

# Analysis of messaging and financing on demand for non-traditional cookstove adoption in Uganda

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## ABSTRACT

Although nontraditional cookstoves have the power to curb the impact of pollution from traditional cookstoves that cause both health and environmental problems, many populations still commonly use traditional cookstoves. Our study investigates two potential reasons: lack of information and liquidity. We conducted randomized control trials (RCTs) in rural Ugandan towns holding two “Vickrey auctions” (where the second highest bid wins) in each; one in which the winner must pay immediately and another where they pay over the course of four weeks. The communities received either no additional messaging, messaging on the health benefits of a nontraditional cookstove, messaging on saving time and money with a nontraditional stove, or messaging on both types of benefits. The flexibility in payment led to an increase in demand for the nontraditional cookstove (as measured by bid price) while the willingness to pay remained the same. Our data concluded that the messaging efforts did not increase demand for the nontraditional cookstove. Efforts to increase demand for nontraditional cookstoves may benefit from examining ways to reduce buyers' risk through longer-term payment schemes. Additionally, donor organizations and governments looking to promote nontraditional cookstove investments may want to explore ways in which they could reduce the risk for suppliers of nontraditional cookstoves, offsetting the effect of longer-term payment plans.

## Introduction

Traditional cookstoves create a variety of harmful impacts on families and the environment. According to the World Health Organization, over 4.2 million people a year die from the impact of ambient pollution while an additional 3.8 million die from household air pollution. These statistics do not include the various morbidities that occur from air pollution, further compounding difficulties for families.<sup>1</sup>

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<sup>1</sup> “Air Pollution.” *World Health Organization*, World Health Organization, [www.who.int/health-topics/air-pollution#tab=tab\\_3](http://www.who.int/health-topics/air-pollution#tab=tab_3).

In Uganda, 56.31% of deaths in the country are attributable to illness caused by air pollution. There is a gender bias concern, as that statistic is higher with 58.4% of deaths in females attributable to illness caused by air pollution.<sup>2</sup>

There is also an environmental concern as traditional cookstoves burn large amounts of wood and contribute to deforestation and land degradation.<sup>3</sup>

Improved cookstoves have the potential to address in part these concerns by decreasing the amount of indoor air pollution and reducing the amount of fuel needed. Our research questions are “How does messaging impact demand for nontraditional cookstoves in Ugandan parishes?” and “How does liquidity impact demand for nontraditional cookstoves?” We designed our project to understand the impact of messaging through a randomized control trial (RTC). We established a control group which received no messaging regarding the cookstove, a group that received the message “You can save time and money by using the nontraditional cookstove,” a group that received the message, “Health will improve with a nontraditional cookstove,” and the message “You will save time, money, and your health will improve with a nontraditional cookstove.” We also studied the impact of cash liquidity by offering a “pay now” option and a “pay in installments” option, which was found to increase the demand for the cookstoves.

We begin by reviewing the literature of cookstove demand (section 1). We then clean the data, examining the randomization success (section 2). Section 3 illustrates the results of our analysis. Section 4 demonstrate predictive modeling. Section 5 concludes.

## 1. Generating Demand for Cookstoves: A Literature Review

Despite the vast evidence supporting the benefits of nontraditional cookstoves, much of the world relies on traditional, less efficient stoves. Previous studies have illuminated the types of households that purchase nontraditional cookstoves. Households with high socioeconomic status, urban households, and more educated households are more likely to adopt a nontraditional cookstove.<sup>4</sup> Income, assets, home ownership, expenditure are also positively correlated with adoption. Finally, health benefits and fuel savings, whether perceived or measured, are an important incentive for investing in a nontraditional cookstove.<sup>5</sup>

Barriers to purchasing a nontraditional cookstove include specific fuel size requirements, preference for smoke to prevent insects in the house, a lack of a permanent home, and living in disaster-prone or cold settings.<sup>5,6</sup> A large family can also be a barrier as the family has many people to gather solid fuel.<sup>6</sup> It is also common for households to not have enough credit or financing to purchase a nontraditional cookstove.<sup>7</sup>

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<sup>2</sup> “Household Air Pollution Attributable Death Rate (per 100 000 Population).” *World Health Organization*, World Health Organization, [www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-death-rate-\(per-100-000-population\)](http://www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-death-rate-(per-100-000-population)).

<sup>3</sup> Parker, et al. *Climate Focus*, 2015, *Linkages between Cookstoves and REDD+ A Report for the Global Alliance for Clean Cookstoves*, [www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/346-1.pdf](http://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/346-1.pdf).

<sup>4</sup> Lewis, Jessica J., and Subhrendu K. Pattanayak. “Review Who Adopts Improved Fuels and Cookstoves? A Systematic Review.” *Environmental Health Perspectives*, vol. 120, no. 5, 2012, pp. 637–46.

<sup>5</sup> Rehfuess, Eva, et al. “Enablers and Barriers to Large-Scale Uptake of Improved Solid Fuel Stoves: A Systematic Review.” *Environmental Health Perspectives*, vol. 122, no. 2, 2014, pp. 120–30.

<sup>6</sup> Lewis, Jessica J., et al. “Piloting Improved Cookstoves in India.” *UHCM*, vol. 20, no. S1, 2015, pp. 28–42, doi:10.1080/10810730.2014.994243.

<sup>7</sup> “Igniting Change: A Strategy for Universal Adoption of Clean Cookstoves and Fuels.” *Global Alliance for Clean Cookstoves*, 2011.

Another study found that poor and female-headed households may be interested in a nontraditional cook stove but are more sensitive to price. It also found that “traditional” households are more likely to have lower education, use free fuel, and be less aware of traditional cookstove’s negative impacts.<sup>8</sup> Finally, a systematic review concluded that lack of user awareness, peer influences, credit constraints, uncertainties over technological performance, risk aversion, and impatience are the main influences when people in developing countries choose to adopt an unknown technology.<sup>8</sup>

There is evidence that households who use inefficient, smoky stoves do not understand the impact a nontraditional cookstove can have on health, time spent gathering firewood, or the economic cost of cooking.<sup>7</sup> Assuming information and awareness are the issues, a study in Bangladesh looked at the effectiveness of information alone on changing behavior. The researchers’ only intervention was informing people about the dangers of drinking contaminated groundwater and found information alone can “induce a large percentage of people who face a risk to health to change their behavior in order to avoid the risk, even if the change is costly.”<sup>9</sup>

To combat the information discrepancy, other work in this area has shown that product demonstration and word of mouth are the most effective forms of marketing a new technology.<sup>5.</sup>  
<sup>7</sup> This study used the former.

Investigating the income and liquidity aspect, one study investigated microloans for treated bed nets in India. Their findings showed that liquidity constraints are a large barrier to uptake and that it can be mitigated by some type of credit.<sup>10</sup> Our study expands on this by offering different payment plans, either one week or four weeks long.

## 2. Data

Our data was gathered from 36 Vickery auctions, each with about 60 participants, in various parishes in rural southwest Uganda. Participants who attended the auction first filled out a survey detailing their cooking practices, socioeconomic information, employment, and household demographics.

Participants were then randomized into the three treatment groups, (1) save time and money, (2) improve health, and (3) save time money and improve health, and one control group, (4) no marketing message and discussion about traditional cooking methods. All four groups then watched a cooking demonstration with the nontraditional cookstove.

After the marketing messages and cooking demonstration, a Vickery auction was held. In this second-price auction, participants bid for the cookstove with a sealed schilling amount. The highest bidder then wins the cookstove, but only pays the second-highest price.<sup>11</sup> The bids which were paid within a week gave us our dependent variable “max bid” and the bids which were paid within four weeks gave us the other dependent variable, “max bid novel.”

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<sup>8</sup> Jeuland, M. A., et al. “Preferences for Improved Cook Stoves : Evidence from Rural Villages in North India.” *Energy Economics*, vol. 52, Elsevier B.V., 2015, pp. 287–98, doi:10.1016/j.eneco.2015.11.010.

<sup>9</sup> Madajewicz, Malgosia, et al. Can Information Alone Change Behavior ? Response to Arsenic Contamination of Groundwater in Bangladesh ☆. 2007, pp. 731–54, doi:10.1016/j.jdeveco.2006.12.002.

<sup>10</sup> Tarozzi, Alessandro, et al. “Micro-Loans, Insecticide-Treated Bednets, and Malaria: Evidence from a Randomized Controlled Trial in Orissa, India.” *American Economic Review*, vol. 104, no. 7, 2014, pp. 1909–41, doi:10.1257/aer.104.7.1909.

<sup>11</sup> Ausubel, Lawrence M., and Paul Milgrom. “The Lovely but Lonely Vickrey Auction.” *Combinatorial Auctions*, 2013, pp. 17–40, doi:10.7551/mitpress/9780262033428.003.0002.

Survey date, household ID, and parish were all used to control for fixed effect variables. We used female, age, marital status, whether the wife is the primary cook, whether the husband and wife make decisions jointly, whether they know how many people ate lunch, how many ate lunch at household, and if that number was typical to describe the household socioeconomic and demographic characteristics.

Variables such as count of phones owned by household, if the household has an income or is self-employed, time breadwinner is employed, and ownership of bicycle, radio, tv, and cows measured wealth. We also created an aggregate asset variable by adding up the value of participants' large assets (see Table 8 for prices).

We also investigated how the household's current cookstove affected their bid through the variables describing whether or not the household uses wood as fuel, whether a three-stone fire is the primary stove, and whether the household buys or gathers wood.

Finally, we created gender interaction variables to see if the intersection of gender and another characteristic had a different impact than the characteristic alone.

## 2.1. Balance check

To confirm the randomization was successful, we performed balance check on the socioeconomic demographic characteristics, wealth characteristics and cookstove related characteristics by message group (table 3). To prove randomization, we used both ANOVA and Kruskal-Wallis tests for comparison. Wealth and cookstove use variables differ by message group.

We conducted three sets of F-joint tests pairwise, as follows

$$Message_i = a + X\beta + \epsilon_i$$

where  $Message_i$  is the dummy for if the respondent receives no message or not, with other three groups, respectively.  $X$  is the collection of different choices of controls. We omit imbalanced variables such as self-employed, time employed and those that have missing values over 10% out of the whole sample. The joint F-tests show that no evidence against appropriate randomization in the four marketing groups.

## 2.2. Multicollinearity

We do not see strong pairwise correlation within the groups of socio-economic and demographic characteristics, wealth characteristics and cookstove related characteristics. Furthermore, we do not see strong correlation across the different groups (Figure 2). We are safe to run the regression with different levels of controls on the explanatory variables.

## 2.3. Establishing the measurement

In order to understand the impact of messaging, we ran a linear regression analysis to look for the significance of each message. We ran the regression using our three messaging variables as controls, so as to determine their variance from “No Message” results. We ran those with the previously explained controlled variables and within a fixed effects model to account for variations in circumstances.

$$y_{ij} = \alpha_i + \beta_i + Message1_{ijp} + Message2_{ijp} + Message3_{ijp} + H_{ij}\delta + W_{ij}\gamma + C_{ij}\phi + \epsilon_{ij}$$

$\alpha_i$  is the survey date fixed effect,  $y_{ij}$  is the MAXBID and NOVEL. A dummy variable for  $j$  being a within-a-week bid (traditional) or 4-week bid (novel),  $H_{ij}$  is the composite of the household variables,  $W_{ij}$  is the wealth variable,  $C_{ij}$  is the cooking and stove variable.

A final regression was conducted to investigate the impact of the novel bid (4-week payment plan).

$$y_{ij} = Novel_{ij} + u_{ij} + v_{ij}$$

In this regression,  $u_{ij}$  is the individual fixed effect, treated UNIQUE\_HHID as the dummies for measuring the fixed effect of individuals.  $Novel_{ij}$  is the payment dummy of the novel bids.  $v_{ij}$  is the error term. We merged the bid prices of the two types of auctions first to form an augmented dependent price vector  $y_{ij}$  then ran the fixed effect model.

## 2.4. Summary of auction data

Table 1 shows an overview of the participants and their bidding prices in the two auctions. The survey covers totally 2303 participants across 36 parishes with 2297 (99.74%) completed the survey and 2234 (97.00%) received messages and reported successfully. Among the 2303 participants, 70.21% are female. Comparing the two different types of auctions, the bidding rate is almost the same (92.27% for pay within a week and 92.71% for time payment, and we deleted those observations with no bidding prices in the later causal inferences). 47 winning bids were recorded in the pay within a week auction with 41 final purchases, and 45 in the time payment with 34 final purchases.

The mean willingness to pay was \$4.86 for the pay within a week auction and \$6.83 for time payment auction. The demand curve the depicts distribution of willingness to pay by different types of auctions are plotted in Figure 1, panel A and panel B, which are of similar shape.

Table 2 shows a full map of willingness to pay by message group. One key point of concern is that regardless of fixed effect and variation explained by explanatory variables, there is no significant difference in willingness to pay by within a week auction bid among the four groups. We see significant difference in willingness to pay by time payment auction.

The descriptive statistics shows that female comprise over 70% percent of the total respondents and they are the primary cook (86.87%) out of the whole sample. Most people are married (79.45%), and about half (44.32%) of the household couples make decisions jointly. On average, the age of respondents is 39 and the number of people who ate lunch in the household yesterday is 4.53. Most of the respondents knows how many people ate lunch (89.59%).

Considering household wealth, most respondents have at least one cellphone (87.43%) and radio (88.91%). Most of them earn income (87.43%), about 70% of respondents are self-employed and about half of them are year-round employed. Half of the respondents own a bicycle and a small portion of them have motorcycle (10.72%). Very few households have cars (1.52%).

For the cookstove use, firewood is the most dominant fuel source (97.14%). The chance of household gathering fire wood (88.38%) is much higher than that buying fire wood (29.98%). Three stone fire is the primary stove for 72.87% of the households. 12.49% of the households already owned charcoal stoves, and 10.71% of the households owned built-in mud stoves.

### 3. Results

We consider the invariant fixed effect of parish and survey date fixed effect and we evaluate different groups of characteristics effect together with the marketing message dummies to evaluate specific effects on willingness to pay. For the evaluation on household demographic and socio-economic characteristics and cookstove related variables, we include the total assets we generated based on the “Durable Good Prices Exchange Rate Uganda 2011-12” file.

#### Descriptive statistics

For the pay within a week auction, we find that the difference in willingness to pay among the four groups is significant (0.0087). The mean bid for the group which received no message is \$4.58, lower than the group which received the ‘improves health’ message (\$5.50), and the group which received both messages (\$4.88), but slightly higher than the mean bid for the group which received the ‘saves time and money’ (\$4.47).

For the auction with time payment, we find that the difference in willingness to pay among the four groups are not significant (0.1336). The mean bid for the group of no message was \$6.73, lower than the group of “saves time and money” (\$7.17) and the group of “improves health” (\$6.82), but slightly higher for the group that received both messages (\$6.61).

#### Message effect: not significant and not consistent overall

To evaluate the effect of marketing message, we perform OLS in different levels of specification as follows.

(1) regression without controls + FE

$$y_{ij} = \alpha_i + \beta_i + Message_{ij}\rho + \epsilon_{ij}$$

(2) regression with HH demographic controls +FE

$$y_{ij} = \alpha_i + \beta_i + w_{ij}\gamma^* + Message_{ij}\rho + H_{ij}\delta + \epsilon_{ij}$$

(3) regression with HH Wealth controls +FE

$$y_{ij} = \alpha_i + \beta_i + Message_{ij}\rho + W_{ij}\gamma + \epsilon_{ij}$$

(4) regression with Cookstove controls + FE

$$y_{ij} = \alpha_i + \beta_i + w_{ij}\gamma^* + Message_{ij}\rho + C_{ij}\phi + \epsilon_{ij}$$

From the result (table 4) we find that marketing messages have no consistent effect on willingness to pay, both for pay within a week auction and time payment auction. Only the message of improving health can steadily increase the willingness to pay for payment within a week, and save time and money message can increase the willingness to pay for time payment with looser significance levels. All the messages have no significant increase effect on willingness to pay in both two types of auctions.

Table 4 shows the regression (1) – (4) in the columns, respectively. We find that part of the wealth factors do have significant impact on people’s willingness to pay. On the other hand, age and if the respondents know the number of people eating lunch have significant positive impact on willingness to pay, while gender (if female) has a significant negative impact on bid. The use of cookstove have no impact on willingness to pay at all.

### Gender effect: women are likely to pay less

From table 5 we find that women's willingness to pay is significantly less than the sample average price (\$2.77 less than average for pay within a week auction and \$4.63 less than average for time payment auction). From table 4 we find that the interaction terms, which implies gender premium on willingness to pay for the stoves, have slight correlations with the bid prices both for within a week auction and time payment. Thus, we will include these interaction terms into the gender effect evaluation while carefully considering the inclusion of a small subset of them to avoid multicollinearity issue. Additionally, when females earn income, there is a significant increase on their willingness to pay (0.584 with p-value = 0.076 for pay within a week and 1.042 with p-value 0.020 for time payment). When females cover the purchase of wood, it also generates significant additional stimulate on their willingness to pay for the stove (0.489 with p-value 0.069 for pay within a week and 0.813 with p-value 0.027 for time payment).

### Intra-person effect: time payment stimulates willingness to pay dramatically

Table 1 shows that the average bidding prices for time payment auctions is \$6.83, higher than that of pay within a week, which is only \$ 4.86. The winning bid amount of time payment is \$16.78, greater than that of pay within a week auction, \$ 12.87 as well. The same applies to the second price paid among winning bids. However, the ratio of completed payment by time payment is lower than that of pay within a week, illustrating the stimulate attribute to the flexibility of time payment option on willingness to pay is transient. It increases the short-term willingness to pay but show a higher retreat likelihood in long term.

Table 6 shows that adding time payment option increased the average bid by USD\$1.96 highly significantly ( $p < 0.0001$ ), comparing with the average of \$ 4.86. This test is performed based on the following specification

$$y_{ij} = Novel_{ij}\psi + u_i\rho + v_{ij}$$

$u_i$  is the individual fixed effect, treated UNIQUE\_HHID as the dummies for measuring the fixed effect of individuals.  $Novel_{ij}$  is if the payment dummy of novel bid.  $v_{ij}$  is the error term. We need to merge the bid prices by two types of auctions first to form an augmented dependent price vector  $y_{ij}$  then run the fixed effect model.

### Wealth Effect

Households' total asset significantly impact their willingness to pay. Table 7 shows that with every 10000 USD increase in total asset, respondents bid \$ 5.33 more for payment within a week auction and \$ 6.29 more for time payment auction. There is very slightly decreasing marginal effect of total asset ( $2 \times -0.000017 = -0.000034$ , and  $2 \times -0.000014 = -0.000028$  for the two auctions), which can be ignored.

Furthermore, we use the logarithmic approximation to percentage changes. First, the coefficient on  $\log(\text{total asset})$  is the elasticity of price with respect to total asset. Second, the logarithmic approximation to percentage changes has an advantage that justifies its reporting even when the percentage change is large. Another potential benefit of using logs is that taking the log of a variable often narrows its range. This is particularly true of variables that can be large numbers as the total asset. Table 7 shows that the elasticity is significantly positive. Household are willing to pay 6.67% of their increase in total wealth for within a week bid and 5.79% for time payment.

## 4. Predicative modeling

### Mixed effect model on auction bids by type

By stepwise selection and variance-stabilizing transformation on dependent variable, we constructed the nonlinear model, summarized in table 9. We have good-fit models with  $R^2 = 88.87\%$  for within a week bid prices and  $R^2 = 89.42\%$  for time payment auction, with all the explanatory variables significant (F-test, p-value=0.0000).

$$\sqrt{y_{ij}} \sim \alpha_{ij} + NoMessage_{ij} + ImprovesHealth_{ij} + TimeMoney_{ij} + TimeMoneyHealth_{ij} \\ + FEMALE_{ij} + AGE_{ij} + TSFPRIMARY_{ij} + ASSETTotal_{ij} + \delta_{ij} + \epsilon_{ij}$$

$\alpha_i$  is the fixed effect of date of parish,  $\delta_i$  is the random effects of individuals.

### Predicting if the bid is >\$10

By splitting the data into training and test set with 4:1 with cross validation, we generate the logistic regression models of auction bids by type on the marketing message dummies, age, marital status, know lunch yesterday, wife is primary cook, household make decision jointly, use wood as fuel, buy wood, gather wood, type of stoves owned, date of survey, parish, and total asset. The prediction accuracy for within a week auction and time payment are both over 90.5%.

## 5. Conclusion

We can potentially increase the adoption rate for fuel-efficient cookstoves by allowing potential adopters of the technology time-based installments to pay for the stoves. However, suppliers of these products must recognize the inherent redistribution of risk from payers to sellers in these circumstances and find ways to offset that challenge. Marketing messages intended to drive up demand are likely to be ineffective in an environment where less efficient cookstoves are free, plentiful, and inherited by most.

Effective increases in adoption also depend on existing factors within rural communities – most significantly related to gender. Our findings indicate that women are willing to pay for improved cookstoves when they generate more wealth and when they are the ones who must chop the wood – opening another avenue to increase demand. Empowering women will be a cornerstone of successful initiatives in increasing demand for higher efficiency cookstoves. Households' total asset positively impact their willingness to pay significantly with no obvious marginal effects.

Combining increased financing with additional empowerment for gender in each group provides a clear road to addressing outstanding problems with the continued use of low efficiency cookstoves in Uganda. A successful program will take these factors into account, and by decreasing the risk which comes with purchasing a new cookstove through financing, better success rates in long term adoption can be achieved.



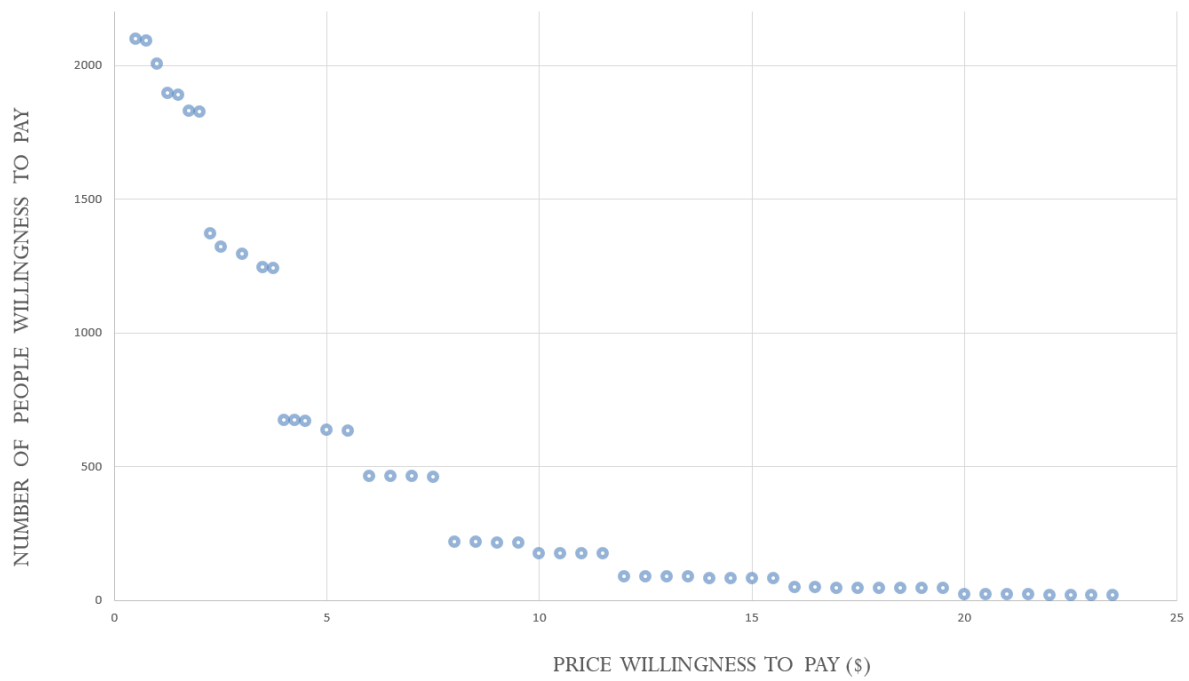
## Appendix I. Tables and Figures

Table 1. Overview of auction bids by two types.

<b>Overall Summary</b>	N	Mean	SD (mean)	p-value	Median
HH total in survey	2303				
HH completed survey	2297	99.74%			
HH are female	1617	70.21%			
HH received messages and reported	2234	97.00%			
Payment type recorded	2018	87.62%			
<b>Auction 1: Pay Within a Week</b>	2125	92.27%			
All traditional bids	2125	\$4.86	\$4.65	0.00 ***	\$3.98
Winning bids	47	\$12.87	\$5.07	0.00 ***	\$11.93
Second price paid among winning bids	38	\$13.35	\$5.16	0.00 ***	\$11.93
Deposit paid for stove	47	\$5.61	\$4.37	0.00 ***	\$3.98
Paid in full	18	38.30%			
Stoves returned among winning bids	4	8.51%			
Defaults among winning bids	2	4.26%			
Payment completed	41	87.23%			
<b>Auction 2: Time Payment</b>	2135	92.71%			
All time bids	2135	\$6.83	\$6.38	0.00 ***	\$4.77
Winning bids	45	\$16.78	\$6.38	0.00 ***	\$15.90
Second price paid	35	\$17.04	\$6.49	0.00 ***	\$15.90
Deposit paid for stove	45	\$5.06	\$2.77	0.00 ***	\$4.77
Paid in full	4	8.89%			
Stoves returned among winning bids	7	15.56%			
Defaults among winning bids	4	8.89%			
Payment completed	34	75.56%			

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. Wining bids percentage is the proportion of winning bids out of the total bid amount for certain type of auction. Paid in full percentage, stoves returned percentage, default percentage and payment completed percentage are the proportion out of the number of winning bids of certain type of auction. Statistical significance is indicated by \* p< 0.10, \*\* p< 0.05, \*\*\* p< 0.01

Figure 1. Demand curves of willingness to pay.  
 Panel A: Demand curve for cookstove by pay within a week auction.



Panel B: Demand curve for cookstove by time payment auction.

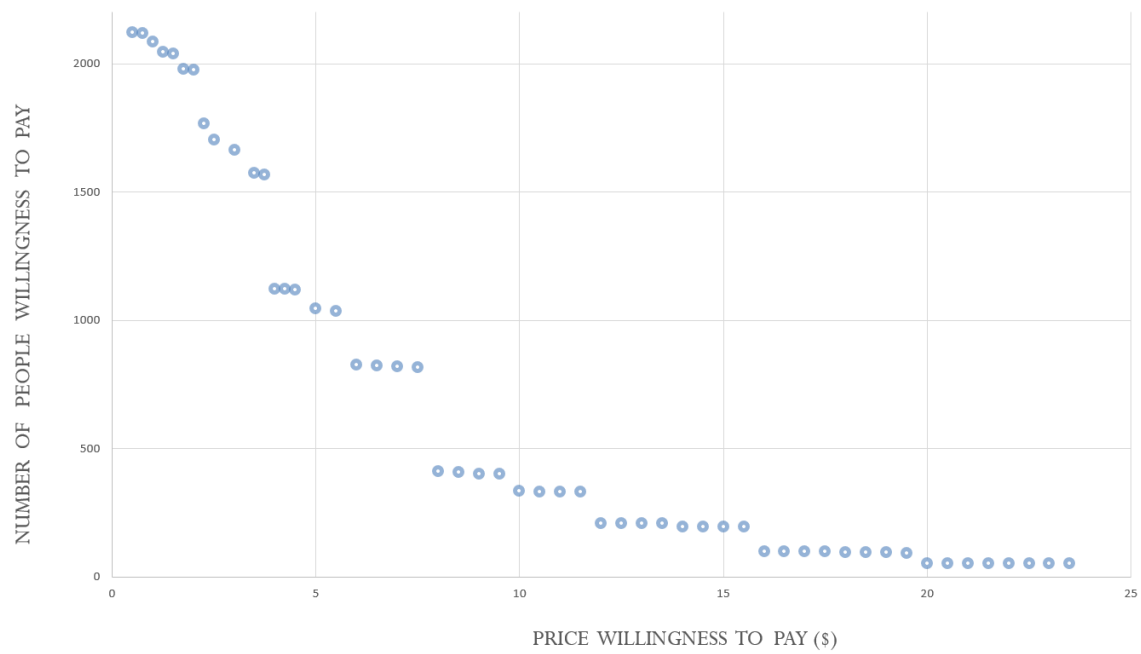
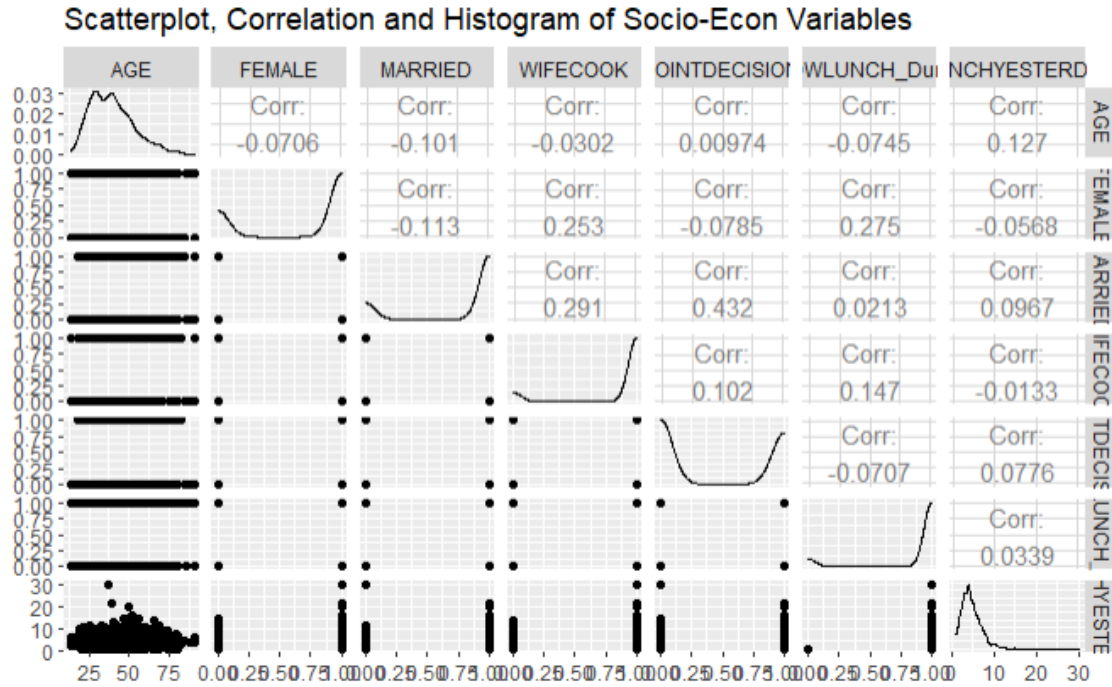


Table 2. Overview of bids under marketing message intervention by auction type

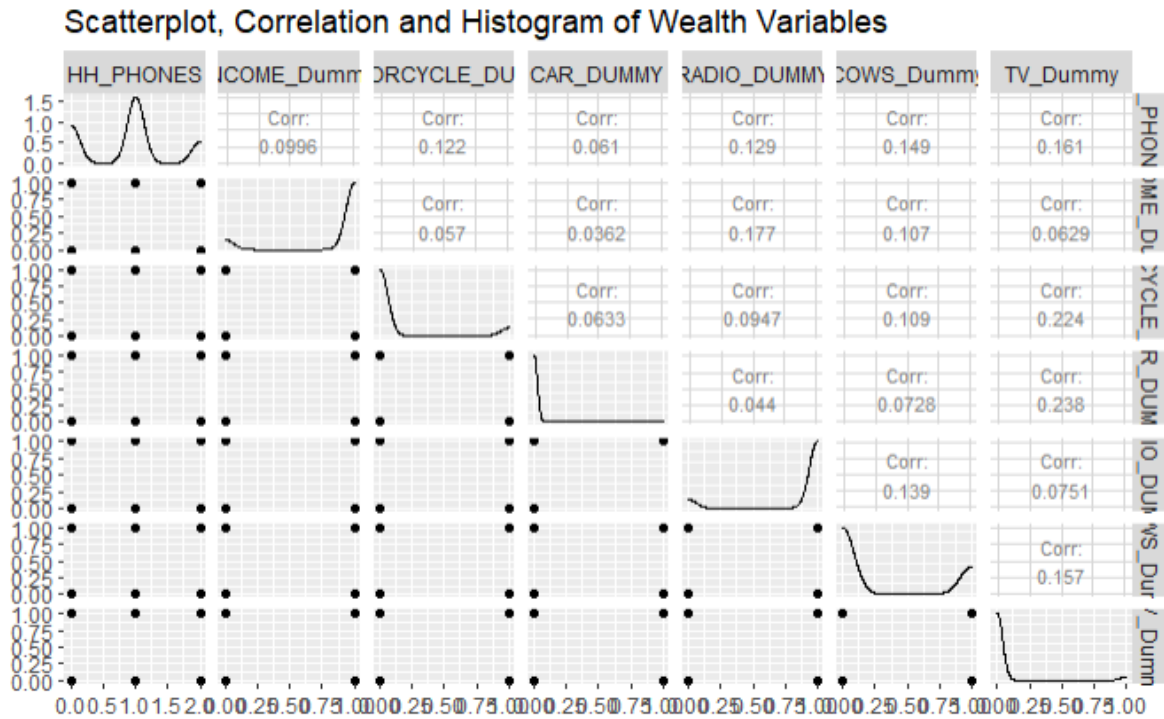
<b>Pay within a week</b>					
	N	Bid Mean	Bid SD	Bid Median	Winners Amount
No Message	546	\$4.58	\$4.82	\$3.98	10
Saves Time & Money	513	\$4.47	\$4.14	\$3.98	7
Improves Health	525	\$5.50	\$5.22	\$3.98	19
Time, Money & Health	541	\$4.88	\$4.28	\$3.98	11
Joint Test		0.0087			
		***			
<b>Time Payment</b>					
	N	Mean	SD	Median	Winners Amount
No Message	546	\$6.73	\$6.87	\$4.77	9
Saves Time & Money	513	\$7.17	\$6.38	\$5.96	20
Improves Health	525	\$6.82	\$6.35	\$4.77	8
Time, Money & Health	541	\$6.61	\$5.90	\$4.77	8
Joint Test		0.1336			

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. The joint test performed here is Kruskal-Wallis test instead of joint F-test. Statistical significance is indicated by \* p<0.10, \*\* p<0.05, \*\*\* p<0.01

Figure 2. Panel A: within-group pairwise correlations and histograms of characteristics.

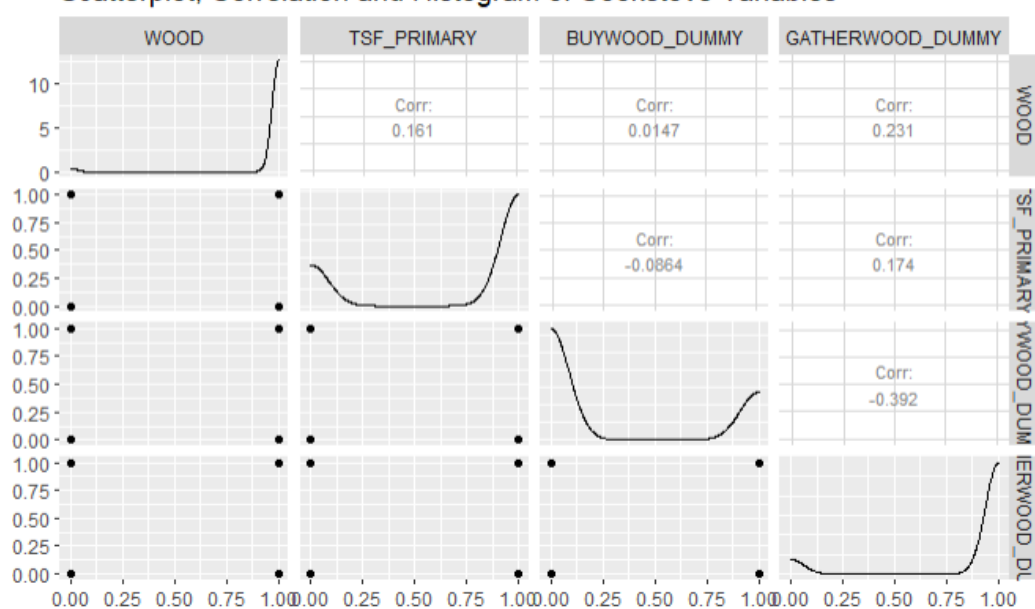


(a) Within socio-economic and demographic characteristics.



(b) Within wealth characteristics

### Scatterplot, Correlation and Histogram of Cookstove Variables



(c) Within cookstove related characteristics

### Panel B: across correlation of gender and cookstove related characteristics

#### Scatterplot, Correlation and Histogram of FEMALE & Cookstove

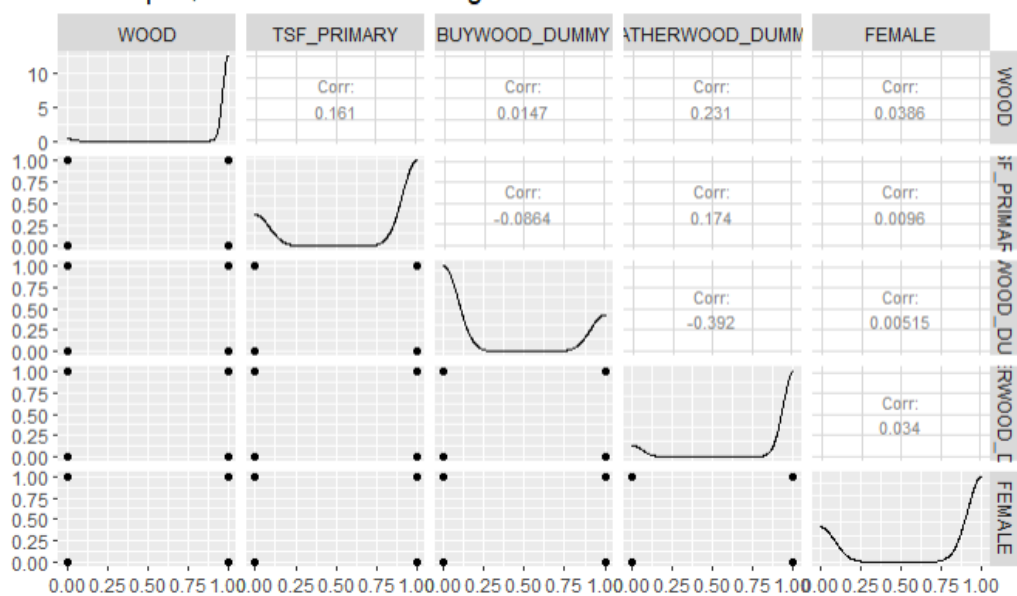


Table 3 Table 3. Balance Check

	Pooled			No Message			Improves Health			Saves Time and Money			Time, Money & Health			Joint Test
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	P-value
Panel A: Socioecon Characteristics																
Age	39.43	13.56	2228	38.77	13.56	570	40.40	13.90	555	39.46	13.32	546	39.10	13.42	557	0.19800
female	71.05%	45.36%	2228	69.12%	46.24%	570	70.09%	45.83%	555	73.08%	44.40%	546	71.99%	44.94%	557	0.45610
Married	79.45%	40.41%	2234	77.89%	41.53%	570	80.72%	39.48%	555	78.75%	40.94%	546	81.33%	39.00%	557	0.02266
Wife is primary cook	86.97%	33.67%	2234	85.96%	34.77%	570	91.89%	27.32%	555	86.81%	33.87%	546	84.20%	36.51%	557	0.00099
Couple make decisions jointly	44.32%	49.69%	2234	43.16%	49.57%	570	33.87%	47.37%	555	45.42%	49.84%	546	55.30%	49.76%	557	0.00000
Knows how many people ate lunch	89.59%	30.55%	2228	92.63%	26.15%	570	98.38%	12.64%	555	73.99%	43.91%	546	93.00%	25.54%	557	0.00000
people # ate lunch at HH yesterday	4.53	2.34	1997	4.61	2.29	529	4.60	2.37	546	4.58	2.45	404	4.35	2.25	518	0.12420
Lunch yesterday was typical	51.03%	50.00%	1997	46.78%	49.94%	528	56.23%	49.66%	546	61.98%	48.60%	405	41.31%	49.29%	518	0.00000
Joint F-test	0.01174						0.00002 ***						0.13720			
Panel B: Wealth Characteristics																
Owms cellphone	87.43%	33.16%	2228	93.88%	72.59%	572	83.60%	65.00%	555	73.41%	60.89%	549	97.49%	69.32%	558	0.00000
Earns income	87.43%	33.16%	2228	96.32%	18.85%	570	77.84%	41.57%	555	82.97%	37.63%	546	92.28%	26.71%	557	0.00000
Owms bicycle	48.97%	50.00%	2230	49.30%	50.04%	570	49.73%	50.04%	555	50.55%	50.04%	546	46.50%	49.92%	557	0.56090
Owms car	1.52%	12.26%	2230	1.40%	11.77%	570	1.26%	11.17%	555	0.55%	7.40%	546	2.87%	16.72%	557	0.01478
Owms motorcycle	10.72%	30.94%	2230	12.63%	33.25%	570	10.63%	30.85%	555	8.06%	27.24%	546	11.49%	31.92%	557	0.08733
Owms radio	88.91%	31.40%	2228	90.70%	29.07%	570	89.73%	30.38%	555	87.18%	33.46%	546	87.97%	32.56%	557	0.22240
Self-employed	67.95%	46.68%	2234	84.44%	36.28%	572	55.32%	49.76%	555	59.74%	49.09%	549	71.68%	45.09%	558	0.00000
Year-round employed	54.66%	49.79%	2234	50.70%	50.04%	572	51.89%	50.01%	555	44.99%	49.79%	549	70.97%	45.43%	558	0.00000
Owms cows	29.26%	45.51%	2228	30.70%	46.17%	570	31.53%	46.51%	555	26.56%	44.20%	546	28.19%	45.03%	557	0.24150
Owms TV	5.07%	21.95%	2228	5.79%	23.37%	570	5.59%	22.99%	555	2.56%	15.82%	546	6.28%	24.29%	557	0.02091
Joint F-test	0.39010						0.01679						0.34970			
Panel C: Cookstove Characteristics																
Uses firewood as fuel source	97.14%	16.69%	2234	97.38%	15.99%	572	99.28%	8.47%	555	95.26%	21.26%	549	96.59%	18.15%	558	0.00079
Three stone fire is primary stove	72.87%	44.47%	2234	69.65%	46.02%	570	77.84%	41.57%	555	76.37%	42.52%	546	68.58%	46.46%	557	0.00034
Bought cooking wood last week	29.98%	45.83%	2228	29.82%	45.79%	570	25.05%	43.37%	555	32.97%	47.05%	546	32.14%	46.74%	557	0.01861
Gathered cooking wood last week	88.38%	32.06%	2228	86.84%	33.83%	570	88.29%	32.18%	555	89.74%	30.37%	546	88.69%	31.70%	557	0.50190
Joint F-test	0.002697 ***						0.002138 ***						0.30090			

Notes: The percentages shows the mean for the dummy variables out of the 2234 observations received and reported messages . The joint test performed is Kruskal- Wallis test.

Statistical significance is indicated by \* p< 0.10, \*\* p< 0.05, \*\*\* p< 0.01

Table 4. Willingness to pay on different characteristics controls and gender interaction terms with fixed effects.

Panel A: Within a week auction.

	Est	Std	p-value		Est	Std	p-value		Est	Std	p-value		Est	Std	p-value
Improve Health	0.968	0.263	0.000 ***		0.952	0.263	0.000 ***		1.148	0.269	0.000 ***		1.007	0.264	0.000 ***
Save Time and Money	0.084	0.265	0.752		0.277	0.272	0.309		0.255	0.269	0.344		0.108	0.268	0.688
Time, Money & Health	0.329	0.261	0.207		0.338	0.260	0.194		0.376	0.261	0.150		0.342	0.263	0.194
Female					-1.234	0.238	0.000 ***								
Age					-0.014	0.007	0.050 *								
Married					0.263	0.277	0.343								
Knows #(people) ate lunch					0.823	0.345	0.017 **								
Wife is primary cook					-0.141	0.315	0.655								
Couple make decisions jointly					0.053	0.214	0.805								
Owns cellphone									0.301	0.147	0.040 **				
Earns income									0.740	0.302	0.014 **				
Owns bicycle									0.203	0.201	0.312				
Owns car									0.823	0.773	0.287				
Owns motorcycle									1.056	0.320	0.001 ***				
Owns radio									0.183	0.316	0.562				
Owns cows									0.361	0.222	0.103				
Owns TV									0.867	0.460	0.059 *				
Self-employed									-0.220	0.250	0.379				
Year-round employed									-0.041	0.219	0.853				
Uses firewood as fuel source													-0.101	0.646	0.875
Three stone fire is primary stove													4.387	0.884	0.000 ***
Bought cooking wood last week													0.232	0.229	0.311
Gathered cooking wood last week													0.044	0.334	0.894
Built-in Mud Stove													4.856	0.921	0.000 ***
Charcoal Stove													4.605	0.880	0.000 ***
Other Stove													4.706	0.970	0.000 ***
HH demographic controls		No				Yes				No				No	
Wealth controls		No				No				Yes				No	
Cookstove use controls		No				No				No				Yes	
Female interaction controls		No				No				No				No	
District FE		Yes				Yes				Yes				Yes	
Survey Day FE		Yes				Yes				Yes				Yes	
Total Asset		Yes				Yes				No				Yes	

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. The total asset is computed based on the “Durable Good Prices Exchange Rate Uganda 2011-12” file. Three levels of explanatory variables’ effect are evaluated here by message group. Statistical significance is indicated by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

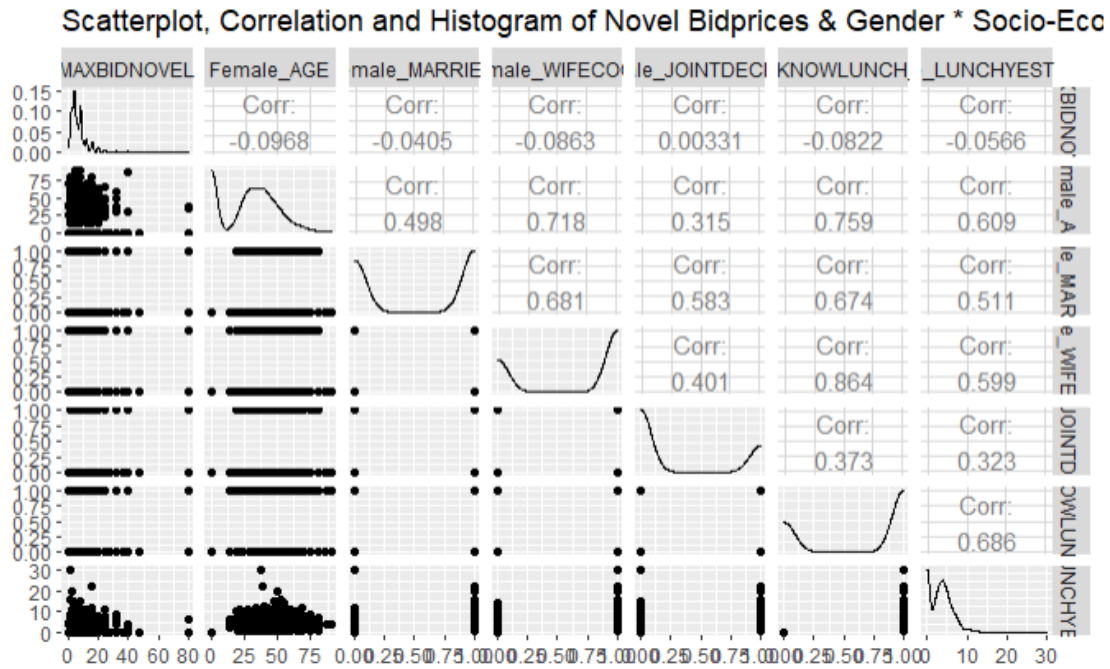
Table 4. Panel B: Time payment auction.

	Est	Std	p-value	Est	Std	p-value	Est	Std	p-value	Est	Std	p-value
Improve Health	0.002	0.365	0.995	-0.063	0.366	0.862	0.268	0.373	0.473	0.051	0.367	0.890
Save Time and Money	0.606	0.362	0.095 *	0.941	0.371	0.011 **	0.856	0.367	0.020 **	0.616	0.366	0.092
Time, Money & Health	-0.142	0.360	0.693	-0.118	0.359	0.743	-0.074	0.360	0.837	-0.157	0.364	0.666
Female				-1.812	0.328	0.000 ***						
Age				-0.017	0.010	0.076 *						
Married				0.441	0.381	0.248						
Knows #(people) ate lunch				1.423	0.471	0.003 ***						
Wife is primary cook				0.046	0.431	0.916						
Couple make decisions jointly				-0.002	0.295	0.996						
Owens cellphone							0.398	0.202	0.050 **			
Earns income							1.082	0.414	0.009 ***			
Owens bicycle							0.412	0.277	0.137			
Owens car							0.804	1.084	0.458			
Owens motorcycle							1.267	0.441	0.004 ***			
Owens radio							0.381	0.432	0.378			
Owens cows							0.327	0.306	0.285			
Owens TV							1.371	0.633	0.030 **			
Self-employed							-0.424	0.342	0.215			
Year-round employed							-0.013	0.301	0.966			
Uses firewood as fuel source										0.170	0.886	0.848
Three stone fire is primary stove										4.325	1.221	0.000 ***
Bought cooking wood last week										0.552	0.314	0.079 *
Gathered cooking wood last week										0.028	0.461	0.952
Built-in Mud Stove										4.839	1.272	0.000 ***
Charcoal Stove										4.753	1.213	0.000 ***
Other Stove										4.383	1.341	0.001 ***
HH demographic controls		No			Yes			No			No	
Wealth controls		No			No			Yes			No	
Cookstove use controls		No			No			No			Yes	
Female interaction controls		No			No			No			No	
District FE		Yes			Yes			Yes			Yes	
Survey Day FE		Yes			Yes			Yes			Yes	
Total Asset		Yes			Yes			No			Yes	

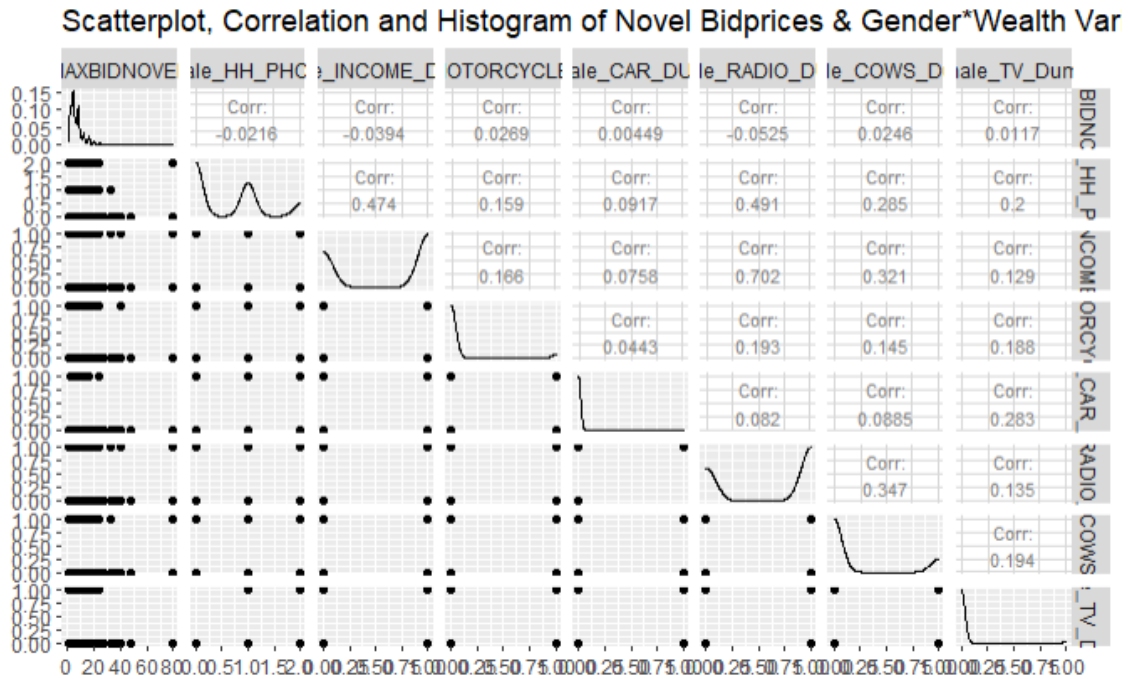
Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. The total asset is computed based on the “Durable Good Prices Exchange Rate Uganda 2011-12” file. Three levels of explanatory variables’ effect are evaluated here by message group. Statistical significance is indicated by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .



Figure 4. Correlation of willingness to pay on the interaction terms of gender with other groups of characteristics.

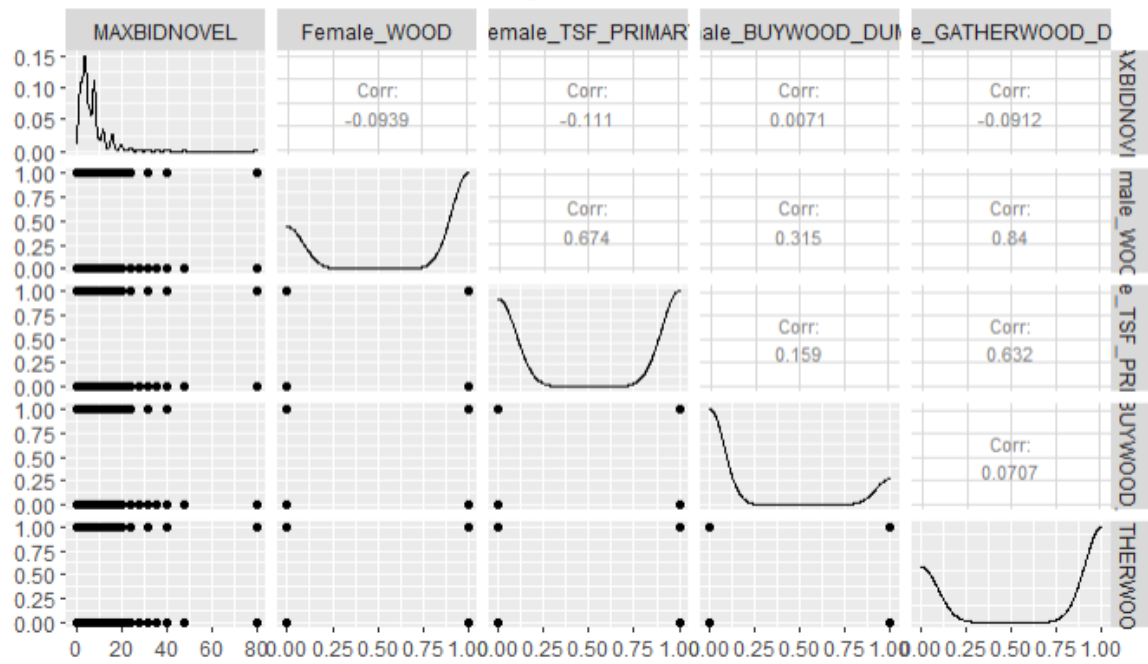


(a) Willingness to pay on gender interacting with socio-economics characteristics.



(b) Willingness to pay on gender interacting with wealth characteristics.

### Scatterplot, Correlation and Histogram of Novel Bidprices & Gender\*Cookstove



(c) Willingness to pay on gender interacting with cookstove characteristics.

Table 5. The effect of gender.

	Pay Within a Week				Time Payment			
	Est	Std	P-value		Estimate	Std	P-value	
Improve Health	1.084	0.269	0.000	***	0.158	0.372	0.671	
Save Time and Money	0.181	0.268	0.500	**	0.791	0.366	0.031	**
Time, Money & Health	0.317	0.262	0.226		-0.144	0.360	0.688	
Female	-2.765	0.948	0.004	***	-4.632	1.285	0.000	***
Wife is primary cook	-0.432	0.407	0.288		-0.262	0.558	0.639	
Female*Age	-0.009	0.009	0.342		-0.006	0.013	0.616	
Female*Married	0.317	0.309	0.306		0.538	0.386	0.163	
Female*Wife is primary cook	0.608	0.613	0.321		0.604	0.842	0.474	
Female*know # of people at lunch	0.501	0.550	0.362		1.022	0.752	0.175	
Female*Earns income	0.584	0.329	0.076	*	1.042	0.446	0.020	**
Female*Buy wood	0.489	0.269	0.069	*	0.813	0.368	0.027	**
Female*Gathered wood	0.341	0.393	0.385		0.365	0.532	0.493	
HH demographic controls				Yes				
Wealth controls				Yes				
Cookstove use controls				Yes				
Female interaction controls				Yes				
District FE				Yes				
Survey Day FE				Yes				
Wealth FE				Yes				

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. The total asset is computed based on the “Durable Good Prices Exchange Rate Uganda 2011-12” file. Statistical significance is indicated by \* p< 0.10, \*\* p< 0.05, \*\*\* p< 0.01.

Table 6. Intra-person difference due to types of auctions.

Unbalanced Panel: n = 2161, T = 1-2, N = 4260				
Coefficients	Estimate	Std. Error	t-value	p-value
Time payment	1.958549	0.081341	24.078	0.0000***
R-Squared	0.21651			
Adj. R-Squared	-0.59051			
F-statistic	579.758	on 1 and 2098 DF		
p-value	2.22e-16			

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. The total asset is computed based on the “Durable Good Prices Exchange Rate Uganda 2011-12” file. Statistical significance is indicated by \* p< 0.10, \*\* p< 0.05, \*\*\* p< 0.01.

Table 7. Wealth Effect

<b>Wealth Effect</b>	<b>Pay within a week</b>			<b>Time payment</b>		
	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Total asset	0.00053	0.00009	0.000***	0.00063	0.00012	0.000***
Total asset square	0.00000	0.00000	0.908	0.00000	0.00000	0.482
Improves Health	0.96830	0.26283	0.000***	0.00650	0.36523	0.986
Time Money	0.08373	0.26520	0.752	0.60435	0.36243	0.096
Time Money & Health	0.32982	0.26091	0.206	-0.14025	0.36041	0.697
<b>Elasticity</b>						
log(Total asset)	0.06673	0.00921	0.000	0.05796	0.00882	0.000

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012. All the prices are in USD. The total asset is computed based on the “Durable Good Prices Exchange Rate Uganda 2011-12” file. Statistical significance is indicated by \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 8. Asset Prices

Average durable goods prices of the 2011/12 Uganda LSMS World Bank survey		
	Shillings	USD
TV	337,692	\$134.27
Bicycle	175,284	69.70
Radio	34,779	13.83
Vehicle	11,341,667	4,509.61
Motorcycle	1,971,212	783.78
Mobile Phone	86,164	34.26
Indigenous Cow	581,266	252.23

Notes: The exchange rate is 2515 UGX to 1 USD during 2011-2012.

Table 9. Mixed effect predicting model of willingness to pay by auction type

Panel A. Predicting willingness to pay by within a week auction

	Coefficient	Std Error	P-value	
No message	2.3430	0.1140	0.0000	***
Improves Health	2.5280	0.1170	0.0000	***
Time Money	2.3590	0.1160	0.0000	***
Time Money & Health	2.4070	0.1140	0.0000	***
Female	-0.2100	-0.0378	0.0000	***
Age	0.0031	0.0012	0.0104	**
Three stone fire is primary stove	0.0945	0.0372	0.0113	**
Total Asset	0.0001	0.0000	0.0000	***
PARISHBujaga	0.7007	0.1535	0.0000	***
PARISHBukiro	0.4329	0.1516	0.0043	***
PARISHBwengure	0.3500	0.1448	0.0157	**
PARISHKabarama	0.5607	0.1436	0.0001	***
PARISHKakigaani	-0.1932	0.1563	0.2164	
PARISHKamomo	-0.7372	0.1468	0.0000	***
PARISHKibingo_Bugamba	-0.5965	0.1577	0.0002	***
PARISHKibingo_Kagogi	-0.4141	0.1468	0.0048	***
PARISHKigaaga	0.3967	0.1570	0.0116	**
PARISHKitojo	-0.3629	0.1577	0.0215	**
PARISHKitunguru	0.1179	0.1672	0.4806	
PARISHKongoro	-0.2079	0.1470	0.1574	
PARISHKyandahi	-0.8438	0.1487	0.0000	***
PARISHMirama	0.4548	0.1541	0.0032	***
PARISHMirongo	0.1219	0.1424	0.3924	
PARISHMitoozo	-0.1424	0.1535	0.3535	
PARISHNcune	-0.0447	0.1517	0.7681	
PARISHNdeija	0.5354	0.1670	0.0014	***
PARISHNgando	0.0122	0.1508	0.9358	
PARISHNgoma	-0.5892	0.1460	0.0001	***
PARISHNgugo	-0.8623	0.1461	0.0000	***
PARISHNsinka	-0.7311	0.1431	0.0000	***
PARISHNtuura	-0.4494	0.1452	0.0020	***
PARISHNyabikungu	0.6232	0.1630	0.0001	***
PARISHNyabisirira	-0.5472	0.1570	0.0005	***
PARISHNyaihanga	0.4988	0.1697	0.0033	***
PARISHNyakabare	0.1694	0.1807	0.3486	
PARISHNyakaikara	-0.0300	0.1539	0.8454	
PARISHNyanja	-0.3540	0.1657	0.0328	***
PARISHNyarubungo_Bwizibwera	-0.0918	0.1491	0.5383	
PARISHNyarubungo_Ndiija	-0.3454	0.2665	0.1951	
PARISHNyaruhandagazi	-0.7014	0.1502	0.0000	**
PARISHOther	-0.3496	0.8570	0.6834	
PARISHRubingo	-0.5056	0.1497	0.0007	***
PARISHRukarabo	0.1993	0.1436	0.1653	
PARISHRweibogo	0.0067	0.1577	0.9661	
PARISHRwensinga	-0.0660	0.1479	0.6552	

Multiple R-squared: 0.891, Adjusted R-squared: 0.8887

F-statistic: 376.9 on 45 and 2074 DF, p-value: &lt; 2.2e-16

Panel B. Predicting willingness to pay by time payment auction

	Coefficient	Std Error	P-value	
No message	2.8907	0.1292	0.0000	***
Improves Health	2.9011	0.1326	0.0000	***
Time Money	3.0211	0.1309	0.0000	***
Time Money & Health	2.8597	0.1294	0.0000	***
Female	-0.2469	0.0437	0.0000	***
Age	-0.0045	0.0014	0.0013	***
Three stone fire is primary stove	-0.1002	0.0431	0.0202	**
Total Asset	0.0001	0.0000	0.0000	***
PARISHBujaga	0.7007	0.1535	0.0000	***
PARISHBukiro	0.4329	0.1516	0.0043	***
PARISHBwengure	0.3500	0.1448	0.0157	**
PARISHKabarama	0.5607	0.1436	0.0001	***
PARISHKakigaani	-0.1932	0.1563	0.2164	
PARISHKamomo	-0.7372	0.1468	0.0000	***
PARISHKibingo_Bugamba	-0.5965	0.1577	0.0002	***
PARISHKibingo_Kagogi	-0.4141	0.1468	0.0048	***
PARISHKigaaga	0.3967	0.1570	0.0116	**
PARISHKitojo	-0.3629	0.1577	0.0215	**
PARISHKitunguru	0.1179	0.1672	0.4806	
PARISHKongoro	-0.2079	0.1470	0.1574	
PARISHKyandahi	-0.8438	0.1487	0.0000	***
PARISHMirama	0.4548	0.1541	0.0032	***
PARISHMirongo	0.1219	0.1424	0.3924	
PARISHMitoozo	-0.1424	0.1535	0.3535	
PARISHNcune	-0.0447	0.1517	0.7681	
PARISHNdeija	0.5354	0.1670	0.0014	***
PARISHNgango	0.0122	0.1508	0.9358	
PARISHNgoma	-0.5892	0.1460	0.0001	***
PARISHNgugo	-0.8623	0.1461	0.0000	***
PARISHNsinka	-0.7311	0.1431	0.0000	***
PARISHNtuura	-0.4494	0.1452	0.0020	***
PARISHNyabikungu	0.6232	0.1630	0.0001	***
PARISHNyabisirira	-0.5472	0.1570	0.0005	***
PARISHNyaihanga	0.4988	0.1697	0.0033	***
PARISHNyakabare	0.1694	0.1807	0.3486	
PARISHNyakaikara	-0.0300	0.1539	0.8454	
PARISHNyanja	-0.3540	0.1657	0.0328	***
PARISHNyarubungo_Bwizibwera	-0.0918	0.1491	0.5383	
PARISHNyarubungo_Ndiiija	-0.3454	0.2665	0.1951	
PARISHNyaruhandagazi	-0.7014	0.1502	0.0000	**
PARISHOther	-0.3496	0.8570	0.6834	
PARISHRubingo	-0.5056	0.1497	0.0007	***
PARISHRukarabo	0.1993	0.1436	0.1653	
PARISHRweibogo	0.0067	0.1577	0.9661	
PARISHRwensinga	-0.0660	0.1479	0.6552	

Multiple R-squared: 0.8965, Adjusted R-squared: 0.8942

F-statistic: 401 on 45 and 2084 DF, p-value: < 2.2e-16



## Appendix II

All codes of Rmarkdown file, the cleaned data in csv and dta and tables summarized from Rmarkdown file are available at

<https://github.com/charlieq3712/Analysis-of-messaging-and-financing-on-demand-for-non-traditional-cookstove-adoption-in-Uganda>