# Adoption Determinants of Improved Cook Stove among Rural Households: The case of Benishngul Gumuz Reginal State, Ethiopia

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***Abstract*-** Energy consumption of rural households' depends on traditional energy sources including wood, crop residue, coal, and animal dung, which inefficient and largely attributed to air pollution and deforestation problems. To this end adoption of improved cook stove has anticipated to reduce these problems. So, the prime objective of the study was to investigate the determinants of improved cook stove adoption in Case of Assosa District, Benishngul Gumuz Reginal State, Ethiopia in the year 2018. The study was conducted based on descriptive design and mixed method research on a target population of 3880 households from Assosa district with sample size of 341 households that determined using Kothari formula based on proportional sampling technique from each selected sub districts and 20 key informants selected using purposive sampling technique. Binary logit regression model was employed for econometrics analysis using STATA software. The finding showed that stove design and neighborhood effect are the most determinants of improved cook stove adoption. Hence, for fast dissemination; cook stove design should not be one fit for all policy rather cooks stove design should take into account the socio-cultural feeding practice of the potential adopters.

***Index Terms*-** Adoption, improved cook stove, Binary logit regression.

## I. Introduction

The open fires and primitive stoves have been used for cooking since the beginning of human history with various sizes and styles and have been modified based on cultures, food preparation approaches and stove models (Sameer and World Bank, 2011). In developing countries about 3 billion people's energy sources is depend on traditional fuel including wood, charcoal, coal, leave, crop residues and animal dung with traditional and inefficient stove technology to meet household cooking and heating needs (World Bank, 2011).

In many countries women are responsible for the collection, transportation, processing and storing of fuel, as well as the cooking activities; burdens associated with traditional biomass cooking are disproportionally felt by women because of their customary involvement in cooking, women's exposure is much higher than Men's (World Bank,2011 and Grace, 2014).

These open fire and traditional cook stove emit substantial amount of smoke which affects human health, high deforestation, negative impact of climate change and losses production opportunity (Puzzolo *et al.,* 2013). According World Health Organization (2017), estimated that about 1.5 million per year pre mature deaths are associated with the indoor air pollution in 2030, which more deaths than malaria. Ethiopia's energy supply is heavily depending on traditional solid fuel energy both in rural and urban areas that account about 95% (World Vision, 2016 and Zenahbezu, 2017).

The government and concerned stakeholders have not give enough attention to the status of adopting improved cook stove. Improved cook stove is a device designed to improve combustion efficiency of biomass, consume less fuel, save cooking time, convenient in cooking practice and creates smokeless environment in the kitchen and reduce the volume of smoke against the traditional stove (Damte and Koch,2011).

## II. Problem Statement and Literature Review

Ethiopia is one of the least developed countries, with the lowest per capita energy consumption and dominated by traditional sources of energy (Mebratu, 2017). About 95% of the total national energy consumption is derived from traditional biomass fuel; only 5% is derived from commercial energy mainly petroleum fuels and electricity (Woldu, 2015).

The extensive poverty in developing countries needs appropriate energy service provision to pull out of poverty which is vital input for socio economic growth, mainly for industries, commerce, agriculture, and social services. The first attempt to improve traditional solid biomass stoves was made in India in the 1950s which have been designed with a chimney to remove smoke from the kitchen (Hammond, 2007 and World Bank, 2011). In 1970s researchers was focused on the technical aspects biomass stoves like thermodynamic and heat transfer but the adoption of stoves still remain at marginal level (Puzzolo *et al.*, 2013; and Gifford, 2010).

These traditional cook stoves have very low energy efficiency, most of the potential energy 85% or more is wasted comparing to improved cooking stoves and mostly causes of indoor and outdoor pollutions (Zenebe, 2007). The nature and concept of improved cook are designed to improve energy efficiency and remove smoke from the indoor living space (Hude,

2014 and Menasbo, 2016). Improved cook stove optimized heat transfer, reduced fuel consumption, reducing health impacts and deforestation that reduce climate impacts (Smith *et al.*, 2014).
The strategy of the Ethiopian government is to reduce the demand on wood fuel, conserve the forest and militate against increase greenhouse gaze effect, and reduces indoor air pollution by introducing improved wood stove. But the current penetration level of improved efficient wood stove for the rural households is still below 23%, that is the adoption of the technology has been slow, unevenly distributed among households and unaware about the technology (Shanko, 2009).

According (Anthony and Chikamso, 2017), even the access to energy is gradually improving to reach 20% by the efforts of the government, but lower than the Sub-Saharan Africa average 26%. As a result, the efficient energy supply coverage in the rural areas still remains low because of limited progress in modern energy supply activities. This major problem leads to biomass which covers 80-95% Ethiopia's primary energy demand by inefficient way (Heimann, 2007: warkaw, 2015).

Unfortunately, studies about the determinant factors of improved cook stove adoption are limited in Ethiopia, studies by Gebreeziabher (*et al.*, 2012) and Warkaw (2011) both in Tigray, Tigabu (2014) in Amhara and Amogne (2014) in Oromia; were based on what factors determine household demand for cook stove energy which are household characteristics, household income, stove price, having separate kitchen, access to open forest and social and institutional influence. But the determinants of improved cook stoves adoption and sustained use have not yet fully examined and the supply side factors such as access to credit, suitable stove design, production site decentralization and early adopter neighbors are not include in identifying determinant factors of rural household improved cook stove adoption decision in previous studies.

Improved biomass energy technologies have the potential to reduce the negative impacts of traditional biomass energy use (Beyene and Koch, 2013). Improved cook stoves are designed to reduce heat loss, decrease indoor air pollution, increase combustion efficiency and heat transfer (Masera *et al.*, 2000).

Additionally, most of the previous studies also conducted on highland areas of Ethiopia in which where the feeding culture of the highlanders are different from the lowlands; the former familiar with 'injera' baking but the later (the study area) familiar with the unique mode of baking porridge (Genfo baking) which consumes more fire wood and time open fire and inefficient way of cooking than 'injera' baking which leads high environmental, health and agricultural productivity effects. Therefore; the researcher concerned about the determinant factors of improved cook stove adoption of the households in the district as a result to fill the above gaps.

## III. METHODOLOGY

It articulates and presents all essential methods which are helpful to meet the desired objectives of the study in efficient and effective manners. The unit of analysis of this study was the efficient cook stove adopters and non-adopter households in rural Assosa district from selected twelve sub districts. Both secondary and primary methods of data collection as well as cross sectional data type were employed over the selected rural households. And as a primary data sources interview, questionnaire and physical observation and as a secondary data sources document review were conducted.

Both probability and non - probability sampling technique procedures were used to select the survey areas and sampling unit of households selected and interviewees. The district was classified in cluster based on the geographical and cultural characteristics of the community in to sub districts in order to select proportionally through random lottery method. Similarly purposive sampling technique was employed to select key informant interviewees.

Sample Size Determination: Using Kothari (2004: pp. 179) sample size determination formula n= $\frac{z^2pq}{e^2}$ with 95% level of confidence interval a total of n= 349 households were selected randomly from the selected 12 sub districts of the study area out of the N= 3880. Each sub district has a sample size proportional to its population.

With the objective of reducing uncertainty, incomplete answers and other fictitious responses the STATA and SPSS software respectively were employed for data analysis. the data. Data collected through semi-structured interviews were analyzed by the use of intensive textual analysis as well as both descriptive and econometrics analyses were used.

Dependent variable: cook stove adoption (csa) was given value '1' if the household adopters while '0'assigned to non-adaptors. To assess the status of cook stove adoption by rural households, respondents were asked whether they purchase cook stove in the form of yes or no questions. Independent variable: The independent variables are selects based on the existing theories and empirical studies.

**Table 3.1 Operational Definition of variables with expected sign**

| Variables | Operational Definition | Expected |
|---|---|---|
| Age (age): | it is a continuous variable measured in years | In determine |
| Marital status (marsta) | is a dummy which refers to single(1) or married (0) | Negative ( -) |
| Education level hh head (litle) | is a dummy which refers to literate(1) or illiterate(0). | Positive (+) |
| Familysize (famsize): | is a discrete variable, the number of family size live in the same hh. | In determine |
| Separate kitchen (sepakich) | is a dummy has separate kitchen(1) or for has not (0). | In determine (+/-) |

| | | |
|---|---|---|
| Source of wood (sowood) | is a dummy that get wood without charge (1) or with charge (0). | Negative ( -) |
| Price (price) | is a continues that refers to the end users cost to buy cook stove. | |
| Distance from stove production center (discenter) | is a dummy that refers hh near (1) or far (1)to production center. | Negative ( -) |
| Stove Design (stodes) | Stove design is a dummy refers to whether the stove is suitable or not. A value of '1' will be assigned for comfortable design '0' for others. | Positive (+) |
| Early adopter neighbors (eanghbo) | A dummy variable refers to early adopt HHs value 1 for early adopters 0 otherwise | Positive (+) |
| Extension worker | A dummy variable value 1 for exist 0 otherwise | Positive (+) |
| Household Income | A continuous variable measured in ETH. birr | Positive (+) |
| (Gender ) | A dummy that reflects households head 1 female 0 other wise | Negative (-) |

*Source: own completion (2018)*

**Model Specification**

The research was used logit regression model, the rural households would decide to adopt improved stove or use traditional cook stove.

$$Yi = \begin{cases} 1 \; if \;\; houshold \; adopts \; improved \; stove \\ 0 \quad otherwises \end{cases}$$

Here the dependent variable is dichotomous, taking 0 or 1 values, there is a need of a probability model that has these two features (1) as Xi increases, Pi = E(Y = 1 | Xi) increases but never steps outside the [0, 1] interval, and (2) the relationship between Pi and Xi is non-linear thus, one can easily use cumulative distribution function (Gujarati, 2004). Both Logistic and probit regression models satisfy the above two conditions. But, even though there is no base statistical theory for preferring one over the other, there are two practical advantages of the logit model than probit model The first one is its simplicity: second its interpretability the inverse linearizing transformation for the logit model is directly interpretable as log-odds, while the inverse transformation for probit does not have a direct interpretation. By taking in to consideration these advantages, the researcher preferred to use binary logistic regression model to predict the effects of independents variables on the dependent variable.

Therefore, the dependent variable is dichotomous, i.e. to adopt or not to adopt: thus, the dependent variable Yi = 1 if the household adopt the stove, and Yi = 0 if the household do not adopt. To adopt or not to adopt in relation to independent variables can be depicted in linear probability as follow: $Yi = \beta 0 + Xi\beta + \varepsilon i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$ This is the usual linear regression model, the drawback of this model is εi only two values: If Yi =1 then εi = 1-Xiβ (with prob. Pi, If Yi = 0 then εi = - Xiβ (with prob. 1- Xiβ) Here, εi is not normally distributed but rather has a discrete (binary) probability distribution. Therefore, the expectation mean of εi conditional on the exogenous variables Xi from the above. $E(\varepsilon i/Xi) = (1 - Xi\beta)Pi + (-Xi\beta)(1 - Pi) = E(\varepsilon i/Xi) = Pi - Xi\beta$ Setting this mean to zero as in the classical regression analysis mean: $\varepsilon i/Xi) = 0, \; PiXi\beta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$ The probability of an event is always a number between 0 and 1(inclusive), so: $Pi = (prob.1/Xi) = Xi\beta \ldots\ldots\ldots\ldots (3)$ Therefore, εi follow the binary distribution, i.e (εi is binary distribution) leads to rise logit model. The logistic distribution function is: $prob.(\varepsilon i < Xi\beta) = \wedge(Xi\beta) = \frac{e^{Xi\beta}}{1+e^{Xi\beta}} \ldots (**)$. Here the response probability prob. (Yi =1) is evaluated as: $Pi = prob.(Yi = 1/Xi) = prob.(\varepsilon i > -Xi\beta/X = 1 - prob.(\varepsilon i < -Xi\beta/Xi)$ $= 1 - \wedge(-Xi\beta) = 1 - \frac{e^{-Xi\beta}}{1+e^{-eXi\beta}}$ $Pi = \frac{e^{xi\beta}}{1+e^{Xi\beta}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$, Similarly, the non- response probability is evaluated as: 1-Pi = prob (Yi = 0/Xi) = 1 - $\frac{e^{xi\beta}}{1+e^{Xi\beta}}$ = 1-Pi $= \frac{1}{1+e^{Xi\beta}} \ldots\ldots\ldots\ldots\ldots$ (5) Note that the response and non- response probabilities both lie in the interval [0, 1] and hence, are interpretable. Therefore, for the logit model, the ratio is given by: $\frac{Pi}{1-Pi} = \frac{prob.(Yi=1/Xi)}{prob.(Yi=0/Xi)} = \frac{\frac{e^{Xi\beta}}{1+e^{Xi\beta}}}{\frac{1}{1+e^{Xi\beta}}} = \frac{Pi}{1-Pi} = e^{Xi\beta} \ldots\ldots\ldots (6)$ Pi/ (1-Pi) are the odds ratio in support of adopting the stove i.e. the household will adopt the stove to the probability that it will not adopt the stove. Taking the natural logarithm of equation (6) which can obtain.

$\text{Ln}\left[\frac{Pi}{1-Pi}\right] = Xi\beta = \beta 0 + X1i\beta 1 + X2i\beta 2 \ldots + Xki\beta k \ldots\ldots (7)$

Here the log of odds ratio is linear both in Xi and in the parameters. Therefore, (βo) stands for intercepts. While $X_i$ is the hypothesized determinants of stove adoption and βk are the parameters to be estimated. Therefore, the model employed has the following form, with the error tem:

$$\ln\left(\frac{pi}{1-pi}\right) = \beta o + \beta 1 age + \beta 2 gender + \beta 3 marsta + \beta 4 famsize + \beta 5 litlev + \beta 6 sepk + \beta 7 sowood + \beta 8 price + \beta 9 houincom + \beta 10 discen + \beta 11 stodesin + \varepsilon i$$

Where, $Xi - independent \; variables, \quad \beta o - constant, \quad \beta i - regration \; coefficients \; of \; the \; independent \; variable \; (slope)$

**Diagnostic Tests**

Any analysis should incorporate thorough examination of logistic regression diagnostics before reaching a final decision on model adequacy (Hosmer –Lemshew 2000). Model-Fit test is one of the most useful tests for truly assessing model fit for binary logistic regression models (Gujarati, 2004). The test shows the overall goodness of the fitted model is indicated by insignificant chi- square (p- value > 0.05) the model produce a significant difference between the observed and predicted probability so, the

predicted model is fitted since the prob> chi2 was found to be 0.239 which is greater than 0.05.

The multi-collinearity is a problem when the correlation result is above 0.80 and below -0.80 (Stock and Watson, 2007). The coefficients of all variables were found to be within the specified range and hence there is no issue of multi-collinearity as it ranges from (-0.5951 to 0.7074). In addition, Variance Inflation Factor (VIF) was tested with a result of 1.80. According to Wooldridge (2002), by rule of thumb, VIF value of 10.00 is used as a critical point to indicate serious multi-collinearity problem. Therefore, there was no severe multi-collinearity problem since 1.80 is less than 10.00.

From the total of 341 respondents 211 (62.2 %) were found non-adopters of improved cook stove while 130 respondents (37.8%) are adopters. This indicates that majority of the households were found to be non-adopters. Based on the data collected through appropriate instruments the most important reason for low adoption rate of improved coke stoves in the study area are poor institutional organization, low community awareness among others. The stove under dissemination is poor in quality the designs are poorly related to the feeding habits of the population in the study area. The major limitations of the current improved stoves under dissemination in the study area are bulky/difficult to transport, easily cracking and heat external part are the main problems that hinder the demand of the stove respectively. So, the existing cook stove has technical problem that hinder the technology adoption by itself and they suggests the stove under distribution requires re-design to solve the existing poor quality of the stove under dissemination and the biomass sources of energy took households' energy consumption which is covered 95.4%, followed by electric and solar energies that for light only 3.4% and 1.2% respectively.

With regard to cooking activities porridge (locally genfo) and injera baking preparation was found to be the largest energy consumption practice for 204 (59.8)% and 131 (34.4%) respondents respectively and followed by water heating 6(1.8%). From the above analysis it can be understand that for most households wood is the main sources of energy for cooking and baking porridge as well as the food preparation responsibility was 100% over done by women's, With regard to fuel-wood supply for the household consumption were done by women, girl children but almost men and child boys do not have contribution for food preparation and wood collection. The distribution of improved cook stove is gonziye 13.7%), lackech 5.2% and mirt 0% with total of 18.9%.

## IV. Results/Findings

The below Table 4.1 presents results of the logistic regression model where the first column (1) depicts the likelihood (probabilities) of adopting improved cook stove in the study area. Column (2) of the same table displays the odds ratio.

**Table: 4.1: Logit regression result (Maximum Likelihood Estimation Result)**

| VARIABLES | (1) Coefficients (dummy for adoption) | (2) Odds ratio (Odds ratio) |
|---|---|---|
| Age of household head (in years) | -0.0379 | 0.963 |
| | (0.049) | (0.039) |
| Household head is female (1=yes) | -1.111* | 0.329* |
| | (0.591) | (0.237) |
| Household head is married (1=yes) | -1.248 | 0.287 |
| | (0.943) | (0.342) |
| Household Size | 0.0796 | 1.082 |
| | (0.167) | (0.164) |
| Household head literate (1=yes) | 1.366*** | 3.920*** |
| | (0.501) | (2.103) |
| Household has separate kitchen (1=yes) | -0.278 | 0.757 |
| | (0.398) | (0.331) |
| Household has access free wood (1=yes) | -0.629 | 0.532 |
| | (0.516) | (0.289) |
| Log of household income | 1.523*** | 4.585*** |
| | (0.447) | (1.588) |
| Log of improved cook stove price | 0.580 | 1.786 |
| | (0.957) | (1.881) |
| Good stove design (1=yes) | 2.609*** | 13.580*** |
| | (0.631) | (8.287) |

| | | |
|---|---|---|
| Log distance improved cook stove production. | -0.851*** | 0.427*** |
| | (0.231) | (0.108) |
| Household has early adopters neighbor (1=yes) | 1.302* | 3.677* |
| | (0.667) | (2.676) |
| Household access extension services (1=yes) | 0.0730 | 1.076 |
| | (0.545) | (0.582) |
| Constant | -11.15* | 0.000* |
| | (5.628) | (0.000) |
| Observations | 341 | 341 |

Standard errors *** p<0.01, **p<0.05, * p<0.1(Gujarati, 2004)

Gender is significant factor at 10% level of significance with p-value 0.06 and odd ratio 0.329, the likelihood adopting improved cook stove is about 67.1% (= 1- 0.329) higher for female household heads as compared male.

Literacy level significantly affects the probability of improved cook stove that literate household head are 3.920 times more likely adopt improved cook stove as compared illiterate household keeping all other covariant constant.

House hold income was found positive significant determinant factor implies that as household income increase by one birr the probability of improved cook stove adoption increase by 4.585 percent keeping other covariates constant.The distance from home to improved cook stove production center has a negative effect implies that as distance from stove production center increase by one kilometer, the probability of improved cook stove adoption decrease (1- 0.427= 0.573) by 57.3 percent keeping other covariate constant. As it was expected stove design was a positive significant factor. All key informants, sub district leaders and development workers are strongly agree that government collaboration with partner to change the present infant stage energy consumption and improved stove adoption are the best mitigation mechanism for the household health and environmental protection.

## V. Conclusion

The finding reveals that majority of households energy consumption, depends on fire wood followed by crop residual leafs and coal which cover 80.7%, 17.8%, and 1.5% respectively while kerosene, solar and electricity are lowest energy consumption in rural district for the purpose of light which may aggravate, deforestation and lose of soil fertility which in turn environmental degradation, human health problem and farm land productivity reduction.

Improvement in resource-use efficiency through technological alternatives like biogas, wind power, solar energy and improved stove technology is vital however; still application of technological alternative energy of the district is in infant stage. The economic, social, environmental and health benefits from these stoves have always outweighed the costs of the stoves. Furthermore, survey result shows that only 38.1 per cent of the households adopt improved cook stove and they become more advantageous in terms of high improvement in speed of baking, reduce biomass collection time and reduce smoke as compared to non-adopters.

Among the improved cook stove adoption factors, gender of the household head is found to be negative and significant to affect adoption *i.e.* female headed households are more likely to adopt energy saving cook stove compared to male headed households. Regarding education only 26.8 percent of literate households found to be not engage on improved cook stove adoption, while 73.2 percent of the literate households adopt improved cook stove, this difference is highly significant which implies that literate household heads have more likelihood to access modern improved cook stove than the illiterate households in the district.

Adoption of improve cook stove is positively and significantly affected by economic status and positively related to neighborhood effect that is improved stove adopter households have 71.9 percent early adopter neighbors while non-adopter households 28.1 percent as well as a stove design which fits the cultural food preparation practice of a community is found to be an important and significant factor for adoption.

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