.970	0.003	0.011	0.056
logIncome	0.136	0.005	24.910	0.000	0.125	0.147
location						
urban	0.093	0.006	16.660	0.000	0.082	0.104
age	0.000	0.000	-3.330	0.001	-0.001	0.000
hhsiz	-0.036	0.001	-30.930	0.000	-0.038	-0.034
gender(male)	-0.019	0.005	-3.670	0.000	-0.029	-0.009
Source	SS	df	MS	Number of obs	8372	
				F(13, 8358)	1511.34	
Model	753.605718	13.000	57.970	Prob > F	0	
Residual	320.583204	8358.000	0.038	R-squared	0.7016	
				Adj R-squared	0.7011	
Total	1074.18892	8371.000	0.128	Root MSE	0.19585	

Table C5: Regression results for GLSS 6

GLSS 6 Multiple regression results

LogWelfare	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Intercept	5.09	0.02	232.37	0.00	5.047	5.133
energy_use						
no energy	-0.13	0.02	-6.38	0.00	-0.167	-0.088
fuelwood/other biomass	-0.07	0.00	-20.05	0.00	-0.082	-0.068
charcoal	-0.08	0.01	-9.39	0.00	-0.091	-0.060
kerosene/other intermediate	-0.06	0.05	-1.18	0.24	-0.153	0.038
LPG	0.11	0.03	3.89	0.00	0.053	0.160
pstatus						
Very poor	-0.59	0.01	-112.83	0.00	-0.601	-0.580
Poor	-0.36	0.00	-102.57	0.00	-0.363	-0.349
emp						
unemployed	0.02	0.01	2.14	0.03	0.002	0.038
inactive	0.01	0.01	1.53	0.13	-0.003	0.025
Logincome	0.09	0.00	24.55	0.00	0.085	0.099
location						
Urban	0.08	0.00	21.08	0.00	0.076	0.092
age	0.00	0.00	-5.29	0.00	-0.001	0.000
hhsiz	-0.03	0.00	-39.94	0.00	-0.034	-0.031
gender(male)	-0.01	0.00	-1.81	0.07	-0.015	0.001

Source	SS	df	MS	Number of obs	16547
				F(14, 16532)	2371.1
Model	1425.500	14	101.821	Prob > F	0
Residual	709.929	16532	0.043	R-squared	0.6675
				Adj R-squared	0.6673
Total	2135.429	16546	0.129	Root MSE	0.2072