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Impact of using improved cooking appliance on household energy Expenditure

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ABSTRACT

Although access to improved biomass stove has been increasing over time and vital to sustainable development, there is very limited trend of using improved cooking facilities for cooking. This is partially due to lack of concrete evidence about the actual impact of using modern cooking facilities on energy expenditure. Although it is expected that using modern cooking facilities reduce energy expenditure, households with an improved stove may use more energy than households with traditional stove if there is strong rebound effect. Hence, the impact of using improved cookstove over traditional cookstove on energy demand is inconclusive. The objective of this study is to investigate the impact of using modern cookstoves on household energy expenditure. The study used a combination of sampling methods. Structured questionnaires were employed to collect primary data. Two sample t-test and PSM are used to investigate the existence of expenditure difference among users of different stoves. The t-test result revealed that using improved biomass stove over traditional stove has no significant impact on household energy expenditure. On the other hand, the PSM result indicates that improved biomass stoves have significant impact on household energy expenditure. The finding of the study suggested that creation of awareness on the benefit of using improved cooking appliance is important.

Key words : *Improved cookstove, Traditional cookstove, Impact, Expenditure, PSM*

Background and Justification of a Problem

In current societies, energy becomes of great importance and it is central to sustainable development and prosperity of a society. Access to energy is a major factor for sustainability in both developed and developing countries (Rezaei *et al.,* 2013). Sustainable development (SD) has traditionally been defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Bundtland, 1987).

Making development more sustainable recognizes that there are many ways in which societies balance the economic, social, environmental, and institutional dimensions of sustainable development (Sathaye *et al.,* 2011). Overall development of humanity over the last decades has led to the increasingly unfavorable climate changes, natural disasters and socio-economic instability. Trough their action, humans have negatively impacted the environment, and the future generations. These conditions have demanded changes in the behavior aiming towards more rational and efficient management of all resources that will allow less pressure and environmental impact (Klarin, 2018).

The transition to sustainable energy systems represents one of the key solutions to our global economy. Renewable energies have an important role to play with in this challenge (Msera and Faaij, 2014). A public concern over the environmental consequences of greenhouse gas emissions from fossil fuels make the increased use of renewable energy sources an important energy policy target in most parts of the world (Rezaei *et al.,* 2013).

Renewable energy sources have significant potential to contribute to the economic, social and environmental energy sustainability of the world. It improves access to energy for most of the population, it also reduces emissions of local and global pollutants and it may create local socioeconomic development opportunities (Jaramillo-Nieves and del Rio, 2010). In attaining sustainable development, increasing the energy efficiencies sustainable energy resources plays an important role. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions for achieving sustainable development (Rezaei *et al.,* 2013).

Among the use of energy in different sectors of the economy (like industrial, transport, commercial sectors), using energy in the residential sector for cooking, heating and lighting is also found to be fundamental to human well-being. Energy access for household consumption purpose is crucial for all countries. However, in every developing country it is a major challenge for government to ensure clean energy for every household. Access of modern energy is the critical challenge in many developing countries to improve the socio-economic status and quality lifestyle. About 17 percent of world populations have no access to electricity of which 95 percent peoples are in sub-Saharan Africa and Asian developing countries where 80 percent people living in rural areas (World Energy Outlook (WEO), 2015).

A recent study shows that over 3 billion people rely on solid fuels and other biomass for cooking and heating. They are using traditional biomass resources to meet their daily energy needs. Inefficient fuel sources contribute to deforestation and global climate change, health problem. They are also costly in terms of time and money required for fuel collection (Burki, 2011). Moreover, many households use biomass fuel sources in traditional cookstoves that have negative impact on the well-being of households (GACC, 2011; IEA, 2011).

Like other developing countries, a great deal of Ethiopian households also uses biomass fuels with traditional cook stoves (Alem *et al.,* 2013; Kooser, 2014). The share of Ethiopian households that used biomass fuel sources in traditional open fire stove was about 93 percent, which was greater than the average of Sub-Sahara African countries which is about 78 percent (IEA, 2011).

Current attention to improved cook stove (ICS) focuses on the many benefits it provides. It improves health status, saves time for households, prevents eradication of forests and associated ecosystem services, and reduces emission which has an impact on global climate change (Jeuland and Pattanayak, 2012). The transition from traditional biomass energy to modern energy sources has big positive implication on the welfare of over 2.5 billion people whom continue to rely on inefficient biomass fuel sources for their cooking energy needs (IEA, 2006).

There any many studies associated with the issue under discussion. The findings of most studies proved that using improved cookstove over traditional cookstove reduce household fuel demand and fuel expenditure. To mention a few; Khanal and Bajracharya (2010) attempted to assess the contribution of improved cookstove on reducing the firewood consumption. Their study used before and after technology intervention method. The study revealed that, adoption ICS reduced firewood consumption. With the effort of investigating the effect of sing improved biomass stove on rural women welfare, Bwenge (2011) found that using improved biomass cookstove significantly reduced fuel consumption compared to tradition biomass cookstoves. Fajola *et al.* (2014) studied the effect of improved stove on fuel efficiency using the data collected from 81 households before adoption and after adoption. They proved that using improved cookstoves reduces the expenses on wood. It is also important to mention the study of Sagbo and Kusunose (2015). They explored the impact of using improved cookstoves on households' energy expenditure using propensity score matching technique. The finding of this study indicates that using improved stove significantly reduced fuel expenditure relative to the traditional counterpart.

Contrary to this, there are also studies their finding indicates that using improved cookstove increases the demand for firewood compared to the demand for wood with traditional cookstove. For example, Nepal *et al.* (2011) conducted a study to analyze the effect of different using improved cookstove on firewood demand. The study used household level data. The result reveals that households who use improved stoves demand more firewood than households who use traditional stove. Therefore, the impact of using improved cookstove on firewood demand depends the strength of rebound effect and it is inconclusive. Therefore, it is very essential to assess the expenditure difference among different types of cookstoves.

Objectives of the Study

The general objective of this study is to investigate the impact of using improved cookstoves on household energy expenditure.

Methodology

Sampling and Data Collection Methods

The study used multistage sampling techniques to draw sample from the target population. Questionnaire survey was used to collect data from the respondents. The study used the survey information obtained from 333 improved biomass cookstove and traditional cookstove users in three study sites of Amhara region, Ethiopia. The total sample is distributed across study sites proportionately to their population size.

Method of Analysis

Two Sample T-test

According to Snedecor and Cochran (1989) two-sample t-test is used to determine if there is a difference in means of a variable between the two groups. A common application is to test if a new process is superior to a current process. The objective of this study is investigating the actual impact of using improved cooking appliance on the demand for energy (household expenditure on energy as a proxy). The survey indicated there are two types of biomass cooking appliance-traditional biomass cookstove, improved biomass cookstove. Hence, independent two sample t-test is used to explore the mean difference in household energy expenditure between these two groups.

Propensity Score Matching

It is well recognized that the estimate of a causal effect obtained by comparing a treatment group with a non-experimental comparison group could be biased because of problems such as self-selection or program selection to be assigned to the treatment Using simple two sample mean test either overstate or understate the actual impact of a program if the program is not assigned randomly to respondents.

Propensity score matching method helps to avoid the sampling bias associated with self-selection or program selection criteria. It involves pairing treatment and comparison units that are similar in terms of their observable characteristics. This method yields an unbiased estimate of the treatment impact. However, it is difficult find two households that are similar to each other in terms of many characteristics (Blackman and Naranjo, 2010). In PSM method, the probability of participating in the program is estimated for each observation based observable characteristics. Then, treatment members are matched with control members on the basis of this propensity score. The average treatment effect of the program is then calculated as the average difference in outcomes between the two groups (Khandker *et al.*, 2010). This study used this method to estimate the impact of using improved cooking appliance on household energy expenditure. It compares the expenditure difference between households who use improved biomass stove and traditional stove.

PSM method involves the following important steps. The first step is estimating the value of propensity scores using a logistic regression/ probit regression model with treatment assignment as the outcome and the balancing covariates as predictors. Once propensity scores are computed, the second step is matching treatment group with control group based on their value of propensity score. And the third main step is comparing the outcome variable between groups and estimating the effects of an intervention (Harris and Horse, 2016)

The average treatment effect of the program on the treated (ATT) is presented by the following equation.

$$ATT = E(Y_i(1) / X, T_i = 1) - E(Y_i(0) / X, T_i = 1)$$

Where,

T_i=1 if the i-th unit was assigned to treatment and T_i=0 if the i-th unit was assigned to control

$Y_i(1)$ and $Y_i(0)$ represents observed values of household energy expenditure (outcome variable) when unit i is subjected to treatment group (1) and control group (0) respectively.

X_i represents a set of observable characteristics of respondents expected to affect the adoption of improved cooking appliance.

However, $E(Y_i(0) / X, T_i = 1)$, the average outcomes of the untreated conditional on being in a treated area is not observable. Therefore, we use the mean outcome for nonparticipants $E(Y_i(0) / X, T_i = 0)$ as a proxy for the value of the average outcomes of the untreated conditional on being in a treated. After matching, it is expected that;

$$E(Y_i(0) / T_i = 1) = E(Y_i(0) / T_i = 0$$

Therefore:

$$ATT = E(Y_i(1) / X, T_i = 1) - E(Y_i(0) / X, T_i = 0)$$

Different methods are used to match the certified and the uncertified land on the basis of the propensity score. In this paper, nearest neighborhood matching method is used.

Results and Discussion

Independent Two Sample T-test Result

Based on the result at Table 1, 285 (85.59 %) of the respondents are traditional biomass cooking appliance users whereas the remaining 48 (14.41%) of the respondent use improved biomass cooking appliance. This shows that majority of the households relay on traditional cooking alternative. The t-test result further indicates that the average monthly household energy expenditure of households with traditional biomass cooking appliance is about 371 ETB but the estimated energy expenditure of households with improved biomass cooking appliance is about 344 ETB. The energy expenditure of improved cookstove user is about 27 ETB less compared to their counterpart. However, the t-value indicates that the difference is not significant even at ten percent.

This research further explored the effect of using modern cookstove on per capita monthly expenditure. The finding shows that the average monthly per capita energy expenditure of households that used traditional biomass cookstove was about 118 ETB. On the other hand, the average per capita expenditure of those households that used improved biomass cookstove was about 102 ETB. The per capita energy expenditure of improved cookstove user is about 16 ETB less compared to their counterpart and the t-value indicates that the difference is statistically significant at ten percent.

The above results, with different level of significance, revealed that the two groups are not similar with respect to covariates (at least with respect to family size). Hence, the estimated difference with simple mean test is either overstated or understated (bias) thus, the effect of other factors must be controlled to get unbiased result.

Propensity Score Matching (PSM) Result

The first step in propensity score matching method of impact evaluation is estimating the probability of being in the treatment group (using improved cooking facilities) for both categories of respondents, given covariates of respondents. The study used probit model to estimate the probability of being in the treatment group for each respondent. The result of the probit regression depicted under (Table 3) shows that sex of the household head, house status (private or rented), access to information and education have significant effect on the probability of adopting improved biomass cookstove. Male headed households are less likely to adopt improved biomass cookstove compared to female headed households. It is due to the fact that in most

Table 1. Household energy expenditure between groups

Group	Obs	Mean	Std.	Err.	t-value
Traditional biomass cookstove	285	371	12.11488	204.5226	t = 0.8609
Improved biomass cookstove	48	345	22.8374	158.2222	
Combined	333	368	10.87934	198.5294	
Diff		26.6758	30.98656		

Table 2. Per capita energy expenditure between groups

Group	Obs	Mean	Std.	Err.	T-value
Traditional biomass cookstove	285	117.6217	4.438422	74.92919	t = 1.4120
Improved biomass cookstove	48	101.7438	7.445078	51.58101	
Combined	333	115.3329	3.955652	72.18388	
Diff		15.8779	11.24528		

households cooking is the obligation of females and they are highly affected by traditional cookstove. Hence, they have big desire to shift to improved cooking alternatives.

The study further revealed that households living in private houses are more likely to adopt improved cookstove relative to household living in rented house. The study considers housing status as indicator of income/wealth. The result related to house status variable proved that households with better income are more likely to adopt improved stoves. It sounds to take traditional stove as inferior good and improved biomass stove as normal good. Theories of consumer behavior explain that there is positive relationship between income and the demand for normal good.

It is also found that households with access to information about the benefit of using improved stove and the cost of using traditional stove are more likely to use improved biomass stove compared to their counterpart. Education also enhances the use of the modern alternative. This is because education increases households' awareness about the multiple benefits of using the modern cookstove.

Having good common support (overlap) is one of the conditions of PSM method that must be satisfied to get valid result. As we can see from the graph below, there exists good common support for both improved biomass stove and electric stove.

Based on the propensity scores generated, the treatment group and the matched control group need to be compared to see whether using improved cooking appliance has an impact on the outcome of interest. Hence, the final step of PSM method is the estimation of the average impact of using improved biomass cooking appliance on household energy expenditure after the treatment and the counterfactual groups are matched by nearest neighborhood matching method.

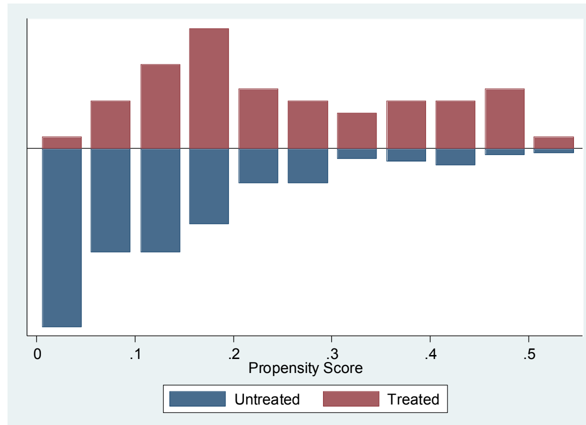

Fig. 1. Common Support Area

The result shows that using improved biomass stove has significant impact on household energy expenditure. On average, the energy expenditure of households that used improved stove was about 86 ETB birr lower compared to households that used traditional stove.

This finding is somewhat consistent with the re-

Table 4. ATT Estimation for Improved Biomass Stove

No. treat	No. control	ATT	Std. Err.	T
48	69	-86.156	37.945	-2.27

Table 3. Probit regression result

Variable	Coefficient	Std. Err.	P-value
Family size	-.0190632	.0739226	0.796
Mekane-eyessus	-.1429188	.2286814	0.532
Sex of household head	-.7675619	.208719	0.000***
House status	.4443061	.2334647	0.057*
Information	1.205831	.4361352	0.006***
Area of cooking	-.228801	.3677343	0.534
Primary and Secondary	.2140252	.2771816	0.440
Diploma and Above	.3745324	.2269004	0.099*
Kitchen	.1609785	.2361049	0.495
_cons	-1.755145	.5579435	0.002
Model Summary	Number of obs = 333		Log likelihood= -115.18795
	LR chi 2 (9) = 44.29		Pseudo R2 = 0.1613
	Prob > chi2 = 0.0000		

*,**,*** are significant at 10 %, 5% and 1% respectively

sults of many empirical studies. For example, the finding of the study by Khana and Bajracharya (2010) in Nepal revealed that firewood demand was reduced by about 45 percent after the use of improved cookstove. Graven (2012) analyzed the effect of improved cook stove intervention in rural Guatemala. The result showed that average wood use dropped by nearly 48 percent. Fajola *et al.* (2014) and Sagbo and Kusunose (2015) also proved that the use of improved cookstove significantly reduces fuel expenditure. The amount of effect of the intervention is not as large as the amount of effect acquired by the previous studies mention above. The researcher has made home to home field observation when the data was collected. From researcher's field observation, it was verified that some households have been using highly damaged improved biomass stoves. Hence, the absence of large energy expenditure difference between users of traditional biomass cookstove and improved biomass cookstove may be the results of this fact.

Conclusion and Recommendation

Current attention to improved cook stove (ICS) focuses on the multiple benefits it provides. One benefit that using improved cooking facility is expected to offer is reducing household energy consumption and household energy expenditure. This study is interested to investigate actual impact of using modern cooking facilities on household energy expenditure. The study used a combination of sampling methods. Structured questionnaires were employed to collect primary data. Two sample t-test and propensity score matching methods are used to investigate the existence of expenditure difference among households that use different stoves. The two sample t-test result indicates that using improved biomass stove over traditional stove has no significant impact on energy expenditure. This result may be bias downward. To control the effects of other variables and estimate the true impact, the study used propensity score matching method. The finding of PSM method indicates that using improved biomass stove has significant impact of energy expenditure. Creation of awareness about the benefit of using improved cooking facilities and continuous maintenance of appliances are highly recommended to promote households to use the modern alternatives and to get the maximum benefit out of it.

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