ANALYSIS OF COOKING FUEL DEMAND PATTERNS AMONG RURAL FARM HOUSEHOLDS IN KIAMBU COUNTY, KENYA

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A RESEARCH THESIS REPORT SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN AGRICULTURAL ECONOMICS, IN THE SCHOOL OF AGRICULTURE AND ENTERPRISE DEVELOPMENT OF KENYATTA UNIVERSITY.

NOVEMBER, 2020

DECLARATION

This thesis report is my unique work and has not been introduced to any other University for the honor of degree

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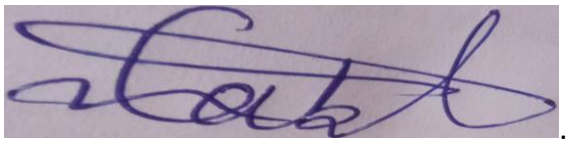
Signature  ... Date: 23/11/2020

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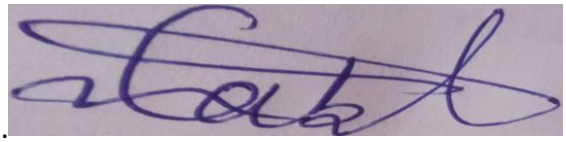
Signature ...  Date.....23/11/2020

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DEDICATION

To my astounding parents Mr. Francis Kago and Mrs. Keziah Wanjiru for their encouragement and backing.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIDS : Almost Ideal Demand System

DC : Developing Countries

GOK : Government of Kenya

IEA : International Energy Agency

IMR : Inverse Mills Ratio

KIPPRA : Kenya Institute for Public Policy Research and Analysis

KNBS : Kenya National Bureau of Statistics

LES : Linear Expenditure System

LPG : Liquefied Petroleum Gas

MOE : Ministry of Energy

QUAIDS : Quadratic Almost Ideal demand System

SE4ALL : Sustainable Energy for All

SSA : Sub-Saharan Africa

UNDP : United Nations Development Programme

ABSTRACT

Cooking fuel energy is an important element in the daily livelihood of households where majority depend on fuel wood which's readily available for energy sources. However, these natural resources experience degradation occasioned by the growing population causing an imbalance in the demand and supply. Therefore, it has decreased fuel wood availability and accessibility thus fuel scarcity making it expensive to acquire which has led households to use alternative sources of fuel. For this reason, there's a dilemma between meeting the growing demand for fuel energy and the sustainable utilization of the limited stock of natural resources. Due to a significance disruption of bio-diversity, it has led to many households depending on the market (prices) as their main source of fuel. More so, there's use of multiple fuel which is influenced by income and other factors. Price volatility as well as income vulnerability significantly affect household consumption patterns. Hence, this study aimed at investigating the influence of household characteristics on energy demand**,** determining the impact of income changes on household energy demand patterns and identifying the energy demand patterns for fuel used by households to address the persistent problem of fuel insecurity. Guided by neoclassical demand of consumer behavior, Quadratic Almost Ideal Demand System (QUAIDS) was used for analysis. Data was collected from 200 respondents using systematic random sampling. Analysis was done using STATA version 13 to obtain descriptive statistics and the empirical results. The results indicated that firewood, charcoal and kerosene are necessary goods while LPG was a luxury. Expenditure elasticity for the fuels were positive implying that the fuels were normal goods and an increase in income will lead to higher consumption. The main determinants of energy demand were gender, education level and occupation of the household head as well as age and household size. It is recommended that government and other stakeholders formulate income oriented policies to augment household earnings which will increase their purchasing power. Furthermore, the government should enact policies to ensure LPG is affordable with a view to mitigate against environmental degradation. Additionally, capacity building by educating both the old and young by giving information on the negative impacts of using such fuel and the benefits derived when the public switch to modern fuels. Besides, strategies are needed to identify affordable, scalable and accessible efficient fuel-saving cooking practices to the local context.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Cooking fuel plays a crucial role in the welfare of households in the world over. Around 2.4 billion people in developing countries use primary sources of energy such as firewood, charcoal and agricultural residues (Ruiz-mercado *et al.,* 2011) where Sub-Saharan Africa (SSA) represents 81% of households depending on firewood for cooking (World Bank., 2011). According to UNDP (2016), Kenya's most central source of energy is fuel wood, accounting over 70% of the total energy requirements for domestic needs (Ngui *et al.*, 2011).

Cooking energy can be classified into traditional which include wood, charcoal and agricultural residues and modern such as petroleum products and electricity (GoK, 2004). In Kenya majority of the households in rural areas rely completely upon fuel wood as the key source of domestic energy (Ngetich *et al.,* 2009). This has largely been determined by the local availability, opportunity and transaction costs involved in accessing, collecting and utilization of the biomass fuels (Kituyi et al., 2001; Niriezono & Kilangla, 2018).

Therefore, it is apparent that most rural households are still engraved by use of primary sources which is firewood (KNBS, 2016) leading at 84.3% as presented in table 1.1.

Table 1. 1: Percentage distribution of the main source of cooking fuel in Kenya by 2016

Fuel type	Rural HH	Urban HH	National
Firewood	84.3	16.1	54.6
Charcoal	8.9	21.9	14.6
Kerosene	2.3	29.0	14.0
LPG	2.5	27.6	13.4
Electricity	0.3	2.0	1.0
Biogas	0.2	0.2	0.2
Straw/shrubs/grass	0.0	0.0	0.0
Animal dung	0.0	0.1	0.1
Agricultural residue	0.3	0.0	0.2
Other	0.9	2.4	1.6
Number of HH ('000)	6442	4972	11415

Source: Kenya integrated household budget survey 2016

This dependence on biomass fuels however, has been cited to have a negative impact on environment by reducing biodiversity and jeopardizing the forest ecosystem (Peter A. Dewees, 1989; FAO, 2009; Akther, Danesh Miah, & Koike, 2010). In fact over reliance of inefficient traditional biomass sources has been accused of exacerbating woodland degradation and climate change, and has detrimental impacts on health and poverty in Kenya (Dalberg, 2013). For example, Kenya's annual demand for biomass was at 34.3 million tons when contrasted with the anticipated supply of 15 million (GoK, 2004).

In the recent past, Kenyan government and other stakeholders have tried to mitigate against over-dependence of biomass fuels by introducing various technologies, including

using improved biomass cook-stoves and encouraging switching to modern fuels such as LPG (Song *et al*., 2018). For instance, since 1980s there have been several promotional efforts by the government, development partners and private stakeholders to increase use of renewable energy, but the uptake is extremely low (GoK, 2004) thereby leading to fuel wood scarcity.

However, it's important to note that rural fuel energy problem cannot be treated in isolation from the similarly persistent issues of food, poverty, environment and culture (Mirza & Kemp, 2003; Narasimha Rao & Reddy, 2007; Danlami, Applanaidu, & Islam, 2018). In recent studies, the focus of household demand for cooking energy has remained on the "energy ladder concept" which argues that households in general change from inefficient fuel source to a more efficient as dictated by the increases in household income (Masera, Saatkamp, & Kammen, 2000; Heltberg, 2003) . But as evidenced by Pundo & Fraser (2006), households in developing countries tend to consume a blend of fuels rather than changing from one source to another. Households tend to combine high-cost and low cost fuels as dictated by the prices of fuel, preference and needs necessitated by household characteristics (World Bank, 2010). Thus households end up adopting the concept of "fuel stacking" (multiple fuel use) instead of fuel switching or an energy ladder (Heltberg, 2003). "Energy stack concept" recognizes that besides income, other aspects such as social, economic, non-economic attributes and technological barriers impact energy choice.

Consequently, the patterns of rural household energy consumption is a result of complex interaction of factors besides income (Nazer, 2016). Elements which if ignored could contribute to the problem of household fuel energy interventions approaches that are

incompetent. Understanding fuel demand patterns of a specific locale or nation is valuable to the policy formulation in addressing three significant strategy issues identified with fuel security. First, it helps to identify most probable policy interventions suitable in improving the households' energy requirement. Second, it is helpful in planning several fuel energy subsidy strategies that must be obligated by the government. Lastly, the information on household fuel demand behavior is fundamental for steering sectoral and macroeconomic policy analyses.

1.2 Problem statement

Globally, in developing countries approximately 2.4 billion people use primary sources of cooking energy such as firewood, charcoal and agricultural residues (Ruiz-mercado *et al.*, 2011). Similarly, in Sub-Saharan Africa 81% of households bank on biomass fuel for cooking (World Bank., 2011). In Kenya, the most basic source of cooking is fuel wood, which accounts for over 70% of total energy requirements for domestic needs (UNDP 2016) and the said demand for biomass energy will continue to rise for the foreseeable future (Mugo, F. and Gathui, 2010).

In recent studies the focus of household demand for cooking energy has been the energy ladder concept which argues that households tend to switch from inefficient fuel source to a more efficient as dictated by the increases in household income (Masera, Saatkamp, & Kammen, 2000; Heltberg, 2003) . But as evidenced by Pundo & Fraser (2006), households in developing countries tend to consume a mix of fuels rather than changing from one source to another.

Kiambu county with poverty levels of 24.2% (KNBS, 2016) can be considered a fairly high income compared to other areas in the country. This would rank the county at higher lever towards use of efficient energy source in the energy ladder argument. Nonetheless, the households in the county uses various sources of energy, with an estimated 80% of rural households use firewood and charcoal (Githiomi et al., 2012; County Government of Kiambu, 2013) and over 10% and 5% use kerosene and LGP sources respectively (Dalberg, 2013). This means that the households in Kiambu have employed the concept of cooking fuel stacking (multiple cooking fuel use) instead of switching energy sources as observed in the energy ladder behaviour. Accordingly, Kiambu County depends on both income and other demand drivers such as prices.

Fuel energy is a necessity for rural households. According to studies firewood accounts for the largest source of energy source in many households (70%). In the past, the energy provision has been viewed for the supply side of the energy equation. That is trees and forests were available to supply the fuel wood. However, it has emerged that the continued use of fuel wood is not sustainable vis a vis the demand in view of the raising population. With the recent clamour for environmental conservation, there's need for paradigm shift and focus on the demand side. The need to understand the household energy consumption patterns is of paramount importance.

Consequently, in absence of a careful examination of the household cooking energy demand behaviour, the county will continue designing inapt policies. This study aims to understand how household energy consumption will respond to income and price changes an important policy implications for ensuring cooking fuel security.

1.3 Objectives

1.3.1 Overall objective

The study sought to analyze the consumption of cooking fuels among rural farm households in Kiambu County

1.3.2 Specific objectives

1. To investigate the influence of household characteristics on energy demand
2. To determine the impact of income changes on household energy demand patterns
3. To study the effect of household's income and energy prices on household energy demand

1.4 Research hypothesis

1. H_0; There is no significant relationship between household characteristics and household energy demand
2. H_0; Varying household income levels have no significant influence on household energy demand
3. H_0; Household fuel income and energy prices have no significant effect on household energy demand

1.5 Significance of the study

Since fuel energy is an essential part of the rural households, appropriate intervention and measures for sustainable and efficient energy cannot be established without a clear understanding of the energy demand system. Most of the households in Kiambu County are dependent on wood fuel as the major source of energy approximately 80% of the county's population. Thus, this has brought change in the household consumption

patterns. Information that will be generated by this study is expected to inform various stakeholders and planners of programs in the energy sector on how to meet the rising demand of energy, by investment strategies on efficient energy. Through analyzing the energy demand system, the study aimed at proposing interventions that will enable households adopt alternative fuels that are sustainable, efficient and environmental friendly.

1.6 Definition of terms

Price elasticity: the measure of responsiveness of demand or supply of a good or service, relative to change in prices.

Demand elasticities: the measure of responsiveness of demand change to changes in prices or incomes.

Hicksian or compensated demand: it shows the relationship between the price and quantity of a good purchased assuming that utility and other prices are held constant.

Marshallian or uncompensated demand: it shows the relationship between the quantities purchased assuming that other prices and consumers' income are held constant.

QUAIDS: the demand system that is derived from a utility function which is expressed in budget share.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a literature on cooking fuel demand plus various approaches to demand estimation. In addition, it gives an empirical review from previous studies on cooking demand as well as identification of a research gap.

2.2 Fuel wood consumption

In several developing countries, particularly Africa, biomass energy especially fuel wood, has remained to be the principal component of domestic energy among rural households (Hosier, 2018). As reported by Kenyan KNBS (2016), firewood remains the predominant cooking source of fuel at 84.3%. As a result, this over-dependence on biomass fuels is degrading the environment, reducing biodiversity and jeopardizing the forest ecosystem. Energy scarcity is thus a challenge in the quest for better livelihood among households (International Energy Agency, 2016; Irfan, Cameron, & Gazi 2017), since wood production has become unsustainable (Heltberg, 2003), brought about by the increasing population pressure (Olasunkamni and Ogunjobi., 2015). Despite the wood fuel scarcity, demand and supply is limited and regarded to have a high level of uncertainty. This has made it challenging in carrying out wood energy planning and formulation of policies (Wambua, 2011; Githiomi et al., 2012). Therefore, fuel wood accessibility is not constant and households are experiencing shortages (Octavio, 2017). Accordingly, given the current consumption patterns, sustainable biomass supply is hardly possible.

2.3 Cooking fuel demand and supply

Cooking fuel security remains a key worldwide challenge particularly with the rising population as well as fuel price volatility. This disparity between fuel demand and supply combined with population pressure and resultant fuel price hike has prompted a major gap between fuel accessibility and requirement with a huge challenge on the general cooking fuel security. Due to fuel scarcity, households' response to alternative energy sources can influence individual consumption patterns (Mahiri & Howorth, 2001).

Price is an essential determinant of cooking fuel demand affecting both the volume and structure of household consumption patterns (Majumder, 2014). For example, reduced purchasing power brought about by price increases, households will lessen their fuel demand and as a result shift their consumption from expensive to cheaper commodities that are pocket friendly which tend to compromise the quality of the good (Akter, 2013). Moreover, price is a key indicator of both supply and demand in the market. Enormous increments in prices negatively affect the capacity of the consumers to satisfy their demand requirements predominantly within less privileged groups (Novshek & Hugo, 1978; Selikoff, 2003).

Price volatility and income vulnerability are listed as the utmost essential risk elements that undermine cooking fuel security throughout the country. For the purposes of this study we emphasis on the two with its relation to rural income (Vigani, Dudu, & Solano-Hermosilla, 2019). Volatility in fuel prices are caused by quite a number of reasons such as change in world fuel prices, strict government regulations and controls, high population growth and hence demand growth (Imran, Özçatalbaş, & Bakhsh, 2019). High prices of different fuels and income vulnerability significantly affect household

consumption patterns (Gundimeda & Köhlin, 2008; Lusambo, 2016). Therefore, understanding how household consumption respond to income and price changes has important policy implications for cooking fuel security. Hence, analyzing the demand patterns of cooking fuels in different country regions and in rural and urban areas is a crucial step to study fuel security.

According to Hosier (1987), so as to understand the variety of energy demand levels and patterns, the suitable method may be to carry out energy expenditure analysis. This is carried out at household level which allows energy consumption patterns to vary within different geographical zones, by income strata and social class (Heltberg, Arndt, & Sekhar, 2000). Households' energy demand surveys gather thorough information on the quantity and expenditure of energy consumed (Rahut, Mottaleb, & Ali, 2017) and the economic and social demographics characteristics of households (Mwenjeri *et al.*, 2016). More so, it can be understood by examining its fuel decision in a constrained utility maximization framework where it maximizes utility subject to a set of economic and non-economic constraints. Understanding household energy choices and transition process is essential in revealing energy demand patterns (Kowsari & Zerriffi, 2011). In addition, by estimating price and income elasticities, it provides an indication of the sensitivity of households to market shocks and accordingly the degree of household's constraint to access cooking energy.

2.4 Energy stack and energy ladder models

The major determinant of supply and demand of energy is the disposable income of the households (Atieno, 2012; Oordt, 2016) in conjunction with the price level of fuel (Rahut *et al*., 2017). As a result, energy ladder model was established, represented by stair steps

(Schlag & Zuzarte, 2008). It hypothesizes that as income increases households gradually adopt modern fuels such as kerosene, coal, charcoal, LPG and electricity (Van Der Kroon, Brouwer, & Van Beukering, 2013). The linear movement along the ladder signifies rise in social-economic status among the households. However, it has been criticized to be one dimensional since there can be other variables that could equally influence fuel demand (Mekonnen & Köhlin, 2009; Vasseur, Marique, & Udalov, 2019). Therefore, it led to researchers bringing forth fuel stacking or energy stack model (Masera et al., 2000). Energy stack recognizes that besides income, other factors such as social, economic, demographic characteristics and technological barriers affect energy choice (Mirza & Kemp, 2003; Narasimha Rao & Reddy, 2007; Danlami, Applanaidu, & Islam, 2018). Generally, households start consuming new technologies without leaving the initial one. Consequently, household consumption patterns while using different types of energy is the result of a complex interaction of other factors (Nazer, 2016). This study therefore hypothesizes that fuel usage among households in Kiambu County follows the fuel stack model and thus the need to reveal the energy demand patterns from different fuel combination.

2.5 Consumer demand estimation models

Demand theory has been broadly applied to model households' consumption behavior. Price and expenditure elasticities provide vital information on how consumers respond to price and income changes (Poi, 2002). Over the years, demand studies have paid attention in analyzing consumer demand behavior across different income groups (Barnett & Usui, 2007; Blundell, 2008). Household expenditure is frequently used as a proxy of income since household-detailed income is commonly viewed as unreliable, mostly in poorer

nations where self-employment is predominant (UNDP/The World Bank Energy Sector, 2004).

In order to estimate household demand, equations representing consumption behavior are used. Linear expenditure system (LES) of stone 1957 is the origin of this literature (Paul Baker, 1989). However, limitations on proportional income and price elasticities as well as no complementary relationship among goods (Blundell, 2008), led to development of Rotterdam and translog model (Barnett, 2007). However, (Deaton & Muellbauer (1980), proposed the linear logarithmic form referred to as Almost Ideal Demand System (AIDS). Nonetheless, AIDS is limiting for some goods and low flexibility of the Engels curve. The succeeding improvement of demand system has focused on improving fit of the model by bringing on more terms that are quadratic in expenditure or income which is known as Quadratic Almost Ideal Demand System (QUAIDS) (Banks, Blundell, & Lewbel, 1961). QUAIDS model is more flexible in modeling consumers' expenses, takes into account social demographic factors, enable in accounting for the effects related to income changes (Ehuitch, 2017) as well as the impact of changes in regulated prices of consumer demand (Dybczak, Tóth, & Voňka, 2014). In QUAIDS, this new variable represents expenditure shares of the commodities. Expenditure shares are quadratic in the logarithm of income. The household expenditure behavior can be analyzed by using Engel curve (Deaton, 1986). In estimation of Engel curves, total expenditure is commonly used as a proxy of income owing to reasons such as unwillingness of consumers to reveal their true income (Deaton & Muellbauer, 1980).

2.6 Empirical review

Osiolo (2006), studied how to enhance households' fuel choice and substitution in Kenya carried out in 2005/06. The study employed multinomial logit model in analyzing determinants of fuel choice as well as fuel substitution. More so, in analyzing wood fuel expenditures, heckman model was used. Households prove to use different types of fuels thus hypothesizing the energy stack model. Gender, income, fuel price, distance to fuel source and education were significant variables on fuel use by households. However, it pays more attention to economic aspects and paid less attention to demand factors as well as specifically rural households.

According to KIPPRA (2010), study based on analyzing energy consumption patterns in Kenya, used AIDS model to reveal the determinants of expenditure on various types of energy. The study analyzed every fuel type to determine expenditure allocation, price elasticity, threshold willingness to pay and share of household budget on energy. Nonetheless, it did not take into account all household characteristics on energy decision such as age and gender.

Ngui *et al*., (2011), based on a survey in Kenya 2009 set to determine the price and fuel expenditure elasticities of demand using LA-AIDS model. Results revealed that energy stacking was adopted by the households, that is, they use multiple fuels. However, study disregards critical factors that influence households' energy access such as age.

Yii & Geetha (2015), analyzed elasticity for energy demand in east Malaysia using LA-AIDS model. Petrol, electricity and LPG were found to be price elastic to low income

groups. However, the study missed to take into account the primary sources of cooking such as firewood, charcoal as well as household characteristics affecting energy demand.

Rajmohan k & Weerahewa J (2016), examines household energy consumption patterns in Sri Lanka. Energy model was found to hold in Sri Lanka and that shifting towards LPG and electricity was embraced by the whole country. Income elasticity was significant in the urban areas. However, income elasticity (estate sector) was insignificant an indication that other determinants other than income influence consumption decision on fuels.

Rahut *et al*., (2017), analyses the factors of household energy choices in Timor-Leste. Econometric analysis was used in the study. However, the econometric analysis did not illustrate the relationship of energy demand factors and specific demand elasticity estimates differentiated by socio-economic variables likely to have an effect on household energy consumption.

2.7 Research gap

Based on the literature review, the most considered methods of demand analysis were AIDS and QUAIDS. However, a study aimed at analyzing energy demand patterns using the QUAIDS model was not found in the existing literature. QUAIDS allows for non-linearity of the Engels curve since AIDS is bias as Engel curve tend to be non-linear. The choice of QUAIDS is based on its flexible functional form which allows coherence with demand and consumer behavior theory, and the possibility to account for the endogeneity between prices and expenditure. Besides, restrictions are automatically imposed by the QUAIDS command which is among the advantages of using QUAIDS commands suite compared to AIDS where these restrictions are imposed manually. Therefore, the study

also aims at exploring alternative measures that will provide increased flexibility to the new model of consumer demand.

Aimed at exploring alternative measures with a clamour for environmental conservation, there's need for paradigm shift and focus on the demand side. Previously, the energy provision was viewed for the supply side of the equation that is, trees and forests were available to supply the fuel wood. Conversely, it has emerged that the continued use of fuel wood is not sustainable vis a vis the demand in view of the raising population. Therefore, the need to understand the household cooking energy consumption patterns is of paramount importance.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the conceptual and theoretical framework used for the study. More so, it gives a study area description, techniques in data collection along with data analysis.

3.2 Study area

Kiambu County is situated in the central highlands of Kenya, near to Nairobi Kenya's capital city. It covers about 2,543.5 Km^2 of which 476.3 Km^2 represent forest cover. The annual precipitation is 1000mm, warm climatic area of temperatures between 12^0c and 18.7^0c. To the south, it borders Nairobi and Kajiado Counties, to the East Machakos County, to the North and North East Murang'a County, Nyandarua to the North West, and Nakuru to the West. The county lies between latitudes 00 25'and 10 20'South of the Equator and Longitude 360 31'and 370 15'East (County Government of Kiambu, 2013). Based on the government projections of 2009 census, Kiambu has a total population of 1623282 with households being 384465 (County, 2014).

3.3 Conceptual framework

According to Kowsari & Zerriffi (2011), a conceptual framework is used in research to represent key ideas and complex interactions on a number of essential factors on the outcome variables. Consistent with figure 4.1 the framework is based on understanding the main factors that determine household cooking consumption patterns. The choice and demand of cooking fuel by households is based on a complex interaction between economic, social or non-economic factors. Whereby, economic factors include household

income and market price of the fuel while non-economic include a set of household characteristics such as gender, age, education level and occupation of the household head, household size and distance of fuel source (Pieters, 2013; Thadeo, 2014). Although these factors are presented in isolation from each other, in the real world they are closely interconnected (Abdul-hanan *et al.*, 2014; Rahut, Behera, & Ali, 2016).

Government policies to control production and distribution of cooking energy directly or indirectly affect household fuel demand (World Bank, 2013). The analyses of fuel demand is expected to provide feedback to policy makers. It flags the essential need for upgrading the current policy measures, proposing innovative and effective along with conversant strategies.

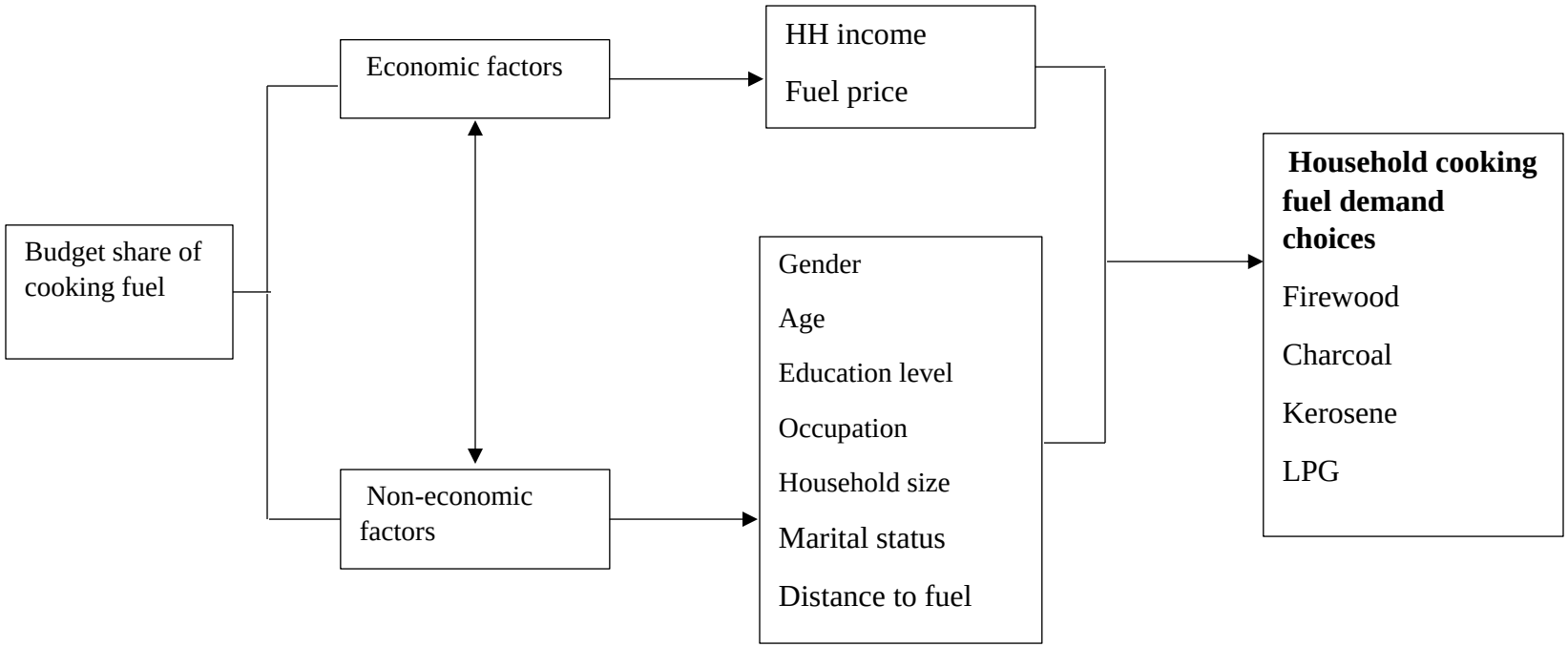

Figure 3. 1 Conceptual framework

3.4 Theoretical framework

Neoclassical approach relates supply and demand to an individual rationality and their capability to maximize utility. Neoclassical consumer theory considers individuals as consumers only, whereby the consumer has to select from a consumption bundles (Selikoff, 2011). For each consumption bundle is a vector of *n* different commodities.

$$x = x_1, \dots \dots . x_n \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . \dots \dots \dots \dots \dots \dots \dots \dots \dots . \dots . . 3.1$$

The theory states that the relationship existing between the quantities demanded and price of that commodity is negative. It is assumed that consumers' derive demand from constrained utility maximization. The basic axiom of utility maximization ensures that a rational consumer constantly select a preferred set of goods from the bundles acceptable to the budget (Deaton, 1986). Mostly, consumers group goods according to value or consumer preference. Hence, the relative prices for all the goods have an independent effect on commodity demand.

The shape of the Engels curve is essential in the demand system modeling. Demand system allowing for flexibility in the Engels curve tend towards providence of extra realistic results in both simulation and prediction exercises (Autor, 2004). To estimate household demand system, there have been widespread interests in the model of analysis representing the consumption behavior. Linear Expenditure System (LES) of stone 1954 being the pioneer and most traditional method. However, it ruled out the complementary relationship among goods and limitations on proportional income and price elasticities (Blundell, 2008). This led to the development of Rotterdam and translog model (Barnett, 2007). However, Angus Deaton and John Muellbauer (2011), proposed the linear

logarithmic form called the Almost Ideal Demand System (AIDS). However, AIDS model is limiting for some goods and low flexibility of the Engels curve (Deaton and Muellbauer, 2011). The succeeding improvement of demand system has focused on improving fit of the model by introducing additional terms which are quadratic in expenditure or income and thus the Quadratic Almost Ideal Demand System (QUAIDS) (Banks & Blundell, 1961).

3.4.1 Model specification

As suggested by FAO (2003), application of households theory needs a precise model. Generally, demand comprises of single and systems of demand equations. The generalized demand function representing purchase of *m* goods by consumers can be written by way of:

$$q_j = q_j(p_1, p_2 \dots \dots \dots p_m R) \quad j = 1,2 \dots m \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 3.2$$

Where q is the quantity demanded, p is the price of j, j represent commodity and R is the income. m represents equations of demand that can be estimated either single or systems of equations.

Equation 3.1 is assessed in a budget share form. Extending the demand function for individuals to that for a group of consumers requires including non-economic variables besides prices and income.

Angus Deaton and John Muellbauer (2011) developed a demand system based on utility function known as AIDS which is attained in a budget share form. However, it does not allow the price and income elasticities to differ with the income levels. As a result, Banks

et al., (1961) derived a model from utility maximization known as QUAIDS. QUAIDS model is more flexible in modeling consumers' expenses, takes into account social demographic factors, enable in accounting for the effects related to income changes (Ehuitch, 2017) as well as the impact of changes in regulated prices of consumer demand (Dybczak et al., 2014).

According to this study, four cooking fuels (firewood, charcoal, kerosene and LPG) that are common in Kiambu County were analyzed. The data was collected from 200 household cooking fuel expenditure in the County. The study used per capita consumption expenditure as a proxy for income. The general function representing demand model that was used in a single equation takes the following format:

Cooking fuel share = f (income, prices, non-economic aspects)

The non-economic factors included in the model were age, gender, education level as well as occupation of the household head, size of the household and marital status. Thus, the functional equation for the study takes the form:

Fuel share (w_i) = f (expenditure, prices, gender, age, educationlevelofHHhead, occupationofHHhead, HHsize, marital status)

The above equation was examined using the QUAIDS model taking the budget share form as:

The QUAIDS model for cooking energy can be estimated as shown:

$$w_i = \alpha_1 + \sum_{j=1}^{n} y_{ij} \ln p_j + \beta_i \ln \left[\frac{R}{a(\boldsymbol{p})}\right] + \frac{\lambda_i}{b(\boldsymbol{p})} \left\{\ln \left[\frac{R}{a(\boldsymbol{p})}\right]\right\}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Where $\boldsymbol{w_i}$the budget share of fuels, $\boldsymbol{p_j}$is the price of fuel j, $\boldsymbol{\beta_i}$ is the expenditure co-efficient, $\mathbf{y_{ij}}$ is the price co-efficient; $\boldsymbol{\lambda_i}$is the quadratic term co-efficient; $\boldsymbol{\alpha_i}$ is the constant co-efficient; $\boldsymbol{R}$ is the overall expenditure. $\boldsymbol{\alpha_i}$, $\boldsymbol{\beta_i}$, $\mathbf{y_{ij}}$, $\boldsymbol{\lambda_i}$are parameters to be estimated.

In order to incorporate demographic variables, QUAIDS uses the scaling technique as introduced by Ray (Poi, 2002). Let **z** represent the total persons in a household, $e^R(\boldsymbol{p}, u)$ to denote the expenditure function of a particular HH and the expenditure function for each HH takes the form $e(\boldsymbol{p}, \boldsymbol{z}, u) = m_0(\boldsymbol{p}, \boldsymbol{z}, u) \times e^R(\boldsymbol{p}, u)$. $m_0(\boldsymbol{p}, \boldsymbol{z}, u)$ Is the expenditure function to account for HH characteristics which is further decomposed to $m_0(\boldsymbol{p}, \boldsymbol{z}, u) = \overline{m_0}(\boldsymbol{z}) \times \emptyset(\boldsymbol{p}, \boldsymbol{z}, u)$.

$\overline{m_0}(\boldsymbol{z})$ Denotes the rise in a HH expenditure as function of **z** not controlling for any changes in consumption patterns such that a HH having five members have higher expenditure than one with a less members even ignoring that goods consumed may change.

$\emptyset(\boldsymbol{p}, \boldsymbol{z}, u)$ Regulates changes in prices and the actual goods consumed; a HH with two adults and three children will purchase different items than one involving five adults.

Therefore, the resultant QUAIDS budget share equation takes the form:

$$w_i = \alpha_1 + \sum_{j=1}^{n} y_{ij} \ln p_j + \beta_i \ln \left[\frac{R}{\overline{m_0}(\boldsymbol{z})a(\boldsymbol{p})}\right] + \frac{\lambda_i}{b(\boldsymbol{p})c(\boldsymbol{p}, \boldsymbol{z})} \left\{\ln \left[\frac{R}{\overline{m_0}(\boldsymbol{z})a(\boldsymbol{p})}\right]\right\}^2 \quad \ldots\ldots 3.4$$

3.4.2 Treating households with zero expenditure and missing price data

Understanding demand systems using household micro data is essential since it avoid the problem of aggregation over consumers and frequently provides a great and statistical rich sample. However, it brings about a major estimation problem from the fact that, quite a number of commodities in the budget, the households are observed to consume zero amounts of the various items under consideration (Helen & Wessells, 2013). Therefore, households with zero consumption or purchases which is the problem of missing price data poses a serious estimation flaw which increases biasness as well as reduces efficiency of results (Zhou, 2015).

There are several ways to approach the issue which reduces zero consumption observation which increases efficiency and the value of the results (Rahaman & Mohammed, 2015). The most common approach is by insertion of the zero purchases by correcting them using the censored dependent variable problem using the censored regression models. Mostly used are the heckman two stage regression and the Tobit model. The budget shares of goods represent dependent variables whereby, if a household does not purchase the good equals to 0 and 1 if it does. Zero shares are censored by an unobservable latent variable (Agbola, 2000; Chern, Ishibashi, Taniguchi & Tokoyama, 2002; Weliwita, Nyange & Tsujii, 2003; Helen & Wessells, 2013).

In order to correct the bias problem of fuel consumption, heckman two stage estimation was applied as suggested by Heckman (1978). Stage one, a probit regression for each fuel item was computed which determines whether a consumer decide to purchase some amount of a particular fuel or not.

$$\mathrm{I}_i = \alpha_0 + \alpha_1 \ln m + \sum \beta_{ij} \ln p_j + \sum_k y_{ik} H_k + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

I_i is one if a HH consume *i*th fuel item that is $w_i > 0$ and zero otherwise. From equation 3.12, the inverse mills ratio (λ) for every household for each fuel was computed, which was used as an instrument incorporating the censoring latent variables in the second regression. Here, the consumer is decisive on the amount they purchase the item thus, dependent variables (budget shares) take value 0 if household expenditure on a particular fuel is zero and a positive value when expenditure is non-zero (Helen & Wessells, 2013). Parameters of the probit regression are used to compute the IMR for each HH for each fuel.

The inverse mills ratio for each HH was computed as follows:

$$\lambda_i = \frac{\emptyset_i(P, x, d)}{\Phi_i(P, x, d)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

P, x and d are prices, expenditure and demographic variable vectors for the HH while $\emptyset_i$ and Φ_i is the density and cumulative probability functions respectively. In the second stage, incorporating the computed inverse mills ratio (λ), as an instrument variable is estimated (Mittal, 2015).

$$\mathrm{w}_i = \alpha_0 + \alpha_1 \ln m + \sum \beta_{ij} \ln p_j + \sum_k y_{ik} H_k + \theta_i \lambda_i + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

θ_i is the parameter related to the inverse mills ratio. By doing heckman two stage, the problem of zero consumption or expenditure is dealt with.

From the economic theory, three restrictions are enforced from properties of consumer theory. They are additivity, homogeneity and symmetry of slutsky matrix. Additivity or adding up ascertains that the sum of the individual expenses on different goods and commodities is equal to the total expenditure.

$$\sum_{i=1}^{n} \alpha_1 = 1 \sum_{i=1}^{n} \beta_i = 0 \sum_{i=1}^{n} y_{ij} = 0 \sum_{i=1}^{n} \lambda_i = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.8$$

Homogeneity ensures that demand functions are homogeneous of degree zero in prices as shown.

$$\sum_{i=1}^{n} y_{ij} = 0 \quad \forall j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . .3.9$$

Slutsky matrix is necessarily for well-defined preferences in the demand system which implies that:

$$y_{ij} = y_{ji} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . . \ldots 3.10$$

To calculate the models elasticities, we differentiate equation 3.2 with respect to $\ln p_j$ *and* $\ln m$ to finally obtain the budget or the income elasticities for i commodities as:

$$e_i = \frac{\mu_i}{w_i} + 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \ldots\ldots\ldots\ldots . . \ldots\ldots\ldots\ldots\ldots . .3.11$$

Where e_i measures the responsiveness of demand of a good in response to consumers' expenditure which indicate the nature of products and how it's perceived by consumers. More so, it gives the level and pattern demand of the goods (Banks et al., 1961). Income

elasticity of between 0 and 1 are referred to as normal goods, elasticity above 1 are luxury goods while negative income elasticity refers to inferior goods whereby demand falls as income rises (Dybczak et al., 2014; Suriani, Cut, & Shabri Abd, 2018)

Price elasticities are obtained from either Marshallian or Hicksian demand equation. Marshallian (uncompensated) is attained by maximizing utility subject to budget constraint while Hicksian (compensated) is derived by solving the dual problem of expenditure minimization at a certain utility level (Dybczak et al., 2014).

The marshallian (uncompensated) price elasticity is as follows:

$$e_{ij}^{u} = \frac{\mu_{ij}}{w_i} + \delta_{ij} \quad \ldots\ldots 3.12$$

δ_{ij} = Kronecker delta that is unity if $i = j$

When e_{ij} is positive, it indicates a gross substitutes and negative shows gross complements.

Hicksian (compensated) price elasticity we use slutsky equation as shown:

$$e_{ij}^{c} = e_{ij}^{\mu} + e_i w_i \quad \ldots\ldots 3.13$$

In addition, to assess the negativity conditions, the matrix with entities $w_i\left[e_{ij}^{c}\right]$ will be examined. This matrix should be symmetric and negative semi-definite (Bily, 2016).

3.5 Data collection

3.5.1 Data types and sources

Both primary and secondary data were used. Primary data obtained included gender, household size, age, education level of household head, occupation of household head energy expenditure and energy prices. Secondary data was collected from published reports.

3.5.2 Sampling technique and sample design

Sampling was constructed on government projections of 2009 census of population and housing in Kiambu County. The total number of the population is 1623282 with households being 384465 (County, 2014). The target population was the rural farm households in the county. Systematic random sampling methodology was used to arrive at the sample.

The sample size was arrived at using the formula adopted from Glenn (2013).

$n = \frac{N}{1+N(e^2)}$ Where: *n* is the sample size, N is the population size of the households and *e* is the precision level chosen. Therefore the sample size was calculated and 200 respondents was the estimated sample size. The sample size was distributed proportionately to the sub-counties using the formula:

$$\frac{number\ of\ households\ in\ the\ subconty}{number\ of\ households\ in\ the\ county} * sample\ size$$

3.5.3 Data collection method

Structured questionnaires were prepared and administered to households in order to obtain information on the energy demand patterns. The questionnaires were pretested to weigh the quality for data collection in line with the specific objectives. Secondary data were collected from publications by other researchers and used in literature review as well as for comparison purposes in results discussion.

3.5.4 Data analysis

Econometric analysis were carried out to provide a deeper understanding on energy demand in Kiambu County. In this study, analysis was done using 178 households out of 200 respondents surveyed. Seven were dropped due to missing data and five because of abnormal expenditure levels. Wald tests were subsequently performed on the all parameters including λ, to show if the quadratic term of log income was significant or not, and therefore if the QUAIDS model was a good model choice. Demand elasticities of price and income were calculated to study the effect and significance on household energy demand. The significance and effect of income changes on future household energy expenditure were analysed using marginal expenditure shares.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter entails an in depth presentation and discussion of the descriptive statistics and empirical results. The descriptive statistics focus on the demographic characteristics of the households which represent the potential factors that directly or indirectly affect the cooking fuel demand. On the other hand, empirical results takes into account estimations from the quadratic almost ideal demand system as well as expenditure and price elasticities.

4.1 Descriptive statistics

4.1.1 Gender of the household head

About 56.7% of the sampled households were male-headed while 43.3% were headed by females.

Table 4. 1 Gender of household head

Sex of HH head	Frequency	Percentage
Men	101	56.74
Women	77	43.26
Total	178	100

Source: Field survey 2019

The distribution of households according to gender was skewed towards the men. The results conquer with other studies that households decision in Sub-Saharan Africa is made

by men (Bandyopadhyay, Shyamsundar, & Baccini, 2011; UNDP, 2012; Rosenthal et al., 2018)

4.1.2 Occupation of the household head

Occupation of the household head was broadly categorized into three groups, explicitly formal, informal and unemployed.

Table 4. 2 Occupation of household head

Occupation of the HH head	Frequency	Percentage
Formal employment	30	16.58
Informal employment	134	75.28
Unemployed	14	7.87
Total	178	100

Source: Field survey 2019

Majority of the households (75%) had informal employment, 16.58% were formally employed and 7.87% were unemployed. Evidently, most households were low income earners since they depended on their wages for family providence. As a result, they are expected to contribute to inexpensive cooking fuels due to low and irregular income (Frederiks, Stenner, & Hobman, 2015). Formally employed households tend to have more disposable income which they invest in energy intensive appliances as well as energy saving measures such as LPG, electricity, biogas and solar (Baiyegunhi & Hassan, 2014). Hence, occupational status in relation to income is likely to have an influence in household energy consumption.

4.1.3 Education level of the household head

According to the results as indicated in table 4.3, 42.7% had attained post primary level of education while 57.3% had primary education or none.

Table 4. 3 Education level of the household head

Education level of HH head	Frequency	Percentage
No formal education	14	7.86
Primary	88	49.44
Secondary	37	20.77
College	39	21.91
Total	178	100

Source: Field survey 2019

Most of the household's heads were primary school holders with a proportion of 46.44%, 20.77% for the secondary level while 21.91% had attained college level. Despite the level of education among most households being generally low, it may be concluded that majority are literate. According to Rosenthal et al., (2018), level of education determines the extent and rate which households adopt technology. Gebreegziabher, Oskam, & Demeke (2010) study in Ethiopia, found that education level of households has a significant relationship with household energy expenditure patterns. In addition, Damte & Koch (2011) in rural Ethiopia reported that higher educated household heads make better decisions in regards to the type of cooking energy. Thus, education of household head is expected to have an effect on decisions of household consumption patterns since it has a direct influence on occupation and income.

4.1.4 Size of the household

Table 4. 4 Size of the household

Household size	Frequency	Percentage
1-3	54	30.34
4-6	99	55.62
7-10	25	14.04
Total	178	100

Source: Field survey 2019

Majority of the households were made up of 4 to 6 members approximately 55.62%. About 30.34% and 14.04% were comprised a family size ranging 1 to 3 and 7 to 10 members respectively. The total household energy consumption may have a negative relationship to the household size such that larger households may consume more energy as compared to smaller ones (Frederiks et al., 2015). Household size is an important element on cooking energy demand. Hence, households' attempt to meet diverse energy requirements according to the size and expenditure available.

4.1.5 Household energy budget share

As imposed in the QUAIDS model, the additivity or adding up ascertains that the sum of individual expenses on different goods is equal to the total expenditure or sum of budget shares are unitary hence, $\sum w_1 = 1$ as presented in table 4.5.

Table 4. 5 Household energy budget shares

Household energy budget share	Mean of fuel shares
Firewood	0.4258
Charcoal	0.2705
Kerosene	0.1733
LPG	0.1304

Source: Field survey 2019

Approximately, the results show that 13.04%, 17.33%, 27.05% and 42.58% of the total fuel budget spent on LPG, kerosene, charcoal and firewood respectively which add up to unity. The study is in line with Kwakwa, Wiafe, & Alhassan (2013) in Ghana, where firewood was the main cooking source at 69.2%. According to Gebreegziabher (2007), fuel wood in the rural households of Ethiopia was the main source of fuel. As reported by Onoja (2012), firewood intake among rural households in Nigeria was declining over time due to unavailability and the increased cost from traders despite it being the main fuel used. Osiolo (2006), found that Kenyans most used fuel in the rural areas was firewood which are consistent with the study results.

4.2 Empirical results

The QUAIDS model results that are presented in table 4.6 represent how the households' income, different cooking fuels, households' demographics and the budget shares of the cooking fuels.

Table 4. 6 Parameter estimates for the QUAIDS model for energy demand among rural households in Kiambu County

	Model Coefficients			
Variables	**Firewood**	**Charcoal**	**Kerosene**	**LPG**
Constant	0.3237***	-0.2554**	0.3070***	0.6246***
	(5.07)	(-2.65)	(4.57)	(7.10)
Expenditure	-0.0803	0.5077***	-0.0734	0.3540***
	(-0.90)	(5.19)	(-0.83)	(4.98)
Firewood (Price)	0.1525***	0.0369*	-0.1023***	-0.0870***
	(5.66)	(2.22)	(-4.54)	(-4.53)
Charcoal (Price)	0.0369*	-0.0640*	-0.0211	0.0482*
	(2.22)	(-2.37)	(-1.21)	(2.14)
Kerosene (Price)	-0.1023***	-0.0211	0.3448***	-0.2214***
	(-4.54)	(-1.21)	(11.62)	(-11.00)
LPG (Price)	-0.0870***	0.0482*	-0.2214***	-0.2602***
	(-4.53)	(2.14)	(-11.00)	(-8.57)
Quadratic term	0.0041	-0.0085***	0.0009	0.0035
	(1.86)	(-5.17)	(0.39)	(1.86)
Gender	0.0364*	0.0143	-0.0326	-0.0642*
	(2.19)	(0.43)	(-1.42)	(-2.41)
Age	-0.0001	-0.0038**	-0.0012	0.0028**
	(-0.10)	(-2.91)	(-1.38)	(3.21)
Education level	-0.0070	-0.0573***	-0.0044	0.0460***
	(-0.53)	(-4.06)	(-0.35)	(5.01)
HH size	0.0226	0.0980**	0.0153	-0.0908***
	(1.13)	(2.80)	(0.79)	(-3.48)
Marital status	0.0189	0.0097	-0.0185	-0.0100
	(1.12)	(0.34)	(-1.10)	(-0.48)
OccupationofHHhead	-0.0182**	0.000184	0.00499	0.0130*
	(-3.15)	(0.04)	(0.83)	(2.08)

*Source: Field survey 2019. *statistically significant at 0.05 level, ** statistically significant at 0.01 level, *** statistically significant at 0.001 level, t- values in parenthesis.*

The expenditure coefficients for charcoal and LPG are significant while that of firewood and kerosene are insignificant. A 100 percent increase in income will increase budget share of charcoal and LPG by 50.77 and 35.4 percent respectively.

Increasing the price of firewood by 100% increases its own budget share by 15.25% suggesting it to be a giffen good. It implies that despite an increase in its price, the rural households cannot afford a more expensive alternative source such as LPG and therefore end up purchasing more of firewood since it's what they can mostly afford. It outweighs the substitution effect. It also increases charcoals budget share by 3.69% but reduces kerosene and LPG by 10.23 and 8.70 percent respectively. An increase in the price of charcoal by 100% increases budget share of firewood and LPG by 3.69% and 4.82% respectively while it decreases its own share by 6.40% an indicator it's an inferior good. It suggest that as income increases, household will demand less of charcoal and have a costly alternative of LPG followed by firewood. Increasing kerosene price by 100% increases its own budget share by 34.48% thus a giffen good and reduces budget shares on firewood by 10.23% and LPG by 22.14%. More so, increasing the price of LPG by 100% increases the budget shares of charcoal by 4.82% and decreases the budget shares of firewood and kerosene by 8.70% and 22.14% respectively and reduces its own share by 26.02% thus an inferior good. It indicate that as income increases, households will demand more of kerosene followed by firewood.

The quadratic expenditure term is statistically significant in one of the expenditure share equations. It is in the expenditure share equations for firewood, kerosene and LPG that the null hypothesis of expenditure linearity is not rejected. However, as presented in Table 4.7 the hypothesis that the quadratic expenditure term is zero across all equations is strongly rejected.

Demographic characteristics of gender, age, education level, household size and occupation of the household head show significant effects in some budget shares. The co-efficient on gender of the household head suggest a negative effect on LPG (-0.0642) and a positive on firewood (0.0364) an indication that budget was allocated more to firewood and less to LPG due to their differences in cost where LPG was at higher cost than firewood. According to Semenya & Machete (2019), male and female make different decisions about household energy. Uhunamure, Nethengwe, & Musyoki (2017), confirm that female has an active role in energy selection. However, Alkon, Harish, & Urpelainen (2016) argues that men control the household budget in most societies and have more influence on energy selection. This indicates that despite women's desire to switch to renewable energies, they may not due to men's concern on costs. More so, traditionally women were and still are the key players in making fires, cooking and so on (Chalise, Kumar, Priyadarshini, & Yadama, 2018). Nonetheless, male are in control of cash and make most household decisions, including which fuel type to be used (Onoja, 2012).

Age of the household head was found to a have negative relationship with the budget share of charcoal and positive on LPG. More so, -0.0012 in kerosene explains that use of kerosene is lower among households headed by lower individuals. As the generation gets older, they tend to spend more on accessible and available fuels such as LPG. According to Olabisi, Tschirley, Nyange, & Awokuse (2019), raising household age by one increased firewood and kerosene in Tanzania. Thus, age is an essential element in energy decisive actions among households.

According to Molina & Gil (2005), if education level of the household head increases, there is a likelihood that the economic situation of the household will improve due to higher chances of secured employment that enhances income. Hence, from the results, a higher education level would result to household reducing charcoal intake by 5.73% and increase LPG by 4.60%. Educated household heads are expected to engage in updated technologies such as biogas installation, solar, electricity as well as LPG due to higher purchasing power which as a result conserves the environment (Buba et al., 2017; Orifah, Ijeoma, Omokhudu, Ahungwa, & Muktar, 2019).

Household size variable suggested a positive and negative relationship on the budget shares of charcoal and LPG respectively. Their budget shares increases by 0.0980 and decline by -0.0908 respectively whenever there's an extra member to the household. This results conquer to those of (Kwakwa, Wiafe, & Alhassan, 2013; Kayode, Akhavan Farshchi, & Ford, 2015) who found positive and significant coefficients on firewood and charcoal but negative for LPG and electricity. It means that for a household to increase fuel consumption due to increased household size, fuel expenditure require to be adjusted downwards so as to obtain low-priced fuel to meet the large household composition. The negative relationship between household size and other cooking fuels could be endorsed by high prices which are not sustainable in an expanding household size.

Finally, occupation of the household head was statistically significant in firewood and LPG. This could be attributed to higher purchasing power as a result of more income. In firewood, it had a negative relationship showing that as income increases, less firewood would be purchased. On the other hand, LPG had a positive correlation which indicated

that increased opportunity in better income, household spend more on LPG. This could also be attributed by educated households who would embrace new technology. The results are in line with other studies which found that occupation of the household head had a positive statistical relationship with LPG and charcoal but decreased the probability of using firewood and kerosene (Menéndez & Curt, 2013; Kiyawa & Yakubu, 2017; Adusah-Poku & Takeuchi, 2019; Imran, Özçatalbaş, & Bakhsh, 2019).

Wald tests were subsequently performed on the all parameters including λ, to show if the quadratic term of log income was significant or not, and therefore if the QUAIDS model was a good model choice (Ayodele & Oni, 2013).

Table 4. 7 Wald tests

	Chi^{2}value	**df**	**p-value**
QUAIDS specification	9.00	3	0.0293
Demographic characteristics	145.83	18	0.0000

Source: field survey 2019

As represented in table 4.7, the AIDS model is rejected in favor of the QUAIDS model hence the QUAIDS model was a good model choice. The results show that all λ=0 were statistically significant confirming that QUAIDS does not get reduced to AIDS model and thus used for elasticity estimations. More so, the null hypothesis that household characteristics are not significant is rejected. It is evident from the results that inclusion of demographic variables has a great impact on cooking demand patterns influencing the consumption behavior.

4.3 Expenditure elasticities

Expenditure elasticities are as shown in table 4.8. The expenditure elasticities are all positive. Expenditure (income) elasticity for the fuels being positive implies that these commodities are normal goods indicating that demand for these fuels increases with the increase in income. However, for LPG an increase in expenditure would result to a slightly greater increase in income. Expenditure elastic implies that the good has elasticity greater than one referring to it as a luxury while inelastic means that goods have inelasticity less than one thus necessary goods.

Table 4. 8 Expenditure elasticities

Type of fuel	Mean of fuel share	Expenditure elasticity	Marginal expenditure share
Firewood	0.4258	0.7522	0.3203
Charcoal	0.2705	0.8182	0.2213
Kerosene	0.1304	0.9882	0.1287
LPG	0.1733	1.0112	0.1752

Source: Field survey 2019

The most essential fuel is evidently firewood, where the expenditure elasticity coefficient is 0.7522. It point out that one percent rise in all expenditure leads to an increase in demand for firewood by 0.7522 percent on average (*ceteris paribus*). Furthermore, charcoal and kerosene had elasticities less than one thus considered as necessary fuels. This implies that the effect of income on these fuels is less than proportional thus a higher frequency of consumption or purchase. Hence, the degree of responsiveness (sensitivity

to income changes) is high on LPG (1.0112) as compared to firewood (0.7522). From the results, LPG is expenditure elastic thus an indicator it is a luxury good. That is, the effect of income on LPG is more than proportional thus relatively low frequency of demand. For instance, LPG with expenditure elasticity of 1.01 means that 10% rise in fuel expenditure will lead to 10.1% increase in LPG expenditure share. The results are consistent with Imran et al., (2019), which reported that in Pakistan demand for LPG increased with higher incomes.

In order to understand the impact of income changes on household energy demand patterns, marginal expenditure shares were derived as proposed by Powel 1974. Marginal expenditure share are estimated as a product of expenditure elasticity and mean of the budget shares. Thus, from the results in table 4.8, an increase in future income would lead to allocation of income on LPG.

4.4 The pricing effect on cooking fuel demand

At the household level, prices determine how much money can buy to meet their fuel requirements. The estimated uncompensated and compensated price elasticities were determined and presented as shown in tables 4.9 and 4.10 respectively.

4.4.1 Uncompensated (Marshallian) own price elasticities

Marshallian is attained by maximizing utility subject to budget constraint and as a result, it considers both the income and substitution effects (Gostkowski, 2018). As shown below, charcoal and LPG own elasticity is close to unity meaning that one percent increase in the price of charcoal results to approximately one percent decrease in quantity demanded.

Table 4. 9 Uncompensated own price elasticities (Marshallian)

Type of fuel	Firewood	Charcoal	Kerosene	LPG
Firewood	**-0.7208**	0.1037	-0.4215	-0.2617
Charcoal	-0.1535	**-0.7018**	-0.3099	-0.4404
Kerosene	-0.4323	-0.1385	**-0.6821**	-0.9294
LPG	-0.0665	-0.0288	-0.8333	**-0.8845**

Source: Field survey 2019

From the results, all the uncompensated own price elasticities are negative as required from the economic demand theory. Thus, existence of the inverse relationship between own price elasticities and quantity demanded. The results indicate that fuels under study have an inelastic demand. Although demands are inelastic, LPG appear to be the most sensitive to price changes as compared to firewood and charcoal with kerosene being the most inelastic. This implies that price increases proportionately more than the quantity demanded decreases, a characteristic for goods regarded as necessities.

4.4.2 Compensated (Hicksian) cross price elasticities

Hicksian is derived by solving the dual problem of expenditure minimization at a certain utility level. Mostly, this demand only considers the substitution effect (Bily, 2016). The substitution effect could be caused by several factors including preferences of consumer, availability and accessibility of the substitute. Hicksian shows the effect on the demand as a result of price changes of other commodities consumed by the households.

Table 4. 10 Compensated cross price elasticities (Hicksian)

Type of fuel	Firewood	Charcoal	Kerosene	LPG
Firewood	**-0.0474**	0.4283	-0.2533	-0.1276
Charcoal	0.2414	**-0.2041**	0.0868	-0.1241
Kerosene	0.1599	0.1958	**0.8553**	0.7913
LPG	-0.1992	-0.2862	-0.9667	**1.4521**

Source: Field survey 2019

From the results, any price increase in firewood will be substituted by kerosene which is available at a lower price than firewood and charcoal. In addition, a price increase in charcoal will lead to households substituting it for kerosene while a price increase in LPG farm households will shift charcoal and firewood thus the substitution effects from Hicksian. However, firewood and LPG have a complementary relationship.

CHAPTER FIVE

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

5.0 Introduction

This chapter presents the summary, conclusion and policy implications based on the findings of the study.

5.1 Summary of the findings

The aim of this study was to analyze the cooking fuel demand patterns among rural farm households in Kiambu County. Specifically, to investigate the influence of household characteristics as well as impact of income changes on household energy demand. In addition, the study undertook to assess the effects of household income and energy prices on household energy demand. Descriptive statistics were used to give an overall socio-economic characteristics of the households while QUAIDS model was used to estimate the extent to which households respond to the fuel prices in association to their income levels as well as their relationship with demographic characteristics. The elasticities provide an indication of sensitivity of the households to the market shocks and hence the degree of households constraints to access cooking fuel in Kiambu.

The distribution of the household head was skewed towards the male (75%) conquering since most household decisions are made by men. Majority of the household heads were literate despite the education level being generally low at 46.44% holders of up to primary level. Households were mainly made up of 4-6 members approximately 62.92% and majority of them had informal employment (75%) an indication of low and irregular

income. The study also established that indeed rural farm households in Kiambu allocated 42.73% of their household budget to firewood.

The quadratic almost ideal demand system (QUAIDS) was used to model demand for the cooking fuels with inclusion of demographic factors in the model. Budget shares, price and expenditure elasticities were computed for the same. Demographics such as gender, age, education level, and household size were statistically significant in charcoal and LPG. In addition, occupation of the household head was significant in firewood and charcoal. Expenditure (income) elasticity for the fuels being positive implies that these commodities are normal goods and an increase in income will lead to higher consumption. Most own and the cross price elasticities were less than one implying that a change in price would lead to a less than proportionate change in the quantity demanded. The study conforms to the literature that cooking fuels are necessities for the households.

5.2 Conclusion

The rural farm households allocated a high budget share of fuel to firewood (42.58%) and charcoal (27.05%). Clearly, wood fuel remain to be the main source of cooking an indication of continuous environmental degradation in the rural area. As firewood shortage keeps on expanding, households faced similar difficulties of significant expenses, utilization of inefficient fuels as provisions decline. Furthermore, a larger part of the rural households had low income and consequently low purchasing power which is an obstruction to adopt better cooking sources, for example, LPG, solar and biogas. Kiambu rural farm households were responsive to changes in incomes and fuel prices

which made adjustments to their fuel demand when prices and income changed in spite of non-uniform adjustments across the fuels.

The price and income elasticities demonstrate that the respondents were sensitive to the income and price changes a sign that arrangements ought to be considered on the recommendations it has on energy security circumstances. In this way, there is requirement for formation of sustainable fuel strategies which can help rural households move to better proficient fuels that will ensure environmental protection as well as sustaining the growing demand.

Results of the study reject the first null hypothesis that households' characteristics are not statistically significant in explaining cooking fuel demand. Variables such as gender, age, education level and occupation of the household head as well as household size had a significant effect in energy demand decisions and choices. Broadly, the analysis affirms that besides income, different variables impact fuel demand. Hence, the households adopt fuel stacking (multiple fuel) other than energy ladder (fuel switching) model.

5.3 Policy recommendations

In view of the previously mentioned findings, the resultant policy recommendations are hereby set:

From the results it's clear that low income households are inclined towards use of low cost fuels example, kerosene, firewood and charcoal. These sources of fuel are blamed for environmental degradation and affect the health of household members through smoke. Therefore, it's imperative for the policies to be guided by strategies of lowering the cost of the LPG (which in many households is a luxury) thereby reducing the prices

to make it closer to substitutes and thereby households will experience less budget impacts. A targeted pricing subsidy will facilitate fuel switching and positively neutralize household budgets.

Secondly, the result shows that firewood which was mostly used by rural households is a necessity commonly due to their low income levels. Linked to this concern is the fact that neutralizing the cost side of the equation which means improving energy use efficiency at the household level would be cost-effective and a sustained way of improving welfare conditions for low income households. As a nation education and innovation on efficient energy use devices would be an option that need to be supported by both policy and incentives.

Thirdly, the results support the argument that households in rural areas are accustomed to use combination of fuels other than switching from lower level of fuel ladder to the higher one. The results also shows that rural households in Kiambu use the four combination of fuels i.e. kerosene, firewood, charcoal and LPG. Strategies to diversify to more fuel sources would be explored. These being rural households, use of biogas technology should be facilitated both at policy level and innovation through incentive. This will relieve the demand for firewood and charcoal and offer a switching option to LPG.

Lastly, accessibility is a critical factor on the choice of fuel source. Some households are accustomed to firewood and charcoal because they are easily available and accessible. Adequate strategies are needed to help spur innovation and identify a suite of affordable, scalable and accessible efficient fuel-saving cooking practices to the local context is therefore crucial.

5.4 Further research

Further research to determine household fuel choices and its effects on the environment and health is important. In addition, the level to which fuel switching is taking place as well as cost benefit analysis of main household fuels to the economy is an essential area of study.

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APPENDICES

Appendix I: Kiambu Map

Appendix II: Questionnaire

ANALYSIS OF COOKING FUEL DEMAND PATTERNS AMONG RURAL FARM HOUSEHOLDS IN KIAMBU COUNTY, KENYA

Questionnaire Serial Number:…….

Section A: Location Data

Questionnaire Identification District:……. Sub-county:……. Division : …… …. Location: …… Sub location/Ward:……. Ward:……. Village:	Enumerator Name: …….. Date of Interview: …… **Monitoring locator** GPS Long: …… Lat: …….....

Name of Respondent:_____

Name of Household Head: _____

Relationship of Respondent to Household Head: _____

Age in years: _____

Gender ( ) Male ( ) Female (*Tick as appropriate*)

Section B: Household Characteristics

B/1 What is the household type? **1**= Male headed/single wife……**2**= Male headed /polygamous …… **3**= Male headed, single ……**4**= Female headed Single ……**5** =Child headed

B/2 Size of your household (Number of HH cooked for) ……

B/3 Please indicate your education level **1**= None..... **2**= Primary..... **3**= Secondary..... **4**= Tertiary.....

B/4 Occupation of the household head: _____

1= Formal **2=** Informal **3=** Unemployed

B/5 Marital status: **1**= Single **2**= Married **3=** Widowed **4**= Divorced

B/6 How long have you resided in this area? _____

1= 6-10 years **2**= 11-15 years **3**= 16-20 years **4**= Over 20 years:_____

B/7 Main cooking material: Firewood □ Charcoal □ Gas □ Electricity □

Other □ (Specify)_____

Section C: Income sources and Levels

C\1 Which of the following activities form a basis of your most important source of household income? ***(List others additional sources)***

Activity	**Tick as appropriate**	**Average monthly income in Kshs**	**Month when important**	**Reason if any**
Food crops production				
Cash crop Production				
Cattle rearing				
Sheep and goat rearing				
Poultry rearing				
Bee keeping- ***(state of individual or group)***				
Wage from working on farm ***(specify type job)***				
Remittance from relatives				
Business e.g. shop keeping				
Business – *sale of jikos*				
Charcoal production locally				
Charcoal trading *(not in production)*				
Sale of fuel wood				
Salary from formal employment				
Others (specify)				

C/2 What is your household average expenditure per month? **1**= <Ksh 2500 **2**= Ksh 2500-5000 **3**= Ksh 5000-7500 **4**= Ksh >7500 **5**= Other

C/3 What are the main items for household monthly expenditure? **1**= Education **2**= Human Health **3**= Veterinary Services **4**= Food **5**= Energy Sourcing **6**= Transport **7**= Clothing **8**= Church **9**= Remittance to Relatives and Friends **10**= Others……..

Please indicate the amount used in purchasing the following items per week

Main expenditure category	Frequency Per week per month	Units	Price per unit	Total amount in Ksh
Fuel items				
Firewood				
Charcoal				
Kerosene				
LPG				
Electricity				
Others				
Food items				
Maize	Per week			
Locally milled	Per week			
Sifted maize mill	Per week			
Beans	Per week			
Rice	Per week			
Green grams	Per week			
Sugar	Per week			
Salt	Per week			
Tea	Per week			
Cooking oil	Per week			
Meat	Per week			
Milk (processed)	Per week			
Milk (unprocessed)	Per week			
Fruits	Per week			
Vegetables	Per week			
Tubers	Per week			
Other expenditures				
Loan repayments	Per month			
Clothing				
Family events				
Gifts				
Transport costs				

Medicinal/health costs				
School fees				
Other (specify)				
EXPENDITURE TOTAL:	Cross check with total income			

Section D: Domestic Energy Demand

F\1 Which types of energy source do you use at the domestic level? Indicate also amount consumed per month for each type by making use of the energy measures indicated in the table.

Household domestic energy source	**Measures**	**(amount used per month estimate)**	**Year adopted**	**Reason for using it**	**Source (*tick as appropriate*)**		
Cooking					**Forest**	**Farm**	**Market**
Fuel wood	Backload; Donkey cart; Bicycle load; Motorbike						
Charcoal	Bags (90 kg) or Debes/Buckets (18 kg);)						
Kerosene /paraffin	Litres						
Gas	Ksh per month						
Biogas	Labour cost						
others							
Lighting							
Kerosene /paraffin	litres						

Household domestic energy source	**Measures**	**(amount used per month estimate)**	**Year adopted**	**Reason for using it**	**Source (*tick as appropriate*)**		
Cooking					**Forest**	**Farm**	**Market**
Gas	Ksh per month						
Biogas	Labour cost per month						
Electricity	Ksh per month						
Solar portable	Purchase cost						
Solar fixed	Purchase cost						

THANK YOU FOR YOUR TIME AND INFORMATION