FUEL EFFICIENT TECHNOLOGY ADOPTION IN ETHIOPIA: EVIDENCE FROM IMPROVED "MIRT" STOVE TECHNOLOGY: A CASE IN SELECTED KEBELES FROM "ADEA" WEREDA[1],[2]

Dawit Woubishet[3]

Abstract

The increasing scarcity of biomass and the increment of the number of people who use biomass, particularly firewood, threaten the capability of the country even to maintain the already existing low income and living standard of the people. Therefore, the need for adopting improved "Mirt" stove technology not only enables the households to use fuel efficiently, but it will enable them to curb the problems caused by using traditional and open fire stoves as well as biomass energy related problems. It can also mitigate the impacts on the users' health, the overall environment and natural resources brought by using those traditional and open fire stoves.

With two estimated equations, that is information and adoption equation. This study result reveals that improvement in socio economic conditions of the people have positive impact on information acquisition and access in urban and rural households. Moreover, the result supports the "energy Ladder" hypothesis as theoretical and functional useful framework to explain the fuel use and improved technology adoption in the study area. The findings also reveal that socio-economic improvement have direct and significant impact on adoption decision. This finding also reinforces the role of government and non-government organizations to play a major role in information diffusion and to enhance the adoption decision of the people to protect the country's natural resources and to resolve environmental problems that arise due to excessive utilization of biomass resources.

Keywords: improved stove, information, adoption and "energy ladder"

---

[1] The final version of this article was submitted in March 2009.
[2] Derived from author Masters Thesis, Addis Ababa University, Addis Ababa
[3] E-mail: hello3days@yahoo.com

I. Introduction

Poor people are both the agents and the victims of environmental damage. Fuel-wood gathering can lead to land degradation, biomass combustion to indoor air pollution, dirty fuels to outdoor air pollution and through green house gas emission, global warming. In all those cases, poor people both contribute to the environmental damage through their actions and suffer from its consequences. Moreover, the energy sector has a significant part to play in reducing the environmental damage and its harmful effects by introducing renewable energy source, supplying modern cooking fuels, and substituting cleaner fuels for dirty ones and increasing energy efficiency.

Energy is vital to economic development. Without fuel that power cars, trains and planes, and without electricity, light and heating, life in industrialized countries would be considerably less comfortable. In developing countries, however, it is not just a question of comfort. Poverty could not be reduced without the greater use of modern forms of energy. Even now, around two billion people have no access to electricity, relying instead on traditional fuels such as dung and fuel-wood. Those who are fortunate in developing countries enough to have electricity, on average spend 12% of their income on energy; more than five times the average for people living in OECD countries. At the same time, the provision of energy services, especially the combustion of fossil fuels and biomass can have adverse effects on the environment (WB, 2000).

Ethiopia has significant energy resource. This resource endowment is said to be enough to meet the present need and long-term energy requirement of the country. Overall, only some of this endowment is being presently exploited (EEA, 1994). The main endogenous sources of energy are biomass, hydropower, fossil fuel (natural gas, coal), geothermal, solar and wind. The country's energy use and/or consumption are 95.6% from traditional source and only 4.4% from modern source. In terms of the level of sectoral use; household accounts for about 91.3% of the total final energy consumption. And the biomass fuel account 98.5 % while the modern energy only takes 1.5%. Within the household sector the rural and urban household energy consumption accounts for 92 and 8%, respectively. (Asres, 2002)

In Ethiopia, few studies have attempted to investigate the problems, constraints and factors affecting the household decision to adopt fuel efficient technology with the context of environment and natural resource protection. Tadelech (2001), considered the problem of population pressure and rural-urban migration and their impact on energy need in urban areas and analyzed the determinants of fuel-efficient technology adoption. She only looked at demographic and socio economic variables and her study were limited to two kebeles with in Addis Ababa. Hence, this study focuses on both rural and urban households. It is obvious that the rural household takes a significant share in energy consumption and the adoption of this technology is extremely low. Along with the socio-economic and demographic factors; dwelling characteristics, information diffusion and attitudinal or perceptions of the household to the technology are considered. The paper also provides knowledge and information with regard to promoting fuel-efficient technology and conserving energy, forest resource and environment.

The major objective of this study is to analyze the nature, problems and main determinant factors in household decision to adopt improved fuel-efficient technology, the factors that determine to acquire information about the technology and their impact on environment, fuel scarcity, household time and income. And also to drive policy implications and interventions on environment, natural resource and energy/

The findings may also help to rehabilitate policy regarding energy, environment, natural resource and information. In addition, the results have anticipated in assisting development practitioners, both governmental and non-governmental organizations that are interested in alleviating poverty, satisfying the energy need of poor households and protecting natural resources.

In Ethiopia, projects involvement in this particular activity has not well developed. One of the projects involved in production and dissemination of improved stove is an improved (“*Mirt*”) “injera”[22] stove, which is undertaken by GTZ- Household Energy and Protection of Natural Resources Project with the participation of private sectors in production and commercialization of the stove.

The Ministry of Agriculture and GTZ, The German Development Cooperation, in 1998 have launched an improved stove dissemination program to promote biomass energy efficiency in households. The main objective of the project is to enhance efficient use of biomass resources by integrating household energy measures into development plan. Moreover, the overall goal of the project is to contribute to environmental protection and sustainable environmental development. The project focuses on the dissemination of improved (“Mirt”) stove fuel saving for “ingera” baking. The technology choice has been taken on the ground that baking “injera” alone takes a significant share of the primary energy consumption.

---

[22] “Injera” is the traditional food in major Ethiopian households, and mostly prepared from “teff”.

The improved ("*Mirt*") stove has been under extensive research and testing by the Ethiopian Rural Energy Development and Promotion Center (EREDPC) in the beginning of 1990s, when the stove was introduced in Addis Ababa market. The improved ("*Mirt*") stove has certain features that make it particularly suitable for commercial dissemination approach. Among the desirable features include it can save fuel expense for the households, accommodate different types of fuel, and it has a modern design and create clean kitchen environment.

2. Theoretical background

From the mid 1970's onwards, the rapidly increasing cost of all forms of energy, led by the world oil price, stimulated the development of new analytical tools and policies (Munasinghe, 1980). First, the need became apparent for greater coordination between energy supply and demand options. Second, energy-macroeconomic link began to be explored more systematically. Third, the more disaggregate analysis of both supply and demands within energy sector offered greater opportunities for inter fuel substitution (especially away from oil). Fourth, the analytical and modeling tools for energy sub-sector planning became more sophisticated. Fifth, in the developing countries, greater reliance was placed on economic principles, including the techniques of shadow pricing. Finally, heightened environmental concerns have led to a better understanding of energy – environment interactions.

The environmental and health consequences associated with various cycles of energy production and consumption is, for a large part, very similar among energy sources. Differences may exist mainly in terms of the magnitude of those effects. Major disruptions in the environment and health impacts are linked to biomass energy from gathering and combustion.

Gathering of fuel-wood and removal of crop residues or animal manures in the course of using biomass as fuel have; for instance, been argued to contribute to serious deforestation in the long run, increased incidence of floods, stream sedimentation, and decreased water yields from watersheds. Excessive removal of agricultural residues or animal dung affects soil fertility, and exposes soil to increase wind and water erosion. Biomass combustion has the potential to create indoor air pollution, if wood stoves are improperly installed. Among the emission control method, improved stove technology is one of the alternatives for most developing countries because biomass is the most important source of energy and its use is wide spread, especially by the poor.

2.1 The energy ladder hypothesis

The most comprehensive hypothesis regarding energy use pattern of households focuses on the concept of "energy ladder". The energy ladder depicts various combinations of fuels used by a household at its different stage of development. With movements up the ladder, fuel mixes are generally considered as clean and efficient. This is also directly correlated with income growth, bringing about an increased use of modern fuels and less use of biomass (Israel, 2002). The basic assumption of energy ladder is that a household is faced with a range of different energy supply choices, which can be classified in order of increasing technological sophistication.

Households use fuel for a variety of activities, including cooking, water heating, lighting, and space heating. The order of different fuel types on the energy ladder can vary according to this end use. For cooking Munasinghe and Meier (1993), for example arranged the range of different energy leader as follows: first, dung and crop residues (which are inferior quality biomass fuels, and grouped at the bottom of the ladder); second, fuel-wood and charcoal (relatively higher quality biomass fuels and placed in the next step); third, kerosene; forth, Liquefied Petroleum Gas (LPG); and finally, natural gas and electricity.

As the economic status of a household rises, reduced use of lower quality fuel type and switch to consumption of relatively higher quality ones occurs. As a result, the household is said to move up in the energy ladder. If, on the other hand, the economic status of a household declines, then it is expected to consume a relative inferior quality fuel. In this regard, Hosier and Dowd (1988) point out that energy ladder acts as a stylized extension of the economic theory of a consumer. That is, as household's income increases, it makes a decision not only to consume more of the same good, but switches towards consuming other goods of higher quality.

2.2 Theoretical background on energy conservation determinants

Economic theory suggests that, in order to gain comfort and time, households are becoming excessive energy users, neglecting the environmental impact of their choices. According to household production theory, households are treating as productive units organized to provide services for the occupants; energy is treat as input in the provision of a range of household services. Consumers' choices define the utility they can derive (Becker, 1965; Muth, 1966). The extent of service that we can derive from a given amount of energy depends not only on the efficiency of the technology but also the consumers' lifestyle. Several theoretical and empirical studies focused on households' energy conserving behavior and its links with socio-economic parameters, which hint at lifestyle changes.

In the context of residential energy use, lifestyle should reflect the understanding that environmental responsibility and concern for energy sources go part and parcel with our daily energy based actions (Held, 1983). This demand-conscious lifestyle does not necessarily imply curtailment or sacrifices as far as the level of comfort or the quality of living are concerned. On the contrary, this approach is centered on an altered awareness of energy consumption in our daily lives.

As Coomer (1977) claimed a significant decrease in energy consumption may mean a perceived lifestyle change and should not be identified by means of reduced quality of life or social status, and as Leonard-Barton (1981) defined in a discretionary change of lifestyle, a low energy lifestyle is characterized by ecological awareness and attempts to become more self-sufficient users, known as voluntary simplicity lifestyle.

Van Raaij and Verhallen (1983) and Weber and Perrels (2000) specified that lifestyle approach should take into consideration a broader socio-cultural concept. In this concept, lifestyle patterns are shaped as a consequence or enduring activities with regards to time, housing, family and income conditions that households face and partly as a way or self-expression and self-realization.

3. Methodology

3.1 Data source and methodology

Adea is selected for this study as it is one of the major urban and rural centers of the country with severe forest degradation and fuel-wood and other energy source problems. The data type used in the study mainly includes primary and cross-sectional for the period of 2006. Data sources were mainly on survey conducted for this purpose and relevant documents from *Adea* Municipality and Rural Administration Office. The primary data were collected by making a household survey with questionnaire having five parts: household information; household energy pattern; fuel use; cooking pattern, kitchen environment and improved stove and household perception, and attitude towards the improved stove technology.

After designing the draft questionnaire, pre-testing of the questionnaire was conducted through a focused group discussion with municipality officials, producers of the improved stove, and fifteen randomly selected households. The purposes of the pre-test were to make some possible modifications in the design of the questionnaire for the main survey, so that objectives of the survey can be met. Based on the pre-test the order of the questionnaire was restructured, making questions on household characteristics (particularly questions with economic characteristics, income, for which households were reluctant to give true responses).

First, the *Adea* wereda divide into rural and urban households. To identify the well informed households'; for urban households GTZ-SUN energy Project organized a demonstration activity about the improved ("*Mirt*") stove technology in different places and time. It is estimated that about 30000 household attend the demonstration activity in *Adea* wereda. For rural households the rural development agent's in collaboration with GTZ-SUN Energy Project provided training and demonstration about the stove in church, local people associations meeting and in extension training programs. According to GTZ-SUN energy in *Adea* wereda approximately 6,856 stoves are distributed of which 1,596 and 5,260 in rural and urban households, respectively.

For consistency of data analysis, for urban households those who attend the demonstration activity effectively had been considered as well informed and know very well about the improved ("*Mirt*") stove technology and those who did not attend the demonstration activity effectively are considered as not well informed about the technology. And for rural households, who are not actively participate in demonstration activity by development agents and weak in extension participation and training programs are considered as not well informed about the technology.

A Stratified and random sampling technique was used for the study. Due to lack of well documented information on number of households and their location for the newly established 9 urban and 27 rural kebeles from each settlement; three kebeles were randomly selected. The rural kebles' were selected from the surrounding eleven kebeles which is near to the town of "Debrezeit". Then from each selected urban and rural kebeles 30 and 40 households are randomly selected, respectively. Time and financial limitations were taken into account and random sampling technique employed to select a sample population of 210 households for this study.

3.2 Model specification

The model begins with the information held by the household, the potential adopters. It would be misleading to categorize the population of households into adopters and non-adopters; if not all members of the potential adoption community are informed. The adopting households are therefore those that are informed about the existence of the technology and find it efficient. Thus, the adoption decision is conditional on the availability of information.

3.2.1 Information equation

A common practice in adoption studies is to divide the adoption population in to adopters and non-adopters without worrying about whether all members of household of the potential adoption population are informed about the existence and utilization the technology under the study. This usually results in inefficient and biased estimator. Then, if in any community, some potential adopters are not informed about the existence and how to use the technology, the information equation should be the first equation of adoption model (Seha. et al 1994).

Let us take a household with a level of information equal i* and let i^0 be the threshold of level of information that a household should have in order to be classified as informed. Then the household is informed if $i^* > i^0$

By defining the latent variable Y^{H^*} as $Y^{H^*} = i^* - i^o$ the condition to classify a household as informed becomes

$$\mathbf{Y^{H^*} = i(X^H) - i^O > O} \qquad \mathbf{1}$$

Where superscript H stands for household who have heard that the technology exists and knows how to use it.
X^H= vector of household characteristics and attributes that could influence i*, say the supply and demand of information
Then the theoretical equation to be estimated is then.

$$\mathbf{Y^{H^*} = X^H . \beta^{H^*} + \epsilon^{H^*}} \qquad \mathbf{2}$$

Where β^{H^*}= *Vector of parameter to be estimated*
ϵ^{H^*}= *error term*

i^*, i^o and consequently Y^{H^*}, are not observable. To estimate the information equation, we need to construct a variable that accounts for whether the household is aware of the technology and how to use it. Let us denote that variable by Y^H. Which takes the value **1** for a positive answer ($Y^{H^*}>0$) and **0** for a negative or null answer ($Y^{H^*} \leq 0$).

The theoretical Probit equation to be estimated is therefore

$$Y^H = \Phi\,(X^H.\ \beta^H) \qquad 3$$

Where β^H = *vector of parameter to be estimated*

3.2.2 Adoption equation

After the information equation formulate, the adoption equation conditional on information. If the household is not informed, it is not possible to consider adoption. Households may well be informed about the existence and use of the technology but there are different factors that affect the decision of the household whether to adopt or not. Therefore, adoption equation formulates to analyze only for informed households.

Dominich and Mc Fadden (1975) used a random utility approach, permit a more systematic look at the primary determinants of adoption behaviour and make possible a systematic sensitivity analysis of the predicted probabilities of adoption decision to changes in key explanatory variables. The model uses the random utility approach; the household chooses the technology because it provides a maximum expected utility among the available choices.

Haab and McConnell (2002) quoted Hanemann (1984) also developed the basic model to analyse dichotomous responses based on the random utility theory. The central theme of this theory is that although an individual knows his/her utility certainly, it has some components, which are unobservable from the viewpoint of the researcher. As a result, the researcher can only make probability statement about respondent's 'YES' or 'NO' responses or decisions.

The Probit Model is used to identify factors that affect the probability of adopting the improved ("Mirt") stove technology. In this study, households are informed about the existence and how to use the technology, which they may adopt or not. Hence, it is a single bounded dichotomous choice model to be framed under the random utility method (approach). The random utility model also provide convenient approach and the point of departure is a utility model that is composed of two parts, one observed by the analyst, the other treated as random.

Let us consider the decision of a household regarding whether he/she adopt the improved ("Mirt") stove or he/she adopt the traditional or open-earthed stove for the household baking appliance.

Let's define that indirect utility function for the j^{th} household can be specified as follows:

$$U_{ij} = U_i\left(Z_j, H_j, C_{j,} D_j, \varepsilon_{ij}\right) \tag{1}$$

Where D_j= j^{th} respondent's dwelling status.

H_j = vector of household socio economic and demographic characteristics and attributes.

Z_j = j^{th} household response about the compatibility and complexity of the technology.

C_j = j^{th} household cost (expense) for fuel, and members of household participate for collection of fuel-wood and other energy sources for the household energy need

ε_{ij}= random component of the given indirect utility

Equation (2) represents the household utility function with the baking appliance (stove) for the household is the improved (”*Mirt*”) stove technology.

$$U_{1j}\left(Z_j, H_j, C_j, D_{j,} \varepsilon_{1j}\right) \tag{2}$$

Equation (3) represents the household utility level with the baking appliance (stove) for the household is the traditional or open hearth stove technology.

$$U_{0j}\left(Z_j, H_j, C_{j,} D_j, \varepsilon_{0j}\right) \tag{3}$$

The household is introduced about the improved (“*Mirt*”) stove technology and knows improvement in household energy efficiency and environment; the household adopts the improved (“*Mirt*”) stove technology if and only if:

$$U_{1j}\left(Z_{j,} H_j, C_j, D_j, \varepsilon_{1j}\right) > U_{0j}\left(Z_j, H_j, C_j, D_j, \varepsilon_{0j}\right) \tag{4}$$

Then, for individual j, the probability statement is:

$$P(Yes) = \left[U_{1j}\left(Z_{j,} H_j, C_{j,} D_j, \varepsilon_{1j}\right) > U_{0j}\left(Z_j, H_j, C_j, D_j, \varepsilon_{oj}\right)\right] \tag{5}$$

This probability statement provides an intuitive basis to analyse binary responses. Assuming that the utility function is additively separable in deterministic and stochastic preferences:

$$U_{ij}\left(Z_j, H_j, C_j, D_j\right) + \varepsilon_{ij} \quad \textbf{6}$$

Given the additive specification of the utility function the probability statement for respondent j becomes:

$$P(Yes) = \left\lfloor U_{1j}\left(Z_j, H_j, C_j, D_j\right) + \varepsilon_{1j} > U_{0j}\left(Z_j, H_j, C_j, D_j\right) + \varepsilon_{0j} \right\rfloor \quad \textbf{7}$$

This probability statement is the point of departure for the linear utility function in a set of covariates, which is assumed by our empirical model. However, the adoption decision of individual household is conditional on the acquisition of information. This procedure needs to be sequential and let denote the vector of explanatory variables that explain adoption decision by $\boldsymbol{X^A}$. Then, we obtain the following theoretical model:

$$Y^{A^*} = X^A.\ \beta^{A^*} + \epsilon^{A^*} \quad \textbf{8}$$

Where: B^{A^*}, vector of parameters to be estimated,

ϵ^{A^*}, error term

The latent variable Y^{A^*} is not observable and we defined by its proxy Y^A taking a value **One (1)** for adopters and **Zero (0)** for non-adopters for the sub-sample of informed households (Y^H=1). Thus, the conditional Probit model to be estimated:

$$Y^A = \Phi\ (X^A.\ \beta^A\ ) \quad \textbf{9}$$

Equation (3) and (9) are model of sequential, adoption of one technology based on information acquisition. This model of sequential adoption of one technology based on information acquisition is in essence different from that of Khanna (2001) as sequential adoption of components of technological package. Nevertheless, the statistical implications for econometric analysis of adoption are quite similar. As in Khanna (2001), under the study of sequential adoption components of technological packages and just making the substitution of technological component for decision. It is possible that, since decisions (information and adoption) are interrelated, single equation is inefficient because they ignore the correlation of error terms of equations that explain each decision. Thus, this correlation arises because the same unobserved characteristics may influence all inter-related decisions.

For the empirical estimation, let us assume that ($\varepsilon^H, \varepsilon^A,$) has a bi-normal distribution. That is:

$$(\varepsilon^H, \varepsilon^A)\, BVN(0,0;1,1,\rho) \qquad \textbf{10}$$

Where: ρ is the correlation coefficient between ε^A *and* ε^H.

Under the above assumption, the conditional probability of the adoption decision given by equation (10) (see Seha et al., 1994; Maddala, 1983)

$$\Pr ob\left(Y^A = 1/Y^H = 1\right)$$
$$= E\left[Y^A / \left(i^* - i^0\right) > 0\right] = \Phi\left(X^A.\beta^A\right) + \rho.\frac{\phi\left(-X^H.\beta^H\right)}{1-\Phi\left(-X^H.\beta^H\right)} \qquad \textbf{11}$$

$$Note\ \alpha = -X^H.\beta^H\ and\ \lambda(\alpha) = \frac{\phi(\alpha)}{1-\Phi(\alpha)};\ \lambda(\alpha)\, is\ the\ inverse\ of\ Mills'\ ratio. Then, we\ have$$

$$\Pr ob\left(Y_A = 1/Y_H = 1\right) = \Phi\left(X_A.\beta_A\right) + \rho.\lambda(\alpha) \qquad \textbf{12}$$

Φ and ϕ are the functions of cumulative distribution and normal probability density, respectively.

For traditional Probit and Logit estimations, only element $\Phi\left(X^A.\beta^A\right)$ is considered in equation (12), resulting in inconsistent estimators β^A. More importantly, application of traditional Probit and Logit estimations that ignore self-section would result in biased estimates of marginal effect on probability of adoption of a variable $\mathbf{X}_j$ that is common to vectors X^H and X^A.
From (12), we have:

$$\partial \Pr ob\,\frac{(Y^A = 1/Y^H = 1)}{\partial \chi_i} = \Phi\left(X^A.\beta^A\right)\beta_j^A + \rho.\beta_j^H.\left(\lambda\alpha - \lambda^2\right) \qquad \textbf{13}$$

If the possibility of self-section is ignored, the second element of the right side of equation (13) will be omitted. For all parameters to be identified, $\mathbf{X^H}$ and $\mathbf{X^A}$ should differ at least in one independent variable.

Therefore, the maximum likelihood estimates of parameters β^A , β^H , ρ can be obtained from maximizing the following log-likelihood function, which rests on the definition of conditional probability:

$$\ln L = \sum_{Y^A=1, Y^H=1} \ln \Phi_2\left[X^H\beta, X^A\beta^A, \rho\right] + \sum_{Y^H=1, Y^A=0} \ln \Phi_2\left[X^H\beta^H, -X^A\beta^A, -\rho\right] + \sum_{Y^H=0} \ln\Phi\left[-x^H\beta^H\right] \qquad 14$$

4. Empirical findings: Results and discussions

4.1 Descriptive results

4.1.1 Socio-economic characteristics of the households

On average 11% of the rural households were female-headed and 89 % were male-headed while the proportions in urban areas were 64 and 34%, respectively. Household age ranges from 20 to 83 years and the sample average equals 47 and 50 years for rural and urban households, respectively. About 78 and 64% of the rural and urban households, respectively, were married. However, the average household consisted of seven individuals for rural areas, ranging from one to eighteen members and five individual for urban areas.

The education of the household head was categorized into four levels. Those who cannot read and write are categorized under illiterate group and constituted 37% of the rural households' heads. Nonetheless, those with a formal education of 1-6 grades are grouped under primary level education since they can read and write and constituted about 40%. Those with a formal education of between 7 and 12 grades accounted for 21% of the rural respondents and were grouped under secondary level. About 2% of the rural respondents have completed high school, and thus they are grouped under tertiary level. In rural areas female literacy level is very low; only 38% of the household wives are literate.

From among urban household heads, about 34% attended primary level education while 30 and 7% attended secondary and tertiary level, respectively. The remaining 29% are disappointedly illiterate. However, female literacy in urban areas takes 56%. The average monthly rural households' income is found to be 656.12 birr and 53% of the respondent rural households earn monthly income of less than five hundred Birr whereas in urban households, the average is only 506.72 birr and the majorities (74%) earn monthly income of less than five hundred Birr. Thus, the study indicates that the average income of the rural households is surprisingly greater than urban households.

The respondents stated that their income is not enough to cover their basic needs. Since the urban households were not interested to disclose their monthly income, expenditure on major items has been taken as a proxy of monthly income. For rural households their monthly income is estimated by considering the major crop they produce per annum, off-farm income source and livestock capital of the household. Currently, there are a number of microfinance institutions and other credit organizations that facilitate credits for dwellers, but only 52% and 58% of the urban and rural households have access to credit facilities, respectively.

Dwelling status is used to indicate the standard of living of the people. As per the survey result, 78% of the rural households live in their own house while the rest 22% live either with their relatives or in rental house. But, in urban households, only half of the sample households live in their own house while the rest reside in kebeles' house, temporary shelter or private rental house. The study found that housing problem is more severe in urban households than in rural households.

The average dwelling size and the kitchen environment are almost similar in both settlements, urban and rural. The great numbers of houses are built with mud, wood and corrugated iron, and they consist of three rooms on average. About 60% of the rural households bake and cook in separate kitchen. However, the remaining 40% bake and cook in open air and in their living rooms. Nonetheless, about 42% of urban households bake and cook in shared kitchen, open air and within their living rooms. Those households, who do not have separate kitchen, are faced problems related to cooking and baking activities such as accident to burning, heat and smoke problem.

About 44 and 51% of the rural and urban households who are interviewed are actively participating in local associations, such as "Idir", "Iqub" and "Mahiber", respectively. Participation in those associations is believed to enable households to get informal source of information.

4.1.2 Fuel consumption and related issues

Most of the interviewed households (92%) mentioned that they are using fuel-wood and cow dung as a major source of energy. About 37 and 44% of the households always use fuel-wood and cow dung as a substitute while facing shortage of any kinds of fuel sources, respectively. This result thus indicates that there is excessive utilization of biomass resources in rural and urban areas, which might cause a negative impact on the natural resources and environment.

Households collect fuel-wood and other energy sources from different areas. In rural areas, 31% collect energy sources from their back yards while 36 and 22 % collect from their own farm (field) and open field, respectively. The remaining 11%, however, purchase from their nearest fuel market. In urban areas 21% of the households collect from their back yard where as 20 and 15% collect from their own field and open field areas, respectively. The remaining 44% are using commercial means to meet their energy need.

The study has identified that households adopt different coping strategy to overcome fuel shortages: Storing of fuel and substituting one fuel source by other are some of the coping strategies to alleviate the problems. About 40 and 32 % of the urban households and 54 and 31 % of rural households use Storing of fuel and substituting strategies, respectively.

Concerning getting information about the new and improved stove technology, around 49% of the urban households obtain their information from demonstration activities undertaken by GTZ- SUN energy whereas 62 % of the rural households obtain from development agents demonstration. Thus, provision of information is important through informal channels to address all the population.

4.1.3 Time and effort involved in gathering fuel wood/dung and expense for fuel.

The responsibility of gathering fuel-wood and other energy sources lay on women and children in most developing countries. It is also known that collection and transportation of fuel involve tedious and tough work such as walking long distance with carrying loads and others that might cause health disorders on individuals. Similarly, the study indicates that those who collect fuel-wood and other energy sources have to cover long and tiresome distances at least two times per week and about sixteen hours per month to fulfill their energy consumption.

About 78% of the rural households meet their energy need from collection. On average, from two to three members of the family, participate in fuel gathering activities and 73% of the households, at least they travel two times per week and two of family members participate in fuel collection. Among the rural respondents who adopt improved stove and their main source of energy is through collection, about 77% of households collect fuel from their own farm to meet their needs and took less than half an hour. However, 45 and 62 % of non-adopters and non-informed households spent more than one hour for fuel collection, respectively. This indicates that the rural households spent a lot of their time for fuel wood collection.

However, 42% of urban respondents have to travel two times per week to collect fuel sources and 48% of the households, at least two member of the family, participate in fuel collection. Accordingly, the study has identified that the effort exerted and the time spent to collect fuel sources in urban areas are relatively less from that of rural areas. It might be because of the prevalent use of commercial energy sources in urban areas.

Since traditional and open fire stoves consume too much fuel, households are not able to meet their fuel need from their surrounding areas, non-informed and non-adopters of the improved stove are forced to move longer distance to find open field and backyard places in order to collect fuel sources. In those areas, fuel-wood and other energy sources are not easily accessible. About 57 and 45% of rural and urban households who use traditional and open fire stoves spent on average more than two hours for gathering energy sources on which at least two household members involve and they travel twice per week, respectively. Therefore, if a household collects fuel for nine months assuming that they may use the stock or any other means of energy need for the rest three months of a year, an individual member of the household will spend 135 working hours per year only for fuel gathering activities in those households. This indicates that children have to miss their school day and women are left less time to carry on other house chores.

The average monthly expenditure for fuel need is 41 and 17 birr in urban and rural households, respectively. Adopters of improved *Mirt* stove on average spent 29 Birr in urban households and 11 Birr in rural households. However, non-adopters of the stove spent 49 Birr in urban areas and 18 Birr in rural areas. In both settlements, the non-informed households mostly use collection of fuel as a source and they spent about 35 and 21 Birr for fuel in urban and rural households, respectively. Thus, if effort is made to distribute one million improved stoves in Ethiopia, it is possible to save on average 11.5 million Birr per month. This result indicates that the contribution of improved fuel saving technology towards households expenditure saving and directly to reduce impacts on fuel-wood and other biomass resources demand.

If this extra effort and time were to be put for some other productive use, it would surely help to reduce the burden of rural women and children in household activities and environment. It might also enhance the economic status of those women who participate in fuel collection. However, it is understood that not all of this time and effort can be put into productive and income earning activities due to many reasons such as child labour, low efficiency, low skill and lack of employment opportunity. Nevertheless, it will be possible for the households to generate income and reduce the burden of women should they utilize sixty percent of the extra time, which they spend to collect fuel, for productive purposes. The children will also able to use the time for their education.

4.1.4 Reasons for not using improved stove

This study focuses on those who are well informed, but not yet adopt the technology. The result reveals that low purchasing power only evidenced by rural households, about 76% of the households responded that the meager income they get prevents them to adopt the improved stove. About 53% of urban households reported that their main reason that hinders them from adoption is financial constraint. About 42% of urban households responded that their housing or dwelling status was the other key reason not to adopt the improved stove, especially the absence of separate kitchen in their living compound for those resides either in kebele house, temporary shelter or in private rental house. Particularly, urban households who use shared kitchen complained that their stove is easily accessible to all who live in the compound and other outsiders. Therefore, improving the kitchen environment and dwelling status of the people may contribute a lot for the household's energy efficiency and usage of better energy appliance. By doing so, households will be able to move into the upper energy ladder.

4.2 The econometric results

The conditional probability functions are very similar for both Probit and Logit models, except in the extreme tails. The Probit model estimation is applied for this study. In order to check whether there is any serious multicollinearity among the explanatory variables, a correlation matrix was generated to drop some variables having higher multicollinearity.

It is worth nothing that the values of certain variable contrast greatly in size with other variables which may induce hetroscedasticity. A test for the presence of heteroscedasticity[23] problem in the model was also done. The test result shows that the null hypothesis of homoscedasticity is rejected implying that there is heteroscedasticity problem in the model as it is expected and common problem in cross-sectional data. To minimize this problem, the natural log of the monthly income of the household is considered in the model and heteroscedasticity-consistent Probit

[23] The LR test is 88.17 and 84.27 for rural and urban estimates, respectively. The critical value of the chi-square at each estimation degree of freedom is at 95% level. Comparison of the results (test statistics) with critical table value shows that all of the test statistics (computed values) are found to be larger than the critical table value. This implies that the null hypothesis of homoscedasticity is rejected, i.e. hetroscedasticity is the problem for the model.

models from STATA 9 program were applied. The empirical results of information and adoption equations of rural and urban households summarized in Annex Table A-1-A and A-1-B, respectively.

4.2.1 The information results

Many empirical evidences show that acquisition of information and adoption decision determined by the socio-economic status, demographic characteristics, modern source of energy, educational attainment and income. Hence, the study tries to analyze the factors that determine information acquiring and adoption decision on improved *Mirt* stove technology in both rural and urban households in the study area.

In rural areas, the probability of information acquisition is higher in female-headed households than in male-headed and significant (at 5%). This supports the common tradition practiced in Ethiopian rural households, women are responsible to prepare food and collect fuel. As a result, rural women are concerned about the improved stove technology information.

Surprisingly, family size has a positive and significant impact on information acquiring in rural households. At the margin, the increase of rural household member by one may raise the probability of information acquiring by 7.9%. This indicates that particular rural family household members may disseminate and pass information to their family.

As expected, household age has negative impact on information acquiring in both urban and rural households, yet it is not significant. An increase in household age causes a reduction on the probability of information acquiring. The result suggests that information acquiring about improved *Mirt* stove is higher in young-headed households than older-headed ones.

On the supply side of the information, the source of information is either formal or informal sources. Access to electricity means that households can attend television and radio programs; as a result the households may get access to formal sources of information. This variable is highly significant and has positive impact in rural households than in urban areas. The probability of information acquisition is higher in rural households that have access to electricity than those of without electricity access. Therefore, provision of electric service to rural areas plays a pivotal role to disseminate information through formal means.

Producers of the improved *Mirt* stove have been exercising different commercialization strategies and promotional activities to introduce *Mirt* stove. The activities of producers may indirectly enable the society to access information about the technology. Thus, the study has revealed that the presence of *Mirt* stove producers in the urban households' living area or market has a positive and highly significant impact on information acquisition. Being the urban households near to market the probability of information acquisition will increase by 45.1%. It has also positive impact on rural household's information acquiring despite its insignificant. The insignificance of this variable in rural households may be due to the inaccessibility of market for *Mirt* stove in the vicinity of the people. This study has also identified that the rural households mainly obtain information about *Mirt* stove from development agents.

Finally, Active participation in local associations such as "Idir", "Iqub" and "Mahiber" bring positive influence and highly significant for information acquiring in both settlements (at 1%). Both in rural and urban households who are actively participating in local associations have higher probability to acquire information than households who are not active in participation. Being active in local associations' participation will increase the probability of information acquiring by 71.4 and 71.8% in rural and urban households, respectively. Indeed, informal channels of information dissemination are more effective for those households who are active in local association participation. As a final point, participation in local association has a great role to acquire information than adoption decision, thus, it is used as an offset variable.

We can conclude, then, among other variables the probability of rural households' information acquiring relating to the improved *Mirt* stove technology are statistically explained by family size, sex of household heads, active participation of households in local associations, and availability of modern source of energy (electricity). Regarding to urban households, the study result has indicated that active participation in local associations, and market or presence of producer of *Mirt* stove technology are the main significant factors to acquire information. Therefore, the study results reveal that improvement in the socio economic status and facilitation of information provision in rural and urban households would bring positive impact on information acquisition.

4.2.2 The adoption results

The "energy ladder" hypothesis relates improvement in socio-economic status of the household with transition to more energy efficient stoves and higher quality and less polluting fuel appliance is often invoked as theoretical model for analyzing household energy demand practice. The finding of this study is consistent with *Barbara D and others (2000)* and *Hosier and Dowd (1987),* and *Reddy* (1995) who have studied in

Mexico, Zimbabwe and India, respectively. The energy ladder hypothesis was also discussed in Ethiopia, by *Tadelech* (2001) in Addis Ababa households and *Berhanu* (1998) in Nazareth town. Those studies tested the hypothesis and found that as socio economic status of the household increases, the households move up to the upper energy ladder.

Income is found to be one of the major variable which has a positive and highly significant (at 1%) impact in rural households. A 10% increase in income will increase the probability of adoption decision for improved *Mirt* stove technology by 0.05% in rural households. However, this variable has positive impact but it is not significant in urban households.

Contrary to the expectation of the study, the probability of adoption decision is higher in female-headed urban households than male-headed and it is highly significant. The finding is contrast to the result by *Tadelech* (2001). The plausible reasons in urban households' female are becoming decision makers, where as in rural households the probability of adoption decision is higher in male-headed household than female-headed and it is insignificant. The result indicates in rural households men are still decision makers on resources than female but for urban households female may have an influence on resource decisions for households' activities.

The coefficient of the household head age is negative, and it is significant in rural households. An increase in household head age causes a reduction in the probability of adopting improved stove. At the margin, an additional year of age reduces the probability of adoption decision by 1.8% and it has negative relation with urban households even if it is insignificant. Thus, the result reveals that the probability of adoption decision for improved *Mirt* stove is higher in younger rural households than older ones.

Similarly, marital status is positively related to household's adoption decision for improved ("Mirt") stove in urban household but due to collinearity problem this variable dropped from the rural households regression. The probability of adoption decision is higher in married urban households than unmarried ones and it is significant (at 10%). This may be due to married people are likely to have a responsibility for family members and mostly in urban areas; unmarried households may outsource their food consumption. Accordingly, family size also has a significant and positive influence on adoption decision of urban households. As the member increase by one, the probability of adoption of the technology will increase by 4.3 %.

Household's schooling has a large positive and highly significant effect (at 1%) on adoption decision of the urban households. The marginal contribution of completion of an additional schooling of the households head on the probability of adoption decision is 43.9%. Education also has significant effect in rural households too, with marginal effect, additional schooling on rural household result increase in the probability of adoption decision by 48.6%. Therefore, household's schooling or the educational level is one of the most important variable explaining the adoption decision of improved *Mirt* stove technology.

Another vital result from this study in relation to education is the literacy level of the rural household wives. This variable has a significant and positive influence on the adoption decision. This finding suggests that provision of education to female would result higher benefit for the rural areas and possible to get economic and environmental benefits that could derive from stove adoption.

The main source of fuel for rural households is through collection. If the rural households have a capacity to participate more of its members for fuel-wood and other energy source collection, the probability of adoption decision will decreased. This variable has a negative sign as expected and it is highly significant. In fact, as members of the family participate for fuel collection increased by one member, the probability of adoption decreased by more than ten percent. The result indicates the availability of labour force in rural areas is one factor that affects the adoption decision.

Households are the users of the technology product and it is important to note that their subjective preferences for the characteristics of new technologies affect adoption decision. Some of the desirable characteristics considered in this case: convenience of the stove, compatibility and a relative advantage. The households' perceptions about those characteristics may have impact on adoption decision. The result is expected because adopters and non-adopters of the technology differ based on their perception about the technology. The probability of adoption decision is higher in rural household that have considered the stove has relative advantage and compatible than those who do not have this perception, and it is insignificant (at 5%).

Existence of separate kitchen in households is the indicators of the household dwelling standing and their living standard. At the margins, the variable indicates that the passage from households whose habitat is without a kitchen room to those whose habitat is provided with separate external kitchen involves a rise of 14.1% in urban households' adoption probability and it is highly significant. The result indicates that the presence of separate kitchen enables the urban households' independent utilization of their stoves and increase in socioeconomic status resulted in better kitchen and housing environment.

Since the majority of rural households may get advantage mainly for fuel storage, to decide on free space and others in their living compound, as a result the existence of separate kitchen may provide weak support for adoption decision in rural households. In addition, surprisingly, the probability of adoption decision is lower in households having external kitchen than households who do not have separate kitchen and it is insignificant variable for rural areas.

5. Conclusion and recommendations

5.1 Conclusion

A number of studies identified many of the population in developing countries are still primarily dependent on biomass energy for domestic use. Fuel efficient and convenient stoves therefore have important implications for a number of interrelated aspects of development including health, protection of natural resource and environment, and household economy. Indeed, various empirical studies reported that "energy ladder" relating improvements in socioeconomic status with transition to more efficient appliance and to higher quality fuels is often invoked as a theoretical model for analyzing household's energy management practice. Thus, the findings of this study also support the energy ladder hypothesis.

This study result reveals that household sector use significant share of energy consumption. The sector was highly dependent on biomass resources. Especially, in rural areas, the major source of fuel is through collection and it has adverse impact on natural resource and environment such as deforestation and soil erosion due to fuel-wood collection, loss of soil fertility due to animal dung used as a source of energy. Although in urban households due to an ever increasing price of electricity and Liquid Petroleum Gas (LPG), household back to use biomass sources. This indicates the need for efficient biomass stoves through promotion of technically simple and economically feasible that could be adopted by the majority of the people.

The result shows that acquiring of information relating to the improved *Mirt* stove technology are significantly explained by the socioeconomic variables that are family size, sex of household heads, active participation of households in local associations, and availability of modern source of energy (electricity). Regarding to the urban households, the study result has indicated that active participation in local associations, and market or presence of producer of *Mirt* stove technology are the main significant factors to acquire information. Therefore, improvement in the socioeconomic status of households and facilitate the provision of information in urban and rural households would bring positive impact on information acquisition.

The study also shows the most important factors that determine the adoption decision of improved *Mirt* stove in rural and urban households. Educational level of the household head is the common significant variables. In addition to this variable, particularly for urban households' existence of separate kitchen, sex of the household head, family size and marital status are the main ones. In rural households members of the family participate in fuel collection, age, compatibility and educational level of the household spouse (wives) are found to be significant. Similarly, improving the dwelling status and cooking and baking environment for urban and rural households has positive impact for energy efficiency.

5.2 Recommendations

With those major findings of the study, the following are the implications of the results for policy:

- The household energy demand has significant adverse impact on natural resource and environment. Therefore, energy policy, programs and measures should give due attention and consideration to the households' rationale, especially, in fuel-wood and other biomass resources gathering and combustion.
- Decision makers should enhance the provision and disseminating information about the environmental and economic benefit of energy efficiency derived from improved stove technology. This would be an effective instrument for economic development. In particular, intervention through provision of information in local associations and demonstration programs are more important.
- Finally, adoption of efficient and improved stove technology has an important implication for natural resource conservation and environmental protection. To this end, policy makers and other stakeholders in energy sector should seriously consider the fact that provision of information and enhancement of the adoption decision for improved stove technology is as a means and ways to create viable economic benefit for the country. Particularly, improve the provision of education and income of the rural people and the dwelling status of the urban households.

References

Albert N-HonLonwow. 2004. Modeling of Adoption of Natural Resource Management Technologies: The Case of Fallow System, *Environment and Development Economics Journal (9),* Cambridge University Press, pp 289-314.

Asres W/Giorgis. 2002. Overview of Ethiopian Energy Status and Trends in Ethiopia, Paper Presented on Energy Conference 2002, Professional Association Joint Secretariat, UNICC, Addis Ababa, 21-22 March 2002.

Barbara D. Saatkamp, Omar R. Masera, Daniel M. Kammen. 2000. Energy and Health Transitions in Development: Fuel Use, Stove Technology and Morbidity in Jaracuaro, Mexico, Energy for Sustainable Development, Volume IV No 2, Aug 2000. pp 7-16.

Becker L. 1965. A Theory of Allocation of Time, *Economic Journal*, Vol. No 75, pp 493-517.

Berhanu Dirissa. 1998. Pattern and Determinants of Urban Household Energy Consumption in Nazareth and the Prospect of the Nazareth Fuel-wood Project, Addis Ababa University, School of Graduate Studies, Department of Geography, June 1998.

Black. J. P. Stern and J. Elworth. 1985. Personal and Contextual Influences on Household Energy Adaptations, *Journal of Environmental Psychology*, Vol. 70(1),pp. 3-21.

Brandon G. and A. Lewis. 1999. Reducing Household Energy Consumption: A Qualitative and Quantitative Field Study, *Journal of Environmental Psychology*, Vol. No 19(1), pp 75-85.

Cecelski, E. 1985. The Rural Energy Crisis, Women's Work and Basic Need: Perspectives and Approaches to Action, Technical Cooperation Report, Rural Employment Policy Research Program, ILO, Geneva, 1985.

Coomer J. 1977. Sowing Energy Dilemma. *The Futurist*, Vol. 11. pp 228-230.

Damodar N. Gujarati. 2001. *Basic Econometrics*, 3rd edition, United States-Military Academy; West Point, Mc Graw Hill Inc, New York.

Dominich T. A. and D. McFadden. 1975. *Urban Travel Demand: A Behavioral Analysis*. Amsterdam, North Holland.

Duncan G. Labay and Thomas C. Kinnear 1981. Exploring the Consumer Decision Process in the Adoption of Solar Energy System, *The Journal of Consumer Research,* Vol 8, No. 3, Dec 1981, pp 271-278.

Eleni Sardinonu. 2005. Household Energy Conservation Patterns: Evidence from Greece, Graduate Program of Sustainable Development, Harokopio University.

Ethiopian Energy Authority/Ministry of Mines and Energy: 1994. Energy Database, Sources and Methods, Addis Ababa 1994, pp 6-12.

Erick Boy, Nigel Bruse, Kirk R. Smith and Ruben Hernandez. 2000. Fuel Efficiency of an Improved Wood Burning Stove in Rural Guatemala: Implication for Health, Environment and Development. Energy for Sustainable Development, Vol IV No. 2 Aug. 2000 pp 23-31.

G. S. Madalla. 1983. Limited Dependant and Qualitative Variables in Econometrics, Econometric Society Monographs, Cambridge University Press.

GTZ-HENRP. 2000. *Project Brief,* First Phase, Jan 1998-Dec2000.

Habb and McConnel. 2002. Valuing Environmental and Natural Resources, The Econometrics of Non-market Valuation, Edward Elgar, Cheltenham, UK

Held M. 1983. Social Impacts of Energy Conservation. *Journal of Economic Psychology,* Vol. No 3(3-4) pp 379-394.

Hosier R. and Dowd J. 1988. Household Energy use in Zimbabwe: An Analysis of Consumption Patterns and Fuel Choice, Energy for Rural Development in Zimbabwe. Energy, Environment and Development in Africa (11). The Beijer Institute and the Scandinavians Institute of African Studies.

Houser R. 1995. Energy Use in Rural Kenya Household Demand and Rural Transformation, Beijer Institute and the Scandinavian; Institute of African Study.

Howes, M. 1985. Rural Energy Survey in Third world, Manuscript Report IDRC-MR 1907e, International Development Research Center, Ottawa, May -1985.

Israel D. 2002. Fuel Choice in Developing Countries: Evidence Economic Development and Culture Change, University of Chicago, Vol No 1, pp 865-890.

Khanna, M. 2001. Sequential Adoption of Site-specific Technologies and its Implication for Nitrogen Productivity: A Double Selectivity Model, *American Journal of Agricultural Economics*, Vol 83, No 1, pp 35-51.

Leonard-Barton D. 1981. Voluntary Simplicity Life Style and Energy Conservation, *Journal of Consumer Research*, Vol. No 8 pp 243-252.

Moges Mesfin. 2005. Fuel-wood Consumption and Forest Degradation in Rural Highlands of Ethiopia: The Case of Amhara Region, School of Graduate Study, Addis Ababa University, Oct. 31, 2005.

Munasinghe M. 1980. An Integrated Framework for Energy Pricing in Developing Countries, *Energy Journal*, London, Oelgeschlager, Gunn and Haine, Vol 1, No 3.

Munasighe M. and Peter Meier. 1993. *Energy Policy Analysis and Modeling*. Cambridge University Press.

Muth R. 1966. Household Production and Consumer Demand Functions, *Econometrica*, Vol 34, pp 699-708.

Reddy, B. S. 1995. A Multi-logit Model of Fuel Shifts in the Domestic Sector Energy, Vol 20, No 9, pp 929-936.

Saha H. A. Love and R. Schwart. 1994. Adoption of Emerging Technologies under Output Uncertainty. *American Journal of Agricultural Economics*, Vol No 76, November pp 836-846

Schipper L. and D. Hawak. 1991. More Efficient Household Electricity Use, Energy Policy, Vol 19(3), pp. 244-265.

Scott S. 1997. Household Energy Efficiency in Ireland: A Replication Study of Owner of Energy Saving Items. *Energy Economics*, Vol No 19 (2) pp 187-108.

Tadelech Debele. 2001. Factors Affecting the Use of Fuel-Saving Technologies in Urban Areas. The Case of Addis Ababa, Addis Ababa University, School of Graduate Studies, Regional and Local Development Studies, June 2001.

Takeshi Amemiye. 1981. Qualitative Response Model: A Survey, Stanford University.

Trudy Koemund, Hiwot Teshome and Samson Tollossa. 2002. What Alternative do we have to Bridge the Gap Between Fuel-wood Demand and Supply in Ethiopia, GTZ-HEPNR, Forum for Environment Rio + 10 Preparation Process, Addis Ababa, Ethiopia.

Van Raaij and T. Verhallen. 1983. A Behavioral Model of Residential Energy Use, *Journal of Economic Psychology*, Vol. No 3, pp 39-63

Vijay Laxmi, Jyoti Parikh, Shyam Karmakar and Pramod Dabrase. 2003. Household Energy, Women's Hard ship and Health Impact in Rural Rajasthan, India; Need for Sustainable Energy Solution. Energy for Sustainable Development Vol V11 No. 1. March 2003, pp 50-67.

Weber C and A Perrels. 2000. Modeling Lifestyle Effects on Energy Demand and Related Emissions, Energy Policy, Vol. 28 (8), pp 549-566.

William W. Greene. 2003. *Econometric Analysis*, New York University, Upper ladder River, New Jersey, Fifth Edition.

World Bank. 2000. Fuel for Thought**,** an Environmental Strategy for the Energy Sector.

Appendix I

Table A-1-A: Probit estimation of sample selection for rural households

Number of obs	= 120	LR chi2(11)	= 88.17
Censored obs	= 62	Pseudo R2	= 0.5304
Uncensored obs	= 58	Wald chi2(11)	= 33.38
Log pseudolikelihood	= -53.3968	Prob > chi2	= 0.0005

Adoption	Coefficient	Marginal Effect	Standard Error	P>|z|	Mean
*Members participate for collection***	*-0.6808*	*-0.1689*	*0.2536*	*0.007*	*1.93333*
Family size	*0.1073*	*0.0266*	*0.0872*	*0.219*	*7.03333*
D[24] Dwelling status	*0.5499*	*0.1161*	*0.8081*	*0.496*	*.783333*
D separate kitchen	*-0.7334*	*-0.1909*	*0.6057*	*0.226*	*0.575*
*D compatibility***	*1.3820*	*0.3788*	*0.6815*	*0.043*	*0.4*
*D spouse education****	*1.3884*	*0.3991*	*0.8413*	*0.099*	*0.35*
*Age***	*-0.0734*	*-0.0182*	*0.0230*	*0.001*	*47.325*
D head of the household	*1.1136*	*0.1928*	*0.9436*	*0.238*	*0.80833*
D access to credit	*0.7870*	*0.1913*	*0.5150*	*0.126*	*0.525*
*D education***	*1.7467*	*0.4864*	*0.8403*	*0.038*	*0.60833*
*L income**	*2.2085*	*0.5479*	*0.6098*	*0.000*	*6.2065*
*_constant**	*-12.3860*	*-*	*3.1867*	*0.000*	*-*
D active participation	*(offset)*				
Information					
D marital status	*0.2955*	*0.0342*	*0.7271*	*0.684*	*0.89166*
*Family size***	*0.1920*	*0.0796*	*0.0753*	*0.011*	*7.03333*
D spouse education	*0.5304*	*0.2077*	*0.3647*	*0.146*	*0.35*
Age	*-0.0092*	*-0.0039*	*0.0135*	*0.494*	*47.325*
*D head of the household***	*-1.0584*	*-0.3803*	*0.4276*	*0.013*	*0.80833*
*D active participation**	*2.1819*	*0.7144*	*0.4050*	*0.000*	*0.441667*
D access to credit	*0.4047*	*0.1730*	*0.3509*	*0.249*	*0.525*
*D electricity access ***	*1.2242*	*0.4469*	*0.4451*	*0.006*	*0.60833*
D market	*0.0815*	*0.0730*	*0.5496*	*0.882*	*0.21666*
D education	*0.2426*	*0.0948*	*0.4593*	*0.597*	*0.597*
L income	*0.4331*	*0.1626*	*0.3012*	*0.150*	*6.2065*
*_constant ***	*-4.9715*	*-*	*2.1584*	*0.021*	*-*
athrho |	*0.6198*		*1.2219*	*0.612*	*0.612*
| rho |	0.5510		0.8509		

**** Significant at 10% ** Significant at 5% *Significant at 1%*

[24] D indicates for variables that are Dummy and level of significance refers to the Marginal effects.

Table A-1-B: Probit estimation of sample selection for urban households

Probit model with sample selection		Number of obs	= 90
LR chi (12) = 84.27		Pseudo R2	= 0.7183
		Censored obs	= 33
		Uncensored obs	= 57
		Wald chi2(12)	= 28.04
Log pseudolikelihood = -33.63697		Prob > chi2	= 0.0055

Adoption	Coefficient.	Marginal effect	Standard Error.	P>|z|	Mean
Age	-0.0593	-0.00759	0.0379	0.118	50.4333
D marital status ***	2.2639	0.29652	1.2361	0.067	.566667
Family size **	0.3366	0.04308	0.1729	0.052	5.31111
D dwelling status	0.2791	0.03603	0.8090	0.730	.488889
D separate kitchen **	1.1748	0.14142	0.8018	0.043	.577778
D compatibility	0.6088	0.07864	1.1171	0.586	.511111
D spouse education	0.5289	0.06928	0.8129	0.515	.488889
D head of the household **	-4.3273	-0.92108	1.4616	0.003	.677778
Fuel expense	0.0131	0.00168	0.0166	0.429	41.0444
D access to credit	1.1795	0.20348	0.7585	0.120	.344444
D education**	3.4843	0.43912	1.2413	0.005	.611111
L income	0.2721	0.03482	0.6331	0.667	5.88359
_constant***	-5.2242	-0.00759	3.1936	0.102	
D active participation	(offset)				
Information					
D marital status	-.4286643	0.07418	.8178782	0.600	0.5666
Family size	.1765413	0.03083	.136889	0.197	5.3111
D spouse education	1.048235	0.18711	.9874462	0.288	0.4888
Age	-.0221105	-0.00386	.0235583	0.348	50.433
D head of the household	-.9716964	-0.14128	1.147533	0.397	0.6777
D active participation *	3.65241	0.71873	.7598789	0.000	0.5111
D access to credit	-.8260403	-0.16356	1.114081	0.458	0.3444
D market ***	2.617077	0.45128	1.41075	0.064	0.4444
D electricity access	.8047146	0.18816	1.190112	0.499	0.7666
D education	.0949537	0.01405	.8640634	0.912	0.6111
L income	.8235751	0.14724	1.122381	0.463	5.8835
_constant|	-6.424711	-	6.698139	0.337	-
/athrho	.0848789	-	3.270068	0.979	-
rho |	.0846757	-	3.246622	-	

**** Significant at 10%* *** Significant at 5%* **Significant at 1%*

Table A-2-A: Descriptive summary for rural households

Variable	Mean	Standard deviation	Minimum	Maximum
Income	656.12	603.2842	95	5000
Marital status	0.89166	0.3121	0	1
Family size	7.03333	2.8252	0	1
Separate kitchen	0.5750	0.4137	0	1
Compatibility	0.40	0.4964	0	1
Spouse education	0.35	0.4789	0	1
Age	47.32	13.570	20	80
Sex of household head	0.8083	0.3952	0	1
Fuel expense	17.69	15.22	0	110
Active participation	0.525	0.5014	0	1
Credit	902.075	1102.36	0	4000
Access to credit	0.525	0.5014	0	1
Electricity	0.3666	0.4137	0	1
Market	0.2166	0.4137	0	1
Members for collection	1.93	1.11	0	6
Education	0.6083	0.4901	0	1
Log income	6.2064	0.7390	4.5538	8.5171
Dwelling status	0.78333	0.413709	0	1
Number of Observation	120			

Table A-2-B: Descriptive summary for urban households

Variable	Mean	Standard deviation	Minimum	Maximum
Income	506.72	586.89	85	3500
Marital status	0.5666	0.4983	0	1
Family size	5.31	2.56	1	12
Separate kitchen	0.5777	0.4966	0	1
Compatibility	0.5111	0.50267	0	1
Spouse education	0.48888	0.502677	0	1
Age	50.43	13.25	20	83
Sex of household head	0.6777	0.4699	0	1
Fuel expense	41.04	27.80	0	130
Active participation	0.5111	0.50267	0	1
Credit	489.76	1014.99	0	7000
Access to credit	0.3444	0.4778	0	1
Electricity	0.7666	0.4253	0	1
Market	0.4444	0.49968	0	1
Education	0.6111	0.4902	0	1
Log income	5.883	0.7701	4.4426	8.1603
Dwelling status	0.4888	0.5026	0	1
Number of Observations	90			

TABLE A-2-C: Factors Affecting household to acquire information and adoption decision for improved ("Mirt") stove

	RURAL HOUSEHOLDS		URBAN HOUSEHOLDS	
1. Head of the household	Frequency	Percentage	Frequency	Percentage
Male	106	88%	59	65%
Female	14	12%	31	35%
2.Dwelling status of the household				
Owners	84	70%	45	50%
Non-owners	36	30%	45	50%
3.Presence of separate kitchen in the house				
YES	72	60%	53	58%
NO	48	40%	37	42%
4. Source of fuel-wood and other energy sources				
Purchase	12	10%	40	44%
Collection and purchase	14	12%	28	31%
Collection	96	78%	22	25%
5. Presence of modern source of energy (electricity)				
YES	52	57%	69	77%
NO	68	43%	21	23%
6. Active participant in local associations and activities				
YES	50	42%	46	51%
NO	70	58%	44	49%
7. Spouse educated or not				
YES	45	38%	50	56%
NO	75	62%	40	44%
8. The stove is compatible				
YES	41	34%	48	54%
NO	79	66%	42	46%
9. Having access to credit				
YES	70	58%	47	52%
NO	50	42%	43	48%
10. Marital status				
Yes	93	78%	58	64%
NO	27	22%	32	36%

TABLE A-2-D: Description of variables.

Independent variable	Description
Age	Number of years the household heads live
Dummy foe sex of the household head	1 If the head is male , 0 otherwise
Income	Log of monthly income of the household head
Dummy for Availability of modern energy source (electricity) for household lightning	1 if the household have access to modern electric source (electricity), 0 otherwise.
Dummy for access to credit	1 if the household get credit during the current six month period, 0 otherwise.
Family size	The number of individuals who are the members in the family
Dummy for households participation in local associations	1 if the household actively participate and involvement in local associations as leader and moderator, 0 otherwise.
Dummy for location of household access to the market for improved ("Mirt") stove	1 if the households near to producers of improved stove or market, 0 otherwise
Dummy for dwelling status of the household	1 if the household is owner of the house, 0 otherwise
Dummy for existence of external and separate kitchen	1 if the household have separate external kitchen, 0 otherwise
Dummy for household response on technology which has a relative advantage, compatible and lower complexity	1 if the household believe that the stove has an advantage and compatible for users, 0 otherwise.
Members of the family who participate in fuel collection	Members of a family participate to collect fuel for the household fuel need or necessity.
Dummy for marital status	1 if the household head is married, 0 otherwise
Dummy for spouse education	1 if the household spouse(wife) is literate, 0 otherwise
Fuel expense	Average monthly expense for fuel need
Dummy for the household head education	1 if the household head is literate, 0 otherwise