LEARNING ABOUT NEW TECHNOLOGIES THROUGH SOCIAL NETWORKS: EXPERIMENTAL EVIDENCE ON NON-TRADITIONAL STOVES IN BANGLADESH*

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Abstract

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 non-traditional 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 in which 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.

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1 Introduction

Understanding how new technologies with the potential to improve human welfare diffuse in less-developed countries (LDCs) 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: non-traditional 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 non-traditional (or "improved")[2] stoves are believed to reduce fuel consumption and lower the prevalence of serious

[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 non-traditional 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). In this paper, we use the label

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 non-traditional cookstoves in rural Bangladesh. In the first round of our fieldwork, we publicize whether or not locally-identified opinion leaders chose to order non-traditional stoves, and 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 (Luoto 2009; Kremer 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

"non-traditional 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 (BCSIR) and over 100 national and local NGOs have developed and attempted to disseminate a variety of low-cost non-traditional cookstoves supposedly tailored to local needs (Sarkar et al. 2006; ESMAP 2010). Nonetheless, 98% of households in rural Bangladesh still cook over an open fire (NIPORT 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 non-profit organizations. 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.

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, while the chimney visibly signals the chimney stove's potential to reduce IAP even before usage. On efficacy, we provide evidence in Section 4 that the chimney stove "works" according to user perceptions at follow-up, while the efficiency stove does not. In other words, the chimney stove reduces IAP, while 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 non-traditional 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 2003; 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. Moreover, having 'close' relationships to first round participants changes the nature of social learning for chimney stoves (undoing negative word-of-mouth information about stoves), but not for efficiency stoves – presumably both because chimney stoves require more direct experience to learn about their attributes and because they are in practice better value.

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 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: Section 2 describes our experimental research design; Section 3 presents empirical results; Section 4 examines concerns relating to our approach and considers competing explanations for the results that we find; Section 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 2004), 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 2012) financial decisions (Duflo and Saez 2003; Beshears et al. 2011; Bursztyn et al. 2013), job information (Beaman 2008; Magruder 2010), health inputs (Kremer and Miguel 2007; Oster and Thornton 2009; 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 other 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 2003; 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 (Figure 1). Jamalpur is an agrarian area of about 490 sq km. It is densely populated, and its landscape has been largely de-forested. 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.

Prior to 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 sub-districts of Bangladesh in 2006 (Mobarak et al. 2012). The survey revealed several key pieces of information that helps to contextualize our experiments: (1) rural Bangladeshis

[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).

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 non-traditional cookstoves; (3) respondents believe that indoor smoke is harmful to health but is not the most important health risk that they face; and (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. While it 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 – but 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

[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).

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 (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 (16-17 per *para*) for a total of 2100 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 – 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 round one participants. We over-sampled 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 vs. full price) at the village level and information about opinion leader choices within villages at the *para* level using the following procedure:

i. 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. The other 20 were assigned to the half price condition.

[7] There was an average delay of four months between initial stove order placement and deliveries. 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.

ii. 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.

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. Ten 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 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 non-traditional 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.

<u>Prices</u>: 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. This resulted in half prices of Tk. 200 and Tk. 375, 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.

<u>Opinion Leaders</u>: 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, etc.). Finally, we asked villagers to nominate the most educated individuals from the neighborhood not already chosen as an economic or political leader.[8]

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) versus 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. While information about the choices of opinion

[8] While 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).

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 (Tk. 200 for efficiency stoves and Tk. 375 for chimney stoves), eliminating the variation in price present in round one. 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. 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 one (Panel A, stratified by price offered) and two (Panel B, stratified by price offered in that same village in round one). 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 below).

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 One: Opinion Leaders

4.2.1 Estimating Equation

For household *h* in *para p* in village *v* we estimate the probability of stove order or purchase as:

$$\Pr(Stove\ Order\ or\ Purchase)_{hpv} = \alpha + \beta_1 \cdot OLaccept_p + \beta_2 \cdot OLmixed_p + \beta_3 \cdot OLreject_p + \gamma \sum X_{pv} + \varepsilon_{hpv} \qquad (1)$$

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

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 β_1, β_2, and β_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 village- and *para*-level stove order rates (calculated excluding the respondent and Opinion Leaders) in $\boldsymbol{X}$. 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 among community members in the same *para*. Table 4 reports estimates from equation (1) for initial orders in local communities. The estimate 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, it reduces their propensity to order the stove 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 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 interactions 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 estimate for unanimous opinion leader rejection is larger in magnitude. One plausible interpretation of these results is as follows. If a new technology like non-traditional 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 or not 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]

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 to 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

[10] Recall from Section 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. While the physical design of the chimney stove visibly hints at its purpose, the design of the efficiency stove does not.

[11] Appendix Table A1 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.

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 Two: 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 non-traditional stove influenced the decision to order a stove.

Owning a stove is not random, and knowing someone who owns a non-traditional stove may be correlated with the strength of an individual's preference for stoves (homophily). To address this issue, 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 variable of interest (the share of a second-round household's social network with a non-traditional stove) is instrumented using whether or not a 50% discount was offered in the village in the first-round:

First Stage:

$$Share\ of\ Network\ with\ stove_h = \alpha + \beta(Discount)_v + \tau \sum X_h + \varepsilon^1_{hv} \tag{2}$$

Second Stage:

$$\Pr(Stove\ Order)_h = \gamma + \theta\left(\widehat{Share\ of\ Network\ with\ stove_h}\right) + \varphi \sum X_h + \varepsilon^2_{hv} \tag{3}$$

Table 6 shows the second-stage estimates, and Appendix Table A2 reports first-stage estimates.[12] Beyond estimating overall network effects, we are also interested in examining if specific types of

[12] **X** is a vector of household-level controls. Specific household characteristics included are number of wage earners in the household, number of male and female household members, number of children under the ages of 5 and 18,

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 amongst network members of a specific type (e.g. bari residents versus non-residents), and these are instrumented with the subsidies offered to network members of that type:

First Stages:

$$\frac{Bari\ members\ with\ Stoves}{Network\ Size}_h = \alpha_1 + \beta_1\left(\frac{\#\ Bari\ members}{Network\ Size} * Discount\right)_{hv} + \tau_1 \sum X_h^1 + \varepsilon_{hv}^1 \quad (4a)$$

$$\frac{Non-Bari\ members\ with\ Stoves}{Network\ Size}_h = \alpha_2 + \beta_2\left(\frac{\#\ Non-Bari\ members}{Network\ Size} * Discount\right)_{hv} + \tau_2 \sum X_h^2 + \varepsilon_{hv}^2 \quad (4b)$$

Second Stage:

$$\Pr(Stove\ Order)_h = \gamma + \theta_1\left(\widehat{\frac{Bari\ members\ with\ Stoves}{Network\ Size}_h}\right) + \theta_2\left(\widehat{\frac{Non-Bari\ members\ with\ Stoves}{Network\ Size}_h}\right) + \varphi \sum X_h + \varepsilon_{hv}^3 \quad (5)$$

Table 7 reports the second-stage results (different rows examine different types of network members, including *bari* members, relatives, and close friends), and Appendix Table A3 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

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.

[13] Equations (4a) and (4b) clearly spells 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.

had been offered stoves. Due to random sampling, some second-round respondents happened to have many bari members who were offered stoves, while 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 over-sampled 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 IV estimates in Table 6 (in the second and fourth columns) then shows 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 OLS estimates (shown in the first and third columns) also suggests some degree of homophily. In general, these results imply that prior to learning about non-traditional 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, while 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 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:

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.

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.

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."

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 relationship, there is little evidence that the "closeness" of network members (e.g. closer friends, closer relatives, those you live 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 non-traditional 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 if the direction of the social learning effects corresponds to first round households' experiences with the stoves. Specifically, test for heterogeneous social network effects for ties to first round households with positive vs. negative experiences with non-traditional stoves (judged according to whether or not first round households use the stoves, report that they work, and would recommend them to others). To do so, we re-estimated equation (3), splitting the share of network members with a non-traditional 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 non-users), 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 non-working 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.

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 Alternate 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 non-experimental studies of social learning is homophily, which is the non-random 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 vs. efficiency), 2) opinion leader choices (unanimous acceptance vs. unanimous rejection), 3) decision stage (stove order vs. stove purchase at the time of delivery), and 4) stove price (discounted vs. 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 non-traditional 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 non-traditional 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. Importantly, 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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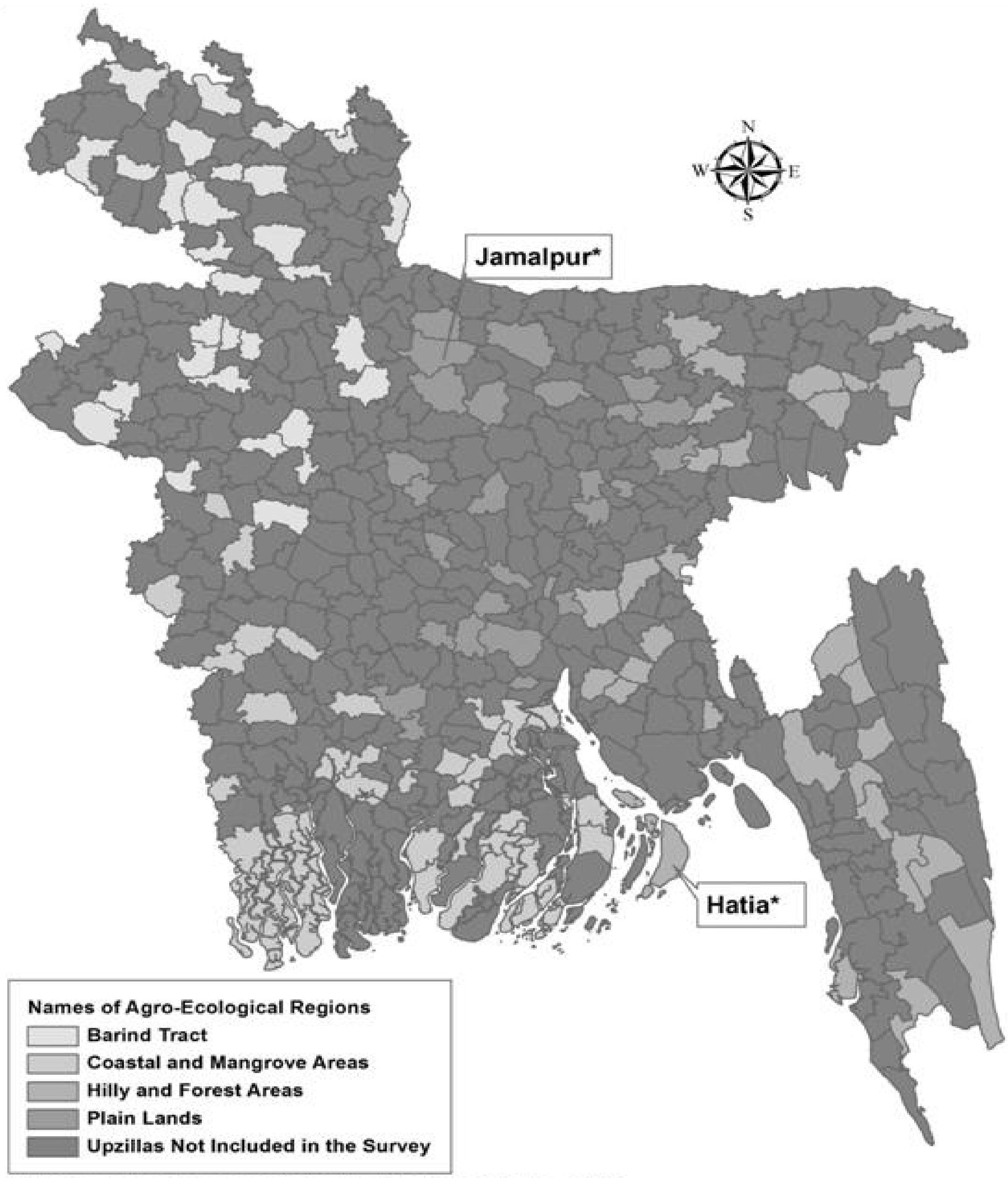
Figure 1: Map



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

Figure 2: Experimental design

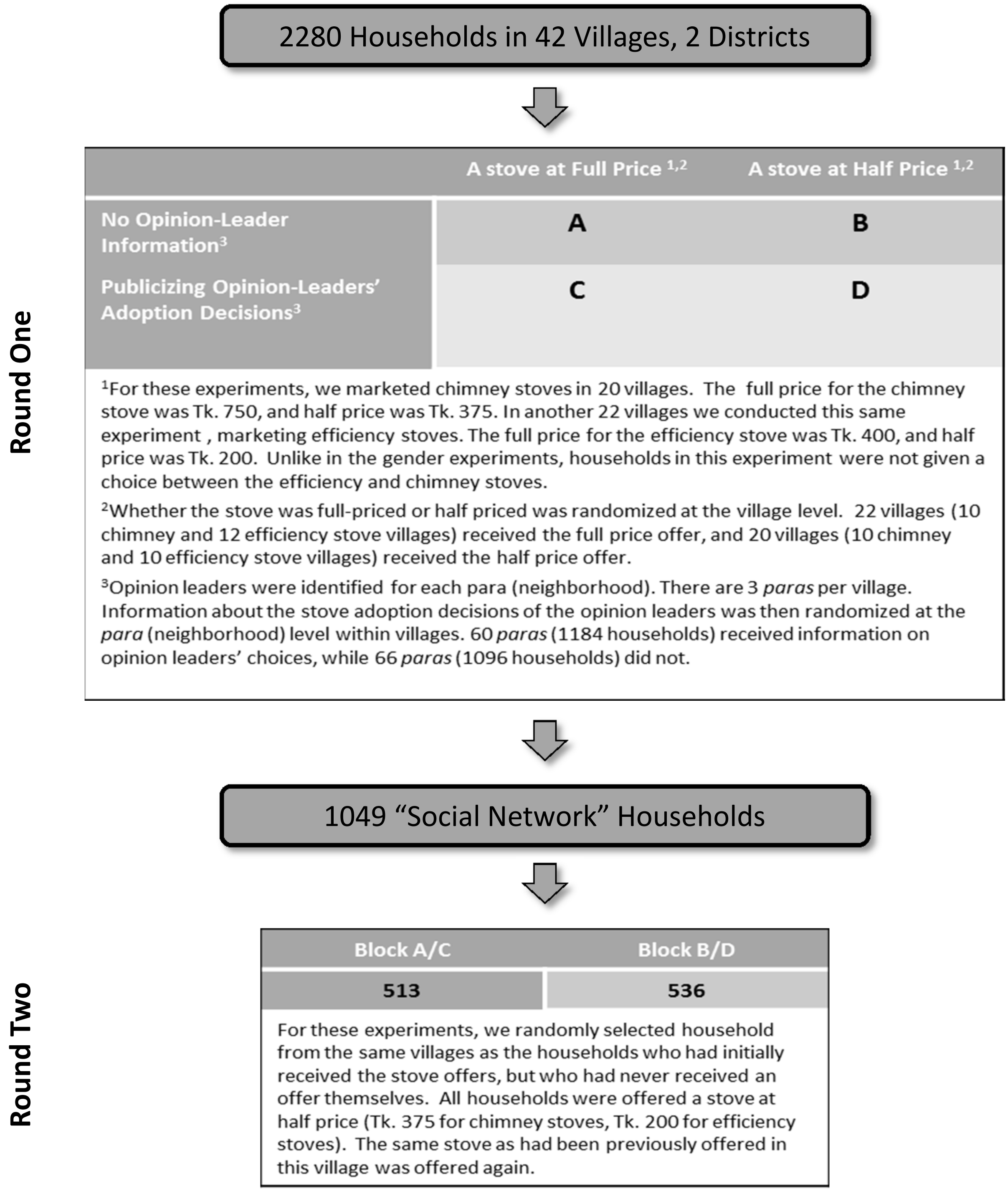


Table 1: Summary Statistics

	Panel A: Baseline (Round 1) Data					Panel B: Social Network (Round 2) Data				
	Full Price	Half Price	Total	Diff	P-value	Full Price (Round one)	Half Price (Round one)	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	Not available	Not available	Not available	Not available	Not available
Household Characteristics										
Total Number of Household 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	Not available	Not available	Not available	Not available	Not available
Average monthly expenses (in Taka)	5,271	5,711	5,481	441	0.41	Not available	Not available	Not available	Not available	Not available
Wealth Index*	-0.14	0.16	0.00	0.30	0.02	Not available	Not available	Not available	Not available	Not available
Household owes money	0.20	0.25	0.22	0.05	0.28	Not available	Not available	Not available	Not available	Not available
Female Characteristics						Not available	Not available	Not available	Not available	Not available
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	Not available	Not available	Not available	Not available	Not available
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 labour (Agriculture)	0.10	0.11	0.11	0.00	0.85	0.10	0.09	0.10	-0.01	0.64
Day labour (Non agriculture)	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

*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 Opinion Leader (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			1100	25%	3%
Half-price			1000	40%	11%
Panel C: Stove Acceptance Rates by OL Information					
No OL Info			1096	34%	8%
OL Info			1004	30%	5%
Panel D: Stove Acceptance Rates by Stove Type					
Efficiency			1100	33%	9%
Chimney			1000	30%	4%
Total			2100	32%	7%

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-squared	0.052	0.013	0.077	0.002	0.051	0.037
Village Fixed Effects?	No	No	No	No	No	No

Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 4: OLS regression resuls 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	-0.088	0.024	-0.006	0.016	0.052	0.064	-0.009	0.023	-0.005	0.003
(OLmixed)	[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-squared	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 variable			0.335					0.309		

Robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

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)										0.069*
Para-level			0.349***	0.290***	0.220**			0.099*	0.063	[0.038]
			[0.113]	[0.099]	[0.092]			[0.056]	[0.038]	
Village-level			0.114					-0.095		
			[0.100]					[0.077]		0.004
Constant	0.110***	0.064	-0.049**	0.031	0.004	0.038**	0.011	0.037*	-0.017	[0.007]
	[0.027]	[0.066]	[0.022]	[0.022]	[0.011]	[0.015]	[0.025]	[0.022]	[0.025]	
										1,000
Observations	1,100	1,100	1,100	1,100	1,100	1,000	1,000	1,000	1,000	0.077
R-squared	0.017	0.156	0.129	0.170	0.181	0.008	0.071	0.012	0.073	Yes
Village Fixed Effects?	No	Yes	No	Yes	Yes	No	Yes	No	Yes	0.0367
F-test (OLaccept=OLreject)	0.856	0.204	0.565	0.359	16.09	0.952	0.383	0.687	0.455	0.849
Prob > F	0.358	0.653	0.455	0.551	0.000159	0.333	0.538	0.410	0.503	0.423
F-test (OLaccept=OLmixed)	0.0138	0.0148	0.986	0.265	12.93	0.455	1.587	0.290	1.481	0.518
Prob > F2	0.907	0.904	0.324	0.608	0.000624	0.503	0.213	0.592	0.228	0.223
F-test (OLreject=OLmixed)	10.59	2.189	0.151	0.216	0.174	0.221	2.321	0.161	2.294	0.639
Prob > F3	0.00180	0.144	0.699	0.643	0.678	0.640	0.133	0.690	0.135	1.09e-08
P-value for difference in OL acceptance effect between Efficiency and Chimney						0.608	0.969	0.567	0.681	0.541
P-value for difference in OL unanimous rejection effect between Efficiency and Chimney						0.0222	0.484	0.223	0.914	0.391
P-value for difference in OL acceptance effect between Subsidy and No Subsidy, Efficiency and Chimney										0.124
P-value for difference in OL unanimous rejection effect between Subsidy and No Subsidy, Efficiency and Chimney										0.0400
Mean of dependent variable			0.0918					0.0400		

Robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 6: Effect of knowing others with stoves on 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-squared	0.053	-0.149	0.013	-0.029
1st partial R2		0.0844		0.101
1st F-test		4.230		5.600
1st F-test pvalue		0.0524		0.0294
Observations	592	592	431	431
Mean of dependent variable	0.16		0.216	
Mean share of network members with stoves in discount vi	0.272		0.162	
Mean share of network members with stoves in full price vi	0.101		0.0444	

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Effects of "Close" Relationships on Own Stove Order

	Efficiency		Chimney	
% of network members that have stoves and are:	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-squared	0.053	-0.268	0.009	-0.025
P-value Bari = Non-Bari Member	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 (Unamed 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-squared	0.053	-0.833	0.012	-0.111
P-value Close = Distant Relative	0.500	0.415	0.939	0.234
P-value Close Relative = Non Relative	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-squared	0.053	-0.178	0.014	-0.041
P-value Close = Medium Close	0.971	0.864	0.537	0.209
P-value Close = Not Close	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-squared	0.025	-0.013	0.009	-0.001
P-value Close Family = Not Close Family	0.0823	0.990	0.176	0.248
Mean of dependent variable stove order	0.160		0.216	
Controls?	No	No	No	No

Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Each category is defined as the % of a household's network members that are members of that type. See text for details on category definitions. Estimations used constants; output was suppressed in the interest of space.

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
If stove works: would recommend to others	0.26	34	0.86	36	0.60	0.00
If 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 Experiences. Stove…						
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

Table 9. Effect of social network members with positive and negative stove experiences on 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-squared	0.043	0.012	0.038	0.009	0.041	0.010
F-test Positive Experiene = 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-val difference postive effect for Chimney vs Efficiency		0.283		0.132		0.330
P-val 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

Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Appendix A: Scripts for the Interventions Translated from Bangla

Information Note - 1
Stove: Efficiency
Price: 400 Taka

Efficiency Stove

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

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 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.

Appendix A: Scripts for the Interventions Translated from Bangla

Information Note - 2
Stove: Chimney
Price: 750 Taka

Chimney Stove

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

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 to 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.

Appendix Table A1. 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-squared	0.192	0.034	0.001	0.021	0.016	0.044
F-test (Rich=Elected)	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=Educated)	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=Educated)	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 for difference in Rich accept Efficiency and Chimney				0.0232	0.159	0.865
P-value for difference in Educated accept Efficiency and Chimney				0.897	0.811	0.902

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

Appendix Table A2: Effect of 50% Discount in Round One on % of network members with non-traditional stoves

	Efficiency	Chimney
Half Price Village	0.172*	0.117**
	(0.083)	(0.050)
Constant	0.101**	0.044**
	(0.038)	(0.021)
Observations	592	431
R-squared	0.084	0.101
Controls?	No	No

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table A3: First Stage Results for Equations 4a, 4b: Different Types of Network Relationships

% of network members that have stoves and are:

Panel A: Close Relationships with Relatives						
	Efficiency		Chimney			
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-squared	0.193	0.077	0.235	0.130		
Panel B: Bari Members						
	Efficiency		Chimney			
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-squared	0.573	0.059	0.604	0.091		
Panel C: Close Relationships						
		Efficiency			Chimney	
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-squared	0.168	0.082	0.238	0.236	0.101	0.363
Panel D: Relatives						
		Efficiency			Chimney	
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 (Unamed 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-squared	0.292	0.031	0.211	0.205	0.078	0.255