GENDER DIFFERENCES IN PREFERENCES, INTRA-HOUSEHOLD EXTERNALITIES, AND THE LOW DEMAND FOR IMPROVED COOKSTOVES

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Abstract

This paper examines whether an intra-household externality prevents adoption of a technology with substantial implications for population health and the environment: improved cookstoves. Motivated by a model of intra-household decision-making, the experiment markets stoves to husbands or wives in turn at randomly varying prices. We find that women – who bear disproportionate cooking costs – have stronger preference for healthier stoves, but lack the authority to make purchases. Our findings suggest that if women cannot make independent choices about household resource use, public policy may not be able to exploit gender differences in preferences to promote technology adoption absent broader social change.

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1. Introduction

Simple, inexpensive, highly-efficacious technologies exist for many important development challenges, but they are adopted and used at surprisingly low rates. Prominent examples span health (insecticide-treated bed nets, drinking water disinfectants, vegetable protein supplements, and condoms), agriculture (high-yield crop varieties and fertilizer), and finance (savings and insurance). Significant resources have been devoted to promoting the spread of such technologies: nearly a quarter of spending on malaria in 2006-07 went towards promoting bed nets (World Health Organization, 2008), and $60 million of the initial commitment goal of $250 million for the Global Alliance for Clean Cookstoves was allocated to disseminating improved cookstove technologies in the developing world (Smith, 2010).

A variety of explanations have been proposed for low adoption rates of seemingly cost-effective technologies in developing countries. Poor households may be liquidity- or credit-constrained (Gine et al., 2008; Cohen & Dupas, 2010; Dupas & Robinson, 2011; Tarozzi et al., 2011; Cole et al., forthcoming), may not fully understand the benefits of adoption (Feder & Slade, 1984; Conley & Udry, 2001; Gine & Yang, 2009), may suffer from self-control problems (Banerjee & Mullainathan, 2010; Duflo et al., 2011), may adopt at sub-optimal rates due to externalities (Kremer & Miguel, 2007), or may experiment inefficiently little (Foster & Rosenzweig, 1995; Conley & Udry, 2010; Bryan et al., 2011).

In this paper, we study another explanation that has received less attention: gender differences in preferences within households. We hypothesize that male decision-makers may not account for the full costs and benefits of a new technology to other household members when deciding whether or not to adopt it. To examine this, we conduct a set of field experiments with

a technology having the potential to address widespread health and environmental problems: improved cookstoves.

Half of the world's population and 75% of South Asians burn biomass fuels for many hours each day using inefficient, high-emissions traditional stoves (World Health Organization, 2002). The smoke from burning biomass fuels contains high concentrations of particulate matter, carbon monoxide, and other pollutants shown to be highly toxic in animal studies and associated with increased rates of infant mortality and respiratory disease (Ezzati & Kammen, 2001b; Ezzati & Kammen, 2002; Chay & Greenstone, 2003a; Chay & Greenstone, 2003b). The 2002 WHO World Health Report identifies indoor air pollution (IAP) as the single largest environmental risk factor for female mortality, attributing 5% of all female deaths in the developing world to indoor smoke. Black carbon emissions from traditional cookstoves are an important contributor to climate change as well (Bond et al., 2004; Ramanathan & Carmichael, 2008; The New York Times, 2009). Many types of cleaner-burning cookstoves that reduce IAP emissions in laboratory settings have been marketed over the past three decades at reasonably low prices (US$0-20). When adopted and used, these stoves have produced promising results, including reduced fuel consumption and lower rates of eye and respiratory infections (Bensch & Peters, 2012).[1, 2] In many parts of the world, however, they remain unpopular with consumers.

[1] Although sustained benefits of some improved stoves have been called into question, see Duflo et al. (2012), The Washington Post, 2012, and The New York Times, 2012.

[2] Many researchers have referred to stoves built with these new technologies as "improved" cookstoves. However, a recent editorial challenged the "improved" label placed on many cookstoves and suggested that it always be written with quotes to convey the idea that improvements are subjective and that some improvements in performance may come at the expense of reduced performance in other areas (Smith & Dutta, 2011). While we recognize this, for clarity and continuity with other research, we continue to use the label "improved" to distinguish these new cookstove designs from the "homemade" traditional clay cookstoves commonly used in rural Bangladesh.

We study gender and intra-household dimensions of decision-making by conducting a randomized controlled trial that offers the choice of either a health-improving "chimney stove" or a budget-saving "efficiency stove" at randomly assigned price points (free or a positive price). We offer the choice to women (who may prefer health-improving technologies) in some randomly selected households and to men (who typically have greater decision-making control over the household budget) in others. This experimental design, depicted in Figure 1, is motivated by a model of intra-household decision-making that we develop.

We find that when stoves are offered for free, women appear to exhibit a stronger preference for any improved stove – and for health-saving chimney stoves in particular. This is consistent with the fact that the health cost of indoor smoke is greater for women. However, when a small positive price is charged for either stove, women become less likely than men to adopt. This result may indicate that despite their preferences, women lack the authority to make purchases. Consistent with theoretical predictions, these differences appear to be driven by women who have lower status or decision-making authority within their households, rather than simply a result of differential price elasticity by gender. We also find that with more time to learn about their husbands' preferences about a new technology, women's choices converge with their husbands'. The key constraint is that one household member (the wife) benefits more from the new technology, but another household member (the husband) controls resources and spending decisions.

These results build on an empirical literature suggesting that aspects of intra-household decision-making can lead to inefficiencies (Udry et al., 1995; Udry, 1996; Anderson & Baland, 2002; Ashraf, 2009; de Mel et al., 2009; Ashraf et al., 2010; Fafchamps et al., 2011; Köhlin et al., 2011). Our use of two different price points goes further towards establishing the existence

of an intra-household externality due to financial decision-makers not fully accounting for costs and benefits to spouses and children. The novelty of the gender-price interactions (cells I-IV in Figure 1) is that they provide direct evidence on differential constraints – in addition to differential preferences – by gender. To interpret our empirical results, we propose a model of intra-household decision-making in which preferences and resources vary by gender. Both the theory and our empirical findings show that intra-household differences in preferences and the bargaining constraints faced by women deter the adoption of a technology that the environmental and biological science literatures suggest improve household welfare (Smith & Haigler, 2008; Miah et al., 2009; Barnes et al., 2012). These findings also relate to the theoretical literature on intra-household bargaining and aggregation of individual preferences (Chiappori, 1988; McElroy, 1990; Lundberg & Pollak, 1996; Browning & Chiappori, 1998; Iyigun & Walsh, 2007).[3]

Our findings also contribute to two other strands of literature. First, biomass combustion in traditional cookstoves and indoor air pollution are the subject of large literatures in epidemiology and in environmental science (Smith et al., 2000; Ezzati & Kammen, 2001a; Ezzati & Kammen, 2001b), but this literature has largely focused on the dose-response relationships between stove use, pollution output, and health outcomes – not demand for stoves. Several economists have studied the productivity and economic benefits of using improved stoves (Pitt et al., 2005; Dasgupta et al., 2006; Duflo et al., 2008; Mueller et al., 2009; Gajate-Garrido, 2010; Levine & Beltramo, 2011; Yu, 2011), but none have examined why most

[3] All our offers are made to married couples, and it is therefore most natural to interpret our results as being mediated through models of intra-household decision-making. However, it is also possible that men and women have other innate differences that lead to gender differences in their responsiveness to price variation that is independent of constraints imposed by a spouse through intra-household bargaining.

households in developing countries continue to rely on a seemingly inferior technology with supposedly substantial negative health consequences.

Second, this paper is part of a broader research agenda that examines multiple constraints to adoption for the same product in the same context. In related work (Miller & Mobarak, 2012; Mobarak et al., 2012), we use data from the same experiments to measure the impacts of both price changes and marketing techniques making use of social networks. This purposeful approach enables us to directly assess and compare the relative importance of different barriers to technology adoption. Different underlying reasons for low adoption rates have different policy implications, making multi-pronged experiments like ours particularly valuable.[4] In comparing the roles of learning, price, different attribute bundles, and gender, we find (as does other recent literature) that price concerns dominate these other factors (Kremer & Miguel, 2007; Cohen & Dupas, 2010; Miller & Mobarak, 2012; Mobarak et al., 2012). However, these other factors also appear to be important, and not well-understood, inputs into the purchasing decision.

The rest of the paper is organized as follows. Section 2 uses a variety of pre-baseline data that we collected to describe the study context and cooking technologies. Section 3 describes our experimental research design. Section 4 provides the theoretical underpinning for our experimental design and specific empirical predictions. Section 5 presents our empirical results. Section 6 studies heterogeneous behavioral responses to our interventions to sharpen our interpretation and address alternative explanations. Section 7 concludes.

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[4] Kremer et al. (2009) and Meredith et al. (2011) also conduct multi-pronged experiments. Other recent studies of technology adoption typically focus on one demand factor at a time, such as price (Kremer & Miguel, 2007; Ashraf et al., 2008; Cohen & Dupas, 2010), the role of social networks (Conley & Udry, 2001; Kremer & Miguel, 2007; Oster & Thornton, 2009; BenYishay & Mobarak, 2013), learning (Dupas, 2010), and persuasion (Luoto, 2009; Bertrand et al., 2010).

2. Context, Technologies, and Project Location

2.1 Context and Knowledge of Health Risks

Prior to designing our demand experiment, we collected qualitative information by conducting focus groups with rural women, talking with engineers and energy experts in Dhaka, and directly observing cooking episodes. These motivated a nationally-representative survey to assess cooking practices in 120 sub-districts of Bangladesh in 2006 (Mobarak et al., 2012). This survey asked questions about current cooking practices, household knowledge about the health risks of indoor air pollution, familiarity with improved cookstoves, and the value placed on improved cookstoves relative to other basic goods and services.

Overall, our survey found that: (1) rural Bangladeshis overwhelmingly burn low-quality biomass fuels in traditional stoves (procured for little or no monetary cost); (2) most rural households have no direct experience with improved cookstoves;[5] (3) respondents believe that indoor smoke is harmful to health but is not the most important health risk that they face;[6] and (4) improved cookstoves rank at the bottom of a list of household expenditure priorities, lower than any of the twelve other basic goods and services we asked about in a contingent valuation survey (spanning infrastructure, education, agriculture, and other dimensions of health) (Mobarak et al., 2012). Appendix 1 provides a summary of survey results.

[5] Rural Bangladeshis are not unique in this respect: the worldwide general lack of awareness of and sustained use of improved stoves (ESMAP, 2010a) serves as a primary motivation for our demand experiments.

[6] 94% of respondents believe that smoke from stoves is harmful to health. 69% of households believe that smoke from a traditional stove is more harmful than breathing dust from sweeping, but only 11% and 18% believe that it is more harmful than consuming "unclean" water and spoilt food. Given contaminants in both surface and ground water in Bangladesh (Harvey et al., 2002; Michael & Voss, 2008), these beliefs reflect the realities of the disease environment.

2.2 Improved Cookstoves in Rural Bangladesh

Given the substantial health and environmental consequences of traditional cookstoves, both the Bangladeshi government and NGOs have made concerted efforts to promote improved cookstove technologies. Since the early 1980s, over 100 national and local NGOs – as well as the government-affiliated Bangladesh Council of Scientific and Industrial Research (BCSIR) – have developed and attempted to disseminate a variety of improved stove models tailored to local needs (Sarkar et al., 2006; ESMAP, 2010b). Working with BRAC, a nation-wide NGO which has a great deal of experience working in rural Bangladesh, we selected two major types of cookstoves for our demand experiment. The first is a round *efficiency stove* that improves fuel efficiency and reduces heat loss relative to a traditional cookstove. The second is a *chimney cookstove* that removes a substantial share of smoke from kitchens via a concrete chimney. Both the efficient cookstove and the base of the chimney cookstove are made locally according to precise design specifications using with materials similar to those used for traditional cookstoves (see Appendix 2 for examples of stoves).

We conducted cooking tests with both types of improved stoves and a traditional stove under controlled field conditions. For each stove, the same individual was asked to cook a standard amount of rice and vegetables using the same type of fuel (firewood) on the same day in the same room (to minimize climatic variation). We measured cooking time using a stopwatch and PM2.5 emissions (particulate matter with aerodynamic diameter of 2.5 micrometers (μ) or less) throughout the cooking period using Side Pack PM 2.5μ monitors (see Appendix 3).

Our test results largely confirm the salient features of each stove. Relative to traditional stoves, efficiency stoves save time and fuel, reducing fuel use by 20-25%, but their average

PM2.5 emissions rates are comparable (0.96 versus 0.95 mg/m^3, respectively) to the traditional stoves'. Alternatively, the chimney stove did not reduce cooking time or fuel consumption relative to the traditional stove, but it did reduce the measured PM 2.5 emissions within the kitchen environment. Our stove test sample included 54 cooking episodes with traditional stoves and 61 cooking episodes with chimney stoves. We found that relative to traditional stoves, chimney stoves reduced PM2.5 concentrations measured in kitchen environments by 17% (p=0.16) and pollution concentrations measured by a monitor attached to the cook's body by 47% (from 1.20 mg/m^3 to 0.626 mg/m^3, p=0.007).

The information we provided about each type of stove (see the scripts in Appendix 4) to households participating in our demand experiment was based both on manufacturer documentation and these test results. Importantly, households appear to retain this information and use it when choosing a stove. In our survey, we asked both male and female respondents to list their reasons for choosing each stove. Figure 2 shows that households were able to identify the salient features of each stove type: the top reason that respondents gave for choosing the chimney stove was that it "reduced smoke emissions", and those who chose the efficiency stove reported that they did so because it is "portable" and it "reduces fuel required to cook".

2.3 Project Location

We conducted our demand experiment in 58 villages in two ecologically diverse rural districts of Bangladesh: Jamalpur in the north and Hatia in the south (see Appendix 5). Jamalpur is a densely populated 490 sq. km. agrarian area that is ecologically representative of most of Bangladesh. Its landscape is largely de-forested, and most residents rely on agricultural residue as their primary cooking fuel. Hatia is an isolated 1500 sq km island in southern Bangladesh.

Firewood for cooking is readily available, but because of Hatia's coastal deltaic land, clay soil needed to build stoves is relatively scarce.

3. Study Design

3.1 3.1 Motivation for the Experimental Design

Our preparatory research (described in Section 2.1) identified four primary reasons explaining the low adoption of improved cookstoves conditional on availability: (1) price; (2) lack of information about the health consequences of traditional stove use; (3) aversion to new technologies that require changing traditional practices, especially when opportunities for experiential learning about new technologies are limited, and (4) gender differences in preferences over stoves (when women have little intra-household bargaining power). This paper focuses on the last factor.[7]

There are two likely sources of gender difference in preferences. One is that women are almost exclusively responsible for cooking in rural Bangladesh (Pitt et al., 2011), and pollutant emissions are concentrated next to stoves and dissipate rapidly over time and space (Ezzati & Kammen, 2001b). As a result, women (and the children for whom they care) disproportionately bear the health burden of traditional stove use (Köhlin et al., 2011; Smith et al., 2011). The other is a gender difference in preferences over child health investments. This has been well-documented in other studies (Thomas, 1990; Thomas, 1994; Duflo & Udry, 2003; Duflo, 2003; Ueyama, 2007; Miller, 2008), and may also lead to a divergence in spending priorities.

[7] Mobarak et al. (2012) specifically addresses price considerations, while Miller and Mobarak (2012) focuses on alleviating (3) through providing opportunities for villagers to see the stove purchase decision of local opinion leaders. In all experiments, information was provided about the health effects of traditional stove use.

3.2 Basic Design: Differences in Preferences and Differences in Ability to Purchase Stoves

Women may differ from men not only in their preferences over stoves, but also in their control over household resources (and therefore, their ability to make purchasing decisions). To distinguish preferences from constraints, we cross the gender of household members to whom we offer improved stoves with the price of the stoves.[8] Specifically, we randomly assigned 16 project villages (half in Hatia and half in Jamalpur) to treatments I-IV (as shown in Figure 1) using the following procedure:

(a) 8 of the 16 villages were randomly assigned to "free stove" cells I and II, and the other 8 villages were assigned to "highly subsidized" cells III and IV. The prices charged for the subsidized stoves were 50 Taka (~US$0.70) for the efficiency stove and 250 Taka (~US$3.50) for the chimney stove. [9,10]

(b) Sample households in all cells were then randomly assigned to either the "husband choice" or the "wife choice" group denoting whether the male household head or his wife (typically the primary cook) would be offered the stove choice. This randomization was performed at the household level.

To implement our allocation to experiment cells, a survey team of two enumerators visited each household. One enumerator interviewed the male household head while the other conducted an interview with his wife at a separate location outside of auditory range. After respondents completed the survey, they received a basic health education message about

[8] Hoffman (2009) also designs intra-household experiments interacted with price, but her interest is in the allocation of a good within the household at different price points, which is very different from our setup.
[9] The move from cell group I-II to cell group III-IV changes the relative price of the two stoves, and the chimney stove becomes relatively more expensive. However, across study arms, men and women across experience the same change in relative price.
[10] Average monthly income for households in our sample was approximately 6000 Taka, or US$75.

traditional cooking practices and health, and also received specific information about the efficiency and chimney stoves (emphasizing their salient characteristics – one as "budget-saving" and the other as "health-improving" – see Appendix 4 for details). Lastly, either the husband or wife (depending on the random assignment) was given the opportunity to choose among an efficiency stove, a chimney stove, or no stove at the randomly assigned prices. Importantly, husbands and wives made these choices without consulting their spouse and while they were still out of auditory range of their spouse.

The comparison between cells I (husband choice, free stove) and II (wife choice, free stove) allows us to study unconstrained gender differences in prioritization of budget-saving and health-improving technologies.[11] Alternatively, the difference-in-difference between the cells I-II and III-IV (gender differences when stoves are free vs. when small positive prices are charged) allows us to uncover the degree to which each gender is able to act on their underlying differences in preferences in the presence of positive prices.[12]

3.3 Sample Size, Data Collection Activities, and Timeline

Our trial profile (Figure 1) provides sample sizes by experimental condition in detail. After a village level survey, we randomly selected 50 households per village, and randomly

[11] An alternative experimental design to study gender differences in preferences would be to ask men or women to simply make a purchase decision about one of the improved stoves (analogous to the Ashraf (2009) experimental design for savings products in the Philippines). However, women in rural Bangladesh typically do not have control over the household budget, and with that design, we would not have been able to separate out differences in preferences from a differential inability to make financial purchases. Yet another way to run the experiment would have been to offer men or women the choice of either a free stove or some cash, but that would conflate preferences with differential access to cash by gender.

[12] If there were a thriving resale market for cookstoves, then the choice would have other implications for household finances. These improved cookstoves are not readily available in local markets, which would make any transfer or resale apparent to our partner NGO, BRAC, and to others in the village. BRAC has a strong presence in these villages given the other development programs they implement, which makes resale difficult.

assigned all 800 project households to 4 experimental conditions. We then conducted baseline surveys and marketing visits in July – September 2008. Cookstove orders were then given to manufacturers, and cookstoves were delivered over the period November 2008 – February 2009.

3.4 Initial Decision (Stove Orders) versus Final Decision (Purchase)

While participants make cookstove choices and place orders without first consulting their spouse, it is reasonable to expect that spouses will learn about these choices after our visit. In our experimental protocol, an individual decides to order a stove in isolation, but after consulting with their spouse, participants can refuse to install or pay for the stove when we return to deliver it (although they are not allowed to change their order from one type of stove to the other). In practice, a large share of households that ordered stoves ultimately refused delivery and payment.[13]

Differences between orders and purchases provide insight into the way that changes in the information set and the identity of the household decision-maker influence demand for stoves. We model this distinction explicitly both theoretically and empirically, and we analyze stove orders and ultimate stove purchases separately to better understand household decision-making. Stove orders are meaningful even though they can be reversed because they are placed with BRAC (the largest NGO in the country), which operates a number of other development programs in localities across the country (including micro-credit, health services, business development opportunities, employment). Refusing delivery to BRAC is therefore not only

[13] For brevity, through the rest of the paper we refer to these two stages as "stove orders" (when individual make their choice without consulting their spouse) and "stove purchase" (when BRAC returns to the village to deliver the stove, and the household can refuse to accept the stove). While we recognize that, in groups I and II, the stoves were free, and therefore stove "purchase" may be somewhat misleading, it is meant to refer to the stage at which the stove actually enters the household (and is paid for in groups III and IV).

interpersonally uncomfortable, but it may also jeopardize credibility or reputation with local BRAC staff. Our theoretical framework allows for a cost associated with this refusal.

4. Theoretical Framework

This section provides a theoretical mapping for our experimental design to motivate why we might observe husbands and wives within the same household reacting differently to the same offers of stoves. The model makes explicit the assumptions about how the constraints and preferences of men and women might be different in this context, and then generates predictions for their behavior in the experiments, including distinct predictions for the stove order and the stove purchase decisions. The experimental results, combined with this conceptual framework, then help us infer certain aspects of decision-making within the household.

Each household in the model is comprised of two married members, $i \in \{w, m\}$, a woman and a man. They make choices on commodities $j \in \{H, E\}$, labeled 'healthy' and 'efficient' stoves. v_j^i is member i's valuation for commodity j, and is drawn from a distribution F_j^i with density f_j^i. The price of commodity j is p_j. The husband, m, is the residual claimant on household resources and therefore pays the price p_j if a commodity is purchased. Payoffs are $u_j^w = v_j^w$ and $u_j^m = v_j^m - p_j$. Decisions are made in the following two stages, and these stages map closely to the experimental setup, including the stove order versus purchase distinction:

- Stage 1 (the "stove order"): Member i is chosen randomly (with probability ½) to learn about the stoves and their prices, and i makes a unilateral decision about the commodity in the first stage. The choices are: accept H, accept E, or neither (N). If N is chosen, the game ends and both players receive zero payoff.

- Stage 2 (the "stove purchase"): After player *i*'s first stage decision, both members truthfully reveal their valuations for the chosen commodity *j*, and simultaneously announce whether they want to accept *j*, or reject it, *R*. If the two players disagree, then the husband's choice is implemented with probability α. Rejecting the commodity after ordering it from the NGO in the first stage imposes a cost on both players: $(-c, -c)$.

The experimental design – i.e. offering the choice to one household member in isolation in the first stage - has two effects: (a) it limits the set of possible choices for the second player, since the choice on stove type cannot be undone, and (b) rejection by the second mover implies a negative payoff for both this player and his/her spouse, and the second mover therefore accepts the stove under a larger range of valuations. In this setup, decision rules in the second stage are very simple. If the husband moves first, then *w* accepts her husband's stove choice if $v_j^w \geq -c$. If the wife moves first, then *m* accepts the wife's choice if $v_j^m - p_j \geq -c$.

We have introduced two sources of asymmetry between husbands and wives: (1) husbands control household resources, and therefore pay for the product, and (2) the decision-making weight (α) may vary between husbands and wives. We now make two more assumptions that are realistic reflections of the setting in which the experiment is conducted:

i. $f_H^i(v)/f_E^i(v)$ is strictly increasing in v.

ii. If we order the players by saying $w > m$, then $f_H^i(v)/f_E^i(v)$ is strictly supermodular in *i, v*.

Assumption *(i)* implies that F_H^i first order stochastically dominates F_E^i and that $F_H^i(v)/f_H^i(v) > F_E^i(v)/f_E^i(v)$.

These assumptions are inspired by descriptive statistics from the data, which clearly show that both men and women have stronger preference for the stove with the chimney. Assumption (*ii*) says that compared to a husband, a wife's likelihood ratio is always higher. In summary, both players prefer the healthy stove over the efficiency stove, but the wife has a stronger preference for the healthy stove relative to her husband. This introduces a third source of asymmetry between husbands and wives.

4.1 Wife's First Stage ('Stove Order')Decision

In making the first-stage choice, the wife knows that her husband will only accept her choice *j* if $v_j^m \geq p_j - c$, and otherwise she will end up with payoff $-c$. The wife's expected payoff from choice *j* is: $E\left[u_j^w\right] = \left[1 - F_j^m(p-c)\right]v_j^w + F_j^m(p-c)\left[(1-\alpha)v_j^w - \alpha c\right]$.

With probability $1 - F_j^m\left(p_j - c\right)$ the husband accepts her choice, and if he does not, then the wife's choice is implemented with probability (1 – α). This expression for expected payoff yields a minimum valuation of *j* for the wife such that she prefers to accept stove *j* rather than reject in the first stage (and receive zero payoff):

$$\underline{v_j^w}\left(p_j\right) = \frac{\alpha F_j^m(p_j - c)c}{1 - \alpha F_j^m(p_j - c)} \qquad (1)$$

This expression is increasing in p_j (stove price) and in α (the husband's weight in decision-making in case of disagreement): she is less likely to accept if the price is high, or if her choice is more likely to get over-turned in the second stage. Also, for a fixed price vector, we can compute the pairs (v_H^w, v_E^w) that will make the wife indifferent between selecting the healthy (*H*) or the efficiency (*E*) stove:

$$[1 - \alpha F_E^m(p_E - c)]v_E^w - \alpha F_E^m(p_E - c)c = [1 - \alpha F_H^m(p_H - c)]v_H^w - \alpha F_H^m(p_H - c)c$$

Rearranging, we get:

$$v_E^w(v_H^w, p_E, p_H) = \frac{[1-\alpha F_H^m(p_H-c)]v_H^w + \alpha[F_E^m(p_E-c) - F_H^m(p_H-c)]c}{[1-F_E^m(p_E-c)]} \quad (2)$$

In v_E^w, v_H^w space, this equation defines a straight line with slope $\frac{1-F_H^m(p_H-c)}{1-F_E^m(p_E-c)}$, and intercept $\frac{\alpha[F_E^m(p_E-c)-F_H^m(p_H-c)]c}{1-F_E^m(p_E-c)}$. From assumption (i), the slope is greater than one and the intercept is positive, for all cases where $p_E \geq p_H$, including the case where $p_E = p_H = 0$, which corresponds to the 'free stove' cells I and II in our experiment. Figure 3 shows the combination of valuations v_E^w, v_H^w under which the wife orders N (no stove), E (efficiency), and H (Healthy) in the first stage. If $p_H > p_E$ (corresponding to cells III and IV in the experiment) the boundary between E and H is still a straight line, but its location will be ambiguous – it depends on the comparison between relative prices and relative valuations for the two stoves.

4.2 Husband's First Stage ('Stove Order') Decision

A husband's payoff is:

$$E[u_j^m] = [1 - (1-\alpha)F_j^w(-c)](v_j^m - p_j) - (1-\alpha)F_j^w(-c)c$$

Since the wife does not pay for the stove, her second-stage acceptance probability does not depend on the stove price. The husband's minimum valuation required for accepting stove *j* instead of choosing no stoves depends linearly on p_j:

$$\underline{v}_j^m(p_j) = p_j + \frac{(1-\alpha)F_j^m(-c)c}{1-(1-\alpha)F_j^m(-c)} \quad (3)$$

The pairs (v_H^m, v_E^m) that will make the husband indifferent between the two options:

$$v_E^m(v_H^m, p_E, p_H) = p_E + \frac{[1-(1-\alpha)F_H^w(-c)](v_H^m - p_H) + (1-\alpha)[F_E^w(-c) - F_H^w(-c)]c}{[1-(1-\alpha)F_E^w(-c)]} \quad (4)$$

Notice that the slope in (v_H^m, v_E^m) space, $\frac{[1-(1-\alpha)F_H^W(-c)]}{[1-(1-\alpha)F_E^W(-c)]}$ does not depend on any price.

4.3 Predictions for Experimental Conditions with Free Stoves (Cells I and II)

For intuition, consider the simplified case where the players' valuations for the good are not too negative: $F_j^i(-c) = 0$. In this case, the wife always accepts her husband's choice in the second stage. The husband's minimum valuation required for accepting stove *j* instead of choosing none is therefore simply determined by his own payoff: $\underline{v}_j^m(p_j) = p_j$. The pairs (v_H^m, v_E^m) that make the husband indifferent between the two stoves:

$$v_E^m(v_H^m, p_E, p_H) = p_E + v_H^m - p_H.$$

In experimental treatment arms I and II where we offer stoves for free ($p_E = p_H$=0), equations (1) and (3) simplify to $\underline{v}_j^w(p_j) = \underline{v}_j^m(p_j) = 0$. Moreover, equations (2) and (4) are the same for both decision makers; that is: $v_E^i(v_H^i, 0,0) = v_H^i$. The relative propensities of husbands and wives to accept stove offers are entirely determined by the relative gender distribution of valuations, since both accept their spouse's choice from the first stage. Since women have a relatively strong preference for improved stoves, and the healthy stoves in particular (since women cook, and breathe in the smoke associated with cooking), we can make the following predictions:

(1) The probability that a wife does not accept any of the stoves is smaller than the probability that the husband does not accept any, when stoves are provided for free.

(2) When stoves are provided for free, conditional on accepting one of the stoves, the wife is more likely to accept a healthy stove compared to the husband.

Assumptions (*i*) and (*ii*) together imply that $F_j^w < F_j^m$. This stochastic dominance and first order stochastic dominance (also implied by (*i*)) gives us the first result. The second result also comes from a combination of assumptions (*i*) and (*ii*).[14]

4.4 Predictions for Experimental Conditions with Positive Prices (Cells III and IV)

To develop intuition with simplified algebra, we first consider the case where the husband holds all bargaining power ($\alpha = 1$), and later consider the effect of decreasing α. When a positive price is charged, the husband (as residual claimant on household resources) might reject the wife's choice from the first stage. The husband's greater valuation for the healthy stove (assumption 1) implies that he may be more likely to reject an 'efficient stove' rather than the healthy stove, but on the other hand, $p_H > p_E$ pushes the husband towards rejecting the healthy choice. Which stove the wife chooses in the first stage is therefore ambiguous. The key comparison here is between $F_E^m(p_E - c)$ and $F_H^m(p_H - c)$, because these determine the husband's rejection propensities in the second stage, which in turn affects the wife's first stage choice. Noting this relationship allows us to make the following predictions for the data:

(3) When positive prices are charged, the husband may reject his wife's first-stage choice, and the wife's decision therefore reflects her husband's preferences more. Wives therefore shift towards choice *E* compared to the zero price case (where *H* was preferred by women).

(4) When positive prices are charged, some men reject the stove in the second stage. This raises $\underline{v_j^w}$, which means more wives choose *N* in the first stage.

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[14] The probability that, say, a wife chooses *H* is $F_E^w(0)\big(1 - F_H^w(0)\big) + \int_0^\infty \big(1 - F_H^w(v)\big) f_E^w(v) dv$. Which is larger than the probability that she chooses *E*, and that difference is smaller in the case of the husband.

(5) The slope and intercept of $v_E^w(v_H^w, p_E, p_H)$ - which determines the wife's choice of *E* vs. *H* – is a function of α. As α decreases, wives are less likely to choose *N*, and their choice of *H* versus *E* reflects their husbands' preferences less.[15]

Rejections in second stage: If the second player's valuation for the stove is less than $-c$, then the initial decision of the spouse can be over-ruled. Moreover, the probabilities of having a decision overruled are continuous on α. A woman is overruled with probability $\alpha F_j^m(p_j - c)$ and a husband is over-ruled with probability $(1-\alpha)F_j^w(-c)$.[16]

5. Empirical Results

Before turning to take-up rates across treatment groups, Table 1 first examines balance on observables at baseline across arms of our experiment. Overall, it suggests that there are no systematic differences in observable baseline characteristics across the (randomly assigned) arms. On average, sample households have 7 members total and 3 children under age 18. Male household heads are 46 years old on average, have roughly 3 years of education, and are most likely to be engaged in agriculture. Their wives are about 10 years younger on average and have one year less of education. Only about 12% of women contribute to household income.[17]

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[15] If $F_E^m(p_E - c) > F_H^m(p_H - c)$, the slope and intercept of $v_E^w(v_H^w, p_E, p_H)$ decrease as α decreases, and this increases the number of wives accepting an efficient stove. Analogously, if $F_E^m(p_E - c) < F_H^m(p_H - c)$ the slope and intercept of $v_E^w(v_H^w, p_E, p_H)$ increase as α decreases.

[16] Note that husbands never get over-ruled if they have full decision-making authority ($\alpha = 1$) or if the wife's valuation for the stoves is not too negative ($F_j^w(-c) = 0$).

[17] A Bonferroni multiple comparison correction for 39 independent tests requires a significance threshold of α=0.001 for each test to recover an overall significance level of α=0.05. Using this criterion, no differences at baseline are statistically meaningful. In some regressions reported later, we control for the few variables that show significant differences at baseline, in addition to the following household characteristics: numbers of household members by gender, numbers of children under 5 and under 18, whether there is a female wage earner in the hh, the total number of wage earners, household expenditures, the household wealth index, female respondent's age and years of education, male respondent's age and years of education, whether male respondents had more education than females, the amount of time spent cooking during the dry season, and an index of health status for females. Results are not sensitive to the set of controls included.

5.1 Stove Orders in the Free Stove Conditions

Table 2 reports unadjusted percentages of people who ordered or purchased stoves by price and gender. Relative to stoves offered for free, order and purchase rates fall sharply when a positive price is charged, but only 70% order a stove even when it is offered for free. Lack of universal adoption (or orders) of free stoves is unsurprising given qualitative evidence from our preparatory work that there are other costs associated with improved stoves.[18] The table also shows the percentage of households who chose the chimney stove, out of those who chose any stove at all (values in parentheses). In all cases, people who chose to order a stove overwhelmingly chose the chimney stove: on average, across all groups, 82% of people who ordered a stove chose the chimney stove, compared with just 18% who chose the efficiency stove.

We examine both the extensive (order *any* stove rather than neither, i.e., choice *N* in the model) and intensive (order *H,* the healthier chimney stove, rather than *E*) margins of these choices. We run separate regressions for households (h) residing in villages (v) in which the stoves are offered for free versus villages in which the stoves are offered at positive price.[19] We conduct statistical hypothesis tests with standard errors clustered at the level of randomization

[18] Our early focus groups revealed a variety of concerns about costs associated with improved stoves independent of purchase price. These include the inability of improved stoves to accommodate all readily available forms of biomass fuels and concerns that improved stoves alter the flavor of prepared foods. As we discuss in related work (Miller & Mobarak, 2012), more men than women cite "Preserving tradition" as a reason for rejecting the stove offer. This could in part explain why men are more likely to reject even the free stove. The chimney stove also has to be installed into the kitchen, so adopting it is not "free" for this reason as well, even if the purchase price is zero. Hanna, Duflo, and Greenstone (2012) show that similar stoves distributed in India are not very durable.

[19] Our dependent variables measure the stove order or purchase decisions, and are typically binary. We have run all regressions in both Probit and OLS (Linear Probability Model) specifications whenever possible and verified that the results are virtually identical. We report Probit results except when we have perfect prediction in a particular experiment cell (e.g. 100% of women offered a free stove order one, and the Probit coefficient is not identified).

(offers were randomized to male and female household heads at the household level, while prices were randomized at the village level). Specifically, we estimate:

$$\Pr(Stove\ Acceptance)_h = \alpha + \beta_1 \cdot Male_h + \gamma \sum X_{hv} + \varepsilon_h \quad (5)$$

$$\Pr(Chimney\ Stove)_h = \alpha + \beta_1 \cdot Male_h + \gamma \sum X_{hv} + \varepsilon_h \quad (6)$$

Table 3 reports coefficient estimates for the variable "Male" (i.e. the randomly assigned treatment condition in which husbands – rather than wives – were asked to make the cookstove choice). Each estimate is derived from a separate regression. The first row in Panel 1 examines gender differences in choices across treatments I and II (choice of either free chimney or free efficiency stove). The first column shows that when improved cookstoves are offered for free, women are 6.1 percentage points (or 6.5%, see panel 1, row 1) more likely than men to order any cookstove, regardless of type. The second column then shows that, conditional on choosing an improved stove, women are 6.4 percentage points (7.9%) more likely initially to choose the healthier chimney stoves over the fuel-saving efficiency stoves. The third column combines these two cookstove choice margins: among households initially offered a stove, there was an 11.3 percentage point (14.9%) higher order rate for the healthier chimney stoves when the marketing offer was made to the wife rather than the husband. These results are consistent with the first two predictions of the theoretical model.

Although *both* men and women overwhelmingly choose the chimney stove, our results also show that women choose the healthier chimney stove more often than men. One clear explanation for this finding is that women are almost exclusively responsible for cooking in rural Bangladesh (and in much of the developing world), and they are disproportionately exposed to cookstove emissions (Dasgupta et al., 2006; Pitt et al., 2010). However, they could also be due

in part to gender differences in preferences over child health. Section 5 provides evidence consistent with the salience of women's own health rather than child health.

5.2 Stove Orders when Positive Prices are Charged

The second row of Table 3 Panel 1 examines gender differences in stove order rates in treatment conditions III and IV (when small positive prices are charged for the stoves). The efficiency stove price was Tk. 50 (<US$1, an 88% subsidy relative to full price), and the chimney stove price was Tk. 250 (~US$3.50, a 67% subsidy). Relative to the free (I-II) conditions, these subsidies change both absolute and relative prices. Price has a more powerful negative effect on women's stove order rate, which now dips below (but is statistically indistinguishable from) the order rate for men. The p-values in the bottom row of panel 1 show that these gender differences in stove orders are statistically different across free (treatments I-II) and subsidized (treatment III-IV) conditions.[20] This finding is consistent with Section 4's theoretical predictions (3) and (4) : women's choices move towards their husbands' preferences when positive prices are charged, and women are more likely to reject the stove altogether.

In our theoretical framework, because men control household finances and are the residual claimant of financial resources not allocated to stove purchases, they have a higher threshold for stove acceptance. In the intra-household decision-making game, women's first stage choices reflect these preferences. The empirical results therefore suggest that women are differentially more resource constrained. When stoves are offered for free, their choices reflect their own preferences, and women express a stronger preference for healthier stoves. However,

[20] All statistical tests on differences in effect across free and subsidized conditions are conducted with standard errors clustered by village, which is the level at which the free versus subsidized treatments were randomized.

they are unable to act on their preferences when even very small positive prices are charged. Panel 2 of Table 3 demonstrates that the results in Panel 1 are robust to controlling for household characteristics.

The second row of Table 3, Panel 1 shows that when modest positive prices are charged, women are also differentially more likely than men to shift their choices from relatively more expensive chimney stoves to relatively cheaper efficiency stoves. This result is also consistent with more stringent resource constraints for women.[21] Combining the extensive (any improved stove order) and intensive (efficiency vs. chimney stove order) margin effects, women shift away from the healthier and more expensive chimney stoves by 15 percentage points relative to men when positive prices are charged (the gender coefficient changes from -0.113 in row 1 to 0.037 in row 2), and this differential shift is statistically significant (p=0.034). These estimates are more precise when household controls are added (Panel 2).

Our theoretical framework predicts these results when α=1, i.e., the husband wields substantial intra-household decision-making authority. As α decreases, these effects theoretically become less prominent (prediction (5) in Section 4). In the next sub-section we test this prediction empirically using variation in measures of gender-specific decision-making authority.

5.3 Stove Purchase Decisions and Refusals

The sixth prediction of the theoretical framework in Section 4 concerns purchase 'refusals' after placing an order for a stove. We first analyze ultimate purchase decisions (in

[21] This interpretation is counteracted by a selection effect in which the group of women who are able to order a stove at positive price may be less constrained on average than the group of women who order free stoves. Even in the presence of such selection we observe that women shift away from the more expensive chimney stove.

columns 4-6 of Table 3) before turning to a more detailed analysis of refusals. During our initial household visits, husbands and wives' individual decisions to accept a cookstove offer were kept private. However, when households made actual purchases during our second visit to deliver and install stoves that were ordered, information about individual preferences and choices had been revealed within the household. In the intervening period, husbands and wives had the opportunity to learn each other's preferences about cookstoves that were otherwise unknown technologies – and importantly, they learned about the choices made by their spouses. This is precisely the way that we model stove order and purchase stages of household decision-making in Section 4.

Given our experimental design, it was possible for households to undo an individual's initial stove order extensive margin choice (by refusing delivery of a stove that was ordered), but it was not possible to change this first-stage choice on the intensive margin (i.e. we did not allow households to purchase an efficiency stove if a chimney stove was ordered). Accordingly, we find that gender differences in the decision to order any stove was undone at the time of delivery purchase stage, but women's relative preference for the healthier chimney stoves conditional on placing any order persists. Specifically, columns 4-6 of Table 3 show that when women are offered stoves for free, the household is ultimately 8-10 percentage points (11.1-18.4%) more likely to accept delivery and purchase a chimney stove – but this gender difference disappears when positive prices are charged for the stoves. This finding is consistent with our predictions in Section 4: husbands were more likely to refuse stoves at positive price.

We next analyze more closely whether or not refusals of stoves that were ordered are due to women's initial choices being undone by their spouses. Theory predicts that husbands, as financial decision-makers and residual claimants on household resources, are the ones more

likely to overturn their spouse's first-stage choice. Column 8 of Table 3 studies the refusal rate (whether or not a stove ordered was not ultimately purchased) in each of the gender-price conditions. In the free (I-II) treatment conditions, the refusal rate was about 3 percentage points (9%) lower (row 3) if the initial offer was made to a man (although not statistically significant at conventional levels). In the second and fourth rows, among those who ordered stoves at positive prices (III-IV) without consulting their spouses given our experimental protocol, the gender pattern of refusals is reversed: those women's decisions are about 5.5 percentage points (9.5%) less likely to get over-turned (again not significant at conventional levels). Comparing the probability of refusal by men vs. women between the free and positive price conditions, the differential change in refusal by women relative to men when prices are increased is about 8.2 percentage points, and this differential is statistically significant.[22] This result suggests that in the free stove condition, women's initial choices were more likely to be un-done by their husbands as information was revealed between first stage offers and second stage deliveries.

In summary, our evidence suggests that women have a relatively stronger preference for improved stoves, and healthier stoves in particular, but they cannot act on that preference when either a small positive price is charged or when their choice can subsequently be undone by their husbands. These findings are also consistent with the stated preference data we collected from the nationally representative survey described in Section 2 (Mobarak et al., 2012). When 2400 rural Bangladeshi women from across the country were asked whether they were interested in receiving an improved stove, interested in receiving cash to purchase such a stove, or nothing at all, 96% opted for a stove, and only 3% opted for the cash to buy it. This is suggestive that the

[22] The p-values presented are those associated with the coefficient on an interaction term between "offered for free" and "offered to men", which is equivalent to a difference-in-differences between the price conditions and the gender conditions. Standard errors are clustered at the village level, which is the level at which prices were randomized.

commitment device offered by a product delivery rather than more fungible cash is valuable to women, possibly because they are unable to resist external demands on their income from either their spouse or from others (Anderson & Baland, 2002; Duflo, 2003; de Mel et al., 2009; Brune et al., 2011; Somville, 2011).

5.4 Variation in Decision-Making Authority (α)

To explore Section 4's predictions about variation in the wife's decision-making authority within the household, Table 4 analyzes heterogeneity in stove orders by gender and (proxies for) intra-household bargaining power of women measured at baseline. Our model predicts that the parameter α only matters when positive prices are charged for stoves, so we therefore conduct analyses using the sub-sample of households in treatments III and IV. Specifically, we add interaction terms between the treatment (whether the woman rather than her husband is offered the stove choice) and baseline measures of female and male age and education, and the presence of children, to proxy for a woman's bargaining power in the household (see Jensen & Thornton, 2003; Suran et al., 2004; Desai & Andrist, 2010).

Overall these regressions provide evidence consistent with the model. When a wife is more than 10 years younger than her husband, she is much less likely to order a chimney stove (18 percentage points or 33%, column 2). Interactions with woman's years of education are insignificant (1.4 percentage points, column 3), although when we discretize our measure of women's education, we find that women with at least some education are more likely to choose the healthier chimney stove (and not the efficiency stove) (21 percentage points or 37%, column 5). Women's education is a reasonable proxy for intra-household bargaining power in this context, and the literature also argues that education can positively influence a woman's

bargaining power (Lundberg & Pollak, 1994; Lundberg & Pollak, 1996).[23] Probing further, we also find that women who are more educated *relative to their husbands* are the ones most likely to order healthier, more expensive chimney stoves (27 percentage points or 42%, column 8) – further reinforcing the interpretation that women's choices at positive prices more closely reflect their husband's preferences when they wield less bargaining power within the household. Finally, we also create an index of female empowerment using principal component analysis to collapse across survey questions measuring women's decision-making power within the household.[24] In households with more empowered women as measured by this index, offering the stove choice to the wife again leads to greater chimney stove orders at positive prices (8 percentage points or 14%, column 9).

The model in Section 4 also predicts that the probability of husbands over-turning (refusing) their wives' stove orders is decreasing in women's empowerment. Table 5 reports estimates obtained by regressing the probability of refusal in the second (stove purchase) stage as a function of randomly assigned stove offers to wives (rather than husbands) and its interaction with the same baseline measures of female empowerment analyzed in Table 4. Because refusal is only defined for the (selected) sample of households who ordered stoves in the first stage – and nearly everyone initially ordered stoves when they were offered for free (but not when

[23] The benefits of smoke escaping through a chimney are actually easier to understand than the improved combustion properties of an efficiency stove. So an alternative hypothesis that education allows women to comprehend stove properties better is not a persuasive explanation for this observation. That theory should lead more educated women to shift towards efficiency stoves.

[24] This index is based on the following dummy variables: Female chooses what foods to cook, Female chooses what food to buy, Female contributes to household wages, Female has at least 1 year of education, Female has more years of education than male; (and the negative of): Female has been denied permission to work in the past by her husband, Female married before age 16, Male more than 10 years older than female, Male has more years of education than female, Female's family paid dowry at time of marriage.

positive prices were charged – leading to selection), we study refusal using the sub-sample offered free stoves (I and II) to minimize selection biases.

For brevity, Table 5 only reports estimates for the interaction term between the treatment variable (stove offered to women) and our proxies for women's bargaining power in the home relative to men (α). While none of the estimates are statistically significant at conventional levels (we presumably lack power in this sub-sample), the signs of all of the estimates are as predicted by the model: when women are more empowered, they are less likely to have their purchase decisions overturned by their husbands.

Finally, if women prefer chimney stoves and are more likely to purchase them when they have greater ability to bargain with their husbands, a natural question is why they prefer chimney stoves. We have proposed to potential explanations: they bear a larger share of the costs/health harm due to traditional cooking practices, or they also place greater weight on child health and welfare. Although we are not able to establish definitively why (and these explanations are neither mutually exclusive nor collectively exhaustive), we investigate this question further using variation in the presence of children and measures of their health status. Table 4 columns 10 and 11 show the coefficients on interaction terms between the variable indicating that the stove choice was offered to the wife and variables indicating the presence of children under 5 in the household and an index of health problems for those children. These coefficients are both very small (-0.9 percentage points or 1.6% in column 10; 0.7 percentage points or 1.2% in column 11), and neither is statistically significant, suggesting that gender differences in stove orders are invariant to the presence of children and children's health status. A reasonable interpretation of these results is that the cook's own health (rather than child health) is the dominant consideration. This interpretation is also consistent with the stated reasons for stove adoption

shown in Figure 2: 33% of women who chose the chimney stove report that they did so because it is better for the cook's health, while only 1% said they did so because it is better for children's health.

6. Alternative Explanations

This section considers potential alternative explanations for our findings. In some cases our evidence against alternative explanations is indirect, but taken together, all pieces of evidence seem most consistent with the interpretations we propose.

One alternative interpretation of our findings is that women may simply have a more difficult time saying "no" to enumerators offering stoves than men do. If this were true, however, refusal rates when the stoves were offered to women should not vary by stove type. In practice, refusal rates in the "wife makes choice" group for chimney stoves are 24 percentage points (300%) higher than for efficiency stoves (p-value of difference = 0.01) even when both stoves are offered for free (in treatment II). Similarly, this interpretation implies that refusal rates should be universally higher when stoves are offered to women. Although they are higher in this group when stoves are offered for free, refusal rates are instead higher in the "husband makes choice" group when a positive price is changed (see Table 3).

Although inconsistent with women simply having a greater propensity to accept stove offers, our pattern of results may be the opposite of what one would expect if women are less able to act on their preference for an improved stove at positive prices. Instead, one might think that husbands would be more likely to overrule their wives when women made choices that cost money. However, this interpretation fails to consider the role of selection: women who order stoves at positive prices have greater bargaining power on average than women who order free

stoves.[25] Overall, we find evidence that more empowered women ordering stoves at positive prices are less likely to have their choices overturned by their husbands.

Second, gender differences in stove choices may reflect stove characteristics other than those that we emphasize (fuel efficiency and pollutant emissions/health benefits) – or better female comprehension of stove attributes. Figure 2 shows that stated reasons for stove choices reflect the salient characteristics that we emphasize, and Table 4 shows that women's years of education is not a significant predictor of stove choice. Portability is the other readily-observable difference between the two stoves, but this characteristic should bias women towards the portable efficiency stove, which is the opposite of the empirical results we are trying to explain.

Third, demand for stoves may simply be more price elastic among women than among men. We did not estimate demand for improved cookstoves among single men and women (and selection into cohabitation presumably leads to unobserved differences between single and married individuals), so we are unable to compare to gender-specific price elasticities absent intra-household bargaining. However, previous studies have examined gender differentials in price elasticities of demand for cigarettes and alcohol in developed countries, and there is no clear consensus that such a gender differential exists.[26] Most relevant to our study is Hersch (2000), who finds no gender differential in aggregate price elasticities - but finds demand is more inelastic for both men and women when they have control over their own income (and that women have a smaller earnings elasticity when the earnings are their own (i.e. not pooled

[25] 58% of women ordering a stove when it's free are illiterate, while only 40% ordering when a positive price is charged are (p-value of difference 0.04). 40% of women ordering a stove when it's free paid a dowry, while only 29% of women ordering a stove under positive prices did (p-value 0.14). This pattern of heterogeneity is entirely consistent with our intra-household decision-making power based interpretation of the gender results.

[26] Manning et al. (1995) and Kenkel (1993) report opposite results for alcohol demand by men and women. Similarly, Chaloupka (1998) and Stehr (2007) find opposing results for cigarette demand.

household income). This finding is consistent with our own, also suggesting that gender differences in demand are related to the control women have over household resources.

Fourth, men may not recognize the harm of indoor air pollution as clearly as women do (or may not as clearly perceive emissions differences between traditional and improved stoves). This alternative explanation is of course closely related to the explanation that we propose (men have less personal exposure to indoor air pollution) and is therefore difficult to distinguish. Prior to making stove offers, we asked men and women about their expectations regarding improved stoves, and we do in fact find that women are more likely than men to say that an improved stove reduces the risk of respiratory illness and increases the likelihood of living longer.[27] Although these data have limitations, it is possible that our results could be due in part to gender-differences in the "salience" of health considerations rather than different innate preferences over women's health.

7. Conclusion

We conducted a demand experiment to study the role of gender – a commonly cited factor about which there is little quantitative evidence – in explaining low adoption rates of improved cookstoves. These stoves are potentially important technologies with substantial implications for population health and the environment, but efforts to promote them around the world have yielded disappointing results to date (Miller & Mobarak, 2012). Importantly, although not the primary focus of our project, we also observe very low adoption rates when incorporating a health education message about the harms of traditional cooking practices and

[27] Men report an expected reduction in the likelihood of respiratory illness after adopting an improved stove of -25%, while women expect this likelihood to fall by -32% (p-value of the difference between these two <0.001). Men expect their lifespan to increase by 0.72 years on average after adopting an improved stove, while women expect an increase in their lifespan of 1.13 years (t-statistic on the difference between these two = 7.97).

the benefits of improved stoves into our study arms – implying that the effectiveness of basic health education may be quite limited in this context.

Other research of ours finds that price is central in rural Bangladeshi households' decision-making, but only 69% of households accept improved cookstoves that are offered for free, suggesting important non-price impediments to stove demand as well. For example, qualitative evidence suggests that even women do not perceive indoor air pollution as an important health hazard, relative to other hazards to which they and their families are exposed (Mobarak et al., 2012). The present research finds that another important non-price impediment is the presence of an intra-household externality: male financial decision-makers do not internalize the costs and benefits of new technology that accrue to their wives. While other studies have noted that women have stronger preferences for welfare-enhancing products and services than men (Duflo, 2003; Miller, 2008; Ashraf et al., 2010; World Bank, 2010), an important implication of our findings is that when individual choices cannot be hidden, public policy may not be able to exploit these stronger preferences absent broader changes in intra-household bargaining power (Doepke & Tertilt, 2011). A more promising approach may be to bundle technologies like cookstoves with products or attributes that men value and cannot easily un-bundle.[28]

Overall, our findings suggest that successful strategies for distributing gender-specific technology will need to simultaneously address both the gender differences in preferences as well as intra-household differences in decision-making power. Evidence to date suggests that subsidies are among the most effective ways to boost inefficiently low adoption rates (as noted in

[28] An example would be the *Biolite* stove (www.biolite.com), which generates small amounts of electricity during the cooking process that can be channeled towards cell phone charging, an attribute that male cell phone users would value relatively more.

many studies, c.f. Kremer & Miguel, 2007; Cohen & Dupas, 2010; Dupas, 2010), but even free distribution of a health-improving product may fall short of socially optimal levels of adoption.

References

Anderson, Siwan & Baland, Jean-Marie. (2002). The Economics of ROSCAs and Intrahousehold Resource Allocation. *The Quarterly Journal of Economics*, 117(3): 963-995.

Ashraf, Nava. (2009). Spousal Control and Intra-Household Decision Making: An Experimental Study in the Philippines. *American Economic Review*, 99(4): 1245-77.

Ashraf, Nava, Field, Erica & Lee, Jean. (2010). *Household Bargaining and Excess Fertility: An Experimental Study in Zambia. Unpublished manuscript.*

Ashraf, Nava, Karlan, Dean & Yin, Wesley. (2008). *Female Empowerment: Impact of a Commitment Savings Product in the Philippines. Unpublished manuscript.*

Banerjee, Abhijit & Mullainathan, Sendhil. (2010). *The Shape of Temptation: Implications for the Economic Lives of the Poor. Working Paper.*

Barnes, Douglas F., Kumar, Priti & Openshaw, Keith. (2012). *Cleaner Hearths, Better Homes: New Stoves for India and the Developing World.* Oxford: Energy Sector Management Assistance Program (ESMAP), The World Bank.

Bensch, Gunther & Peters, Jorg. (2012). *A Recipe for Success? Randomized Free Distribution of Improved Cooking Stoves in Senegal.* Bochum, Germany: Ruhr-Universitat Bochum, Department of Economics. Ruhr Economic Papers. No. 325.

BenYishay, Ariel & Mobarak, A. M. (2013). *Communicating with Farmers through Social Networks. Unpublished manuscript.*

Bertrand, Marianne, Karlan, Dean, Mullainathan, Sendhil, Shafir, Eldar & Zinman, Jonathan. (2010). What's Advertising Content Worth? Evidence from a Consumer Credit Marketing Field Experiment. *Quarterly Journal of Economics*, 125(1): 263-305.

Bond, Tami C., Streets, David G., Yarber, Kristen F., Nelson, Sibyl M., Woo, Jung-Hun & Klimont, Zbigniew. (2004). A Technology-Based Global Inventory of Black and Organic Carbon Emissions from Combustion. *Journal of Geophysical Research*, 109

Browning, M. & Chiappori, Pierre-André. (1998). Efficient Intra-Household Allocations: A General Characterization and Empirical Tests. *Econometrica*, 66(6): 1241-1278.

Brune, Lasse, Gine, Xavier, Goldberg, Jessica & Yang, Dean. (2011). *Commitments to Save: A Field Experiment in Rural Malawi.* Washington, DC: The World Bank. Policy Research Working Paper. No. 5748.

Bryan, Gharad, Chowdhury, Shyamal & Mobarak, A. M. (2011). *Seasonal Migration and Risk Aversion. Unpublished manuscript.*

Caselli, Francesco & Coleman II, Wilbur J. (2001). Cross-Country Technology Diffusion: The Case of Computers. *The American Economic Review*, 91(2): 328-335.

Chaloupka, Frank & Liccardo Pacula, Rosalie. (1998). *An Examination of Gender and Race Differences in Youth Smoking Responsiveness to Price and Tobacco Control Policies.* National Bureau of Economic Research. NBER Working Paper Series. No. 6541.

Chay, Kenneth Y. & Greenstone, Michael. (2003a). *Air Quality, Infant Mortality, and the Clean Air Act of 1970.* National Bureau of Economic Research, Inc.

Chay, Kenneth Y. & Greenstone, Michael. (2003b). The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by A Recession. *The Quarterly Journal of Economics*, 118(3): 1121-1167.

Chiappori, Pierre-André. (1988). Rational Household Labor Supply. *Econometrica*, 56(1): 63-90. Retrieved from http://www.jstor.org/stable/1911842

Cohen, Jessica & Dupas, Pascaline. (2010). Free Distribution Or Cost-Sharing? Evidence from a Randomized Malaria Prevention Experiment. *The Quarterly Journal of Economics*, CXXV(1)

Cole, Shawn A., Giné, Xavier, Tobacman, Jeremy B., Topalova, Petia B., Townsend, Robert M. & Vickery, James. (forthcoming). Barriers to Household Risk Management: Evidence from India. *American Economic Journal: Applied Economics*

Comin, Diego & Hobijn, Bart. (2004). *Neoclassical Growth and the Adoption of Technologies.* National Bureau of Economic Research, Inc.

Conley, Timothy & Udry, Christopher. (2001). Social Learning through Networks: The Adoption of New Agricultural Technologies in Ghana. *American Journal of Agricultural Economics*, 83(3): 668-73.

Conley, Timothy & Udry, Christopher. (2010). Learning about a New Technology: Pineapple in Ghana. *The American Economic Review*, 100(1): 35-69.

Dasgupta, Susmita, Huq, Mainul, Khaliquzzman, M., Pandey, Kiran & Wheeler, David. (2006). Indoor Air Quality for Poor Families: New Evidence from Bangladesh. *Indoor Air*, 16: 426-444.

de Mel, Suresh, McKenzie, David & Woodruff, Christopher. (2009). Are Women More Credit Constrained? Experimental Evidence on Gender and Microenterprise Returns. *American Economic Journal: Applied Economics*, 1(3): 1-32.

Dehijia, Vivek. (2012, April 23). The Cookstove Conundrum. *The New York Times.*

Desai, Sonalde & Andrist, Lester. (2010). Gender Scripts and Age at Marriage in India. *Demography*, 47(3): 667-687.

Doepke, Matthias & Tertilt, Michèle. (2011). *Does Female Empowerment Promote Economic Development?* The World Bank Poverty Reduction and Economic Management Network, Gender and Development Unit. No. 5714.

Duflo, Esther. (2003). Grandmothers and Granddaughters: Old-Age Pensions and Intrahousehold Allocation in South Africa. *The World Bank Economic Review*, 17(1): 1-25.

Duflo, Esther, Greenstone, Michael & Hanna, Rema. (2008). Indoor Air Pollution, Health and Economic Well-being. *S.A.P.I.EN.S*, 1(1): 7-16.

Duflo, Esther, Greenstone, Michael & Hanna, Rema. (2012). *Up in Smoke: The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves.* MIT Department of Economics Working Paper. No. 12-10.

Duflo, Esther, Kremer, Michael & Robinson, Jonathan. (2011). Nudging Farmers to use Fertilizer: Theory and Experimental Evidence from Kenya. *The American Economic Review*, 101(6): 2350-2390.

Duflo, Esther & Udry, Christopher. (2003). *Intrahousehold Resource Allocation in Côte D'Ivoire: Social Norms, Separate Accounts and Consumption Choices.* Economic Growth Center, Yale University.

Dupas, Pascaline. (2010). *Short-Run Subsidies and Long-Run Adoption of New Health Products: Evidence from a Field Experiment.* National Bureau of Economic Research. No. 16298.

Dupas, Pascaline & Robinson, Jonathan. (2011). *Why Don't the Poor Save More? Evidence from Health Savings Experiments. Unpublished manuscript.*

ESMAP. (2010a). *Energy Sector Management Assistance Program 2010 Annual Report.* The World Bank.

ESMAP. (2010b). *Improved Cookstoves and Better Health in Bangladesh: Lessons from Household Energy and Sanitation Programs.* Washington, D.C.: The International Bank for Reconstruction and Development/The Work Bank.

Ezzati, Majid & Kammen, Daniel M. (2001a). Indoor Air Pollution from Biomass Combustion and Acute Respiratory Infections in Kenya: An Exposure-Response Study. *The Lancet*, 358(9282): 619-624.

Ezzati, Majid & Kammen, Daniel M. (2001b). Quantifying the Effects of Exposure to Indoor Air Pollution from Biomass Combustion on Acute Respiratory Infections in Developing Countries. *Environmental Health Perspectives*, 109(5)

Ezzati, Majid & Kammen, Daniel M. (2002). The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs. *Environmental Health Perspectives*, 110(11): 1057-1068.

Fafchamps, Marcel, McKenzie, David, Quinn, Simon R. & Woodruff, Christopher. (2011). *When is Capital enough to Get Female Microenterprises Growing? Evidence from a Randomized Experiment in Ghana.* Washington, D.C.: National Bureau of Economic Research. Working Paper. No. 17207.

Feder, Gershon, Just, Richard E. & Zilberman, David. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2): 255-98.

Feder, Gershon & Slade, Roger. (1984). The Acquisition of Information and the Adoption of New Technology. *American Journal of Agricultural Economics*, 66(3): 312-320.

Foster, Andrew & Rosenzweig, Mark R. (1995). Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. *Journal of Political Economy*, 103(6): 1176-1209.

Foster, Andrew & Rosenzweig, Mark R. (2010). Microeconomics of Technology Adoption. *Annual Review of Economics*, 2(1): 395-424.

Gajate-Garrido, Gissele. (2010). *Is there a Differential Impact of Indoor Air Pollution on Child Health? Exploring Gender Disparities in Peru. Working Paper.*

Gine, Xavier, Townsend, Robert & Vickery, James. (2008). Patterns of Rainfall Insurance Participation in Rural India. *The World Bank Economic Review*, 22(3): 539-566.

Gine, Xavier & Yang, Dean. (2009). Insurance, Credit, and Technology Adoption: Field Experimental Evidence from Malawi. *Journal of Development Economics*, 89(1): 1-11.

Harvey, Charles F., Swartz, Christopher H., Badruzzaman, A. B. M., Keon-Blute, Nicole, Yu, Winston, Ali, M. A., Jay, Jenny, Beckie, Roger, Niedan, Volker, Brabander, Daniel, Oates, Peter, Ashfaque, Khandaker N., Islam, Shafiqul, Hemond, Harold F. & Ahmen, M. F. (2002). Arsenic Mobility and Groundwater Extraction in Bangladesh. *Science*, 298: 1602-06.

Hersch, Joni. (2000). Gender, Income Levels, and the Demand for Cigarettes. *Journal of Risk and Uncertainty*, 21(2/3): 263-282.

Hoffmann, Vivian. (2009). Intrahousehold Allocation of Free and Purchased Mosquito Nets. *American Economic Review*, 99(2): 236-41.

Iyigun, Murat & Walsh, Randall P. (2007). Building the Family Nest: Premarital Investments, Marriage Markets, and Spousal Allocations. *Review of Economic Studies*, 74(2): 507-535.

Jensen, Robert & Thornton, Rebecca. (2003). Early Female Marriage in the Developing World. *Gender and Development*, 11(2): 9-19.

Kelly, Jeffrey, St. Lawrence, Janet S., Stevenson, L. Y., Hauth, Allan, Kalichman, Seth, Diaz, Yolanda, Brasfield, Ted, Koob, Jeffrey & Morgan, Michael. (1992). Community AIDS/HIV Risk Reduction: The Effects of Endorsements by Popular People in Three Cities. *American Journal of Public Health*, 82(11): 1483-1489.

Kenkel, Donald S. (1993). Drinking, Driving and Deterrence: The Effectiveness and Social Costs of Alternative Policies. *The Journal of Law Economics*, 36(2): 877-913.

Köhlin, Gunnar, Sills, Erin O., Pattanayak, Subhrendu K. & Wilfong, Christopher. (2011). *Energy, Gender and Development: What are the Linkages? Where is the Evidence?* Washington, D.C.: The World Bank. Social Development Working Paper. No. 125.

Kremer, Michael & Miguel, Edward. (2007). The Illusion of Sustainability. *The Quarterly Journal of Economics*, 122(3): 1007-1065.

Kremer, Michael, Miguel, Edward, Mullainathan, Sendhil, Null, Clair & Zwane, Alix P. (2009). *Making Water Safe: Price, Persuasion, Peers, Promoters, Or Product Design? Working Paper.*

Levine, David I. & Beltramo, Theresa. (2011). *The Effect of Solar Ovens on Fuel use, Emissions, and Health: Results from a Randomized Controlled Trial. Working Paper.*

Lundberg, Shelly & Pollak, Robert A. (1994). Noncooperative Bargaining Models of Marriage. *The American Economic Review*, 84(2, Papers and Proceedings of the Hundred and Sixth Annual Meeting of the American Economic Association): 132-137. Retrieved from http://www.jstor.org/stable/2117816

Lundberg, Shelly & Pollak, Robert A. (1996). Bargaining and Distribution in Marriage. *Journal of Economic Perspectives*, 10(4): 139-58.

Luoto, Jill. (2009). *Information and Persuasion: Achieving Safe Water Behaviors in Kenya. Job Market Paper.*

Manning, Willard G., Blumberg, Linda & Moulton, Lawrence H. (1995). The Demand for Alcohol: The Differential Response to Price. *Journal of Health Economics*, 14(2): 123-148.

McElroy, Marjorie B. (1990). The Emprical Content of Nash-Bargained Household Behavior. *The Journal of Human Resources*, 25(4): 559-83.

Meredith, Jennifer, Robinson, Jonathan, Walker, Sarah & Wydick, Bruce. (2011). *Keeping the Doctor Away: Experimental Evidence on Investment in Preventative Health Products. Unpublished manuscript.*

Mestieri, Marti & Comin, Diego. (2010). *The Intensive Margin of Technology Adoption. NBER Working Paper No. 16379.*

Miah, Md D., Al Rashid, Harun & Shin, Man Y. (2009). Wood Fuel use in the Traditional Cooking Stoves in the Rural Floodplain Areas of Bangladesh: A Socio-Environmental Perspective. *Biomass and Bioenergy*, 33(1): 70-78. doi:10.1016/j.biombioe.2008.04.015

Michael, Holly A. & Voss, Clifford I. (2008). Evaluation of the Sustainability of Deep Groundwater as an Arsenic-Safe Resource in the Bengal Basin. *Proceedings of the National Academy of Sciences*, 105(25): 8531-8536.

Miller, Grant. (2008). Women's Suffrage, Political Responsiveness, and Child Survival in American History. *The Quarterly Journal of Economics*, 123(3): 1287-1327.

Miller, Grant & Mobarak, A. M. (2012). *Social Marketing for Improved Cookstoves: A Field Experiment in Rural Bangladesh. Unpublished Manuscript.*

Mobarak, Ahmed M., Dwivedi, Puneet, Bailis, Robert, Hildemann, Lynn & Miller, Grant. (2012). Low Demand for Nontraditional Cookstove Technologies. *Proceedings of the National Academy of Sciences*, 109(27): 10815-10820. doi:10.1073/pnas.1115571109

Mueller, Valerie, Pfaff, Alexander, Peabody, John, Liu, Yaping & Smith, Kirk R. (2009). Improved Estimates of Improved Stove Health Benefits: Bringing 'Matching' Approaches to Indoor Air Quality. *Under Revision, International Journal of Epidemiology*

Oster, Emily & Thornton, Rebecca. (2009). *Determinants of Technology Adoption: Private Value and Peer Effects in Menstrual Cup Take-Up.* National Bureau of Economic Research, Inc.

Palmer, Brian. (2012, April 16). `Clean Cookstoves' Draw Support, but they may Not Improve Indoor Air Quality. *The Washington Post.*

Pitt, Mark M., Rosenzweig, Mark R. & Hassan, Nazmul. (2005). *Sharing the Burden of Disease: Gender, the Household Division of Labor and the Health Effects of Indoor Air Pollution.* Bureau for Research in Economic Analysis of Development (BREAD). No. 093.

Pitt, Mark M., Rosenzweig, Mark R. & Hassan, Nazmul. (2010). *Short- and Long-Term Health Effects of Burning Biomass in the Home in Low-Income Countries. Unpublished manuscript.*

Pitt, Mark M., Rosenzweig, Mark R. & Hassan, Nazmul. (2011). Human Capital Investment and the Gender Division of Labor in a Brawn-Based Economy. *American Economic Review, Forthcoming*

Ramanathan, V. & Carmichael, G. (2008). Global and Regional Climate Changes due to Black Carbon. *Nature Geoscience*, 1(4): 221-227.

Rosenthal, Elizabeth. (2009, 15 Apr). Third-World Stove Soot is Target in Climate Fight. *The New York Times.*

Sarkar, M., Akter, N. & Rahman, M. (2006). *Assessment of Existing Improved Cook Stove in Bangladesh.* Dhaka, Bangladesh: BRAC.

Smith, Kirk R. (2010). What's Cooking? A Brief Update. *Energy for Sustainable Development*, 14(4): 251-2.

Smith, Kirk R. & Dutta, Karabi. (2011). Cooking with Gas. *Energy for Sustainable Development*, 15(2): 115-116. doi:10.1016/j.esd.2011.05.001

Smith, Kirk R. & Haigler, Evan. (2008). Co-Benefits of Climate Mitigation and Health Protection in Energy Systems: Scoping Methods. *Annual Review of Public Health*, 29: 11-25.

Smith, Kirk R., McCracken, John, Weber, Martin W., Hubbard, Alan, Jenny, Alisa, Thompson, Lisa, Balmes, John, Diaz, Anaite, Arana, Byron & Bruce, Nigel. (2011). Effect of Reduction in Household Air Pollution on Childhood Pneumonia in Guatemala (RESPIRE): A Randomised Controlled Trial. *The Lancet*(- 9804): - 1717.

Smith, Kirk R., Samet, Jonathan M., Romieu, Isabelle & Bruce, Nigel. (2000). Indoor Air Pollution in Developing Countries and Acute Lower Respiratory Infections in Children. *Thorax*, 55(5): 518-532.

Somville, Vincent. (2011). *Daily Collectors, Public Good Provision and Private Consumption: Theory and Evidence from Urban Benin.* University of Namur, Department of Economics.

Stehr, M. (2007). The Effect of Cigarette Taxes on Smoking among Men and Women. *Health Economics*, 16(12): 1333-1343.

Suran, Luciana, Amin, Sajeda, Huq, Lopita & Chowdury, Kobita. (2004). *Does Dowry Improve Life for Brides? A Test of the Bequest Theory of Dowry in Rural Bangladesh.* Population Council. Policy Research Division Working Paper. No. 195.

Tarozzi, Alessandro, Mahajan, Aprajit, Blackburn, Brian, Kopf, Dan, Krishnan, Lakshmi & Yoong, Joanne. (2011). *Micro-Loans, Insecticide-Treated Bednets and Malaria: Evidence from a Randomized Controlled Trial in Orissa (India). Unpublished manuscript.*

Thomas, Duncan. (1990). Intra-Household Resource Allocation: An Inferential Approach. *Journal of Human Resources*, 25(4): 635-664.

Thomas, Duncan. (1994). Like Father, Like Son; Like Mother, Like Daughter: Parental Resources and Child Height. *Journal of Human Resources*, 29(4): 950-988.

Udry, Christopher. (1996). Gender, Agricultural Production, and the Theory of the Household. *Journal of Political Economy*, 104(5): 1010-46.

Udry, Christopher, Hoddinott, John, Alderman, Harold & Haddad, Lawrence. (1995). Gender Differentials in Farm Productivity: Implications for Household Efficiency and Agricultural Policy. *Food Policy*, 20(5): 407-423.

Ueyama, Mika. (2007). *Income Growth and Gender Bias in Childhood Mortality in Developing Countries.* International Food Policy Research Institute (IFPRI), Food Consumption and Nutrition Division. No. 00739.

Weimann, Gabriel, Tustin, Deon H., van Vuuren, Daan & Joubert, J. P. R. (2007). Looking for Opinion Leaders: Traditional Vs. Modern Measures in Traditional Societies. *International Journal of Public Opinion Research*, 19(2): 173-190.

World Bank. (2010). *World Development Report 2012: Gender, Equality and Development.* The World Bank. World Development Report. No. 57627.

World Health Organization. (2002). *The World Health Report 2002 - Reducing Risks, Promoting Healthy Life.*

World Health Organization. (2008). *World Malaria Report 2008.* World Health Organization. . (WHO)

Yu, Fei. (2011). Indoor Air Pollution and Children's Health: Net Benefits from Stove and Behavioral Interventions in Rural China. *Environmental and Resource Economics*: 1-20.

Figure 1: Experimental design

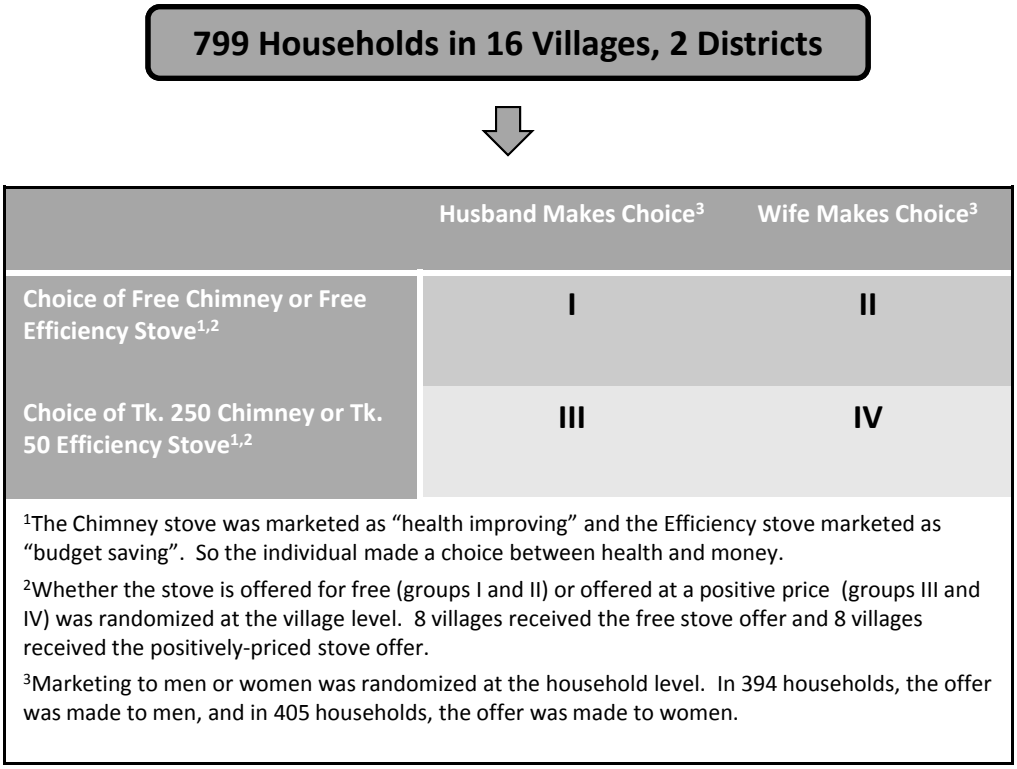


Figure 2a: Reasons Given for Accepting Stove Offer, by Type of Stove Chosen - Men[(1)]

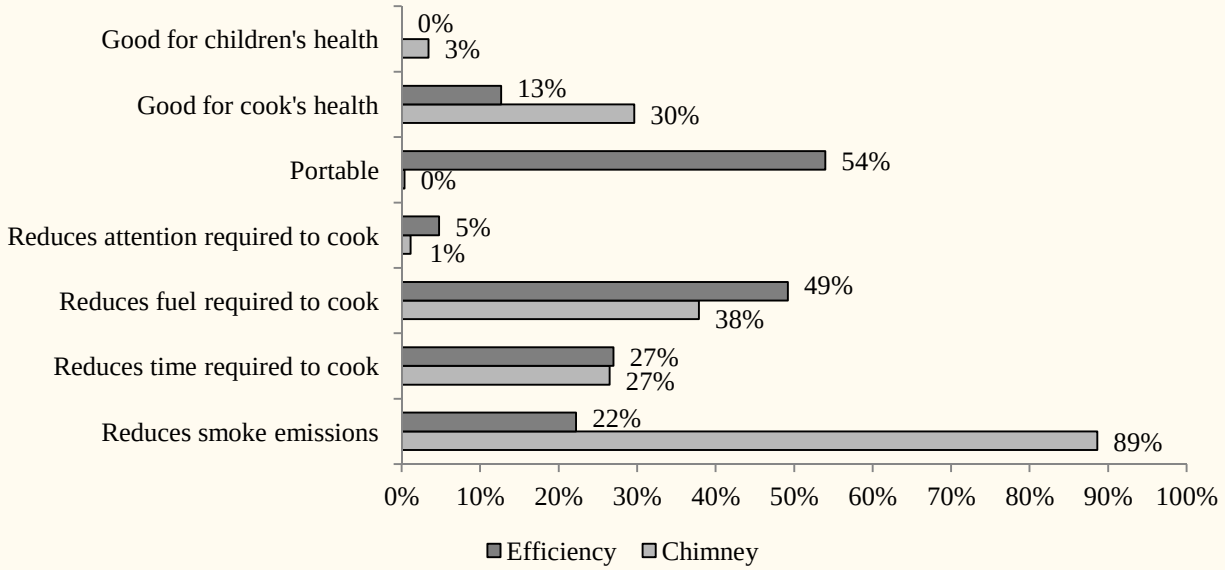
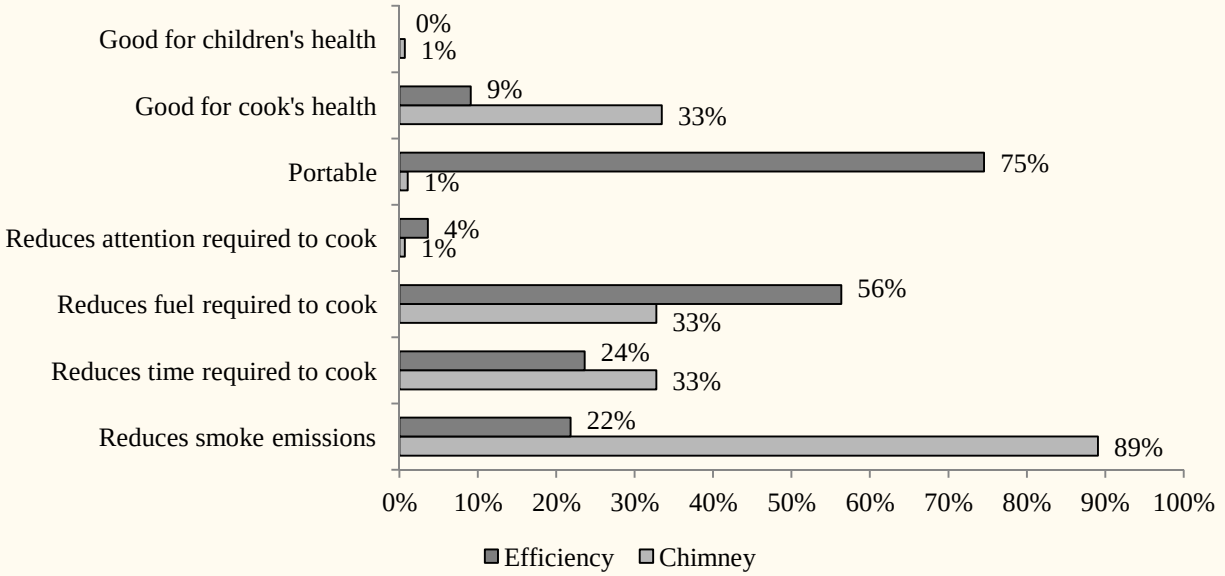


Figure 2b: Reasons Given for Accepting Stove Offer, by Type of Stove Chosen - Women [(1)]



[(1)] Percentages given are the number of men or women who selected that reason, divided by the total number of men or women who initially accepted the indicated stove type. 264 men and 284 women selected the chimney stove, while 63 men and 55 women selected the efficiency stove. Respondents could select multiple reasons, so responses total greater than 100%.

Figure 3: Women's Stove Order Decisions

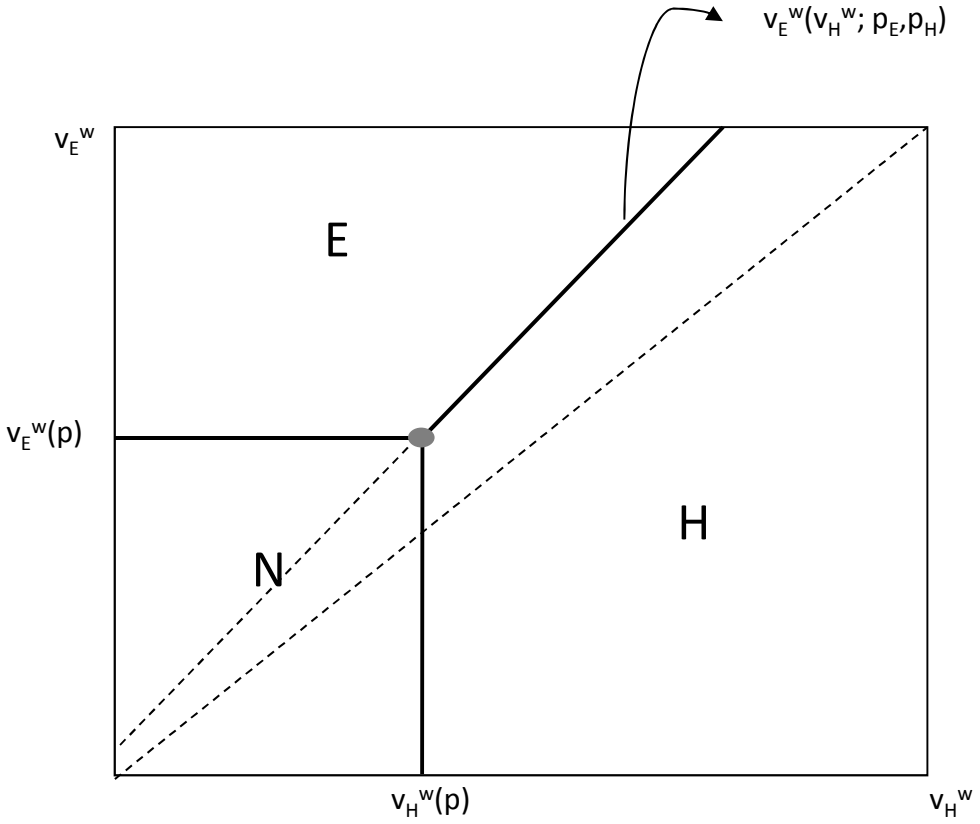


Table 1: Summary Statistics and Balance Across Treatment Cells at Baseline

	Free Stove Offer	Subsidized Stove Offer	P-value	Husband Makes Choice	Wife Makes Choice	P-value	Total
N	399	400		394	405		799
Household Characteristics							
Household size	6.73	6.73	0.994	6.66	6.80	0.432	6.73
Number of Wage Earners	1.78	1.91	0.538	1.88	1.82	0.489	1.85
Number of female HH members	3.51	3.43	0.792	3.44	3.49	0.681	3.47
Number of male HH members	3.23	3.30	0.815	3.22	3.30	0.488	3.26
Number of children under 5	0.84	0.66	0.154	0.73	0.77	0.448	0.75
Number of children under 18	3.02	2.64	0.310	2.76	2.90	0.081	2.83
Average monthly HH income (in taka)	4,936.78	5,922.47	0.205	5,323.92	5,534.19	0.393	5,430.24
Average monthly HH expenditures (in taka)	4,709.77	4,472.68	0.646	4,428.17	4,750.25	0.236	4,591.23
Household Wealth Index [(1)]	-0.14	-0.16	0.943	-0.17	-0.13	0.575	-0.15
HH owes money (Y/N)	0.26	0.18	0.280	0.21	0.23	0.605	0.22
Female Characteristics							
Age	35.94	37.23	0.208	36.30	36.87	0.493	36.59
Married	1.00	1.00	0.155	1.00	1.00	0.985	1.00
Education (in years)	2.42	3.11	0.121	2.79	2.74	0.873	2.77
Wage earner (Y/N)	0.08	0.16	0.214	0.12	0.13	0.461	0.12
Male Characteristics							
Age	45.15	46.30	0.347	45.52	45.92	0.632	45.72
Education (in years)	2.80	4.00	0.070	3.28	3.52	0.596	3.40
Wage earner (Y/N)	0.98	0.99	0.640	0.98	0.99	0.068	0.98
Male Occupations							
Agriculture (Own)	0.41	0.47	0.306	0.42	0.45	0.511	0.44
Business	0.19	0.20	0.671	0.19	0.20	0.654	0.19
Day labour (Agriculture)	0.13	0.08	0.166	0.11	0.09	0.195	0.10
Day labour (Non agriculture)	0.13	0.09	0.136	0.13	0.09	0.241	0.11
Service	0.06	0.08	0.180	0.06	0.08	0.267	0.07
Other	0.10	0.09	0.691	0.09	0.10	0.714	0.09
Additional Gender Variables							
Denied permission to work	0.36	0.32	0.798	0.35	0.34	0.833	0.34
Female chooses what foods to cook	0.64	0.58	0.463	0.61	0.60	0.727	0.61
Female chooses what food to buy	0.11	0.10	0.807	0.11	0.10	0.702	0.11
Woman's age at marriage	14.85	14.97	0.686	14.83	14.99	0.241	14.91
Woman married before age 15	0.69	0.63	0.419	0.67	0.65	0.345	0.66
Male >10 yrs older female	0.29	0.29	0.904	0.27	0.30	0.423	0.29
Female has some education	0.44	0.49	0.330	0.46	0.47	0.854	0.47
Male has some education	0.39	0.51	0.114	0.44	0.45	0.832	0.45
Dif educ men women	0.38	0.89	0.185	0.49	0.78	0.275	0.64
Male more educated than female	0.29	0.39	0.094	0.32	0.35	0.433	0.34
Female more educated than male	0.22	0.18	0.163	0.21	0.19	0.441	0.20
Dowry paid?	0.38	0.36	0.851	0.37	0.37	0.928	0.37
Gender empowerment index[(2)]	-0.02	-0.08	0.611	-0.03	-0.07	0.615	-0.05
Has children under 5	0.58	0.49	0.103	0.54	0.53	0.821	0.54
Female health index[(3)]	0.26	0.43	0.701	0.17	0.51	0.076	0.34
Child health index[(3)]	0.40	0.02	0.355	0.15	0.26	0.528	0.21

[(1)] Wealth index is constructed using principal component analysis of variables indicating if the household owns land, a vehicle, or other assets.

[(2)] Female empowerment index is constructed through principal component analysis of the following dummy variables: Female chooses what foods to cook, Female chooses what food to buy, Female contributes to household wages, Female has at least 1 year of education, Female has more years of education than male; (and the negative of): Female has been denied permission to work in the past by her husband, Female married before age 16, Male more than 10 years older than female, Male has more years of education than female, Female's family paid dowry at time of marriage

[(3)] Female and child health indices are constructed using principal component analysis of variables indicating if the wife or the child has suffered from any of the following illnesses: Eye problems, diarrhea, difficulty breathing, night sweats, dry cough, phlegmy cough, blood in sputum, or fever

Table 2: Stove Acceptance rates for groups I-IV

Cluster	Group	Households	Ordered Stove*	Purchased Stove*
Free Stove (I/II)	I - Stove offered to men	197	94% (81%)	69% (75%)
	II - Stove offered to women	202	100% (87%)	70% (83%)
Subsidized Stove (III/IV)	III - Stove offered to men	197	72% (81%)	26% (75%)
	IV - Stove offered to women	203	69% (79%)	29% (73%)
	Total	799	84% (82%)	49% (78%)

*Numbers in parenthesis give percentages, by group, of those who chose the chimney stove, conditional on having ordered any stove at all. So, for example, 94% of group I ordered a stove, and of these, 81% order the chimney stove (so 19% ordered the efficiency stove).

Table 3: OLS Regression coefficients of the indicator that Males (rather than Females) are presented with the stove choice [(1)]

	Row		Any Stove Order (1)	Ordered a chimney (rather than efficiency) stove[(3)] (2)	Ordered a chimney stove out of those offered a stove (3)	Any Stove Purchase (4)	Purchased a chimney (rather than efficiency) stove [(3)] (5)	Purchased a chimney stove out of those offered a stove (6)	Refused to Purchase (of those who ordered)[(4)] (8)
Panel 1: Not controlling for any household characteristics [(2)]	1	Free Stove Condition (Groups I and II)	-0.061***	-0.064*	-0.113***	-0.018	-0.083*	-0.071	-0.027
		[standard error]	[0.017]	[0.038]	[0.039]	[0.046]	[0.049]	[0.050]	[0.046]
		Sample size [(5)]	399	384	396	399	277	399	387
		Mean of dep variable[(6)]	1.00	0.87	0.87	0.70	0.83	0.58	0.30
	2	Subsidized Stove Condition (Groups III and IV)	0.031	0.017	0.037	-0.027	0.021	-0.014	0.055
		[standard error]	[0.046]	[0.048]	[0.050]	[0.045]	[0.084]	[0.040]	[0.058]
		Sample size	400	282	400	400	111	400	282
		Mean of dep variable[(6)]	0.69	0.79	0.55	0.29	0.73	0.21	0.58
		p-value for equality of coefficients on 'male' between free and subsidized cases [(7)]	0.056	0.159	0.034	0.802	0.222	0.213	0.039
Panel 2: Controlling for household characteristics [(2)]	3	Free Stove Condition (Groups I and II)	-0.059***	-0.068*	-0.114***	-0.009	-0.099**	-0.064	-0.036
		[standard error]	[0.017]	[0.038]	[0.039]	[0.048]	[0.050]	[0.052]	[0.047]
		Sample size	399	384	396	399	277	399	387
	4	Subsidized Stove Condition (Groups III and IV)	0.033	0.003	0.051	-0.021	-0.010	0.000	0.061
		[standard error]	[0.046]	[0.045]	[0.048]	[0.046]	[0.072]	[0.040]	[0.060]
		Sample size	398	282	398	398	111	398	282
		p-value for equality of coefficients on 'male' between free and subsidized cases [(7)]	0.085	0.093	0.022	0.747	0.168	0.150	0.021

*** p<0.01, ** p<0.05, * p<0.1

(1) Households were randomly allocated to have either the male head of household (groups I and III) or the female primary cook (groups II and IV) make the decision as to whether and what type of stove to accept. The estimates in this table are the regression coefficients resulting from regressing the variable in the column header on the indicator that the male head of household was presented with the decision, under the conditions specified in the row header.

(2) Control variables included all variables for which balance was not achieved through randomization, as well as other variables of interest. These were: number of female hh members, number of male hh members, number of children under 5, number of children under 18, whether there is a female wage earner in the hh, the total number of wage earners, household expenditures, the hh wealth index, female respondent's age and years of education, male respondent's age and years of education, whether male respondents had more education than females, the amount of time spent cooking during the dry season, and the female health index.

(3) For specifications (2) and (5), the dependent variable is only defined for those households who chose to order or purchase a stove. It is a dummy variable of value one if the household ordered/purchased a chimney stove, zero if the household ordered/purchased an efficiency stove, and missing if the household declined the stove offer. These dependent variables are only defined conditional on take-up, so this is not a regression on a full experimental sample.

(4) Dependent variable (refused) equals one if the household initially ordered a stove that they later refused to purchase, defined only for the households who initially ordered a stove.

(5) Sample size: 399 households were offered the free stove (groups I and II); 400 were offered the subsidized stove (groups III and IV). These numbers fall slightly in specifications 3, 6, and 7, due to missing values either in the dependent variables or in the controls for household characteristics.

(6) Indicates the mean of the dependent variable for women (Groups II or IV)

(7) The test for equality of coefficients across free and subsidized cases clusters standard errors by village, which is the level at which prices are randomized

Table 4: Gender Differential in Chimney Stove Orders at a Positive Price (Groups III-IV) [1]

	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)
Female offered choice of stove	-0.037	0.014	-0.087	-0.043	-0.147**	-0.034	-0.087	-0.034	-0.031	-0.037
	[0.050]	[0.059]	[0.064]	[0.064]	[0.069]	[0.063]	[0.054]	[0.050]	[0.065]	[0.050]
Male >10 yrs older than female		0.140*								
		[0.079]								
Interaction: offered to female*Male >10 yrs older than female		-0.183*								
		[0.110]								
Female Education (years)			0.010							
			[0.010]							
Interaction: offered to female*Female Education			0.014							
			[0.013]							
Male Education (years)				0.027***						
				[0.008]						
Interaction: offered to female*Male Education				-0.004						
				[0.011]						
Female has some education					0.030					
					[0.070]					
Interaction: offered to female*Female has some education					0.208**					
					[0.098]					
Male more educated than female						0.225***				
						[0.073]				
Interaction: offered to female*Male more educated than female						-0.044				
						[0.100]				
Female more educated than male							-0.220**			
							[0.090]			
Interaction: offered to female*Female more educated than male							0.269**			
							[0.129]			
Index of Female Empowerment [2]								-0.062**		
								[0.028]		
Interaction: Offered to female* Female Empowerment Index								0.082**		
								[0.040]		
Number of Children Under 5									0.041	
									[0.045]	
Interaction: offered to female*Number of Children Under 5									-0.009	
									[0.062]	
Child health index										0.007
										[0.017]
Interaction: offered to female*Child health index										0.008
										[0.024]
Constant	0.584***	0.545***	0.555***	0.489***	0.570***	0.504***	0.625***	0.582***	0.557***	0.583***
	[0.035]	[0.041]	[0.045]	[0.044]	[0.047]	[0.043]	[0.039]	[0.035]	[0.046]	[0.035]
Observations	400	400	400	400	400	400	400	399	400	400
R-squared	0.001	0.010	0.021	0.053	0.031	0.041	0.017	0.015	0.005	0.004
F test: (Cond_F + Interaction) = 0		3.284	1.665	0.655	0.738	0.971	2.427	0.530	0.552	0.270
Prob > F		0.0707	0.198	0.419	0.391	0.325	0.120	0.467	0.458	0.603

Standard errors in brackets *** p<0.01, ** p<0.05, * p<0.1

[1] Dependent variable is a dummy variable with a value of 1 if the household ordered a chimney stove and 0 if the household ordered either the efficiency stove or no stove at all

[2] Female empowerment index is constructed through principal component analysis of the following dummy variables: Female chooses what foods to cook, Female chooses what food to buy, Female contributes to household wages, Female has at least 1 year of education, Female has more years of education than male; (and the negative of): Female has been denied permission to work in the past by her husband, Female married before age 16, Male more than 10 years older than female, Male has more years of education than female, Female's family paid dowry at time of marriage

Table 5: Gender Differential in Refusal Rates for Free Stoves [(1)]

	(1)	(2)	(3)	(4)	(5)	(6)
Interaction: offered to female*Male >10 yrs older than female	0.015					
	[0.101]					
Interaction: offered to female*Female Education		-0.008				
		[0.014]				
Interaction: offered to female*Female has some education			-0.069			
			[0.093]			
Interaction: offered to female*Male more educated than female				0.080		
				[0.102]		
Interaction: offered to female*Female more educated than male					-0.175	
					[0.110]	
Interaction: offered to female*Female empowerment index [(2)]						-0.048
						[0.035]
Constant	0.271***	0.240***	0.237***	0.258***	0.248***	0.270***
	[0.039]	[0.043]	[0.046]	[0.039]	[0.038]	[0.033]
Observations	387	387	387	387	387	387
R-squared	0.001	0.004	0.004	0.010	0.007	0.006
F test: (Cond_F + Interaction) = 0	0.191	0.684	0.0178	0.954	1.251	0.152
Prob > F	0.663	0.409	0.894	0.329	0.264	0.697

Standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

[(1)] The dependent variable is defined only if the household agreed to purchase a stove at the time the offer was made, and is a dummy with a value of 1 if the household refused to accept the stove when it was delivered, and 0 otherwise. Each regression shows the coefficient on the interaction between the condition that the initial stove offer was made to the wife, and a variable that proxies for female empowerment in the household. Each of these variables are also included separately in the regressions (coeffcients not shown for space reasons).

[(2)] Female empowerment index is constructed through principal component analysis of the following dummy variables: Female chooses what foods to cook, Female chooses what food to buy, Female contributes to household wages, Female has at least 1 year of education, Female has more years of education than male; (and the negative of): Female has been denied permission to work in the past by her husband, Female married before age 16, Male more than 10 years older than female, Male has more years of education than female, Female's family paid dowry at time of marriage

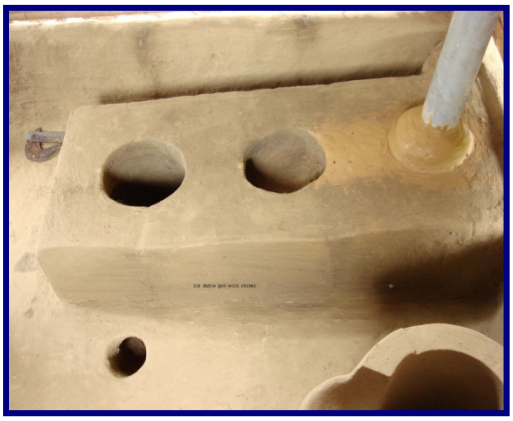
Appendix 1: Findings from a Nationally-Representative Qualitative Survey [(1)]

	N	Percent of Total
Full Sample	2400	--
Currently use traditional stove	2400	99%
Currently using an improved stove	2400	0.8%
Aware of, or heard about improved cookstoves	2397	12%
Have ever seen an improved cookstove	2397	8%
Believes indoor smoke is harmful to health	2256	94%
Believes indoor smoke is less harmful than:		
Dust	294	12%
Spoiled Food	1589	66%
Polluted Water	1820	76%
Characteristics of improved stoves valued by respondent:		
Reduced fuel costs	1120	47%
Reduced time to cook	346	14%
Uses more types of fuel	515	21%
Reduced smoke in house	101	4%
Reduced monitoring while cooking	75	3%
More cooking chambers	215	9%
Maintains taste of food	8	0%
Portable	5	0%
Elasticity of willingness to pay for:		
An improved cooking stove		-0.0115
Medical consultations		-0.0016
New primary school for kids		-0.0014
Paved road to local market		-0.0009
Electricity connection for house		-0.0008
New sanitary latrine		-0.0016
New higher yield seed		-0.0028

[(1)] Data from Mobarak et al. (2012)

Appendix 2: Examples of Stoves

Efficiency Stove



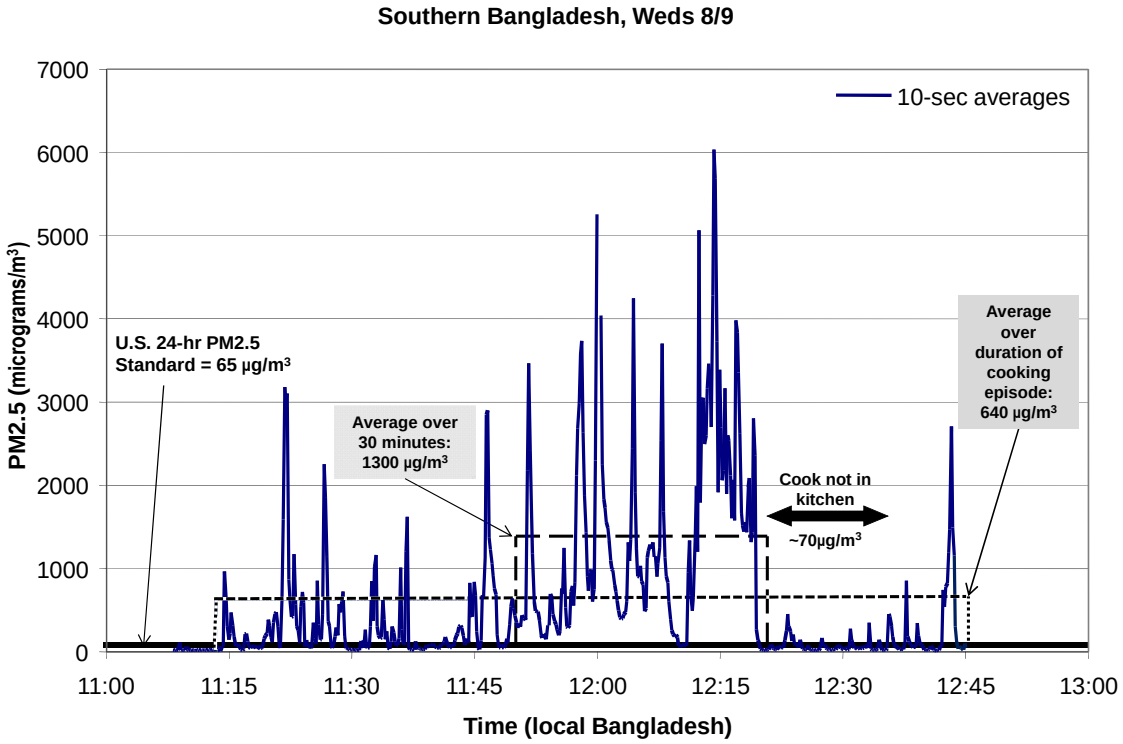
Chimney Stove

Traditional Stove

Appendix 3: Pollution testing

Emissions tests of the three types of stoves (traditional, efficiency, and chimney) were conducted using a SIDEPAK™ AM510 Personal Aerosol Monitor. The SIDEPAK monitors can measure particulate matter with a diameter of <1.0, <2.5 and <10 micrometers (μ). Following standard environmental protocols, we focus on PM2.5: the concentration of particles of 2.5μ or less, in milligrams per cubic meter (mg/m^3) of particulate matter.

During the tests, cooks were instructed to cook the same amount of rice and vegetables with the same amount of fuel, using each of the stoves. Each test used three monitors. One was attached to the cook, with an input tube fastened close to the cook's mouth and nose. Another was placed one meter from the stove. The last was placed three meters from the stove, in another room if possible but otherwise facing away from the stove, to estimate particulate matter received by people not directly involved in the cooking. The monitors began logging particulate matter concentrations 10 minutes before cooking began, and continued until 10 minutes after the cooking ended. See chart below for an example of a traditional stove's measured emissions.[1]



[1] Our thanks to Lynn Hildemann, Professor, Dept. of Civil and Environmental Engineering at Stanford University, for creating and allowing us to use this diagram.

Appendix 4: Scripts

Choice between Efficiency Stove and Chimney Stove (only relevant for groups I and II):

We would like to offer you one of two types of improved stoves. These are made of clay, just like the traditional stove you use. Both stoves can burn wood like your current stove. You will also face some difficulty burning crop refuse, hay etc. in both stoves.

The main difference between the efficiency stove and your current stove is that the wood burns efficiently in this improved stove. Based on our tests, we have found that this stove requires less wood and time than traditional stoves, but during cooking this stove will produce similar amount of smoke. The stove is also movable – you can take it outdoors during the winter.

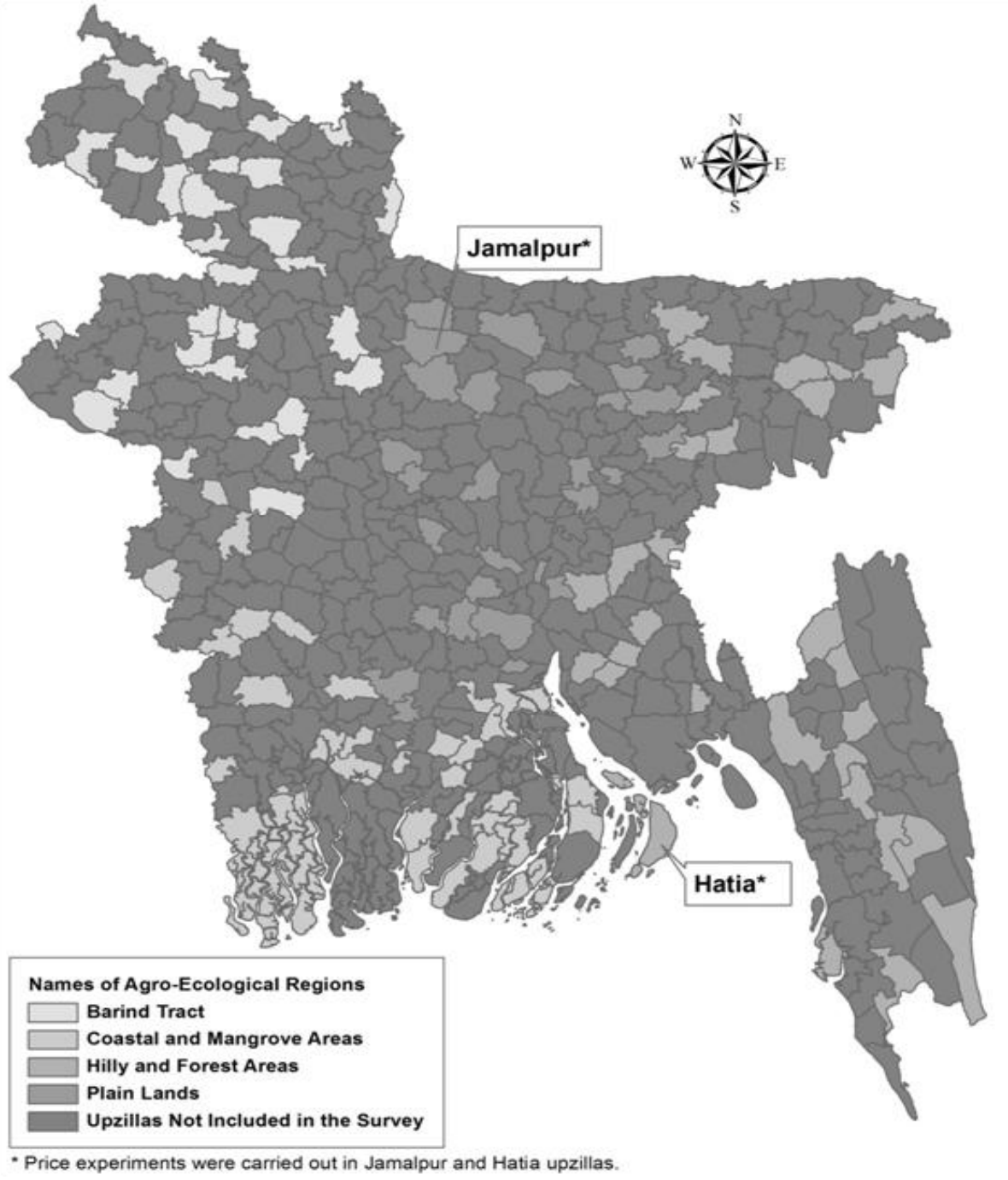
The main difference between the chimney stove and your current stove is the chimney you see in the picture (see photos below). The smoke that is created during cooking leaves the kitchen through the chimney. Based on our tests, we have found that this chimney stove emits less smoke inside the kitchen. With this stove, fuel use and cooking time remains about the same as a traditional stove.

If you agree, then we can provide one of the two stoves for free and explain in detail how to use it.

Efficiency Stove

Chimney Stove

Appendix 5: Map



* Price experiments were carried out in Jamalpur and Hatia upzillas.