Where There's Smoke…: Measuring Preferences for Improved Cookstove Attributes using Choice Experiments in Northern Ghana

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Abstract

Nearly 3 billion people cook over open fires on a daily basis. This behavior impacts local and regional air quality, global climate, and human health. A wide variety of cleaner burning cookstove technologies have been developed worldwide, but, as with many development challenges, inadequate attention to local preferences and needs has contributed to many failed cookstove interventions. At the outset of a randomized cookstove intervention study in Northern Ghana, a set of choice experiments was conducted with study households to assess demand for cleaner stove technologies in general and for specific stove attributes. Results show relatively high demand for reduction in smoke from cookstoves as well as reduction in fuel use, while households placed relatively little value on reducing cooking time, and did not indicate a preference for domestically-made (as opposed to imported) stoves. We also observe significant heterogeneity in stove preferences, with some of this variation related to observed covariates, including respondents' education and occupation as well as current cooking practices. Follow up analyses will assess how these stated preferences measured before the cookstove intervention are related to subsequent stove use, satisfaction, and willingness to pay measurements.

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I. Introduction

Cooking with biomass over open fires is a widespread practice throughout much of the developing world. Wood, dung, agricultural residues, and coal produce large amounts of respirable particles, carbon monoxide, and other toxic pollutants when used to fuel simple cooking stoves (Smith 1987). A growing body of evidence links household air pollution (HAP) to acute lower respiratory infections in young children and chronic obstructive pulmonary disease and lung cancer (for coal) in adults (Ezzati and Kammen 2001; Smith et al. 2004). Biomass cooking also impacts regional and global climate through black carbon particulates and other emissions (Bond et al. 2004). Furthermore, gathering fuels is a time-consuming activity in locations where environmental damage has often already made resources scarce. This time burden, which falls disproportionately on women, could be better spent on domestic care or income-generating activities, aggravating the problem of "time poverty" (Blackden and Wodon 2006).

The Global Alliance for Clean Cookstoves, a public-private partnership currently entering its second phase of "investment and innovation", has set a goal to foster the adoption of clean cookstoves and fuels in 100 million households by 2020 (Anthony 2010). However, while a multitude of technologies exist that could potentially address the suite of problems linked to current biomass cooking practices, efforts to disseminate these technologies and promote changes in cooking behaviors have often fallen short (Hanna et al. 2012; Smith et al. 2014). Indeed, low adoption rates of seemingly efficient technologies is not unique to the cookstove problem – examples range from bed nets to fertilizer to deworming drugs, and a variety of explanations have been proposed (Kremer and Miguel 2007; Cohen and Dupas 2010; Conley and Udry 2010), suggesting that single, simple solutions are not realistic. Certainly, cooking is both a mundane daily activity and a deeply cultural, ingrained behavior. Therefore, promoting behavior change and adoption of new cooking technologies requires an understanding of households' needs and preferences. We must examine the costs and benefits for households considering a switch to a cleaner cooking technology, relative to their existing cooking practices. A better understanding of these drivers of demand can direct more effective cookstove interventions and scale-up efforts that match technologies to the needs and preferences of local users.

This paper reports on the results of a discrete choice experiment we conducted in the context of a clean cookstove intervention launched among a sample of 200 homes in Northern Ghana in 2013. We measured respondents' preferences for five different attributes of improved cookstoves: smoke emissions, fuel use, cooking time, place of manufacture (imported or domestic), and cost. Results indicate that cooks in this region demonstrate the strongest preference for stoves that reduce smoke emissions, and, to a somewhat lesser degree, reduce fuel use. Demand for faster cooking times is lower, and respondents did not express a strong preference for either domestically made or imported stoves. Heterogeneity in preferences for stove attributes is also observed among respondents, with some (but not all) of this variation linked to observed respondent characteristics including education and the number and types of stoves used prior to the intervention. Follow up analyses will assess how these stated preferences measured before the cookstove intervention are related to subsequent stove use, satisfaction, and willingness to pay measurements.

II. Background

Interventions to reduce HAP exposure may be separated into three categories: those addressing the *source* (e.g., improved cookstoves), the *living environment* (e.g., improved ventilation), and *user behaviors* (e.g., proper stove maintenance) (Ballard-Tremeer and Mathee 2000). Thus far, most interventions that have been evaluated systematically have targeted emissions sources. These studies have found somewhat mixed results across different communities and geographic regions. For example, in Kenya, cheap ceramic wood-burning stoves without chimneys were able to reduce daily particulate matter (PM) concentrations by up to 50%, although overall pollutant levels remained significant (Ezzati et al. 2000). In the same study, it was also noted that charcoal stoves provided the largest reduction to emission concentration (and therefore are likely to provide the greatest benefit to public health) but are also more environmentally damaging. The well-known RESPIRE study provided an improved chimney woodstove to households in highland Guatemala and saw encouraging results, finding a significant reduction in carbon monoxide exposure for groups receiving the clean stove over an 18 month period (Smith-Sivertsen et al. 2009).

On the other hand, studies in India and Nepal featuring stoves with chimneys varied in their effectiveness in reducing PM (Smith and Aggarwal 1983; Pandey et al. 1990). Randomized trials of a locally-made mud stove in India observed disappointing initial adoption and maintenance rates and, in the long run, failed to reduce exposure to dangerous air pollutants (Hanna et al. 2012). These authors specifically contrasted their intervention with the RESPIRE study and argued that they provided households with greater ability to reveal their valuation in usage rates: stoves were locally made and significantly cheaper, were not inspected weekly (Smith et al. 2009), and were followed for a longer period of time. In response, Kirk Smith argued that the Indian "improved" stove was not truly an improvement over existing technologies since it failed to alter combustion and reduce smoke in any meaningful way (Smith 2012).

This debate highlights the fact that, while much attention and effort have been devoted to engineering better and cleaner-burning stoves, households' adoption and stove use behaviors are also an important determinant of the success or failure of any stove intervention. Yet systematic attention to the determinants of stove adoption has been relatively low (Lewis and Pattanayak 2012). Moving forward, there is a need to understand what features of cookstoves appeal to consumers. That is, what kinds of stoves would truly be perceived as offering desired improvements over the status quo, such that households would be willing to pay for and use them sustainably over time? For example, although interventions are often motivated by public health concerns, household-level demand for health improvements alone may be low (Pattanayak and Pfaff 2009). Stated preference measures have seen relatively little application in these contexts, but they can provide a first indication of households' willingness to pay (WTP), particularly in locations where improved stoves are not currently available. A recent nationally representative survey of rural households in Bangladesh demonstrated that stoves are considered to be near the bottom of household expenditure priorities (including infrastructure, education, agriculture, and other health dimensions) and then revealed very low preference for improved stoves based on purchase rates in an offer experiment (Mobarak et al. 2012). This study also uncovered important differences in stove preference by gender: women preferred healthier stoves but lacked the (male) authority to authorize purchases (Miller and Mobarak 2013).

Discrete choice experiments build on prior studies showing low demand for stoves by helping to unpack what particular attributes individuals value (or do not value) in an improved stove. For example, a discrete choice experiment was conducted in India to characterize heterogeneity in household preferences for different stove options and compute willingness to pay (WTP) values for smoke emission reduction, fuel usage reduction, and convenience (Jeuland et al. 2014). They found that households had a strong preference for traditional stoves and had a greater WTP for smoke reduction than for decreased fuel use or increased convenience. These authors also used a latent class approach to identify groups of respondents with varying interest in improved stoves, and use class membership to analyze stove adoption decisions in a subsequent promotion experiment. A DCE approach has also been used in Ethiopia, with additional distinctions for fuel type and household income (Takama et al. 2012), and in Haiti (Sagbo 2014).

Our approach contributes to this line of inquiry in several important ways. First, we are examining stove preferences in West Africa, a region that has not received much focused attention in prior studies of stove adoption behavior. Based on pretesting efforts, we also include location of stove manufacture as an additional attribute in the choice experiments, allowing us to assess whether households have a preference for stoves that are made domestically versus stoves that are imported. We examine heterogeneity in stove preferences using mixed logit models, which allow us to estimate individual-level preferences for stove attributes, and covariate interaction terms. Finally, our stated preference measurements are being conducted in the context of an intervention study, allowing for the possibility of assessing how preferences change over time as experience with new technologies increases. This framework will allow us, in future work, to assess how initial preferences relate to actual stove use patterns.

III. Methods

Study Area

The cookstove choice experiments discussed in this paper were conducted as part of a baseline survey for the Research on Emissions, Air quality, Climate, and Cooking Technologies in Northern Ghana (REACCTING) study (Dickinson et al. In review). This study involves 200 rural households in the Kassena-Nankana (K-N) District in Northern Ghana (Figure 2), located in northern savanna vegetation zone dominated by woody shrubs and grassland. The climate in this region is generally hot and arid, with a single rainy season lasting from approximately May to October. Much of the land is used for subsistence agriculture, with the dominant crop being millet.

The district has an area of 1,657 km^2 and a population of about 156,000 (Oduro et al. 2012) that is fairly homogeneous culturally. According to data from a district-wide Health and Demographic Surveillance Survey (HDSS) (Oduro et al. 2012), about 80% of households in the district are located in rural areas, while 20% live in areas classified as urban. Among rural households, 88% report using biomass (wood or agricultural waste) as their main cooking fuel, while another 9% rely primarily on charcoal, and only about 3% of households cook primarily with gas or electricity. The traditional cooking method in this area is a three-stone open fire, and cooking is done in both indoor and outdoor areas.

The 200 households participating in the REACCTING study were systematically randomly sampled from the population of the K-N District that met the study eligibility criteria using data from the HDSS. First, eligible households had to report using biofuels (wood, animal waste, or crop residue) as their main cooking fuel source. Second, because the REACCTING study collects data on behaviors and health outcomes among those in closest proximity to cooking activities –i.e., women and children – households had to include at least one woman between the ages of 18-55 and one child under five to be eligible for inclusion.

Using this eligible subpopulation, sample selection proceeded in two phases. First, we randomly selected 25 clusters (geographical units defined for the purposes of the HDSS) using population weighting to determine the number of clusters selected per region: five clusters were randomly selected from the East, six from the North, eight from the South, and six from the West (Figure 1). Next, ten households (eight primary households and two alternates to be used if the primary households could not be enrolled) were randomly selected from the population of eligible households in each of these clusters. Since cooking duties may be shared within compounds and emissions from one household's cooking could affect exposure and health outcomes of other households within the compound, we included a maximum of one household per compound. Given this sampling methodology, our study sample can be said to be representative of the subpopulation of the K-N District that meets our eligibility criteria: rural, uses biofuels as their main cooking source, and has women and young children in the household. Overall, this subpopulation from which our sample was selected includes 59% of all clusters in the district (194 out of 331) and about 20% of all households in the district (5,918 out of 29,403).

Survey and Choice Experiment Design

A baseline survey was conducted in all 200 study households in November/December of 2013 by trained and experienced interviewers who were native speakers of the two predominant local languages, Kasem and Nankam. The survey lasted about an hour and covered several topics including household composition and demographics, attitudes and priorities, cooking behaviors, knowledge and perceptions of health and environmental issues related to cooking practices, demand for new stoves, and self-reported health symptoms. All aspects of the survey, including the choice experiment described below, were extensively pretested in the study area. The full study protocol was reviewed and approved by the Human Subjects Committee at the National Center for Atmospheric Research and the Institutional Review Board of the Navrongo Health Research Centre.

Given that prior studies had observed low levels of demand for improved cookstoves (Hanna et al. 2012; Mobarak et al. 2012), a key objective of the REACCTING study was to understand both overall willingness to pay for stoves in this region and demand for specific stove attributes. A choice experiment was thus included in the baseline survey in order to shed light on what features of stoves respondents cared about (or said they cared about), prior to any exposure to improved cookstove technologies. The design of the choice experiment and selection of stove attributes were informed by a prior cookstove choice experiment conduced in Kenya (Saba, personal communication) as well as the pretesting conducted in our study area. This process resulted in the selection of five attributes for inclusion in the experiment. These attributes were represented to respondents using low-literacy visual materials (see Figure 2). First, since cookstove interventions are often motivated by their potential health impacts, participants' demand for reductions in *smoke* emissions were of key interest. This attribute had two levels: "A lot of smoke" and "Very little smoke." Second, since fuel collection is time consuming and difficult work, households may value stoves that reduce fuel use. Stoves were described as using “A lot of fuel” or “Less fuel.” Third, households may prefer stoves that cook foods faster. Study collaborators familiar with local cooking practices estimated that existing stoves cooked rice, a commonly consumed dish, in about 60 minutes, while we estimated that some of the improved stove models being used in the intervention study might be able to cook rice in approximately 30 minutes. In addition, another feature that varied across the two stove models ultimately being deployed in the REACCTING intervention study were that one was made locally in Ghana, while the other is the Philips Smokeless Stove which was being manufactured at the time in Lesotho. To assess whether or not respondents in this area had an *a priori* preference for stoves made domestically versus imported stoves, we included these places of manufacture as an additional attribute. Finally, stove cost was varied between 15 and 120 Ghanaian Cedis, or roughly US$7 to US$60 at the time of the survey.

Given this set of attributes, we employed the SAS statistical software package to generate an efficient blocked factorial choice design consisting of four blocks of five choice tasks. In each choice task, respondents were given a choice between two hypothetical stoves and a “neither stove” status quo option. A sample choice task is shown in Figure 3.

Data Analysis

To use the choice experiment data to estimate preferences for cookstove attributes, we start from a basic random utility model (McFadden 1978) in which the utility that respondent *i* perceives from stove *j* in choice task *t* is given by:

$$V_{ijt} = \alpha'_{it} X_{ij} + \varepsilon_{ijt} \qquad (1)$$

where X_{ij} is a vector of attributes of alternative *j* potentially cross-multiplied with characteristics specific to respondent *i* and α_{it} is a vector of taste coefficients. Individuals’ utility also has a random component (ε_{ijt}) that is unobservable to the researcher. In this framework, selection of stove *k* means that the utility from *k* is higher than utility from any alternative. That is,

$$\pi_{ikt} = \Pr\left(V_{ikt} > V_{ijt}\right) \forall j \neq k \qquad (2)$$

In the context of our study, we are interested in using this model for two main purposes. First, we wish to estimate preferences and willingness to pay for the four stove attributes (smoke, fuel, time, and place of manufacture). Second, we are interested in whether and how these preferences vary across respondents based on both observed and unobserved characteristics. To this end, our first step is to implement a mixed logit model in which ε_{ijt} is distributed i.i.d extreme value, and the taste coefficients are distributed according to a parametric density function $f(\alpha|\theta)$, where θ is a vector of estimable parameters. The benefit of this approach is that it allows tastes to vary across respondents in a fairly flexible way and allows us to explicitly test whether this heterogeneity exists, and whether it persists when additional control variables are added.

Using the output from these models, we can also estimate taste parameters for each individual respondent. This is accomplished as follows. If all respondents face the choice situation sequence described by attributes X, and some choose alternatives Y, a conditional distribution of coefficients emerges (Revelt and Train 2000; Train 2009). We use $g(\alpha|Y, X, \theta)$ to denote this distribution of α in the sub-population who choose alternative Y, given the choice situation described by X. Using the McFadden random utility model, the probability of an individual i’s sequence of choices Y_i is an integral over the unknown distribution of coefficients α:

$$P(Y_i|X_i,\theta) = \int P(Y_i|X_i,\alpha)f(\alpha|\theta)d\alpha \tag{3}$$

and the conditional distribution can be derived using Bayes' rule, to obtain

$$g(\alpha|Y_i,X_i,\theta) = \frac{P(Y_i|X_i,\theta)f(\alpha|\theta)}{P(Y_i|X_i,\theta)}. \tag{4}$$

Thus we can characterize various statistics which are conditional on the choice sequence Y_i. For example, the mean coefficient for this subpopulation is

$$\bar{\alpha}_i = \int \alpha g(\alpha|Y_i,X_I,\theta)d\alpha. \tag{5}$$

These estimated coefficients do not have a closed form, but can be estimated by simulation, as the population-level coefficients are. We do this using the *mixlogit* package in Stata (Hole 2007), which includes a *mixlbeta* command to compute these individual-level parameters.

Finally, to examine the effects of observed respondent characteristics on stove preferences, we include several household and individual covariates Z_i listed in Table 1. Since these individual-level variables do not vary across alternatives (stoves) within a choice task, their effect must be estimated by interacting these covariates with the stove attributes.

IV. Results

Attribute preferences: Main effects

Table 2 presents results for four different models examining respondents' preferences for the stove attributes included in the discrete choice experiments. In each of these models, the dependent variable records the respondent's choice of stove model in the choice task, while the explanatory values are the attributes of those stoves (*smoke*, *fuel*, *time*, and *made*) and the stove's cost. In addition, all models include a dummy variable for the *neither* stove choice (status quo). The attribute levels for the status quo option were set to the "inferior" levels of all other attributes (high smoke, high fuel, high cooking time, made in Ghana), and the cost of the *neither* option was set to zero. Including a separate dummy variable for the *neither* option allows for the possibility that respondents may have a preference (or dispreference) for the status quo that is not fully captured by these assumed attribute levels.

Model 1 shows results from the conditional logit model. As discussed above, this model imposes the restrictive assumption that the preferences captured by the α coefficients in Equation 1 are fixed across the population, and also imposes the irrelevance of independent alternatives assumption. In contrast, Models 2-3 are estimated using mixed logit specifications that allow the parameters on the attributes to be random. In these models, both the mean and the standard deviation of the attribute coefficients are shown in Table 2. These models also constrain the cost coefficient to be negative using a lognormal distribution for cost (or, more accurately, the negative of the cost level.) Model 2 is a mixed logit specification in which the coefficients on the attributes are assumed to be independently normally distributed. Finally, Model 3 shows the attribute main effects from a mixed logit model assuming independently distributed coefficients (like Model 2), as well as a set of covariate interaction terms shown in Table 3 and discussed in more detail in the next subsection. In this model, preferences for each attribute are a combination of main effects and the many interaction terms (whose coefficients are shown in Table 4), so the main effects on their own do not tell us much about preferences for these attributes.

Examining results across Models 1 and 2 in Table 2, the overall pattern indicates that respondents had the strongest preference for decreases in *smoke* emissions, followed by reductions in *fuel* use. The coefficients on the *time* attribute are also positive and significant, though substantially smaller. The *made* variable indicates whether the stove was made in Ghana versus imported; results show that, if anything, respondents on average have a slight preference for imported as opposed to domestically made stoves. Coefficients on cost are negative and statistically significant, indicating that demand curves for new stoves are downward sloping as expected.

Willingness to pay estimates implied by these coefficients are shown in Table 3. On average, respondents were willing to pay roughly 211 Ghanaian Cedis (about US$100 in 2013) for a stove that reduced smoke, 95 Cedis (~US$45) for a stove that used less fuel, and 24 Cedis (~US$12) for a stove that shortened cooking time. On average, respondents were also willing to pay a small (19 Cedi or US$8) premium for *imported* versus domestically made stoves, though the confidence interval for this estimate includes zero.

The negative coefficient on the *neither* variable in Table 2 indicates that respondents had a general dispreference for the status quo. That is, respondents tended to choose one of the "new" stove options over the status quo at a rate that cannot be explained by the assumed attribute levels alone. Indeed, across the 1000 total choice tasks (5 per respondent times 200 respondents), *neither* was selected only 34 times.

Comparing the conditional and mixed logit models, we see that the standard deviations are large (relative to coefficient values) and statistically significant for all attributes. This suggests that the conditional logit assumption of fixed coefficients does not fit the data well in this case; indeed, goodness of fit statistics (Pseudo-R^2, AIC, and BIC) all indicate that Model 2 is a significant improvement over Model 1.

Using the mixed logit model coefficients from Table 2, we estimated the individual-level coefficients for the stove attributes and plotted them in Figure 4. These plots reinforce the finding that there is significant heterogeneity in preferences for stove attributes across our sample. Interestingly, the *smoke* coefficient shows a clear bimodal distribution of preferences within the population, suggesting that there are two classes of respondents with varying levels of demand for smoke reduction. The *smoke* coefficient is positive in both groups, but substantially higher the larger group. Multiple peaks are also observed for the *fuel* coefficient: it appears that most of the respondents fall into one group with a positive but relatively smaller demand for fuel reduction, while there are possibly one or two additional classes with increased *fuel* demand. Demand for *time* savings appears more concentrated around a single mean, which is positive but small relative to the *smoke* and *fuel* coefficients. Preferences for place of manufacture are also more tightly distributed, and are negative but small, indicating a slight preference for imported stoves among most respondents. The cost coefficient also has a fairly concentrated distribution. Latent class analysis of these data will be used in future analysis to further explore these results.

Attribute preferences: Covariate interactions

To examine preference heterogeneity and its relationship with individual characteristics, we now turn to the coefficients on covariate interaction terms (Table 4). The covariates included in this regression are listed in Table 1. They include the education level of the respondent (primary or above versus less than primary) and the occupation of the respondent (self-employed vs other – primarily agriculture). We also include an indicator for whether or not the household had any children under five. While the study was designed such that all households were supposed to have a child in this age range based on data from the most recent demographic surveillance survey, in about 7% of households the baseline survey indicated that there were no children under five in the household, possibly because the child had passed away or moved. We also include two covariates that capture the household's cooking practices: the total number of stoves being used in the household, and whether or not one of the household's stoves was a charcoal stove or "coal pot." Since all but two households in the sample had at least one traditional three stone stove (which uses wood or agricultural waste), the coal pot variable can be interpreted as an indicator that the household relies on a mix of cooking methods (and fuels). We also include access to a bank account as a socioeconomic indicator, as well as a variable indicating whether or not the respondent said that she commonly experienced headaches while cooking.

We find some evidence that higher socioeconomic status (indicated by self-employed respondents and access to a bank account) is positively related to preferences for reduced *smoke*. Households with a larger total number of stoves also had higher demand for smoke reduction, possibly because the use of multiple stoves exposes individuals to higher smoke levels and worse household air quality. Households owning a coal pots also indicate a higher dispreference for smokiness. Charcoal stoves emit less smoke than traditional wood stoves, and households that already rely on a mix of technologies may be more receptive to new stoves overall and stoves that reduce smoke emissions specifically. Finally, respondents that indicated that they often suffered from headaches while cooking were also more likely to choose stoves that produced less smoke.

Higher socioeconomic status (education and self-employed occupation) also appears to be positively correlated with demand for reduced *fuel* use. A complicated relationship is observed between this attribute and current cooking practices. On the one hand, respondents with a greater total number of stoves were less likely to demand new stoves that reduced fuel use. Having more stoves may indicate that households have easier access to fuel sources. On the other hand, households using charcoal stoves had a greater preference for fuel reduction. Since most of these households must purchase their charcoal, fuel-reducing stoves may be more attractive to them. Finally, respondents who had headaches while cooking were less likely to choose fuel-reducing stoves.

Turning to cooking *time* preferences, we observe that demand for reduced cooking time is positively associated with primary or greater education, and negatively associated with self-employment among survey respondents. Interestingly, households with at least one child under five were much less likely to demand stoves that promised to cook food faster. Households with larger total numbers of stoves had higher demand for reduced cooking time, while this demand was lower among households with access to a bank account.

Overall, the main effect results indicated that respondents did not have strong preferences for either domestically-made or imported stoves. However, we do observe that respondents with a primary or higher education were more likely to prefer the domestically-made stoves, as were respondents in households with a greater total number of stoves. Meanwhile, respondents with charcoal stoves tended to prefer imported stoves.

Only three of the variables examined here were significant predictors of stove *cost* preferences. Self-employed respondents and respondents with children under five were both somewhat less cost-sensitive, while respondents with more stoves had more negatively-sloping (i.e., more elastic) stove demand curves, possibly indicating less need for additional cooking surfaces.

Finally, we noted previously that the *neither* stove status quo option was selected very rarely (in just .34% of tasks) in the choice experiment. The last column in Table 4 shows interactions of covariates with the *neither* dummy variable. These coefficients are quite large due to the fact that there is very little overall variation in *neither* selection, and for this reason we are hesitant to read too much into these results.

V. Discussion

Tackling the challenge of changing cooking practices to reduce household air pollution and related health, environmental, and social problems will require greater attention to the cooking-related needs and preferences of diverse populations around the globe. Discrete choice experiments of the kind we report on in this paper are a promising tool for eliciting these (stated) preferences as a first step toward designing more effective interventions and stove distribution programs.

In contrast with prior studies finding low demand for improved stoves (Hanna et al. 2012; Mobarak et al. 2012), respondents in our study expressed high demand for improved stoves overall. In the choice tasks, respondents almost always selected one of the new stoves over the “neither stove” option, and willingness to pay for stoves overall and specific stove attributes (particularly smoke and fuel reduction) was quite high. There are a few possible explanations for this finding. It may in fact be the case that this population in West Africa is more receptive to this new technology than the populations in South Asia that were examined in the studies cited above. However, as with all stated choice studies, it is also possible that households were overstating their willingness to pay for new stoves in this hypothetical exercise. Interviewers were trained to remind respondents of their budget constraints by telling them that money spent on stoves would not be available to purchase food or other necessities. Nevertheless, it seems likely that households indicated that they would buy these new stoves at a higher rate than we would observe in a revealed preference setting. It is also very important to note that prior to the REACCTING intervention study, no improved biomass-burning cookstoves were actually available in our study area. Lacking any experience with these technologies, it is possible that respondents were overly optimistic about the benefits of these stoves, further leading to high stated willingness to pay values.

Thus, the results presented here are more informative for the relative preferences indicated for the different attributes rather than the quantitative WTP values. Specifically, it is notable that households indicated a high demand for smoke reduction relative to other stove attributes; this finding is similar to what Jeuland et al. (2014) found in their stove DCE in India. While the smokiness of traditional stoves contributes to negative health impacts and is the largest motivator of stove interventions from a public health perspective, other studies and the experiences of prior stove distribution efforts have emphasized that health impacts alone are unlikely to motivate behavior change (Pattanayak and Pfaff 2009; Mobarak et al. 2012). However, it is worth noting that along with longer term health issues like respiratory illness and cardiovascular disease, smoke also bundles more immediate, tangible physical effects such as headaches and eye irritation, along with negative aesthetic impacts of soot, which accumulates on pots and walls. Thus, this finding seems to suggest that noticeable reductions in smoke emissions would potentially hold value for users, though this feature on its own may be unlikely to induce widespread adoption if stoves are not otherwise well-suited to local cooking needs.

These results will be most useful when they are used in combination with data from the ongoing REACCTING intervention study. As noted previously, this study involves distributing two types of new stoves in a randomized manner to the group of households that completed the baseline survey from which the choice experiment data analyzed here were drawn. These two stoves represent two real-world combinations of the attributes we hypothetically and experimentally manipulated in the initial discrete choice experiment: one stove is a domestically-made, inexpensive, but high (or possibly medium) smoke and fuel use model, while the other is an imported, more expensive, and (at least in a laboratory setting) low-smoke and fuel efficient stove. Thus, combining the results presented here with follow-up data from this experiment will enable us to ask several important questions. For example, do the preferences expressed in the initial choice experiment predict subsequent use or and satisfaction with the different stove models? After gaining experience with these two stoves, how do households rate their performance according to the attributes we included in the experiment? How do preferences for these attributes change over time with variation in experience with the different stove models? What other attributes, not captured in the initial experiment, are important to users? Answers to these and other questions will assist in the development of subsequent efforts to design both small-scale interventions and larger-scale programs aimed at scaling up use of cleaner cookstoves in this region.

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Figures

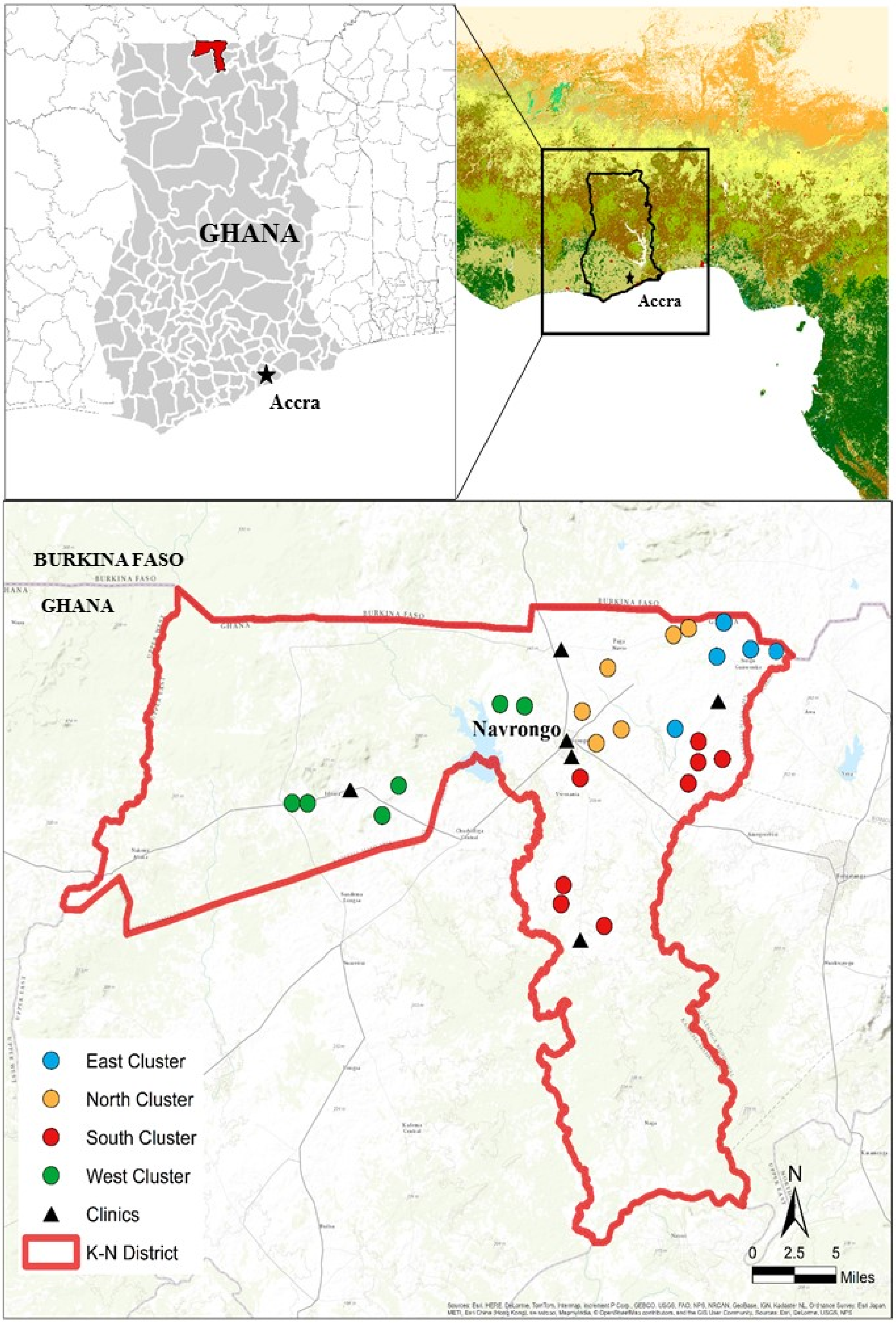


Figure 1: Map of Study Area with Locations of Household Clusters and Health Clinics

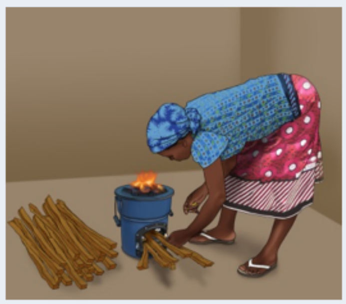
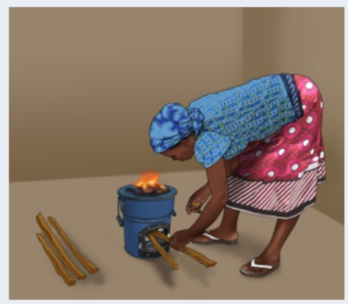
<table>
<tr><th colspan="6">Stove Features</th></tr>
<tr><td>HOW MUCH
SMOKE
DOES THE STOVE PRODUCE?</td><td colspan="2">
A LOT OF SMOKE</td><td colspan="3">
LESS SMOKE</td></tr>
<tr><td>HOW MUCH
FUEL
DOES THE STOVE USE?</td><td colspan="2">
A LOT OF FUEL</td><td colspan="3">
LESS FUEL</td></tr>
<tr><td>HOW MUCH
TIME
DOES IT TAKE TO COOK RICE WITH THE STOVE?</td><td colspan="2">60 MINUTES</td><td colspan="3">30 MINUTES</td></tr>
<tr><td>WHERE WAS THE STOVE MADE?</td><td colspan="2">GHANA</td><td colspan="3">LESOTHO
(Small country in Southern Africa)</td></tr>
<tr><td>HOW MUCH DOES THE STOVE COST?</td><td>15 Cedis</td><td>25 Cedis</td><td>50 Cedis</td><td>80 Cedis</td><td>120 Cedis</td></tr>
</table>

Figure 2: Description of Stove Attributes (Features) Included in the Discrete Choice Experiment

Figure 3: Sample Choice Task from Discrete Choice Experiment

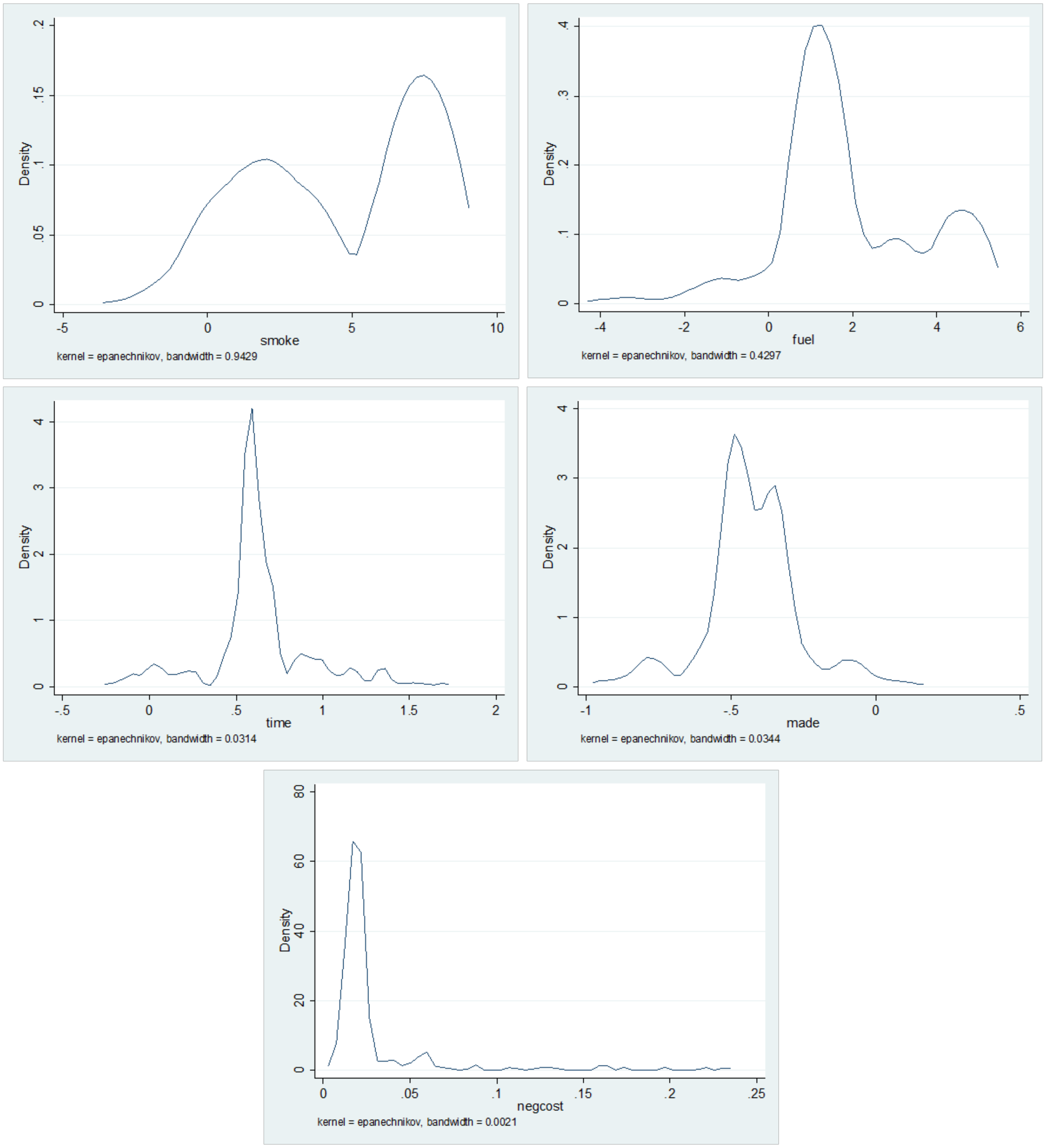


Figure 4: Distribution of respondent-level coefficients for stove attribute preferences

Table 1: Descriptive Statistics for Covariates Included in Choice Models

Variable Name	Description	Descriptive Statistics
rocc_se	Respondent occupation: self-employed vs	54.5%
reduc_primplus	Respondent education: primary or above vs less than primary	58.5%
anykids	Household has at least one child under 5	93%
numstv	Total number of stoves	Mean: 2.58 Median: Range: 1-6
hascoalpot	Has at least one charcoal stove	70.5%
accessbank	Household has access to bank account	22.7%
headache	Respondent reports headaches from cooking	68.7%

Table 2: Results from conditional logit and mixed logit models for discrete choice data

	(1)	(2)		(3)	
	clogit	mixlogit		mixlogit, covars	
VARIABLES	selected	Mean	SD	Mean	SD
smoke	1.47***	4.35***	4.25***	-0.15	9.13***
	(0.000)	(1.0e-10)	(1.5e-08)	(0.97)	(8.1e-06)
fuel	0.73***	1.65***	2.65***	1.88	6.35***
	(0.000)	(4.5e-09)	(4.3e-09)	(0.51)	(0.000027)
time	0.30***	0.63***	-0.87**	7.67**	2.12**
	(0.00041)	(0.0020)	(0.018)	(0.035)	(0.014)
made	-0.092	-0.43*	0.72**	-5.96*	2.79***
	(0.27)	(0.051)	(0.034)	(0.062)	(0.000050)
neither	-1.54***	-3.94***	2.03***	-16.9***	-17.4***
	(0.000)	(1.5e-09)	(1.1e-06)	(0.0035)	(0.000014)
cost[a]	-0.0063***	-4.21***	-1.22***	-4.28***	2.72***
	(5.5e-06)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	2,994	2,994		2,994	
Pseudo R^2	0.25	0.41		0.48	
AIC	1276	1002		940	
BIC	1486	1140		1265	

[a] In the mixed logit models (2) and (3), the cost coefficient is constrained to have a lognormal distribution. p-values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Willingness to pay estimates from discrete choice experiment

	Mean [Range]
smoke	211 [123 – 299]
fuel	95 [49 – 140]
time	24 [3 – 45]
made	-19 [-41 – 4]

Table 4: Covariate interaction terms for discrete choice models (Model 3 in Table 2)

	Smoke	Fuel	Time	Made	Cost	Neither
educ_primplus	-0.20	1.37*	1.95**	3.98***	-0.015	7.68***
	(0.82)	(0.096)	(0.012)	(0.00063)	(0.34)	(0.0036)
occ_se	3.52***	3.62***	-1.63**	-0.40	0.027*	-10.8***
	(0.0027)	(0.0033)	(0.043)	(0.64)	(0.095)	(0.0015)
anykids	-2.99	3.97	-8.92***	0.84	0.044**	-22.6***
	(0.50)	(0.15)	(0.0080)	(0.75)	(0.046)	(0.00015)
numstv	2.32***	-1.66**	0.95**	1.60***	-0.023**	10.7***
	(0.00037)	(0.034)	(0.034)	(0.0028)	(0.020)	(0.000014)
hascoalpot	5.07***	5.35***	-1.39	-2.58***	0.022	-25.1***
	(0.0026)	(0.0018)	(0.14)	(0.0076)	(0.19)	(0.00012)
accessbank	3.31**	-0.59	-1.65*	1.10	0.010	-0.34
	(0.021)	(0.53)	(0.076)	(0.30)	(0.52)	(0.88)
haveheadache	4.00***	-3.58***	0.96	-0.49	-0.00029	-26.8***
	(0.0032)	(0.0038)	(0.19)	(0.55)	(0.98)	(0.000050)