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Socio-Economic Determinants for Household Uptake of Modern Energy Technologies: Evidence from Rwanda Panel Data (2016-2017)

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Abstract

The major causes of deforestation worldwide from human activities is the reliance of world population on the biomass fuel for domestic energy consumption through cooking, heating and lighting, the usage of biomass in inefficient way increase the fuel demand for the household. This paper provides evidence of household driving factors that play a crucial role in the uptake of improved cook stove empirically in Rwanda. The study used data from fifth integrated household living standards survey (EICV-5) carried of by National Institute of Statistics of Rwanda. Using binary logistic regression analysis, the study shows that homeownership, age of household head, household location and household size are the main significant household factors influencing the adoption of improved cook stove while time spend on cooking fuels is the most significant stove and fuel factors determining the adoption of usage of improved cook stove. The study shown 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.

Keywords: Household, Adoption, Cooking Fuels, Improved Cook Stoves, Binary Logit Regression

1. Introduction

Worldwide, energy is very crucial in meeting households' basic need majorly for cooking, heating and lighting. Correspondingly, sustainable development recognizes the significance of key resources such as energy, water, forests and soil in helping to create the base for human development needs in terms of human welfare and biophysical environmental supports (Guta, 2014). 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 according to (who, 2006). household access to clean and affordable energy is critical for realization of the Millennium Development Goals(MDGs) (Ibitoye, 2013). However, in many developing countries, a large proportion of the household energy requirements are met by using non-commercial fuels such as wood, animal dung, crop residues, etc. so this traditional household energy sources associated health and environmental hazards. As result use of improved energy technologies for cooking in a reduction of in the overall biomass and wood fuel consumption is a vital as well as to achieve MDGs (Ibitoye, 2013). Hence, household with access to improved energy technology, clean energy sources expected benefits in health, work and education according to (Muggen-burg *et al*., 2012). The main objective of this study as to assess the determinants of the adoption of stove technology to reduce the burden of biomass energy sources at the household level and suggest the possible solution.

They are some studies conducted on the determining factors inducing household adoption of stove technology 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) [2] revealed 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.

(Malla, M.B., NBruce, E. Bates, and E.Rehfuess., 2011) [11] 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) [13] 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) [9] Found that both household head education level and household size have significant positive impact on household adaptation of improved cook stove.

(Ozcan, K.M., Gulay, E., & Ucdogruk, S., 2013) [14] Designated that increase of household size prefer to use traditional fuels over improved clean fuels. (Ouedrago, B., 2006) [13] 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 (Guta, D.D, 2012) [7]; (Gebrregziabher, Z., Mekonnen, A., Kassie,M., & Kohlin, G., 2012) [4] Concluded that the old people are associated with high probability of adapting improved cooking fuels indicating the relationship between age the household head and the household adoption of the technology (Global Alliance for clean cook stoves, 2014) [6].

Numerous studies have been conducted in developing countries to identify the factors that determining household cook stove decision, in Rwanda studies carried out predominantly in both urban and rural area, attempted to distinguish the determining 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 adaptation of improved cook stove as the previous studies showed that Multinomial probability models using cross-section data are unsuitable for investigating the cook stove adaptation at household level which requires panel data.

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) [5]. 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 influenced 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) [19], 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.

3. 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.

4. 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) [10] 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) [20] 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) [5] 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) [18] 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) [9], 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) [2] 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) [11] 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) [13] 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) [9] 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) [14] Designated that households with increased household size prefer to use traditional fuels over modern clean fuels. (Ouedrago, B., 2006) [13] 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) [15] 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) [12]; (Pine, K., Edwards, R, Masera, O., Schilmann, A., Marron-Mares, A, & Riojas-Radriguez, H., 2011) [16] Discovered that opinions and pure pressure within the community influence household adaptation of improved cook stove in Bangladesh. (Guta, D.D, 2012) [7]; (Gebrregziabher, Z., Mekonnen, A., Kassie, M., & Kohlin, G., 2012) [4] Concluded that the old people are associated with high probability of adapting modern cooking fuels (Global Alliance for clean cook stoves, 2014) [6], 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) [8], 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.

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 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.

5. Methodology

5.1 Model specification

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 dictums variables with values 1 if household adopt 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) [3] 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:

$$Y = Ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{i=8}^{k} \beta_j X_{ij} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where the subscript I means the i[th] 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
β_0, β_1, β_2, $\ldots\ldots\ldots\beta_k$ are the coefficients of interest of independent control variables X_{1j}, X_{2j}, $\ldots\ldots\ldots X_{kj}$.. ε_i is the error term

5.2 Method of data analysis
In this study, both descriptive statistics and econometric model were used for the analysis of data collected. The descriptive statistics was used to describe the relevant aspects of observable facts about the variables there by providing detailed information about relevant variables. More specifically percentage, mean, standard deviation, maximum and minimum values were computed. For quantitative binary logit model and t-test were used to analyze the determinants of the adoption of improved cook stove technology using STATA software.

6. Results and Discussions
Here we first represent the results from descriptive statistics analysis and thereafter we describe the results from multinomial logit regression model.

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					
hhwithICS	Household with ICS	0.217	0.412	0.14	0.347
Independent /other control variables					
Lnincome	Log of household income	13.992	1.619	13.02	0.948
Homeowner	Household homeownership	0.454	0.498	0.854	0.353
Hhsize	Household size	4.247	2.4	4.445	2.053
hrs cooking	Total hours spent on cooking in a week	229	209.1	222.202	161.473
hrs firewood	Total hours spent on cooking fuels	3.913	15.342	9.719	23.954
basic educ	Household head with formal basic education	0.242	0.429	0.224	0.417
Agehhd	Age of household head	40.592	14.036	46.114	15.791
Typhbt	Household type of habitat	0.287	0.452	0.668	0.471

Source: Author's computed using EICV5 (2016-2017)

From the Table1 above report the descriptive statistics for all variables used in the binary logit model showing that in EICV5 (2016/17) 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 cook stoves are from rural region. Interestingly, 45.4 percent of households in urban region live in their own houses while 85.4 percent of the households in rural regions live in their own houses. 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. The households within urban regions spend 4 hours on cooking activities while the rural households spend 3 hours in cooking activities and 6percent of urban households adopting the improved clean fuel for cooking purposes while only 0.2 percent of the rural households adopting the improved clean cooking fuel as primary sources of cooking fuel.

6.1 Results from estimations of Binary Logit Regression Model

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

Variables	Variable Description	coefficient	S.d
Household characteristic factors			
Lnincome	Log of household income	0.00111	0.028
Homeowner	Household homeownership	0.652***	0.085
Typhbt	Household type of habitat	-0.059	0.063
Agehhd	Age of household head	0.00835***	0.002
basic_educ	Household head with formal basic education	-0.0777	0.064
Urban	Household location /urban	-0.311***	0.085
Hhsize	Household size	0.0390**	0.015
Cooking fuel characteristic factors			
hrs_firewoood	Total hours spent on cooking fuels	0.00468***	0.001
Constant		-1.489***	0.379
Observations		6,524	
Notes_Titles: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1			

From the Table 2 above reports that he odds of the households using the improved cook stoves increased by $e^{(0.652)}$ which is almost 2 households additional to that adopt the improved cook stoves when the households live in their own homes increase by one more compared the households living in the rent homes which is significant at p<0.01. This is related the characteristics of the cook stoves since some cook stoves need to be built and fixed with in the cooking room and some other efficient cook stoves are easily movable. This shows that the homeownership driving factors is important to consider when adopting the improved energy technology like cook stoves. 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 $e^{(0.00835)}$ which is 1 more household adopt the improved energy technology which is significant at p<0.01 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.

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 $e^{(0.311)}$ which almost 1 household adopting improved energy technology where this is significant at p<0.01 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 improved 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.

When the household member increased by one more additional member that is the increase in the household size by one unit, the odds of the households adopting the usage of the improved cook stoves increase by $e^{(0.039)}$ which is 1 household adopting improved cook stoves while this is significant at p<0.01. And this is associated to the fact that when the household member increase there will be increase in consumption of solid biomass fuel through cooking activities hence these households with increased size are likely to adopt the improved cook stove for effective and reduced consumption of solid biomass for cooking purposes.

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 incline by $e^{(0.00468)}$ which is 1 household adopt to use the improved energy technology like improved cook stove which is significant at p<0.01 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 and 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.

7. Conclusion and Recommendation

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) [17] 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.

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, wareness 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 improved 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.

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