UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

SOCIO-ECONOMIC DETERMINANTS FOR HOUSEHOLD UPTAKE OF MODERN ENERGY TECHNOLOGIES: EVIDENCE FROM RWANDA PANEL DATA

A Thesis submitted to the African Centre of Excellence in Energy studies for sustainable development (ACE-ESD) in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE IN ENERGY ECONOMICS

By: Anastase NSHIMIYIMANA (220000367)

Advisor: Dr. Johnson Bosco RUKUNDO

December, 2021

Kigali-Rwanda

Declaration

I, the undersigned, declare that this Thesis is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials that will be used for the thesis work will have been fully acknowledged.

Names: Anastase NSHIMIYIMANA (220000367)

Signature:



Date of Submission:

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

Dr. Johnson Bosco RUKUNDO

Thesis Advisor

Signature 

Dedication

To my beloved Family

Acknowledgements

Firstly, I would like to express my special appreciation thanks to my Master thesis supervisor, Dr. Johnson Bosco RUKUNDO for his support and guidance during the course of this thesis. I would especially like to thank the World Bank, which has provided scholarships to pursue higher education at the African Centre of Excellence in Energy for Sustainable Development (ACE-ESD) in University Of Rwanda-College of Science and Technology.

Lastly, I would like to thank my family for their continued support and encouragement

Abstract

The world population has continued to use biomass fuel for domestic energy consumption through cooking, water boiling, heating, and lighting. The usage of biomass in an inefficient way increase the fuel demand for the households. Despite the multiple social economic, health and environmental benefits of improved cook stove programs, they failed to capture the recognition worldwide and a set of sociocultural, economic, institutional barriers and cook stove and fuel characteristics contribute to the slow adoption of this program. This study provides an evidence of household driving factors that play a crucial role in the uptake modern energy technologies in Rwanda. The study is based on panel dataset built from third, fourth and fifth integrated household living standards survey (EICV 5) of the National Institute of Statistics of Rwanda. Using binary logistic regression analysis, the study shows that type of habitant, age of household head, household location are the main significant household factors influencing the adoption of improved cook stove while value of cook stove, amount spent on cooking fuel and time spend on cooking fuels are the most significant stove and fuel factors determining the adoption of usage of improved cook stove. The study revealed that for substantially improved rate of adoption they should be consistent and focused cooperation of government and non -governmental organizations to work in parallel for developing energy policy frameworks like dissemination of modern energy technologies.

Keywords: Biomass, rural household; improved cook stoves, Binary Logit regression, Rwanda

Table of Contents

Declaration ii
Dedication iii
Acknowledgements iv
Abstract v
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF ABBREVIATIONS ix
Certification 11
CHAPTER ONE: GENERAL INTRODUCTION 12
1.1 Background of the study 12
1.2 Statement of the problem 15
1.3 Research questions 16
1.4 Major objectives 16
1.4.1 Specific objectives ..... **Error! Bookmark not defined.**
1.5 Research hypothesis 16
1.6 Significance of the study 17
1.7 Scope of the study 17
CHAPTER TWO: LITERATURE REVIEW 18
2.1 Empirical Review ..... **Error! Bookmark not defined.**
2.2 Research gaps 21
CHAPTER THREE: RESEARCH METHODOLOGY 22
3.1 Conceptual framework 22
3.2 The theoretical framework 23
3.3 The data source 24
CHAPTER FOUR: RESULTS AND DISCUSSIONS 25
4.1 Descriptive results 25
4.2 Results from estimations of Binary Logit Regression Model 27
CHAPTER FIVE: CONCLUSION AND RECOMMENDATION 30
References 32

LIST OF TABLES

Table 1.descriptive statistics of dependent and all control variables by household location in EICVs (2010, 2013/14 and 2016/17) to be used in Binary Logit Regression Model 25

Table 2.Estimations of factors influencing the household's adoption of improved energy technology in Rwanda..... 27

LIST OF FIGURES

Figure 1.Conceptual framework of factors inducing adoption of improved cook stoves.....22

Figure 2.Cumulative probability distribution of annual income and using ICS 36

Figure 3.Cumulative probability distribution of household size and using ICS.....**Error! Bookmark not defined.**

Figure 4.Cumulative probability distribution of annual hours spent on collecting cooking fuels and using ICS 37

Figure 5.Cumulative probability distribution of annual hours spent on cooking activities and using ICS.....38

Figure 6.Cumulative probability distribution of total value of cook stove and using ICS 39

Figure 7.Cumulative probability distribution of total amount spent on cooking fuels and using ICS 40

LIST OF ABBREVIATIONS

EICV**:** Integrated Household Living Conditions Surveys

NISR**:** National Institute of Statistics of Rwanda

ICS**:** Improved Cooking Stove

LPG**:** Liquefied Petroleum Gas

WHO**:** World Health Organization

IEA**:** International Energy Agency

GIZ**:** Gesellschaft fur Internationale Zusammenarbeit (German Technical Cooperation Agency)

GACC**:** Global Alliance for Clean Cook stoves

SDG**:** Sustainable Development Goal

Copyright

Anastase, 2021

Certification

This is to certify that this thesis has passed through the antiplagiarism and found compliant and this is approved final version of the thesis.

Title: SOCIO-ECONOMIC DETERMINANTS FOR HOUSEHOLD UPTAKE OF MODERN ENERGY TECHNOLOGIES: EVIDENCE FROM RWANDA PANEL DATA

Names: Anastase NSHIMIYIMANA

T**hesis Advisor**: Dr. Johnson Bosco RUKUNDO

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background of the study

Worldwide, energy is very crucial in meeting households' basic needs majorly for cooking, water boiling, heating and lighting. Worldwide over 3billion people rely on solid fuels including biomass materials as the main source of energy for the household and more than 90% of the consumption took place in developing countries. About of half of global population is dependent on traditional fuels and stoves to fulfill their energy prerequisite (Gebrregziabher, Z., Mekonnen, A., Kassie,M., & Kohlin, G., 2012).

(Rehfuess,E.A.,Puzzolo,E.,Stanistreet,D.,Pope,D.,&Bruce,N.G, 2014)Designate that the traditional fuels and stove to be inefficiency and are presumed to contribute about a third of worldwide carbon monoxide emission and other pollutants in biomass smoke affecting global climate change. In developing countries the unprocessed solid biomass such as wood, bio char, charcoal, animal dung among others serve as the main source of energy (GIZ, 2013). According to (International Energy Agency(IEA), 2010) , there were approximately 2.5 billion of people in developing countries more specifically in rural regions that relied on solid biomass to meet their energy needs and this report suggest that by 2030, the figure would even incline to more than 2.7 billion of people. Consequently, household's solid fuel low combustion affects both local and region quality of air to a long extend and hence influence human health (Anenberg,S.;Balakrishnan,K.;Jetter,J.;Masera,O.;Mehta,S.;Moss,J.;Ramanathan,V., 2013).

Today, middle income countries are facing the main challenge of accessing clean and efficient household energy (Levine,D., Bertramo, I., Blalock, T.G., & Cotterman, C., 2012). In the sub-Saharan region, the unprocessed solid biomass is the primary energy source used by approximately 80 percent of the households (World Bank, 2011)**.** Additionally, wood consumption is about 300

million tons, and the dependence is higher in the regions where population have low-income activities or are near to the forest resulting to the raised demand hence unsustainable harvest of fuel wood as the source of energy (Rysankova,D.,Putti,V.R,Hyseni,B.,Kammila,S.,and Kappen,J.F, 2014).

The combustion process of these solid biomass fuels consumes more energy than any other service as emphasized by (Diaoglou,V.,Van Ruijven,B.J., and van Vuuren,D.P., 2012)as consequence producing smoke that will negatively influence on the health contributing to the global burden of disease and imposing burden on the women and children. (Lim,S.;Vos,T.;Flaxman,A.;Danaei,G.;Shibuya,K, 2013) Estimated approximately 3.5 million of premature deaths occurred as results of indoor air pollution due to the incomplete combustion process of the solid biomass fuels. According to the world health organization , inefficient solid biomass fuels combustion is linked to household air pollution increasing the risk score of the pneumonia in children under age of 15, lung cancer in adults among other illness (Bonjour,S.Adair-Rohani,H.,Wolf,J.,Bruce,N.G.,Mehta,S.,Pruss-Ustun,A.,& Smith,K.R., 2013). If no quick reaction is taken by 2030, approximated 870 thousand of people will die from infections related to the solid biomass fuels from cooking (Rysankova,D.,Putti,V.R,Hyseni,B.,Kammila,S.,and Kappen,J.F, 2014).

Access to clean modern cooking fuel is a global challenge and therefore, efforts to develop, adopt and use modern energy technologies for solid biomass are the best intermediate solution of improving the supply side of the solid biomass and usage in addressing the adverse impacts of open-air fire (GIZ, 2013)**.** In developing countries, the intervention of disseminating the solid biomass modern energy technologies date back in the 1970s by the donors, governments and non-governmental organizations since it had a promising impact on health and environment (Gifford,M.L., 2011)**.**

Like many developing countries, Rwanda energy supply is heavily dependent on traditional solid fuels like fuel wood and charcoal that account for over 83 percent of the total energy consumption (National Institute of Statistics of Rwanda(NSIR), 2017)**.** Traditional fuels and cook stoves have

been widely used in Rwanda by many communities to meet their energy needs for over decades. Inefficient design of the solid biomass cook stoves allows escape of heat and smoke which later on are assumed to contribute to global disease burden and climate change (United Nation Energy(UN Energy), 2006). For instance, in Rwanda household air pollution cause deaths of approximately 15 thousand people and more than 100 thousands of direct health impacts on people (World Health Organisation(WHO), 2009). The modern energy technologies have been the evident efficient tools that would benefit human health, local environment and global climate through reductions in solid fuel wood harvest and particulate matter emissions (Lewis,J.J.,and Pattanayak,S.K, 2012). The global initiatives like global alliance for clean cook stoves (GACC) aim to reduce the smoke exposure from cooking activities and heating (Globall Alliance for clean cookstoves(GACC), 2013). Numerous international bodies, like united nations, the world bank showed their concern about the adoption of clean cook stoves and have raised funds to foresee its implementation (Puzzolo,E.,Stanistreet,S.,Pope D.,Bruce N.G,Rehfuess, E.A., 2013).

Few efforts devoted to understanding and analyze the adoption the modern energy technologies for sustained long term usage (Global Alliance for clean cook stoves, 2014). Cooperation between the implementing organization, community and product designer could help to develop cost effective and efficient energy stoves that are well designed and installed (Foell,W.,Pachauri,S.,Spreng,D., and Zerriffi,H., 2011), hence this will not only ensure that the socio-economic and cook stoves aspects are well incorporated to ensure long-term sustainable usage and stove maintenance (Puzzolo,E.,Stanistreet,S.,Pope D.,Bruce N.G,Rehfuess, E.A., 2013) but also mitigate the health and environmental impacts of traditional solid biomass cook stoves (Ruiz-Mercado,I., Masera,O.Zamora,H. and Smith,K.R., 2011)..

1.2 Statement of the problem

Many households in Rwanda mostly rely on the solid biomass fuels (firewood, charcoal, crop residues) among others for cooking, heating, and lighting purposes with the total of approximately 85 percent using firewood and 13 percent using charcoal (National Institute of Statistics of Rwanda(NSIR), 2017). The modern and clean cooking fuels like liquefied petroleum gas (LPG), Biogas and electricity account for less than 5 percent. Over 85 percent of the population largely depends on traditional cook stoves and fuels despite the associated health impact with like pneumonia among children under the age of 5 years and lung cancer among adults. Women and children are mainly engaged in drudgery home tasks with gathering fuel wood which has a crucial and significant opportunity cost, limiting the opportunity to improve their education level and engage in income generating activities (Foell,W.,Pachauri,S.,Spreng,D., and Zerriffi,H., 2011).

Modern energy technologies were developed to address the health and livelihood impacts of cooking with traditional three stones (GIZ, 2013). In Rwanda, interventions to distributing modern energy technologies It has been identified as a promising option to benefit human health, the local and global climate change resulting to decline in deforestation and hence reduced emission. There are several non-governmental organizations and government initiated in production and distribution of modern energy technologies through local stakeholders and community based organizations. Despite the availability of these modern cook stoves, it is not yet clear what really influence the adoption to use this modern energy technology among different households in Rwanda. Some observations found by (Delahunty-Pike,A., 2012)revealed that institutional factors like policy mechanism, market development, subsidy and standardization have influence the adoption of modern energy technologies even though they play a crucial role in implementation and distribution.

According to the study by (Rehfuess,E.A.,Puzzolo,E.,Stanistreet,D.,Pope,D.,&Bruce,N.G, 2014), Showed that other stoves factors like quality, durability, cost, and size could be influencing factors for adoption. Therefore this study pursues to identify socio-economic, fuels and stoves factors influencing the adoption of modern energy technologies and propose some of strategies that would help to enhance the uptake in Rwandan households.

1.3 Research questions

Regarding the dissemination of the improved cook stoves, what are the aspects influencing the adoption of this modern energy technology. With the following sub-questions:

- What are the socio-economic factors inducing the household adoption of the modern energy technologies in Rwanda?
- What are the factors related to the fuels and cook stoves inducing the adoption of modern energy technologies in Rwandan households?

1.4 Major objectives

To identify and investigate the factors influencing the household adoption of modern energy technologies in Rwanda. The specific objectives are;

- To analyze the socio-economic factors inducing the household adoption of improved cook stoves
- To identify the existing modern energy technologies at households level in Rwanda

1.5 Research hypothesis

H_0: socio-economic inducing factors do not influence household adoption of modern energy technologies in Rwanda

H_1: socio-economic inducing factors do have significant influence household adoption of modern energy technologies in Rwanda

1.6 Significance of the study

The accessibility of modern, clean, cheap, reliable, and sufficient energy provide the opportunities for developing countries to eradicate the poverty through achieving the economic development (Barnes,D.F.,Kumar,P. and Openshaw,K., 2012). The global initiatives have shown their concern especially in developing countries like Rwanda and have raised funds to foresee the implementation and adoption of clean cook stoves (Global Alliance for clean cook stoves, 2014). As a result this study is in the same direction as Rwandan government effort to accomplish the United Nations Sustainable Development Goals (SDGs). As the expected outcomes for this study will be worthwhile tool for policy makers in energy sector in the policy frameworks formulation in relation to training and regulation of modern energy technologies quality towards the adoption of this technology while at the disaggregated level, this will be helpful for market developers to design and develop stoves which are important to the community but also make clear to the demand side on the benefits of modern energy technologies and to the future researchers with knowledge on household characteristics towards the sustainable energy.

1.7 Scope of the study

The study area was limited to cover only household sector in Rwanda for adoption of the improved cook stoves. More specifically it will cover on the socio-economic factors, fuels and stoves characteristic factors that might induce the household adoption of the modern energy technology. The data to be used in this study will be panel dataset created from three Integrated Household Living standards from 2012 to 2018 surveys (EICV3/4/5) collected by National Institute of Statistics of Rwanda (NISR) and the analysis carried out using STATA software tool.

CHAPTER TWO: LITERATURE REVIEW

The review of empirical studies show that a great number of researchers have obtained set of socio-economic factors inducing the adoption to use the modern energy technologies but in the pas review of literature has focused on the income and other demographic household characteristics with a little on the other cook stove and cooking fuels related characteristics that might influence the uptake of the modern energy technologies at household level.

The study carried out by (Lim,S.;Vos,T.;Flaxman,A.;Danaei,G.;Shibuya,K, 2013) revealed that Globally exposure to smoke from household solid combustion is one the largest risk factor resulting in proximately 3.5 million premature death 4.5 global DALYs (Disability Adjusted Life years) in 2010.The pollutants emissions resulted from the process of fuels combustion are influenced by factors including fuels properties and stove design. (Rysankova,D.,Putti,V.R,Hyseni,B.,Kammila,S.,and Kappen,J.F, 2014) Illustrated that if no action takes place by 2030 approximately 0.9 million of population will die from infection associated with solid fuels cooking.

(GIZ, 2013) reported that accessibility to modern clean cooking fuel is global challenge and hence fourth enough effort to design, adopt and use improved cook stove are the best intervention solution for enhancing the way biomass is used in addressing advice resulting impact.

(Puzzolo,E.,Stanistreet,S.,Pope D.,Bruce N.G,Rehfuess, E.A., 2013) Reported that in middle income countries like Rwanda, intervention for improved cooking stove by the government donors and non-governmental organization, it had promising impact on health and environment.

(Lewis,J.J.,and Pattanayak,S.K, 2012), Reported that improved cook stove have been the evident efficient tool that would benefit human health, environment and climate through decline in fuel wood harvesting and emissions. Few effort have been devoted to understanding how improved cook stove are currently adopted for a long time sustainable use and this will ensure the social economic aspects that are well incorporated to ensure a long term sustained usage of improved cook stove.

They are some studies conducted on the socio economic factors influencing household adoption of improved cook stove which was developed for reducing the health and livelihood consequence resulting from the usage of solid cooking fuels, the study carried out by (Bonjour,S.Adair-Rohani,H.,Wolf,J.,Bruce,N.G.,Mehta,S.,Pruss-Ustun,A.,& Smith,K.R., 2013) the study carried out said that the transition from traditional to clean cooking fuel began in 1990s and the switching movement was slow especially in most of low income countries and many people still relying on traditional fuels for their cooking purpose and hence effort needed towards improvement the household usage of improved cook stoves.

The study conducted by (Malla,M.B.NBruce,E.Bates, and E.Rehfuess., 2011) identified various socio economic factors such as education, household size, income and price of cook stove, time spent in firewood collection as having influence on household adaptation of improved cook stove. In Burkina Faso, (Ouedrago,B., 2006) Observed that there is positive correlation between household income and fuels consumption and then don't switch to clean energy when the income increased but consume a set of fuels which may include solid fuels depending on their preference, need and their budget. (Lewis,J.J.,and Pattanayak,S.K, 2012) Found that both household head education level and household size have significant positive impact on household adaptation of improved cook stove.

According to the study carried out by (Ozcan,K.M.Gulay,E.,&Ucdogruk,S., 2013) Designated that households with increased household size prefer to use traditional fuels over modern clean fuels. (Ouedrago,B., 2006) Discovered that preparing traditional meals increase the likelihood of using fuels wood hence significant influence of using traditional cook stove for rural household despite the introduction of improved cook stove so this believes influence both choices for existing cook stove and adaptation of new model, according to (Person,B.,Loo,J.D.,Owuor,M.,Ogange,L.,Jefferds,M.E.D., & Cohen,A.L., 2012) in rural Kenya the revealed that purchasing improved cook stove for the household was influenced by the neighbor experience and relative who have already adapted the stoves. (Miller, G., & Mobarak, M., 2013); (Pine ,K.,Edwards, R, Masera,O., Schilmann,A.,Marron-Mares,A, &Riojas-Radriguez,H., 2011) Discovered that opinions and pure pressure within the community influence household adaptation of improved cook stove in Bangladesh. (Guta , D.D, 2012); (Gebrregziabher, Z., Mekonnen, A., Kassie,M., & Kohlin, G., 2012)Concluded that the old people are associated with high probability of adapting modern cooking fuels (Global Alliance for clean cook stoves, 2014), Expressed that the lack of demand for modern energy technologies especially among the low income population is driven by perceived values of cook stove such efficiency ,health environment benefit and culture belief without addressing this concern , the improved cook stove will never be adapted that is why (Levine,D., Bertramo, I., Blalock, T.G., & Cotterman, C., 2012), they expressed that the creation of demand among the low income household will improve the adaptation of cook stoves and fuels technology.

Various studies have been conducted in developing countries to identify the factors that determine household cook stove decision, in Rwanda studies carried out particularly in both urban and rural area, attempted to distinguish the determine factors of fuels and cook stove adoption with measure

concentration on institutional and stove relation factors and little on disaggregated level factors using panel data.

This study will contribute to existing literature though providing empirical evidence of the factors influencing the household adoption of improved cook stove as the previous studies showed that Multinomial probability models using cross-section data are unsuitable for investigating the cook stove adoption at household level which requires panel data.

2.1 Research gaps

There are numerous research studies conducted in middle income and developing countries to identify the control variables that influence the fuels transition and cook stoves decision at household level. In Rwanda, there are limited studies carried out in both urban and rural regions that have tried to distinguish the determining factors of fuel energy and cook stoves adoption with major concern on fuel energy and cook stoves characteristic factors and little on socio-economic factors. Consequently, this investigation tend to fill the hole in the literature by investigating the chosen independent control variables that are fuel energy and cook stove , socio- economic characteristic factors and analyze how they influence the household level adoption of modern energy technologies.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Conceptual framework

The conceptual framework of the research study is based on the level of household adoption of modern energy technologies as dependent variable influenced by socio-economic driving factors and fuels and stoves characteristic factors as independent variables and the diagram shows the proposed Relationship between the variables factors studied.

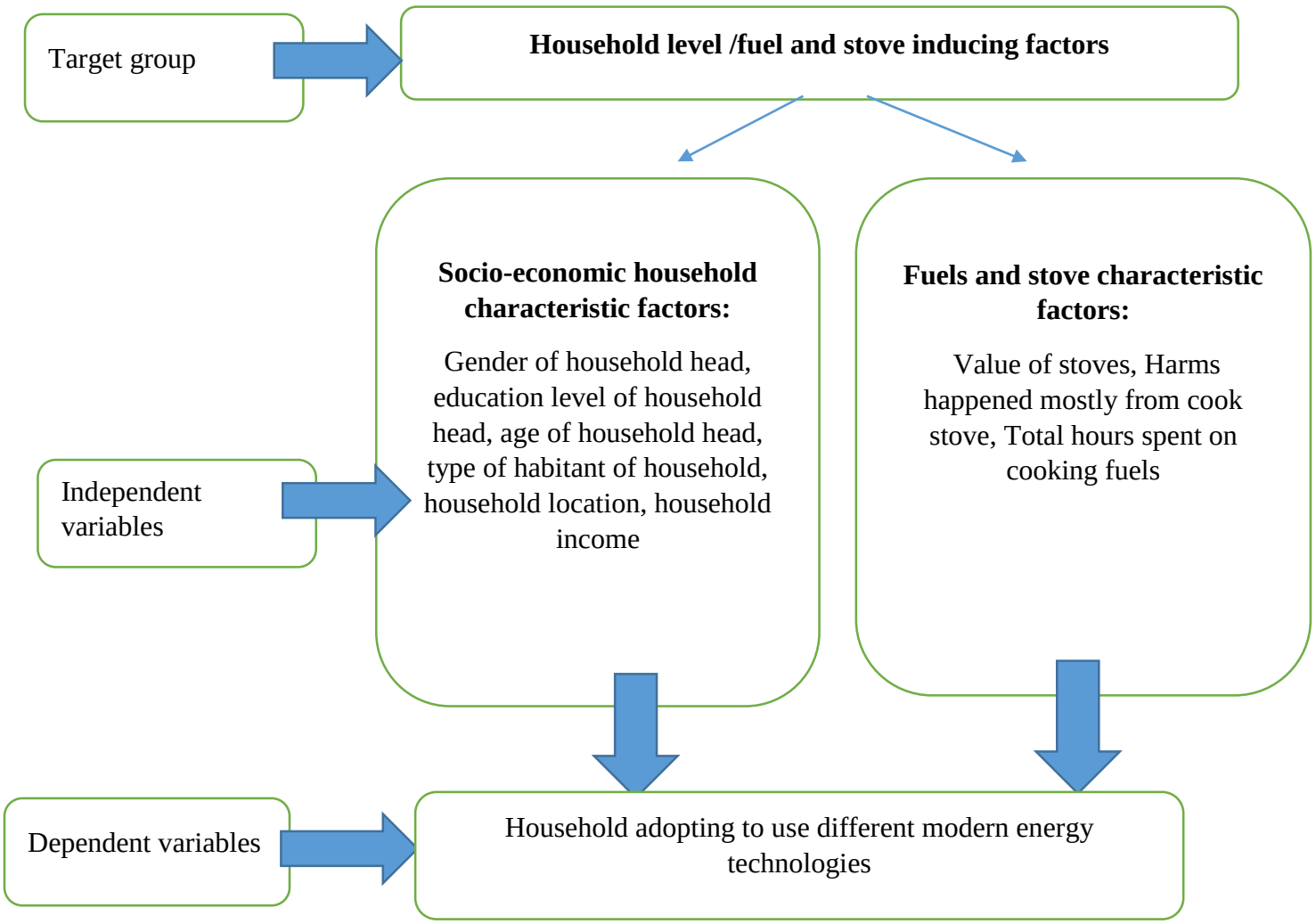


Figure 1Conceptual framework of factors inducing adoption of improved cook stoves

Source: (Author's conceptual framework)

3.2 The Empirical model

The study applied a binary choice model, as it is the relevant for the model with dummy and categorical dependent variable, Binary logistic regression is frequently used as regression approach for evaluating discrete choice data such as household adoption improved cook stove, household adoption of improved cook stove is modeled as dummy variables with values 1 if household adopt improved cook stove and 0 otherwise, the probability of household adoption of improved stove is formulated as function of household level driving factors, the predictor variable in the model include attributes of individual and household characteristics that could influence the decision to adopt improved solid fuel stove,

According to (Fox,J., 2010) the binary logistic regression model has two practical advantages, where the simplicity is the first one, this emprise that logistic equation is very simple. Interpretability is the second that is inverse of linear transformation for the Logit model is merely interpretable as log-odds with considering the odd ratios.

The binary logistic model regression:

$$Ln\left(\frac{P_i}{1-P_i}\right) = \pi_0 + \pi_1 X1_i + \pi_2 X2_i + \cdots \ldots \ldots \pi_k Xk_i + \varepsilon_i \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

Where the subscript I means the ith observation in the sample.

P is the probability that the household adopts the improved solid fuel cook stoves; and (1-P) is the probability that the household does not adopt an improved solid fuel cook stove.

π_0 is the intercept term

π_0 , π_1 , π_2 , $\ldots \ldots \ldots \pi_k$ are the coefficients of interest of independent control variables $X1_i$, $X2_i$, $\ldots \ldots \ldots Xk_i$, ε_i is the error term

3.3 The data source

This study was centered on panel data from Integrated Household Living Conditions Surveys (EICVs), conducted by the National Institute of Statistical of Rwanda (NISR) fifth wave (2016/17). The survey is a broadly agent test study intended to give data on the different parts of family unit government assistance in Rwanda. The reviews gathered data from three waves-based family units measurably intended to be delegate at both public, locale, metropolitan and provincial levels, empowering the arrangement of dependable appraisals for these levels. The survey is carried out to gather an extensive arrangement of information on the distinctive part of family government assistance, for example, demography, utilization, earnings, lodging, work market, instruction, wellbeing, and other financial variables.

The dependent variable is the dummy variable indicating whether the household adopt to use (equal to 1) or the household do not adopt to use the improved cook stove as modern energy technology and the independent variables comprise of the two set in which one set encompasses of Socio-economic household characteristic factors**(**Gender of household head, education level of household head, homeownership for household, age of household head, type of habitant of household, household location, type of dwelling for household, household income, non-farm activities, household size) while the second set encompasses of Fuels and stove characteristic factors**(**Type of stoves, value of stoves, design of stoves, Harms happened mostly from cook stove, amount spent on cooking fuel, Total hours spent on cooking in a week, Total hours spent on cooking fuels) that have a significant influence on the household adoption of the improved cook stove as modern energy technology.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Descriptive results

Here we first represent the analysis from descriptive statistics of all variables of interest to be used in this study

Table 1.descriptive statistics of dependent and all control variables by household location in EICV5 (2016/17) to be used in Binary Logit Regression Model

Variables	**Variable Description**	**Urban Households**		**Rural Households**	
		mean	**S.d**	**mean**	**S.d**
Dependent variable					
household adopt to use ICS	Household adopting to use modern energy technologies	0.217	0.412	0.14	0.347
Independent /other control variables					
Income	Log of household income	13.992	1.619	13.02	0.948
value of cook stoves	value of household cook stove	7.046	2.17	7.524	1.659
is there any harm happened on cook stoves	Harms happened mostly from cook stove	0.025	0.156	0.04	0.195
time spent on cooking fuels	Total hours spent on cooking fuels	3.913	15.342	9.719	23.954
if household head has formal education	Household head with formal basic education	0.242	0.429	0.224	0.417
age of household	Age of household head	40.592	14.036	46.114	15.791
type of habitant	Household type of habitant	0.287	0.452	0.668	0.471

Source: Author's own computation using EICV5 (2016/17).

From the table1 above report the descriptive statistics for all variables used in the binary Logit model showing that in Rwanda panel dataset on average comparison, 21.7 percent of the households adopt the usage of improved cook stoves in urban region while only 14 percent of the households adopt to use the improved cooks stoves are from rural region, 22 percent of households

with basic formal education in rural region while only 24.2 percent of households have basic formal education in urban region. Interestingly, only 28.7 of the urban households live in Umudugudu and modern planned areas while 66.8 percent of the rural households live in Umudugudu and the modern planned areas.

More interestingly rural households spent more time on cooking fuel at average of 10 hours while urban households only spent averaged time of 4 hours on cooking fuel. Surprisingly, almost 4percent of rural households suffered harms happened from the cook stoves while only 2 percent of the urban households suffered from the harm happened from the cook stoves.

From the figure 2, we report that the cumulative probability distribution of total household income and adoption of modern energy technology in Rwanda. It shows that the households which adopt to use the improved cook stoves have higher total income compared to the households which do not adopt to use the modern energy technology. Figure 4 we represent Cumulative probability distribution of annual hours spent in collection of cooking fuels and adoption of the modern energy technology in Rwanda. It delivers that the households which do not adopt to use the improved cook stoves many hours in collecting the cooking fuels compared to the households which adopt to use the improved cook stoves at 33 hours spent in collection of cooking fuels the cumulative probability for both households which adopt to use and those which do not adopt to use the improved cook stoves and this means that the probabilities look the same for both. From the figure 6, we report that the cumulative probability distribution of total value of the cook stoves used by household and adoption of modern energy technology in Rwanda. It shows that the households which adopt to use the improved cook stoves have cook stoves of higher total value compared to the households which do not adopt to use the modern energy technology. From the above figures described above identified that the households adoption to use the modern energy technology not

only save our environment and health as global benefits but also save time and money for the households which adopt to use the modern energy technologies.

4.2 Results from estimations of Binary Logit Regression Model

Table 2.Estimations of factors influencing the household's adoption of improved energy technology in Rwanda

	(1)
Variables	Model 1
Total household income	0.320***
	(0.020)
Type of habitant for household	0.205***
	(0.051)
Household head with formal basic education	0.007
	(0.055)
Household location(urban=1)	0.270***
	(0.005)
Age of the household head	0.009***
	(0.002)
Total hours spent on cooking fuels	0.002*
	(0.001)
Harms happened mostly from cook stove	-0.232*
	(0.139)
Total value of household cook stove	0.000***
	(0.000)
Constant	-6.181***
	(0.276)
Observations	14,580

Standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1
Source: Author's own computation using EICV5 (2016/17).

From the table 2 above reports that when the household income increase by one unit Rwandan franc, the odds of households u

sing the improved cook stove increases by 1 household additional to the households using improved cook stoves and this is significant at 1 percent, so the income is a crucial factor to be

considered when adopting the modern energy technologies since the manufactured cook stoves and other improved cook stoves need to be purchased at some cost associated with its production. Surprisingly, when the age of household head increased by one more year, the odds of the households that use the improved cook stoves is increased by 1 more household adopt the modern energy technology which is significant at 1 percent while this is related to the fact that the aged household heads easily adopt the technology than the younger one towards the households efficient and effective consumptions. This shows that the households with older heads are more likely to adopt the improved cook stoves. When the household lives in umudugudu and modern planned areas this is associated with the incline of one household on the number of the households adopting to use the modern energy technology which is significant at 1 percent and this is due to the fact that in the modern planned areas the households improved infrastructure are provided including the modern energy technologies like improved cook stoves for the health and economic benefits of the living households.

Interestingly, when the households living in the urban region increase by one additional household the odds of the households adopting the improved cook stoves decreased by 1 household adopting improved energy technology where this is significant at 1 percent and this is related to the fact that most of the urban households use the traditional cook stoves and many of them try to shift to modern cooking fuel and the rural household mostly depend on solid biomass fuel for cooking purposes and hence the rural households are the first and more ones to adopt the improved cook stoves for effective biomass consumption.

Too much interesting, when the value of cook stove is increased by one unit Rwandan franc, the odds of the households adopting the improved cook stoves increased by 1 household adopting the modern energy technology while this is significant at 1 percent and this is associated to the datum

that the more efficient cook stove is the more the cost it is, so when the value of the cook stoves that the household would receive when the sell their cook stove increase this will lead to increase in adoption of the cook stove when its value is increased hence more efficient cook stove adoption.

Surprisingly, when the time spent by the household on cooking fuels increased by one more hour additional the odds of the households adopt using the improved cook stove decline by 1 household adopt to use the modern energy technology like improved cook stove which is significant at 10 percent and this is linked to the fact that when the household spend much time on the cooking fuels the households try to reduce the time spent of cooking fuels by using the efficient and effective cook stove to reduce the consumption of that fuels. Hence the households that adopt to use the improved cook stove increase due to the cook stove productivity for households time allocation on cooking fuels that can be used for other income generating activities and hence increased household income and expectedly when there are harms mostly happened to the improved cook stoves this is associated with the decline of one household in the number of households adopting to use the improved cook stove as modern energy technology which is significant at 10 percent and this goes in line with the fact that most of the people choose the safer modern energy technologies compared to dangerous technologies which are commonly associated with harms which sometimes leads to the death and this hinder the households to adopt to use the modern energy technologies.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The study carried out on the driving forces influencing the household adoption support the arguments that the households adopting to use improve cook stoves is crucial for socio economic and environmental reasons. The adoption of improved cook stove is highly reliant on the household's homeownership, total income ,age of household head and the number household members while household location especially Urban region slow the adoption whereas the household with polygamous household head are likely to adopt improved cook stoves so the adoption is increased by increase in household total income .The basic formal education for the household head is not sufficient for raising the adoption since the adoption require more information and training program about cook stove .

For the cook stove and fuel characteristics, the study shows that as the value household cook stove that is the amount received by the household from the cook stove sales increase the adoption incline while the amount spend on cooking fuel that is associated with prices of the fuel slows the adoption and rise in numbers of total hours spend on cooking fuels leads to incline in adoption. As ((Pohekar,S.D.,Kumar,D.,Ramachandran,M., 2005) identified that there is a set constraints and barriers, although varying in different socio economic culture and environment situations contributes to slowing the adoption of improved cook stove, for example household members without formal basic education, low income for the household, inadequate of knowledge of health and environmental harms resulted from inefficient usage of biomass and lack of trainings programs for awareness about improved cook stove and these are among the main driving factors.

5.2 Recommendations

In Rwanda ,as the subject area of this research it was identified practically that the most crucial driving factors that slow the adoption are lack of motivation, awareness and training program about the cook stove and lack direct institutional support. The study recommend that voluntary , non-governmental organization and the government should intervene to work in parallel for enhancing and developing energy policy framework like deployment and dissemination of modern energy technologies like improved cook stove in regions that are highly reliant on solid biomass. There is direct prerequisite of consistent and focused cooperation of stakeholders on the demand and the supply side as consequence this will not only enhance the health, socioeconomic and environmental situation but will also play a crucial role in achieving sustainable development goals.

References

Anenberg,S.;Balakrishnan,K.;Jetter,J.;Masera,O.;Mehta,S.;Moss,J.;Ramanathan,V. (2013). Cleaner cooking solutions to achieve health, climate and economic cobenefits. *environmental science and technology 47*, 3944-3952.

Barnes,D.F.,Kumar,P. and Openshaw,K. (2012). *cleaner hearths, better homes; new stoves for india and developing world.* Washington D.C.: world bank.

Bonjour,S.Adair-Rohani,H.,Wolf,J.,Bruce,N.G.,Mehta,S.,Pruss-Ustun,A.,& Smith,K.R. (2013). Solid fuel use for household cooking :country and regional estimates for 1980-2010. *Environmental Health Perspective(Online),121(7)*, 784.

Delahunty-Pike,A. (2012). *Gender equiity , charcoal and the value chain.* western kenya: Delahunty-Pike,A.

Diaoglou,V.,Van Ruijven,B.J., and van Vuuren,D.P. (2012). Model projections for households energy use in developing countries. *Energy 37(1)*, 601-615.

Foell,W.,Pachauri,S.,Spreng,D., and Zerriffi,H. (2011). Household cooking fuels and technologies in developing economies. *energy policy, 39(12)*, 7487-7496.

Fox,J. (2010). *Logit and Probit Models.* New York: SPIDA.

Gebrregziabher, Z., Mekonnen, A., Kassie,M., & Kohlin, G. (2012). Urban energy transition and technology adoption : the case of Tigrai, Northern Ethiopia. *Energy Economics 34(2)*, 410-418.

Gifford,M.L. (2011). *A global review of cook stoves programmes.Master thesis.* California: energy and resources group UC Berkeley.

GIZ. (2013). *Clean and Efficiency cooking energy for 100 Million homes.* Bonn International cooking Energy forum 26-28 June 2013.

Global Alliance for clean cook stoves. (2014). *Igniting Chanche: a Strategy for Universal Adoption of Clean Cook stoves and Fuels.* Washington DC.: GACC.

Globall Alliance for clean cookstoves(GACC). (2013). *Global alliance for clean cookstoves.* homepage:retrieved from:http/www.cleancookstoves.org.

Guta , D.D. (2012). Application of an almost ideal demand system(AIDS) to Ethiopian rural residential energy use : Panel data evidence. *Energy policy,50.*, 528-539.

International Energy Agency(IEA). (2010). *energy poverty: how to make modern energy access universal? special early excerpt of the world energy outlook2010 for th UN general assembly of the MDGs.* IEA.

Levine,D., Bertramo, I., Blalock, T.G., & Cotterman, C. (2012). *What impedes efficient adoption of products?Evidence from randomized variationin sales offers for improved cookstoves in Uganda.* Uganda: GACC.

Lewis,J.J.,and Pattanayak,S.K. (2012). Who adopts improved fuels and cookstoves?A systematic review. *Environmental health prespectives,120(5),* 637-645.

Lim,S.;Vos,T.;Flaxman,A.;Danaei,G.;Shibuya,K. (2013). A comparative risk assessment of burden of deseaseand injury attributable to 67risk factors and risk factor clusters in 21 regions,1990-2010: a systematic analyisis for the global Burden of desease study2010 . *The lancet 380,,* 2224-2260.

Malla,M.B.NBruce,E.Bates, and E.Rehfuess. (2011). Appling global cost-benefit analysis methods to indoor air pollution mitigation interventions in Nepal, Kenya and Sudan :Insights and challenges. *Energy Policy 39(12)*, 7518-7529.

Miller, G., & Mobarak, M. (2013). Gender Differences in Preferences ,Intra-household Externalities, and the low Demand for Improved Cookstoves. *Working Paper*.

National Institute of Statistics of Rwanda(NSIR). (2015). *Rwanda poverty proifle report.* Kigali,Rwanda: NSIR.

Ouedrago,B. (2006). Household energy preferences for cooking in urbanOuagadougou,Burkina Faso. *Energy policy,34(18),* 3787-3795.

Ozcan,K.M.Gulay,E.,&Ucdogruk,S. (2013). Economic and Demographic determinants of household energy use in Turkey. *Energy Policy,60*, 550-557.

Person,B.,Loo,J.D.,Owuor,M.,Ogange,L.,Jefferds,M.E.D., & Cohen,A.L. (2012). It good for my Family's Health and Cooks Food in a Way that my Heart Loves:Qualitative Findings and Imlications for Scaling up an Improved Cook stove Project in Rural Kenya. *International journal of environmental research and public health, 9(5),* , 1566-1580.

Pine ,K.,Edwards, R, Masera,O., Schilmann,A.,Marron-Mares,A, &Riojas-Radriguez,H. (2011). Adoption and use of improved biomass stoves in Rural MEXICO. *Energy for Sustainable Development15 (2),* 176-183.

Pohekar,S.D.,Kumar,D.,Ramachandran,M. (2005). Dissemination of cooking energy alternatives in India. *Renewable and Sustainable energy Reviews*, 379-393.

Puzzolo,E.,Stanistreet,S.,Pope D.,Bruce N.G,Rehfuess, E.A. (2013). Factors Influencing the Large Scale Update by Households of Cleaner and More Efficient Household Energy Technologies.A systematic Review. *Evidence for policy and practice information and co-ordinating Centre.* London: University of London.

Rehfuess,E.A.,Puzzolo,E.,Stanistreet,D.,Pope,D.,&Bruce,N.G. (2014). Enablers and barriers to large scale uptake of improved solid fuel stoves:a systematic review. *Environmental health perspectives,122(2),* 120-130.

Ruiz-Mercado,I., Masera,O.Zamora,H. and Smith,K.R. (2011). adoption and sustained use of improved cookstoves. *Energy polcy,39(12),* 7557-7566.

Rysankova,D.,Putti,V.R,Hyseni,B.,Kammila,S.,and Kappen,J.F. (2014). *Clean and Improved Cooking Cooking in Sub-Sahara Africa.* A Landscape report.

United Nation Energy(UN Energy). (2006). *the energy challenge for achieving MDGs.* retreived from :web:http/www.esa.un.org.

World Bank. (2011). *household cook stoves, environment, health and climate change: a new look and old problem.* washington DC: World Bank.

World Health Organisation(WHO). (2009). *Fuel for life: household energy and health.* Geneva , Switzerland: WHO.

Appendices

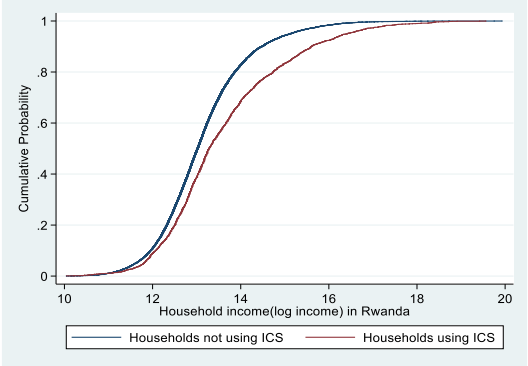


Figure 2.Cumulative probability distribution of annual income and adoption of ICS

Notes: the cumulative distribution is drawn across all regions in Rwanda using EICVs (2010, 2013/14 and 2016/17)

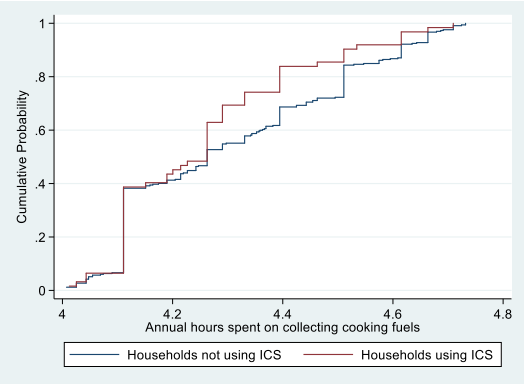


Figure 3.Cumulative probability distribution of annual hours spent on collecting cooking fuels and adoption of ICS

Notes: the cumulative distribution is drawn across all regions in Rwanda using EICVs (2010, 2013/14 and 2016/17)

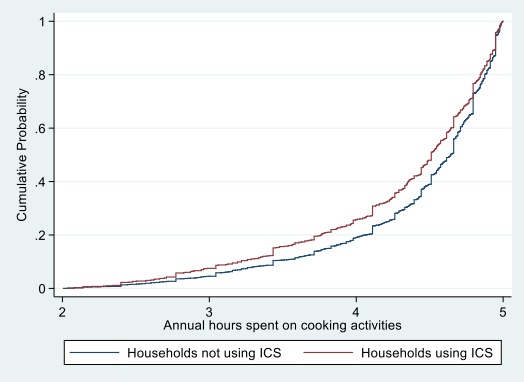


Figure 4.Cumulative probability distribution of annual hours spent on cooking activities and adoption of ICS

Notes: the cumulative distribution is drawn across all regions in Rwanda using EICVs (2010, 2013/14 and 2016/17)

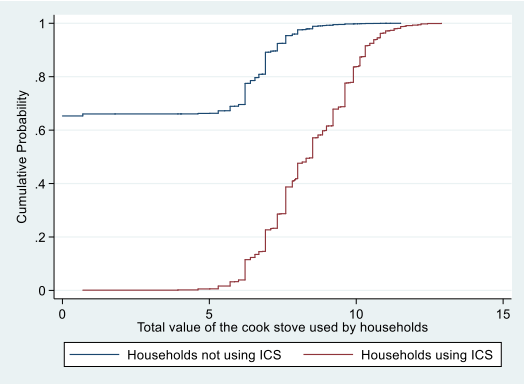


Figure 5.Cumulative probability distribution of total value of cook stove and adoption of ICS

Notes: the cumulative distribution is drawn across all regions in Rwanda using EICVs (2010, 2013/14 and 2016/17)

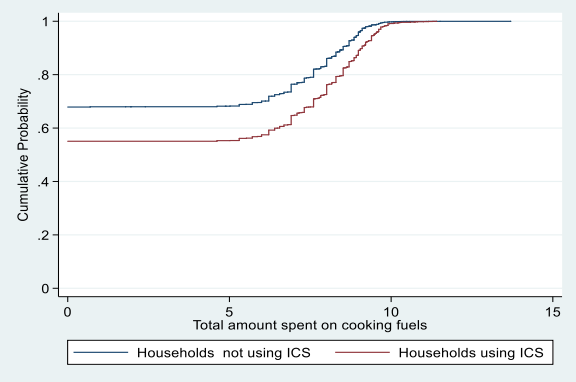


Figure 6.Cumulative probability distribution of total amount spent on cooking fuels and adoption of ICS

Notes: the cumulative distribution is drawn across all regions in Rwanda using EICVs (2010, 2013/14 and 2016/17)