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DECLARATION

I, **Fabrice MUYOBOKE**, declare that this dissertation is my original work, and has not been submitted for a degree to the University of Rwanda or any other University.

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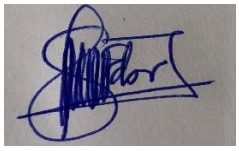
Signed……  ……

Date…05 November 2021

This thesis has been submitted for examination with my approval as a university advisor.

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Dr. KABANDA RICHARD

Thesis Advisor Signature

DEDICATION

This study is wholeheartedly dedicated to my dear parents.

To my brothers, sisters, family, and friends who have given me their advice and encouragement to complete this study.

Finally, we dedicate this dissertation to Almighty God, thank you for the guidance, power of the Spirit, and protection we offer you.

Thank you, God, for this far.

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I praise the name of Almighty God who has given me wisdom, faith, courage, and protection in every endeavor of my life. The completion of this dissertation is the culmination of a long process that was characterized by challenges and opportunities and in which many people and institutions have been of great help.

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All I can say to all of you is God bless you abundantly.

ABSTRACT

Energy consumption has been increasing in developing countries and play a crucial role in the lifestyle of millions of human beings in recent decades. Energy accessibility is increasing in Sub-Saharan Africa as well as in Rwanda. Considering access and energy use there is a substantial difference among households with different socio-economic characteristics. However, the key factors of that inequality remain a subject of debate among different scholars all over the world. In the case of Rwanda, there is insufficient empirical evidence to provide a full understanding of key factors determining household energy consumption specifically cooking fuel choice. This study contributes to that problem by examining the key factors of household energy consumption choice in Rwanda.

This study employed a multinomial logistic regression model to examine the key determinants of household energy consumption in Rwanda and it has specifically focused on cooking energies amongst households by using the EICV5 dataset. The regression analysis has mainly considered only three cooking fuels in Rwanda namely: firewood, charcoal, and gas. The marginal effects of each explanatory variable have been computed to show the probabilities of each in determining the outcome variable. The study findings show that area of residence, age, marital tutus, ownership of dwelling have a significant effect on choosing gas as cooking fuel. On other hand, the choice to use charcoal is significantly influenced by residence, education level, and ownership of the dwelling by household. The study reveals that use firewood and charcoal are still mostly used in Rwanda as cooking fuels across the different socio-economic classes. The use of gas is still low even in urban regions. The findings suggest that government should emphasize increasing clean and modern cooking energy among households through subsidies to both gas distributors' companies and poor households to enhance the use of cooking stoves to mitigate the health problems that arise from using traditional fuels.

Keywords: **Cooking, logistic, LPG, EICV, Rwanda**

LIST OF ACRONYMS

EDCL: Energy Development Corporation Limited

EICV: Integrated Household Conditions Living Survey

EPD: Energy Private Developers

FAO: Food and Agriculture Organization

FDI: Foreign Direct Investment

IEA: International Energy Agency

Kwh: Kilowatt-hour

LCH: Life Cycle Hypothesis

LPG: Liquefied Petroleum Gas

MININFRA: Ministry of Infrastructure

NISR: National Institute of Statistics of Rwanda

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Chapter I: GENERAL INTRODUCTION

1.0. Introduction

This section is made of the background of the study, problem statement, research objectives, research questions, expected outcome, the scope of the study, and the significance of the study**.**

1.1. Background of the study

Household energy consumption is defined as the number of energy resources spent by households on different appliances. The energy resources can include but are not limited to biofuel, waste, kerosene, electricity, gas, and solar (see, IEA, 2014). Energy is considered one of the very crucial aspects of human life**.** It is a vital commodity for the existence of modern life because in all economies all sectors, from housing, manufacturing, agriculture, transportation, and services, are highly dependent on various energy sources to function. However, even though energy is more important, many ends use for energy are different from country to country because of different climate conditions, policies, levels of economic development, and other factors (Bhattacharyya, 2019), it's normally agreed that the household sector is one of the most leading power consumption sectors. For instance, the energy consumption of the residential sector accounts for about approximately 30% of the total world energy consumption (Nnaji et al., 2012).

The household energy consumption pattern can be divided into several categories, including cooking, lighting, heating and cooling, and transportation. The numerous sources accessible for cooking include animal dung plant wastes, fuel-wood (primarily in developing nations), kerosene, gas, and electricity (Julius, 2013). Electricity/solar, petroleum/diesel (used for fueling generators), kerosene, candles, and traditional lamps, as well as firewood, are among the different options for lighting, which are generally determined by a household's socioeconomic standing (see, Barness and Floor, 1996). In addition, for space heating and cooling (also drinks cooling), Electricity and petroleum/diesel power generators are the most common energy sources accessible.

Finally, there are some options for transportation, where petroleum and diesel are used for fueling various transport vehicles (Ekholm et al., 2010). The fact that a household chooses one or more of these energy sources is a result of the interaction of many factors, including socioeconomic factors, household demographic characteristics, climatic conditions, house/product/vehicle characteristics, attitudinal variables, and environmental factors as cited by (Ekholm et al., 2010).

However, due to indoor air pollution, the use of biomass fuels for cooking is a major cause of health concerns in developing countries (Bruce et al. 2000; Ezzati and Kammen, 2001). For example, the World Health Organization (WHO) estimates that 1.5 million people die prematurely each year as a result of indoor air

pollution caused by solid fuel use (IEA, 2006). Recognizing the negative effects of traditional biomass fuels, the United Nations Millennium Project advises that by 2015, the number of families using traditional biomass for cooking be reduced by half, resulting in around 1.3 billion people moving to alternative fuels (IEA, 2006).

Most rural people in developing nations have limited access to modern and clean energy sources, relying on conventional fuel/biomass (woods, twigs, leaves, charcoal, animal dung, and crop residue) for nearly all of their energy needs. More than 2 billion people throughout the world are projected to rely on biomass for their basic energy needs, and biomass currently accounts for 20% of the global energy supply (FAO, 2006). Unless new policies are established, due to population growth, the number of people who rely on biomass fuels is expected to rise to 2.6 billion by 2015 and 2.7 billion by 2030 (IEA, 2006; Nnaji et al., 2012). According to the (EPD, 2019) report, 54 percent of Rwandan households have access to electricity, with 39 percent connected to the national grid and 15% using off-grid solutions. Rwanda, on the other hand, has set a goal to reach 512 MW of installed power generation capacity by 2023/24 through its electrification plans, intending to provide universal access to 100 percent of the population by 2023/24, with 52 percent on-grid and 48 percent off-grid connections (EDCL, 2018).

Rwanda's per capita energy consumption has risen from 175.394 Kwh in 1980 to 425.29 Kwh in 2016 (Ritchie & Roser, 2020). According to the Ministry of Infrastructure's Strategic Energy Sector Report (MININFRA, 2018), energy consumption is increasing today, with electricity accounting for only 2%, biomass accounting for approximately 85%, and petroleum accounting for 13% of total energy consumed in 2016. Energy is essential in human daily life (see, Tsani, 2010), and its consumption is increasing rapidly in developing countries. However, we know less about the factors that influence energy consumption in developing countries like Rwanda.

Empirical studies (Azam et al., 2016; Hondroyiannis et al., 2002; Liu, 2009; Zaman et al., 2012) point to a variety of factors, including population growth, economic growth reflected in industrial development, and FDI, to name a few. The majority of these studies are based on the realities of developed countries and are skewed toward macroeconomic implications. However, the successful adoption of clean energy is interconnected to household demand and energy usage preferences (Fydess Khundi-Mkomba et al., 2020).

This study argues that the microeconomic approach would provide a contextual and comprehensive understanding of factors influencing energy use considering the heterogeneity of energy consumers. This supports the aim of this study to determine the key drivers of energy consumption choice in Rwanda. The study specifically focuses on cooking in explaining energy consumption as empirically adopted by academicians and scholars in the energy studies field (Alemu & Gunnar, 2009; Bamiro & Ogunjobi, 2015; Nnaji et al., 2012; Ouedraogo, 2006).

1.2. Problem statement

Providing clean and affordable energy reliably for poor households in developing countries is an important prerequisite in the fight against poverty. Even though rural households frequently have simple access to traditional forms of energy such as firewood, charcoal, and agricultural residues to meet their primary energy demands, these fuels have negative effects such as harmful particulate matter emissions, deforestation, and environmental degradation. The longer it takes to acquire, transport, and use these fuels, the less time to spend on more productive labor or study. Furthermore, because women and children are more likely to be affected by many of these negative consequences, the issue has a significant gender and equality component (Bahadur et al., 2014). We know from empirical studies that energy use has both macro and microeconomic implications which can be either positive or negative depending on the development of the country, technology of generation, distribution, and use.

According to (NISR, 2018), even though the government of Rwanda has put in more efforts to increase energy access to clean energy, most people use traditional energy (wood) in cooking, and the percentage of the household that use cooking cleaner fuels (such as gas or electricity) increased from 13.9 percent in 2014 to 16.0 percent in 2017. There is still a significantly large gap among different classes of households regarding energy consumption choice and use. The available data on Rwanda shows that considering the welfare categories, poor households use 10% of electricity, while those in the rich households equivalent to 76% have electricity whereas the percentage of people who uses electricity from the grid or solar panels increased from 4 to 10.2% for quintile 1 (very poor) and charcoal or clean fuels(such as gas or electricity) increased from 13.9 to 16 % but there is a large gap between 1.3% for poor and 52.9% for rich households (NISR, 2018). This supports the idea that there are still some key aspects and factors of that unbalanced distribution and accessibility even usage among households. This study seeks to examine the key determinants that drive certain households to use a certain type of energy for cooking by employing data from the National Institute of Statistics of Rwanda EICV 5.

Current research will answer the following questions;

- How energy use is distributed among the different socio-economic classes in Rwanda?
- What is the marginal effect of each of the socio-economic variables on energy type used by households in Rwanda?
- What are the most significant factors governing energy use choice in Rwanda?

1.3. Research objectives

1.3.1. Major objective

The major objective of the research is to examine the determinants of energy household consumption use in Rwanda.

1.3.2. The Specific objectives

The specific objectives are the following:

- Determine energy consumption patterns across different socio class of households
- Examine the economic factors that affect the cooking fuel consumption choice among different households in Rwanda.
- Determine social factors that influence the household cooking energy consumption choice

1.4.Scope of the study

This research will be carried out in Rwanda and consider key determinants of household energy consumption choice in Rwanda and the research will consider data related to the determinants of household energy consumption from EICV5 which was carried out in 2016-2017 by NISR.

1.5. Expected Outcomes

This study will contribute to the literature by providing up-to-date evidence for Rwanda household energy consumption choice parameters, this study will also reveal the factors considered by different households in determining the energy type to be consumed in Rwanda. This study will help us to know consumption choice with the respect to the level of household energy consumption in Rwanda.

1.6. Significance of the study

This research will educate the Rwanda Rural duellers on which type of clean energy to be used and raise awareness of the related negative effects of the chosen type of energy. This research also will help the community to will gain through the recommendations from the research, as a result, the current study will benefit the community by connecting their living situation to the world of energy and environmental safety.

Chapter II: LITERATURE REVIEW

This section of the study is made of the definition of the key concepts, review of the related theoretical literature, empirical literature, empirical and theoretical gaps, the conceptual framework of the study.

2.1. Definition of Key Concepts

1. Biomass energy

Biomass energy refers to the energy of biological systems such as wood and waste (Gumau, 2007). Biomass has crucial importance in household cooking fuels. Biomass fuel is largely free and relatively available to most communities.

2. Kerosene

Kerosene is a significant petroleum fractional distillate. It is a relatively volatile liquid that is widely used in many households as the primary source of energy for cooking, lighting lamps, burning bush, and automobile fuel. It's also used as an insect repellent due to its strong odor. Kerosene causes numerous casualties as a result of exposure to kerosene fumes and poisoning of children who accidentally consume kerosene drink bottles (Amakiri et al., 2009).

3. Electricity

Electricity is a fuel obtained through other energies conversion, requiring inflated technology space. Generation and distribution require high-cost equipment. More so it is used for different purposes namely industrial, commercial, and residential purposes (Babatunde & Shuaibu, 2010).

2.2. Theoretical literature

2.1.1. Social cognitive theory

The theory has been started by the famous American social psychologist Bandura A, (1986). This theory suggests that individual motivation is a combination of behavior and environment. According to social cognitive theory, there exist two main important aspects of self-efficacy which is the confidence that one has in their action. The probability of finishing the tasks determines one's outcome anticipation. Positive results are supposed to encourage individual activity, and negative consequences are expected to discourage individual actions. Researchers have investigated energy-saving behavior determining factors where they are intended to see the effect of culture, economy, and education on energy consumption behavior among households. The study by (Wallis et al., 2016) found Income to have a positive effect on power and energy usage. An empirical study of (Ntona et al., 2015) in his research on student perceptions on energy usage relating to the environment, related to a sustainable environmentally friendly. However, the study concluded that apart from education, a household is a key to promoting energy use among people in the family.

2.2.1. Energy ladder theory

In the past, household fuel choice and energy demand were frequently viewed through the lens of energy ladder theory. This has highlighted the importance of income in evaluating fuel choices. The theory supposed that the traditional cooking stoves and fuels are mainly used by low-income households. While modern cooking technology and fuels are for the higher income level individuals. This means that when household earnings increase the households switch from using traditional to modern and clean energies such as electricity, and gas. The study of (Heltberg, 2005; Kroon et al., 2013) incorporated the energy demand ladder by arguing that household earnings increase, the demanding fuel is mainly influenced by types of appliances and where the choice depends on user objective.

This concept of an energy-demand ladder has also been heavily criticized because the widespread use of multiple fuels for a single purpose (such as cooking) implies the presence of fuel stacking for a given purpose (Davis, 1998; Heltberg, 2005). The theory is explained in three main stages. Firstly, families relying on biomass only in the second energy users move from using biomass to transitional energies like charcoal, and coal. Lastly, people because of the increase in earning level they use modern and clean energy like gas and electricity for cooking (see, Leach, 1992; Barnes, Krutilla, and Hyde, 2004).

2.2.2. Consumption theory

The fundamental choice-theoretic concept illustrates that an end-user has an intertemporal utility function that is influenced by consumption at all stages of life. Consumers structure their consumption plans to maximize their satisfaction or utility, according to the first principle of microeconomics. According to Abel, (1990) the consumer maximizes the utility subject to life budget constraints. The major theories of consumer behavior are the life-cycle and permanent-income hypotheses, which both relate consumption to lifetime income.

1. **Life-Cycle -Income Hypothesis**

Modigliani & Brumberg, (2013) have adopted this hypothesis and supposed that a household plans its entire life spending habits to maximize the total utility obtained from consumption over the course of its life. The LCH assumes that people plan their spending over their lives, taking into account their future earnings. As a result, they incur debt when they are young, assuming that future earnings will allow them to repay it. They then save during their middle years to maintain their standard of living when they retire. The LCH graph depicts a hump-shaped pattern of wealth generation and which becomes low during youth and old age and high during middle age.

2. **The permanent income Hypothesis**

Milton Friedman, (1957) the Nobel Prize-winning economist, proposed the permanent income hypothesis. Changes in consumer behavior, according to the hypothesis, are unpredictable because they are based on individual expectations. The permanent income hypothesis is referred to as a consumer spending theory that

argues that people spend money corresponding to the expected future average income. The level of expected long-term income is then regarded as the level of "permanent" income that can be safely spent. To protect against future income declines, a worker will only save if their current income is greater than their expected level of permanent income.

2.2.3. Demand theory

Demand theory is an economic concept that describes the relationship between consumer demand for goods and services and market prices. The demand curve, which relates consumers' needs to the number of goods readily accessible, is based on demand theory. As more of a good or service becomes available, demand falls, and the equilibrium price falls with it (A. Greenlaw et al., 2017). Demand theory emphasizes the role of demand in price formation, whereas supply-side theory emphasizes the importance of supply in the market. The demand for a product at a given price reflects the feeling of comfort that a consumer expects from the product. This level of satisfaction is known as utility, and it varies by consumer. The utility of a good or service to satisfy a want or need, and the consumer's ability to pay for the good or service, determine its demand. In effect, real demand occurs when an individual's ability and willingness to pay are matched by his or her willingness to satisfy a desire.

2.3. Empirical literature

According to a study in Nigeria on energy use drivers using a multinomial logistic model (Ogwumike et al., 2014), most Nigerian households use firewood for cooking and kerosene for lighting. Another study (Bartiaux & Gram-hanssen, 2005; Cramer et al., 1985) discovered that as the education level increased, domestic electricity consumption significantly reduced. Alemu and Gunnar, (2009) conducted an empirical study to investigate the factors influencing household fuel choice in Ethiopia. The findings show that the distribution of fuels used for a single purpose like cooking, recommends fuel stacking than energy-ladder. The high kerosene prices cause people to use solid fuels like wood, charcoal, or a combination of non-solid fuels (gas, electricity, wood, charcoal).

According to the research of Ogwumike et al.,(2014), father and mother education are negatively related to firewood but positively related to the use of kerosene and gas. The father's education level was found to be positively significantly related to electricity use for cooking, whereas the mother's education level was not statistically significant in electricity use. Similarly, the same study discovered household size to be insignificant for choosing both gas (LPG) and electricity as cooking fuels, resulting in to increase in the use of firewood and decreasing in using kerosene. A change in the household poverty status has a 1.59 percent increase probability in firewood use and but it decreases 2.45 percent probability for kerosene use.

Démurger & Fournier, (2011) conducted an empirical study in 10 villages of Labagoumen Township in northern China, to examine energy consumption patterns. The study revealed that income is an important factor for determining energy use and wealth has a significant negative impact on firewood consumption. More

so in some of the top wealth distribution, some households may not be able to change their cooking stoves which cause continuing reliance on traditional cooking methods.

The studies of (Bamiro & Ogunjobi, 2015; Rao & Reddy, 2007) discovered that households with either of these two education levels were more likely to use cleaner and more efficient fuels, and households with postsecondary education were even more likely to use cleaner and more efficient fuels than those with secondary education. Households with a more educated member are more likely to use cleaner, more efficient fuels as their primary source of energy. The results also show that the choice of energy varies depending on where you live, with cities preferring to use modern energies in our day and age. This could be because these households are aware of the health and environmental risks of these fuels. Adetunji et al., (2007) conducted an empirical study on household energy consumption patterns in the Osogbo Local Government Area of Osun State. The data was analyzed using ordinary least square regression. In this study, variables such as age, level of education, occupation, income, and household size were used. The regression results show that the age, level of education, and occupation of the household head have no bearing on the household's choice of energy consumption. The study of (Özcan et al., 2013) discovered that the use of natural gas is positively correlated with monthly earnings and the age of the head of the household.

According to the findings of (Nnaji et al., 2012), being married versus not being married and other legal statuses results in a negative estimated coefficient for charcoal and kerosene. In particular, the percentage ratio shows that married people are.197 less likely than others to switch from firewood to kerosene. This could be because married people tend to have large families, which necessitate the use of firewood, which is inexpensive. The level of education corresponds to the hypothesized theoretical expectation of a positive effect on the choice of charcoal and kerosene as respondents' level of education increases. This is obvious because a highly educated respondent (especially a woman) is more likely to lack time to gather firewood due to involvement in other activities and thus may value using firewood alternatives more profoundly. According to the empirical study conducted by (Rahut et al., 2017), household size is positively and significantly associated with the use of fuelwood, electricity, and other fuels, but negatively and significantly correlated with the use of kerosene. Based on the theory of reasoned action, many researchers have designed an energy consumption behavior model. (Pothitou et al., 2016) investigated the role of environmental knowledge and attitudes. Habits and energy issues in households and potential pro-environmental behavior. Hast et al.,(2015) evaluated Chinese consumers' attitudes toward green energy as well as their intentions to buy green electricity or renewable energy systems. Income, building type, and perceptions of renewable energy potential all influence willingness to pay for a green electricity product, according to the findings. As previously stated, financial status is strongly related to electricity consumption, whether on a national or individual level.

According to Farsi et al. (2007), better education improves family awareness of the adverse effects of biomass resources such as firewood, as well as the benefits of modern fuel use in terms of efficiency and convenience. According to Chambwera and Folmer (2007), education can be viewed as a long-term approach to addressing

and managing the family heads' demand for firewood (Farsi et al., 2007). Other research indicates that tastes and cultural preferences influence the choice of fuel sources in many developing countries (Arthur et al., 2012; Farsi et al., 2007; Schlag and Zuzarte, 2008).

According to Gupta and Köhlin, (2006)'s research, availability and ease of use are critical factors in fuel selection. Fuel selection is also related to other factors such as ethnicity and region of residence. For example, (Rao & Reddy, 2007) examine household fuel choice decisions separately for rural and urban households in India and discover that the factors influencing fuel choice are completely different in the two areas.

Based on the theory of planned behavior, Abrahamse and Steg, (2009)proposed the following hypothesis. 1. There is a significant relationship between household energy usage and social demographic factors (such as income, family population). 2. Psychological factors were the primary determinants of energy consumption. The results of the regression analysis revealed that demographic factors influenced the use of household energy. Yazdanpanah et al., (2015)investigated the link between social psychological factors and the use of renewable energy. Researchers concluded that social-psychological factors (such as behavior, perception, and subjective norm) had a significant impact on the adoption of the Energy Sources Renewable (RES) project.

An Empirical Study by Botetzagias et al., (2014)investigated the relationship between various factors and energy-saving behavior using a telephone interview. He assumed demographics, psychological variables, and moral variables to be explanatory variables, with energy conservation behavior serving as the explanatory variable for regression analysis. The researchers proposed that demographic characteristics, psychological factors, and moral factors all influence power-saving behavior. The findings revealed that age, gender, and perceived behavioral control all have a significant impact on power reduction.

A multinomial logit model was used in the study of Ouedraogo, (2006) to analyze the factors determining urban household energy preferences for cooking in Ouagadougou. The analysis demonstrated that poverty factors such as low income, poor access to electricity for primary and secondary energy use, low housing standards, and household size contributes to the inertia of household cooking energy preferences. The use of firewood decreases as one moves from low-income to higher-income households. For firewood and charcoal, the marginal effects of household income are negligible. The marginal effect of primary education level is meaningful at the one percent level and with a sign: when switching from higher education to primary education, the probability of using firewood as the primary cooking energy increases by 0.61 percent. The size of the household, cooking habits, and formal education level of the household heads all have a significant impact on wood energy preferences. Wallis et al., 2016 discovered that income has a positive effect on electricity usage in their empirical study. Ntona et al., (2015) researched students' perspectives and attitudes toward energy and its use in the environment; their findings indicated that education requires a critical shift toward an environmentally sustainable orientation. Aside from school, the family is an important place to instill energy-saving habits. Subsidies, for example, influence electricity consumption behavior.

Ordered logit and probit models were used in the empirical studies of (Nlom and Karimove,2014, Eakins,2013; Mensah and Adu, 2013) to examine the factors that influence household energy choice to cleaner sources. Income, firewood price, education level of household head, the share of dwelling with other people, urban household, and access to Liquefied Petroleum Gas (LPG) were discovered to have a positive influence on adopting more cleaner sources. Other variables, such as electricity price, kerosene price, age of the household head, household size, gender (male) of the household head, and access to firewood, have a negative impact on the likelihood of using clean and efficient fuels.

2.4. Empirical and theoretical gaps

Most empirical studies on energy use focus on macroeconomics analysis factors governing energy patterns and apply to developed countries, while other studies on developing countries use microdata, but the exhaustibility of all variables remains a point of debate among scholars and an important gap to discuss

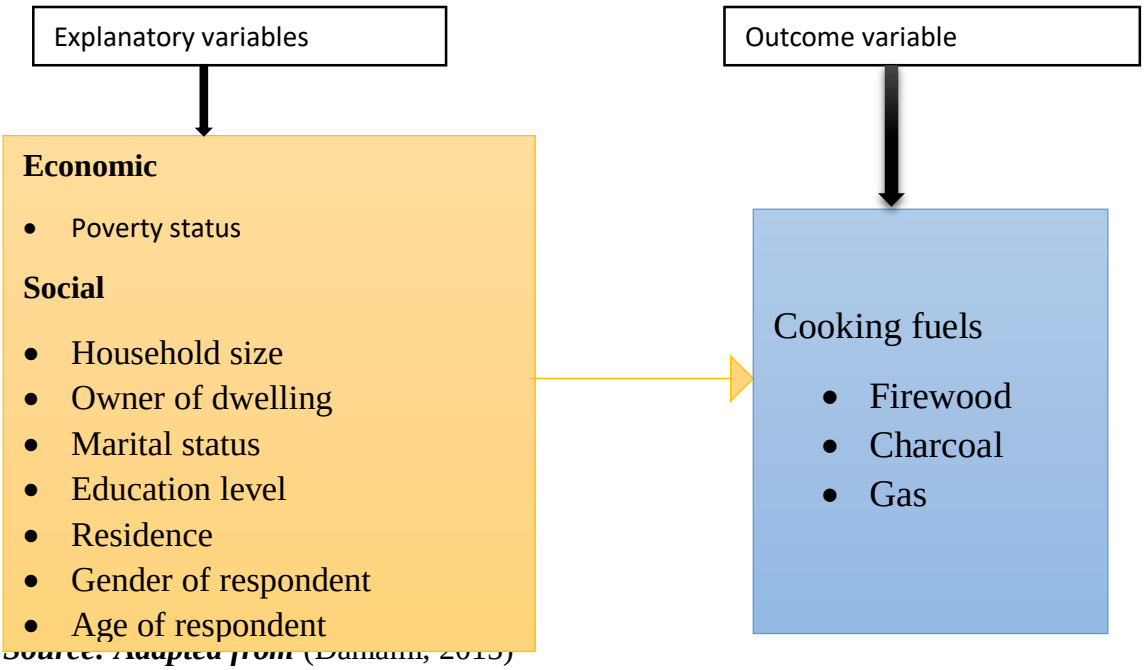
The empirical findings present mixed findings of various socioeconomic, demographic variables from different studies, but the inconclusiveness appears to be attributed to the study's scope and context. In the case of Rwanda, there are few studies on energy consumption choices, and the few that are available are based on a small scope of the study, covering only a small portion of the country in their analysis. Therefore, previous studies did not consider variables related to cooking fuel choice like quintile in their analysis. This study fills the gap by employing the latter variables in the analysis.

2.5. Conceptual framework

The conceptual framework was built based on the findings from the theoretical and empirical review of previous works on energy consumption choice. This conceptual framework clearly explains the causal relationship between outcome variables and dependent variables. The dependent variable in this study is the main source of cooking and it is a categorical variable (firewood, charcoal, and gas). The independent variables are divided into economic such as poverty status while the social variables like marital status, residence, gender of respondent, owner of the dwelling, education level, household size. The control variable is the age of the respondent. The inclusion of those independent variables was informed by both empirical and theoretical literature, and the choice of outcome variables cooking fuel choice informed by related energy studies (Abrahamse & Steg, 2009; Bedir et al., 2013; Guo et al., 2018; Heltberg, 2005; Jan et al., 2012; Marathe & Eltrop, 2017; Ogwumike et al., 2014).

To explain the energy consumption in the context of Rwanda, we have decided to use energy consumption in terms of cooking as a proxy, the reason here is that the micro dataset from NISR, EICV5, contains the main source of cooking, we have chosen to use (Firewood, charcoal, and gas) as cooking fuels in explaining the consumption behavior of the households who are the unit of analysis of this study. This is also based on the

available previous empirical and theoretical studies on energy use that consider lighting and cooking in their analysis (see, Fydess Khundi-Mkomba et al., 2020; Ouedraogo, 2006).



Source: Adapted from (Danlami, 2015)

Empirical studies by (Ouedraogo, 2006; Pundo & Fraser, 2006) show that the household size, level of education, and whether or not a household own dwelling has a significant impact on household energy use choice. People with more education levels tend to shift from firewood to charcoal and kerosene. Similarly, the empirical study by Ogwumike et al.,(2014) points out that Nigeria uses firewood as cooking fuel and kerosene for lighting. It has been argued that the age of household head has an impact on energy use for lighting and cooking among households (Mekonnen, 2014). Those empirical findings and many others support our main hypothesis that socioeconomic characteristics have a significant impact on energy use fuels choice are in line with our conceptual framework.

Chapter III: RESEARCH METHODOLOGY

3.1. Data

The study used data from Rwanda's National Institute of Statistics' fifth Integrated Living Standards Survey (EICV5) (NISR). This survey included 14580 households units that constitutes 64314 individuals(people). This survey has taken place in 2016/2017 and participants answers questions related to their spending on different activities, income, and many other household characteristics. NISR (2018). The stratified multi-stage sample design was used in EICV5. In 27 of the country's 30 districts, 40 sample clusters were selected, with 12 households interviewed in each cluster; in the remaining three districts (in Kigali City), 60 clusters were selected, with 9 households interviewed in each cluster. Each district's clusters (villages or neighborhoods) were chosen at random, with probabilities proportional to the number of households counted in the 2012 Rwanda Census. Households were chosen at random within each cluster.

3.2. Study variables

This study includes two categories of variables, the outcome variable is the main source for cooking which is the categorical outcome variable. The selected variables as covariates in this study are household size, residence (Urban or Rural), level of education, gender of respondent, age of respondent, quintile of household, owner of the dwelling, marital status, poverty status (welfare categories) as depicted in table 6 **(see appendix)**

3.3. Econometric analysis

For modeling consumer behavior, we take into consideration consumer preference. The consumer is always willing to the consumer the most preferred products and subject to their budget (Varian, 2010). There are a lot of factors that may influence household fuel consumption choices can be economic or non-economic. The data analysis in this study uses a multinomial logistic regression model to capture well the microeconomic key drivers of the household's energy use in Rwanda.

3.3.1. Multinomial Logistic Regression model

Referring to (Ogwumike et al., 2014), multinomial is used when the dependent variable is categorical and has more than two categories. This model shows the probability of each explanatory variable in determining the outcome(dependent) variable. we adopted the Multinomial logistic model to analyze the determinants of energy use for cooking as the dependent variable in our study have three categories. The calculation of marginal effects of each variable on the outcome variable in the model has been done also.

3.3.2. Model Specification

The analytical framework will adopt the following multinomial logistic regression model,

$$Prob(Y_i = j) = \frac{e^{\beta_j X_i}}{\sum_{k=1}^{K} e^{\beta_k X_i}} \; ; j = 1,2,..K$$

Where $\boldsymbol{Y_i}$: is the observed energy (fuel) used by households.

e: Exponential function

X_i: vector of household characteristics in the model

β: vector of parameters

j: fuel is chosen by household

i: observation of household

K= Number of fuels

The coefficient results can be positive or negative, therefore a positive sign shows that the variable is increasing the likelihood of the outcome. whereas the negative means that it is reducing the likelihood of the outcome to happen. A large coefficient means that this has a high effect on the outcome and small or nearly zero means that the effect is very low.

Chapter IV: RESULTS AND DISCUSSION

2.2. Introduction

The chapter presents the descriptive statistics and empirical analysis related to the energy use in form of cooking using Rwanda household data from EICV5 conducted to 14,580 households in 2016-2017. Furthermore, the study uses a Multinomial logistic regression model and the Marginal effect of each explanatory variable on the outcome variables.

2.3. Descriptive statistics of respondents

The distribution of respondents is most important in any study since it allows the researcher to examine the relationship between different data from various variables considering responses from respondents. It considers also the distribution across different socioeconomic characteristics of respondents.

2.3.1. Distribution of the respondents by the main source of Cooking

Table 1 shows the distribution of the main source of cooking in Rwanda, these results indicate that the number of respondents who use gas is 1.12%, 85.49 % use firewood and 13.40% uses charcoal for cooking. Implying that the highest number of people in Rwanda still rely on firewood when cooking.

Table 1:Distribution of the respondents by the main source of cooking

The main source of cooking fuel	Freq.	Percent
Firewood	42057	85.49
Charcoal	6591	13.40
Gas	550	1.12
Total	49198	100.00

Source: Author' computation using EICV5

2.3.2. Distribution of the respondents by the level of education

Table 2 indicates the distribution of education levels of respondents in Rwanda. Results indicate that out of all respondents under study 8.97% have no education, 73.97% have primary, 14.28% have secondary and 2.83% have university education respectively. The majority of respondents have primary level education (73.97%) followed by secondary education (14.28%).

Table 2: Distribution of the respondents by the level of education

Level of education	Freq.	Percent
No education	4412	8.97
Primary	36371	73.93
Secondary	7025	14.28
University	1390	2.83
Total	49198	100.00

Source: Author' computation using EICV5

2.3.3. Distribution of respondents by area of residence

Table 3 shows rural-urban distribution among respondents, these results indicate that the number of people in rural was 83.39%, the number of people living in urban was 16.61% in Rwanda so it clearly shows that a high number of people in Rwanda live in rural areas.

Table 3:Distribution of the respondents by residence

Area of Residence	Freq.	Percent
Rural	41024	83.39
Urban	8174	16.61
Total	49198	100.00

Source: Author' computation using EICV5

2.3.4. Distribution of the respondents by welfare categories

Table 4 shows welfare categories distribution among respondents, these results indicate that the number of respondents who belong to severely poor was 14.26%, the number of respondents belonging to the moderately poor category was 21.55 % in Rwanda and 64.19% are in the non-poor welfare category. Therefore, the highest number of respondents are in the non-poor category.

Table 4:Distribution of the respondents by welfare categories

Welfare categories	Freq.	Percent
Severely poor	7015	14.26
Moderately poor	10601	21.55
Non-Poor	31582	64.19
Total	49198	100.00

Source: Author' computation using EICV5

2.4. Distribution of the main source of cooking considering socio-economic characteristics

As shown in Table 5, among the respondents with no education 90.07% use firewood, which is higher compared to those who use charcoal 9.27% and 0.6% use gas. The results show that the number of people who use firewood decreases when people have attended school, among respondents with primary to university 13.8% of them uses charcoal and 1.16% uses Gas for cooking in their homes. This highlights the impact of school attendance on the reduction of firewood and the adoption of clean cooking energies like gas.

The results in Table 5 indicate that among the respondents who live in rural areas (95.96%) use firewood when cooking in their homes, 3.93 uses charcoal and 0.12 % uses gas which implies that most rural dwellers use firewood as the main cooking fuel. 60.92 % of urban people use charcoal when cooking and 6.14% uses gas as cooking fuel. This shows that urbanization has a positive effect on the use of charcoal and gas as cooking fuel even if the users of gas are still low considering the importance of decreasing environmental degradation. In the case of marital status, the results show that 86.41% of married respondents use firewood, 12.68% use charcoal, and 0.91 % use gas. 83.92 % others (this includes divorced, widow, separated, single) use firewood,14.73% uses charcoal, and 1.35 uses gas for cooking.

Considering the gender of the respondent, the results in Table 5 show that among female respondents 86.27% use firewood, 12.68 uses charcoal, and 1.05 uses gas for male respondents 84.67% use firewood. 14.15% uses charcoal and 1.18% uses gas this implies that there is a small impact of the sex of the respondent on the choice of cooking fuel. Table 5 shows that based on the welfare categories of the respondents, 98.68 of severely poor and moderately poor people use firewood in cooking, 1.32 use charcoal and none of them use gas when cooking. In the case of non-poor category respondents, among them 78.13% use firewood, 20.13% uses charcoal and 1.74 % uses gas in cooking.

Table 5:Distribution of the main source of cooking considering socio-demographic characteristics

Variables	Categories	The main source of cooking fuel		
		Firewood	Charcoal	Gas
Level of education	no education	90.07	9.27	0.66
	primary up to university	85.03	13.8	1.16
Area of residence	Rural	95.96	3.93	0.12
	Urban	32.93	60.92	6.14
Marital status	Others	83.92	14.73	1.35
	Married	86.41	12.68	0.91
Sex of respondent	Female	86.27	12.68	1.05
	Male	84.67	14.15	1.18
Welfare categories	Severely poor and moderately poor	98.68	1.32	0
	Non poor	78.13	20.13	1.74
Quintile of household	quintile 4 and quantile 5	69.64	27.72	2.63
	quintile 1 up to quintile 3	97.19	2.81	0

Source: Author' computation using EICV5

The results in table 5 also show that for people in quintile 1 up to quintile 3, 97.19% of them use firewood when cooking, 2.81% uses charcoal, and none of them uses gas. This implies that gas is expensive for those people in lower quantiles. Of the people in quintiles 4 and 5, 27.72% uses charcoal and 2.63% uses gas this shows increases in the use of gas in upper quintiles.

2.5. Results of Multinomial Logistic Regression Model

By using STATA Statistical Software version 15, we have got the marginal effect results presented in Table 7. The sample size of the study was decreased from 64,314 respondents to 45,423 respondents, it is because during the interview some respondents have not answered the questions which have been taken as missing values in data entry during EICV5. As variables contain some missing values, during the analysis we used

only valid observations.
Multinomial Logistic regression was selected because the response variables source of cooking is a categorical variable (Firewood, charcoal, and gas). Further, logistic regression provides an opportunity to investigate multiple factors at a time and estimate the effect of one factor compared to the reference.

The results show that being in an urban area has a positive effect on using charcoal in cooking. As shown in results being in an urban area increases statistically significantly the chance of using charcoal when cooking by 16.98 percentage points rather than being in a rural area. Being in an urban area increases statistically significantly the chance of using gas when cooking by 1.71percentage point rather than being in a rural area. Implying that living in urban areas encourages the use of gas and charcoal over firewood.

The results in table 7 show that being married increases insignificantly the probability of using charcoal by 0.24 % than another marital status. Similarly, being married decreases statistically insignificantly the probability of using gas by 0.40% than another marital status (separated, widow, single, divorced). The results in table 7 show that a one-year increase in age decreases statistically significantly uses of charcoal by 0.80 percent points and but it decreases statistically significantly the chance of using gas. The results in table 7 show that one increase in household members increases statistically insignificantly the chance of using charcoal by 0.01 percent points and it decreases statistically significantly the chances of using the gas by 0.35 percent points.

Table 7 shows that ownership of dwelling by household decreases statistically significantly the use of charcoal by 10.09 percent points than living in a dwelling owned by others. Similarly, owning a dwelling by household decreases statistically significantly the use of gas by 0.88 percent points than living in a dwelling owned by others. Results in Table 7 reveal that being male decreases statistically significantly the chance of using gas when coking by 0.30 percent point rather than being female. Implying that the effect of gender in choosing cooking fuel is meaningful for gas only.
The results in table 7 show that having at least a primary education level increases statistically significantly the probability of using charcoal as cooking fuel by 0.99 percent points rather than having no formal education. Having at least primary education to university studies decreases statistically insignificantly the probability of using gas as cooking fuel by 0.23 percentage points rather than having no formal education. This shows the significant influence of education level on choosing charcoal as cooking fuel over firewood.

The results show that the poverty status of the household has a significant effect on the choice of cooking fuel in Rwanda. Belongingness of people in severely poor and moderately poor categories decreases statistically chances of using charcoal by 8.87 percent points than belonging in a non-poor category. Similarly, the belongingness of people in severely poor and moderately poor categories increases statistically chances of using gas by 0.96 percent points than belonging in the non-poor category.

Table 7 shows that belonging in quintile 1 up to quintile 3 increases statistically insignificantly the chance of using charcoal when coking by 6.23 percent point rather than being in quintile 4 and 5. Belong in quintile 1 up to quintile 3 decreases statistically insignificantly the chance of using gas when coking by 21.85 percent point rather than being in quintile 4 and 5. Implying that the effect of quintile in choosing cooking fuel is not meaningful in this study.

Chapter V: SUMMARY, CONCLUSION AND POLICY IMPLICATION

This chapter presents the summary of all findings of the study, conclusion, and policy implications. It also suggests future areas of study.

5.1. Summary of the Main Findings

The study revealed that the use of firewood in Rwanda is about 85.49%, which is still high and 13.40% uses charcoal when cooking. Conversely, only 1.12% of the total sample uses gas for cooking this shows that the uptake of clean cooking fuels is still low.

The study findings showed that the choice of using gas is mainly influenced by household size, residence, marital status, age, sex, and ownership of the dwelling. Studies find that increases in household size have a negative effect on the use of gas because since it is comparatively cheaper to use firewood to cook for many people as it has a lower consumption rate per unit of time compared to gas and charcoal similar to what was concluded by(Nnaji et al., 2012). One year increases in age resulting in decreasing probability of using gas cooking fuel this happens mainly in rural areas. Being married significantly decreases the probability of using gas a cooking fuel. The study found that one-year increases in age are linked to the decreases in the use of charcoal because the more people get older there is need of increasing the use of firewood as cooking fuel.

The study findings showed that the choice of using charcoal is mainly influenced by education level, age, residence, ownership of the dwelling. The study results showed that having education primary to university studies strongly influence charcoal cooking respectively which is similar (Nnaji et al., 2012) who found that level of education concurs with the hypothesized theoretical expectation of a positive effect on the choice of charcoal this because educated people lack time to collect firewood to uses and also they know the effect of using more firewood on environment degradation. The current study also finds that being in urban areas has a significant positive impact on the use of charcoal as cooking fuel in their home. Owning a dwelling as a household statistically decreases the use of charcoal for cooking also influences negatively the use of gas in the household. This study shows mixed evidence regarding traditional energies as being the most dominant fuel for the poor households for cooking in their homes. However, the study found the people in quintile one up to quintile none of them who use gas a cooking fuel. This shows the high dependence of the traditional cooking energies in Rwanda and also the use of the modern cooking energies is slightly increase mainly in urban areas for example charcoal is the one mostly used in cities, use of gas is still low in developing countries like Rwanda where people capacity to afford the cost is an issue.

5.2. Conclusion

This research study was aimed at analyzing determinants of energy consumption fuel choices in Rwanda by employing a multinomial logistic regression model employing nationally representative household-level dataset EICV5 conducted by NISR in 2016-2017 with the sample of 14,580 households which contain 64,314 respondents. The study examines the probability of each selected explanatory variable in determining the uses of firewood, charcoal, and gas for cooking in Rwanda.

The study found that household size, gender, education level, area of residence, ownership of the dwelling is among the important factors that significantly drive the household in the choice of cooking fuels among households in their homes. The findings reveal that the uptake of using gas is still low for cooking. In Rwanda, the majority of households (%) still use traditional energies for cooking such as charcoal, firewood, etc….., which harms the environment, climate change, and health effects on people. This low modern energy use can be a result of the poverty status of people in most of the developing countries as well as Rwanda. Where some people cannot afford the costs of modern cooking fuels. Due to the constraint of data availability and composition where the dataset doesn't contain all variables that can be helpful explicitly explain energy fuel choice, the study didn't include all factors that may influence households to choose firewood, charcoal, and gas as cooking fuel in Rwanda. Therefore, there is a need for further inclusion of other important variables such as tastes, attitudes, head of household information, perception, and awareness levels about clean cooking energy technologies that would help capture the full pattern of cooking fuels as well as the choice of using one among others.

5.3. Policy implication

The policy implications are informed by the analysis and the finds of the study. Therefore, this study suggests out some policies which can be useful.

- The need for government and non-state actors to have joint efforts in prioritizing generation of household wealth, non-farm enterprises, and comply with the Liquefied Petroleum Gas (LPG) manufacturers and retailers to facilitate easy access to specifically in rural areas.
- to encourage the urbanization policy as well as to reduce the wealth inequality across different regions of the country to help people to lift their welfare status may help households to switch to clean and modern energy sources for cooking purposes.
- Also, the enhancement of green and clean energy use policy in the country will reduce the use of traditional sources to reduce the health effects on people across the country. This enhancement can be done by facilitating people in remote rural areas to have access to clean and modern energy by giving subsidies to poor people to afford the use of improving cooking stoves.

5.4. Suggestions for Future Research

Future studies could investigate the factors that influence the uptake of renewable energies in Rwanda including ease of access, behavior, psychological factors, and also energy consumption in terms of lighting as well as exploiting cooking fuels using an extension of the scope by increasing the types of fuel under consideration as current study considered only three of them.

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Appendix

Table 6:List of variables and definitions used in the analysis of household cooking fuel choice.

Variable	Descriptions
Age of respondent	Quantitative(years)
Household size	Households' members (numbers)
Gender of respondents	Dummy (1 if male, 0 female)
Level of education	1: Primary to university education 0: no education
Residence	Dummy (1 if Urban, 0 Rural)
Poverty status	1: Severely poor and moderately poor 0: non-poor
Marital status	1: Married [1] 0: others [2]
Quintile of household	1: quintile 1 up to quintile 3 0: quintile 4 and quintile 5
Owner of the dwelling	1: owned by household 0: others

Table 7:Results of Multinomial Logistic Regression Model for Cooking/Marginal effects[3]

Variables	Charcoal	Gas

[1] Married include married monogamously with legal certificate, married monogamously without legal certificate married polygamously
[2] Others here includes separated, divorced, widow(er), single

[3] These estimates were obtained from running Multinomial Logistic regression in Stata 15 with firewood as base category.

Education level[4]	0.0099**	-0.0023
logage	-0.0080***	-0.0074***
Loghhsize	0.0001	-0.0035***
Residence (Urban)[5]	0.1698***	0.0171***
Marital status[6]	0.0024	-0.0040***
Dwelling [7]	-0.1009***	-0.0088***
quintile [8]	0.0623	-0.2185
Sex of respondent (male)[9]	-0.0004	-0.0030***
Poverty status [10]	-0.0887	0.0096

Total Observations 45,423

*** p<0.01, ** p<0.05, * p<0.1 (statistically significant)

[4] For variable Education "no education" used as reference
[5] For variable residence "rural" used as reference
[6] For variable marital status "other legal status than married" used as reference
[7] For variable dwelling "owned by others than household" used as reference
[8] For variable quintile "quintile 4 and quantile 5" used as reference
[9] For variable sex of respondent "female" used as reference
[10] For variable poverty "non-poor" used as reference