Gendered demand for modern cookstoves in the presence of environmental health complementarities

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Abstract

We study how household demand for a technology that improves environmental health - an electric cookstove - is related to exposure to prior health-related interventions, among households in 40 villages in rural Odisha. More than a decade before the demand study, a random half of our sample had been exposed to an intensive village-level behavior change campaign aimed at reducing open defecation. We observe that auction bids for electric cookstoves vary according to both gender and prior exposure to the sanitation campaign. These results suggest the importance of interactions between information, preferences and bargaining power.

JEL: I12, J16, O13

Keywords: improved cookstoves, sanitation, complementarities, gender, India

The global burden of disease related to the environment remains high today, despite the fact that it is mostly preventable using existing technology (Pruss-Ustun et al., 2016). Unsurprisingly, this burden is concentrated in less developed countries (LDCs), where resources

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to invest in disease avoidance are limited, especially among the poor. In fact, many of the conditions and behaviors leading to these environmental health illnesses also entail myriad other non-health costs - in terms of drudgery and time losses, damages to environmentally-dependant livelihoods activities, and the necessity of engaging in resource-intensive coping behavior - that fall disproportionately on the global poor and on women (Pattanayak and Pfaff, 2009). This paper focuses on two environmental domains with particularly high burdens, especially in our context in rural South Asia: Household air pollution from use of solid and other highly polluting fuels, and water contamination due to poor drinking water quality and sanitation (Shannon et al., 2019). Indeed, the high co-prevalence of these two particular environmental health problems in settings such as rural India has led some public health researchers to call for integrated approaches to address them (Clasen and Smith, 2019).

More specifically, we consider the individual demand for one environmental health improving technology - a modern induction cookstove that runs on electricity - in a context that is characterized by differential village-level exposure to a prior intensive behavior change campaign implemented to end open defecation. Household exposure to air pollution in most rural developing country settings is largely attributed to cooking food using solid fuels such as firewood, charcoal, coal, dung, and agricultural residue. According to the last Census of India (2011), 86.7 percent of rural households continue to use these solid fuels in inefficient traditional chulhas as their primary cooking energy source (Venkataraman et al., 2010), and the Government of India has made increased access to modern fuels a key policy priority.[1] Incomplete combustion of solid fuels using inefficient technology releases a collection of toxic emissions such as carbon monoxide, nitrous oxides, sulphur oxides, formaldehyde, polycyclic organic matter and benzo(a)pyrene (Bruce et al., 2000; Zhang et al., 2000). Besides risks to public health, the need to harvest firewood and other solid fuels from the environment entails significant time and productivity loss, while also contributing to deforestation and forest degradation in many locations (Bailis et al., 2015), and damaging the global climate due to net CO2 releases associated with nonrenewable harvesting as well as black carbon emissions (Ramanathan and Carmichael, 2008). This negative combination of factors imposes significant economic damages on society, that could be efficiently alleviated with broader use of cleaner solutions.

[1] Census of India, 2011

Within households as well, the burdens imposed by solid fuel burning are not evenly shared. For example, women and young children spend more time around the kitchen and are therefore more vulnerable to the HAP-related health risks (Bruce et al., 2000). They are often also more involved in fuel harvesting or preparation. It is often men, however, who have authority to make financial decisions in these households, especially when it comes to investments in durable goods such as cookstoves. Therefore, although women may have stronger preferences for cleaner fuels and cookstoves relative to men, they may not be able to follow through on these preferences with actual purchases of less polluting alternatives, as shown in settings as diverse as Bangladesh and Uganda (Miller and Mobarak, 2013; Beltramo et al., 2015). Complementing this evidence on differential gendered demand for a key environmental health technology, several other studies have found that households in which women have more say in household decisions are also more likely to adopt clean fuels (Alem et al., 2018; Kishore and Spears, 2014). It is worth noting that in the presence of divergent interests for clean alternatives, policy outcomes depend on the extent of the gap in the preferences, information and intra-household bargaining power (Alem et al., 2018; Ghosh and Krishnapriya, 2019).

Our specific context - and namely the differential and exogenously-determined, prior exposure to an intensive sanitation behavior change campaign among households living in different sample communities - adds a unique dimension to our study. Most existing studies on environmental health demand and behavior ignore the history of prior institutions or interventions in the broader environmental health domain. Yet such history may influence the success of new interventions; some for example have speculated that ignoring complementarities may lead to underestimates of an intervention's overall effectiveness in the presence of multiple health risks (Dow et al., 1999). Along these lines, a recent paper finds that a decrease in the probability of mortality due to diarrhoea increases households' investments in the prevention of malaria in Africa (Yarnoff, 2011). Liu and Neilson (2005) in contrast point out that households who adopt costly measures to lower their health risks ex-ante, may under certain conditions, experience a depletion of wealth that also diminishes their marginal willingness to pay for further (or other) risk reductions. In addition, the notion of prevalence elasticity suggests that individuals facing declining risks in one domain may in some cases compensate by increasing risky behaviors and thereby undermining the benefits of continuing intervention (Ahituv et al., 1996). Hence, the impact of prior interventions on

the willingness to pay for improved cookstoves is ambiguous.

The objectives of this study are two-fold. First, we examine the patterns and correlates of willingness to pay for an electric induction cookstove as elicited in a series of Vickrey second price auctions held in 2016 in 40 villages located in rural Odisha, India. In particular, how does willingness to pay for this clean technology differ according to the gender of the bidder? During our survey visits to households to implement the auction, household heads were the preferred bidders, owing to their greater control over household financial resources. Due to their frequent unavailability, however, other household members often replaced them to place bids for the stoves. Of course, this situation gives rise to possible selection bias in the gender and position of the bidder within the household, that may contaminate the comparison between male and female bidding households. To address this issue, we use propensity score matching to construct a suitable counterfactual of male-bidder households for the households from which females placed bids.

The second objective is to determine the causal effect of the prior, exogenous health behavior change intervention on willingness to pay. To isolate this effect, we leverage the fact that half of the sampled villages in our sample were randomly assigned to a Community-led Total Sanitation campaign ten years before the stove auction experiment in 2006 - a campaign that we discuss in more detail in Section 2 below. We use the same matched sample of households constructed to consider the influence of gender on bids to explore the potential complementarity between different the prior health behavior intervention and the demand for the second environmental health improving technology, using a difference-in-differences approach. Furthermore, building on the observation that a subset of households had begun to abandon the latrines they had constructed following the intensive 2006 sanitation campaign by 2016, we explore how latrine abandonment is related to demand for the second (i.e., modern cookstove) environmental health technology.

We find that female bidders in our sample place significantly lower bids than male bidders, which is consistent with prior literature that finds lower willingness to pay among women. Nonetheless, we find that female bidders from villages that were exposed to the sanitation campaign placed bids that were comparable to their male counterparts in those villages. In contrast to the conventional wisdom that might suggest that the prior sanitation campaign

would increase female bidders' willingness to pay, we find that it is actually the men who bid lower in these intervention villages, whereas women bid at similar levels across the two types of villages. Several potential channels for this effect include learning from the previous intervention, asymmetric intra-household welfare effects of the prior intervention, changes in intra-household bargaining power, changes in preferences, or interactions among these. Our paper adds to a small body of literature that studies the possibilities of spill-over effects of one health intervention on other interventions, and on mechanisms through which these complementarities manifest.

The paper is organised as follows. Section 1 discusses the data used in the study, the auction experiment, and the sanitation campaign. The conceptual framework is outlined in Section 2. The details of participating households and bids are given in Section 3. Section 4 outlines the estimation strategy, and is followed by Section 5 that summarises our results. Section 6 discusses the possible policy implications that emerge from this study.

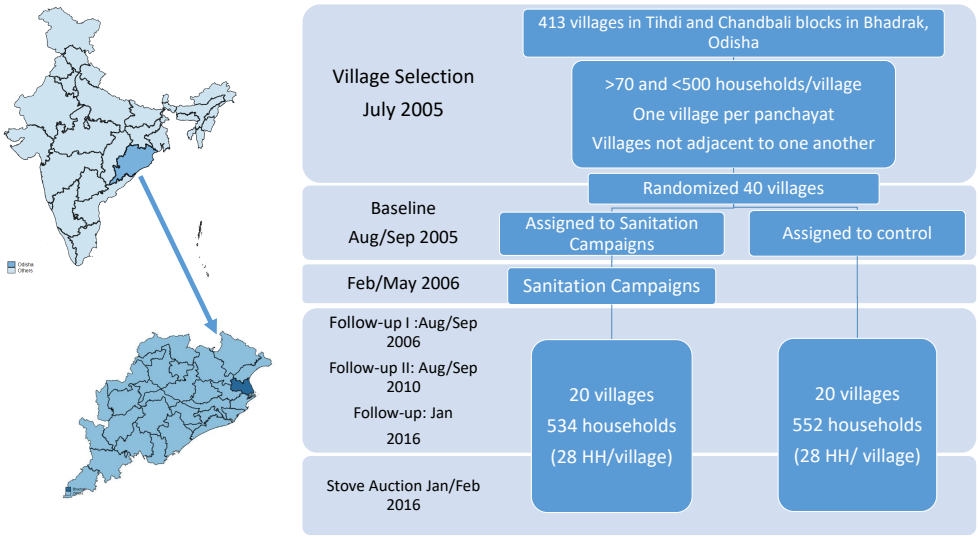
1 Study context and implementation

We use survey data collected from households belonging to 40 villages - randomly selected for surveys at the time of planning the original sanitation behavior change study in 2005 (Pattanayak et al., 2009) - in the Tihdi and Chandrabali blocks of Badhrak district in Odisha, India. To minimize spillovers across villages in the original study, each of the chosen villages were selected from a non-contiguous sample of distinct Gram-Panchayats, which is the smallest unit of local governance. Participating villages were also restricted in size to contain at least 70 households and no more than 500 households (Figure 1).

To draw the original sample of survey respondents in each of the selected 40 villages, a listing was first conducted to identify all households having at least one child under 5 years of age in 2005. This sample eligibility criterion was established on the basis of power calculations for detecting impacts of the sanitation campaign on diarrheal disease prevalence, which is highest among young children. A random sample of about 28 such households was then selected from these lists of eligible households in every village, yielding a total of 1,088

households. Following the baseline in 2005, these households were again surveyed in three waves in 2006, 2010 and 2016, respectively. In each wave of the survey, information was collected on demographic composition, socio-economic characteristics, health status, knowledge and perceptions towards the environment and sanitation, and participation in various community activities. The individual primarily responsible for children's care was the preferred respondent for these general surveys, except as noted below for the auction conducted in 2016.

Figure 1: Sampling design.



Source: Baseline and follow-up surveys administered in Odisha, India from 2005 to 2016.

1.1 Sanitation campaign in 2006

As noted above, the sample that we leverage in this paper is based on that drawn to support an impact evaluation of a randomized, intensive Community-Led Total Sanitation (CLTS) campaign that took place between February and April 2006.[2]. That intervention, which was based on a village-wide mobilization strategy, was implemented at the Gram Panchayat level. Of the 40 villages in our sample, 20 villages took part in the sanitation campaign,

[2]Details of sampling and the sanitation campaign is available in Pattanayak et al. (2009), and results related to sustainability and impacts from the long term follow-up are presented in Orgill-Meyer et al. (2019) and Orgill-Meyer and Pattanayak (2019).

with the other 20 acting as controls. It is important to note that that RCT took place in the context of the broader 'Total Sanitation Campaign' that was being implemented by the Indian government at the time, and which has evolved over the time since the original RCT. The national campaign consisted of various sanitation promotion activities - that varied substantially across Indian states - supported by infrastructure subsidies provided to eligible below poverty line (BPL) households.

What differentiated the intervention being tested in the RCT from the prevailing national and state-level efforts was the intensity of its "softer" sanitation promotion components. In treatment villages only, a specialized team of community-based organizations, working with state and local government leaders, implemented three key elements that were mostly absent from alternative sanitation interventions in the region: a) A set of information, education and communication (IEC) activities; b) establishment of accessible latrine production centers and institutions at the village-level, and c) a concerted effort to raise awareness among eligible households of the availability of the sanitation subsidies. The IEC effort was itself comprised of three activities. First was the 'walk of shame', which required villagers to walk together around the village to identify common defecation sites, noting their proximity to other important community locations, such as water sources and health clinics. Second was a 'defecation mapping' exercise, during which villagers drew maps of the village and noted distances on the map between those defecation sites and water sources, agricultural fields and schools or health clinics. Lastly, in each village, the total visible faecal matter was collected by facilitators during the 'walk of shame' and weighed during a community debriefing meeting. The behavior change facilitators also helped to inform villagers of the health risks associated with open defecation. Overall, the campaign sought to increase awareness of the open defecation problem in the intervention villages, and to invoke an emotional response that would induce collective action to improve sanitation.

The impact evaluation of this intensive behavior change effort revealed that households in intervention villages were much more likely to own a latrine that those in comparison villages in 2006 and 2010, and that the largest increases had occurred among BPL households. By 2016, though the proportion of households ever owning latrines remained higher (by a similar percentage) in treated villages, ownership and use of functioning latrines had converged across the sample villages, suggesting that the initial gains from the CLTS approach had

not been sustained (Orgill-Meyer et al., 2019). Furthermore, rates of ownership and use of latrines remained considerably higher in some treated villages than in the comparison sample, but was also much lower in other high-abandonment villages. We exploit these asymmetries in our empirical analyses.

1.2 The second-price auction in 2016

While the historical and institutional information reviewed above is important and key to our empirical questions about complementarities, this study primarily uses data from a Vickrey second price auction for an electric induction cookstove that was conducted during the final survey wave in 2016. The full original sample of households was targeted for participation in this auction, and bids for the cookstove were collected during private household visits, at the end of the survey described above. In each household, the (self-identified) head received an explanation about the technology and a tea-making demonstration (if electricity was available at the time), was given the chance to examine it, and was finally informed about how the auction would work (Refer to the appendix for the english language version of the script). Specifically, the potential bidder was told that only one stove would be awarded in each village, to the highest bidder, but that he/she would pay only the second highest bid price. The incentive compatibility of this auction mechanism was also explained using a simple example. If the household head was not available, his/her spouse (first preference) or another responsible adult (if neither head nor spouse were available) were asked to place a bid instead. The number of observers present during the bid elicitation exercise was recorded, as well as the gender balance in this group, plus the gender and roster id of the actual bidder.

Unlike the traditional biomass cookstoves used by the households in the region, the auctioned cookstoves were electric induction stoves manufactured by a local manufacturer – *Prestige*. These cook-stoves typically use 1000-2000 Watts of electricity and can cook a typical meal for 5 persons in this region in about one and half hours. Households were told that they would need to use flat bottomed utensils made of steel on these stoves, and that there would be a running cost associated with the household's increased electricity use. Each cookstove came with a one year warranty and could be repaired or replaced at any local *Prestige* retailer.

2 Conceptual framework

Consider a representative household comprising of a man, m and a woman, f. Let $\ _i$ be the individual's decision making power such that $\ _m + \ _w = 1$. The household is endowed with a total wealth w. We follow Pratt and Zeckhauser (1996) and assume that individuals can experience two possible states of health: low $\ _h$ and high $\ _l$ with probabilities p and $(1 \quad p)$, respectively, and where $0 \quad \ _l < \ _h \quad 1$. Let $\ ^i$ be the value individual i places $(i = m; f)$ on the expected health outcomes. Each individual in the household derives utility from individual-specific control over household wealth, and from the benefits associated with expected health. We further assume that individuals in the household can invest in certain female centric health technologies (e.g., latrines) I, which reduce the probability of $\ _l$ by R_1, where $R_1 = r_1 p$ and $r_1 \quad 1$. In particular, $I \ 2 \ f0; 1g$; if $I = 1$, the household adopts a latrine while if $I = 0$, the household chooses open defecation. Control over household wealth is given by $\ _i w$. Similar to Ghosh and Krishnapriya (2019), we employ a quasi-linear utility function familiar from the public goods literature.[3]

$$U^i = ln(\ _i(w \quad I:z_1)) + \ ^i((p \quad I:R_1)\ _l + (1 \quad p + I:R_1)\ _h) \tag{1}$$

where z_I is the cost of building the latrine. We assume that $\ ^f > \ ^m$, which indicates that women care more about the improvement in expected health outcomes that result from latrines than men.

Given this utility function, an individual's initial utility when the household does not adopt a latrine is:

$$U_0^i = ln(\ _i w) + \ ^i(p\ _l + (1 \quad p)\ _h) \tag{2}$$

and similarly, an individual's initial utility when the household adopts a latrine is:

[3]We assume a log-linear function with a log transformation of disposable income for simplicity, but results hold for any function $u^i(\ _i(w \quad I:z_1))$ that is a twice differentiable, increasing and invertible

$$U_1^i = ln(\ _i(w \quad z_l)) + \ ^i((p \quad R_1)\ _l + (1 \quad p + R_1)\ _h) \tag{3}$$

Next, we introduce a second female centric health intervention: a cleaner cookstove $s\ 2\ f0; 1g$. Again, if $s = 1$, the household adopts this technology, and if $s = 0$, it does not. The use of s reduces the probability of poor health p by R_2 on its own. We further assume a multiplicative risk reduction by $R_1{:}R_2$ if the household has already adopted l, where $R_2 = r_2 p$ and $r_1 + r_2 + r_1{:}r_2 \quad 1$. In the case the household continues to practise open defecation, the use of s decreases p by R_2. The maximum amount, z_s^i, that the individual is willing to pay is given by the following expression:

$$U_2^i = ln(\ _i(w \quad z_l) \quad z_s^i) + \ ^i((p \quad R_1 \quad R_2 \quad R_1R_2)\ _l + (1 \quad p + R_1 + R_2 + R_1R_2)\ _h) \quad U_1^i \tag{4}$$

This further implies:

$$^i((R_1R_2 + R_2)(\ _h \quad\ _l)) \quad ln(\ _i(w \quad z_l)) \quad ln(\ _i(w \quad z_l) \quad z_s^i) \tag{5}$$

In other words, the perceived marginal benefit from the increased probability of the high health outcome relative to the low health outcome arising from investment in the improved stove must be at least as large as the loss in the utility from income devoted to that investment.

Solving for z_s^i gives the following condition.

$$z_s^i \quad\ _i(w \quad z_l)[1 \quad e^{-p\ ^i((r_1r_2+r_2)(\ _h-\ _l))}] \tag{6}$$

An increase in $\ _i$, r_1 or $\ _i$ increases this maximum willingness to pay z_s^i. As shown in Table 1, for similar bargaining power within the household, in any given scenario (sustained

latrine adoption, latrine adoption and abandonment, and no latrine adoption), women are willing to pay more than the men, owing to their higher preference and benefits from these female-centric technologies. Additionally, we find that willingness to pay is higher when the household has sustainably adopted a latrine, vis-à-vis one that never did or that adopted a latrine and then later abandoned it.

Table 1: Upper limits of willingness to pay for the improved stove.

	ceiling on z_s^f	ceiling on z_s^m
Latrine adoption	$_f(w \quad z_1)[1 \quad e^{-p \ i((r_1 r_2 + r_2)(\ _h - \ _l))}]$	$_m(w \quad z_1)[1 \quad e^{-p \ i((r_1 r_2 + r_2)(\ _h - \ _l))}]$
Latrine adoption and abandonment	$_f(w \quad z_1)[1 \quad e^{-p \ ^f r_2(\ _h - \ _l)}]$	$_m(w \quad z_1)[1 \quad e^{-p \ ^m r_2(\ _h - \ _l)}]$
No latrine adoption	$_f(w)[1 \quad e^{-p \ ^f r_2(\ _h - \ _l)}]$	$_m(w)[1 \quad e^{-p \ ^m r_2(\ _h - \ _l)}]$

3 Sample Description

We begin by describing the analytical sample for which we analyze the 2016 stove demand data. Of the 1088 original households, 1066 participated in the cookstove auction. The remaining 22 either could not be relocated (7 households) or declined to participate (15 households). Those who refused to participate stated that they had no interest in the modern stoves and that they were satisfied with their traditional stoves.

As mentioned in the previous section, one bidder from each household submitted a bid. About 35.5 percent of these bidders were household heads, 27.8 percent were the spouses of the heads, and the remaining were other household members. Most of the household heads were males and approximately 16 percent of the household heads were females. It is worth noting that the share of heads who participated in the auction is similar across the male- and female-headed households. Despite the gender distribution of the household heads, the share of female and male bidders is comparable at 52.6 percent and 47.5 percent, respectively. The majority of these female bidders were spouses of the household heads. It also appears that female headed households were more likely to have a female bidder though fewer than one

third of the female heads participated in the auction (Table 2).

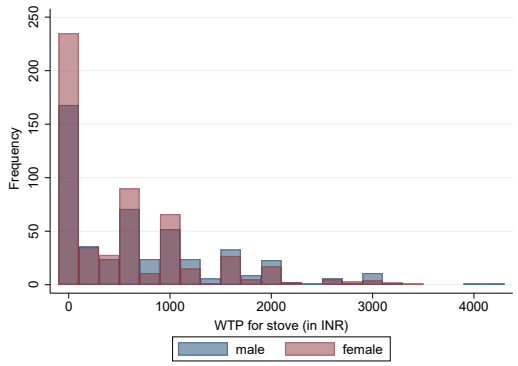
Table 2: Bidder gender by bidders identity.

Identity	Male bidders	Female bidders
Household head	317	53
	(85.68)	(14.32)
Spouse of household head	0	290
	(0.00)	(100.00)
Others	177	205
	(46.34)	(53.66)
Total	494	548
	(47.41)	(52.59)

Percentages in parentheses. Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

Although most bidders submitted positive bids, about 38.6 percent of the bidders (mostly women) submitted zero bids (Figure 2). The most common reason given for submitting zero bids was that they preferred to use their traditional cookstoves and were unwilling to switch to the improved one that was being offered. Another third of these zero bidders felt that they could not afford the stoves due to poor financial conditions at home. Finally, 14 percent of the zero bidders reported that they did not have an electricity connection at home.

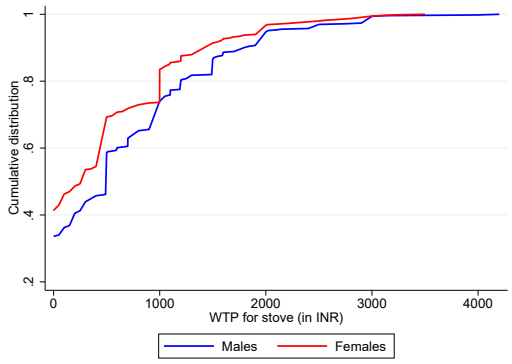
Figure 2: Distribution of bids by gender.



Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

The average bid by female bidders was 521.2 Rupees, which was considerably lower than the average bid of Rs 685.4 put forth by males (Figure 3). This is consistent with other findings in the literature, which suggest that women often have lower willingness to pay due to low intra-household bargaining power, even for goods for which they have stronger preferences (Alem et al., 2018). Still, naive comparisons of bids submitted by women and men may be confounded by bidder selection, since bidder gender may be correlated with other household characteristics that are related to lower demand.

Figure 3: Cumulative distribution of bids placed by women and men.



Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

In fact, we do find evidence of selection on bidder gender. Socio-economic characteristics of households with male and female bidders are systematically different (Table 2). Besides being mostly from female-headed households, female bidders come from significantly poorer households than their male counterparts.[4] On average, the shares of household heads who were salaried individuals or had been in school until at least grade 10 were lower among households with female bidders, and only about 5 percent of female bidders were salaried employees as compared to 56 percent of male bidders. Female bidders were also younger on average than the male bidders, and fewer female bidders had completed schooling up to grade 10. These various differences may partly explain why bids from female bidders are lower than those from males: In particular, not having a source of steady personal income and lack of education may depress willingness to pay by the female bidders in our sample.

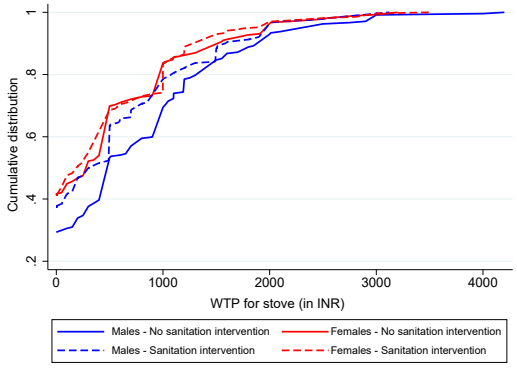
Low bids for the improved cook-stoves may also indicate a lack or lower level of information

[4]Households' economic status is captured through a wealth index created from the first principal component of a Principal Component Analysis of household assets.

about the benefits of using health-improving measures among female bidders. We do not find differences in the proportion of male and female bidders exposed to the prior CLTS sanitation campaign, however. In addition to ruling out differences in this prior exposure to health information, the exogenous exposure allows us to study its effect on the willingness to pay for the improved cook-stoves.

As mentioned in Section 2, the assignment of villages to the sanitation campaign was random. This helps us to rule out any possible endogeneity in the administration of the original intensive behavior change campaign. To check whether the villages across the campaign assignment groups remained similar in 2016 on dimensions unrelated to sanitation coverage, we examine a set of village, household and bidder level characteristics across these formerly treated and control villages. In particular, we estimate an ordinary least squares (OLS) regression model in which the dependant variable is an indicator variable that takes a value 1 if a village was administered the CLTS campaign and is 0 otherwise. The covariates for this regression include a set of village, household and bidder characteristics (Table 7 in Appendix). We find that characteristics across these two sets of villages were generally similar even in 2016, but that individuals from the villages exposed to the CLTS campaign submitted different bids. Parsing the data by gender, we observe that men from villages that were not exposed to the CLTS campaign placed higher bids compared to men in treated villages. Women on the other hand submitted comparable bids irrespective of whether or not they resided in villages exposed to the CLTS campaign (Figure 4).

Figure 4: Bid distribution by gender and sanitation campaign.



Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

Table 3: Household and individual characteristics of female and male bidders.

Characteristics	Male bidders	Female bidders
Household wealth index	0.14	-0.10*
	(2.14)	(2.25)
Female household head (%)	9.57	22.12***
	(29.45)	(41.54)
Household size	8.74	8.13***
	(3.73)	(3.62)
Bidder's age (years)	46.08	39.74***
	(13.95)	(10.30)
Bidder completed grade 10 (%)	45.84	34.28***
	(49.88)	(47.51)
Salaried bidder (%)	56.28	4.93***
	(49.66)	(21.66)
Head's age (years)	55.57	54.27
	(14.27)	(14.53)
Head completed grade 10 (%)	31.77	29.74
	(46.61)	(45.75)
Salaried head (%)	52.03	46.35*
	(50.01)	(49.91)
Access to daily electricity (%)	28.54	29.56
	(45.21)	(45.67)
Exposed to sanitation campaign (%)	51.01	49.45
	(50.04)	(50.04)

Standard deviations in parentheses. $p < 0.10$, $p < 0.05$ and $p < 0.01$. Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

In two villages, there was actually a tie between the highest bids. In such cases, both bidders won and could purchase a cookstove at the next (third) highest price. Besides these deviations, in some villages, the highest bidders also refused to pay the winning amounts for the stoves in their locations. In such situations, the next (second) highest bid became the winning bid and the bidder was then required to pay the next (third) highest bid. If the second highest bidder also refused to pay, the next highest bid became the winning bid and so on. There were a total of 24 such incidents, in which a declared winner (or replacement winner) refused to pay. Of these 24 bidders, 46 percent were women and 13 percent came from female-headed households. These shares are not substantially different from the shares of female bidders and bidders from female headed households in the full sample (53, and 16 percent, respectively). Since, the sample of households that did not pay for the cook-stoves after winning the auction do not seem to vary considerably from the full sample in terms of these key characteristics, all results presented in Section 5 include the full sample. Still, given the rate of defection from the rules of the auction, it is possible that the bid distributions somewhat overestimate real demand in this sample.

4 Empirical Strategy

Despite the defections described previously, the use of the Vickrey second price auction mechanism should help minimize the likelihood that participating individuals would bid anything other than their true valuation. Although the shares of female and male bidders in our sample were comparable, we showed above that the bids submitted by women were systematically lower than those submitted by men. Also, the share of female bidders was substantially higher for households with female heads than for male-headed households. Yet Table 1 also makes evident that the household characteristics of households with female bidders were different from those with male bidders. This raises the possibility that selection bias might result from households of a specific type (e.g., lower or higher valuation) systematically being represented by bidders of a certain gender, causing the gender of the bidder to be endogenous. Estimations using naive OLS regressions - which we provide only as a starting point in our analysis below - could then result in inconsistent and biased estimates.

In order to better account for this possibility, we use propensity score matching (PSM) algorithms to match households having differently gendered bidders. More specifically, for each household with a female bidder, we construct a counterfactual from the households with male bidders. We use observable household and village characteristics in this matching procedure to generate propensity scores to match these households.[5] We use a logit model to compute the propensity scores, and use two different PSM algorithms to check the consistency of the approach: Kernel and Radius matching with replacements. The Kernel matching algorithm matches each of the female bidder households in the common support to a weighted average of counterfactual households, where the weights are a function of the propensity score distance between the female bidder household and the male bidder household.[6] The radius matching algorithm, in contrast, matches each of the female bidder household in the common support with an equally weighted average of the counterfactuals within a given caliper, or a limit on the maximum distance between the propensity score of the female bidder household and its counterfactuals. T-tests and Pseudo R^2 are used test the balance in the characteristics of the matched samples (Caliendo and Kopeinig, 2008). We then estimate the following OLS regression for the matched households using the weights generated by each of the PSM algorithms (Equation 7).

$$b_{ij} = \ _0 + \ _1 G_{ij} + \ _2 D_j + \ _3 G_{ij} \quad D_j + \ _4 X_{ij} + v_{ij} \tag{7}$$

where, b_{ij} is the auction bid amount submitted by individual i in village j; G_{ij} is the gender of the bidder; D_j is a treatment indicator variable that takes a value of 1 if the village j received the sanitation campaign in 2005 and, X_i is a vector of bidder level characteristics.

To further examine the possible reasons for different bids placed by individuals in the group originally treated by the sanitation behavior change intervention, and in line with our ana-

[5] A critical assumption used is that of Conditional Independence which assumes that all characteristics that determine the bidder's gender and the bid are observable and included in this procedure (Caliendo and Kopeinig, 2008). We use characteristics such as household level wealth index, household size, the square of household size, gender of the household head, an indicator for the household head having completed grade 10, an indicator for the household head being a salaried individual and an indicator for the household having daily access to electricity.

[6] We use weights based on the Normal distribution with mean centred around the propensity score of the female bidder household.

lytical framework discussed previously, we next constructed an "abandonment" variable A_j that captured the status of latrine ownership among households in 2016. More specifically, A_j is an indicator variable that takes a value of 1 if any household that stopped using latrines whether households were in the CLTS group or not. This was much more likely in the CLTS villages as described previously. For all other situations, A_j takes the value 0. This abandonment A_j is clearly an endogenous regressor in an estimation of the demand for the electric stoves, so we instrument it with D_j as described below. In addition, as A_j is a binary variable, we use a probit model to estimate the following first-stage equation to avoid estimating a 'forbidden regression' (Wooldridge, 2010). '

$$A_j = \ _0 + \ _1 D_j + \ _2 X_{ij} + v_{ij} \tag{8}$$

We then use the predicted values of A_j, $\widehat{A_j}$ to estimate the following two-stage least squares model.

$$b_{ij} = \ _0 + \ _1 G_{ij} + \ _2 \widehat{A_j} + \ _3 G_{ij} \quad \widehat{A_j} + \ _4 X_i + u_{ij} \tag{9}$$

More specifically, the average bid placed by men in households that adopted a latrine and did not abandon it was about 688.9 Rupees, while that placed by men in households that adopted a latrine and later abandoned it was about 539.5. Meanwhile, the average male's bid in households that never adopted latrines was 700.7 Rupees. In comparison the average bids placed by women in these three categories were about 514.06, 611.2 and, 520.9 Rupees, respectively.

5 Results

We first present the naive OLS estimates for two specifications of equation 7, the first of which includes only bidder gender and controls, and the second that adds in the prior sanitation campaign exposure and its interaction with bidder gender. In both specifications, the coefficient on the female gender is negative and significant, suggesting that women, on average, bid lower than males. We further find that the coefficient on the sanitation campaign

variable is negative and significant, but that bids by women in sanitation campaign villages are much more comparable to those of their male counterparts (Table 3). As mentioned before, these estimates may suffer from selection bias, however, since the gender of the bidder is correlated with many other household characteristics that may also affect bids. Other controls in these models were not found to be significant predictors of the auction bids.

Table 4: OLS Regression results.

Dependent variable	Bid amount Model 1	Bid amount Model 2
Female bidder (d)	-206.58***	-274.19***
	(63.34)	(81.32)
Sanitation campaign (d)		-201.11**
		(82.89)
Female bidder (d)		
Sanitation campaign (d)		142.26*
		(82.36)
Other controls	Yes	Yes
N	963	963
Adj R squared	0.024	0.033
Root MSE	735.82	733.02

Clustered standard errors at village level are given in parentheses. $p < 0.10$; $p < 0.05$ and $p < 0.01$. The covariates include household level wealth index, household size, square of household size, household head's gender, household head's age, household head having completed grade 10, household head being salaried individual, household having daily access to electricity, bidder's age, bidder having completed grade 10 and bidder being salaried individual.Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

Despite this concern about potential selection, results obtained after matching female and male bidder households on observable household and village characteristics present similar patterns. The coefficient for the gender of the bidder being female is negative and significant suggesting that on average women bid about 274 Rupees lower than men for the improved stoves, which is similar to the OLS estimate. Also similar to the OLS results, the coefficient on the sanitation campaign dummy variable is negative and significant, and similar

in magnitude to that obtained using OLS. The coefficient on the interaction of the indicators for female bidder gender and prior exposure to the sanitation campaign is positive and also similar to that obtained from OLS, though it is somewhat imprecisely estimated. In other words, the bids of female bidders from villages which received the CLTS campaigns are comparable to those of male bidders (Table 4), while they are much lower in the non-CLTS villages, confirming the descriptive results obtained in Section 3. Moreover, these results are consistent across both matching algorithms.[7]

These results and those shown in Figure 4 indicate that it is actually the lower bids placed by men in villages exposed to the CLTS campaign that are comparable to those placed by women. So, what is it about these CLTS villages that reduces men's bids? The two-stage least square estimates suggest that men in households that abandoned are the ones for whom bids are similar to those of women (Table 5). The instrumental variable estimates again show that women place lower bids than men. Yet the coefficient on the instrumental variable estimate for abandonment is strongly negative (though it is also imprecisely estimated). These results reaffirm the predictions of the theoretical framework discussed in Section 2, and indicate the possibility of a backlash that might impede adoption of the electric stoves.

[7]We also corrected for potential selection over unobserved characteristics using the Heckman correction method (Heckman, 1976). We do not find that selection of bidder gender is related to unobservable characteristics, since the correlation between the errors of the first stage and the second stage regressions given by is relatively modest (Table 8 in Appendix).

Table 5: OLS Regression results after Propensity Score Matching over gender of the bidder.

Dependent variable: Bid amount	Radius matching	Kernel matching
Female (d)	-257.59***	-252.99***
	(77.27)	(77.08)
Sanitation campaigns (d)	-209.23***	-198.63***
	(67.62)	(67.57)
Female (d)		
Sanitation campaigns (d)	139.19	128.91
	(94.68)	(94.73)
Bidder's characteristics	Yes	Yes
N	944	944
Adj R squared	0.026	0.026
Root MSE	726.34	726.81

Clustered standard errors at village level in the parentheses. * p¡0.10; ** p¡0.05; p¡0.01. (d) indicates a dummy variable that takes the value 0 and 1. The covariates used for matching include household level wealth index, household size, square of household size, household head's gender, household head's age, indicator for household head having completed grade 10, indicator for household head being salaried individual, indicator for household having daily access to electricity, and the number of households dwelling in the village. Additional controls include bidder's age, bidder having completed grade 10 and bidder being salaried individual.Figures are based on the authors' calculations. Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

Table 6: Backlash effects through latrine abandonment: IV regression estimates

Dependent variable	Abandonment (Probit)	Abandonment (First-stage)	Female Abandonment (First-stage)	Bid amount (Second-stage)
Female (d)	0.27*	0.00	0.00	-208.64***
	(0.14)	(0.02)	(0.02)	(74.42)
Sanitation campaign (d)	1.21***			
	(0.20)			
$\widehat{Abandonment}$ (d)		1.09***	0.00	
		(0.26)	(0.03)	
Female (d) $\widehat{Abandonment}$ (d)		-0.07	1.01***	
		(0.29)	(0.26)	
$\widehat{\widehat{Abandonment}}$ (d)				-1060.03**
				(559.48)
Female (d) $\widehat{\widehat{Abandonment}}$ (d)				380.97
				(487.07)
Other controls	Yes	Yes	Yes	Yes
N	963	963	963	963
Pseudo R squared	0.18			
Adj R squared		0.09	0.14	
Root MSE		0.25	0.19	759.13
Wald chi squared	85.69			61.97

Clustered standard errors at village level are given in parentheses. $p < 0.10$; $p < 0.05$ and $p < 0.01$. The covariates include household level wealth index, household size, square of household size, household head's gender, household head's age, household head having completed grade 10, household head being salaried individual, household having daily access to electricity, bidder's age, bidder having completed grade 10 and bidder being salaried individual.Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

6 Discussion

HAP is the fourth largest cause of mortality in Asia and sub-Saharan Africa. For decades, governments and private agencies have struggled to increase the uptake of improved cook-stoves in these regions. Often, factors such as lack of community participation, technology that is insufficiently tailored to local preferences, poor implementation, and lack of training are highlighted as major roadblocks to the success of the cook-stove programmes (Urmee and Gyamfi, 2014). In recent times, the differences in preferences for improved cooking technologies by gender has similarly been identified as one of the critical factors that determine adoption of these technologies. Higher preferences for these technologies can be driven by the disproportionate sharing of HAP related risks. Willingness to pay by women for such technologies is however off-set by low authority to make purchase-based decisions (Miller and Mobarak, 2013; Alem et al., 2018). We find similar patterns for the willingness to pay for cook-stoves in our sample. Female bidders placed significantly lower bids compared to their male counterparts. These bids proxy for true willingness to pay and indicate that women are therefore less likely to adopt clean technologies with a positive price. Yet, targeting men for such policy interventions is not ideal as they may not prefer these technologies to the extent that women do. Therefore, besides increasing awareness through information, it is imperative to address the low intra-household bargaining power which prevents women from opting for less polluting technologies. These choices in turn have implications for public health and environment. Recognising this, the Indian government recently took a step to leverage the female preference for liquefied petroleum gas (LPG) and improve the women's access to household finance through a nation-wide programme called *Pradhan Mantri Ujjwala Yojana (PMUY)*. The eligible beneficiaries of the PMUY were women belonging to the below poverty line households.This programme provided subsidised LPG connections to these women.[8] Subsidized domestic LPG users in India are required to pay the market price for refill cylinders. The subsidy is directly remitted into the bank account of the users. PMUY required its beneficiaries' bank accounts and unique identity numbers to be linked to their LPG connection to ensure that the subsidy can be transferred directly to the women. In this paper, we find that another exogenous health intervention in the form of a sanitation campaign administered a decade prior to the stove auction seems to have depresses men's

[8]The subsidy provided per new connection under PMUY was 1600 INR.

willingness to pay for the improved cook-stove. Backlash due to latrine abandonment by households appears to be the primary cause for effects. However, due to lack of data that captures preferences or extent of household bargaining power that women have, we cannot infer about the possible interaction between policy failure and these factors Nonetheless, our results indicate that evaluating health policy outcomes independently may underestimate the possible complementarities or substitution that exist between different policy instruments. This in turn points to the possibility of achieving better outcomes for cook-stove (and other similar) programmes through combination with efforts to increase awareness and augment women's say within the household. It brings us to the puzzle of designing optimal policies and targeting them efficiently. Existing literature presents mixed evidence, consequently, there is no one unique way of designing policy instruments (Köhlin et al., 2011).

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A Appendix

Table 7: Ex-post balancing of characteristics across villages that were and not exposed to the sanitation campaigns in 2006

Dependent variable	Sanitation campaign
Household wealth index	-0.01
	(0.01)
Female household head (d)	0.06
	(0.07)
Household size	0.01
	(0.01)
Bidder's age (years)	0.00
	(0.00)
Bidder completed grade 10 (d)	-0.01
	(0.05)
Salaried bidder (d)	0.08
	(0.05)
Head's age (years)	0.00
	(0.00)
Head completed grade 10 (d)	0.01
	(0.04)
Salaried head (d)	0.02
	(0.06)
Access to daily electricity (d)	0.07
	(0.18)
Female bidders (d)	0.02
	(0.05)
R2	0.14
RMSE	0.50
N	963

Coefficients estimated using an OLS model. Clustered standard errors at village level in parentheses. $p < 0.10$, $p < 0.05$ and $p < 0.01$; (d) indicates a dummy variable. Figures are based on the authors' calculations.
Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

Table 8: Heckman two-step estimation results.

Dependent variable	Bid amount (Second stage)
Female (d)	-196.11**
	(76.89)
Sanitation campaigns (d)	-202.35**
	(82.48)
Female Sanitation campaigns	141.99*
	(82.80)
Other controls	Yes
	Female bidder (First stage)
Female household head (d)	1.15***
	(0.16)
Bidder' age (d)	-0.03***
	(0.01)
Bidder' completed grade 10 (d)	-0.70***
	(0.16)
Salaried bidder (d)	-2.61***
	(0.17)
Other controls	Yes
Log pseudolikelihood	-8096.79
Wald test of independence p-value (chi2)	0.64
atanh( )	-0.06
	(0.07)
N	963

Clustered standard errors at village level in the parentheses. $p < 0.10$; $p < 0.05$; $p < 0.01$. (d) indicates a dummy variable that takes the value 0 and 1. The covariates in the second-stage include the household level wealth index, household size, square of household size, household head's age, indicator for household head having completed grade 10, indicator for household head being salaried individual, indicator for household having daily access to electricity, and the number of households dwelling in the village. The covariates in the first stage include household level wealth index, household head's gender, household head's age, indicator for household head having completed grade 10, indicator for household head being salaried individual, bidder's age, indicator for bidder having completed grade 10, indicator for bidder being salaried individual. Figures are based on the authors' calculations.

Source: Follow-up data and stove auction data collected in Odisha, India during 2016.

Auction Script (2016)

Introduction
Thank you for your participation. I will first provide some information about the stove and with your permission, conduct a demonstration. Then I will tell you about an auction in which you will have a chance to purchase this stove.

Benefits of the Stove *(Please show the stove to the respondent)*
This stove uses electricity to cook food. Have you ever seen or heard about this kind of stove before? Since you do not have to burn biomass, it produces a lot less smoke than a traditional chulha. The stove will increase your electricity consumption, but it is a much healthier cooking technology than the traditional chulha, because you and your children do not inhale smoke, which can be dangerous to health. This stove uses between 100-2000 Watts and can cook a full meal for 5 people in around an hour and a half. It can boil water for tea in under one minute. You need to use special cookware (utensils) with the stove, and you need to be careful not to damage it. This cookware should be flat and made of steel.

Stove Demonstration: *If electricity is available, please demonstrate how to use this stove, perhaps by brewing tea.*
Whether demonstrated or not, please emphasize the following points:

- The up/down buttons control the wattage or how much electricity your stove is using.
- The menu button switches the mode of cooking. You can cook everything on the pressure cooker mode.
- Before unplugging the stove, you must wait for the fan to turn off. If you turn off the stove prematurely, you may shorten the lifespan of the stove.
- When the stove is in use, make sure no cookware touches the portion of the stove with the controls.

Demand Elicitation
Now I want to tell you about the promotion. You and around 25 other households in this village have been selected to participate in this promotion have the chance to join an auction to win this stove. Here is how the auction works.

I am going to ask you what price you would be willing and able to pay for this stove. The household that gives the highest bid will win the stove, but he/she will only pay the second highest price. This is to ensure that if you win you are still happy with the price you finally pay, which is lower than what you would be willing to pay. If you think about this auction, I think you will conclude that you should tell the truth about your willingness to pay. If you bid lower than your true limit, you may lose the chance to obtain the stove because someone else may outbid you. If you bid higher than your true limit, you might win and then end up having to pay more than you really want to.

For example, let's pretend we were playing this game with my pen. Pretend that you really liked my pen and that you said you would pay 20 rupees for the pen. Your price was higher than all of the other prices that the households gave. The next highest person said they would pay 5 rupees. In that case, you would purchase the pen, because you gave the highest price, but you would only have to pay 5 rupees (the cost of the second highest price). After I have visited all 25 households in this village, I will return two days later to deliver the stove to the winner and collect the payment. The winner will also be given a free set of utensils *(show to respondent)* to use with the stove. This stove comes with a one-year warranty. If you face any problems with the stove during this time, you may take it to any Prestige outlet for repairs or a replacement. If you are the winner, you must be ready to pay for the stove at that time (two days later). Do you have any questions about how this auction works? Remember that the person with the highest bid wins the stove, but that they pay the price of the second highest bid.

Questionnaire ID: _____ **Date: _ _ / _ _ / _ _ (DD/MM/YY)**
Village: _____ **Time: _____**

Name of Respondent: _____ **Phone number: _____**

Respondent ID: _____ **Salesperson ID: _____**

Consent
Greetings! My name is _____, and I am working for CTRAN-Consulting and Duke University in North Carolina in the U.S.A. CTRAN Consulting is a research firm in India and Duke University is an academic research organization based in the U.S.A.

Greetings! I am a salesperson working with CTRAN Consulting. Recently, a researcher came to ask you some questions about the health of your household. I am here to promote induction stoves in this village, which produce much less smoke than a traditional chulha. Because you participated in the survey with us a few days ago, you were selected to participate in this promotion. There is no requirement to participate if you do not want to; just let me know at any time if you are not interested. The purpose of this part of the study is to understand demand for products like this induction stove, which may be beneficial to your household's health and your community's environment.

Your participation in this part of this study is completely voluntary. If you decide to participate in this study, I will make a brief five-minute presentation about the benefits of this induction stove. At the end of my presentation, I will explain an auction, which you have been selected to participate in, in which you may win the opportunity to purchase one of these technologies. You will not be required to pay anything for this demonstration and are not required to purchase the technology either. You can stop your participation at any time. All information you provide will be kept confidential, that is, your name or other identification will not be associated with your answers to the questions. As part of this study, if you win the auction, you will be able to purchase this induction stove. There is no other direct compensation for participating in this part of the study.

C.1. Are you willing to participate in this part of the study and answer a few questions about your demand for induction stoves?
[0] No *(Enumerator: Thank you for your time! Terminate interview)*
[1] Yes

1. What is the price that you would pay for the stove? _____Rupees *(Investigator: Please confirm the price with the respondent)*

2. Only ask if "0" was the respondent's answer to 1. Why do you not want to purchase this stove?
[0] I am not connected to electricity
[1] Electricity is very expensive
[2] I am not sure this is a good product
[3] I like my current cooking option
[95] Other, specify: _____

Thank you! If you have the winning bid, I will inform you at the end of my visit today and return in two days to deliver the stove.

Salesperson observations

On the accompanying roster, please circle the ID of the household members that were present during the sale. If there were new household members, please record their name to the roster. If they were neighbors or friends but not members of the roster, do not add them to the roster. Also indicate (1) if the person made the decision about the price. You may select multiple 1 if the decision was made jointly.

3. How many adults were present while you were showing this stove? _____Males _____Female
3a. Were all of these people members of this household?
[0] No
[1] Yes
[-9] Don't know/not sure

4. What was the gender of the person that decided the price of the bid for the stove?
[1] Male
[2] Female
4a. What is the person ID? ____

Only answer 5-7b if there was more than one household member present while presenting the stove.

5. Was there any discussion or conflict about the price of the bid that the household should give?
[0] No *(Finish)*
[1] Yes

6. What was the gender of the person who wanted to offer a higher bid?
[1] Male
[2] Female

6a. What was the price that this person wanted to offer? _____ Rupees

6b. What is the person ID? ____

7. What was the gender of the person who wanted to offer a lower bid?
[1] Male
[2] Female

7a. What was the price that this person wanted to offer? _____ Rupees

7b. What is the person ID? _____

Questionnaire ID:_____

Respondent ID:_____

Salesperson ID: _____

Date: _ _ / _ _ / _ _ (DD/MM/YY)

Return visit

Congratulations! You had the highest bid for this stove of _____ Rupees. The second highest bid for this stove was _____Rupees. Please pay me _____Rupees *(second highest bid)* for this stove.

1. Did respond pay the second highest bid price for the stove?
[0] No
[1] Yes *(Thank you! I hope that you enjoy using this stove. End interview)*

2. Can you please tell me why you are unwilling to pay ____ Rupees *(second highest bid price)* for the stove?
[1] I am no longer interested in this stove
[2] I do not have the money to pay for the stove right now *(skip to Q4)*
[3] I can't actually afford the stove at that price *(skip to Q5)*
[95] Other, specify: _____

3. Can you please tell me why you are no longer interested in this stove? *(Circle all that apply)*
[1] Do not have adequate electricity supply to support it *(skip to Q5)*
[2] My family/friends convinced me it was not a good idea *(skip to Q5)*
[3] Unfamiliar with how to use the technology / not sure it will work *(skip to Q5)*
[4] Cannot afford this stove *(skip to Q5)*
[95] Other, specify: _____*(skip to Q5)*

4. Is there a time in the next few days that I could return to give you time to collect the money?
[0] No, I will not have the money ready
[1] Yes, record date: _____ *(end interview and return to household on specified date)*

5. I understand. Could you tell me the actual price that you would be willing to pay for this stove? I will not ask you to purchase the stove at this price—I am just trying to understand your actual demand for this stove?
_____Rupees
[-88] Refused to answer

Thank you for your time.

Enumerator:
If the respondent refused to pay, please visit the household with the second highest bid and repeat this process. Note that now the price that you will ask the household to pay is the third highest bid.