WPS8499

Policy Research Working Paper 8499

Improved Biomass Cook Stoves for Climate Change Mitigation?

Evidence of Preferences, Willingness to Pay, and Carbon Savings

Sahan T. M. Dissanayake
Abebe Damte Beyene
Randall Bluffstone
Zenebe Gebreegziabher
Gilbert Kiggundu
Shannon H. Kooser
Peter Martinsson
Alemu Mekonnen
Michael Toman

WORLD BANK GROUP
Development Economics
Development Research Group
June 2018

Abstract

This paper investigates household preferences for improved cook stoves using a choice experiment administered in rural Ethiopia, and the cost-effectiveness of an improved stove for reducing global greenhouse gas emissions. In Ethiopia, about 96 percent of household energy demand is fulfilled by biomass. Improved stoves use less firewood and produce less smoke, and they have been touted as a way to reduce greenhouse gas emissions and health effects from indoor air pollution, as well as to improve forest conservation. Although there are many studies on the adoption of improved stoves, there is limited information on the willingness to pay for particular attributes of stoves, information that is vital for designing effective stoves and improving stove adoption. The paper finds that households have a positive willingness to pay for the durability, fuelwood use reduction, smoke reduction, and cooking time reduction of improved stoves. It also shows that the stove used in this experiment can be cost-effective for reducing greenhouse gas emissions, which suggests that programs providing payments for reducing greenhouse gas emissions could strengthen stove adoption if they are well implemented. The main reason the stoves are not being adapted is the lack of availability, which is a key message to policy makers.

This paper is a product of the Development Research Group, Development Economics. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/research. The lead author may be contacted at sdissan2@gmail.com.

Improved Biomass Cook Stoves for Climate Change Mitigation? Evidence of Preferences, Willingness to Pay, and Carbon Savings

Sahan T. M. Dissanayake*, Abebe Damte Beyene, Randall Bluffstone, Zenebe Gebreegziabher, Gilbert Kiggundu, Shannon H. Kooser, Peter Martinsson, Alemu Mekonnen, Michael Toman

Sahan T. M. Dissanayake*, Portland State University, Portland, OR, USA; Abebe Damte Beyene, Environmental Economics Policy Forum for Ethiopia, Addis Ababa, Ethiopia; Randall Bluffstone, Portland State University, Portland, OR, USA; Zenebe Gebreegziabher, Environmental Economics Policy Forum for Ethiopia and Mekelle University, Addis Ababa, Ethiopia; Gilbert Kiggundu, Colby College, Waterville, ME, USA ; Shannon H. Kooser, Colby College, Waterville, ME, USA ; Alemu Mekonnen, Environmental Economics Policy Forum for Ethiopia and Addis Ababa University, Addis Ababa, Ethiopia; Peter Martinsson, University of Gothenburg, Gothenburg, Sweden, ; Michael Toman, The World Bank, Washington DC, USA.

Keywords: Improved cookstoves, choice experiment, Ethiopia, climate change

JEL Codes: Q56, Q51, O13

Acknowledgements: Financial support for this work was provided by the World Bank and from the Knowledge for Change Trust Fund. We would like to thank participants at the Seminar Series at the University of Illinois, and Resources for the Future, the 2014 World Congress on Environmental and Resource Economics, and the 2014 Environment for Development (EfD) Annual Meeting for valuable feedback and suggestions on this work. We acknowledge research assistance work by Sangay Thinley. Responsibility for the content of the paper rests solely on the authors.

*Corresponding author: Sahan T. M. Dissanayake, Department of Economics, Portland State University, Portland, OR, USA. sdissan2@gmail.com, +1 217-419-0452

1. Introduction

Fuelwood for cooking and heating is generally the most important direct use of forest ecosystems in low-income countries, with nearly half the world's population relying on solid fuels, such as biomass, for cooking (IEA 2014). In Sub-Saharan Africa, 68% to 90% of the population relies on biomass fuels (Rehfuess 2006, Smith et al. 2004). Without any major change in policy, the number of people relying on traditional biomass fuels in 2030 is expected to remain roughly the same as now, about 40% of the current world population (IEA 2012).

Deforestation and forest degradation related to extraction and use of biomass fuels is a significant part of global forest biomass loss[1], which causes destruction of local ecosystem services and releases CO2 emissions into the atmosphere. Sub-Saharan Africa has the highest rates of deforestation in the world and fuelwood use that leads to (net) deforestation is not carbon neutral. For example, in Ethiopia, about 88% of forest fuelwood harvests are considered nonrenewable (UNFCCC, 2012)[2]. Black carbon, another byproduct of burning biomass fuels for cooking and heating is believed to be another key contributor to climate change (Rosenthal 2009, Bond *et al.* 2013). Smith *et al.* (2000) find that, depending on the timeline examined, the global warming contribution of a meal cooked using biomass can be significantly higher than one cooked using fossil fuels.

Traditional cook stoves can be particularly dangerous to human health as well. Inefficient and poorly vented stoves create a hazardous indoor environment, as smoke often pollutes the insides of homes. According to the World Health Organization (2016), over four million premature deaths are caused each year from indoor air pollution. Traditional stoves also foster gender inequalities because women are typically the ones who spend hours collecting wood and who are exposed to smoke while cooking in the home. Furthermore, children are often expected to collect firewood, which can be time-consuming and dangerous.

Replacing traditional stoves with fuel-efficient and lower-emitting improved stoves can help mitigate these problems (Anenberg et al. 2013, Bensch and Peters 2013, Bensch and Peters

[1] Over 50% of global forests have been converted to human use since the advent of modern agricultural practices. Tropical forest area is decreasing at over 10 million hectares per year, with much of the deforestation occurring in developing countries (MEA, 2005, Pan et al., 2011).

[2] Bailis et al. (2015) argue that the UNFCCC (2012) non-renewable biomass estimates for low-income countries like Ethiopia are too high.

201, Dresen 2014). In order to realistically promote the uptake of these stoves among people in developing nations, however, organizations have to meet the needs of the people who will use them. Traditions, social interactions, and family dynamics differ across cultures, but they play an integral role in people's willingness to adopt and ultimately use a new technology. Therefore, it is important to understand which aspects of stoves are important to households. Though there are a large number of studies on the adoption of improved stoves, which we discuss in the literature review, most of these studies focus on a particular stove and are not able to identify preferences for attributes of stoves. There is currently limited information on preferences and willingness to pay for particular attributes of stoves in general and this information is important for policy makers working on designing effective stoves and increasing stove adoption and the information is also needed to conduct cost benefits analysis of stove programs.

We use a choice experiment study to fill this knowledge gap and identify preferences for attributes of improved stoves. We conduct the choice experiment in rural Ethiopia. Ethiopia provides an interesting context for the study of improved stove initiatives, as about 96% of the population's household energy demand is fulfilled by wood, charcoal, branches, dung and agricultural residues, which all produce smoke and harmful emissions when they are burned (Bizzarri 2010, Beyene et al. 2015). Within the household sector, cooking compromises virtually 100% of energy demand (Practical Action Ethiopia 2015). Every year, nearly 150,000 hectares of land, 1.1% of forest area is deforested in an effort to collect wood (FAO 2010). Dissemination of efficient stoves is an important part of Ethiopia's strategy for the energy and forestry sectors. For example, the country's Climate Resilient Green Economy (CRGE) Strategy projects that reducing demand for fuelwood through efficient biomass stoves could reduce emissions by almost 35 Mt CO2e by 2030 and involve about 20 million households (FDRE, 2011). We focus on Ethiopia because the Ethiopian government is planning to disseminate around 11.45 million improved fuel-saving cook stoves during the period from 2015/16 to 2019/20 (MoWIE 2013, Accenture 2013). The results of our study can therefore potentially inform these stove dissemination efforts. Most of the improved stoves to be distributed are designed to more efficiently cook *injera*, which is the staple bread consumed in Ethiopia and is the end us of over half the primary energy consumed in the country (Bizzarri, 2010; Practical Action Ethiopia). The Mirt (i.e. "Best") stove is one example of an improved *injera* stove. It has been estimated to use 20% to 30% less fuelwood under field-based controlled cooking tests in a related study (Gebreeziabher et al., 2015). Later in this paper the Mirt stove is used as an example for estimating the potential cost-effectiveness of improved biomass cookstoves for combatting climate change.

Generally, improved stove trials and randomized control trials have found mixed evidence about the adoption and effectiveness of improved stoves (we discuss a selection in the literature review below). Moreover, as previously mentioned, most of these studies are limited to evaluating the stove that is being distributed. There is limited understanding about household preferences for the characteristics of the stoves (in general as opposed to for a specific stove) and the resulting WTP by households for particular characteristics of the stoves. However, to promote stove adoption, it is important to determine what factors make the new technology more or less attractive to households.

The choice experiment reported in this study examines the preferences for different features of improved stove technology in the Ethiopian context, as well as what types of households are more likely to place a high value on this new technology. The analysis is based on different characteristics of a generic improved stove (discussed below in the experiment design), and therefore the information about preferences for different stove characteristics is applicable to multiple stoves and provides information useful for policy makers and practitioners working on improved stove adoption since they are expressed as WTP. In addition, we analyze the cost-effectiveness of improved stoves for greenhouse gas mitigation using the Mirt stove as an example under different assumptions about the "price of carbon." We also discuss how payments for carbon reduction could potentially affect the economics of stove adoption.

We find that households have a positive WTP for all the attributes of the improved stoves, though durability and fuel use reduction have the highest marginal WTP. We find that the number of women and children in the household does not significantly affect preferences, but having seen an improved stove earlier increases the WTP for their attributes. We also find that even at a relatively low carbon price of $5 per ton of CO_2, paid via an international climate change program such as Reduced Emissions from Deforestation and Forest degradation (REDD+) or other sources, the Mirt stoves is a cost-effective way to reduce greenhouse gas emissions. In turn, the receipt of payments for greenhouse gas emissions reductions from adopting the improved stoves can influence the adoption decisions of individual households by lowering the net cost of the stoves.

2. Literature on Improved Stove Attributes

Several previous studies have examined the effects of traditional cookstoves and analyzed how to effectively encourage adoption of improved cookstoves. Most studies have found that traditional stoves have high nonmonetary costs, because of high fuelwood consumption and associated air pollution emissions. Duflo, Greenstone and Hanna (2008) found that in rural India, there was a high correlation between using a traditional stove and having symptoms of respiratory illness. Parikh (2008) observed connections among gender, energy use, and health in the Himachal Pradesh region in India. Certain groups suffer from the negative effects of traditional stoves and fuels more than others. Survey data provide evidence that women generally walk the most to collect fuel, they lose potential work days, and they suffer from physical stress from the long and often strenuous walks. Parikh (2008) also found that girls below age 5 as well as females age 30 to 60 show more symptoms of respiratory illness than do males of similar ages, because women and female children are the ones who spend the majority of their days inside their smoky homes.

Simon, Bumpus and Mann (2012) explored possibilities of “win-win” programs for climate protection and economic development and found that distributing lower-emitting stoves and using carbon finance could support both objectives in a poor country. These programs set both local (ex. economic development and improvement of children’s health) and global (mitigating climate change) goals, and results showed that economic development success was linked directly to environmental improvements.

There are, however, various challenges for stove adoption, as not everyone in developing countries is willing to pay for or wants to use such new technologies (Lewis and Pattanayak 2012, Bensch et al. 2015, Hanna et al. 2016). Previous efforts to encourage people to adopt and use new stoves in Ethiopia have met with limited success. The government has tried to promote clean stove technology, and though adoption rates have steadily increased over time, the large-scale adoption of stoves necessary to achieve climate benefits has not occurred. Beyene and Koch

(2013) examined the correlation between adoption of new stoves and different socioeconomic factors in Ethiopia, and found that the price of the stove, household income, and household wealth all have significant effects on a household's willingness to adopt new stoves. On the other hand, if traditional stove technology is available, families are less likely to want a new stove. Takama, et al. (2012) examined household decision-making regarding cookstove choices in Addis Ababa, and found that preferences for higher quality fuels and products increased with increasing wealth. Analyses by Lewis and Pattanayak (2012) determined that for various improved stove adoption initiatives, income, education and urban location were positively associated with stove adoption.

Besides considering household-level factors that lead families to adopt improved stove technology, numerous studies in different parts of the world have examined how attributes of the technology itself affect valuations. Adkins et al. (2010) found that in Sub-Saharan Africa, an individual's valuation of new stove technology was determined by a combination of different attributes of the stove, including cooking time, stove size and how easy the stove was to use. Another study by Mobarak et al. (2012) studied households in rural Bangladesh and found that women in these communities did not consider indoor air pollution to be a problem nor a danger to their health. Households that relied on traditional cookstoves wanted to use technology that was familiar to them and were not willing to pay much for new, cleaner stoves. However, Mobarak et al. (2012) found that organizations were more successful in promoting the adoption of these cleaner stoves if they highlighted the features that were highly valued by users, instead of just focusing on the health and environmental benefits of the stoves. Nyrud et al. (2008) added to this analysis and determined that, when distributing new technology, it is most effective to emphasize attributes that relate to the "users' perception of subjective norm" including the perceived status of those who use advanced technology, instead of focusing on objective benefits of the equipment.

Much of the existing research on stoves, including the studies discussed above, uses existing improved stoves and is therefore not able to study the preferences for individual stove characteristics, because the stove characteristics are fixed for the stove being studied. Identifying preferences for characteristics of stoves is important as this will allow researches and policy makers to focus on the most important characteristics in assessing the potential dissemination of stoves. To our knowledge only two recent studies, van der Kroon et al. (2014) and Jeuland et al. (2015), have attempted to elicit preferences for attributes of generic improved fuelwood stoves.

In their study van der Kroon et al. (2014) compare preferences across multiple fuel sources and cooking technologies. In our work we focus solely on improved biomass stoves, an energy source that is projected to be the main fuel source for 40% of the global population out to 2030 (IEA 2012). Jeuland et al. (2015) conduct a comprehensive analysis of factors influencing the adoption of improved stoves using both revealed and stated preference data from India. Our analysis, which focuses on Ethiopia, complements their work in that it is the first study to explicitly elicit preferences for improved fuelwood stoves in Africa. Our sample differs from Jeuland et al. (2015), as their sample includes many households that already use other (non-biomass) fuel technologies (20% LPG). Only 24% of their respondents were using traditional three stone stoves, whereas in the Ethiopian context over 90% of the households, and in our rural sample 100%, use traditional three stone tripod stoves.

By using a choice experiment that presents respondents with the ability to make choices over stoves with different combinations of characteristics, we contribute to the literature on improved stove adoption by analyzing the attributes of stoves that are most important for households. We also examine how socio-demographic factors impact preferences for stoves. Results from this study also contribute to the growing body of research about global sustainable development, as clean cookstoves provide a solution for both human health and environmental issues and may promote development in many parts of the world.

3. Choice Experiment Design

Choice experiments are a stated preference valuation tool used to determine someone's marginal willingness to pay (WTP) or willingness to accept (WTA) for goods, or characteristics of goods, when market data are not available for assessing these valuations. A choice experiment survey presents the respondent with choice scenarios where each choice scenario has alternatives with varied levels of different attributes of the good or policy being evaluated. The, respondents choose one of the alternatives or a status quo option and the results from the choice experiment provide information about the value of individual features of the goods and policies being valued. Alpizar et al. (2003), Boxall et al. (1996), Hanley et al. (2001), Hensher et al. (2005), Hoyos (2010), and Louviere et al. (2000) provide reviews of the choice experiment methodology.

We follow standard practice in the choice modeling literature for this research (Adamowicz et al. 1997, Adamowicz et al. 1998, Carlsson and Martinsson 2003, Louviere et al. 2000). We initially conducted informal focus groups, engaged in discussions with researchers and then finally conducted 15 formal focus groups and a field trial of the survey. Through this process we identified five attributes that we use for the final choice experiment; durability of the stove, the reduction of fuel use, the reduction of smoke, decrease in cooking time, and the cost of the stove. Durability was highlighted, because improved biomass stove availability is found to be an important issue for respondents. Durable stoves will not need to be replaced as often as poorly constructed stoves. As already discussed in the context of the work of Parikh (2008) in India, fuelwood collection can be extremely time-consuming and arduous. Focus group participants noted that reducing the demand for fuelwood would reduce household labor requirements and represent potentially important benefits.

The smoke from traditional biomass cookstoves is a very serious health hazard. Though it is not clear that improved biomass stoves reduce household air pollution enough to affect human health (e.g. see Jeuland et al. 2015), focus group respondents noted that for stoves to reduce smoke would be desirable. The final attribute noted (other than cost) was cooking time. *Injera* cooking can be time-consuming, taking more than one hour to cook 4 kg of *teff* flour (Gebreegziabher et al. 2015) and respondents would like, if possible, to decrease cooking time.

Every attribute had 3 or 4 systematically-identified levels[3] as described in Table 1. Each respondent answered seven different choice questions; the first and seventh question were identical, and the first question was dropped from the data analysis to account for possible learning (Carlsson et al. 2010). Figure 1 shows an example of one choice question. We explicitly designed the choice question to clearly identify attributes both graphically and numerically. This

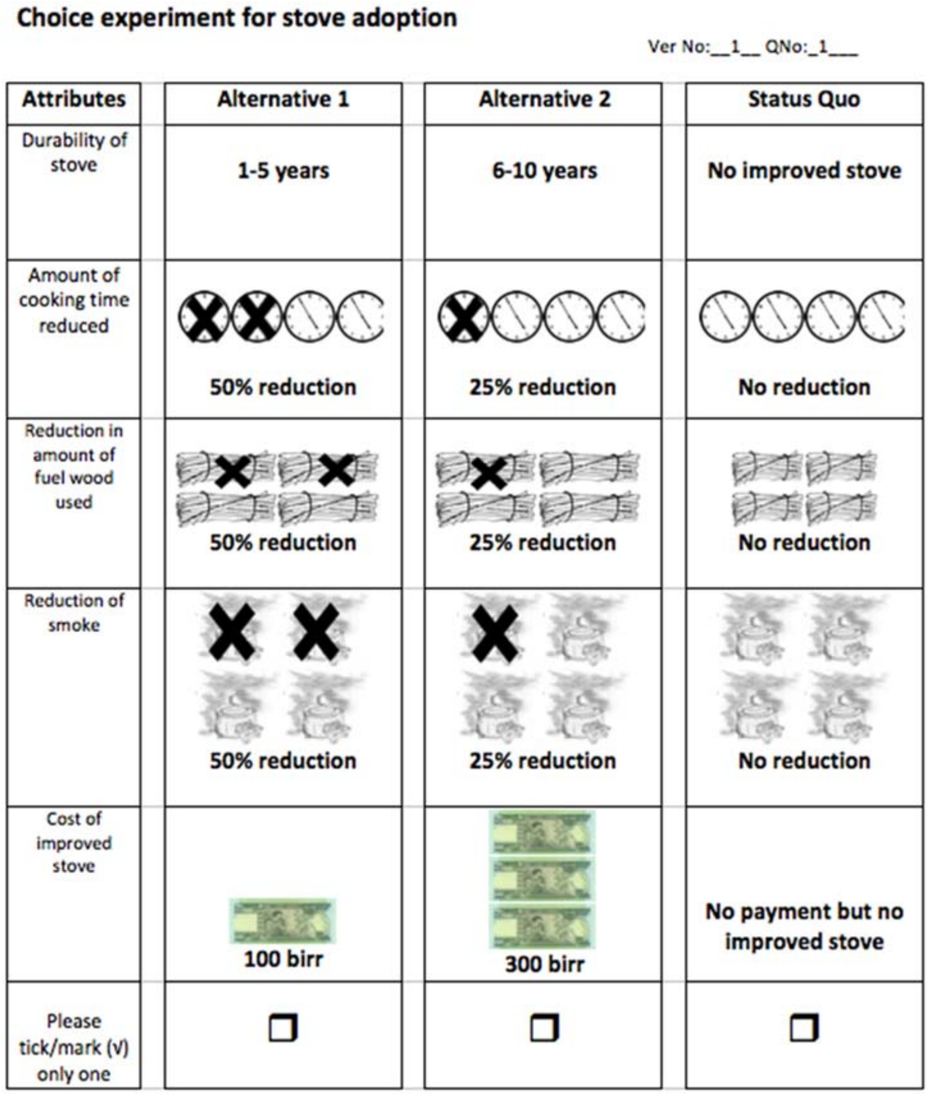
[3] The levels for each choice question were determined using an orthogonal fractional factorial experiment design that was 100% D-efficient (Kuhfeld 2010).

aspect also differentiates our study from the two previous studies to elicit preferences for improved stoves, where the choice cards did not contain both numeric and graphical representations of the levels of the attributes.

Attributes	**Description**	**Levels**
Durability of stove	How long the stove would be functional	❖ No improved Stove ❖ 1-5 years ❖ 6-10 years ❖ 11-15 years
Reduction in amount of fuel wood used	The reduction in fuelwood use in comparison to using the traditional cook stove.	❖ No reduction ❖ 25% reduction ❖ 50% reduction
Reduction of smoke	The reduction of smoke as a result of using an improved stove	❖ No reduction ❖ 25% reduction ❖ 50% reduction
Amount of cooking time reduced	The amount of cooking time reduced by adopting an improved stove.	❖ No reduction ❖ 25% reduction ❖ 50% reduction
Cost of Improved Stove	The amount paid to acquire a new improved stove.	❖ No payment ❖ 100 Ethiopian Birr (ETB) ❖ 200 Ethiopian Birr (ETB) ❖ 300 Ethiopian Birr (ETB) ❖ 400 Ethiopian Birr (ETB)

Table 1: Attribute Levels

Figure 1 – Choice Experiment Question Example



Choice experiment for stove adoption

Ver No:__1__ QNo:_1___

Attributes	Alternative 1	Alternative 2	Status Quo
Durability of stove	1-5 years	6-10 years	No improved stove
Amount of cooking time reduced	50% reduction	25% reduction	No reduction
Reduction in amount of fuel wood used	50% reduction	25% reduction	No reduction
Reduction of smoke	50% reduction	25% reduction	No reduction
Cost of improved stove	100 birr	300 birr	No payment but no improved stove
Please tick/mark (√) only one	☐	☐	☐

4. Methods of Analysis

4.1 Econometric model specification

We follow the standard practice in the choice experiment literature and use a conditional logit and a mixed multinomial logit model to analyze the data. We use a linear random utility model (RUM) for the econometric specification. The general form of the conditional logit (CL) model includes attributes as a linear summation in the following general form:

$$V_i = \sum_{k=1}^{K} \beta_k X_{ki_1} + \beta_{price} X_{price} + \varepsilon_i \quad (1)$$

With the specific attributes included in this choice survey, the model takes the form:

$$V_n = \beta_0 ASC + \beta_1 X_{durability} + \beta_2 X_{time\_reduction} + \beta_3 X_{firewood\_reduction} + \beta_4 X_{smoke\_reduction} + \beta_{price} X_{price} + \varepsilon_n \quad (2)$$

The alternative specific constant (ASC) term accounts for the fact that option A and option B are both improved stoves and therefore are closer substitutes with each other than with option C, the status quo option (Haaijer et al. 2001, Blaeij et al. 2007). The ASC term identifies the overall likelihood of choosing a stove (option A or option B) regardless of the levels of the specific attributes. The conditional logit model assumes that respondents all have homogeneous preferences and thus it provides a limited analysis of unobserved heterogeneity (β_i.in specification (2) estimates the mean value for the sample). In order to account for preference heterogeneity we also use a mixed multinomial logit (MMNL) model to analyze the data (Hensher et al. 2005, Carlsson et al. 2003, Train 2003).

To test for the robustness of the results we use two forms of the MMNL model. The first holds price constant and the second assumes price is normally distributed. For both of these models we use a linear random utility model for the main effects estimation.

$$V_{ni} = \beta_{0n} ASC + \beta_{1n} X_{durability} + \beta_{2n} X_{time_{reduction}} + \beta_{3n} X_{firewood\_reduction} + \beta_{4n} X_{smoke\_reduction} + \beta_{pricen} X_{price} + \varepsilon_{ni} \quad (3)$$

The coefficient estimates from the conditional logit model and the mixed multinomial logit model cannot be interpreted directly. Therefore, the average marginal WTP is calculated for a change in each attribute *i* by dividing the coefficient estimate for each attribute with the coefficient estimate for the payment term, as given in (3).

$$MWTP_i = -\frac{\beta_i}{\beta_{price}} \quad . \quad (4)$$

The mixed multinomial logit model does not explicitly identify the factors that lead to heterogeneous preferences. In addition to the above standard main effects specification we also analyze the data using the specification that incorporates demographic interactions terms to better understand the heterogeneity in the sample.

$$V_{ni} = \beta_{0n}ASC + \beta_{1n}X_{durability} + \beta_{2n}X_{time_{reduction}} + \beta_{3n}X_{firewood\_reduction} + \beta_{4n}X_{smoke\_reduction} + \beta_{5n}X_{cost} + \beta_{kn}ASC * Z_{kn} + \varepsilon_{ni} \quad (5)$$

The Z variable represents socio-demographic interaction terms. Specifically, we test whether household size, gender composition, the presence of the cook, number of children, or having previously seen an improved stove impact the preferences for an improved stove.

4.2 Study site and stove technology

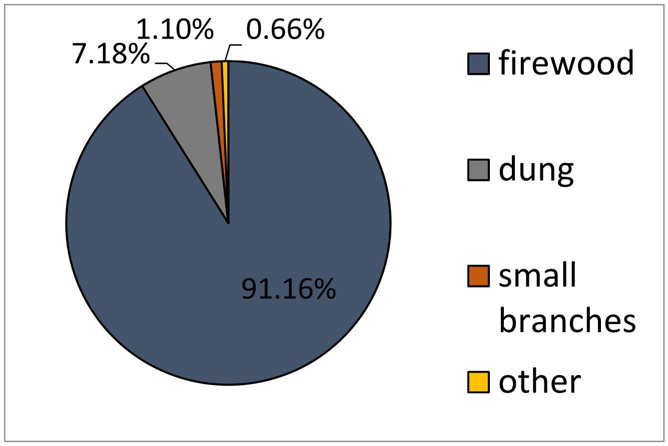
Data for this study were collected from 504 randomly selected households in 36 sites from Oromia, Ahmara and SNNP, the three largest regions that together represent 80% of Ethiopia's population and 70% of Ethiopia's forest cover. The survey was conducted by 20 enumerators and 5 supervisors who went out to the communities in groups of five, four enumerators and one supervisor. The enumerators spoke local languages and were trained in conducting choice experiment surveys (and most had previous experience with collecting choice experiment data in similar field settings).

Several different ethnicities are represented in the study area; the largest groups represented are Oromos (39.04%), Amharas (24.5%), and Wolaytas (13.74%). All respondents live in rural areas, and the average walk time to the nearest road is 63.8 minutes. The average number of children in a household is 3.38, and most households consist of about 6 people. Only 5.38% of the households have a female head of the household.

As seen in Figure 2, which presents the primary sources of fuel used by respondents, using the forest sustainably should be an urgent priority for Ethiopians. Over 91% of respondents use firewood as their main source of fuel, while only 7.2% of people use dung and 1.1% use small branches to fuel their stoves. Just under half of the respondents (44.6%) had seen an improved stove before they took the survey, and nearly all (more than 92%) of respondents said they used a three-stone stove for cooking. Most households (over 77%) report that children were usually in the kitchen when food is cooked, and nearly all households (88%) belong to forest user groups

(FUGs), which are groups of community-members that are involved in forest management and land use decisions. Respondents reported that they did not because new stoves were unavailable (64.2%), they did not know how to use one (20.1%) or because they were expensive (11.2%).

Figure 2 – Primary Fuel Sources (%)



5. Results and Discussion

5.1 Choice experiment results

The results of the main effects specification using a conditional logit, a mixed multinomial logit with fixed price and a mixed multinomial logit with a random price are presented in Table 2. The coefficients for all the attributes are significant and positive but respondents most preferred choices were characterized by high levels of durability, cooking time reduction, fuel use reduction and smoke reduction.

The MMNL model also provides information about the heterogeneity of preferences. In the main effects model, the standard deviations for durability, time reduction, smoke reduction and fuel reduction and cost are significant. This implies that there is heterogeneity within the sample and significant variation among responses regarding these attributes and that a MMNL model should be used for the analysis.

Table 2 –Parameter Estimates from Main Effects Models

	(1) CL	(2) MMNL Cost Random	(3) MMNL Cost Fixed
Mean			
ASC	3.405***	19.25***	20.10***
	(0.348)	(4.119)	(5.711)
Durability	0.0530***	0.0708***	0.0759***
	(0.00774)	(0.0105)	(0.0105)
Time Reduction	0.0128***	0.0193***	0.0153***
	(0.00187)	(0.00254)	(0.00223)
Fuel Reduction	0.0175***	0.0263***	0.0217***
	(0.00175)	(0.00318)	(0.00284)
Smoke Reduction	0.0119***	0.0195***	0.0177***
	(0.00307)	(0.00433)	(0.00431)
Cost	-0.00266***	-0.00402***	-0.00384***
	(0.000543)	(0.000822)	(0.000670)
Standard Deviation			
ASC		-7.972***	-8.265***
		(1.804)	(2.368)
Durability		-0.0553***	0.0861***
		(0.0190)	(0.0129)
Time Reduction		0.0118*	-0.00807
		(0.00687)	(0.00711)
Fuel Reduction		0.0431***	0.0410***
		(0.00378)	(0.00357)
Smoke Reduction		0.0200*	0.0281***
		(0.0118)	(0.00791)
Cost		0.00814***	
		(0.000977)	
Observations	9054	9054	9054
Log lik.	-1936.2	-1824.8	-1844.4
Chi-squared	2758.9	222.7	183.6

Standard errors in parentheses $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

To better interpret the results, we calculate the respondents' WTP for each attribute. Table 3 presents marginal WTP estimates for each attribute for each model (holding other attributes constant). Durability has the highest marginal WTP per unit of each attribute, with respondents' WTP 19.11 ETB on average (across the three models) for each additional year of use, followed by fuel reduction at 6.27 ETB on average for each additional percentage of fuel reduction, smoke reduction at 4.63 ETB on average for each additional percentage of smoke reduction and time reduction at 4.53 ETB on average for each percentage of time reduction. Of course, these monetary values are difficult to compare directly as the units differ (i.e. durability is given per year from a range of 1-15, whereas the other three attributes are denominated per percent change).

Table 3 – WTP Estimates for Each Attribute in CL and MMNL Models (ETB per unit of attribute)

	(1) CL	(2) MMNL Cost Random	(3) MMNL Cost Fixed
Durability	19.90***	17.63***	19.80***
	(2.926)	(2.880)	(2.642)
Time Reduction	4.797***	4.810***	3.986***
	(1.307)	(1.229)	(0.967)
Fuel Reduction	6.584***	6.555***	5.668***
	(1.725)	(1.699)	(1.385)
Smoke Reduction	4.458***	4.848***	4.605***
	(1.716)	(1.662)	(1.584)

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

To determine what household characteristics lead to the improved stove being more attractive, we analyze the data using a series of demographic interaction terms (Specification 4). The specific interactions were selected based on household factors that may influence the selection of stoves. Specifically, we included interaction terms that identified the number of children, the number of female members of the household, whether the cook was present during the survey, if the respondent had seen an improved stove previously, and if the household only had wood burning stoves. As seen in Table 4, none of household demographic interaction terms are significant. The lack of significance is robust across multiple other specifications and definitions of variables, except for the number of children. The number of children is significant in some model specifications that we analyzed but the result is not robust across all specifications.

We include an interaction term for whether the cook participated in the survey and find that this does not significantly determine the preferences for individual stove characteristics. The interaction between the ASC term and the "cook participation" variable is significant and positive, indicating that when the cook participated in the survey the likelihood of choosing a stove is higher. In a similar manner the ASC interaction terms for "seen an improved stove" and "only have wood burning stoves" is significant and positive, indicating that respondents that have previously seen an improved stove and respondents that currently only have a wood burning stove are more likely to choose an improved stove and therefore are willing to pay more for the improved stoves.

Table 4– Parameter Estimates from Interaction Effects Models

	MMNL	
	Mean	**Standard Deviation**
ASC	15.94***	7.137***
	(3.416)	(1.446)
Durability	0.0653***	0.0550**
	(0.0108)	(0.0215)
Time Reduction	0.0186***	0.0103
	(0.00287)	(0.00778)
Fuel Reduction	0.0283***	0.0375***
	(0.00939)	(0.00620)
Smoke Reduction	0.0153***	0.00806
	(0.00474)	(0.0222)
Cook Part In Survey X Smoke Reduction	0.00370	0.0182
	(0.00977)	(0.0183)
Cook Part In Survey X Time Reduction	0.00392	0.0119
	(0.00611)	(0.0122)
Cook Part In Survey X Fuel Reduction	0.00500	-0.0231
	(0.00759)	(0.0150)
Children > 3 X Fuel Reduction	-0.00909	-0.0122
	(0.00577)	(0.0198)
HH % Female X Fuel Reduction	0.00393	-0.0223
	(0.0171)	(0.0231)
Cook Part In Survey X ASC	8.234*	16.72***
	(4.294)	(3.593)
Only Wood Burning X ASC	10.97***	6.632***
	(2.495)	(2.127)
Seen Improved Stove X ASC	13.14***	2.304
	(3.843)	(1.694)
Cost	-0.0374***	0.0816***
	(0.00855)	(0.00983)
Observations	8262	
Log lik.	-1675.0	
Chi-squared	203.0	

Standard errors in parentheses* $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$

5.2 Valuation of carbon reductions from improved stoves

Next, we calculate the carbon benefit from the reduction in fuelwood use by switching to an improved stove and discuss the cost-effectiveness of including stoves in a carbon mitigation program like REDD+[4]. The Mirt stove saves 25% of fuelwood in the field or 634 kg per household per year.[5] We convert fuelwood savings to CO_2 emissions reductions and find that if fully adopted a Mirt stove will lead to a decrease of 0.94 tons of CO_2 per stove per year.[6] The Ethiopian government initiative to distribute 11.45 million improved stoves (MoWE 2013, Accenture 2013) would therefore lead to a reduction of approximately 10.77 million tons of CO_2 per year, if the average stove distributed reduces emissions at a level similar to the Mirt stove.

These savings would be worth about $54 million, or approximately $4.70 per household per year, using a fairly low price for carbon emissions reductions of $5.00 per ton. Based on the 2015 price of $13.93 per ton from carbon allowance auctions in California's greenhouse gas control system, the carbon savings would be worth about $150 million per year, or approximately $13 per household.

We can combine this carbon valuation information with our analysis of household attribute valuations to explore how potential payments for reducing fuelwood-based deforestation, as under REDD+, can create incentives for improved stove adoption. The current price of the Mirt stove is approximately $12 per stove, and it is expected to have a life of roughly 4-5 years. Respondents' average marginal WTP for a stove with a 25% reduction in fuelwood required, holding all other attributes constant is 6.27 ETB/% * 25% = 157 ETB, or approximately

---

[4] Reducing Emission from Deforestation and Forest Degradation (REDD+) is a payment for ecosystem services (PES) system created under the United Nations Framework Convention on Climate Change (UNFCCC). REDD+ is an important tool to create incentives for those who control forests to sequester carbon and for those who emit carbon into the atmosphere to pay for forest carbon sequestration services (Bluffstone 2013).

[5] Bluffstone et al. (2015) find that on average the Mirt stove is used in a manner consistent with standard injera cooking frequencies of at least two times per week.

[6] The value of 0.94 tons of CO_2 per stove is based on a net calorific value of 15 MJ/kg of woody biomass (IPCC; Hall et al. 1994), 112 g of CO_2 per MJ of fuelwood (IPCC) and 88% nonrenewable firewood use for Ethiopia (CDM value for Ethiopia obtained from UNFCC (2012) and Lee et al. (2013). For details of the calculation refer to Gebreegziabher et al. 2015.

$8. As noted in the previous paragraph, even with a carbon price of $5 per ton of CO_2, households can gain $4.70 per year over the life of the stove. A household thus could totally recoup the cost of the Mirt stove in three years.[7] Note also that our calculation is fairly conservative in not including payments for reducing black carbon emissions. Nor does it incorporate households' willingness to pay to have a stove with reduced smoke emissions.

However, the carbon savings and reduced deforestation will only be realized if the stoves continue to be consistently used (Simon et al. 2012). The results from the choice experiment survey indicate that rural Ethiopian households value the attributes of the stove and therefore are likely to use the stoves. This result is reinforced in findings from Gebreegziabher et al. 2015 that used a stove satisfaction survey and controlled cooking tests to evaluate actual Mirt Stoves. A natural question then is why households are not more widely adopting the improved stoves on their own. When this question was posed to the respondents in the choice experiment, the most commonly cited reason for not having a stove was the lack of availability of stoves, not their cost.[8] If, as our results suggest, the demand exists, there would seem to be an opportunity for businesses or other organizations to enter the market to provide the stoves.

6. Conclusions and Policy Implications

Nearly half the world's population relies on solid fuels, such as biomass, for cooking, and in Sub-Saharan Africa there is a much higher reliance, with 68% to 90% of the population using biomass fuels (IEA 2014, Rehfuess 2006, Smith et al. 2004). Improved (fuel-efficient and lower-emitting) stoves have long been viewed as a solution to reduce both environmental and health impacts from the use of traditional biomass stoves. In order promote improved stoves and increase the uptake of improved stoves it is important to understand which aspects of stoves are important to households. Though there are a large number of studies on the adoption of

[7] The additional carbon payments would be available to help finance the cost of replacing the cooking surface, should it crack or break. A portion of the total carbon revenues also could be retained to help finance the cost of implementing the stove distribution program, and educating households regarding how to use the improved stove.
[8] In a stove satisfaction survey 100% of the users rated the MIRT stoves as good or very good, 90% said that they would buy the stove at full market price. For more details of the satisfaction survey refer to Gebreegziabher et. al. 2015.

improved stoves, most of these studies focus on a particular stove and are not able to identify preferences for attributes of stoves in general. There is limited information on preferences and willingness to pay for particular attributes of stoves in general and this information is vital for policy makers working on designing effective stoves and improving stove adoption.

In this paper we use a choice experiment survey to elicit preferences for improved stoves and to evaluate the benefits relative to costs of stove adoption taking into account both household level benefits and the potential economic value of payments for reducing deforestation. We conduct the choice experiment in Ethiopia as Ethiopia provides an interesting context for the study of improved stove initiatives with about 96% of the population dependent on biomass for household energy needs (Bizzari 2010, Beyene et al. 2015) and the government currently engaged in effort to increase improved stove adoption. Though we focus on Ethiopia the results and the policy recommendations are applicable broadly to Sub-Saharan Africa and other developing countries in Asia and South America.

Our results indicate that rural Ethiopian households put significant value on each of the attributes of the improved stove that we consider– durability, cooking time reduction, fuelwood use reduction, smoke reduction and cost. We find that durability has the highest average WTP per unit of each attribute, though because units differ we cannot directly compare the average WTPs across attributes. Among cooking time reduction, smoke reduction and fuelwood reduction (all denominated as percentages), respondents have the highest WTP for fuelwood reduction. Contrary to our expectations, most of the household demographic variables that we believed would influence stove adoption are not significant and robust determinants of household stove adoption. We do find that having previously seen an improved stove increases the respondents' WTP for improved stoves. Finally, we find that using estimates of fuelwood savings derived from field measurements for the Mirt stove, our choice experiment valuation of fuelwood savings and at a modest carbon price, Mirt stoves would lead to avoided greenhouse gas emissions valued at a significant percentage of the cost of Mirt stoves.

Often, campaigns by international organizations to make improved stoves available focus on an initial wave of distribution for a new design. Our results suggest the need to first ascertain and emphasize the attributes of the stove that are most important to households. With the Mirt stove, these were durability and fuel savings. In addition, since our results indicate that having seen an improved stove increases WTP for such stoves, promotional efforts can benefit from demonstrations of the stove in the field, as well as encouraging improved stove owners to demonstrate the technology to others. As people see that the stove is effective, they will have more confidence in the technology. Finally, monetizing GHG emission reductions from improved stove adoption can close gaps between stove cost and the benefits realized by households from adoption.

The survey results also suggest that one important reason why many Ethiopians have not yet adopted an improved stove on their own is a lack of availability. To address this, barriers to the development of capacities for scaling up production and distribution need to be improved. This topic has received considerably less attention in cleaner cooking research than the issues affecting willingness to pay and adoption on the demand side. Beyond having good designs, and providing information to potential users on stove characteristics which the government could help finance, potential barriers may include unreliable availability of inputs, or high taxes on them; and difficulties in obtaining adequate finance, and managing financial risks combined with thin margins. Further research on these issues is very much needed in order to scale up markets for cleaner-cooking technology not just in Ethiopia, but throughout Sub-Saharan Africa and in countries in Asia and South America with a high percentage of traditional stove use.

References

1. Accenture 2013, Enhancing Markets for Delivery of Improved Cookstove Development and Promotion Support in Ethiopia. Available online: www.cleancookstoves.org/resources_files/ethiopia-market-assessment-report.pdf (accessed on 20 August 2015).
2. Adamowicz, W., Boxall, P., Williams, M. and Louviere, J., 1998. Stated preference approaches for measuring passive use values: choice experiments and contingent valuation. *American Journal of Agricultural Economics*. 80, 64-75.
3. Adamowicz, W., Swait, J., Boxall, P., Louviere, J. and Williams, M., 1997.Perceptions versus objective measures of environmental quality in combined revealed and stated preference models of environmental valuation. *Journal of Environmental Economics and Management*. 32, 65-84.
4. Adkins, E., Tyler, E., Wang, J., Siriri, D., & Modi, V. (2010). Field testing and survey evaluation of household biomass cookstoves in rural sub-Saharan Africa. *Energy for Sustainable Development*, *14*(3), 172-185.
5. Alpizar, F., F. Carlsson and P. Martinsson (2003) Using choice experiments for non-market valuation, *Economic Issues*, 8, 83-110.
6. Anenberg, S. C., Balakrishnan, K., Jetter, J., Masera, O., Mehta, S., Moss, J., & Ramanathan, V. (2013). Cleaner cooking solutions to achieve health, climate, and economic cobenefits. *Environmental science & technology*, 47(9), 3944-3952.
7. Bensch, G. and J. Peters. 2013. "Alleviating Deforestation Pressures? Impacts of Improved Stove Dissemination on Charcoal Consumption in Urban Senegal." *Land Economics*, Vol. 89: 676-698.
8. Bensch, G., M. Grimm and J. Peters (2015), Why Do Households Forego High Returns from Technology Adoption? Evidence from Improved Cooking Stoves in Burkina Faso. *Journal of Economic Behavior and Organization.* 116: 187-205.
9. Bensch, G. and J. Peters. (2015). "The Intensive Margin of Technology Adoption – Experimental Evidence on Improved Cooking Stoves in Rural Senegal," *Journal of Health Economics*, 42: 44 – 63.
10. Beyene, A. D., & Koch, S. F. (2013). Clean fuel-saving technology adoption in urban Ethiopia. *Energy Economics, 36, 605-613.*
11. Beyene, A, R. Bluffstone and A. Mekonnen, 2015. "Community Forests, Carbon Sequestration and REDD+: Evidence from Ethiopia," Forthcoming *Environment and Development Economics*
12. Bizzarri, M. 2010. "Safe Access to Firewood and Alternative Energy in Ethiopia: An Appraisal Report." Prepared for the World Food Program. http://www.genderconsult.org/uploads/publications/doc/SAFE_Ethiopia_Appraisal_Report_Final_Draft_2.pdf Accessed May 12
13. Bluffstone, R, A. Beyene, Z. Gebreegziabher, P. Martinsson, A. Mekonnen and F. Vieider, "The Improved Biomass Stove Saves Wood, but How Often do People Use it?" Policy Research Working Paper 7297, June 2015. The World Bank, Washington, DC.

14. Bluffstone, R, E. Robinson and P. Guthiga. 2013. "REDD+ and Community Controlled Forests in Low-Income Countries: Any Hope for a Linkage?" *Ecological Economics*, 87: 43-52.
15. Blaeij, A.T. de, Nunes, P.A.L.D. and J.C.J.M. van den Bergh (2007), 'No-choice'options within a nested logit model: one model is insufficient. *Applied Economics*, 39: 1245-1252.
16. Bond, T., Doherty, S., Fahey, D., Forster, P., Bernsten, T., DeAngelo, B., Flanner, M., Ghan, S., Karcher, B., Koch, D., Kinne, S., Kondo, Y., Quinn, P., Arofim, M., Schultz, M., Schulz, M., Venkataraman, C., Zhang, H., Zhang, S., Bellouin, N., Guttikunda, S., Hopke, P., Jacobsen, M., Kaiser, J., Klimont, Z., Lohmann, U., Schwarz, J., Shindell, D., Storelvmo, T., Warren, S. and Zender, C. 2013. Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment. *Journal of Geophysical Research Atmospheres*, 118: 5380–5552.
17. Boxall, P.C., Adamowicz, W.L., Swait, J., Williams, M. and Louviere, J., 1996.A comparison of stated preference methods for environmental valuation. *Ecological Economics*. 18, 243-253.
18. Carlsson, F. and P. Martinsson (2003) Design techniques for choice experiments in health economics, *Health Economics*, 12, 281-94.
19. Carlsson, F., Mørkbak, R. and Olsen, B., 2010. The first time is the hardest: A test of ordering effects in choice experiments. Working Papers in Economics 470.
20. Cookstove Projects. (2014). *Berkeley Lab*. Retrieved April 28, 2014, from http://cookstoves.lbl.gov/ethiopia.php.
21. Dresen, E., DeVries, B., Herold, M., Verchot, L., & Müller, R. (2014). Fuelwood savings and carbon emission reductions by the use of improved cooking stoves in an Afromontane Forest, Ethiopia. *Land*, 3(3), 1137-1157.
22. Diarrassouba, M., & Boubacar, I. (2009). Deforestation in Sub-Saharan Africa. *Souther Agricultural Economics Association, 1(1), 1-14.*
23. Duflo, E., Greenstone, M., & Hanna, R. (2008). Cooking Stoves, Indoor Air Pollution and Respiratory Health in Rural Orissa. *Economic and Political Weekly*, *32*, 71-76.
24. IEA (2012). *World Energy Outlook 2012*. International Energy Agency, Paris. http://www.worldenergyoutlook.org.
25. Ethiopia. (2014, April 28). *U.S. Agency for International Development*. Retrieved April 28, 2014, from http://www.usaid.gov/ethiopia
26. FAO (2010) Global Forest Resources Assessment 2010. Food and Agricultural Organization of the United Nations. http://www.fao.org/forestry/fra/fra2010/en/
27. Hanna, R, E. Duflo, and M. Greenstone. 2016. "Up in Smoke: The Influence of Household Behavior on the Long-run Impacts of Improved Cooking Stoves," American Economic Journal, 8, 80-114.
28. Gebreegziabher, Z., Beyene, A. D., Bluffstone, R., Martinsson, P., Mekonnen, A., & Toman, M. A. (2018). Fuel savings, cooking time and user satisfaction with improved

biomass cookstoves: Evidence from controlled cooking tests in Ethiopia. *Resource and Energy Economics*, 52, 173-185.

29. Haaijer, R., Kamakura, W., and Wedel, M. (2001), The 'no-choice' alternative in conjoint choice experiments, *International Journal of Market Research*, 43, 93-106.
30. Hall, D.O., Rosillo-Calle, F, Woods, J. 1994. Biomass Utilization in Households and Industry—Energy Use and Development. *Chemosphere* 29: 1099–1119.
31. Hanley, N., Mourato, S. and Wright, R.E., 2001. Choice Modelling Approaches: A Superior Alternative for Environmental Valuatioin? *Journal of economic surveys*. 15, 435-462.
32. Hanley, N., Wright, R. E., & Adamowicz, V. (1998). Using choice experiments to value the environment. *Environmental and resource economics*, 11(3-4), 413-428.
33. Hensher, D.A. and Greene, W.H., 2003. The mixed logit model: the state of practice. *Transportation*. 30, 133-176.
34. Hensher, D.A., Rose, J.M. and Greene, W.H., 2005. Applied choice analysis: a primer. Cambridge UnivPr, .
35. Hole, A.R. and Kolstad, J., 2012. Mixed logit estimation of willingness to pay distributions: a comparison of models in preference and WTP space using data from a health-related choice experiment. *Empirical Economics* 42(2): 445-469.
36. Hoyos, D., 2010. The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*. 69, 1595-1603.
37. IEA (International Energy Agency). 2014. *World Energy Outlook 2014. Executive Summary,* International Energy Agency Paris.
38. IEA (2012). *World Energy Outlook 2012*. International Energy Agency, Paris. http://www.worldenergyoutlook.org.
39. Inefficient developing world stoves contribute to 2 million deaths a year. (2011, October 12). *NIH News*. Retrieved April 28, 2014, from http://www.nih.gov/news/health/oct2011/nichd-13.htm
40. van der Kroon, B., Brouwer, R., & van Beukering, P. J. (2014). The impact of the household decision environment on fuel choice behavior. *Energy Economics*, *44*, 236-247.
41. Jeuland, M, S. Pattanayak and R. Bluffstone. 2015. The Economics of Household Indoor Air Pollution, *Annual Review of Environmental and Resource Economics,* 7: 81-108.
42. Jeuland, M., Bhojvaid, V., Kar, A., Lewis, J. J., Patange, O. S., Pattanayak, S. K., Ramanathan, N., Rehman, H., Soo, T., Sheng, J. and Ramanathan, V. (2015). Preferences for improved cook stoves: Evidence from North Indian villages. *Energy Economics. 25, 287-298*.
43. Kuhfeld, W.F., 2010. Marketing research methods in SAS: Experimental design, choice, conjoint, and graphical techniques. Cary, NC, SAS-Institute

44. Lee, Carrie M., Chelsea Chandler, Michael Lazarus and Francis X. Johnson, 2013. "Assessing the Climate Impacts of Cookstove Projects: Issues in Emissions Accounting," Challenges in Sustainability, 1(2), 53.
45. Lewis, J. J., & Pattanayak, S. K. (2012). Who Adopts Improved Fuels and Cookstoves? A Systematic Review. *Environmental Health Perspectives*, *120*(5), 637-645.
46. Louviere, J.J., Hensher, D.A. and Swait, J.D., 2000.Stated choice methods: analysis and applications. Cambridge University Press.
47. MEA. 2005. *Millennium ecosystem assessment: Ecosystems and human well-being*. Washington, D.C.: Island Press.
48. MoWIE (2013). National Improved Cookstoves Program (NICSP) of Ethiopia. Ministry of the Water Irrigation and the Environment.
49. Mobarak, A. M., Dwivedi, P., Bailis, R., Hildemann, L., & Miller, G. (2012). Low demand for nontraditional cookstove technologies. *Proceedings of the National Academy of Sciences*, *109*(27), 10815-10820.
50. Nyrud, A. Q., Roos, A., & Sande, J. B. (2008). Residential bioenergy heating: A study of consumer perceptions of improved woodstoves. *Energy Policy*, *36*(8), 3169-3176. Retrieved May 11, 2014, from the ScienceDirect database.
51. Pan, Y, R. Birdsley, J. Fang, R. Houghton, P. Kauppi, W. Kurz, O. Phillips, A. Shvidenko, s. Lewis, J. Canadell, P. Ciais, R. Jackson, S. Pacala, A. D. McGuire, S. Piao, A. Rautiainen, S. Sitch, D. Hayes. 2011. A Large and Persistent Carbon Sink in the World's Forests, *Science*, 333:988-993.
52. Parikh, J. (2011). Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. *Energy Policy, 39(12), 7587-7594.*
53. Practical Action Ethiopia. *Healthy Hoods Ethiopia Fact Sheet*, (2015) https://practicalaction.org/healthy-smoke-hoods-tool/country_data/ethiopia.pdf Accessed May 12.
54. Rehfuess, E., Mehta, S., Prüss-Üstün, A. 2006."Assessing Household Solid Fuel Use: Multiple Implications for the Millennium Development Goals", *Environmental Health Perspectives* 114.
55. Rosenthal, E. 2009. Soot from Third-World Stoves is New Target in Climate Fight. *The New York Times,* 16 April, Vol. 54,647.
56. Ruiz-Mercado, I., Masera, O., Zamora, H., & Smith, K. R. (2011). Adoption and sustained use of improved cookstoves. *Energy Policy*, *39*(12), 7557-7566.
57. Simon, G. L., Bumpus, A. G., & Mann, P. (2012). Win-win scenarios at the climate-development interface: Challenges and opportunities for stove replacement programs through carbon finance. *Global Environmental Change, 22(1), 275-287.*
58. Smith, K.R., S. Mehta, M. Maeusezahl-Feu. 2004. "Indoor air pollution from household use of solid fuels, in: M. Ezzati, A. D. Lopez, A.Rodgers, C. J. L. Murray (Eds.).*Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*. World Health Organization, Geneva, pp. 1435 -1494.

59. Smith, K. R. (n.d.). Health impacts of household fuelwood use in developing countries. *Forests and human health*. Retrieved April 28, 2014, from http://www.fao.org/docrep/009/a0789e/a0789e09.htm
60. Smith, K. R., Uma, R., Kishore, V.V.N., Zhang, J., Joshi, V. and Khalil, M.A.K. 2000 Greenhouse Implications of Household Stoves: An Analysis for India. *Annual Review of Energy and the Environment*, 25: 741–63
61. Takama, T., Tsephel, S., & Johnson, F. X. (2012). Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives. *Energy Economics, 34(6), 1763-1773.*
62. Train, K.E., 2003.Discrete choice methods with simulation. Cambridge university press.
63. UNFCCC, (2012). "Default Values of Fraction of Non-Renewable Biomass for Least Developed Countries and Small Island Developing States." 67th Meeting Report, Annex 22. United Nations Framework Convention on Climate Change, Executive Board of the Clean Development Mechanism, Bonn. http://cdm.unfccc.int/DNA/fNRB/index.html.
64. WHO. (2014) Household air pollution and health. (n.d.). *World Health Organization*. Retrieved May 10, 2014, from http://www.who.int/mediacentre/factsheets/fs292/en/.
65. WHO, (2016). Household air pollution and health – Fact Sheet N292. World Health Organization. Available at http://www.who.int/mediacentre/factsheets/fs292/en/ Accessed on February 1st 2016.