American Journal of Rural Development, 2017, Vol. 5, No. 3, 73-80
Available online at http://pubs.sciepub.com/ajrd/5/3/3

DOI:10.12691/ajrd-5-3-3

Smallholder Farmers' Willingness to Pay for Improved Cookstoves in Dedza, Malawi

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Abstract As improved cookstove programs increase in popularity, policy makers need accurate estimates of their constituents' willingness to pay for the stoves. Knowing which socioeconomic factors affect willingness to pay will allow program planners to price and target the stoves effectively. This study elicits the willingness to pay of 300 rural Malawians in Dedza District for two types of stove and explores the determinant socioeconomic factors. Respondents were willing to pay a median price of 7 USD for a clay stove and 9 USD for a rocket stove. In the clay stove regression model, willingness to pay is positively correlated with dietary diversity and negatively correlated with fuel expenditure. In the rocket stove regression model, willingness to pay is positively correlated with net household income and dietary diversity, and negatively correlated with higher incidence of cooking-related ailments. A literature review reveals that because of the discrepancy between short-term and long-term impacts of improved cookstove adoption, the focus of stove programs should be sustained, proper stove use by adopters, not just dissemination. Positive impact estimates are inflated when only short-term adoption data and laboratory fuel test results are used; more long-term impact evaluations are needed. Further, the study of socioeconomic determinants of stove adoption alone is inadequate for a self-sustaining, unsubsidized improved cookstove market. Choice elicitation experiment studies on product-specific attributes, that is stove characteristics, should complement socioeconomic findings to determine what is most desired by the target market.

Keywords: *improved cookstove, willingness to pay, chitetezo mbaula, rocket stove*

Cite This Article: Emily McNulty, Thea Nielsen, and Manfred Zeller, "Smallholder Farmers' Willingness to Pay for Improved Cookstoves in Dedza, Malawi." *American Journal of Rural Development*, vol. 5, no. 3 (2017): 73-80. doi: 10.12691/ajrd-5-3-3.

1. Introduction

The widespread use of biomass fuel for heating and cooking has strong negative impacts on human health and the environment. Biomass, mainly charcoal and wood, is the main cooking fuel for 2.7 billion people around the world [2,3]. In Sub-Saharan Africa, biomass is the primary fuel for 81% of the general population, and for close to 100% of the rural population [2,3]. The pollutants given off by the combustion of solid fuel are extremely harmful to human health, particularly when cooking is done indoors without adequate ventilation [6,12].

Each year, 2 million deaths are attributed to household air pollution, which is more than the number of deaths caused by malaria, and makes cooking with biomass fuels the world's primary environmental cause of death [2,18,22]. The deaths occur when ailments like low birthweight, high blood pressure, acute lower respiratory infection, chronic obstructive pulmonary disease, and asthma are caused or worsened by the pollutants [12]. Because women are generally responsible for preparing meals, and they tend to have their children nearby during cooking activities, women and children are most affected by indoor air pollution [2,12,20]. More than 50% of all premature deaths caused by household pollution occur in children under five years of age due to their vulnerability during critical growth stages [12,26].

Cooking with biomass fuels is not only harmful to women's health, but it also constitutes a heavy opportunity cost. Women in developing countries are commonly charged with the chore of household fuel acquisition. Collecting or purchasing charcoal and firewood can be very time consuming and often dangerous [2]. The inefficiency of biomass fuels also contributes greatly to deforestation through unsustainable firewood and charcoal production [11] and to global climate change through its removal of carbon sinks, and the release of carbon dioxide and black carbon during cooking [18].

Widespread dissemination of ICS is seen by many to be a feasible and effective intervention to improve human health, promote gender equality, relieve pressure on forests, and mitigate climate change [2,11,12,20]. The term ICS covers a broad range of stove technologies that are all an improvement on the traditional three-stone stove in terms of fuel efficiency and emissions. ICS can be made from clay, brick, or metal, and have a form that to some extent encloses the cooking fire. The most fuel efficient ICS models are almost entirely enclosed and have a chimney to transport smoke and fumes outside of the home. The less fuel efficient ICS models do not have a chimney, but are transportable to encourage outdoor cooking during favorable weather conditions. Further

studies establishing the exact benefits of various ICS models to air pollution and health are described by Bensch and Peters [2] and Fitzgerald et al. [12].

The first ICS dissemination programs were launched in the 1970s [1]. They were focused mainly on the deforestation mitigation effects of widespread adoption [14], and received relatively little policy attention [20]. ICS programs recently reemerged in the policy spotlight, this time with the focus more on human health and women's empowerment [14,30]. The ICS trend gained a major foothold when in 2010, Hillary Clinton, who at the time was the United States Secretary of State, together with the United Nations Foundation, launched the Global Alliance for Clean Cookstoves [2,18,32]. The Alliance's goal is to have 100 million households adopt ICS by the year 2020. If ICS are priced appropriately and targeted effectively, production and demand may develop simultaneously in a way that is self-sustaining and allows the stoves to survive on the free market. Further, if ICS adoption can outgrow its subsidy-requiring stage, rural people in developing countries may not have to wait for the stoves to be on trend a third time to enjoy the benefits.

Despite the newfound attention to ICS programs and the potential of the stoves to combat an array of issues, their adoption and sustained use face several challenges. The benefits of an ICS are not immediately apparent to the rural poor who because of a lack of education may undervalue the fuel saving and health improving traits of the stoves [2,11,15,24]. Understandably, poor households struggling to meet their most basic needs are not interested in a technology with a relatively high price and fairly abstract benefits [24].

ICS are known as a "bridging technology" because they bridge the gap between the status quo of inefficient three-stone stoves and the ideal of universal clean fuel use and electricity grids [12]. ICS are a vast improvement on the three-stone stove, but because they still require biomass for fuel they are not clean enough to meet the World Health Organization's emissions recommendations [26]. The enormous cost and task of providing access to clean energy and electricity to rural households is too much to take on at once, so policy makers settle for the ICS bridging technology.

There are few studies on the impacts of ICS adoption in Malawi, and none could be found on socioeconomic determinants of adoption in Malawi. One study modelled the adoption of institutional-scale ICS for use in school lunch programs and found that they had a net positive affect on the Malawian economy after ten years [17,26]. With numerous agencies disseminating different ICS models throughout Malawi, there is no data on the current extent of ICS adoption available. The goal of Malawi's National Cookstove Taskforce, which started in 2013, is to have 2,000,000 households adopt ICS by 2020 [33]. The potential for ICS to benefit Malawians is enormous given that 91.4% of the population uses wood for cooking and 13,250 people die of household air pollution each year, 5,852 of whom are children [16]. The firewood savings attributed to ICS would also be of great benefit to Malawi as the deforestation rate is 2.8% per year due to human activities [13].

The two types of ICS in this study are clay stove and a rocket stove. Figures A-C of the Appendix show the traditional three-stone stove, the clay stove, and the rocket stove. The clay stove is called *chitetezo mbaula* in Malawi. It is made of locally-sourced fired clay and has an enclosed form. At the time of the survey, the clay stove was available for purchase in the research area at certain gas stations and supermarkets, as well as from NGOs promoting the stoves in some villages. The rocket stove is a gasifying metal stove made by a South African company called Rocket Works. The rocket stove is even more fuel efficient than the clay stove and at the time of the survey was unavailable in Malawi. Both stoves are more fuel efficient than the standard three-stone stove used throughout Dedza. The clay stove becomes hot to the touch when in use, while the rocket stove does not. The clay stove is heavy and will crack if dropped. When cool and not in use, the rocket stove can be turned on its end and used as a stool.

This paper elicits the willingness of smallholder farmers to pay for the clay stove and the rocket stove, and explores socioeconomic determinants of their WTP.With the aim of informing future ICS program developers, this study explores which socioeconomic traits influence consumers' stated willingness to pay (WTP) for two types of ICS: a clay stove and a rocket stove. Findings are compared with those from studies done in other regions with different stoves [11,20,24,27]. The novelty of this study is that it is the only one to compare the socioeconomic determinants of WTP for the clay stove and the rocket stove in Malawi. Explanatory models are composed of independent variables including time spent acquiring fuel, fuel expenditures, household characteristics, social capital, dietary diversity, health indicators, and credit access.

Given the study's objectives, four research questions emerge:

(1) What is the average WTP for the clay stove?
(2) What is the average WTP for the rocket stove?
(3) Which socioeconomic characteristics influence a households' WTP for the clay stove?
(4) Which socioeconomic characteristics influence a households' WTP for the rocket stove?

2. Methodology

2.1. Survey Methodology

The 300 smallholder farming households in Dedza District were sampled using stratification of randomization [8]. A list of Dedza District's 2,840 villages was acquired from the Ministry of Agriculture, Irrigation, and Water Development. The statistical population was 242,519 households. The eight TAs of the district were used as the strata; 30 villages were randomly sampled from the strata proportionate to TA population. Up-to-date lists of the sampled households were then obtained from the district agricultural extension office. From these lists, ten households were randomly selected per village. The households were interviewed in May and June of 2014.

Villages with access to the clay stove were purposively omitted from the sample, however, five households that owned a clay stove were inadvertently included in the sample. These households had purchased their clay stoves

from a business-minded agricultural extension officer. This extension officer had purchased a large number of stoves and at the time of the survey had just begun to sell the stoves during his field visits. No villages had access to the rocket stove.

Upon entering a village and before beginning the individual household interviews, respondents were gathered for a group meeting. It was emphasized that the availability of both ICS for purchase was purely hypothetical and that farmers' identities would remain confidential. The two ICS, namely, the clay stove and the rocket stove, were presented. Respondents were informed about the advantages and disadvantages of the stoves and how the stoves function. Respondents were also given the opportunity to handle the stoves and ask questions. Later, when the household interviews were done in private, respondents were asked how much they would be willing to pay for each type of stove. All survey respondents were present at their village's group meeting. The group meeting was led by the same enumerator using the same script in every village.

Given financial and temporal constraints, the contingent valuation methodology was used without the addition of "cheap talk" scripts, follow-up certainty questions, or other tools to control for hypothetical bias. Findings in the literature are inconclusive on which, if any, methods can reliably mitigate hypothetical bias [4,9,19,25]. Despite the emphasis given on the confidentiality of the survey's results and the hypothetical nature of the questions, it is possible that respondents over-stated their WTP in the hope that their village would be chosen for an ICS program. ICS promoters should be aware of this possibility when determining the price at which to sell their stoves.

2.2. Econometric Methods

Ordinary least squares (OLS) regression analyses were performed to discover which socio-economic characteristics influence respondents' WTP for both types of stove. Initially, both regression analyses contained 11 independent variables that were chosen based on the theoretical likelihood that they would impact WTP for an ICS. For both the clay stove and the rocket stove WTP models, the number of explanatory variables had to be greatly reduced to improve the models' statistical significance.

The original 11 independent variables were: per capita household income, credit access score, social network score, household size, cook's education, cook's age, cook's gender, sickness score, dietary diversity score, amount spent buying fuel, and time spent acquiring fuel. These variables and their hypothesized effect on WTP for an ICS are shown in Table 1.

The per capita household annual net income variable represents income from all possible sources, including crops sold, livestock sold, forestry, hunting, wage labor, aid, retirement payments, and remittances. Households with more income per capita are expected to be willing to pay more for an ICS, because they may have disposable income that they are willing to invest. The access to credit score is a composite of responses about the ability to acquire loans of different amounts from formal and informal sources. Because purchasing an ICS may use up savings, households with better access to loans are expected to be more willing to draw from their savings to purchase a stove. The household social network score variable is a summation of organization membership and informal borrowing ability, based on the concept that participation in community activities enriches social capital (Putnam, 1995). The higher the social network score, the higher the household's social capital. Those households with strong social networks are hypothesized to be willing to pay more for an ICS as their social nature may make them willing to try new technologies. Isham (2002) found this to be true in rural Tanzania in a study on the positive correlation between social capital and adoption rates of a new fertilizer. Households with relatively more members are also expected to be willing to pay more for an ICS because they may be interested in increasing the amount they can cook at once by having a more efficient stove or by adding an additional stove to their kitchen. If the household's main cook has completed a higher level of formal education, is female, or is older, the household is hypothesized to be willing to pay more. The sickness score is a composite of responses about cooking-related ailments, including burns, eye infections, and respiratory illness. Because of the health benefits associated with ICS adoption, households with higher sickness scores are expected to be willing to pay more to improve their household's overall health. The dietary diversity score is a sum of food groups consumed by household members within the 24 hours preceding the survey; the score ranges from 0 to 12. This study uses the 12 food groups set forth by the FAO's "Guidelines for Measuring Household and Individual Dietary Diversity" [21]. Households with higher dietary diversity scores are hypothesized to be willing to pay more for an ICS, which would support their well-balanced diets by making slow-cook foods, like legumes, less costly to prepare. Households that spend more per month on fuel purchases were expected to be willing to pay more for an ICS as the fuel efficiency would off-set their fuel costs. Similarly, those households that spend more time acquiring fuel, whether purchasing or collecting, are expected to be willing to pay more.

Following each regression analysis, diagnostic tests were run. The distribution of residuals and the variance inflation factor of each model was checked. The average variance inflation factors were 1.03 and 1.05 for the clay stove model and the rocket stove model, respectively, indicating that multicollinearity is not an issue [7]. Model specification was checked with the Ramsey Regression Specification Error Test. After the models failed the Breusch-Pagan test for heteroscedasticity, the regressions were re-run with robust standard errors [29,34].

3. Results

3.1. Descriptive Statistics

Given the size and the geographical range of the sample, the survey respondents can be considered representative of the rural population of Dedza District. The average household size of the sample was five and the average age of all household members was 23 years.[1] Household heads

[1] Unless otherwise stated, all statistical findings are for the agricultural year 2012/2013 (defined as November 2012 to October 2013).

have an average age of 47 years, most are male (72%) and have a primary occupation as crop production (83%). A slight majority (52%) of household heads have not completed any level of formal education, 27% have completed the first four years of primary school, and 15% have completed all eight years of primary school.

All respondents are smallholder farmers; on average, they operate 1.15 hectares of land. Farmers' land is divided into three parcels on average with the majority (84%) dedicated to the cultivation of crops. Land has mostly been received as a gift or inherited (85%), though some respondents lease land for a fixed payment (7%) and others have been granted access to land by local leaders (5%).

Dedza District is renowned among Malawians for its production of Irish potatoes, groundnuts, and beans. This is reflected in the respondents' reporting of their crop cultivation. Beans are grown by 49% of respondent households, groundnuts by 46%, soy by 39%, and Irish potatoes by 14%. However, as in the rest of Malawi, maize is the main crop in Dedza; 98% of respondents grow maize. Malawians consider maize to be almost synonymous with food; a maize porridge called *nsima* dominates the national diet. Informal interviews repeatedly showed that Malawians without *nsima* would consider themselves to be food insecure, even if other food sources were abundant. This cultural belief has wide-reaching effects on nutrition security and agricultural policy.

Table 1. Independent variables and their hypothesized effect on willingness to pay

Independent Variables			
Variable Name	*Description*	*Mean (Median)*	*Hypothesized Impact on WTP*
Per capita HH income (USD)	Annual net household income from all sources	93 (0)	Higher income, higher WTP
Credit access score	Ability to acquire formal and informal loans of varying amounts, scored 0-10	1.3 (0)	Higher score, higher WTP
Social network score	Organization membership and informal borrowing, scored 0-20	7.7 (7)	Higher score, higher WTP
Household size	Number of permanent household residents	5.1 (5)	More members, higher WTP
Cook's education	Highest level of education completed by main person responsible for cooking, 0-14 years	2.4 (0)	More years of education, higher WTP
Cook's age	Age of main person responsible for cooking	40.2 (36)	Older, higher WTP
Cook's gender	Gender of main person responsible for cooking, 0=male, 1=female	1 (1)	Female, higher WTP
Sickness score	Burns, eye infections, and respiratory illness among household members, scored 0-8	0.9 (0.7)	Higher score, higher WTP
HH dietary diversity score	Sum of food groups consumed by household in 24 hours preceding interview, scored 0-12	5.4 (5)	Higher score, higher WTP
Amount spent buying fuel (USD)	Household fuel expenditure per month	4 (0)	Higher expenditure, higher WTP
Time spent acquiring fuel (minutes)	Time spent in week preceding interview purchasing or collecting fuel	190 (120)	More time spent, higher WTP

Source: Own survey, 2014, Stata output.

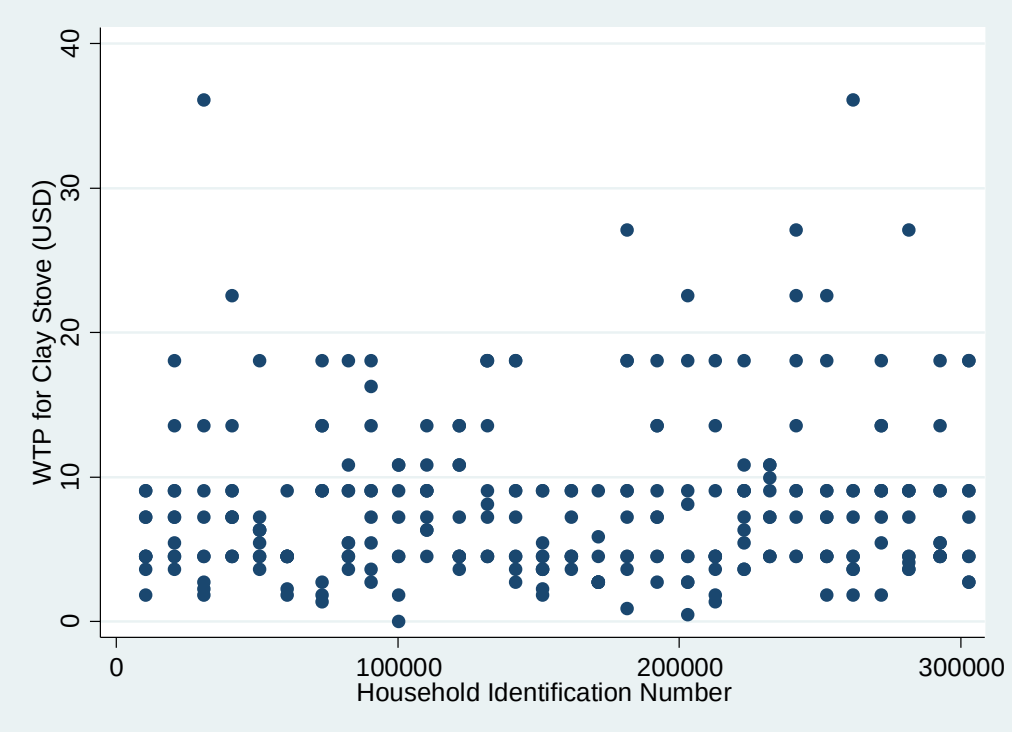

Figure 1. WTP for Clay Stove (Source: Own survey, 2014, Stata output)

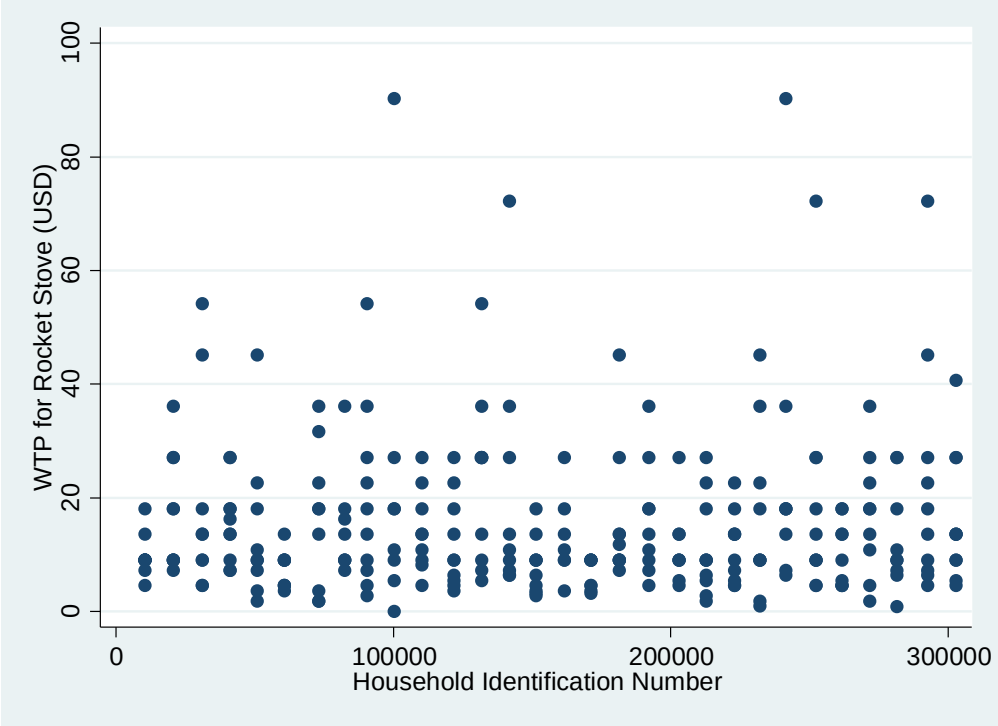

Figure 2. WTP for Rocket Stove (Source: Own survey, 2014, Stata output)

3.2. Willingness to Pay for ICS

The average WTP for the clay stove was 8.02 USD.[2,3] As shown in Figure 1, the data was heavily skewed towards zero. Only 25% of respondents were willing to pay more than 9.02 USD for the clay stove.

The average WTP for the rocket stove was 15.34 USD. Again, the data was skewed towards zero, as shown in Figure 2. Only 25% of respondents were willing to pay more than 18.05 USD for the rocket stove.

Because of the negative skew in the WTP for both stove types, ICS promoters should use the median, rather than the mean, when making pricing decisions to avoid overestimates. The median WTP is 7.22 USD and 9.03 USD, for the clay stove and the rocket stove, respectively.

Hypothetical bias appears to be a threat, especially in the rocket stove results, as some of the reported WTPs may be considered unreasonably high. Thirteen respondents were willing to pay the equivalent of more than 12 days of hard labor wages.[4] Otherwise, these high WTP results may be attributed to respondents being eager to adopt a new technology.

3.3. Socio-Economic Determinants of Willingness to Pay

Regressions were run on the both WTP models using estimates of robust standard errors. To achieve models that were as a whole statistically significant at the 10% level or better, the number of independent variables was reduced from 11 to three in the clay stove model and to five in the rocket stove model. Both of the resulting models passed the regression diagnostic test for multicollinearity, but only the clay stove model passed the diagnostic test for model specification, the Ramsey Regression Equation Specification Error Test (Ramsey RESET). The failure of the rocket stove model to pass the Ramsey RESET indicates that there are explanatory variables missing from the model. Both models, despite the use of robust standard error estimates, had vertically spread distribution of residuals indicating that there are respondents whose WTP is influenced by unknown factors. The distrust of, or disinterest in, new technology is suspected to be an important intangible variable.

The regression results of both models are shown in Table 2 and Table 3. Both regressions yield low R-squared and adjusted R-squared values, indicating that the independent variables have limited predictive power and should be used only for explanatory purposes. There are small but reliable relationships between the independent and dependent variables.

The WTP for a clay stove model is statistically significant at the 10% level. The model shows household dietary diversity to be positively correlated with WTP, as hypothesized. Ceteris paribus, an increase in the WTP for a clay stove by 0.36 USD can be explained by a household's consumption of one additional food group. It is interesting that those households with more balanced diets exhibit a need for improved cooking technology to facilitate the preparation of multiple food groups, while those households with less balanced diets do not, or because of their circumstances are unable to. Wealthier households in the sample have higher dietary diversity scores, shown by a pairwise correlation coefficient of 0.188 that is statistically significantly different from zero at the 1% level of error probability.

[2] All USD values in this paper are converted from Malawian kwacha and adjusted for purchasing power parity and inflation. Malawian kwacha, the local currency, was used during the survey.

[3] At the time of the survey, the clay stove sold at supermarkets and gas stations for 9.02 USD (adjusted for inflation and purchasing power parity).

[4] At the time of the survey, a person in Dedza could expect to earn 3.61 USD for a full day of hard labor (such as clearing a field or digging a canal).

Table 2. Clay stove regression results

Linear regression				Number of obs	=	273
				F(3, 269)	=	2.08
				Prob > F	=	0.1038
				R-squared	=	0.0246
				Root MSE	=	5.6283
				Adjusted R-squared	=	0.0138

WTP for Clay Stove	Coefficient	Robust Std. Err.	t	P>t	Beta
Social Network Score	-.0715312	.0569251	-1.26	0.210	-.0721934
Household Dietary Diversity Score	.3645998	.1934134	1.89	0.060	.1370554
Amount Spent on Fuel (USD per month)	-.0499961	.0303674	-1.65	0.101	-.0813125
Constant	6.833105	1105005	6.18	0.000	.

Source: Own survey, 2014, Stata output
* Indicates statistical significance at the 10% level.

Table 3. Rocket stove regression results

Linear regression				Number of obs	=	271
				F(5, 265)	=	3.09
				Prob > F	=	0.0099
				R-squared	=	0.0934
				Root MSE	=	13.13
				Adjusted R-squared	=	0.0763

WTP for Rocket Stove	Coefficient	Robust Std. Err.	t	P>t	Beta
Social Network Score	-.1147545	.1341294	-0.86	0.393	-.0481666
Household Net Income (USD per capita)	.0114854	.0054435	2.11	0.036	.1949898
Household Dietary Diversity Score	1.291833	.5682548	2.27	0.024	.2054453
Sickness Score	-1.450235	.7768815	-1.87	0.063	-.0957259
Amount Spent on Fuel (USD per month)	-.1158185	.0791707	-1.46	0.145	-.0778656
Constant	10.03332	2.696223	3.72	0.000	.

Source: Own survey, 2014, Stata output
*, ** Indicate statistical significance at the 10% and 5% level, respectively.

Counterintuitively, the model shows a negative correlation between the amount spent on fuel per month with the WTP for a clay stove. Ceteris paribus, a decrease in the WTP for a clay stove by 0.05 USD can be explained by the increase in monthly fuel expenditure by 1 USD. This finding may be due to illegal acquisition of fuel sources. If a household is acquiring the fuel illegally, for example from forest reserves, their fuel expenditure would be low or zero. They would likely be interested in reducing their fuel consumption through the purchase of an ICS, to reduce the risks associated with illegal fuel acquisition.[5]

The WTP for a rocket stove model as a whole is statistically significant at the 1% level. As predicted there is a positive correlation between net household income per capita and WTP. Ceteris paribus, an increase in the WTP for a rocket stove by 0.01 USD can be explained by a 1 USD increase in annual net income per capita. A greater effect was expected; this shows the need for stove demonstrations and other marketing efforts.

Household dietary diversity is an even stronger explanatory variable in the WTP for a rocket stove model than in the clay stove model. This is likely because the fuel efficiency of a rocket stove is even greater than that of a clay stove, meaning that households could cook more types of food with even less fuel. Ceteris paribus, an increase in the WTP for a rocket stove by 1.29 USD can be explained by the consumption of one additional food group by a household.

It was hypothesized that households with higher (worse) sickness scores would recognize the health benefits of ICS and therefore report a higher WTP, however, the opposite was revealed in the regression results. Ceteris paribus, a decrease in the WTP for a rocket stove by 1.45 USD can be explained by one additional cooking-related ailment within the household. This finding may be due to illnesses affecting households' ability to generate income, and thus their willingness to purchase new technologies. Or, those households that cook in poorly ventilated areas, and thus suffer more cooking related ailments, are unaware of the health impacts of fuel efficient cooking, and therefore are

[5] Illegal fuel acquisition in Malawi is punishable by fines and prison time. Women and girls are traditionally responsible for fuelwood collection; those who collect firewood illegally are particularly at risk of sexual abuse by forest reserve guards and thus HIV contraction [35].

less willing to pay for an ICS. Or, it is possible that the sickness score variable is flawed, causing the regression results to be erroneous.

Several studies have explored the reliability of health self-assessment variables [5,10], results are mixed but the subjectivity of health is unanimously accepted. The relationship between wealth and self-rated health scores are of particular interest in developing countries where the poorest may score themselves as healthy because of illiteracy and lack of disease awareness, while the better-off may score themselves as ill because of their improved ability to identify illness (King et al., 2004; Salomon et al., 2004; Sen, 1993; Sen, 2002). On the other hand, a study by Subramanian et al. (2009) finds the inverse to be true: that self-reported morbidity is more likely among the disadvantaged and least educated.

Of the seven independent variables that were not found to have explanatory power in either of the WTP models, credit access score and household size were most expected to be statistically significant. Credit access likely did not have an impact on WTP because respondents would not be willing to go into debt to purchase a stove. Larger households were hypothesized to be willing to pay more for ICS, because speed of food preparation and fuel savings would have the greatest relative returns for them. It is probable, however, since household size is largely accepted as a predictor of poverty (Lanjouw, 1995), that larger households have more thinly spread income and so are unable to invest in a new stove. Or, it is possible, that the larger households have more available labor to devote to collecting firewood, and therefore, the fuel efficiency of the ICS is not as attractive as it is to labor constrained households.

4. Conclusions

This study finds four socioeconomic indicators that explain WTP for clay stoves and rocket stoves. Household dietary diversity is positively correlated with WTP for both the clay stove and the rocket stove. Fuel expenditures are negatively correlated with WTP for the clay stove. Annual net income per capita is positively correlated with WTP for the rocket stove. Cooking-related ailments are negatively correlated with WTP for the rocket stove.

The household dietary diversity score in the WTP for a rocket stove model had the greatest impact on WTP. Households that consume more food groups, either because they are better-off and can afford to, or because they are knowledgeable about nutrition and make it a priority, are keen to reduce the fuel costs associated with their diverse diets by purchasing an efficient stove. ICS promoters would do well to target those households first as early adopters who can influence their neighbors' perceptions informally (Rogers & Scott, 1997). Households that do not consume varied foods, either because they cannot afford to, or are unaware of the benefits of a balanced diet, would then witness the fuel saving attributes of the ICS and become later adopters. This could potentially occur without further intervention from ICS promoters, resulting in program savings.

The negative correlation between fuel expenditure and WTP for a clay stove, most likely due to respondents looking to decrease their risky, illegal firewood collecting activities, is yet another reason for intensive ICS promotion. Greater fuel efficiency not only decreases pressure on forest resources, but it also relieves the burden of illegal activity from those who have no other options. A lower demand for firewood would alleviate some of the government's cost of patrolling forest reserves and slow deforestation.

Two groups that would benefit most from ICS adoption, large households and households with cooking-related ailments, are willing to pay less. Larger households have a lower WTP for ICS because their resources are spread more thinly across members, but they would reap the greatest relative returns to fuel savings. Households with cooking-related ailments may have lower income generating abilities and are unable to afford the very stoves that would improve their health situation. These two groups should be targeted with lower pricing by ICS promoters.

Comparing these results with those of other studies, the major similarity is in the positive effect of income [11,20,27,31]. The overall low WTP for ICS can be explained by the fact that the sampled households are all poor and as such face difficult challenges in meeting their basic needs. The purchase of a stove with rather abstract benefits cannot be expected to be high on their priority list [24]. Other socioeconomic factors that were hypothesized in this study to have an effect but were insignificant, were found to be significant in other studies. This may be indicative of the difference between eliciting stated WTP and recording exhibited WTP or observing adoption. As hypothesized in this study, being relatively more educated increases the likelihood of ICS adoption in the literature [11,20]. This study anticipated that households suffering from cooking related ailments would be eager to purchase a stove and improve their health, and this is confirmed by Pine et al. [27] who show that sufferers of eye irritation were twice as likely to be early adopters.

Because of the discrepancy between short-term and long-term impacts of ICS adoption, the focus of ICS programs should be sustained, proper stove use by adopters, not just dissemination [27,30]. Positive impact estimates are inflated when only short-term adoption data and laboratory fuel test results are used; more long-term impact evaluations are needed [3,18,27,30]. Further, the study of socioeconomic determinants of ICS adoption alone is inadequate for a self-sustaining, unsubsidized ICS market. Choice elicitation experiment studies on product-specific attributes, that is stove characteristics, should complement socioeconomic findings to determine what is most desired by the target market. Knowing which type of ICS should be sold at what price to maximize sustained adoption by rural populations in developing countries may preserve the environment and improve human health until clean fuel can be made accessible to all.

Acknowledgements

Support for this study, provided by the International Food Policy Research Institute (IFPRI) and the University of Hohenheim, is gratefully acknowledged. This study forms a part of IFPRI's project, "Policies and Institutions

for Achieving the Virtuous Food-Energy-Water Nexus in Sub-Saharan Africa", which is funded under a research grant by the German Ministry of Development and Economic Cooperation (BMZ).

Statement of Competing Interests

The authors have no competing interests.

List of Abbreviations

ICS – improved cookstove
OLS – ordinary least squares
TA – Traditional Authority Area
WTP – willingness to pay.

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