INTRA-HOUSEHOLD EXTERNALITIES AND LOW DEMAND FOR A NEW TECHNOLOGY: EXPERIMENTAL EVIDENCE ON IMPROVED COOKSTOVES*

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Abstract

This paper studies the behavioral underpinnings of low demand for a technology with substantial implications for population health and the environment: improved cookstoves. We conduct a multi-pronged field experiment in rural Bangladesh to investigate two commonly-cited reasons for low demand: (1) intra-household externalities and (2) lack of trustworthy local information about new technologies. On the former, we find that women – who bear disproportionate cooking costs – have stronger preference for improved stoves, especially health-saving stoves, but lack the authority to make purchases. On the latter, we find that revealing information about technology choices by respected community members ("Opinion Leaders") influences adoption decisions more for technologies lacking self-evident benefits and more before common experience accumulates. Overall, our findings suggest that (1) If women cannot make independent choices, public policy may not be able to exploit gender differences in preferences to promote technology adoption absent broader social change; and (2) Marketing and persuasion techniques may only increase adoption temporarily and may be less effective for technologies with self-evident benefits.

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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 improved cookstove technology dissemination in the developing world (Smith, 2010).

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

In this paper, we consider two additional under-studied explanations: (1) Gender differences in preferences within households, resulting in male decision-makers not accounting for the full costs and benefits of a new technology to other household members, and (2) Lack of local information from a trustworthy source about an unknown new technology. To study the relative importance of these explanations, we conduct a set of field experiments using a

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

Half of the world's population and 75% of South Asians burn biomass many hours each day using inefficient, high-emission traditional stoves (World Health Organization, 2002). The smoke from burning solid 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 (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 exposure have been marketed over the last three decades at reasonably low prices (US$10-20), but they remain unpopular with consumers. Our demand study seeks to shed light on this puzzle.

Our experiments – depicted in Figure 1 – are designed to study what have informally been proposed as the leading barriers to improved cookstove adoption (Manibog, 1984): gender differences in preferences within households and "tradition"-based aversion to new cooking technology that may require external influence from a trusted source to overcome. In one branch of experiments, we offer 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). Across price points, we offer the choice of stoves to women (who may prefer to invest in health-improving technologies) in some randomly selected households and to men (who have greater decision-making power over the household budget) in others. We find that when stoves are

offered for free, women appear to exhibit a stronger preference for any improved stove – and for the 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 finding may indicate that despite their preferences, women lack authority to make purchases. We also find that with more time to learn about their husbands' preferences about a new technology, women's choices converge with their husbands'.

These results build on an earlier empirical literature showing that preferences varying by gender can lead to inefficiencies (Udry et al., 1995; Udry, 1996; Anderson & Baland, 2002; Ashraf, 2009; de Mel et al., 2009; Ashraf, Field et al., 2010; Fafchamps et al., 2011; Köhlin et al., 2011).[1] Our use of two different price points goes further towards establishing the existence of an intra-household externality stemming from the financial decision-maker 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.[2] Our results also demonstrate that the intra-household externality and added constraint faced by women deter the adoption of a technology that the scientific literature claims to be efficient for the household. These findings relate to the theoretical literature on intra-household bargaining and aggregation of individual preferences (Chiappori, 1988; McElroy, 1990; Lundberg & Pollak, 1996; Iyigun & Walsh, 2007).[3]

[1] In contrast, Dupas (2009) finds that for insecticide-treated bed nets in Kenya, men and women do not respond any differently to different marketing techniques.
[2] The previous experimental literature in this area was not designed to separate the gender differential in preferences from that in constraints.
[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.

A second branch of experiments tests a common social marketing strategy for conveying credible, contextually appropriate information about a new technology from trusted sources. Specifically, it pairs randomized price variation with information about the purchase decisions of village "Opinion Leaders" (cells V-VIII in Figure 1).[4] Although external information about new health technologies has dubious consequences for adoption (Luo et al., 2011), knowledge about the adoption decisions of respected community members (opinion leaders) may be more trustworthy and salient (Becker, 1970; Feder & Savastano, 2006). Numerous studies in sociology and economics document the central role of social networks in information transmission (Griliches, 1957; Rogers, 2003), and sociologists have proposed two distinct mechanisms of diffusion through social networks: "contagion by equivalence" and "contagion by cohesion" (Merton, 1968; Burt, 1999). Contagion by equivalence refers to transmission within groups among similar types of people, reflecting hands-on learning through personal experience (and has been studied relatively more by economists, see Foster & Rosenzweig, 1995; Conley & Udry, 2001; Munshi, 2004; Bandiera & Rasul, 2006; Pattanayak et al., 2009). Contagion by cohesion, on the other hand, refers to the transmission of information by brokers across social boundaries between dissimilar groups. Our study refers to trustworthy between-group brokers as "opinion leaders" who channel information between outsiders (such as development organizations or our own research team) and villagers in Bangladesh. This concept is related to the product "promoters", "ambassadors" or "extension partners" being employed in a number of

[4] Harnessing the influence of 'opinion leaders'is a common strategy used in the non-profit world to market socially-minded products. Population Services International (PSI) has developed a catalogue of "Behavior Change Communication" materials, with which they target key community members to create a snowball effect in information diffusion on topics ranging from malaria prevention to family planning. A safe-sex campaign successfully used opinion leaders to change social norms surrounding condom use in the gay community (Kelly et al., 1992). The concept of opinion leadership has played an important role in marketing research as well, since leaders can help increase the effectiveness of marketing campaigns (Weimann et al., 2007).

marketing studies on new technologies in developing countries (Kremer et al., 2009; Luoto, 2009; BenYishay & Mobarak, 2011).

Of the two technologies we market, the chimney stove's value in removing indoor smoke is apparent and easy to explain, while the efficiency stove's combustion properties are much less obvious. We find that villagers' adoption decisions for efficiency stoves change more than do their adoption decisions for chimney stoves when we reveal opinion leaders' choices.[5] Moreover, the relationship between opinion leader choices and other villager choices dissipates over time after it is revealed (as village residents gain first-hand experience with the new technology). These experiments hold insight into how people may filter external signals and combine private with external information in their technology adoption decisions. A central implication is that persuasion techniques promoted by psychology and marketing research (Saltiel et al., 1994; Fernandez et al., 2003; Bertrand et al., 2010) may produce only temporary increases in adoption. Similarly, external influence and the provision of information may be less effective for technologies that households can evaluate for themselves, and the value of external signals and influence may decline with experience over time (Dupas, 2010).[6]

Finally, our results 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;

[5] We (appropriately) make inferences about preferences and behavior on the basis of household reactions to experiments and interactions over which the randomization was stratified (e.g. gender/price, and marketing/stove type). However, when we stratify on stove type, we are forced to offer two real-world technologies (the chimney and the efficiency stove), each of which is composed of a bundle of characteristics, as opposed to a lab experimental setting where we might have hypothetically varied just one targeted feature of the stove, leaving all other characteristics unchanged. In the penultimate section of the paper we examine whether the differential responses across the two stove types could be related to some other features of the stoves.

[6] The fact that these inferences are based on revealing opinion leader choices that were not randomly assigned is an important concern with our interpretation. However, we document heterogenous effects of opinion leader choices across the two types of stoves, and asymmetric influence of opinion leaders when they accept versus reject the stove. These patterns of heterogeneity and asymmetry are more difficult to reconcile with other competing explanations.

Ezzati & Kammen, 2001b), but this literature has largely focused on the dose-response relationships between stove use, pollution output, and health outcomes. A few economists have studied the productivity and economic benefits of improved stove use (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 the majority of developing country households continue to rely on an inferior technology with enormous adverse health implications.

Second, conducting multi-pronged experiments in the same context for the same product enables us to make direct comparisons of the relative importance of different barriers to technology adoption.[7] Different underlying reasons for low adoption suggest different policy prescriptions, making such multi-pronged experiments particularly valuable.[8] We run experiments with randomly varying prices to benchmark the gender and social marketing effects, and like other recent literature, find that price concerns ultimately dominate these other factors.

The rest of the paper is organized as follows. Section 2 uses a variety of pre-baseline data we collected to describe the context and the technologies. Section 3 describes our experimental research design. Section 4 presents empirical results. There are a number of potential identification concerns with the interpretation of results we provide. For example, differential household receptiveness to the two stove types may be related to some other differential stove attribute than the ones we highlight, or the gender differences may reflect differences between men and women that are independent of decision-making power. Section 5

[7] A micro-development literature (Feder et al., 1985; Foster & Rosenzweig, 2010) and a parallel macroeconomics literature on technology and growth (Caselli & Coleman II, 2001; Comin & Hobijn, 2004; Mestieri & Comin, 2010) have argued that differences in technology account for the majority of the variation in per-capita GDP across countries. A better understanding of technology adoption constraints at the micro level is therefore required to understand a major component of growth.

[8] This approach is most closely related to the Kremer et al. (2009) and Meredith et al. (2011) suite of take-up experiments on preventative health technologies. 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), learning (Dupas, 2010),and persuasion (Luoto, 2009; Bertrand et al., 2010).

examines these concerns systematically by using our survey data to probe heterogeneity in household responses to the experiments in ways that are informative about alternative, competing interpretations of the experimental results. Section 6 concludes.

2. Context, Technologies, and Project Location

2.1 Context and Knowledge of Health Risks

Prior to designing the demand experiments, we collected qualitative information by conducting focus groups with rural women, talking to sector experts in Dhaka, and directly observing cooking episodes. These motivated a nationally representative survey to assess cooking practices conducted across 120 sub-districts of Bangladesh in 2006 (Figure 2) (Mobarak et al., 2011). 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 (both procured for little or no monetary cost); (2) most rural households have no direct experience with improved cookstoves;[9] (3) respondents believe that indoor smoke is harmful to health but is not the most important health risk that they face;[10] and (4) improved cookstoves feature 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 (Mobarak et al., 2011).

[9] 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.

[10] 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 numerous efforts to promote non-traditional 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 non-traditional cookstove models tailored to local needs (Sarkar et al., 2006; ESMAP, 2010b). We selected two major types of cookstoves for our demand experiment. The first is a round *efficiency stove* which improves fuel efficiency and reduces heat loss relative to a traditional cookstove. The second is a *chimney cookstove*, which 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 with materials similar to those used for traditional cookstoves, but they are constructed using very precise design specifications.

We conducted cooking tests using both types of improved stoves and a traditional stove under controlled field conditions. Using the three stoves in turn, 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[11] emissions throughout the cooking period using a Side Pack PM 2.5μ monitor (see appendix).

Our test results confirmed 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 and 0.95 mg/m^3, respectively). Alternatively, the

[11] Particulate matter with mean aerodynamic diameter of 2.5 micrometers (μ) or less.

chimney stove did not reduce cooking time or fuel consumption relative to the traditional stove, but it reduced the measured PM 2.5 emissions within the kitchen environment (channeling smoke outside). Our limited sample trials with 54 traditional stove and 61 chimney stove users suggest that average emissions were reduced by only 17% in the kitchen environment (p-value 0.16), but the pollution meter placed on the cook's body experienced a 47% decrease (0.626 mg/m^3 with the chimney stove compared to 1.20 mg/m^3 with traditional stoves; p-value of difference 0.007).

The information we provided to households participating in our demand experiment about each type of stove (see appendix) was based on both manufacturer documentation and our own test results. Importantly, households appear to retain this information. The second panel in Table 1 shows that households correctly recalled the salient features of each stove type when asked: the top two responses for why households ordered a chimney stove were "reduced smoke emissions" and "good for cook's health" whereas the top two responses for those who ordered efficiency stoves were "reduced fuel" and "reduced time required to cook." Qualitatively, BRAC field-workers noted during the intervention that study subjects could immediately grasp the indoor smoke reduction benefits of adding a chimney. Explaining the efficiency stoves' beneficial properties required a little more effort. This is reflected in the stated preference data in the second panel of Table 1: of the reasons households provided for their choice, reduced emissions is clearly the most popular for chimney stoves, whereas the efficiency stoves produce a more mixed set of responses.

2.3 Project Location

We conducted our demand experiments in 58 villages in two ecologically diverse rural districts of Bangladesh: Jamalpur in the north and Hatia in the south (Figure 2). 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 Motivation for the Experimental Design

Our preparatory research (described in Section 2.1) identified four primary reasons to explain the low adoption of improved cookstoves conditional on availability: (1) price; (2) lack of information about the health consequences of traditional stove use; (3) gender differences in preferences over stoves (when women have little intra-household bargaining power); and (4) aversions to changing traditional practice and switching to a new unknown technology.

There are two likely sources of gender difference in preferences over improved stoves. One is that women are almost exclusively responsible for cooking in rural Bangladesh (Pitt et al., 2011), and emissions are both concentrated next to stoves and dissipate rapidly over time (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 (D. Thomas, 1990; D. Thomas, 1994; Duflo & Udry, 2003; Duflo, 2003; Ueyama, 2007; Miller, 2008), and may also lead to a divergence in spending priorities.

Risk aversion regarding a new, unknown technology may also reduce stove uptake. For example, both women and men may be concerned that using the new stove will entail a

significant investment in learning the new technology or may worry that using the stove will change the flavor of the food produced or the practice of cooking (Stewart, 1987; Troncoso et al., 2007; Slaski & Thurber, 2009). However, these concerns may be mitigated if households infer a positive signal from others' purchase decisions – particularly the decisions of people whose opinions they respect and who share common local customs and traditions (Weimann, 1994; Feder & Savastano, 2006). We therefore study the influence of contextually-appropriate information by publicizing village "opinion leaders'" adoption decisions.

A growing number of studies find highly price-elastic demand for new technologies in developing countries (Dupas, 2009; Hoffmann et al., 2009; Hoffmann, 2009; Ashraf et al., 2010). Our hypothetical willingness-to-pay estimates obtained through contingent valuation also suggest that price will play a dominant role in adoption decisions (Mobarak et al., 2011).

We designed two sets of overlapping demand experiments to investigate each of these factors. The full study is divided into two treatment arms: a 2x2 design to study intra-household differences in preferences and another 2x2 experimental design to study the importance of price and social marketing. Each incorporates both efficiency stoves and chimney stoves.

3.2 Sample Size, Data Collection Activities, and Timeline

The trial profile (Figure 1) describes sample sizes by experimental condition in detail. We first conducted a village level survey to identify distinct neighborhoods (or "*paras*") within each village, and to identify "opinion leaders" within each of these neighborhoods. We randomly selected 50 households per village, and randomly assigned all 3080 project households to the 8 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.

3.3 Experiments on Gender Differences in Preferences and Ability to Purchase Stoves

As Figure 1 shows, the first arm of our experiment (labeled I - IV) examines the role of intra-household differences in preferences by gender in the decision to purchase stoves.[12] Women may differ from men not only in their preferences over stoves, but also in 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. Specifically, we randomly assigned 16 (of 58) project villages (half in Hatia and half in Jamalpur) to treatments I-IV 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" (50 Taka efficiency stove or 250 Taka chimney stove) cells III and IV.[13]

(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 and received our health education, either the husband or wife (depending on the random assignment) was given the opportunity to choose between an efficiency stove, a

[12] Hoffman (2009) also designs intrahousehold 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.

[13] 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.

chimney stove, or no stove, at the randomly assigned price. Importantly, husbands and wives made these choices without consulting with their spouses.

The information we provided about efficiency stoves and chimney stoves emphasized their salient characteristics (one as "budget-saving," the other as "health-improving."). The comparison between I (husband choice, free stove) and II (wife choice, free stove) allows us to uncover unconstrained gender differences in prioritization of budget-saving and health-improving and technologies.[14] Alternatively, the difference-in-difference between the cells I-II and III-IV (gender differences when stoves are free or cost a small positive price) allows us to uncover the degree to which each gender is able to act on underlying differences in preferences.[15]

3.4 Experiments on Price and External Influence

Our second set of experiments (labeled V-VIII in Figure 1) studies the role of price, the effect of publicizing the cookstove choices of opinion leaders, and their interaction. We conduct this experiment separately using efficiency stoves in some villages and chimney stoves in others.

Forty- two of our 58 project villages were allocated to experimental cells V-VIII. We then randomized stove price (50% subsidy vs. full price) at the village level and information about opinion leader choices within villages at the neighborhood (or *para*) level using the following procedure:

[14] 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.

[15] 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 BRAC and to others in the village. BRAC has a strong presence in these villages given other development programs they implement, which makes resale difficult.

(a) Eleven of the 21 villages in each of the two districts (or 22 of the 42 villages in total) were randomly assigned to the full price condition (cells V and VII). The other 20 were assigned to the 50% subsidy condition (cells VI and VIII)

(b) All 42 villages were divided into *paras*. There were approximately 3 *paras* per village, yielding a total of 126 *para* clusters. *Paras* have natural boundaries, which we demarcated in consultation with village residents.

(c) 30 out of 66 *paras* in the full price villages and 30 out of 60 paras in the half-price villages were randomly assigned to the opinion leader treatment (groups VII and VIII).

All respondents in groups V-VIII received the same simple, culturally-salient health education message about indoor air pollution and improved stoves. Our pure control arm (group V) therefore allows us to estimate adoption rates under ordinary circumstances in the presence of health education.

Subsidies: We set our full prices at procurement cost: Tk. 400 (about US$5.80) for efficiency stoves and Tk. 750 (about US$ 11) for chimney stoves. We charged these prices in groups V and VII, while in groups VI and VIII we charged Tk. 200 and Tk. 375 respectively. Households were not told that they were being subsidized (all prices were portrayed as full stove prices), and our village-level randomization minimizes information spillovers between households assigned to different prices.

Opinion Leaders: We identified three opinion leaders in each *para* through focus group discussions. Specifically, we asked villagers to nominate leaders in each of three domains that are important in rural Bangladeshi society: economics, politics, and education/literacy. For economic leadership, we asked villagers to nominate those owning the most land (the most important durable asset in Jamalpur and Hatia). For political leadership, we solicited

nominations of local elected politicians and informal "village elders" (respected individuals who mediate or resolve disputes, etc.). Finally, we asked villagers to nominate the most educated individuals from the neighborhood not already chosen as an economic or political leader.

For the opinion leader treatment, we first offered stoves to the three opinion leaders at the prices assigned to a given village (at full price to group VII and at half price to group VIII). We then told villagers in treatment *paras* what the opinion leaders' adoption decisions were (*paras* correspond to natural social networks with corresponding social boundaries).

Stove Types: 10 of 21 villages in each district were randomly assigned to receive efficiency stoves, and the other 11 received chimney stoves. Stove type assignment cuts across all four experimental cells V-VIII, and the random assignment of stove type was orthogonal to the random assignment of price (see Figure 1 for sample size details).

3.5 Initial Decision (Stove orders) versus Final Decision (Purchase)

When participants (wives in particular) 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. Our experimental protocol revealed individual choices in terms of stove orders, but after consulting with their spouses, participants could refuse to install or pay for the stove when we returned to deliver it (although they were not allowed to change their orders from chimney to efficiency or vice versa). In fact many households refused to make payments after ordering stoves across all eight of our treatment arms. We analyze stove orders separately from final stove purchases to gain additional insight into the process of household decision-making.

The differences between stove orders and stove purchase are also relevant for experimental conditions V-VIII, since much more information about the stoves gets publicized between the two decision points. Villagers are able to observe the stoves received by others in

their neighborhood and village. The differences between orders and purchases are therefore informative about how changes in the information set affect the demand for stoves. The stove order is a meaningful outcome even though it can be reversed, because households are relaying their initial acceptance of the stove offer to BRAC, the largest NGO in the country (and in the world) which offers a number of other development programs (in micro-credit, health, business development, employment) to this same population. Refusing delivery when staff arrive to install a stove is also naturally uncomfortable, causing loss of face.

4. Results

Before beginning the analysis of take-up rates across treatment groups, Table 2 presents results on balance in observables at baseline across the different treatment groups. The results are consistent with successful randomization – there are no systematic differences in the set of baseline characteristics across the (randomly assigned) treatment conditions, either in the sample for experimental cells I-IV or for cells V-VIII. In regressions reported later, we control for the few variables that show significant differences at baseline.[16]

4.1 Gender Differences in Preferences, Intra-household Disagreement and Stove Adoption

We first examine gender differences in cookstove adoption using experimental cells I-IV (see Figure 1) that randomly assigned the choice of a chimney stove or a efficiency stove to either the husband or to the wife in different households. The options were framed as a choice between a health-saving technology (the chimney stove) and a fuel-saving technology (the efficiency stove). Table 3 provides the raw percentages of people who ordered or purchased stoves. Order and purchase rates fall sharply when a positive price is charged, but only 70%

[16] A Bonferroni multiple comparison correction for 66 independent tests requires a significance threshold of $\alpha=0.0008$ for each test to recover an overall significance level of $\alpha=0.05$. Using this criterion, no differences at baseline are statistically meaningful.

accept 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 of other costs associated with improved stoves.[17] Duflo, Greenstone and Hanna (2011)'s results also show that rural South Asian households may have legitimate concerns about the value of new stove technologies in their lives.

We examine both the extensive (order *any* stove rather than neither) and intensive (order the healthier chimney stove) margins of these choices. We run separate regressions for households (h) residing in villages (v) where the stoves are offered for free versus villages where the stoves are offered at positive price.[18]

$$\Pr(\text{Stove Acceptance})_h = \alpha + \beta_1 \cdot Male_h + \gamma \sum X_{hv} + \varepsilon_h \quad (1)$$

$$\Pr(\text{Chimney Stove})_h = \alpha + \beta_1 \cdot Male_h + \gamma \sum X_{hv} + \varepsilon_h \quad (2)$$

Results reported in Table 4 focus on the coefficient on "Male" (i.e. the randomly assigned treatment condition where husbands – rather than wives – were asked to make the cookstove choice). Each coefficient reported in the table is derived from a separate regression. The first row in panel 1 examines the gender differences in choices across treatments I and II, when the choice of chimney versus efficiency stoves is offered for free. The first column shows that when improved cookstoves are offered for free, women are 6.1 percentage points (or 6.5%) 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

[17] 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 shown in the top panel of Table 1, 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.

[18] 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).

initially to choose the healthier chimney stoves over the fuel-saving efficiency stoves. The third column combines these two margins of gender preference to show that of the households initially offered a stove, there was an 11.3 percentage point (14.9%) larger order rate for the healthier chimney stoves when the marketing offer was made to the wife rather than the husband.

Although *both* men and women overwhelmingly choose the chimney stove (even though it is more expensive than the efficiency stove), our results show that women choose the healthier chimney stove more often than men. These results are unsurprising given that women are almost exclusively responsible for cooking in rural Bangladesh (and in much of the developing world), and are disproportionately exposed to cookstove emissions (Dasgupta et al., 2006; Pitt et al., 2010). While these findings are consistent with women having relatively stronger preferences for a technology that improves their own health, they could also be driven by differences in gender preferences over child health. Section 5 reports evidence consistent with the salience of women's own health rather than child health).

The second row of results in Table 4 examines the gender differences in stove order rates in treatment conditions III and IV, once small positive prices are charged for the stoves. For the efficiency stove we charge a nominal amount of Tk. 50 (<US$1, representing an 88% subsidy relative to full price), and for the chimney stove Tk. 250 (representing a 67% subsidy). In other words, both absolute and relative prices change relative to the free (I-II) conditions. Once positive prices are charged, women drop out at a higher rate than men, and their stove order rate dips below (but is statistically indistinguishable from) men's stove order rate. The p-values in the bottom row of panel 1 show that these gender effects on the stove orders are statistically different across the free (treatments I-II) and subsidized (treatment III-IV) cases.[20] This suggests

[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.

that women are differentially more liquidity constrained: they express a stronger preference for healthier stoves when the stoves are offered for free, but they are unable to act on that preference when even very small positive prices are charged. Panel 2 of the table demonstrates that the results are robust to controlling for household characteristics, including any variables on which we did not have statistical balance at baseline.

The second row in panel 1 of Table 4 also shows that when small positive prices are charged, women are differentially more likely than men to shift away from the relatively more expensive chimney stove towards the efficiency stove. This is again suggestive of a more stringent liquidity constraint for women, if it is easier for women to make Tk. 50 purchase decisions than Tk. 250 purchase decisions.[21] Combining the extensive (any improved stove order) and intensive (chimney stove order) margin effects, women shift away from the healthier and more expensive chimney stoves by 15-16 percentage points relative to men when positive prices are charged, and this differential shift is statistically significant. These results become statistically more precise when household controls are added.

4.2 Stove Purchase Decisions once Choices become Public

Columns 4-6 in Table 4 examine final purchase decisions. During the initial offer individual choices were kept hidden through our experimental protocol. However, when households make final purchase decisions as we attempt to deliver stoves several weeks later, much of the information on preferences, options and choices have been revealed both within the household and across the village. In the intervening period between stove orders and stove purchase, husbands and wives have had the opportunity to learn each other's preferences about

[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.

technologies that were heretofore unknown in the village, and importantly, both men and women learn about both the options offered and the choices made by their spouse.

In this context, we see that much of the gender differences in order rates disappear in the final purchase decision. Given our experimental design, it was possible for households to undo the individual's extensive margin choice (by refusing to take a stove that was ordered), but not the 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 see that the gender difference in overall stove orders was undone at the final purchase stage, but women's relative preference for the healthier chimney stoves persists in these regressions. Overall, when women are made the free marketing offer, those households are 8-10 percentage points (11.1-18.4%) more likely to purchase a chimney stove, but this gender difference disappears when positive prices are charged for the stoves.

We next examine whether the change from stove order to stove purchase is due to women's initial choices being undone by their partners or vice versa. To analyze this, it is useful to study the refusal rate (stove ordered but not purchased) in each of the gender conditions. We do this in column 7 of Table 4. In the free (I-II) treatment conditions, the refusal rate was over 4 percentage points (16.9%) higher when the initial marketing offer was made to women. In the second row of panel 1 (also row 4 in panel 2), when we examine the behavior of the selected group of men and women who felt comfortable ordering a stove that cost money without the ability to consult their spouse (due to our experimental protocol, in conditions III-IV), we see that the refusal rate reverses. The 10 percentage point greater refusal rate for women in the free (relative to positive price) condition is statistically significant, which suggests that women's initial choices started converging towards their partners' once more information was revealed.

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 husband. These experimental findings are entirely consistent with stated preference data we collected from the nationally representative survey described in section 2. 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 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).

4.3 Effects of Revealing Opinion Leader Choices on Stove Orders

Tables 5, 6 and 7 turn to the data from experimental conditions V-VIII to consider the role of credible local information about a technology conveyed by learning the choices of opinion leaders. Table 5 provides the overall stove acceptance rates for each condition, and Table 6 studies the variation using regressions. The first and seventh columns in Table 6 suggest that knowledge of opinion leader choices *per se* is unrelated to the ordinary village residents' cookstove orders. To probe heterogeneity in this effect, the other specifications in this table divide up the set of opinion leader choices into (a) *paras* (neighborhoods) where the three opinion leaders were unanimous in choosing to order the stove (*OLaccept*), and (b) *paras* where they unanimously rejected the stove (*OLreject*), with the intermediate outcomes acting as the omitted category in the regression. To be clear, we are unable to randomize the adoption

decisions made by opinion leaders (as would be difficult to do under any circumstance), but studying heterogeneous effects allows us to learn more about the role that opinions leaders play as information brokers. Although there are important empirical identification concerns with this approach, we attempt to address the concerns below using multiple strategies.

The estimating equation for a household *h* in para *p* in village *v*:

$$\Pr(\text{Stove Acceptance})_{hpv} = \alpha + \beta_1 \cdot OLaccept_{pv} + \beta_2 \cdot OLreject_{pv} + \gamma \sum X_{pv} + \varepsilon_{hv} \quad (3)$$

Since we are unable to randomize opinion leader choices, the coefficients β_1 and β_2 could reflect a spurious relationship driven by a village-level or para-level unobservable (if both leaders and residents of a sophisticated village choose to adopt, while the leaders and residents of an unsophisticated village choose not to adopt, for example). We control for this effect directly by including in *X* measures of the average village-level and the *para*-level stove order rate (excluding self). The *para* (village)-level order rate would capture the effects of such *para* (village) level correlated unobservables, allowing β_1 and β_2 to reflect the influence of opinion leader choices on para residents' adoption. In some specifications we also control for a full set of village dummies to address this concern. Furthermore, we document important (and sensible) heterogeneity in opinion leader influence across the two stove types, and an asymmetry in effects when opinion leaders accept or reject the marketing offer. It is more difficult to generate these specific patterns of asymmetry on the basis of a competing explanation that simple unobservable heterogeneity drives these differences.

Rows 4 and 5 (specifications 2-6 and 8-12) in Table 6 show that there is (a) some asymmetry in the effect of unanimous opinion leader adoption versus rejection in influencing the subsequent choices of *para* residents and (b) an asymmetry in the effects of opinion leader choices on the two stove types. In the most conservative specification, the propensity to order

efficiency stoves in a neighborhood increases by 14 percentage points (41% gain at the mean order rate) when residents are told that the leaders all order the stoves, and decreases by 28 percentage points (82%) when all three leaders reject the stove, relative to the intermediate case of leader disagreement on stove orders. In contrast, only opinion leader rejection has a significant negative effect on *chimney* stoves orders of 22 percentage points (69%), while unanimous opinion leader acceptance does not increase villagers' propensity to order chimney stoves.[22]

The first asymmetry (in the effects of OL acceptance versus rejection) is statistically significant (see p-value for chi-square test) and may be related to the socio-economic characteristics of opinion leaders relative to the other villagers. Opinion leaders are among the most well-educated and affluent, so even if a technology is good for them, it might not necessarily be appropriate for the modal villager (Munshi, 2004; Feder & Savastano, 2006). On the other hand, if it is not beneficial (on net) for an opinion leader, then it is almost surely not beneficial for the typical villager.

The second asymmetry is apparent when we combine the efficiency and chimney stove samples and run regressions with interaction terms between stove type and opinion leader choices. We find that opinion leader influence on other households' purchase decisions is indeed significantly larger for efficiency compared to chimney stoves (see p-values reported at the bottom of the table). Our early-stage focus groups suggested that the value of the chimney in reducing indoor smoke is immediately apparent, while the precise design benefits of the clay efficiency stove are more difficult for households to comprehend. This asymmetry may therefore mean that households rely more heavily on external cues when it is more difficult to

[22] The various specifications in this table show that the effects of opinion leader acceptance and rejection are robust to alternative ways to account for village and para level unobservables, such as controlling for the village or para average adoption rate, or for village fixed effects.

evaluate the technology by oneself. This type of asymmetry has been noted for other products in the industrial organization, marketing (Ackerberg, 2001; Ackerberg, 2003), and sociology (Sapp & Korsching, 2004) literatures as well.

Specifications 6 and 12 add interaction terms between opinion leader choices and the randomized 50% subsidy condition, showing that external influence is 10-18 percentage points larger when more is charged for the efficiency stove. This may be because households pay closer attention to such information inputs when making decisions with larger financial consequences.

4.4 Opinion Leader Choices and Stove Purchase

Table 7 considers the role of opinion leader influence in final stove purchase. Comparing Tables 6 and 7 suggests considerable attenuation of opinion leader estimates when we move from stove orders to the final purchase decisions. The initial stove order decisions occurred almost simultaneously across all households within a village, with very limited information about the new technologies available in the village except for the opinion leader purchase decisions that we revealed. After orders were placed, cookstoves were delivered over a period of several weeks within a given village, and those receiving cookstoves later could learn about improved cookstoves from those receiving early deliveries. If so, this pattern of attenuation may suggest a declining value of information acquired from opinion leader choices as common experience with the technologies grows.[23] With the smaller coefficients on *OLaccept* and *OLreject* variables, the asymmetric effects on chimney and efficiency stoves become statistically insignificant in some specifications, but the asymmetry in the influence of unanimous acceptance versus rejection is retained.

[23] Purchase rates are lower than order rates across all experimental conditions, but this inference is based on how correlated opinion leaders' orders are to other households' stove orders and stove purchases.

Overall, the pattern of results in this sub-section suggests that people may rely more heavily on external information that they find trustworthy when they possess less information about the product themselves, or when that information is noisier (McKelvey & Page, 1990; Ackerberg, 2001). An important implication of this is that social marketing programs – which often attempt to use opinion leader influence to increase the adoption of health technologies – are probably less effective in the long run (even if effective in the short run) as common experience with technologies grows (Dupas, 2010). This is in contrast to claims from psychology and sociology about persistent influence of opinion leaders (Fernandez et al., 2003; Sapp & Korsching, 2004).

We also document important heterogeneity in the influence of different types of opinion leaders. In Table 8, rich and educated leaders appear more influential in households' stove order decisions than political leaders. Furthermore, when we examine the determinants of refusal (from stove order to a decline to purchase), we find that refusal rates are greater if the initial purchase was influenced by the 'political' opinion leader. This suggests that some types of external influence have longer-lasting effects than others.

4.5 Effects of Price on Stove Orders and Stove Purchase

Table 9 shows regression results on the effects of random variation in stove price on both initial stove order and ultimate stove purchase for efficiency and chimney stoves. Although studying price effects is not a central objective of this paper, given emphasis on price in previous studies (Kremer & Miguel, 2007; Ashraf et al., 2010; Cohen & Dupas, 2010), we examine these results to benchmark the magnitudes of the observed gender and opinion leader effects. Specifically, we estimate the effect of price subsidy on stove order or purchase rates separately for each stove type:

$$\Pr(\text{Stove\_Acceptance})_{hv} = \alpha + \beta \cdot \text{Subsidy}_{v} + \gamma \sum X_{hv} + \varepsilon_{hv} \quad (4)$$

Standard errors are clustered by village (the level at which the subsidy treatment was randomized). Table 9 reports marginal probabilities obtained using probit specifications.

Reducing cookstove prices by 50% increases efficiency stove orders by 25 percentage points (with an implied price elasticity of demand of -2.3) and efficiency stove purchases by 11.6 percentage points (with an implied elasticity of -5.0). In contrast, we cannot reject perfectly inelastic orders for chimney stoves: the 50% subsidy moved the order rate from 31.4% to 34.5% only. Given differences in household perceptions about the salient characteristics of each stove (expressed when placing the order, see Table 1), the marked differences in price elasticity suggest that in ordering stoves, households are less willing to trade off smoke emissions and health than they are the cook's time and fuel costs. However, the refusal rate (in the move from orders to actual purchases) is much higher at full price than at subsidized price, and this makes the chimney stoves purchases elastic. The 5.4 percentage point gain in chimney stove purchases with the 50% subsidy implies a price elasticity of -5.4.[24]

Refusal rates are highly correlated with the price charged, which suggests that liquidity constraints likely played a role. In fact, most people who ordered a stove but ultimately refused to purchase cited "lack of funds" for their refusal. The fact that two unrelated treatments with roughly equivalent out-of-pocket costs for households - half-price chimney cookstoves and full-price efficiency cookstoves - led to very similar purchase rates is also consistent with this view.

[24] The even-numbered columns add household baseline characteristics and examine heterogeneity in the treatment effect using interactions terms. In the villages where efficiency stoves were marketed, households with more children are more responsive to the subsidy, and households where women have less decision-making power (women reporting that they need their husband's permission to leave the house to visit relatives) are less responsive to the subsidy. These households are also less likely to purchase the more expensive chimney stoves.

The most common reason provided by those who declined to order stoves initially was also that the stoves are "too expensive".

5. Alternative Explanations

This section considers potential alternative explanations four our findings, first for the analysis of gender and intra-household externalities and then for the opinion leader analysis. 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 throughout Section 4.

5.1 Gender and Intra-Household Externalities

One alternative interpretation of our gender-price results is that women may simply have a more difficult time saying "no" to enumerators offering stoves than men. If this were true, refusal rates among women should not vary by stove type; however, women's refusal rates 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 among women. Although they are higher among women when stoves are offered for free, refusal rates are instead higher among men when a positive price is changed (see table 4).

Although inconsistent with women simply having a greater propensity to accept stove offers, this pattern of results may seem the opposite of what one would expect if women were less able to act on their desire for an improved stove when a positive price is charged. One might instead 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 are more empowered/have more bargaining power

than women who order free stoves.[25] More empowered women ordering stoves at positive prices are less likely to have their choices overturned by their husbands.

Another alternative interpretation is simply that demand is more price elastic among women than among men. We did not estimate demand for improved cookstoves among single men and women, so we are unable to compare to gender-specific price elasticities absent intra-household bargaining. The existing literature has examined gender differentials in price elasticity only in the context of the demand for cigarettes and alcohol in developed countries, and overall there is no clear consensus that such a gender differential exists. Manning et al. (1995) and Kenkel (1993) report opposing results for alcohol demand by men and women. Chaloupka (1998) and Stehr (2007) find opposing results for cigarette demand. Most relevant to our study is Hersch (2000), who finds no gender differential in price elasticity in aggregate, but finds that both men and women have more inelastic demand when they have access to their own income, and that women have a smaller earnings elasticity when the earnings are their own (i.e. not pooled household income). This is entirely consistent with our findings and our interpretation that the gender differences in demand are related to the control women have over resources.

A third possible alternative interpretation is that men may not recognize the harms of indoor air pollution as much as women do (or may less clearly recognize emissions differences between traditional and improved stoves). This is very closely related to our explanation (in the sense that the health issues may not be as salient for men either because they don't suffer the consequences themselves or because they simply do not know), and therefore very difficult to distinguish from our interpretation of the data. Nevertheless, we examine gender-specific

[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.

subjective expectations data we collected in our survey to study whether men and women have differential awareness or beliefs about the health benefits of improved cookstoves. When we ask men and women about their expectations regarding improved stoves, prior to making a stove offer, we do in fact find that women are more likely than men to believe that an improved stove will reduce the risk of respiratory illness and increase the likelihood of living longer.[26] This suggests that the gender-differences in stove adoption may be driven by the relative "salience" of the health issue rather than different innate preferences over women's health.

Finally, gender differences in stove choices may reflect stove characteristics other than those that we emphasize (efficiency and emissions/health benefits) – or better female comprehension of stove attributes. To explore this possibility, Table 10 analyzes heterogeneity in differential stove orders by gender across a variety of household characteristics at baseline. To do so, we add interaction terms between the treatment (whether the woman is offered the choice) and baseline measures of female and male education, presence of children, and proxies for the wife's status (relative to her husband) in the household. We conduct these analyses in treatments III and IV (where a positive stove price is charged) to examine heterogeneity by education or wife's status when women are making different choices both due to differences in preferences and differences in constraints by gender.

Consistent with stated reasons for adoption of each stove (shown in the top half of each panel of Table 1), these regressions offer further evidence in favor of our interpretation. When a wife is more than 10 years younger than her husband (a proxy for the wife's status relative to her husband, see Jensen & Thornton, 2003; Suran et al., 2004; Desai & Andrist, 2010), she is much

[26] 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 0.000). 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 (p-value of the difference between these two 0.000).

less likely to order a chimney stove. Interactions with woman's years of education are insignificant, suggesting that the gender effect is not due to a gender differential in comprehension about efficiency stoves' characteristics. When we discretize our measure of women's education, we find that women with at least some education are actually more likely to choose the healthier chimney stove (and not the less comprehensible efficiency stove), probably because it also proxies for status within the household. Probing further, we find that women who are more educated *relative to their husbands* are the ones most likely to order healthier, more expensive chimney stoves – even when they are charged positive prices. This result likely also reflects women's bargaining position within the household. Finally, gender differences are invariant to the presence of children and children's health status, suggesting that the cook's own health (and not child health) is the dominant consideration. This is entirely consistent with stated reasons for adoption shown in Table 1.

There are two other readily-observable differences between efficiency and chimney stoves: efficiency stoves are portable, and chimney stoves have an additional surface for a second pot. Several considerations suggest that these attributes do not explain gender differences in preferences. First, convenience associated with portability should be more salient for female cooks rather than for their husbands, which we would expect would lead women to prefer the portable efficiency stoves (all else equal). Moreover, the modal number of stoves in our sample households is two: households build one stove indoors and one outdoors. This indicates that the constraint on cooking outside is weather (during monsoon season in particular), not inability to move a stove outside (Sarkar et al., 2006). Second, chimney stoves' additional cooking surface does not have an independent source of heat; instead, it draws residual heat from the other burner. In BRAC's follow-up visits, most households using chimney stoves were generally

observed to be using one cooking surface at a time. Households reported that the second surface is largely useful for keeping food warm, rather than for cooking. This indicates that low residual heat is of limited use and is not an important efficiency gain.

5.2 Revelation of Opinion Leader Choices

An alternative interpretation of our opinion leader findings is that they could be produced by revealing the stove adoption choices of any three randomly selected villagers. We did not test our opinion leader intervention against this procedure, and the experiment cannot rule out the possibility that the "leader" label does not really matter; all that matters is the knowledge that someone else in the village either accepted or rejected the stove. However, the fact that we observe heterogeneity in the influence of the three types of leaders (the economic, the political or the educated leader) appears inconsistent with the simpler interpretation. Table 8 shows that the political leader is both less influential at the outset, and that the refusal rate is greater for stove order decisions that were originally influenced by him. The fact that the relationship between opinion leader adoption and own adoption dissipates over time does suggest that own experience or the experience of peers (that are more slowly revealed) can substitute for opinion leader influence.

Our research design with opinion leaders was inspired by leader-based social marketing approaches commonly used to promote new technologies in the both the NGO and policy worlds, as well as private sector marketing campaigns (Weimann et al., 2007; Population Services International, 2011). Documenting the effects of revealing leader choices is therefore independently valuable for policy, and these results complement a much larger literature on the effects of peer influence in technology adoption (Foster & Rosenzweig, 1995; Munshi, 2004; Oster & Thornton, 2009; Godlonton & Thornton, 2012).

6. Conclusion

We conducted multi-pronged demand experiments to study low adoption rates of improved cookstoves, an important technology with substantial implications for population health and the environment. Stove purchase rates at full price were very low, reflecting the disappointing experiences of improved cookstove promotion programs globally. Importantly, we observe these low adoption rates when pairing marketing efforts with a health education message about the harms of traditional cooking practices and the benefits of improved stoves, indicating that the effectiveness of basic health education is quite limited in this context.

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. We find that one 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, Field 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.[27]

[27] 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.

Another important non-price impediment is tradition, which many believe can be overcome through external influence. Models of herd behavior suggest that one person's decision to adopt a new technology can set off a cascade effect if others assume that the initial adopter has access to information that they do not (Banerjee, 1992). However, sociological research suggests that salient types of external information depend on the characteristics of the person making the decision, the environment in which the decision is to be made, and the characteristics of the technology to be implemented (J. Thomas et al., 1990; Saltiel et al., 1994; Sapp & Korsching, 2004). We find that receiving external information from opinion leaders matters more when the costs and benefits of a technology are not readily apparent and when people are unfamiliar with it. These findings are consistent with empirical observations made in industrial organization, marketing, and development sociology literatures. Sapp and Korsching (2004), for example, postulate that when the costs and benefits of a technology cannot be easily observed, opinion leader endorsement is important. On the other hand, when a technology's characteristics are easily observable through personal experience, additional promotion of the product has little effect. Ackerberg (2001) finds that advertising does not affect the purchase rates of people who have had previous experience with a product (in this case yogurt), because consumers who have tried the product have already formed their own opinions about it. Similarly, Dupas (2010) finds that people who are offered an insecticide-treated bed net for free or highly subsidized are more likely to purchase a bed net the following year, even when the subsidy is removed, because they have gained personal knowledge about bed net effectiveness in preventing malaria.

Overall, we find that persuasion campaigns are likely to have short-lived effects in many cases unless a technology's benefits are particularly obfuscated. Successful marketing strategies

for a gender-specific technology will need to simultaneously address both the gender differences in preferences as well as intra-household differences in decision-making power. Subsidies are effective at improving adoption rates (as noted in 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, unless the aversions related to non-price attributes of a technology are understood and addressed.

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Figure 1: Experimental design

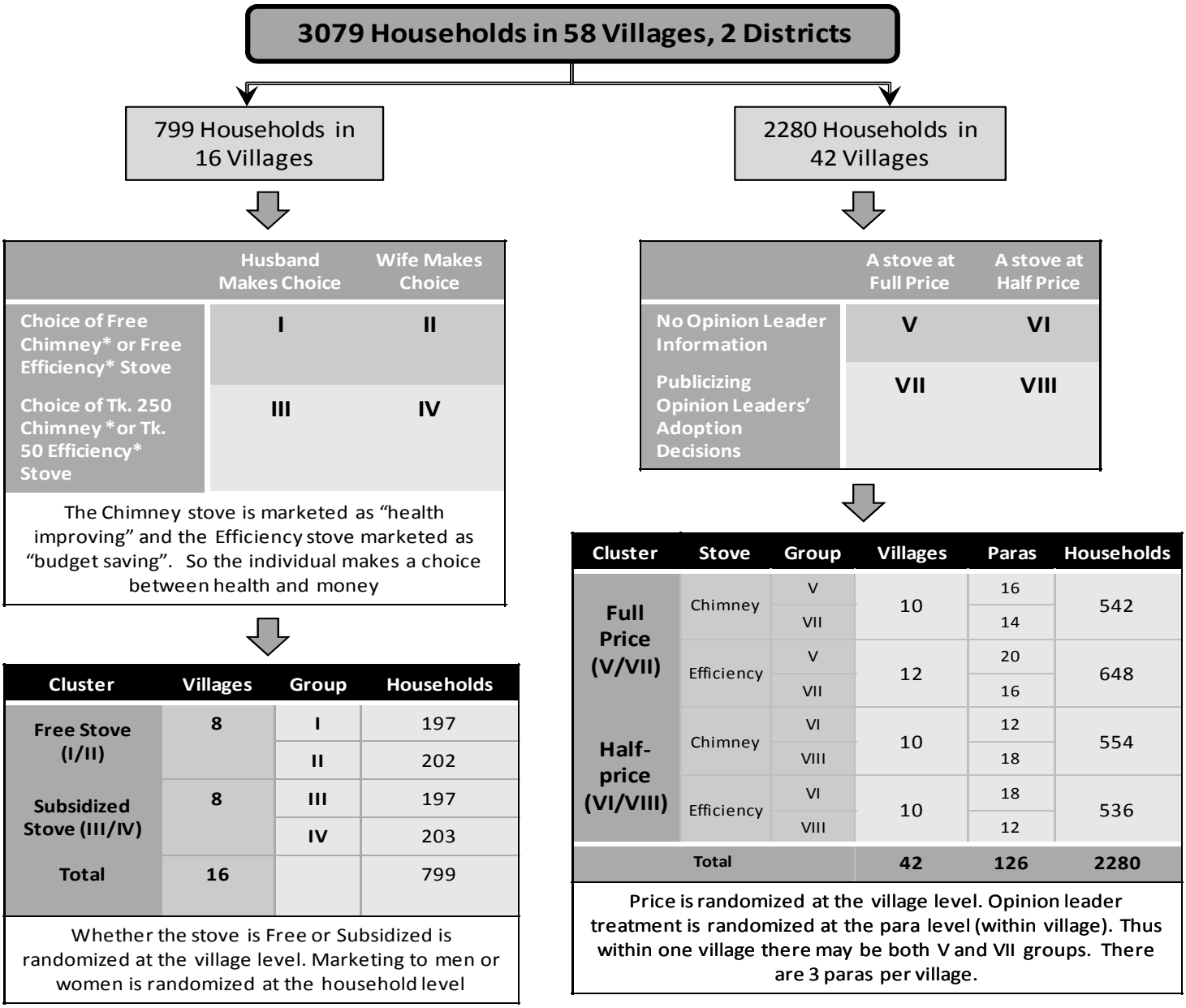
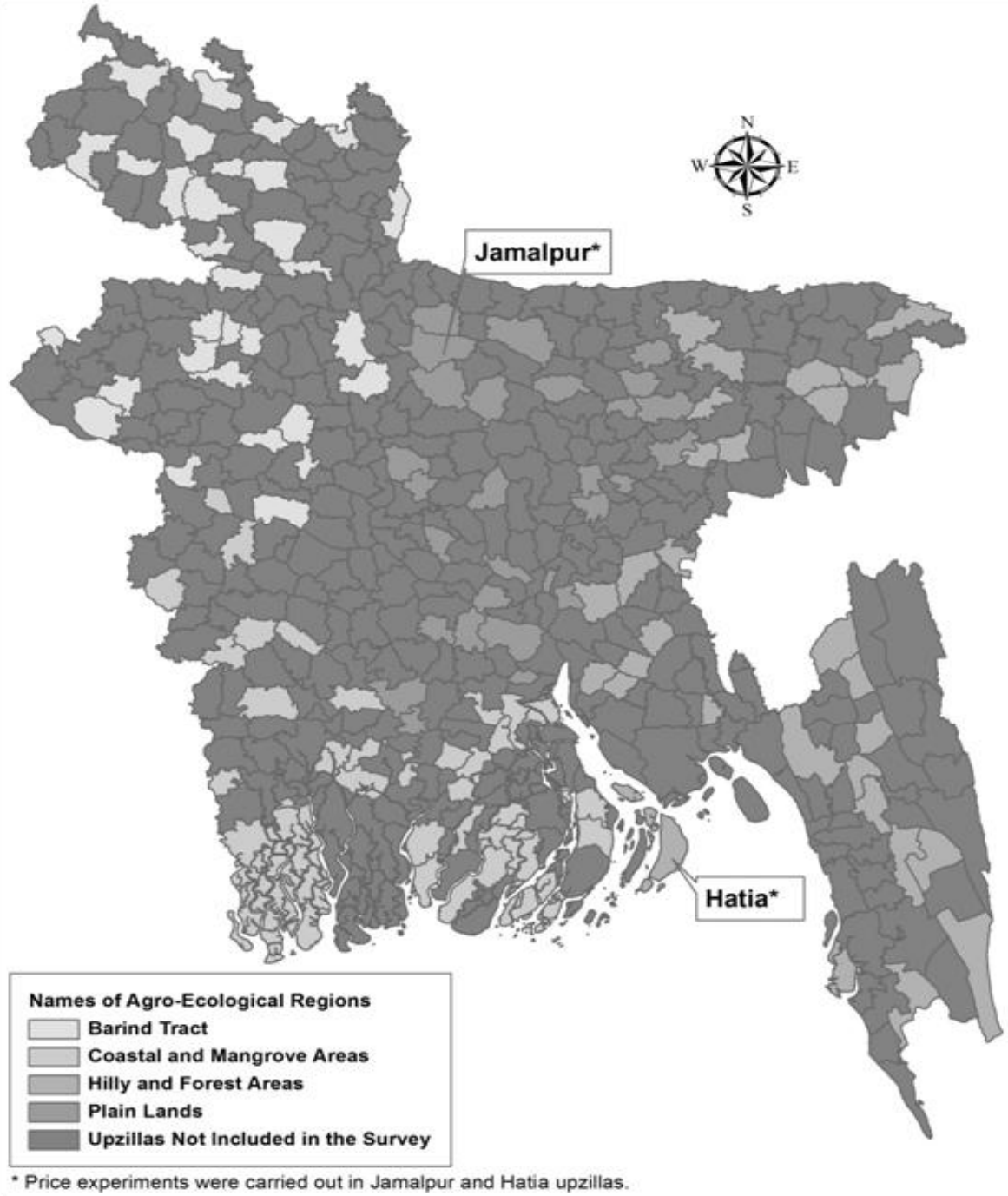


Figure 2: Map



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

Table 1. Respondents' Stated Reasons for Accepting/Rejecting Stove Offer
(Percentage ranking each reason as 4 (important) or 5 (very important))

Panel 1: Groups I-IV (both Stove Types)

		Men's Responses			Women's Responses			P-value[1]
Accepted Stove Offer?	Reason	N	mean	se(mean)	N	mean	se(mean)	
	Reduce Smoke Emissions		0.76	0.02		0.78	0.02	0.44
	Reduce time required to cook		0.27	0.02		0.31	0.03	0.21
	Reduce fuel required to cook		0.40	0.03		0.36	0.03	0.31
Yes	Reduce attention rqd to cook	327	0.02	0.01	342	0.01	0.01	0.48
	Portability		0.11	0.02		0.13	0.02	0.39
	Good for cooks health		0.26	0.02		0.30	0.02	0.28
	Good for children health		0.03	0.01		0.01	0.00	0.03
	Too expensive		0.36	0.06		0.51	0.06	0.09
	Increase time to cook		0.00	0.00		0.03	0.02	0.16
	Increase fuel required to cook		0.04	0.03		0.06	0.03	0.64
No	Increase attention rqd to cook	67	0.01	0.01	63	0.00	0.00	.
	Afraid of burning food		0.01	0.01		0.00	0.00	.
	Change the taste of food		0.00	0.00		0.00	0.00	.
	Preserve Tradition		0.51	0.06		0.25	0.06	0.00

[1] P-values for t-test of equality of means between the percentage of men and the percentage of women giving each response

*** Significant at 99%; ** Significant at 5%; * Significant at 10%

Panel 2: Groups V-VIII[(1)]

		Efficiency Stove			Chimney Stove		
Accepted Stove Offer?	Reason	N	mean	se(mean)	N	mean	se(mean)
	Reduce Smoke Emissions		0.39	0.02		**0.84**	0.02
	Reduce time required to cook		**0.42**	0.02		0.26	0.02
	Reduce fuel required to cook		**0.57**	0.02		0.25	0.02
Yes	Reduce attention rqd to cook	411	0.04	0.01	361	0.02	0.01
	Portability		0.20	0.02		0.01	0.00
	Good for cooks health		0.20	0.02		**0.38**	0.03
	Good for children health		0.04	0.01		0.06	0.01
	Too expensive		0.69	0.02		0.74	0.02
	Increase time to cook		0.02	0.01		0.03	0.01
	Increase fuel required to cook		0.01	0.00		0.01	0.00
No	Increase attention rqd to cook	773	0.00	0.00	735	0.01	0.00
	Afraid of burning food		0.00	0.00		0.00	0.00
	Change the taste of food		0.00	0.00		0.00	0.00
	Preserve Tradition		0.34	0.02		0.20	0.01

[1] Table shows only women's responses, as typically only women responded to the survey.

Table 2: Summary Statistics of Baseline data

	I-II	III-IV	Total	Diff	P-value	V-VII	VI-VIII	Total	Diff	P-value
Household Characteristics										
Total Number of Household Members	6.73	6.73	6.73	-0.00	0.99	6.52	6.44	6.48	-0.08	0.77
Number of Wage Earners	1.78	1.91	1.85	0.13	0.54	1.83	1.99	1.91	0.16	0.07
Total Number of Female HH members	3.51	3.43	3.47	-0.07	0.79	3.38	3.28	3.33	-0.10	0.50
Total Number of Male HH members	3.23	3.30	3.26	0.07	0.82	3.14	3.16	3.15	0.02	0.90
Number of Children <= Age 5	0.84	0.66	0.75	-0.17	0.15	0.80	0.71	0.76	-0.08	0.25
Number of Children <= Age 18	3.02	2.64	2.83	-0.38	0.31	2.80	2.49	2.65	-0.30	0.14
Average monthly income (in Taka)	4,937	5,922	5,430	986	0.21	5,908	6,368	6,128	460	0.38
Average monthly expenses (in Taka)	4,710	4,473	4,591	-237	0.65	5,432	5,888	5,650	456	0.38
Wealth Index*	-0.14	-0.16	-0.15	-0.01	0.94	-0.08	0.20	0.05	0.28	0.02
Household owes money	0.26	0.18	0.22	-0.08	0.28	0.20	0.25	0.23	0.04	0.28
Female Characteristics										
Age	35.94	37.23	36.59	1.29	0.21	36.18	37.66	36.89	1.48	0.02
Married	1.00	1.00	1.00	-0.00	0.15	0.99	1.00	0.99	0.00	0.35
Education (in years)	2.42	3.11	2.77	0.69	0.12	3.19	3.09	3.14	-0.10	0.67
Wage Earner	0.08	0.16	0.12	0.08	0.21	0.17	0.25	0.21	0.08	0.27
Male Characteristics										
Age	45.15	46.30	45.72	1.15	0.35	44.23	46.11	45.13	1.88	0.01
Education (in years)	2.80	4.00	3.40	1.20	0.07	3.98	4.27	4.12	0.29	0.39
Wage Earner	0.98	0.99	0.98	0.01	0.64	0.98	0.98	0.98	-0.00	0.97
Male Occupations										
Agriculture (Own)	0.41	0.47	0.44	0.06	0.31	0.44	0.40	0.42	-0.04	0.47
Business	0.19	0.20	0.19	0.01	0.67	0.23	0.24	0.23	0.01	0.75
Day labour (Agriculture)	0.13	0.08	0.10	-0.05	0.17	0.10	0.10	0.10	0.00	0.87
Day labour (Non agriculture)	0.13	0.09	0.11	-0.04	0.14	0.09	0.07	0.08	-0.02	0.22
Service	0.06	0.08	0.07	0.03	0.18	0.07	0.08	0.08	0.01	0.65
Other	0.10	0.09	0.09	-0.01	0.69	0.07	0.10	0.09	0.03	0.35

Additional Gender Variables	Husband Makes Choice Groups I/III	Wife Makes Choice Groups II/IV	Difference	Standard Error	P-Value
Female denied permission to work	0.35	0.34	-0.01	0.03	0.84
Female chooses what foods to cook	0.61	0.60	-0.01	0.03	0.79
Female chooses what food to buy	0.11	0.10	-0.01	0.02	0.72
Woman's age at marriage	14.83	14.99	0.15	0.17	0.38
Woman married before age 15	0.67	0.65	-0.02	0.03	0.51
Male >10 yrs older than female	0.27	0.30	0.03	0.03	0.40
Female contributes to HH income	0.12	0.13	0.01	0.02	0.69
Female Education (years)	2.79	2.74	-0.05	0.25	0.84
Male Education (years)	3.28	3.52	0.24	0.31	0.44
Female has some education	0.46	0.47	0.01	0.04	0.84
Male has some education	0.44	0.45	0.01	0.04	0.77
Difference in education between men and women	0.49	0.78	0.29	0.24	0.23
Male more educated than female	0.32	0.35	0.03	0.03	0.36
Female more educated than male	0.21	0.19	-0.02	0.03	0.47
Dowry paid?	0.37	0.37	-0.00	0.03	0.94
Number Children Under 5	0.73	0.77	0.05	0.06	0.43
Number of Children <= Age 18	2.76	2.90	0.14	0.12	0.25
Has children under 5	0.54	0.53	-0.01	0.04	0.78
Female health index*	0.17	0.51	0.34	0.14	0.01
Child health index*	0.15	0.26	0.11	0.17	0.52

*Wealth index is constructed using principal component analysis of variables indicating if the household owns land, a vehicle, or other assets.

Table 3: Stove Acceptance rates for groups I-IV

Cluster	Group	Households	Initial Acceptance*	Final Acceptance*
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.

Table 4: 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[6] (2)	Ordered a chimney stove out of those offered a stove (3)	Any Stove Purchase (4)	Purchased a chimney (rather than efficiency) stove [6] (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	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	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	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 [3]	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	-0.027
		[standard error]	[0.017]	[0.038]	[0.039]	[0.048]	[0.050]	[0.052]	[0.046]
		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	0.055
		[standard error]	[0.046]	[0.045]	[0.048]	[0.046]	[0.072]	[0.040]	[0.058]
		Sample size	398	282	398	398	111	398	282
		p-value for equality of coefficients on 'male' between free and subsidized cases [3]	0.085	0.093	0.022	0.747	0.168	0.150	0.039

*** 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) 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

(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) 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.

Table 5: Stove Acceptance rates for groups V-VIII

Cluster	Stove	Group	Households	Initial Acceptance	Final Acceptance
Full Price (V/VII)	Chimney	V – No OL Information	268	29%	2%
		VII – Public OL information	274	33%	2%
	Efficiency	V – No OL Information	332	25%	4%
		VII – Public OL information	316	22%	6%
Half-price (VI/VIII)	Chimney	VI – No OL Information	200	34%	7%
		VIII – Public OL information	354	35%	8%
	Efficiency	VI – No OL Information	296	49%	19%
		VIII – Public OL information	240	48%	13%
		Total	**2280**	**34%**	**7%**

Table 6: Probit regression results for the effects of Opinion Leader choices on initial stove orders

	Efficiency Stove Orders						Chimney Stove Orders					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Publicizing Opinion Leaders' Decisions Groups VII and VIII	-0.042						0.038					
	[0.079]						[0.054]					
50% Subsidy Groups VI and VIII	0.237**					0.020	0.046					-0.005
	[0.105]					[0.038]	[0.084]					[0.051]
Interaction: Subsidy*Publicizing OL decisions	0.032						-0.031					
	[0.114]						[0.105]					
Indicator of unanimous initial acceptance among opinion leaders (OLaccept)[2]		0.338***	0.206***	0.143**	0.262***	0.238***		0.016	0.072	0.044	0.062	0.020
		[0.077]	[0.061]	[0.058]	[0.097]	[0.059]		[0.053]	[0.044]	[0.027]	[0.088]	[0.046]
Indicator of unanimous initial rejection among opinion leaders (OLreject)[2]		-0.334***	-0.393***	-0.284***	-0.419***	-0.330***		-0.294***	-0.229***	-0.227***	-0.309***	-0.228***
		[0.048]	[0.016]	[0.026]	[0.032]	[0.030]		[0.056]	[0.081]	[0.056]	[0.104]	[0.088]
Average stated acceptance in para - Initial				0.215	-0.272	0.181				0.372*	-0.918**	0.359*
				[0.145]	[0.264]	[0.169]				[0.192]	[0.457]	[0.210]
Average stated acceptance in village - Initial				0.448***		0.463***				0.070		0.053
				[0.109]		[0.148]				[0.204]		[0.212]
Interaction term: Subsidy*OLaccept						-0.105***						0.048
						[0.037]						[0.074]
Interaction term: Subsidy*OLreject						0.184**						-0.009
						[0.091]						[0.122]
Village fixed effects?	No	No	Yes	No	Yes	No	No	No	Yes	No	Yes	No
Observations[1]	1184	556	517	556	517	556	1096	628	608	628	608	628
Chi-squared test (OLaccept=OLreject)		1.302	52.92	10.77	26.43	11.16		8.171	1.967	5.856	1.993	2.643
Prob > chi2		0.254	0	0.00103	2.73e-07	0.000836		0.00426	0.161	0.0155	0.158	0.104
P-value for difference in OL acceptance effect between Efficiency and Chimney								0.001	0.065	0.029	0.06	0.021
P-value for difference in OL rejection effect between Efficiency and Chimney								0.303	0.001	0.075	0.002	0.057
Mean of dependent variable				0.347						0.329		

Robust standard errors in brackets. Standard errors are clustered at the para level for all but regressions (1), (6), (7) and (12), for which s.e.'s are clustered by village.

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

[1]1184 households were offered efficiency stoves, while 1096 were offered chimney stoves. Sample size numbers subsequently drop to 556 and 628 for efficiency and portable stoves, respectively, as the independent variables "unanimous initial acceptance among opinion leaders (OLaccept)" and "unanimous initial rejection among opinion leaders (OLreject)" are only defined for those households in groups VII and VIII (publicizing opinion leaders' decisions). When village-level fixed effects were included, an additional 39 observations were dropped in the efficiency stove group and 20 observations in the chimney stove group, as variables for villages number 43 and 56 predict failure perfectly.

[2] OLaccept and OLreject are only defined for paras in groups VII and VIII, where the opinion leaders' choices were publicized.

Table 7: OLS regression results for the effects of Opinion Leader choices on final stove purchase [1]

	Efficiency Stove Purchases						Chimney Stove Purchases					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Publicizing Opinion Leaders' Decisions	0.021						0.003					
Groups VII and VIII	[0.028]						[0.019]					
50% Subsidy	0.156**					0.024	0.046					0.077**
Groups VI and VIII	[0.063]					[0.059]	[0.035]					[0.034]
Interaction: Subsidy*Publicizing OL decisions	-0.088						0.011					
	[0.060]						[0.049]					
Indicator of unanimous initial acceptance among opinion leaders (OLaccept)[3]		0.055	0.073*	-0.017	0.101*	0.118**		-0.028	-0.003	-0.025	-0.006	-0.011
		[0.064]	[0.038]	[0.043]	[0.053]	[0.044]		[0.034]	[0.017]	[0.036]	[0.020]	[0.014]
Indicator of unanimous initial rejection among opinion leaders (OLreject)[3]		-0.095***	-0.125***	-0.062**	-0.171**	-0.043		-0.079***	-0.117**	-0.093**	-0.133**	-0.053
		[0.019]	[0.039]	[0.028]	[0.062]	[0.031]		[0.021]	[0.049]	[0.038]	[0.059]	[0.034]
Average stated acceptance in para - Initial				0.057	-0.152	-0.014				0.106	-0.144*	0.101*
				[0.119]	[0.116]	[0.144]				[0.084]	[0.085]	[0.053]
Average stated acceptance in village - Initial				0.197		0.296				-0.180		-0.223
				[0.170]		[0.220]				[0.139]		[0.146]
Interaction term: Subsidy*OLaccept						-0.184**						-0.005
						[0.079]						[0.033]
Interaction term: Subsidy*OLreject						-0.074						-0.081**
						[0.057]						[0.033]
Village Fixed Effects?	No	No	Yes	No	Yes	No	No	No	Yes	No	Yes	No
Constant	0.036*	0.095***	0.125***	0.030	0.188**	0.015	0.019**	0.079***	0.117**	0.107*	0.133**	0.076
	[0.021]	[0.019]	[0.039]	[0.033]	[0.071]	[0.036]	[0.008]	[0.021]	[0.049]	[0.056]	[0.059]	[0.053]
Observations[2]	1184	556	556	556	556	556	1096	628	628	628	628	628
R-squared	0.044	0.032	0.119	0.053	0.122	0.064	0.016	0.019	0.103	0.025	0.106	0.045
F-test (OLaccept=OLreject)		0.295	0.924	1.863	0.964	1.798		3.639	4.896	4.699	4.388	1.768
Prob > F		0.591	0.345	0.183	0.335	0.200		0.0657	0.0344	0.0380	0.0444	0.201
P-value for difference in OL acceptance effect between Efficiency and Chimney								0.253	0.0704	0.672	0.0550	0.805
P-value for difference in OL rejection effect between Efficiency and Chimney								0.590	0.893	0.404	0.629	0.145
Mean of dependent variable				0.099						0.047		

Robust standard errors in brackets, standard errors are clustered at the para level for all but regressions (1), (6), (7) and (12), for which s.e.'s are clustered by village.

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

[1] OLS rather than probit estimates were used for this table because, given the low stove purchase rates, under the probit model some independent variables were dropped due to perfect prediction of failure

[2] 1184 households were offered efficiency stoves, while 1096 were offered chimney stoves. Sample size numbers subsequently drop to 556 and 628 for efficiency and portable stoves, respectively, as the independent variables "unanimous initial acceptance among opinion leaders (OLaccept)" and "unanimous initial rejection among opinion leaders (OLreject)" are only defined for those households in groups VII and VIII (publicizing opinion leaders' decisions).

[3] OLaccept and OLreject are only defined for paras in groups VII and VIII, where the opinion leaders' choices were publicized.

Table 8: Heterogeneity in Influence Across Types of Opinion Leaders

	Stove Order	Stove Purchase	Refusal Rates [(1)]			
50% Subsidy	0.077	0.045	-0.092	-0.099	-0.075	-0.109*
	[0.061]	[0.031]	[0.055]	[0.060]	[0.051]	[0.057]
Rich opinion leader said yes - initial	0.143**	0.032		0.037		
	[0.061]	[0.030]		[0.061]		
Elected opinion leader said yes - initial	0.025	-0.031			0.105**	
	[0.055]	[0.021]			[0.052]	
Educated opinion leader said yes - initial	0.113*	0.009				0.071
	[0.057]	[0.027]				[0.058]
Constant	0.195***	0.044***	1.053***	0.835***	0.790***	0.825***
	[0.040]	[0.016]	[0.039]	[0.043]	[0.045]	[0.044]
Observations	1184	1184	397	397	397	397
R-squared	0.059	0.016	0.025	0.015	0.029	0.020

Robust standard errors in brackets, clustered at the para level

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

[(1)] The dependent variable refusal is defined only for those households who initially said they would buy the stove and then refused at the time of sale, within the groups for which the opinion leaders' decisions were publicized (VII and VIII)

Table 9: Effects of Price on Stove Orders and Stove Purchase - Probit

	Efficiency Stoves				Chimney Stoves			
	Stove Orders		Stove Purchase		Stove Orders		Stove Purchase	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
50% Subsidy	0.252***	0.514***	0.116**	0.181*	0.031	0.093	0.054**	-0.003
	[0.085]	[0.140]	[0.045]	[0.100]	[0.062]	[0.069]	[0.024]	[0.019]
Observations [(1)]	1184	1183	1184	1183	1096	1095	1096	1095
Mean of dependent variable at full price	0.233		0.0463		0.314		0.0203	
Mean of dependent variable at subsidized price	0.485		0.162		0.345		0.0740	

Robust standard errors in brackets, clustered by village

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

Even numbered columns include the following control variables: number of female HH members, number of male HH members, number of children under 5, number of children under 18, dummy for has children under 5, dummy if the female contributes to HH income, number of wage earners in the HH, HH monthly expenditures, HH wealth index, female respondent's age, male respondent's age, female years of education, male years of education, dummy if male is more educated than female, time spent cooking during the dry season, female health index, female needs permission to visit relatives in the village, female denied permission to work, interaction: received subsidized stove offer*number of children, interaction: subsidy*wealth index, interaction: subsidy*needs permission to visit, interaction: subsidy*denied permission to work.

(1) Sample size is the number of people in groups V-VIII who were offered the efficiency stove (1184) and the chimney stove (1096). These numbers drop slightly in specifications including control variables due to missing values in the independent variables.

Table 10. Gender Differential in Chimney Stove Orders at a Positive Price (Groups I-IV) [(1)]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Female offered choice of stove	-0.037	0.014	-0.087	-0.043	-0.147**	-0.027	-0.034	-0.087	-0.031	-0.037
	[0.050]	[0.059]	[0.064]	[0.064]	[0.069]	[0.051]	[0.063]	[0.054]	[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]					
Difference in education between men and women (years)						0.036***				
						[0.011]				
Interaction: offered to female*Dif. educ. men women						-0.023*				
						[0.014]				
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]		
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***	0.560***	0.504***	0.625***	0.557***	0.583***
	[0.035]	[0.041]	[0.045]	[0.044]	[0.047]	[0.036]	[0.043]	[0.039]	[0.046]	[0.035]
Observations	400	400	400	400	400	400	400	400	400	400
R-squared	0.001	0.010	0.021	0.053	0.031	0.033	0.041	0.017	0.005	0.004
F test: (Cond_F + Interaction) = 0		3.284	1.665	0.655	0.738	1.053	0.971	2.427	0.552	0.270
Prob > F		0.0707	0.198	0.419	0.391	0.305	0.325	0.120	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

Appendix

Script: 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.

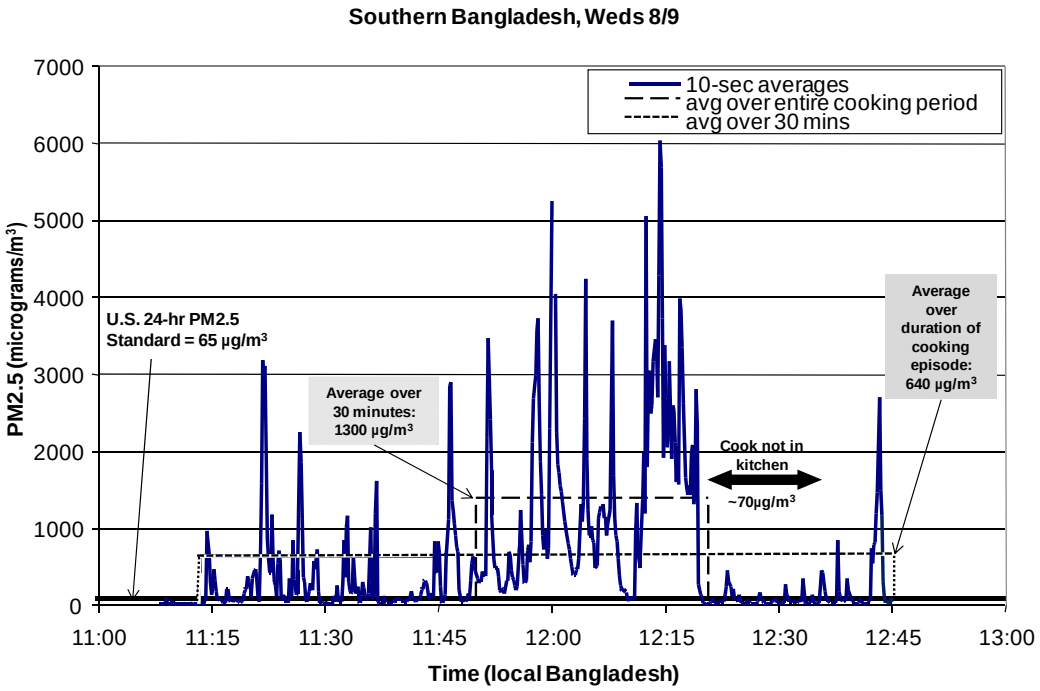
The main difference between the chimney stove and your current stove is the chimney you see in the picture (see photos below). The smoke that is created during cooking leaves the kitchen through the chimney. Based on our tests, we have found that this chimney stove emits less smoke inside the kitchen.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

Pollution testing:

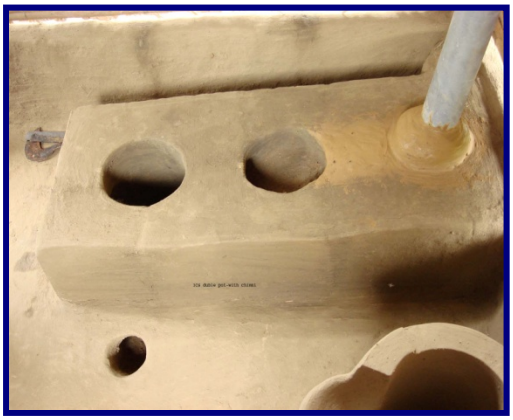
Emissions tests of the three types of stoves (traditional, efficiency, and chimney) were conducted using a SIDEPAK^{TM} AM510 Personal Aerosol Monitor. The SIDEPAK monitors can measure particulate matter with a diameter of <1.0, <2.5 and <10 micrometers (μ). Following standard environmental protocols, 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.



Examples of Stoves

Efficiency Stove



Chimney Stove

Traditional Stove