Covariates of fuel saving technologies in urban Ethiopia

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Abstract: The current government of Ethiopia has devised supply augmented and demand management strategies in order to reduce pressure on forests and the adverse impact of indoor air pollution. This paper tries to examine and understand the determinants of the speed of adoption of one of the demand side strategies, fuel saving technologies (Mirt and Lakech), in urban Ethiopia. The result of the duration analysis shows that income level is a significant factor in the adoption decision of the technologies. This indicates that households will not shift to other better sources of energy as their income increases, as postulated by the energy ladder hypothesis. Education is positively and significantly related to the speed of adoption of Mirt biomass cook stoves but its effect on adoption of Lakech charcoal stove is insignificant. Electric Mitad (substitute for Mirt *injera* stove) does not have any effect on the adoption of Mirt biomass cook stoves. However, ownership of Metal charcoal stove is negatively correlated with the adoption of Lakech charcoal stoves. This may suggest that there is a need to reconsider the promotion strategy given the better performance of Lakech charcoal stove over Metal charcoal stove. The implications of other covariates have also been discussed.

Keywords: *Improved stoves, Duration, Adoption, Ethiopia*

1. Introduction

The heavy dependence and inefficient utilization of biomass resources for energy have resulted in high depletion of the forest resources in Ethiopia (EPA, 2004). In order to reduce pressure on forests and plantations and the adverse impact of indoor air pollution, the government has devised supply augmented and demand management strategies. The supply side management deals with increasing the availability of fuel wood through distribution of free seedlings, plantations, supply restrictions, and enforcement of property rights. The demand side management deals with reducing the demand for biomass energy sources by promoting alternative modern fuels, promoting income growth and increasing the availability of fuel saving technologies such as improved biomass cooking stoves (Cook et al., 2008). Large scale distribution of improved stoves will help reduce pressure on biomass resources, increase land productivity by reducing crop residue and dung usage for fuel, and improve family health. The intervention benefits women and children in particular, minimizing their high workloads to collect and supply fuel wood, and their exposure to flame hazard, high smoke emission and harmful pollutants (EPA, 2004).[1] It is assumed that if all rural and urban households (estimated to be about 14.44 million) in Ethiopia shift to the improved *Lakech* and *Mirt* stoves[2], a saving of about 7,778,800 tones of fuel wood which requires clear cutting of 137,192.24 ha of forest will be achieved on an annual basis (EPA, 2004). This implies that

[1]The World Health Organization estimates that, each year, 1.6 million women and children in developing countries are killed by the fumes from indoor biomass stoves (IEA, 2004).

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[2]Lakech and Mirt are local words which mean 'excellent' and 'best', respectively.

sufficient distribution of these improved stoves will have significant contribution to save the biomass resources of the country in general and forest resource in particular and to combat land degradation and mitigate the effects of drought (EPA, 2004).

By recognizing the benefits of improved stoves, a number of governmental and non-governmental institutions have been involved in the development and dissemination of different types of biomass stove technologies since early 1970s in the history of Ethiopia (EPA, 2004). However, the efforts by these institutions to disseminate various types of fuel saving technologies have faced different problems at different times. Some introduced improved biomass cook stoves were not successful due to problems related to the stove itself (technical problems), lack of understanding of consumer's taste, lack of appropriate promotion strategy, etc. Most of these inferences are based on qualitative assessments by various stakeholders and scholars working on the area of natural resource conservation and energy. Moreover, the available limited studies on technology adoption in general and improved biomass cook stoves technologies in particular in most developing countries have generally focused on applying the limited dependent variable models such as probit or logit models. Although informative, these types of specifications are static and ignore the dynamic nature of the adoption process. That means, the binary dependent variable (adoption or non-adoption), which is commonly applied in empirical works, does not pick up adoption over time, as it does not allow for household's different waiting times. In general, the available studies failed to examine and understand why some households take some time to adopt the technology while others are quick to adopt and exploit the benefits of using the technology. Therefore, this paper has tried to address this gap and employs a duration analysis. To our knowledge, this technique is applied for the first time in fuel saving technology adoption studies. The next section deals with explaining the methods of analysis. Section three presents the data and some descriptive statistics. The results of the empirical analysis are presented in section four. The last section is the conclusion.

2. Duration analysis

Analysis of duration data is often referred to as survival analysis. This term is mostly used in the medical research, analysis of child mortality, and unemployment. It has also been applied in the area of technology adoption (i.e. Hannan and MacDowell, 1984; Dadi et al., 2004 and Burton et al., 2003). The purpose of Duration Analysis is to statistically identify those factors which have a significant effect (both positive and negative) on the length of a spell. A spell starts at the time of entry into a specific state and ends at a point when a new state is entered. For details on duration analysis see Kiefer (1988) and Green (2003).

The presence of unobserved heterogeneity leads to bias in the estimates of duration dependence. Following Gutierrez (2002), we fit a Weibull regression model with gamma-distributed heterogeneity using the frailty (gamma) option to streg. One can estimate frailty models and test whether unobserved heterogeneity is relevant using likelihood ratio tests based on the results from a likelihood ratio test that STATA reports.

3. Data and descriptive statistics

3.1. The nature and source of data

The data for the empirical analysis come from the survey on 'Mirt Biomass Injera Stoves Market Penetration and Sustainability' study conducted by Megen Power Limited in 2009. The survey was conducted in Amahra, Oromiya and Tigray Regions. Three towns from each

region were selected for the survey. The sample size for each region and town was determined proportionately based on the total number of households. Finally, based on sampling frames (lists of households) obtained from the respective Kebeles[3], households were selected using a simple random sampling technique. Accordingly, Oromiya region was allocated 667 households (42.3%) followed by Amhara with 580 households (36.8%) and Tigray with 330 (20.9%). Therefore, the total number of sample households was 1577.

3.2. Description of covariates and descriptive statistics

Table 1: The descriptive statistics of covariates of fuel saving technologies and their expected signs (N=1557)

Variable[4]	Mean	S.D.	Min	Max
GENDER(Gender of household head) (-)	0.68	0.47	0	1
AGEHH (age of household head at the time of the survey)(+)	44.88	13.50	18	102
EDUCATION				
EDilliterate (if the household head is illiterate)(-)	0.21	0.41	0	1
EDreadelm (if the head can read and write or grade (1-8)(+)	0.42	0.49	0	1
EDsecond (if the head is between grade 9 & 12)(+)	0.20	0.40	0	1
EDhigher (if the head has a certificate or above)(+)	0.17	0.37	0	1
CHILD15(No. of children and youths whose age ≤ 15 (+)	1.75	1.54	0	14
ADULTS15(number of adult members of the family)(+/-)	3.38	1.87	1	15
HOWNERSHIP(Ownership status of the house, 1 if privately owned and 0 otherwise)(+)	0.72	0.45	0	1
COOKINGPLACE (1 if the HH has a separate kitchen, 0 otherwise)(+)	0.75	0.44	0	1
INCOME (+)				
MONINCOME1(if monthly income is less than 500 Birr*)	0.57	0.49	0	1
MONINCOME2 (if Monthly income is between 501 & 1499)	0.30	0.46	0	1
MONINCOME3 (if monthly income is between 1500 & 2499)	0.09	0.29	0	1
MONINCOME4 (if monthly income is above 2500)	0.04	0.20	0	1
DELEMITAD (dummy for electric Mitad) (-)	0.08	0.27	0	1
DMETALSTOV (dummy for Metal stove)(-)	0.48	0.50	0	1

NOTE: The signs on the second parenthesis show the expected sign. Birr is the national currency of Ethiopia and the exchange rate was 1 USD ≈ Birr 12.615 during the survey period

The majority of households are highly dependent on biomass energy sources for baking *injera* which is the main staple food in most parts of the country. The descriptive statistics in table 1 above show that only 7.8% of the sampled households use electricity for baking *injera*. More than 85 % of the household heads who are using electric *Mitad*[5] have secondary education or above. This may suggest that education is important for households to move up the energy ladder.

[3]Kebele is the lowest administrative unit in Ethiopia.
[4]Except for the variables AGEHH, CHILD15 and ADULT15, the rest are dummy variables. This is because of the nature of the data. For example, since the data do not have information on income as a continuous variable, we considered it as a categorical variable.
[5]The preparation of the traditional pan-cake like Ethiopian food, *injera*, requires an appliance known as Mitad. 'Mitad' is a clay-made circular pan used for baking '*injera*'

The dependent variable used in the analysis was the time (in years) households waited before adopting Mirt and Lakech improved stoves, measured by the number of years elapsed since their introduction, which was taken to be in the year 1991 and 1994 for Lakech and Mirt biomass cook stoves, respectively. For those households who had not yet adopted, the duration was right-censored at the year of data collection.[6] That is, we know the period of introduction of the technology (the beginning of the duration), but we do not know the end for some observations. The start date is the time when the improved biomass cook stoves were first introduced and the exit date, or the end of a spell, is the time a household adopts the fuel saving technology (Mirt improved biomass cook stove or Lakech Charcoal stove).

4. Results of duration analysis

4.1. Non parametric results

When the data is censored the density and cumulative distributions are not appropriate. An alternative non parametric approach called Kaplan Meier-Estimator has been developed for non-parametrical estimation of survival functions and the related distributions. This is a non-parametric approach, making no assumptions regarding the underlying distribution of survival times. The figure below shows the survival functions for the Mirt biomass *injera* stoves by income level. The survival function for income category 1 is higher than category 2, which in turn is higher than category 3. The survival function for income category 1 suggests that households in the lower income groups have higher probability of survival than those households from the relatively high income groups. We used both the logrank and Wilcoxon test to test whether the above graphs are statistically different or not. Both tests for equality of survivor functions show that we reject the null hypothesis of equality at 1% level of significance. In other words, we can reject the null hypothesis that the four groups face the same hazard of failure. The results of both tests are also the same for Lakech charcoal stove.

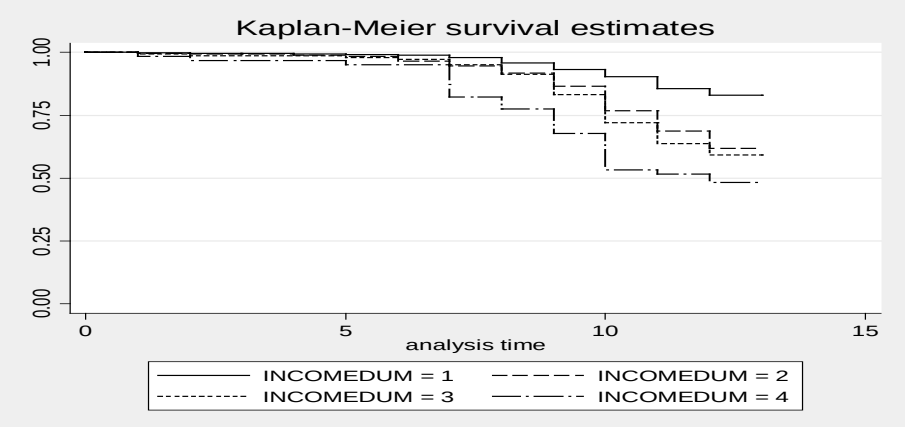

Figure 1. Survival function for MIRT improved biomass cook stoves

When we see the nature of the graphs it seems constant for the first 6 or 7 years. The Kaplan-Meier survivor function does not change indicating that there are no adoptions of the stove at the beginning, irrespective of the level of income. Then the values of the function fall quickly

[6]Lack of consistency in the various reports was our main problem in setting the period of introduction of the fuel saving technologies. Moreover, there is no information on the specific year for the introduction of each technology in each region. So we take the same year for all surveyed households.

from year to year. That means there are adopters of Mirt biomass cook stove every year. We did not report the survival function for Lakech charcoal stove since it is more or less similar with Mirt *injera* stove. That of Lakech charcoal stove falls quickly at a later stage (after 10 years) compared with Mirt.

4.2. Results of parametric regression

The results of the Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) model selection criteria show that the Weibull model is preferred to the exponential model for both kinds of stoves. Hence we report the results of the Weibull model only. Another issue in duration analysis is the issue of unobserved heterogeneity. The 'theta' value reported in table shows that the frailty model is preferred to the reference non-frailty model according to the likelihood ratio test (for Mirt). For lakech charcoal stove, we estimated without taking the issue of hetrogenity since convergence was not achieved. Table 2 presents the results of the Weibull estimation for Mirt and Lakech stoves.

Table 2: Determinants of covariates of Mirt injera and Lakech charcoal biomass cook stove

	MIRT			Lakech		
Variables	Coef.	S. E.	*p*>z	Coef.	S.E.	*p*>z
GENDER	-0.321	0.151	0.034	0.114	0.111	0.307
AGEHH	0.006	0.006	0.296	-0.036	0.005	0.000
EDreadelm	0.636	0.220	0.004	-0.039	0.138	0.777
EDsecond	1.240	0.253	0.000	-0.015	0.164	0.927
EDhigher	1.085	0.267	0.000	0.156	0.172	0.365
CHILD15	-0.042	0.040	0.292	-0.043	0.031	0.165
ADULTS15	0.088	0.033	0.008	0.069	0.024	0.005
HOWNERSHIP	0.296	0.153	0.053	0.117	0.109	0.286
DELEMITAD	0.206	0.198	0.297			
DMETALSTOV				-0.906	0.107	0.000
COOKINGPLACE	0.486	0.170	0.004	-0.053	0.111	0.634
MONINCOME2	0.695	0.152	0.000	0.378	0.111	0.001
MONINCOME3	0.692	0.219	0.002	0.351	0.165	0.033
MONINCOME4	1.303	0.297	0.000	0.541	0.215	0.012
DTigray	-1.184	0.216	0.000	-0.045	0.165	0.786
DAmhara	-0.447	0.137	0.001	0.044	0.102	0.668
_cons	-11.995	0.765	0.000	-11.391	0.523	0.000
/ln_P	1.287	0.071	0.000	1.481	0.039	0.000
/ln_the	-0.343	0.610	0.574			
P	3.620	0.257		4.398	0.173	
1/P	0.276	0.020		0.227	0.009	
Theta	0.710	0.433				

Likelihood-ratio test of theta=0: chibar2(01) = 3.05, Prob>=chibar2 = 0.040

In the Weibull model, P >1 means that the hazard is monotonically increasing. That is the observations are failing at a faster rate as time goes on. The value of P for Lakech charcoal stove is also greater than one, showing that the hazard, like in the case of Mirt, is monotonically increasing. Stata also estimates the log of P (for computational reasons) and

provides a test of the hypothesis that the log of p is equal to zero (which is equivalent to testing for P=1), which is rejected as indicated in the table above. That means the test also rejects the null hypothesis of no duration dependence; i.e log of P is equal to zero.

Note that a negative value of a coefficient β implies that the variable increases the time until adoption whereas a positive coefficient means that the times taken to adopt the fuel saving technology were shorter. Our result shows that education will speed up the adoption of the Mirt biomass *injera* stove compared with illiterate households. Surprisingly, education has no effect on the adoption decision of Lakech charcoal stove. For Lakech charcoal stove income is more important than education. Compared with households earning monthly income of Birr 500 or less, the probability of adopting Lakech charcoal stove increases for those households whose monthly income is 501 and above. The effect of income on the speed of adoption of Mirt biomass *injera* stove is not different from Lakech charcoal stove. The result implies that the design and price of new improved biomass stoves should take into consideration the capacity of households to pay for it. This is very important given the nature of households who are highly biomass dependent. Poor households are usually dependent on biomass sources for cooking. In general, the higher the income, the higher the probability of adopting improved stoves in urban Ethiopia. According to Jones (1989), cited in Barnes et al. (1994), middle-income families have adopted improved stoves far more quickly than poor families in most African countries. In our case, even high income households are using the improved biomass stove. This also shows that households may not necessarily shift to other better sources of energy as their income increase, as postulated by the energy ladder hypothesis. This is because the process depends on many other factors such as affordability, availability, and cultural preferences.

The estimated coefficient for the variables 'ownership of private house' and 'separate kitchen' suggests that households who possess these basic facilities are more likely to adopt Mirt Biomass *injera* stove. Mirt is a domestic appliance which requires some space and larger in size than many modern and improved-biomass cook stoves. Hence, its installation and proper utilization requires access to basic facilities (Shanko et al., 2009). However, these variables do not have any significant effect in the case of Lakech charcoal stove. This is for the simple reason that the stove is simple and easily mobile. Similarly, Lakech does not require separate kitchen. It is usually used in the main house since it is small, light and convenient for cooking. As a result, the ownership of house and possession of separate kitchen may not be significant factors in adopting Lakech charcoal stove.

The negative sign of the variable 'Gender' suggests that the conditional probability of adoption of Mirt Biomass stove declines if the household head is male. The result is expected because female headed households can appreciate the importance of the stove more than male headed households. This variable is, however, not significant in the case of adoption of Lakech charcoal stove. Age of the household head is negatively related to the speed of adoption of Lakech charcoal stove suggesting that younger households are more likely to adopt the technology compared with households with older heads. The number of adults is positively and significantly correlated with the speed of adoption of both types of stoves. The number of children and youths with age less than 15 does not affect the speed of adoption of both types of stoves. This result may not be reliable as the variable includes household members whose ages are less than 15 years old. The data do not have separate information for children and youths. It is known that availability of children (less than 5 years) usually increase the probability of adoption of the improved biomass stove technologies.

The impacts of substitute technologies were also examined. Electric Mitad is considered as a substitute for Mirt *injera* stove. Metal charcoal stove is a substitute for Lakech charcoal stove. The coefficient for electric Mitad is not significant suggesting that households are not using electric Mitad for baking *injera*. The reason might be the relative cost of using electric Mitad is so expensive compared with Mirt *injera* biomass cook stove. The availability of metal charcoal stove, however, negatively and significantly affects the probability of adopting Lakech charcoal stove. Given the better performance of Lakech charcoal stove over that of Metal charcoal stove, we need to understand why households with metal charcoal stove take longer time to adopt the Lakech charcoal stove than those without metal charcoal stove. The role of marketing and promotion strategies may be significant here. We need to design marketing strategies that attracts households who already possess other kind of stoves, serving the same purpose.

Location variable shows that the speed of adoption of Mirt *injera* stove decreases for a household in Amhara and Tigray region compared with households residing in Oromiya region. We would have expected a different sign as the level of biomass in these areas is usually low (relatively degraded compared with Oromiya region). The result may be justified by the fact that households in Oromiya region are better exposed to the technology than households in Amhara and Tigray regions. Moreover, differences in other factors such as price and level of involvement of NGOs could result in differences in the adoption decision of households between the regions.

5. Conclusions and policy implications

This paper deals with one of the demand side strategies, distribution of improved biomass cook stoves, which will help reduce pressure on biomass resources, save fuel, reduce time for cooking, and reduce the risk of fire hazards. The paper tried to find out the determinants of adoption of two different types of fuel saving technologies (Mirt and Lakech) in Ethiopia by using data collected from selected towns in three regions of the country. We applied a duration analysis to examine the impacts of different socioeconomic variables on the speed of adoption of both types of stove technologies.

The result of the analysis shows that income level is a significant factor in the adoption decision of the improved biomass cook stoves in urban Ethiopia. This may suggest that households will not shift to other better sources of energy as their income increase, as postulated by the energy ladder hypothesis. Moreover, since poor households are highly dependent on biomass sources for cooking, the design and price of new technologies should take into consideration the interest of the lower income groups.

Education (increasing awareness of the people) might increase the probability of adopting the Mirt biomass *injera* stove. We also found possession of Electric Mitad (a technological substitute for Mirt *injera* stove) does not have any effect on the adoption decision of Mirt biomass cook stoves. This may be due to the better performance of Mirt in reducing the energy cost of preparing the staple food, *injera*. Therefore, ownership of electric Mitad does not necessarily mean that households will substitute it for Mirt. This requires the attention of policy makers or energy planners to further assess the potential impact of electric Mitad on household's overall welfare and biomass use (forest pressure). However, ownership of Metal charcoal stove is negatively correlated with the adoption of Lakech charcoal stoves. This may suggest that there is a need to reconsider the promotion strategy given the better performance

of Lakech charcoal stove over Metal charcoal stove. The findings further show that access to basic facilities such as private house and separate kitchen for cooking increases the probability of adopting Mirt biomass improved stove. Given the importance of the improved biomass stoves in saving biomass, money, reducing indoor air pollution, etc. future study should give more attention to collecting more information such as prices and subsidies (if any) and examine their impact on the adoption decision. Second, this study examined the adoption of improved stoves technologies, but not the efficient use. We need to see how much fuel wood and charcoal were saved due to these improved biomass cook stoves. Some studies (for ex, Muneer and Mohamed, 2003) also shows that convenience of new stoves over the traditional stoves has increased consumption of fuel wood or charcoal (rebound effect). Future study on this area should also address this issue.

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