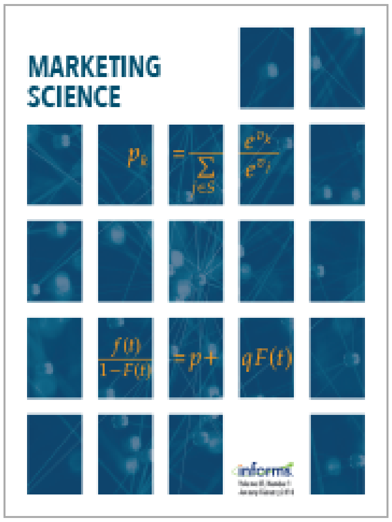


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# Learning About New Technologies Through Social Networks: Experimental Evidence on Nontraditional Stoves in Bangladesh

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There are few marketing studies of social learning about new technologies in low-income countries. This paper examines how learning through opinion leaders and social networks influences demand for nontraditional cookstoves—a technology with important health and environmental consequences for developing country populations. We conduct marketing interventions in rural Bangladesh to assess how stove adoption decisions respond to (a) learning the adoption choices of locally identified "opinion leaders" and (b) learning about stove attributes and performance through social networks. We find that households generally draw *negative* inferences about stoves through social learning and that social learning is more important for stoves with less evident benefits. In an institutional environment where consumers are distrustful of new products and brands, consumers appear to rely on their networks more to learn about negative product attributes. Overall, our findings imply that external information and marketing campaigns can induce initial adoption and experiential learning about unfamiliar technologies, but sustained use ultimately requires that new technologies match local preferences.

*Keywords*: technology adoption; cookstoves; Bangladesh; opinion leaders; social networks
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## 1. Introduction

Understanding how new technologies with the potential to improve human welfare diffuse in less-developed countries is important for the design of effective development programs. Simply developing and introducing efficacious new technologies has proven insufficient:[1] promoting adoption through effective marketing is critical for developing sustained solutions. Research in sociology (Rogers 2003), marketing (Coleman et al. 1957, Manchanda et al. 2008, Iyengar et al. 2011), and economics (Foster and Rosenzweig 1995, Conley and Udry 2010) argues that social networks are often a key source of information about new products. Identifying how social relationships influence technology adoption in developing countries is critical for formulating effective marketing strategies to distribute new products and technologies in these markets.

We study social learning about a potentially important health product: nontraditional cookstoves. Nearly half of the world's population uses traditional cookstoves despite evidence that the indoor air pollution (IAP) produced by traditional cooking practices has harmful health and environmental consequences (World Health Organization 2002). Most of these stoves burn biomass fuels that release emissions containing high concentrations of particulate matter, carbon monoxide, and other pollutants that are associated with increased rates of infant mortality, acute respiratory and eye infections, and lung cancer (Chay and Greenstone 2003). Black carbon (a common by-product of biomass combustion) is also an important contributor to climate change (Bond et al. 2004, Ramanathan and Carmichael 2008, Rosenthal 2009). Many nontraditional (or "improved")[2] stoves are believed to reduce fuel consumption and lower the prevalence of

[1] Notable examples of technologies that have failed to "take off" include drinking water disinfectants (Luby et al. 2008, Kremer et al. 2009), deworming drugs (Kremer and Miguel 2007), condoms (Kamali et al. 2003, Martinez-Donate et al. 2004), and nontraditional cookstoves (Hanna et al. 2012, Mobarak et al. 2012).

[2] A recent editorial challenged the "improved" label placed on many cookstoves and suggested that it always be written with quotes to convey the idea that improvements are subjective and that some improvements in performance may come at the expense of reduced performance in other areas (Smith and Dutta 2011).

serious health problems (Smith-Sivertsen et al. 2009, Bensch and Peters 2012), although there is some controversy about the performance of some stove models (Hanna et al. 2012, Palmer 2012). Nonetheless, they remain unpopular with consumers in many parts of the world, even when marketed at reasonable prices (US$0–$20).[3]

We conduct marketing interventions to study how stove adoption by opinion leaders and other social network members influences the diffusion of nontraditional cookstoves in rural Bangladesh. In the first round of our fieldwork, we publicize whether or not locally identified opinion leaders chose to order nontraditional stoves, and we examine how households' adoption decisions respond to this information. Studies of opinion leadership are prominent in marketing research (Weimann et al. 2007)[4] and are related to the use of product "promoters" or "ambassadors" in a few economics experiments (Kremer et al. 2011, Luoto et al. 2011, BenYishay and Mobarak 2013).

With a second round of marketing interventions, we study how subsequent adoption choices by other households vary by their social ties to first-round households (see Hartmann et al. 2008 for a review of diffusion models). Quantifying these social network effects is empirically challenging because it is difficult to distinguish social learning from common unobservable shocks faced by network members (Manski 1993, Bemmaor 1994, Aral et al. 2009, Shalizi and Thomas 2011). We address this challenge using an experimental design in which subsidies to induce stove purchase are randomly assigned in the first round, and then about 18 months later, we market stoves to those with social ties to first-round households. This allows us to study whether the presence of network members who are (randomly more likely to be) stove owners affects rural Bangladeshi households' subsequent propensity to purchase stoves.

We use two distinct stove technologies in our study that provide us with variation in product attributes. One is an "efficiency" stove designed to burn fuel more efficiently, reducing fuel costs to the home. The other is a "chimney" stove designed to reduce IAP via a cement chimney that removes smoke from the kitchen. Although there are a variety of ways in which these stove types differ, we emphasize two: observability of salient features and efficacy. On observability, direct experience using the efficiency stove is relatively more important for learning about its actual fuel efficiency gains, whereas the chimney visibly signals the chimney stove's potential to reduce IAP even before usage. On efficacy, we provide evidence in §4 that the chimney stove "works" according to user perceptions at follow-up, but the efficiency stove does not. In other words, the chimney stove reduces IAP, whereas the efficiency stove is not perceived to reduce fuel consumption in practice. The two technologies therefore enable us to study the role of learning through opinion leaders and social networks when both the value of direct experience and the type of information transmitted (positive or negative) vary.

In our opinion leader analysis, we find that villagers' decisions to adopt nontraditional stoves are related to the choices of opinion leaders—positively when opinion leaders unanimously adopt stoves and negatively when opinion leaders reject them. Notably, this result is more pronounced for efficiency stoves, whose benefits are less readily apparent, than for chimney stoves. This effect is also stronger and more robust for unanimous opinion leader rejection than for unanimous opinion leader acceptance, suggesting that negative information may be more salient than positive information (Chevalier and Mayzlin 2006, Nam et al. 2010).

Findings from our social network analysis strongly support the asymmetric importance of negative information. By the time the second-round marketing was conducted, first-round participants had learned that efficiency stoves provided little efficiency gain in practice—but that chimney stoves reduced indoor smoke. On average, social ties to first-round participants reduced the likelihood that second-round participants purchased either stove, suggesting overly optimistic priors about both technologies. However, this negative social network effect is much larger and stronger in statistical significance for the ineffective efficiency stoves.

Our study fits within the large marketing literature on word-of-mouth communication and opinion leadership and within the economics literature on peer effects and social learning. Despite the volume

In this paper, we use the label "nontraditional cookstoves" to distinguish these new cookstove designs from the "homemade" traditional clay cookstoves commonly used in rural Bangladesh.

[3] Since the early 1980s, both the government-affiliated Bangladesh Council of Scientific and Industrial Research and more than 100 national and local non-governmental organizations (NGOs) have developed and attempted to disseminate a variety of low-cost nontraditional cookstoves supposedly tailored to local needs (Sarkar et al. 2006, World Bank 2010). Nonetheless, 98% of households in rural Bangladesh still cook over an open fire (National Institute of Population Research and Training 2009).

[4] Opinion leadership has much academic and marketing policy relevance. Early research on diffusion suggests a two-step flow model where opinion leaders, or innovators, influence imitators (Bass 1969, Midgley 1976). On the policy side, harnessing the influence of "opinion leaders" is a common strategy used in social marketing campaigns conducted by nonprofit organizations. Population Services International 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.

of marketing research in this domain, there are relatively few studies in low-income settings. The marketing and managerial value of our paper is twofold. First, we demonstrate social learning in a developing economy, building on a marketing literature primarily focused on wealthy countries. Second, we analyze asymmetries in information transmission using two technologies that vary in efficacy and in observability of product features. In an institutional environment where consumers find it difficult to trust new products and brands, negative information is much more salient in social learning processes than positive information. Furthermore, external information plays a more important role for technologies with less apparent benefits.

The rest of the paper is organized as follows: §2 describes our experimental research design, §3 presents empirical results, §4 examines concerns relating to our approach and considers competing explanations for the results that we find, and §5 concludes.

## 2. Literature Review

Research on product diffusion in the marketing literature has focused on when, and more recently why, consumers decide to adopt products or innovations in developed countries (Abrahamson and Rosenkopf 1997). Early work by Coleman et al. (1957) finds that the adoption of a new pharmaceutical drug is spurred by opinion leadership (i.e., adoption by respected physicians) and that doctors with larger social networks adopt new drugs earlier than those with smaller networks. Despite disagreement about the results of this seminal paper (see Burt 1987, Marsden and Podolny 1990, Strang and Tuma 1993, Van den Bulte and Lilien 2001), a sizable literature links social connections to increased diffusion. This body of evidence has accumulated for a variety of markets, including prescription behavior among physicians (Manchanda et al. 2008, Nair et al. 2010, Iyengar et al. 2011), television viewership (Godes and Mayzlin 2004), grocery purchases (Bell and Song 2007), and choices of health plans (Sorensen 2006). In economics and finance, social learning has been documented in educational choices (Bobonis and Finan 2009, Carrell and Hoekstra 2010, De Giorgi et al. 2010, Duflo et al. 2011, Garlick 2013), financial decisions (Duflo and Saez 2003, Beshears et al. 2011, Bursztyn et al. 2013), job information (Magruder 2010, Beaman 2012), health inputs (Kremer and Miguel 2007, Oster and Thornton 2011, Godlonton and Thornton 2012), agricultural technologies (Foster and Rosenzweig 1995, Conley and Udry 2010), and energy choices (Allcott 2011).

Negative information about unattractive attributes of products can also spread through social networks, deterring product diffusion (Richins 1983, Charlett et al. 1995, Laczniak et al. 2001). Research in developed countries finds that when users, especially opinion leaders, discontinue using a new technology, it may lead to discontinuation by others or cause others to not adopt at all (Black 1983, Leonard-Barton 1985, Greve 1995).[5] Relative to the spread of positive information, negative information can also be more salient, having an asymmetrically large influence on technology adoption decisions (Chevalier and Mayzlin 2006, Nam et al. 2010).

The only marketing study of social learning conducted in a developing country setting of which we are aware (Valente and Saba 1998, 2001) finds that traditional mass-media marketing for a contraceptive technology in Bolivia is less effective for people who have more contraceptive users in their social network. The low-income setting of our study is therefore an important part of its contribution to the marketing literature.

## 3. Study Design

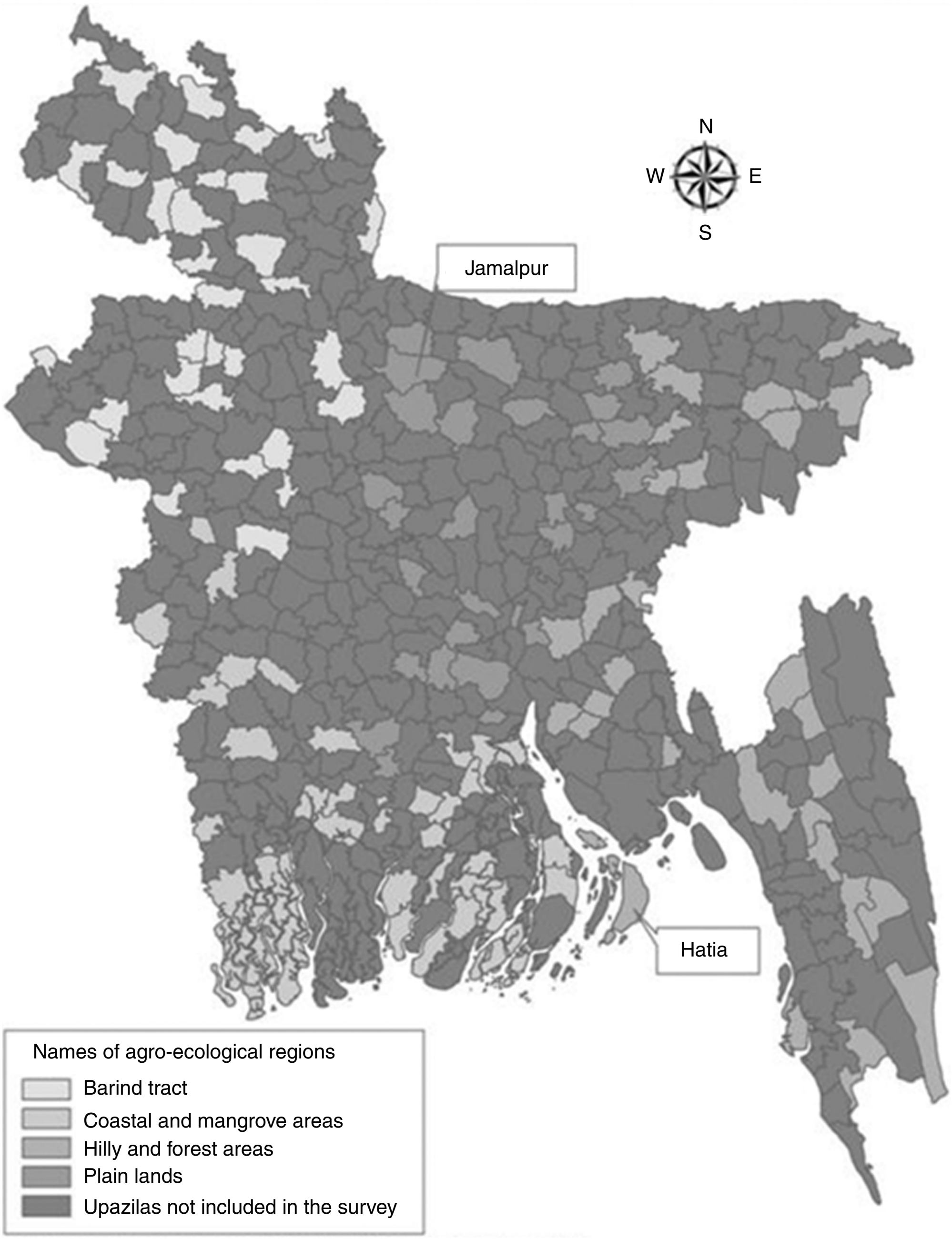
### 3.1. Context and Background: Study Sites and Stove Types

We conducted our demand experiments in 42 villages in two ecologically diverse rural districts of Bangladesh: Jamalpur in the north and Hatia in the south (see Figure 1). Jamalpur is an agrarian area of about 490 sq. km. It is densely populated, and its landscape has been largely deforested. Most residents rely on agricultural residue as their primary cooking fuel. Hatia is an isolated 1,500 sq. km island in southern Bangladesh. Firewood for cooking is readily available, but because of Hatia's coastal deltaic land, the clay soil needed to build stoves is relatively scarce.

Before designing the study, 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 subdistricts of Bangladesh in 2006 (Mobarak et al. 2012). The survey revealed several key pieces of information that help to contextualize our experiments: (1) rural Bangladeshis overwhelmingly burn low-quality biomass fuels in traditional stoves (procured for little or no monetary cost), (2) most rural households have no direct experience with nontraditional cookstoves, (3) respondents believe that indoor smoke is harmful to health but is not the most important health risk that they face, and

[5] Additionally, social norms and conformity may lead to product bandwagons in which fads foster continued use of old, inefficient technologies and rejection of novel, efficient innovations (Abrahamson 1991, Abrahamson and Rosenkopf 1993).

**Figure 1** **Map of the Physical Geography of Bangladesh**




*Note*. Price experiments were carried out in the two labeled upazilas.

(4) cookstoves were prioritized at the bottom of a list of household expenditure priorities in a contingent valuation survey.

The first round of experiments therefore introduced a "novel" product in these villages, albeit one in which villagers were not initially very interested. The information scripts about the stoves used in the experiments (translated from Bangla) are provided in Appendix A. The marketing messages were the same in the first and second rounds of the study.

We marketed two types of stoves in our study areas. The first is a chimney stove designed to reduce IAP via a cement chimney that removes smoke from the kitchen produced by cooking. The second is an efficiency stove designed to burn fuel more efficiently, reducing fuel costs to the home. Although the latter does not otherwise reduce smoke emissions, it is small enough to be portable and can therefore be used outdoors during dry seasons. Both types of stoves are manufactured locally using materials similar to those used for traditional stoves according to very precise design specifications.[6]

Focus group discussions conducted early in the project suggested that the benefits of the chimney stove were more immediately apparent and more easily understood than the benefits of the efficiency stove. The design and function of the chimney stove are visible and obvious: the chimney channels emissions outdoors. The efficiency stove was engineered for portability and fuel efficiency, and the benefits of these features are not as readily apparent or easily understood as the benefits of a chimney. Unlike the concrete chimney, there is no visible additional component to the efficiency stove that makes it particularly visually distinctive from traditional stoves.

### 3.2. Timeline of Activities

The trial profile (see Figure 2) describes sample sizes by study arm in detail. We conducted a village-level survey to identify three distinct neighborhoods (*paras*) within each village and randomly assigned villages and paras to one of four experimental conditions. For paras assigned to opinion leader information, the baseline also identified three opinion leaders within each para. We then randomly selected 50 households per village (16 or 17 per para) for a total of 2,100 households to participate in the first round of interventions. We conducted baseline surveys and marketing visits, collecting stove orders between July and September 2008. Cookstoves were then delivered between October 2008 and March 2009.[7] The baseline survey gathered information on the names and addresses of social network members from all first-round households. In December 2009 and January 2010, we conducted our second round of the study, returning to the villages to offer stoves to randomly selected members of social networks of the first-round participants. We oversampled households from villages where stoves were (randomly) offered at a lower price in the first round.

### 3.3. First-Round Design: Price and Opinion Leader Influence

We randomized stove price (half price versus full price) at the village level and information about opinion leader choices within villages at the para level using the following procedure:

i. Of the 21 villages in each of the two districts (or 22 of the 42 villages in total), 11 were randomly assigned to the full-price condition. The other 20 were assigned to the half-price condition.

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

iii. Thirty 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.

iv. Of 21 villages in each district, 10 were randomly assigned to receive efficiency stoves and the other 11 received chimney stoves. Stove type assignment cuts across all four study arms, and the random assignment of stove type was orthogonal to the random assignment of price and opinion leader information.

All respondents received the same simple, culturally salient health education message about IAP and nontraditional stoves. We consider the full-price, no-opinion-leader information group to be a pure control arm (or the reference group) that allows us to estimate adoption rates under ordinary circumstances in the presence of health education.

*Prices*: We set our full prices at procurement cost: Tk400 (about US$5.80) for efficiency stoves and Tk750 (about US$11) for chimney stoves. This resulted in half prices of Tk200 and Tk375, respectively. Households were not told that the prices were being discounted (all prices were portrayed as full stove prices), and our village-level randomization minimizes information spillovers between households assigned to different prices.

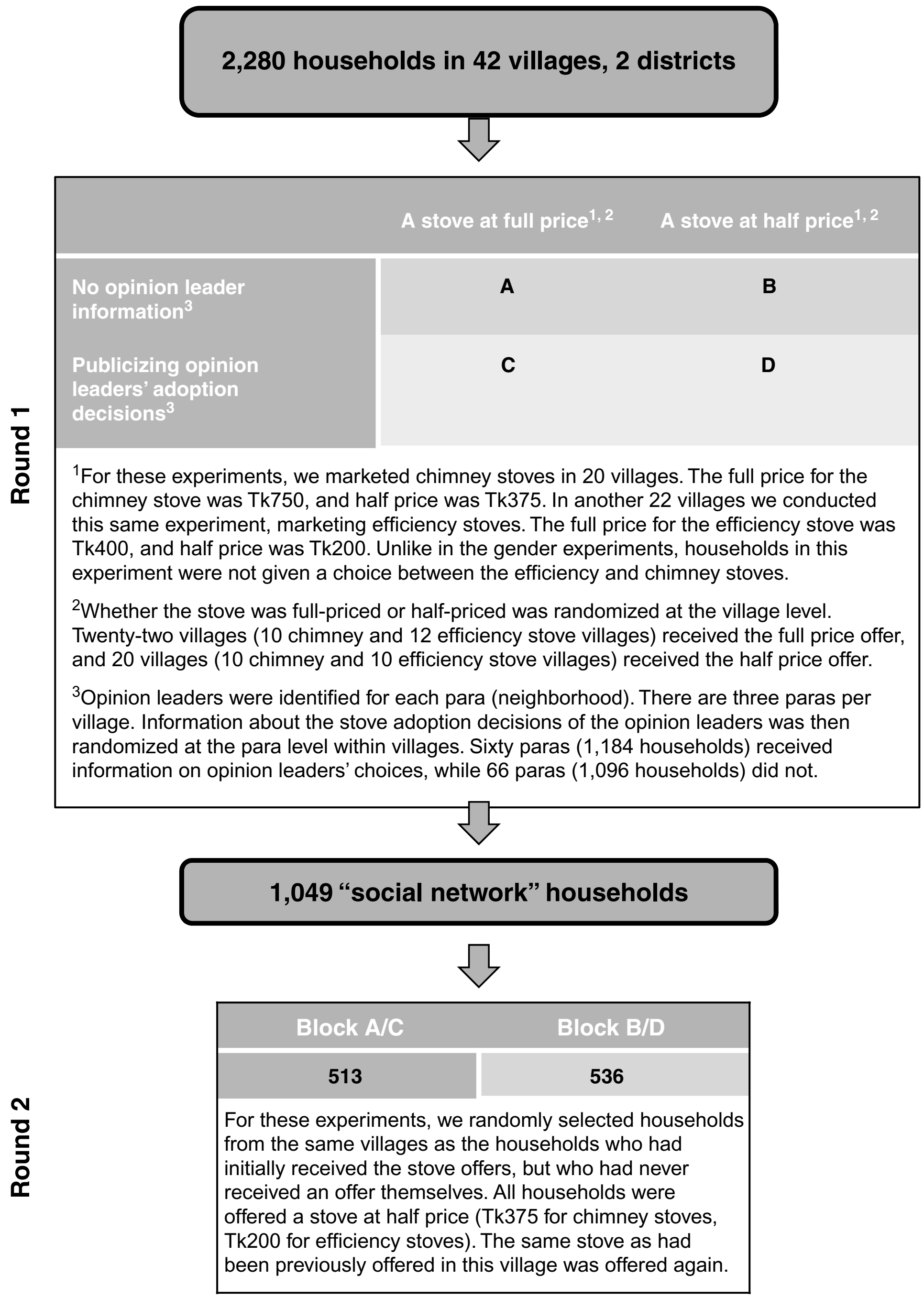
*Opinion leaders*: For paras assigned to the opinion leader information groups, we used focus group discussions to identify three opinion leaders. Specifically, we asked villagers to nominate leaders in each of three domains that are important in rural Bangladeshi society: economics, politics, and education/literacy. 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, for example). Finally, we asked villagers to nominate the most educated individuals from the neighborhood not already chosen as an economic or political leader.[8]

[6] Together, these two types of stoves are representative of stove models commonly promoted by development organizations in Bangladesh. We conducted our own emissions and fuel consumption tests in the field to confirm their salient features (see Miller and Mobarak 2013 for details).

[7] There was an average delay of four months between the initial stove order placement and delivery. However, there was essentially no para- or village-level variation in delay time, and stove deliveries generally occurred on the same day in each para.

[8] Although research has shown that opinion leaders in one area (say, politics) may not be opinion leaders in other areas (e.g., technology) (Van den Bulte and Joshi 2007), they may well still be drivers of cultural change and thus still may impact the perceived risk (in this case, social risk) of adopting a new technology. We used focus groups to identify opinion leaders, as opinion leaders identified in this manner have been shown to most reliably be first adopters (Iyengar et al. 2011).

**Figure 2 Experimental Design**




For the opinion leader treatment, we first offered stoves to the three opinion leaders at the prices assigned to their village. We then told residents of treatment paras what their opinion leaders' adoption decisions were.

### 3.4. Initial Decision (Stove Orders) vs. Final Decision (Purchase)

There was an average delay of four months between initial stove order placement and delivery. Payment was not collected until the delivery stage, which allowed the possibility for households to refuse to purchase stoves they had ordered. Because many households across all four of our treatment arms refused to make payments after ordering stoves, we analyze stove orders separately from final stove purchases to gain additional insight into the process of household decision making. The stove order is a meaningful outcome even though it can be reversed. Refusing delivery would be naturally uncomfortable and cause "loss of face." This effect is intensified as households were interacting with BRAC, who implemented this stove marketing program. BRAC is the largest NGO in the country (and in the world), and it offers a number of other development programs (in micro-credit, health, business development, employment) to this same population.

### 3.5. Second-Round Design: Learning from Social Networks

In December 2009 and January 2010, we returned to the first-round villages to offer the same stoves to members of the village who had social ties to members of the first-round sample but who were not in the first-round sample themselves. Although information about the choices of opinion leaders may influence initial uptake, models of herd behavior suggest that one person's decision to either adopt or refuse 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). To measure these effects, we analyze the effect of knowing someone who purchased a stove in the first round on a household's decision to order a stove in the second round. We also study heterogeneity in this influence across first-round households who had positive versus negative experiences with the stoves.

Our baseline survey asked all households to identify close members of their social networks, and we generated a weighted random sample from this list of network members. The second-round sample was weighted in favor of network connections of households who (randomly) received low-price offers for stoves in the first round. We provided second-round households with the same information about the stoves as had been provided to first-round participants. All households in this round were offered stoves at half price (Tk200 for efficiency stoves and Tk375 for chimney stoves), eliminating the variation in price present in round 1. We surveyed the sample about the nature of their social ties with all first-round households in the village. Our measures of social ties are characterized by type (relative or neighbor), by "closeness" (as reported on a scale of 1–10 by the respondent), and by proximity (*bari* member, i.e., one who resides in the same compound, or not).

## 4. Results

### 4.1. Summary Statistics

Table 1 shows observable characteristics at baseline by treatment group for rounds 1 (panel A, stratified by the price offered) and 2 (panel B, stratified by the price offered in that same village in round 1). The results are consistent with successful randomization: there are no systematic differences in baseline characteristics across the randomly assigned treatment conditions. Because the randomization appears successful, we also assume that there are also no systematic differences in unobservable characteristics such as preferences or culture across treatment groups. In the analysis that follows, we report estimates from regressions with and without controls for the few (observable) variables for which there are significant differences at baseline.[9]

Table 2 shows stove acceptance rates for each treatment condition jointly and separately. In general, the table suggests that liquidity constraints are an important determinant of stove acceptance. Indeed, in a related study, we find that price is the single most important determinant of stove purchases (Mobarak et al. 2012). Given the strong price effect, we utilize randomized discounts as an instrument in our second-round analysis of social network effects (described in §4.3).

Table 3 examines the effect of subsidies and revealing opinion leader choices on stove orders, purchases, and refusals. The finding that price is a significant determinant of stove purchases is confirmed, but the estimate is statistically significant only for efficiency stoves. This result could be due to the overall price difference between efficiency and chimney stoves: even at half price, the chimney stove is nearly as expensive as the efficiency stove at full price. Table 3 also suggests that knowledge of opinion leader choices per se is unrelated to cookstove orders, purchases, and refusals.

### 4.2. Round 1: Opinion Leaders

**4.2.1. Estimating Equation.** For household $h$ in para $p$ in village $v$, we estimate the probability of a stove order or purchase as

$$\begin{aligned}\Pr(\mathit{Stove\_Order} \text{ or } \mathit{Stove\_Purchase})_{hpv} &= \alpha + \beta_1 \cdot \mathit{OLaccept}_p + \beta_2 \cdot \mathit{OLmixed}_p + \beta_3 \cdot \mathit{OLreject}_p \\ &\quad + \boldsymbol{\gamma}\mathbf{X}_{pv} + \varepsilon_{hpv}, \qquad (1)\end{aligned}$$

where *OLaccept*, *OLmixed*, and *OLreject* indicate unanimous opinion leader acceptance, mixed opinion leader acceptance, and unanimous opinion leader rejection, respectively. The reference group is paras, in which information about opinion leader choices is not revealed. Because opinion leader choices were not randomized, the coefficients $\beta_1$, $\beta_2$, and $\beta_3$ could reflect a spurious relationship due to village-level or para-level unobservables such as shared culture or consumer sophistication. We include measures of

[9] A Bonferroni multiple comparison correction for 23 independent tests requires a significance threshold of $\alpha = 0.002$ for each test to recover an overall significance level of $\alpha = 0.05$. Using this criterion, no differences at baseline are statistically meaningful.

**Table 1 Summary Statistics**

| | Panel A: Baseline (round 1) data | | | | | Panel B: Social network (round 2) data | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full price | Half price | Total | Diff | *P*-value | Full price (round 1) | Half price (round 1) | Total | Diff | *P*-value |
| *N* | 1,100 | 1,000 | 2,200 | | | 498 | 526 | 1,024 | | |
| *Accepted stove offer* | 0.25 | 0.40 | 0.32 | 0.15 | 0.02 | 0.24 | 0.13 | 0.18 | −0.12 | 0.03 |
| *Purchased stove* | 0.03 | 0.11 | 0.07 | 0.08 | 0.01 | N/A | N/A | N/A | N/A | N/A |
| Household characteristics | | | | | | | | | | |
| *Total number of HH members* | 6.40 | 6.31 | 6.35 | −0.09 | 0.75 | 5.32 | 4.89 | 5.10 | −0.43 | 0.21 |
| *Number of wage earners* | 1.81 | 1.97 | 1.89 | 0.16 | 0.08 | 2.08 | 2.06 | 2.07 | −0.01 | 0.96 |
| *Total number of female HH members* | 3.31 | 3.19 | 3.25 | −0.12 | 0.46 | 2.56 | 2.34 | 2.44 | −0.22 | 0.14 |
| *Total number of male HH members* | 3.09 | 3.12 | 3.10 | 0.03 | 0.87 | 2.76 | 2.55 | 2.65 | −0.21 | 0.32 |
| *Number of children ≤ Age 5* | 0.81 | 0.74 | 0.77 | −0.07 | 0.34 | 0.59 | 0.51 | 0.55 | −0.08 | 0.27 |
| *Number of children ≤ Age 18* | 2.80 | 2.50 | 2.66 | −0.29 | 0.16 | 2.26 | 2.04 | 2.15 | −0.22 | 0.36 |
| *Average monthly income* (in taka) | 5,503 | 6,028 | 5,753 | 525 | 0.27 | N/A | N/A | N/A | N/A | N/A |
| *Average monthly expenses* (in taka) | 5,271 | 5,711 | 5,481 | 441 | 0.41 | N/A | N/A | N/A | N/A | N/A |
| *Wealth index*[a] | −0.14 | 0.16 | 0.00 | 0.30 | 0.02 | N/A | N/A | N/A | N/A | N/A |
| *Household owes money* | 0.20 | 0.25 | 0.22 | 0.05 | 0.28 | N/A | N/A | N/A | N/A | N/A |
| Female characteristics | | | | | | | | | | |
| *Age* | 35.68 | 37.01 | 36.31 | 1.33 | 0.05 | 38.18 | 36.66 | 37.39 | −1.52 | 0.12 |
| *Married* | 0.99 | 1.00 | 1.00 | 0.00 | 0.24 | N/A | N/A | N/A | N/A | N/A |
| *Education* (in years) | 3.01 | 2.90 | 2.96 | −0.11 | 0.68 | 3.56 | 3.16 | 3.35 | −0.40 | 0.22 |
| *Wage earner* | 0.18 | 0.25 | 0.21 | 0.08 | 0.33 | 0.37 | 0.48 | 0.42 | 0.11 | 0.26 |
| Male characteristics | | | | | | | | | | |
| *Age* | 43.64 | 45.34 | 44.45 | 1.70 | 0.03 | 45.98 | 44.77 | 45.36 | −1.21 | 0.18 |
| *Education* (in years) | 3.60 | 3.83 | 3.71 | 0.24 | 0.47 | 4.13 | 3.91 | 4.02 | −0.22 | 0.63 |
| *Wage earner* | 0.98 | 0.98 | 0.98 | 0.00 | 0.81 | 0.96 | 0.98 | 0.97 | 0.02 | 0.05 |
| Male occupations | | | | | | | | | | |
| *Agriculture (own)* | 0.45 | 0.41 | 0.43 | −0.04 | 0.45 | 0.36 | 0.36 | 0.36 | −0.01 | 0.86 |
| *Business* | 0.22 | 0.24 | 0.23 | 0.02 | 0.73 | 0.22 | 0.20 | 0.21 | −0.02 | 0.66 |
| *Day labor (agriculture)* | 0.10 | 0.11 | 0.11 | 0.00 | 0.85 | 0.10 | 0.09 | 0.10 | −0.01 | 0.64 |
| *Day labor (nonagriculture)* | 0.10 | 0.08 | 0.09 | −0.02 | 0.21 | 0.11 | 0.14 | 0.13 | 0.03 | 0.30 |
| *Service* | 0.06 | 0.07 | 0.06 | 0.01 | 0.50 | 0.13 | 0.13 | 0.13 | 0.00 | 0.83 |
| *Other* | 0.07 | 0.10 | 0.09 | 0.03 | 0.38 | 0.05 | 0.05 | 0.05 | 0.00 | 0.84 |

*Notes*. HH, household; N/A, not available.
[a]Wealth index is constructed using principal component analysis of variables indicating if the household owns land, a vehicle, or other assets.

**Table 2 Stove Acceptance Rates**

| Price | Stove | OL information | Households | Stove orders (%) | Stove purchase (%) |
|---|---|---|---|---|---|
| Panel A: Stove acceptance rates by price, stove type, and OL information | | | | | |
| Full price | Efficiency | No | 332 | 25 | 4 |
| | | Yes | 268 | 18 | 4 |
| | Chimney | No | 268 | 29 | 2 |
| | | Yes | 232 | 29 | 2 |
| Half price | Efficiency | No | 280 | 50 | 20 |
| | | Yes | 220 | 44 | 10 |
| | Chimney | No | 200 | 34 | 7 |
| | | Yes | 300 | 32 | 6 |
| Panel B: Stove acceptance rates by price | | | | | |
| Full price | | | 1,100 | 25 | 3 |
| Half price | | | 1,000 | 40 | 11 |
| Panel C: Stove acceptance rates by OL information | | | | | |
| No OL info | | | 1,096 | 34 | 8 |
| OL info | | | 1,004 | 30 | 5 |
| Panel D: Stove acceptance rates by stove type | | | | | |
| Efficiency | | | 1,100 | 33 | 9 |
| Chimney | | | 1,000 | 30 | 4 |
| Total | | | 2,100 | 32 | 7 |

*Note*. OL, opinion leader.

**Table 3** **Effect of Revealing Opinion Leader Decision and Subsidy on Stove Uptake**

| | Stove purchase | | Stove order | | Stove refusal | |
|---|---|---|---|---|---|---|
| | Efficiency | Chimney | Efficiency | Chimney | Efficiency | Chimney |
| *Publicizing opinion leaders' decisions* | 0.005 | −0.001 | −0.071 | −0.006 | −0.085 | 0.004 |
| | [0.026] | [0.017] | [0.065] | [0.054] | [0.083] | [0.060] |
| *50% subsidy* | 0.156** | 0.046 | 0.240** | 0.045 | −0.249** | −0.128 |
| | [0.063] | [0.035] | [0.106] | [0.084] | [0.092] | [0.093] |
| Interaction: *Publicizing OL decision* × *Subsidy* | −0.095 | −0.004 | 0.032 | −0.017 | 0.249** | −0.002 |
| | [0.057] | [0.048] | [0.106] | [0.110] | [0.111] | [0.124] |
| *Constant* | 0.036* | 0.019** | 0.250*** | 0.295*** | 0.855*** | 0.937*** |
| | [0.021] | [0.008] | [0.052] | [0.042] | [0.070] | [0.023] |
| Observations | 1,100 | 1,000 | 1,100 | 1,000 | 368 | 309 |
| $R^2$ | 0.052 | 0.013 | 0.077 | 0.002 | 0.051 | 0.037 |
| Village fixed effects? | No | No | No | No | No | No |

*Notes*. Robust standard errors are in brackets. OL, opinion leader.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

village- and para-level stove order rates (calculated excluding the respondent and opinion leaders) in **X**. The village- and para-level order rates capture some of these effects correlated within villages and paras. In alternative specifications, we include a full set of village fixed effects to capture unobserved village-level heterogeneity.

To study how opinion leader influence varies with stove price, we also estimate variants of Equation (1) in which we include interaction terms between opinion leader choices and randomly assigned stove discounts.

**4.2.2. Effects of Revealing Opinion Leader Choices on Stove Orders.** Tables 4 and 5 explore the relationship between revealing the initial orders of opinion leaders and stove orders and purchases, respectively, among community members in the same para. Table 4 reports estimates from Equation (1) for initial orders in local communities. The estimated effect for unanimous rejection among opinion leaders is negative and statistically significant across nearly all specifications for both stove types and is robust to controlling for village fixed effects and para-level adoption rates (to control for unobserved heterogeneity). When households are informed that all opinion leaders in their neighborhood rejected the efficiency stove, their propensity to order the stove is reduced by 7.2 percentage points in the most conservative specification, relative to providing no information about opinion leader choices. This represents a 21% decrease in adoption at the mean order rate. The magnitudes of the adverse effects of opinion leader rejection on stove orders are statistically comparable across chimney and efficiency stove samples. Estimates for the coefficient on unanimous opinion leader acceptance are positive and significant for efficiency stoves, but interestingly, this estimate is close to zero and insignificant for chimney stoves. This difference by stove type is statistically significant (see $p$-values reported at the bottom of the table) and suggests that opinion leadership may play a more important role when stove attributes are more difficult to observe.[10]

Columns 5 and 10 of Table 4 show estimates for the interaction terms between opinion leader choices and randomized discounts. In general, when prices are lower, the role of information about unanimous opinion leader acceptance is attenuated—but the estimated impact of unanimous opinion leader rejection is larger in magnitude. One plausible interpretation of these results is as follows. If a new technology such as nontraditional stoves is outside of a household's price range entirely, no amount of information about opinion leader choices will influence adoption. Thus, opinion leader influence becomes more salient at lower prices. However, this salience depends asymmetrically on whether opinion leaders adopt or reject the technology. Because opinion leaders are typically the most affluent and well-educated people in a para, even if a new technology is affordable and appropriate for them, it is not necessarily affordable or appropriate for the average household (Munshi 2004, Feder and Savastano 2006). However, if a new technology is inappropriate for opinion leaders, it is almost surely perceived to be inappropriate for the average household.[11]

[10] Recall from §2 that the benefits and features of the chimney stove were more readily understood than those of the efficiency stove, as revealed through focus group discussions. Although the physical design of the chimney stove visibly hints at its purpose, the design of the efficiency stove does not.

[11] Table B.1 in Appendix B reports heterogeneous opinion leader estimates from Equation (1) that vary by type of opinion leader (using the subsample in which opinion leader information was revealed). Only unanimous acceptance among opinion leaders who are rich landowners is statistically significant, and this is true only for efficiency stoves.

**Table 4 OLS Regression Results for the Effects of Opinion Leader Initial Choices on Stove Orders**

| | Efficiency stove orders | | | | | Chimney stove orders | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *50% subsidy* | | | | | 0.356*** | | | | | 0.027 |
| | | | | | [0.089] | | | | | [0.063] |
| OL initial decisions | | | | | | | | | | |
| *Unanimous acceptance (OLaccept)* | 0.245*** | 0.117 | 0.044* | 0.075 | 0.318*** | −0.003 | −0.061 | −0.005 | −0.039 | −0.055* |
| | [0.083] | [0.073] | [0.025] | [0.050] | [0.064] | [0.060] | [0.057] | [0.025] | [0.039] | [0.032] |
| *Mixed acceptance and rejection (OLmixed)* | −0.088 | 0.024 | −0.006 | 0.016 | 0.052 | 0.064 | −0.009 | 0.023 | −0.005 | 0.003 |
| | [0.069] | [0.039] | [0.019] | [0.025] | [0.031] | [0.055] | [0.082] | [0.025] | [0.052] | [0.035] |
| *Unanimous rejection (OLreject)* | −0.323*** | −0.202*** | −0.072*** | −0.131*** | −0.098** | −0.186*** | −0.056 | −0.070** | −0.036 | −0.038** |
| | [0.047] | [0.042] | [0.021] | [0.037] | [0.042] | [0.063] | [0.043] | [0.030] | [0.030] | [0.017] |
| Interactions | | | | | | | | | | |
| *Unanimous acceptance × Subsidy* | | | | | −0.294*** | | | | | 0.038 |
| | | | | | [0.075] | | | | | [0.067] |
| *Mixed acceptance × Subsidy* | | | | | −0.071 | | | | | −0.015 |
| | | | | | [0.065] | | | | | [0.084] |
| *Unanimous rejection × Subsidy* | | | | | −0.100** | | | | | −0.004 |
| | | | | | [0.045] | | | | | [0.073] |
| Order rates (initial) | | | | | | | | | | |
| *Para level* | | | 0.618*** | 0.376*** | 0.301** | | | 0.604*** | 0.387** | 0.382* |
| | | | [0.081] | [0.120] | [0.144] | | | [0.133] | [0.187] | [0.192] |
| *Village level* | | | 0.318*** | | | | | 0.074 | | |
| | | | [0.063] | | | | | [0.133] | | |
| *Constant* | 0.363*** | 0.401*** | 0.040** | 0.015 | 0.059* | 0.314*** | 0.485*** | 0.114*** | 0.309*** | 0.038*** |
| | [0.043] | [0.086] | [0.017] | [0.025] | [0.033] | [0.036] | [0.073] | [0.034] | [0.104] | [0.012] |
| Observations | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| $R^2$ | 0.073 | 0.245 | 0.239 | 0.254 | 0.258 | 0.024 | 0.075 | 0.074 | 0.087 | 0.087 |
| Village fixed effects? | No | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes |
| $F$-test ($OLaccept = OLreject$) | 0.482 | 1.009 | 0.873 | 1.003 | 12.72 | 6.727 | 0.00633 | 3.082 | 0.00594 | 0.437 |
| Prob $> F$ | 0.490 | 0.319 | 0.354 | 0.320 | 0.000686 | 0.0120 | 0.937 | 0.0843 | 0.939 | 0.511 |
| $F$-test ($OLaccept = OLmixed$) | 1.601 | 1.482 | 1.447 | 1.354 | 24.57 | 0.399 | 0.761 | 0.187 | 0.774 | 0.820 |
| Prob $> F2$ | 0.210 | 0.228 | 0.233 | 0.249 | 5.42e−06 | 0.530 | 0.387 | 0.667 | 0.383 | 0.369 |
| $F$-test ($OLreject = OLmixed$) | 17.49 | 8.901 | 11.45 | 6.568 | 0.873 | 1.537 | 0.386 | 1.318 | 0.400 | 0.714 |
| Prob $> F3$ | 8.81e−05 | 0.00401 | 0.00122 | 0.0127 | 0.354 | 0.220 | 0.537 | 0.256 | 0.530 | 0.402 |
| $P$-value for difference in OL acceptance effect between efficiency and chimney | | | | | | 0.0166 | 0.0559 | 0.0315 | 0.0767 | 2.00e−06 |
| $P$-value for difference in OL unanimous rejection effect between efficiency and chimney | | | | | | 0.0809 | 0.0166 | 0.0854 | 0.0263 | 0.188 |
| $P$-value for difference in OL acceptance effect between subsidy and no subsidy for efficiency and chimney | | | | | | | | | | 0.561 |
| $P$-value for difference in OL unanimous rejection effect between subsidy and no subsidy for efficiency and chimney | | | | | | | | | | 0.960 |
| Mean of dependent variables | | | 0.335 | | | | | 0.309 | | |

*Notes.* Robust standard errors are in brackets. OL, opinion leader.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 5 reports estimates for household's final purchase decisions. Final purchases are conditional on having ordered a stove, but Table 5 shows results using the entire sample. Compared with initial order estimates in Table 5, the role of information about opinion leader choices is much smaller. This result may suggest that the value of information from opinion leader choices declines over time and is attenuated when households are forced to make actual expenditure decisions. Unanimous rejection by opinion leaders continues to deter adoption more strongly than unanimous leader acceptance promotes adoption.

### 4.3. Round 2: Social Networks

**4.3.1. Estimating Equation.** To study learning and diffusion through social networks, we conducted a second round of interventions in which we marketed stoves to social network members of first-round participants. Our goal was to examine how social ties to someone with a nontraditional stove influenced the decision to order a stove.

Owning a stove is not random, and knowing someone who owns a nontraditional stove may be correlated with the strength of an individual's preference for stoves (homophily). To address this issue,

**Table 5 OLS Regression Results for the Effect of Opinion Leader Stove Order on Stove Purchase**

| | Efficiency stove purchase | | | | | Chimney stove purchase | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *50% subsidy* | | | | | 0.151** | | | | | 0.045 |
| | | | | | [0.064] | | | | | [0.041] |
| OL initial decisions | | | | | | | | | | |
| *Unanimous acceptance (OLaccept)* | 0.037 | −0.035 | −0.064 | −0.067 | 0.164*** | 0.002 | −0.032 | 0.007 | −0.028 | −0.017 |
| | [0.063] | [0.080] | [0.059] | [0.071] | [0.043] | [0.026] | [0.027] | [0.025] | [0.025] | [0.017] |
| *Mixed acceptance and rejection (OLmixed)* | −0.047 | −0.025 | −0.007 | −0.032 | 0.027** | 0.021 | −0.002 | 0.022 | −0.001 | −0.029* |
| | [0.033] | [0.028] | [0.021] | [0.024] | [0.012] | [0.025] | [0.026] | [0.026] | [0.025] | [0.016] |
| *Unanimous rejection (OLreject)* | −0.110*** | −0.072*** | 0.019 | −0.017 | −0.017 | −0.038** | −0.051** | −0.035** | −0.047** | −0.020* |
| | [0.027] | [0.020] | [0.021] | [0.025] | [0.019] | [0.015] | [0.022] | [0.015] | [0.020] | [0.011] |
| Interactions | | | | | | | | | | |
| *Unanimous acceptance × Subsidy* | | | | | −0.286*** | | | | | −0.034 |
| | | | | | [0.071] | | | | | [0.048] |
| *Mixed acceptance × Subsidy* | | | | | −0.161*** | | | | | 0.037 |
| | | | | | [0.040] | | | | | [0.038] |
| *Unanimous rejection × Subsidy* | | | | | −0.001 | | | | | −0.060 |
| | | | | | [0.033] | | | | | [0.043] |
| Order rates (initial) | | | | | | | | | | |
| *Para level* | | | 0.349*** | 0.290*** | 0.220** | | | 0.099* | 0.063 | 0.069* |
| | | | [0.113] | [0.099] | [0.092] | | | [0.056] | [0.038] | [0.038] |
| *Village level* | | | 0.114 | | | | | −0.095 | | |
| | | | [0.100] | | | | | [0.077] | | |
| *Constant* | 0.110*** | 0.064 | −0.049** | 0.031 | 0.004 | 0.038** | 0.011 | 0.037* | −0.017 | 0.004 |
| | [0.027] | [0.066] | [0.022] | [0.022] | [0.011] | [0.015] | [0.025] | [0.022] | [0.025] | [0.007] |
| Observations | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| $R^2$ | 0.017 | 0.156 | 0.129 | 0.170 | 0.181 | 0.008 | 0.071 | 0.012 | 0.073 | 0.077 |
| Village fixed effects? | No | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes |
| $F$-test ($OLaccept = OLreject$) | 0.856 | 0.204 | 0.565 | 0.359 | 16.09 | 0.952 | 0.383 | 0.687 | 0.455 | 0.0367 |
| Prob > $F$ | 0.358 | 0.653 | 0.455 | 0.551 | 0.000159 | 0.333 | 0.538 | 0.410 | 0.503 | 0.849 |
| $F$-test ($OLaccept = OLmixed$) | 0.0138 | 0.0148 | 0.986 | 0.265 | 12.93 | 0.455 | 1.587 | 0.290 | 1.481 | 0.423 |
| Prob > $F2$ | 0.907 | 0.904 | 0.324 | 0.608 | 0.000624 | 0.503 | 0.213 | 0.592 | 0.228 | 0.518 |
| $F$-test ($OLreject = OLmixed$) | 10.59 | 2.189 | 0.151 | 0.216 | 0.174 | 0.221 | 2.321 | 0.161 | 2.294 | 0.223 |
| Prob > $F3$ | 0.00180 | 0.144 | 0.699 | 0.643 | 0.678 | 0.640 | 0.133 | 0.690 | 0.135 | 0.639 |
| $P$-value for difference in OL acceptance effect between efficiency and chimney | | | | | | 0.608 | 0.969 | 0.567 | 0.681 | 1.09e–08 |
| $P$-value for difference in OL unanimous rejection effect between efficiency and chimney | | | | | | 0.0222 | 0.484 | 0.223 | 0.914 | 0.541 |
| $P$-value for difference in OL acceptance effect between subsidy and no subsidy, efficiency and chimney | | | | | | | | | | 0.391 |
| $P$-value for difference in OL unanimous rejection effect between subsidy and no subsidy, efficiency and chimney | | | | | | | | | | 0.124 |
| Mean of dependent variables | | | 0.0918 | | | | | 0.0400 | | 0.0400 |

*Notes.* Robust standard errors are in brackets. OL, opinion leader.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

we use random variation in first-round stove adoption created by randomized discounts provided in the first round. Specifically, we estimate a two-stage model in which the endogenous right-hand-side (RHS) variable of interest (the share of a second-round household's social network with a nontraditional stove) is instrumented with whether or not a 50% discount was offered in the village in the first round:

First stage:

$$Share\_of\_Network\_with\_Stove_h = \alpha + \beta(Discount)_v + \boldsymbol{\tau}\mathbf{Y}_h + \varepsilon^1_{hv}. \quad (2)$$

Second stage:

$$\Pr(Stove\_Order)_h = \gamma + \theta(\widehat{Share\_of\_Network\_with\_Stove_h}) + \boldsymbol{\varphi}\mathbf{Y}_h + \varepsilon^2_{hv}. \quad (3)$$

Table 6 shows the second-stage estimates, and Table B.2 in Appendix B reports first-stage estimates.[12]

[12] $\mathbf{Y}$ is a vector of household-level controls. Specific household characteristics included are the number of wage earners in the household, number of male and female household members, number of children under the ages of 5 and 18, education levels of the male and female heads of household, ages of the male and female heads of household, and indicators for whether the male and female heads of household work outside the home for wages.

**Table 6** Effect of Knowing Others with Stoves on One's Own Stove Order

| | Efficiency stove | | Chimney stove | |
|---|---|---|---|---|
| | OLS | IV | OLS | IV |
| *% of network members with stove* | −0.284*** | −0.839** | −0.255** | −0.712 |
| | [0.060] | [0.377] | [0.101] | [0.609] |
| *Constant* | 0.212*** | 0.316*** | 0.243*** | 0.291*** |
| | [0.039] | [0.073] | [0.042] | [0.073] |
| $R^2$ | 0.053 | −0.149 | 0.013 | −0.029 |
| First partial $R^2$ | | 0.0844 | | 0.101 |
| First $F$-test | | 4.230 | | 5.600 |
| First $F$-test $P$-value | | 0.0524 | | 0.0294 |
| Observations | 592 | 592 | 431 | 431 |
| Mean of dependent variables | 0.16 | | 0.216 | |
| Mean share of network members with stoves in discount villages | 0.272 | | 0.162 | |
| Mean share of network members with stoves in full-price villages | 0.101 | | 0.0444 | |

*Note.* Robust standard errors are in brackets.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Beyond estimating overall network effects, we are also interested in examining whether specific types of network members—e.g., people who live in the same compound (bari) or close friends—influence decisions to order stoves to varying degrees. We therefore also estimate variants of Equations (2) and (3) in which the endogenous variables of interest are stove ownership rates among network members of a specific type (e.g., bari residents versus nonresidents), and these are instrumented with the subsidies offered to network members of that type.

First stages:

$$\left(\frac{Bari\_Members\_with\_Stoves}{Network\_Size}\right)_h = \alpha_1 + \beta_1\left(\frac{\#Bari\_Members}{Network\_Size} \times Discount\right)_{hv} + \boldsymbol{\tau}_1 \mathbf{Y}_h^1 + \varepsilon_{hv}^1, \tag{4a}$$

$$\left(\frac{Non\text{-}Bari\_Members\_with\_Stoves}{Network\_Size}\right)_h = \alpha_2 + \beta_2\left(\frac{\#Non\text{-}Bari\_Members}{Network\_\ Size} \times Discount\right)_{hv} + \boldsymbol{\tau}_2 \mathbf{Y}_h^2 + \varepsilon_{hv}^2. \tag{4b}$$

Second stage:

$$\Pr(Stove\_Order)_h = \gamma + \theta_1\left(\frac{\widehat{Bari\_Members\_with\_Stoves}}{Network\_Size}_h\right) + \theta_2\left(\frac{\widehat{Non\text{-}Bari\_Members\_with\_Stoves}}{Network\_Size}_h\right) + \boldsymbol{\varphi}\mathbf{Y}_h + \varepsilon_{hv}^3. \tag{5}$$

Table 7 reports the second-stage results (different rows examine different types of network members, including bari members, relatives, and close friends), and Table B.3 in Appendix B reports the corresponding first-stage estimates.[13] Our second-round social network survey asked each respondent about the specific nature of their relationship to all 50 first-round village residents who had been offered stoves. Because of random sampling, some second-round respondents happened to have many bari members who were offered stoves, and others may have had more "close friends" who were offered stoves. This is the source of the underlying data variation that allows us to estimate Equations (4) and (5) for different *types* of network members in the different rows of Table 7. We normalize both the endogenous variables and the instruments by network size (i.e., the number of first-round households that the respondent knows), because we strategically oversampled social network connections of first-round households.

**4.3.2. Effects of Social Network on Stove Orders.** Before presenting social network estimates obtained from Equations (2)–(5), we first examine first-round study participant perceptions of stove performance (because these reflect the information transmitted through social networks). Table 8 shows that at the time of the social network round of marketing offers, efficiency stoves were much more likely than chimney stoves to be broken or not in use. The majority of chimney stove owners would recommend the stove to others, but only a minority of efficiency stove owners would recommend their stove. In fact, only 33% of efficiency stove owners believed that the stove was actually reduced fuel use. In contrast, 94% of chimney stove owners believed the stove reduced smoke emissions in the home. The differences between stove types in Table 8 are all highly statistically significant.

The instrumental variable (IV) estimates in Table 6 (in the second and fourth columns) then show that if more network members (aggregated across all types) purchased stoves in the first round, then that household's likelihood of ordering a stove in the second round is *reduced*. This effect is statistically significant for efficiency stoves (reflecting the negative perceptions of efficiency stoves shown in Table 8) but not for chimney stoves. The fact that the IV estimates are larger in magnitude than the corresponding ordinary least squares (OLS) estimates (shown in the first and third columns) also suggests some degree

[13] Equations (4a) and (4b) clearly spell out only one instrument per endogenous RHS variable for brevity, but both instruments are included in both first-stage regressions. Our instruments (based on first-round discounts) generally have a positive, statistically significant relationship to the share of people in the household's social network who purchased stoves in the first round.

**Table 7 Effects of "Close" Relationships on One's Own Stove Order**

| | Efficiency | | Chimney | |
|---|---|---|---|---|
| % of network members that have stoves and are/have | OLS | IV | OLS | IV |
| Panel A: Bari members | | | | |
| Bari members | −0.254*** | −0.161 | −0.062 | −0.014 |
| | [0.047] | [0.100] | [0.203] | [0.314] |
| Non-bari members | −0.308*** | −1.269* | −0.266** | −0.837 |
| | [0.076] | [0.657] | [0.111] | [1.293] |
| $R^2$ | 0.053 | −0.268 | 0.009 | −0.025 |
| $P$-value: Bari members = Non-bari members | 0.266 | 0.0972 | 0.290 | 0.587 |
| Panel B: Relatives | | | | |
| Close relatives (relationships with a name) | −0.270*** | −0.559** | −0.029 | 1.112 |
| | [0.055] | [0.283] | [0.293] | [0.853] |
| Distant relatives (unnamed relationship types, "other" relatives) | −0.213** | −3.105 | −0.055 | −0.958 |
| | [0.088] | [3.355] | [0.236] | [1.430] |
| Non-relatives | −0.317*** | −0.984* | −0.345** | −0.783 |
| | [0.077] | [0.565] | [0.147] | [0.509] |
| $R^2$ | 0.053 | −0.833 | 0.012 | −0.111 |
| $P$-value: Close relatives = Distant relatives | 0.500 | 0.415 | 0.939 | 0.234 |
| $P$-value: Close relatives = Non-relatives | 0.438 | 0.310 | 0.391 | 0.0639 |
| Panel C: Close relationships | | | | |
| Close relationships (8–10 of 10 on closeness scale) | −0.288*** | −0.864** | 0.018 | 0.002 |
| | [0.053] | [0.413] | [0.269] | [0.667] |
| Medium-close relationships (5–7 of 10 on closeness scale) | −0.287*** | −0.924 | −0.226 | −1.095 |
| | [0.058] | [0.575] | [0.184] | [1.036] |
| Not close relationships (1–4 of 10 on closeness scale) | −0.272** | −0.808* | −0.375*** | −0.558 |
| | [0.116] | [0.479] | [0.130] | [0.396] |
| $R^2$ | 0.053 | −0.178 | 0.014 | −0.041 |
| $P$-value: Close relationships = Medium-close relationships | 0.971 | 0.864 | 0.537 | 0.209 |
| $P$-value: Close relationships = Not close relationships | 0.872 | 0.899 | 0.236 | 0.455 |
| Panel D: Close relationships with relatives | | | | |
| Close family relationships (close relatives rated 8–10 on closeness scale) | −0.305*** | −0.597* | 0.156 | 0.475 |
| | [0.065] | [0.358] | [0.231] | [0.622] |
| Not close family relationships (close relatives rated 1–7 on closeness scale) | −0.220*** | −0.590 | −0.392* | −0.234 |
| | [0.063] | [0.736] | [0.223] | [1.052] |
| $R^2$ | 0.025 | −0.013 | 0.009 | −0.001 |
| $P$-value: Close family relationships = Not close family relationships | 0.0823 | 0.990 | 0.176 | 0.248 |
| Mean of dependent variable stove order | 0.160 | | 0.216 | |
| Controls? | No | No | No | No |

*Notes.* Robust standard errors are in brackets. Each category is defined as the percentage of a household's network members that are members of that type. See §4.3.2 for details on category definitions. Estimations used constants; output was suppressed in the interest of space.

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

of homophily. In general, these results imply that prior to learning about nontraditional stoves through social networks, participating households may have been overly optimistic about the net benefits of stove use.

The social learning effects in Table 6 are large in magnitude. To aid in interpretation, note that 10% of network members owned efficiency stoves at the time orders were taken in full-price villages, whereas 27% of network members in villages with randomly assigned discounts. This 17-percentage-point increase in network members with stoves is associated with a 14.3-percentage-point reduction in a household's own propensity to order an efficiency (in the IV specification)—or an 89% decline at the mean order rate of 16%.

The social network effect for the chimney stove sample is not statistically distinguishable from zero, but even taken at face value, the move from full price to discounted price villages represents a 39% decline in adoption at the mean, much smaller than the 89% decline in the efficiency stove sample. The fact that the negative social learning effect is stronger for efficiency stoves than for chimney stoves is also consistent with

**Table 8 Experience with Stoves by Type**

| | Efficiency | | Chimney | | | |
|---|---|---|---|---|---|---|
| | Mean | *N* | Mean | *N* | Diff | *P*-value |
| Usage | | | | | | |
| Stove still works | 0.43 | 102 | 0.77 | 47 | 0.33 | 0.00 |
| Uses stove consistently | 0.05 | 76 | 0.57 | 42 | 0.52 | 0.00 |
| Recommendations | | | | | | |
| Would recommend | 0.15 | 86 | 0.72 | 47 | 0.57 | 0.00 |
| Stove works: would recommend to others | 0.26 | 34 | 0.86 | 36 | 0.60 | 0.00 |
| Stove works: would not recommend to others | 0.74 | 34 | 0.14 | 36 | −0.60 | 0.00 |
| Stove works: would recommend | 0.11 | 85 | 0.66 | 47 | 0.55 | 0.00 |
| Stove works: would not recommend | 0.29 | 85 | 0.11 | 47 | −0.19 | 0.01 |
| Positive stove experiences… | | | | | | |
| Reduces cooking time | 0.54 | 87 | 0.70 | 47 | 0.16 | 0.07 |
| Reduces smoke emissions | 0.66 | 87 | 0.94 | 47 | 0.28 | 0.00 |
| Burns food less | 0.45 | 87 | 0.79 | 47 | 0.34 | 0.00 |
| Uses less fuel | 0.33 | 87 | 0.64 | 47 | 0.30 | 0.00 |

our opinion leader results. This underscores the larger role of social learning for new technologies without readily apparent attributes (desirable or undesirable).

We then turn to heterogeneity of social network effects by type (and strength) of social ties, estimating Equation (5) for four different (overlapping) types of network members:

1. *Bari members:* A bari is a compound consisting of multiple households. Members of the same bari are likely to share meals or watch each other cook.

2. *Relatives:* Close relatives include any type of family relationship that was specifically named, including parents, grandparents, aunts, uncles, children, grandchildren, siblings, nieces, nephews, and in-laws. Other relatives include cousins and other unspecified types of family relationships. Any identified network member who is not a relative is a neighbor.

3. *Close relationships:* Second-round households ranked all first-round households in their social network on a 1–10 scale of how close their relationship was. We code 8–10 as "close," 5–7 as "medium-close," and 1–4 as "not close."

4. *Close family relationships:* Close family relationships are defined as named family relationships with people ranked 8–10 of 10 for closeness. Not close family relationships are defined as named family relationships with people ranked 1–7 of 10 for closeness.

Table 7 reports social network estimates obtained from Equations (4) and (5) for each of these types of relationships. Overall, the IV estimates in the second and fourth columns suggest that when social learning occurs, it is due to the transmission of negative information—and consistent with the perceptions of stoves shown in Table 8, this learning reduces adoption of efficiency stoves, but not chimney stoves. Examining the gradient of social network effects by the degree of closeness within each type of relationship, there is little evidence that the closeness of network members (e.g., closer friends, closer relatives, those one lives in close proximity to) influences the propensity to order efficiency stoves. For chimney stoves, close social ties to first-round adopters (relative to more distant ties) appears to raise the probability of adoption, but not significantly so. Overall, the pattern of results generally matches those in Table 6: knowing a larger share of people with nontraditional stoves is associated with a reduction in the likelihood of ordering a stove, and this effect is stronger for efficiency stoves.

Using follow-up data from first-round households about their experiences with the stoves, we next examine whether the direction of the social learning effects corresponds to first-round households' experiences with the stoves. Specifically, we test for heterogeneous social network effects for ties to first-round households with positive versus negative experiences with nontraditional stoves (judged according to whether first-round households use the stoves, report that they work, and would recommend them to others). To do so, we reestimated Equation (3), splitting the share of network members with a nontraditional stove into two groups (those with positive and negative experiences) coded accordingly. Because the follow-up survey could only collect this information from stove users (not from nonusers), we cannot construct multiple instruments for the multiple endogenous variables distinguished by the nature of the experience. We therefore only report OLS estimates.

Table 9 shows these results, suggesting that negative information is much more salient than positive information. For efficiency stoves, which were widely disliked, this overall negative experience dominated any positive experience that some network members might have had (even if a network member had a working stove or would recommend one, for example). On the other hand, having a network member with a negative experience with a chimney stove was associated with reduced adoption of chimney stoves in the second round (even though the stove was generally liked by villagers). A 10-percentage-point increase in the fraction of network members with nonworking chimney stove leads to a 4-percentage-point decrease in the chimney stove order rate, which represents a 20% drop at the mean order rate. In contrast, an increase in network members with positive chimney stove experiences has no statistically significant effect on order propensity in the second round.

**Table 9 Effect of Social Network Members with Positive and Negative Stove Experiences on One's Own Stove Order**

| % of network members with a stove that... | Efficiency | Chimney | Efficiency | Chimney | Efficiency | Chimney |
|---|---|---|---|---|---|---|
| They use | −0.244* | −0.034 | | | | |
| | [0.127] | [0.149] | | | | |
| They do not use | −0.336*** | −0.494*** | | | | |
| | [0.072] | [0.154] | | | | |
| Works | | | −0.346*** | −0.130 | | |
| | | | [0.077] | [0.120] | | |
| Does not work | | | −0.233*** | −0.399** | | |
| | | | [0.081] | [0.159] | | |
| They would recommend | | | | | −0.398*** | −0.223 |
| | | | | | [0.105] | [0.147] |
| They would not recommend | | | | | −0.263*** | −0.218 |
| | | | | | [0.055] | [0.182] |
| Constant | 0.201*** | 0.233*** | 0.199*** | 0.234*** | 0.199*** | 0.238*** |
| | [0.037] | [0.043] | [0.037] | [0.044] | [0.038] | [0.044] |
| Observations | 592 | 431 | 592 | 431 | 592 | 431 |
| $R^2$ | 0.043 | 0.012 | 0.038 | 0.009 | 0.041 | 0.010 |
| $F$-test: Positive experience = Negative experience | 0.404 | 6.612 | 2.972 | 3.946 | 3.445 | 0.000340 |
| Prob > $F$ | 0.532 | 0.0192 | 0.0994 | 0.0624 | 0.0775 | 0.985 |
| $P$-value: Difference positive effect for chimney vs. efficiency | | 0.283 | | 0.132 | | 0.330 |
| $P$-value: Difference negative effect for chimney vs. efficiency | | 0.352 | | 0.351 | | 0.812 |
| Mean of dependent variable (*stove orders*) | 0.160 | 0.216 | 0.160 | 0.216 | 0.160 | 0.216 |
| Mean share of network members with positive stove experience | 0.00469 | 0.0539 | 0.0750 | 0.0708 | 0.0230 | 0.0620 |
| Mean share of network members with negative stove experience | 0.121 | 0.0311 | 0.0605 | 0.0233 | 0.117 | 0.0385 |

*Note*. Robust standard errors are in brackets.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

All of this suggests that negative information about disliked technologies appears to flow more freely through networks in rural Bangladesh. A plausible explanation is that consumers find it difficult to trust new products and brands in rural areas of developing countries, where institutions protecting consumers are either weak or absent. In such environments, consumers may have to rely more on their networks to learn about products that do not work.

## 5. Alternative Explanations

In this section we evaluate alternative explanations for our findings, emphasizing our analysis of opinion leader influence (given that, unlike our analysis of social networks, it does not rely only on experimental variation). First, an explanation frequently invoked in nonexperimental studies of social learning is homophily, which is the nonrandom formation of social ties according to homogeneity of preferences (Manski 1993, Bemmaor 1994, Aral et al. 2009, Shalizi and Thomas 2011). The random variation in first-round adoption induced by the random allocation of discounts in our research design allows us to circumvent this challenge in our social network analysis. However, homophily is a potential alternative explanation for our opinion leader findings. Without rejecting the presence of homophily, our opinion leader results require an explanation beyond simple homogeneity of preferences between leaders and other villagers. Throughout our analysis, we find evidence of heterogeneity on a variety of dimensions of stove choice: (1) type of stove (chimney versus efficiency), (2) opinion leader choices (unanimous acceptance versus unanimous rejection), (3) decision stage (stove order versus stove purchase at the time of delivery), and (4) stove price (discounted versus full price). In contrast to predictions based on homophily, the patterns of heterogeneity we document suggest that social networks matter more when a product is more difficult to understand and when negative information is revealed.

Second, in interpreting the fact that social networks have less "negative" impact for chimney stoves than for efficiency stoves, rather than this being due to differences in the observability of their costs and benefits, efficiency stoves may simply be worse value for money—and so more negative information is transmitted about them through social learning. Efficiency stoves could certainly be worse value for money than chimney stoves. However, this explanation would also require that the value of the efficiency stove is relatively harder to perceive prior to purchase—in which case our original interpretation (that social learning is more important for products with less evident costs or benefits) would still be appropriate.

Finally, our opinion leader results may not be explained by the influence of opinion leaders per se; rather, they could be a response to learning the decisions of any community members, regardless of their identity. In future research this possibility could be investigated by revealing opinion leader choices to some and choices of randomly selected village or para residents to others.

## 6. Conclusions

Although nontraditional stoves are believed to have beneficial health and environmental consequences, adoption rates are low—even at highly subsidized prices. We conducted two rounds of an intervention study in rural Bangladesh to analyze how learning through opinion leaders and social networks affect decisions to adopt nontraditional stoves. We find that opinion leadership and social networks are more influential when the advantages and disadvantages of a technology are not easily observed or understood (and that the amount of influence varies with the price of the technology—or the opportunity cost of adoption). These findings are consistent with empirical observations made in the fields of industrial organization, marketing, and development sociology. It is worth noting that we also show that in institutional environments in which consumers are distrustful of new products and brands, negative information is much more salient than positive information in social learning.

Despite the disappointing levels of stove adoption during the course of our study, we make an important contribution to the marketing literature by using experimental methods to document the transmission of information through opinion leaders and social networks in a developing country setting. As an early contribution to the marketing literature on developing countries, it provides new evidence that social learning in low-income country markets may function similarly to the way it does in wealthy countries.

Overall, our findings have several important broader implications. First, 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. Second, external influence and the provision of information may be less effective for technologies that households can evaluate for themselves (Iyengar et al. 2011), and the value of external signals and influence may decline with experience over time. Third, for external information and marketing efforts to result in sustained adoption and use, a new technology fundamentally must match local preferences at least as well as, if not better than, traditional technologies do.

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### Appendix A. Scripts for the Interventions Translated from Bengali

**Efficiency Stove**
Here is a picture of the improved stove that we are talking to you about:

*Source*: The authors.

As a project participant, we would like to offer this special improved stove for your cooking needs. The stove you see in the picture is made of clay, just like the traditional stove you currently use. This stove can burn the same wood like your current stove can. But you will also face some difficulty burning crop refuse, hay, leaves, and branches in this stove.

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.

However, during cooking this stove may produce a similar amount of smoke. This stove is movable—you can use it wherever you like. The stove can be used indoors during monsoon and outdoors during the winter.

If you agree to take this stove, then we can bring it to you and explain in detail how to use it. The stove will cost 400 taka.

**Chimney Stove**
Here is a picture of the improved stove that we are talking to you about:

*Source*: The authors.

As a project participant, we would like to offer this special improved stove for your cooking needs. The stove you see in the picture is made of clay, just like the traditional stove you currently use. This stove can burn the same wood like your current stove can. But you will also face some difficulty burning crop refuse, hay, leaves, and branches in this stove.

The main difference between the chimney stove and your current stove is the chimney. The smoke that is produced during cooking leaves through the chimney. Based on our tests, we have found that this chimney stove emits less smoke inside the kitchen compared with your current traditional stove. With this stove, fuel use and cooking time remains about the same as a traditional stove.

If you agree to take this stove, then we can bring it to you and explain in detail how to use it. The stove will cost 750 taka.

**Table B.2 Effect of 50% Discount in Round 1 on the Percentage of Network Members with Nontraditional Stoves**

| | Efficiency stove | Chimney stove |
|---|---|---|
| *Half-price village* | 0.172* | 0.117** |
| | [0.083] | [0.050] |
| *Constant* | 0.101** | 0.044** |
| | [0.038] | [0.021] |
| Observations | 592 | 431 |
| $R^2$ | 0.084 | 0.101 |
| Controls? | No | No |

*Note*. Robust standard errors are in brackets.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

## Appendix B. Supplemental Tables

**Table B.1 Heterogeneity in Influence Across Types of Opinion Leader Initial Acceptance (OL Information Group Only)**

| | Efficiency stoves | | | Chimney stoves | | |
|---|---|---|---|---|---|---|
| | Stove order | Stove purchase | Stove refusal | Stove order | Stove purchase | Stove refusal |
| *50% subsidy* | 0.104 | 0.023 | 0.006 | 0.021 | 0.047** | −0.146** |
| | [0.070] | [0.037] | [0.121] | [0.062] | [0.023] | [0.067] |
| *Rich OL initial accept* | 0.305*** | 0.073* | −0.001 | 0.086 | −0.002 | 0.028 |
| | [0.081] | [0.038] | [0.158] | [0.069] | [0.027] | [0.072] |
| *Elected OL initial accept* | 0.069 | 0.009 | 0.031 | 0.033 | 0.027 | −0.059 |
| | [0.099] | [0.038] | [0.081] | [0.071] | [0.026] | [0.066] |
| *Educated OL initial accept* | 0.061 | 0.021 | −0.029 | 0.057 | 0.006 | 0.014 |
| | [0.087] | [0.043] | [0.100] | [0.059] | [0.026] | [0.076] |
| *Constant* | 0.042 | 0.009 | 0.762*** | 0.208*** | −0.002 | 0.961*** |
| | [0.048] | [0.021] | [0.103] | [0.060] | [0.015] | [0.061] |
| Observations | 472 | 472 | 140 | 532 | 532 | 162 |
| $R^2$ | 0.192 | 0.034 | 0.001 | 0.021 | 0.016 | 0.044 |
| $F$-test (Rich OL initial accept = Elected OL initial accept) | 2.249 | 1.050 | 0.0439 | 0.186 | 0.445 | 0.734 |
| Prob > $F$ | 0.145 | 0.315 | 0.836 | 0.669 | 0.510 | 0.398 |
| $F$-test (Rich OL initial accept = Educated OL initial accept) | 5.672 | 1.375 | 0.0190 | 0.110 | 0.0309 | 0.0118 |
| Prob > $F$ | 0.0245 | 0.251 | 0.891 | 0.742 | 0.862 | 0.914 |
| $F$-test (Elected OL initial accept = Educated OL initial accept) | 0.00200 | 0.0275 | 0.141 | 0.0559 | 0.225 | 0.430 |
| Prob > $F$ | 0.965 | 0.870 | 0.711 | 0.815 | 0.638 | 0.517 |
| $P$-value: Difference in rich OL initial accept efficiency and chimney | | | | 0.0232 | 0.159 | 0.865 |
| $P$-value: Difference in educated OL initial accept efficiency and chimney | | | | 0.897 | 0.811 | 0.902 |

*Notes*. Robust standard errors clustered at the para level are in brackets. The dependent variable *Stove refusal* is defined only for those households who initially ordered a stove but refused payment or purchase on delivery.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

**Table B.3 First-Stage Results for Equations (4a) and (4b): Different Types of Network Relationships**

% of network members that have stoves and are/have

Panel A: Close relationships with relatives

| | Efficiency | | Chimney | |
|---|---|---|---|---|
| | Close family | Not close family | Close family | Not close family |
| Close family relationships (close relatives rated 8–10 on closeness scale) | 0.246*** | −0.049** | 0.198*** | −0.041** |
| | [0.072] | [0.018] | [0.053] | [0.015] |
| Not close family relationships (close relatives rated 1–7 on closeness scale) | −0.065*** | 0.179* | −0.028 | 0.127** |
| | [0.021] | [0.091] | [0.030] | [0.059] |
| $R^2$ | 0.193 | 0.077 | 0.235 | 0.130 |

Panel B: Bari members

| | Efficiency | | Chimney | |
|---|---|---|---|---|
| | Bari members | Non-bari members | Bari members | Non-bari members |
| Bari members | 0.877*** | 0.108 | 0.685*** | 0.162 |
| | [0.040] | [0.071] | [0.099] | [0.105] |
| Non-bari members | −0.035* | 0.103 | 0.001 | 0.064** |
| | [0.018] | [0.062] | [0.011] | [0.030] |
| $R^2$ | 0.573 | 0.059 | 0.604 | 0.091 |

Panel C: Close relationships

| | Efficiency | | | Chimney | | |
|---|---|---|---|---|---|---|
| | Close relationships | Medium-close relationships | Not close relationships | Close relationships | Medium-close relationships | Not close relationships |
| Close relationships (8–10 of 10 on closeness scale) | 0.231*** | −0.078** | 0.000 | 0.205*** | −0.035** | 0.000 |
| | [0.068] | [0.032] | [0.011] | [0.051] | [0.014] | [0.007] |
| Medium-close relationships (5–7 of 10 on closeness scale) | −0.037** | 0.177** | −0.004 | −0.022 | 0.107** | −0.014 |
| | [0.014] | [0.074] | [0.012] | [0.020] | [0.044] | [0.011] |
| Not close relationships (1–4 of 10 on closeness scale) | 0.013 | −0.026 | 0.230* | 0.014 | 0.001 | 0.197*** |
| | [0.028] | [0.044] | [0.112] | [0.019] | [0.022] | [0.061] |
| $R^2$ | 0.168 | 0.082 | 0.238 | 0.236 | 0.101 | 0.363 |

Panel D: Relatives

| | Efficiency | | | Chimney | | |
|---|---|---|---|---|---|---|
| | Close relatives | Distant relatives | Non-relatives | Close relatives | Distant relatives | Non-relatives |
| Close relatives (relationships with a name) | 0.441*** | −0.025* | −0.012 | 0.214*** | 0.048** | −0.009 |
| | [0.072] | [0.014] | [0.025] | [0.070] | [0.020] | [0.014] |
| Distant relatives (unnamed relationship types, “other” relatives) | −0.052* | 0.058 | −0.064** | 0.006 | 0.078* | −0.014 |
| | [0.026] | [0.042] | [0.023] | [0.032] | [0.038] | [0.012] |
| Non-relatives | −0.026 | −0.013 | 0.221** | −0.004 | 0.018 | 0.164*** |
| | [0.021] | [0.013] | [0.084] | [0.011] | [0.020] | [0.054] |
| $R^2$ | 0.292 | 0.031 | 0.211 | 0.205 | 0.078 | 0.255 |

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

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