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Preference Heterogeneity and Adoption of Environmental Health Improvements: Evidence from a Cookstove Promotion Experiment

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The role of preference heterogeneity in adoption of environmental health improvements: Evidence from a randomized cookstove promotion experiment

Abstract

Household preferences should influence adoption of environmental health-improving technologies, but there has been limited empirical research to isolate their importance, perhaps due to challenges of measurement and attribution. This paper explores first the heterogeneity in household preferences for different features of improved cookstoves (ICS). Second, we assess the degree to which these preferences are associated with actual adoption of ICS (electric and biomass-burning) during a randomized stove promotion campaign in northern India. Analyzing data from a discrete choice experiment (DCE) conducted during baseline surveys with 1060 households, we identify three distinct preference types using latent class analysis (LCA). These can be characterized as 1) disinterested (54%); 2) low demand but primarily interested in reduced smoke emissions (27%); and 3) high demand with interest in most features of the ICS (20%). The ICS intervention, which was stratified according to communities' prior history of interactions with the NGO marketing the stoves, was then randomized to 762 of these households. We find that households in the disinterested class are less likely to purchase an ICS; also, preference class is more strongly related to stove purchase than common socio-demographic drivers of technology adoption identified in the literature. Distaste for smoke emissions appears to be a particularly strong driver for adoption of an electric ICS, rather than an improved biomass one. Interestingly, the effect of preference class changes over time, which may indicate that initially recalcitrant households were influenced by the adoption decisions taken by those around them. The effect of preferences on purchase also varies across institutional strata, suggesting in particular that prior interaction with a trusted promoting institution may help to overcome disinterest in unknown technologies such as ICS. Lastly, there is some limited evidence that preference class explains changes in downstream outcomes across households exposed to the intervention.

Keywords: Improved cookstoves, discrete choice experiment, latent class analysis, field experiment, India

JEL Codes: C93, D12, Q41, Q53

1. Introduction

The use of solid biomass or coal fuels for basic household cooking and heating remains widespread throughout the world, and represents approximately 15% of global energy use (Smith et al. 2000; Legros et al. 2009). Such fuels are often burned in inexpensive yet inefficient stoves, which results in damages to health from respiratory illnesses and other conditions (Ezzati and Kammen 2001; Bruce et al. 2006; Martin et al. 2011), to local environments and development due to unsustainable and time-intensive harvesting of biomass, and to the global climate system as a result of emission of black carbon particles and ozone precursor gases (Bond et al. 2004; Ramanathan and Carmichael 2008). These negative effects of traditional stoves have prompted great interest in, and a new push towards development and dissemination of more efficient and cleaner-burning improved cook stoves (ICS) such as gas-, electric-, or cleaner biomass-burning technologies (GACC 2010).¹

Yet despite the very significant problems associated with traditional stoves, adoption of cleaner burning stoves has been slow. New biomass-burning technologies have not reached scale, and other alternatives – mainly electric and gas stoves – have been constrained by the lack of a robust distribution system for the energy sources and fuels on which they depend. Perhaps nowhere is the scale of this challenge greater than in India, the largest potential market for such technologies and one of the world’s hot spots for biomass burning in inefficient stoves. Progress in India has been particularly slow with only several tens of thousands of more efficient biomass stoves sold in each of 2011 and 2012, even though globally sales were in the millions (GACC 2012; Colvin et al. 2013). Beyond well-known problems of high costs and a weak supply chain, researchers and practitioners have claimed, with only limited evidence from rigorous field studies, that the existing range of biomass ICS prototypes are unreliable and not sufficiently adapted to local cooking requirements and user preferences (Duflo et al. 2008; GACC 2011; Jeuland and Pattanayak 2012; Lewis and Pattanayak 2012; Singh and Pathy 2012; Shell Foundation 2013). Meanwhile, more widely accepted ICS technologies such as LPG and electric stoves remain costly for poor households, and the fuels lack a robust and strong supply chain or distribution system in many rural areas (Lewis et al. 2014). Thus, a range of recent studies conducted in South Asia suggest that major challenges remain in the push to promote ICS, with regards both to private demand for these new technologies (Mobarak et al. 2012), and to the realization of health and other welfare benefits from their use (Hanna et al. 2012).

¹ We use the term improved cook stoves (ICS) in this paper to refer to both of these types of technologies, e.g., more efficient biomass stoves, as well as stoves that use advanced, cleaner-burning fuels such as LPG or electricity.

These recent negative findings raise important questions about ICS promotion and dissemination, but they stand in sharp contrast to those from other field studies, mainly conducted in East and West Africa, that suggest that ICS promotion can in fact succeed, at least in the short-term (Bensch and Peters 2012; Levine and Cotterman 2012). Indeed, the range of recent findings on ICS highlights several points that have previously been emphasized in the broader literature on demand for environmental health improvements. First, the demand for such health improvements is often low, and is related to consumers' diverse preferences, circumstances and constraints (Pattanayak and Pfaff 2009). For example, households cannot be expected to adopt a stove that is inconvenient to use or that is insufficient for their specific cooking needs, even if it is highly efficient. Second, heterogeneity (across communities and individuals) translates into substantial variation in the real costs and benefits of ICS (Jeuland and Pattanayak 2012; Whittington et al. 2012). To address these challenges of low demand and the diversity of preferences and net benefits of ICS, part of the solution has to lie in learning to engineer and adapt stoves and services to local cooking requirements and conditions, and perhaps in delivering incentives for adoption.

Third, household decisions about whether or not to adopt and continue to use ICS may not always follow from simple comparisons of economic costs and benefits. Lack of user awareness of ICS and exposure to existing technologies (especially in terms of understanding their maintenance requirements), peer influences, credit constraints, risk aversion and impatience, all influence decisions about whether or not to adopt an unknown technology with highly uncertain returns (Liu 2011; Tarozzi et al. 2011). Given the strong positive externalities associated with adoption of such technologies, outside intervention and subsidy may also be justified (Pattanayak and Pfaff 2009); as such, the effectiveness and nature of the institutions promoting them become critical. Successful promotion strategies for ICS and other environmental health technologies have worked to address some of these barriers, by engaging with institutions that are able to effectively implement social mobilization campaigns (Pattanayak et al. 2009), or by providing financing options and reducing the risk of adoption (Levine et al. 2013).

The purpose of this paper is to shed light on several aspects of this ICS adoption puzzle that have not been previously considered. First, we work to better characterize variation in household preferences for ICS, and the extent to which those preferences relate to uptake and subsequent use of ICS during a randomized ICS promotion campaign. To understand these preferences, we apply generalized multinomial logit methods to analyze discrete choice experiment (DCE) data collected during baseline surveys among all sample households in Uttarakhand, India (Magidson and Vermunt 2004). In the DCE, respondents completed a series of choice tasks in

which they considered differences – in terms of price, number of cooking surfaces, amount of smoke emissions, and fuel requirements – between biomass-burning ICS and traditional stoves. In the context of studying demand for ICS, for which well-developed markets do not currently exist, a particular advantage of DCE preference elicitation is to allow consumers to explicitly consider tradeoffs between hypothetical stove alternatives with varying levels of these types of attributes (Louviere et al. 2000; McFadden and Train 2000). In particular, we use latent class analysis to look for regularities in the choice patterns of different respondents.

We then consider whether households with specific types of preferences, as categorized through the latent class analysis (LCA) of DCE choices, are more or less likely to purchase an ICS during a randomized ICS promotion campaign. The promotion campaign was stratified along institutional lines; roughly half of households targeted by a stove sales pitch lived in communities in which the ICS-promoting NGO had a history working on a variety of other projects, while the other half were from a set of communities that did not. This stratified design allows us to consider whether the influence of preferences is sensitive to supply-side characteristics of the promotion campaign. A follow-up survey conducted several months after the intervention sheds additional light on longer-term adoption and use of the intervention ICS, as well as downstream outcomes: biomass fuel savings, time spent collecting fuel, and self-reported respiratory illness.

We find that about half (52%) of sample households can be categorized as initially ‘uninterested’ (we call these class 3) in the positive attributes of ICS. These households have lower wealth, are older, and are less aware of the health damages caused by smoke inhalation at baseline. The other two classes are primarily distinguished by their relative responses to smoke emissions reductions versus reduced fuel requirements and increased convenience, with class 1 (27%) being mainly interested in smoke emissions reductions, and class 2 (~20%) having much higher relative demand for the full set of ICS attributes. Consequently, we observe that class 3 households were significantly less likely to purchase any ICS during the first of three visits by the sales teams implementing the randomized sales campaign (especially in communities without a prior relationship with the sales NGO), an effect that however faded by the end of the sales period. Among the other two groups, class 1 was more likely to adopt an electric, rather than a biomass-burning ICS, suggesting that distaste for smoke may play a particular role in motivating purchase of the electric stove. We also find some evidence that class 2 households respond more strongly to randomized rebates when considering the purchase of the cleaner-burning biomass ICS. Few of the other household or community-level covariates that are commonly associated with demand for environmental health improvements explain stove purchases.

Looking beyond stove purchase, we also find that household use of either ICS, conditional on stove purchase, is not significantly different across preference classes. And though statistical power is limited, ICS use in all three preference classes does appear higher among households living in communities with prior interactions with the promoting NGO. Lastly, there is some limited evidence that preference class explains differential changes in downstream outcomes measured several months after the intervention. Treatment households in class 1, who were most likely to purchase the electric stove, report higher gains in ownership and use of ICS, and are the only group to experience decreases in self-reported respiratory illness. Meanwhile, class 2 households, who were most likely to purchase the biomass-burning stove, do not experience the fuel savings gained by other household types in the treatment group.

Our paper makes several contributions. First, we add to a thin literature on private demand for ICS by being the first to examine how households respond to an ICS sales offer that offers a choice between two very different technologies – an improved biomass-burning stove, and an electric coil stove. Existing ICS intervention studies largely ignore user preferences and focus on the demand for a single pre-selected technology with a specific set of features, or seek to isolate differences in demand by varying technologies across the arms of an experiment rather than allowing users to choose the technologies they prefer from several options (Mobarak et al. 2012). Second, we seek to better understand the variation in preferences and tastes for different ICS options, by conducting latent class analyses of stated DCE data. Third, after systematically characterizing the choice patterns revealed in the DCE data, we investigate the extent to which these preference classes relate to the choices revealed in the randomized ICS promotion campaign, and several important outcomes that result from it. Fourth, we generate new evidence on the interaction between preferences and prior exposure to promoting micro-institutions. These contributions serve to elucidate important supply- and demand-side features of the market for ICS, which are critical for product development and market segmentation needed for the successful dissemination and diffusion of these and similar technologies.

2. Modeling

Modeling preferences for ICS

The framework for analyzing the DCE data used in this study is based in random utility theory. We model the repeated household choices from among different combinations of stove alternatives that vary according to well-defined levels of 4 attributes: price, fuel requirement, smoke emissions, and the number of cooking

Table 3. Balance tests, for treatment vs. control hamlets

Variable	Mean	Mean	Normalized	Normalized
	Control	Treatment	Difference Overall	Difference NGO stratum only
Village has paved road	0.26	0.31	0.080	0.315
Distance to doctor (km)	9.14	9.48	0.031	-0.091
Bank facility in village	0.32	0.33	0.007	0.299
Presence of NGO	0.43	0.53	0.134	n.a.
Household size	4.98	4.77	-0.070	-0.135
Education- head of household (yrs)	5.59	5.88	0.044	0.096
Education- primary cook (yrs)	4.63	4.70	0.011	0.085
Female head of household	0.32	0.25	-0.107**	-0.133*
Below poverty line household	0.60	0.56	-0.060	-0.101
Scheduled Caste/Scheduled Tribe	0.24	0.26	0.034	-0.045
% household cold/cough in past 2 wks	0.06	0.08	0.059	-0.008
Relative wealth (1-low to 6-high)	2.12	2.13	0.007	0.060
Household has taken loan in past yr	0.12	0.16	0.088	0.046
Household saved money in past year	0.24	0.26	0.021	-0.033
Hours of electricity per day	17.9	17.0	-0.084	-0.001
Log of total expenditure (Rs./month)	8.38	8.42	0.036	0.019
Number of cell phones owned	1.3	1.3	0.014	0.146*
Total rooms in house	4.43	4.70	0.082	0.147*
Presence of toilet	0.88	0.84	-0.071	0.004
Owns/leases agricultural land	0.94	0.98	0.153	0.188
Most patient respondent	0.43	0.50	0.098*	0.163*
Most risk-taking respondent	0.41	0.43	0.036	0.133
Household believes ICS/clean fuels are beneficial	0.30	0.05	0.046	-0.037
Believe smoke is unsafe	0	1	0.054	-0.098
Traditional stove ownership	1	1	0.077	-0.055
Improved stove ownership	0.30	0.32	0.034	0.326***
Minutes traditional stove use (min/day)	307	285	-0.110	-0.217**
Amount of solid fuel used (kg/day)	6.7	6.9	0.026	0.044
Total fuel expenditure (Rs./month)	257	272	0.016	0.172*
Sample size: Households	770	293		
Sample size: Hamlets	71	26		

Notes: Balance was also assessed by regressing each variable in the left-hand column on treatment status using OLS, clustering standard errors at the hamlet level. Significance of the coefficient for treatment status from these regressions is indicated in the two rightmost columns as follows: *** p-value < 0.01; ** p<0.05; * p<0.1. There are 532 total observations in the NGO stratum (126 controls and 406 treated).

Table 4. Balance tests across rebate levels (treatment group only)

Variable	Mean Low Rebate N=255	Mean Med Rebate N=259	Mean High Rebate N= 248	Normalized differences (R1 vs. others)	Normalized differences (R2 vs. others)	Normalized differences (R3 vs. others)
Village has paved road	0.31	0.33	0.29	0.002	0.038	-0.043
Distance to doctor (km)	8.8	9.4	9.7	-0.084*	-0.004	0.027
Bank facility in village	0.33	0.31	0.31	0.015	-0.032	-0.027
Presence of NGO	0.49	0.52	0.56	-0.068	-0.011	0.071*
Household size	4.9	4.7	4.8	0.055	-0.059	0.011
Education- head of household (yrs)	5.9	6.2	5.7	0.009	0.064	-0.051
Education- primary cook (yrs)	4.5	5.0	4.6	-0.044	0.067	-0.028
Female head of household	0.28	0.20	0.26	0.071	-0.128**	0.020
Below poverty line household	0.55	0.57	0.54	-0.005	0.031	-0.023
Scheduled Caste/Scheduled Tribe	0.22	0.29	0.27	-0.091*	0.070*	0.022
% household cold/cough in past 2 wks	0.06	0.08	0.09	-0.077	0.003	0.078
Relative wealth (1-low to 6-high)	2.1	2.1	2.2	-0.051	-0.012	0.079
Household has taken loan in past yr	0.12	0.16	0.21	-0.124***	0.008	0.127*
Household saved money in past year	0.22	0.27	0.27	-0.089*	0.044	0.026
Hours of electricity per day	17.7	16.5	17.0	0.098*	-0.080	-0.004
Log of total expenditure Rs./month)	8.4	8.4	8.4	-0.031	0.029	0.020
Number of cell phones owned	1.3	1.3	1.3	-0.002	0.037	-0.039
Total rooms in house	4.7	4.7	4.7	-0.009	0.009	-0.001
Presence of toilet	0.84	0.85	0.83	0.004	0.022	-0.020
Owns/leases agricultural land	0.98	0.98	0.98	-0.002	0.003	-0.005
Most patient respondent	0.50	0.49	0.50	-0.003	-0.015	0.006
Most risk-taking respondent	0.42	0.47	0.40	-0.016	0.088	-0.075
Household believes ICS/clean fuels are beneficial	0.29	0.31	0.33	-0.0397	0.012	0.052
Believe smoke is unsafe	0.51	0.47	0.52	0.014	-0.068	0.027
Traditional stove ownership	0.98	0.98	0.96	0.047	0.050	-0.093*
Improved stove ownership	0.30	0.32	0.33	-0.039	0.012	0.036
Minutes traditional stove use (min/day)	288	283	280	0.029	-0.011	-0.034
Amount of solid fuel used (kg/day)	7.2	6.6	7.0	0.044	-0.043	0.013
Total fuel expenditure (Rs./month)	308	251	262	0.051	-0.032	-0.016

Notes: Balance was also assessed by regressing each variable in the left-hand column on treatment status using OLS, clustering standard errors at the hamlet level. Significance of the coefficient for treatment status from these regressions is indicated in the three rightmost columns as follows: *** p-value < 0.01; ** p<0.05; * p<0.1. Rebate was assigned prior to the intervention; the means and comparisons above include only households that ended up receiving a sales offer (results among all households by rebate level are available upon request).

Table 5. Mixed logit analysis of DCE choices¹

Variables	Fixed price		Lognormal price	
	(1) Mean	(2) SD	(3) Mean	(4) SD
Price (Rs) ²	-0.239*** (0.000)		-1.03*** (0.000)	2.53*** (0.000)
Fuel requirement	-0.143*** (0.000)	-0.043 (0.836)	-0.158*** (0.000)	0.147*** (0.321)
Smoke emissions	-0.350*** (0.000)	-0.046 (0.865)	-0.368*** (0.000)	0.071 (0.680)
Number of pots	0.358*** (0.000)	0.099 (0.828)	0.389*** (0.000)	0.260 (0.357)
Traditional stove ³	2.76*** (0.000)	5.08*** (0.000)	1.32*** (0.000)	4.19*** (0.000)
Partwise utility associated with 1-unit decrease (\$US) ⁴				
Fuel requirement		\$5.8		\$4.3
Smoke emissions		\$14.1		\$9.9
Number of pots		-\$14.4		-\$10.5
Observed choices		9162		9162
Likelihood ratio (χ^2)		1278.0		1336.6

Notes: *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses

¹ Model excludes respondents who answered any one of four comprehension questions incorrectly prior to the first choice task.

² Note that price is in Rupees divided by 500 (2012\$US= 52 Rs.), and -500 in the logged version.

³ Traditional stove type = 1 if it was the traditional stove, 0 if improved.

⁴ 1 unit in the DCE represents 33% of traditional stove smoke emissions and fuel consumption, and a single cooking surface.

Table 6. Latent class analysis of DCE data

Variables	(1) Class 1	(2) Class 2	(3) Class 3
Price ¹	-0.338*** (0.000)	-0.137*** (0.0020)	-1.135 (0.614)
Fuel requirement	-0.114** (0.048)	-0.211*** (0.0016)	0.0778 (0.804)
Smoke emissions	-0.507*** (0.0004)	-0.326* (0.060)	1.586 (0.376)
Number of pots	0.244* (0.099)	0.647*** (0.000)	-1.493 (0.461)
ASC – Traditional stove ²	0.588** (0.034)	-2.509** (0.016)	0.828 (0.804)
Fraction of households in class (based on predicted probability from LCA)	0.27	0.20	0.52
Observations	9,168	9,168	9,168
Number of groups	3,060	3,060	3,060

Notes: *** p<0.01, ** p<0.05, * p<0.1 ; p-values in parentheses

¹ Note that price is in Rupees divided by 500 (2012\$US= 52 Rs.)

² This is the alternative-specific constant: Traditional stove type = 1 if it was the traditional stove, 0 if improved.

Table 7. Correlates of latent class membership

Variables	(1) Class 1	(2) Class 2
Relative wealth	0.066 (0.11)	0.34*** (0.12)
Took loan in past year	0.28 (0.25)	0.37 (0.25)
Age of household head	-0.014** (0.007)	-0.016*** (0.006)
Education of household head	-0.011 (0.026)	0.004 (0.024)
Female household head	0.25 (0.24)	0.28 (0.24)
Scheduled caste or tribe	0.21 (0.28)	0.25 (0.26)
Household size	-0.064 (0.046)	0.042 (0.060)
HH has child <5 yrs old	0.15 (0.12)	0.022 (0.12)
Respondent is primary cook	-0.16 (0.18)	-0.19 (0.21)
% of household sick with cough/cold in past 2 wks	-0.16 (0.47)	0.059 (0.67)
Believe traditional stoves have negative health impacts	0.46** (0.22)	0.67*** (0.25)
Aware of clean stoves	0.65*** (0.20)	-0.22 (0.30)
Traditional stove use (hrs/day)	-0.075** (0.038)	0.001 (0.040)
Sales NGO presence	0.17 (0.23)	0.26 (0.25)
Most patient ¹	-0.048 (0.23)	0.83*** (0.25)
Most risk-seeking ¹	0.19 (0.22)	-0.059 (0.19)
Constant	-0.083 (0.59)	-2.2*** (0.62)
Observations	1002	1002

Notes: Multinomial logit specification, class 3 is the omitted class; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹Most patient and most risk-seeking as determined by responses to 3 hypothetical time and risk preference questions.

Table 8. ICS purchase by latent class

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Basic	+Rebate	+Basic	+All controls	Basic	+Rebate	+Basic	+All controls
VARIABLES	Visit 1	Visit 1	Visit 1	Visit 1	With later	With later	With later	With later
	purchase	purchase	purchase	purchase	purchases	purchases	purchases	purchases
Treatment group (exposed to sales)	0.52*** (0.000)	0.24*** (0.000)	0.24*** (0.000)	0.26*** (0.000)	0.56*** (0.000)	0.28*** (0.000)	0.24*** (0.000)	0.28*** (0.000)
Treatment*Rebate amount (Rs.)		0.0015*** (0.000)	0.0015*** (0.000)	0.0015*** (0.000)		0.0015*** (0.000)	0.0015*** (0.000)	0.0015*** (0.000)
Electricity supply (hr/day)			0.006*** (0.001)	0.006*** (0.001)			0.005*** (0.005)	0.006*** (0.0023)
General caste			0.019 (0.53)	0.024 (0.43)			0.027 (0.38)	0.033 (0.27)
Age of household head			-0.00 (0.82)	-0.00 (0.75)			-0.00 (0.66)	-0.000 (0.54)
Education of household head			0.0013 (0.69)	-0.0014 (0.70)			0.003 (0.45)	0.000 (0.090)
Relative wealth			0.0073 (0.67)	0.0048 (0.78)			0.002 (0.92)	-0.000 (0.99)
Treatment*Class 2 ¹	0.018 (0.75)	0.010 (0.85)	0.012 (0.82)	0.008 (0.88)	0.015 (0.77)	0.007 (0.89)	0.009 (0.85)	0.000 (0.99)
Treatment*Class 3 ¹	-0.11*** (0.007)	-0.087** (0.044)	-0.088** (0.035)	-0.10** (0.016)	-0.095** (0.031)	-0.067 (0.13)	-0.067 (0.12)	-0.076* (0.078)
Constant	-0.00*** (0.004)	-0.00*** (0.000)	-0.13* (0.099)	-0.20* (0.030)	0.00*** (0.000)	0.00*** (0.000)	-0.12 (0.13)	-0.17* (0.076)
Other controls ²	No	No	No	Yes	No	No	No	Yes
Observations	1,049	1,049	1,031	996	1,049	1,049	1,031	996
R-squared	0.204	0.309	0.325	0.330	0.228	0.332	0.344	0.354

Notes: Linear probability model; *** p<0.01, ** p<0.05, * p<0.1; p-value in parentheses. Standard errors clustered at the hamlet level.

¹ 'Class 2' and 'Class 3' are indicator variables denoting assignment to a latent classes 2 and 3, respectively. Class 1 is the omitted class.

² The other controls include all but the respondent gender and NGO presence covariates shown in Table 7 plus toilet ownership, solid fuel collection time and price of firewood. None of these were found to be significantly related to purchase; as shown they did not alter the sign or significance of the main results shown here. Observations with missing values for these additional covariates are omitted from these regressions (Columns 4 and 8).

Table 9. Differential responses to rebate amount and prior institutional presence (first sales visit only), by preference class

VARIABLES	(1) Visit 1 purchase	(2) Visit 1 purchase	(3) Visit 1 purchase	(4) Visit 1 purchase
Treatment group (exposed to sales)	0.19*** (0.002)	0.22*** (0.000)	0.24*** (0.000)	0.24*** (0.002)
Treatment*Rebate amount (Rs.)			0.0015*** (0.000)	
Electricity supply (hr/day)		0.0064*** (0.002)		0.0059*** (0.004)
Treatment*Class 2 ¹	0.013 (0.89)	-0.010 (0.92)	-0.015 (0.87)	-0.034 (0.78)
Treatment*Class 3 ¹	-0.012 (0.87)	-0.041 (0.57)	-0.16*** (0.013)	-0.11 (0.20)
Treatment*Rebate*Class 1	0.0017*** (0.000)	0.0017*** (0.000)		0.0017*** (0.000)
Treatment*Rebate*Class 2	0.0017*** (0.000)	0.0018*** (0.000)		0.0017*** (0.000)
Treatment*Rebate*Class 3	0.0013*** (0.000)	0.0013*** (0.000)		0.0013*** (0.000)
Treatment*NGO*Class 1			-0.009 (0.91)	-0.036 (0.63)
Treatment*NGO*Class 2			0.032 (0.75)	0.019 (0.85)
Treatment*NGO*Class 3			0.14** (0.040)	0.11* (0.10)
Constant	-0.00*** (0.000)	-0.20** (0.034)	-0.00 (0.32)	-0.19* (0.055)
Other controls ²	No	Yes	No	Yes
Observations	1,049	996	1,049	996
R-squared	0.31	0.33	0.32	0.34

Notes: Linear probability model; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹ Class 2 and Class 3 are indicator variables denoting assignment to latent classes 2 and 3, respectively. Class 1 is the omitted class.

² The other controls include all of those from the complete model in Table 8 (e.g., the basic controls from Table 8 Column 3 plus those indicated in the notes below Table 8). Very few of these were found to be significantly related to purchase; as shown they did not alter the sign or significance of the main results shown here. Observations with missing values for these additional covariates are omitted from these regressions (Columns 2 and 4).

Table 10. ICS choice among households exposed to sales intervention, by latent class (marginal effects)

VARIABLES	(1) Basic		(2) +Rebate & Controls		(3) +Rebate-class interactions	
	Biomass ICS	Electric ICS	Biomass ICS	Electric ICS	Biomass ICS	Electric ICS
Rebate amount (Rs.)			0.00070*** (0.000)	0.0010*** (0.000)	0.00057*** (0.002)	0.0015*** (0.000)
Electricity supply (hr/day)			0.0010 (0.54)	0.010*** (0.001)	0.0010 (0.57)	0.010*** (0.001)
Class 2 ¹	0.083** (0.011)	-0.062 (0.18)	0.079** (0.022)	-0.082 (0.11)		
Class 3 ¹	0.028 (0.34)	-0.14*** (0.000)	0.021 (0.40)	-0.15*** (0.001)		
Rebate*Class 2					0.00034** (0.014)	-0.00035 (0.18)
Rebate*Class 3					0.00012 (0.24)	-0.00075*** (0.001)
Other controls ²		No		Yes		Yes
Observations	761 0.012		721 0.13		721 0.13	

Notes: Multinomial logit model using initial purchase decision only; we report marginal effects at the mean of the sample covariates; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹ Class 2 and Class 3 are indicator variables denoting assignment to latent classes 2 and 3, respectively. Class 1 is omitted.

² The other controls include all of those from the complete model in Table 8 (e.g., the basic controls from Table 8 Column 3 plus those indicated in the notes below Table 8). Very few of these were found to be significantly related to purchase; as shown they did not alter the sign or significance of the main results shown here. Observations with missing values for these additional covariates are omitted from these regressions (Columns 2 and 4).

Table 11. ICS use conditional on purchase, by latent class

VARIABLES	(1) Basic Daily use	(2) +Rebate Daily use	(3) +NGO interact Daily use	(4) +SES Daily use	(5) Electric ICS Daily use	(6) Biomass ICS Daily use
Rebate amount (Rs.)		0.001*** (0.005)	0.001*** (0.008)	0.001*** (0.002)	0.0004 (0.12)	0.0006 (0.19)
Electricity supply (hr/day)				-0.010** (0.014)	-0.007 (0.19)	-0.002 (0.68)
Class 2	-0.073 (0.39)	-0.080 (0.33)	-0.088 (0.46)	-0.097 (0.41)	-0.080 (0.61)	-0.009 (0.97)
Class 3	-0.033 (0.55)	-0.013 (0.82)	-0.0025 (0.98)	-0.022 (0.80)	-0.036 (0.74)	-0.26 (0.16)
Class 1*NGO			0.16 (0.14)	0.17* (0.09)	0.088 (0.35)	0.024 (0.91)
Class 2*NGO			0.15 (0.23)	0.16 (0.16)	0.022 (0.87)	0.29 (0.11)
Class 3*NGO			0.14* (0.050)	0.17*** (0.009)	0.10 (0.23)	0.25* (0.099)
Constant	0.56*** (0.000)	0.38*** (0.000)	0.30*** (0.0081)	0.46** (0.001)	0.39* (0.067)	0.62* (0.063)
Other controls ²	No	No	No	Yes	Yes	Yes
Observations	386	386	386	369	303	116
R-squared	0.003	0.027	0.048	0.15	0.10	0.36

Notes: Linear probability model using all households that purchased ICS; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹ Class 2 and Class 3 are indicator variables denoting assignment to latent classes 2 and 3, respectively. Class 1 is omitted.

² The other controls include all of those from the complete model in Table 8 (e.g., the basic controls from Table 8 Column 3 plus those indicated in the notes below Table 8). Very few of these were found to be significantly related to purchase; as shown they did not alter the sign or significance of the main results shown here. Observations with missing values for these additional covariates are omitted from these regressions (Columns 2 and 4).

Table 12: Difference-in-difference analysis of the effect of NGO history on improved stove ownership, use, and fuel collection outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Basic DiD ¹	...+Rebate +NGO int ²	Basic DiD ¹	...+Rebate +NGO int ²	Basic DiD ¹	...+Rebate +NGO int ²	Basic DiD ¹	...+Rebate +NGO int ²	Basic DiD ¹	...+Rebate +NGO int ²
VARIABLES	Own improved stove	Own improved stove	Use improved stove daily	Use improved stove daily	Firewood (kg/day)	Firewood (kg/day)	Fuel collection time (min/day)	Fuel collection time (min/day)	% in hh w/cough or cold – past 2 wks	% in hh w/cough or cold – past 2 wks
Post	-0.017 (0.65)	-0.017 (0.65)	-0.028 (0.46)	-0.028 (0.46)	5.57*** (0.000)	5.57*** (0.000)	14.9 (0.43)	14.9 (0.43)	0.094 (0.11)	0.094 (0.11)
Post*Treatment	0.34*** (0.000)	0.25*** (0.002)	0.28*** (0.000)	0.20** (0.014)	-1.37 (0.11)	-2.14** (0.030)	-36.9 (0.11)	-30.1 (0.32)	-0.13* (0.083)	-0.14 (0.17)
Post*Treatment* Rebate		0.0008*** (0.000)		0.0006*** (0.001)		0.0006 (0.75)		0.017 (0.60)		0.0001 (0.32)
Post*Treatment* Class 2	-0.025 (0.68)	-0.072 (0.37)	-0.044 (0.48)	-0.12 (0.17)	2.82*** (0.002)	2.63** (0.047)	-1.9 (0.90)	-5.0 (0.83)	0.075 (0.33)	0.060 (0.62)
Post*Treatment* Class 3	-0.032 (0.47)	-0.081 (0.20)	-0.002 (0.96)	-0.049 (0.46)	-1.29* (0.085)	-0.35 (0.69)	6.3 (0.67)	26.8 (0.17)	0.16*** (0.006)	0.13 (0.14)
Post*Treatment* NGO*Class 1		-0.10 (0.28)		-0.062 (0.48)		1.22 (0.31)		-18.8 (0.48)		-0.037 (0.71)
Post*Treatment* NGO*Class 2		-0.017 (0.89)		0.068 (0.54)		1.31 (0.40)		-11.0 (0.72)		-0.007 (0.96)
Post*Treatment* NGO*Class 3		0.019 (0.78)		0.052 (0.35)		-0.59 (0.48)		-11.4 (0.40)		0.015 (0.87)
Constant	0.29*** (0.000)	0.29*** (0.000)	0.28*** (0.000)	0.28*** (0.000)	6.18*** (0.000)	6.18*** (0.000)	96.9*** (0.000)	96.9*** (0.000)	0.20*** (0.000)	0.20*** (0.000)
Observations	2,098	2,098	2,098	2,098	2,097	2,097	2,098	2,098	2,098	2,098
R-squared	0.10	0.13	0.073	0.098	0.12	0.12	0.010	0.027	0.012	0.014

Notes: Linear probability models using all treatment and control group households; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹ The basic DiD also includes controls for baseline differences across preference classes among those exposed to the intervention (e.g. treatment, Treat*class2, and Treat*class3; treated class 1 households are the omitted group).

² The fully-interacted DiD also includes controls for baseline differences across preference classes and preference class interactions (e.g. treatment, Treat*class2, Treat*class3, Treat*NGO*class1, Treat*NGO*class2, and Treat*NGO*class3; treated non-NGO stratum class 1 households are the omitted group).

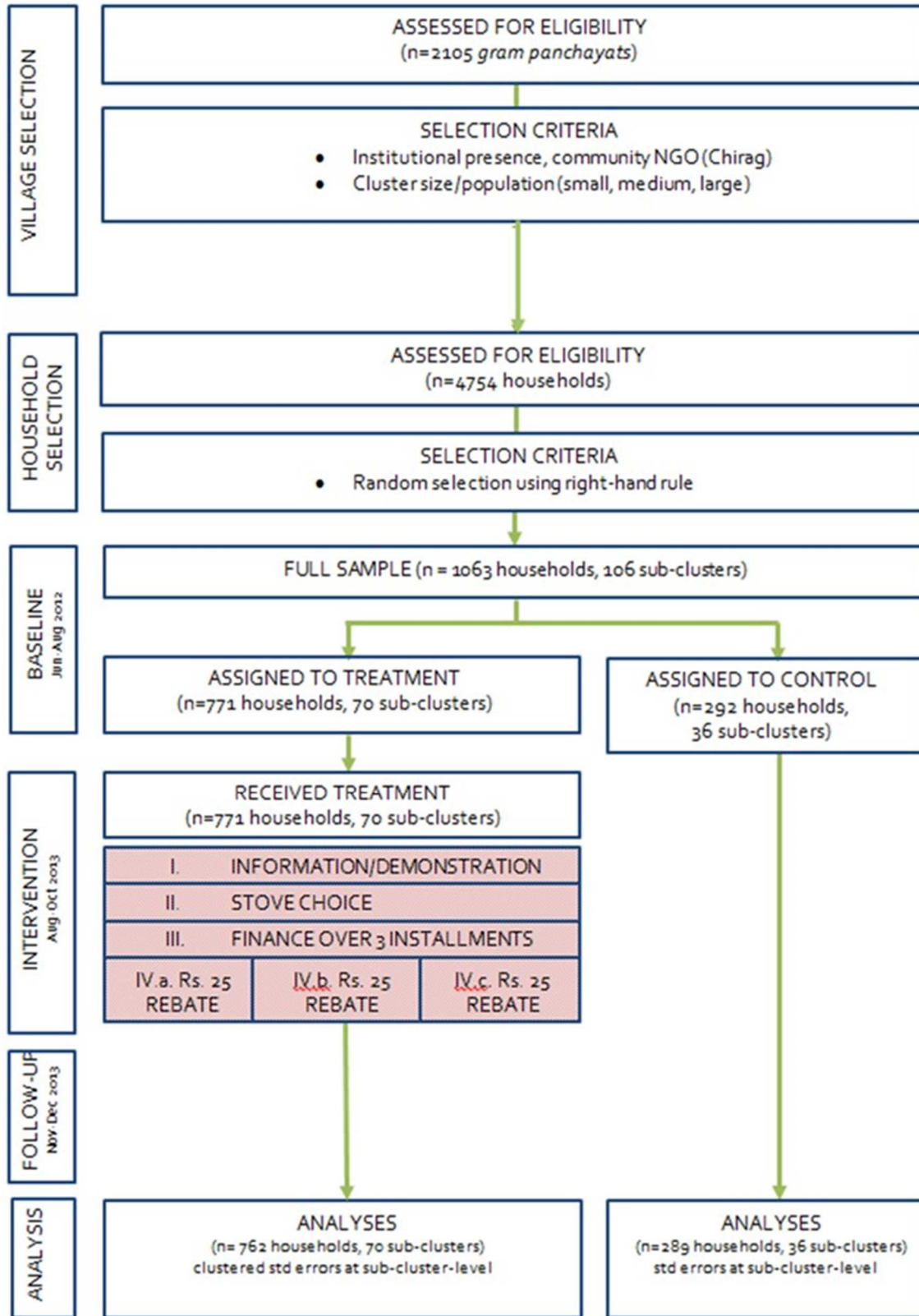


Figure 1. Study design







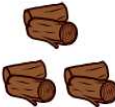

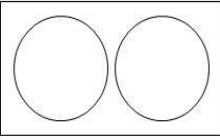
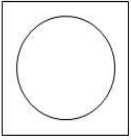
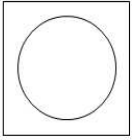
	ICS 1	ICS 2	Traditional stove
Attribute <u>चूल्हे</u>	<u>उन्नत चूल्हा 1</u>	<u>उन्नत चूल्हा 2</u>	<u>भिट्टी का चूल्हा</u>
Price <u>दाम</u>	1000 रुपए 	1000 रुपए 	0 रुपए
Smoke <u>धुआं</u> Emissions			
Fuel <u>ईंधन की</u> <u>जरूरत</u>			
<u>चूल्हे के मुंह</u> # of <u>की गिनती</u> Surfaces			

Figure 2. An example choice task in the stove decision exercise

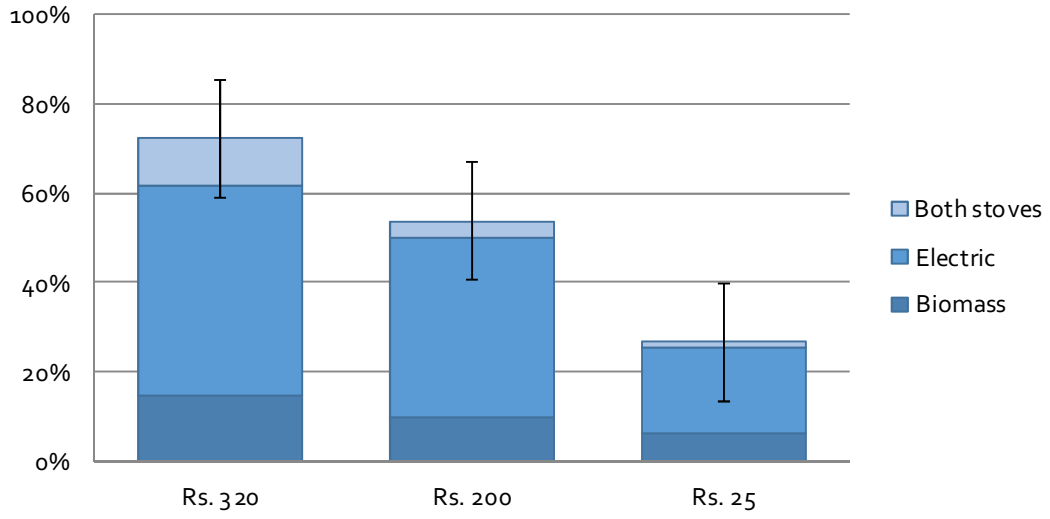


Figure 3. Purchase of intervention stoves, by rebate group

Appendix: Additional Tables

Table A1. Analysis of serial non-response and class 3 membership

VARIABLE	Serial non-respondent	Other respondent	N
Household in class 3	332	245	577
Household not in class 3	0	486	486
N	332	731	1063

Notes: Serial non-respondents are households who selected the traditional stove alternative in the DCE in all 4 choice tasks, no matter the attributes of the ICS options.

Table A2. Differential responses to rebate amount and prior institutional presence (all sales visits), by preference class

VARIABLES	(1) All purchases	(2) All purchases	(3) All purchases	(4) All purchases
Treatment group (exposed to sales)	0.19*** (0.002)	0.22*** (0.001)	0.25*** (0.000)	0.22*** (0.004)
Treatment*Rebate amount (Rs.)			0.0015*** (0.000)	
Electricity supply (hr/day)		0.0062*** (0.002)		0.0058*** (0.004)
Treatment*Class 2 ¹	-0.003 (0.98)	-0.031 (0.76)	-0.005 (0.96)	-0.049 (0.68)
Treatment*Class 3 ¹	0.069 (0.40)	0.049 (0.54)	-0.11 (0.11)	0.004 (0.97)
Treatment*Rebate*Class 1	0.0019*** (0.000)	0.0019*** (0.000)		0.0019*** (0.000)
Treatment*Rebate*Class 2	0.0020*** (0.000)	0.0020*** (0.000)		0.0020*** (0.000)
Treatment*Rebate*Class 3	0.0012*** (0.000)	0.0012*** (0.000)		0.0012*** (0.000)
Treatment*NGO*Class 1			0.035 (0.62)	
Treatment*NGO*Class 2			0.048 (0.63)	
Treatment*NGO*Class 3			0.12 (0.10)	
Constant	-0.00*** (0.000)	-0.17* (0.088)	-0.00 (0.32)	-0.15 (0.12)
Other controls ²	No	Yes	No	Yes
Observations	1,049	996	1,049	996
R-squared	0.34	0.36	0.324	0.36

Notes: Linear probability model; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹ Class 2 and Class 3 are indicator variables denoting assignment to latent classes 2 and 3, respectively. Class 1 is the omitted class.

² The other controls include all of those from the complete model in Table 8 (e.g., the basic controls from Table 8 Column 3 plus those indicated in the notes below Table 8). Very few of these were found to be significantly related to purchase; as shown they did not alter the sign or significance of the main results shown here. Observations with missing values for these additional covariates are omitted from these regressions (Columns 2 and 4).

Table A3. ICS choice among households exposed to sales intervention, by latent class (marginal effects), including all sales

VARIABLES	(1) Basic		(2) +Rebate & Controls		(3) +Rebate-class interactions	
	Biomass ICS	Electric ICS	Biomass ICS	Electric ICS	Biomass ICS	Electric ICS
Rebate amount (Rs.)			0.00036*** (0.003)	0.0012*** (0.000)	0.00020 (0.24)	0.0018*** (0.000)
Electricity supply (hr/day)			-0.0002 (0.90)	0.012*** (0.000)	0.0025 (0.89)	0.012*** (0.000)
Class 2 ¹	0.084** (0.012)	-0.079* (0.09)	0.064* (0.064)	-0.098* (0.051)		
Class 3 ¹	0.053* (0.10)	-0.16*** (0.000)	0.040 (0.20)	-0.15*** (0.001)		
Rebate*Class 2					0.00033** (0.037)	-0.00041 (0.13)
Rebate*Class 3					0.00015 (0.25)	-0.00086*** (0.000)
Other controls ²	No		Yes		Yes	
Observations	761 0.014		721 0.12		721 0.13	

Notes: Multinomial logit model using initial purchase decision only; we report marginal effects at the mean of the sample covariates; *** p<0.01, ** p<0.05, * p<0.1; p-values in parentheses. Standard errors are clustered at the hamlet level.

¹ Class 2 and Class 3 are indicator variables denoting assignment to latent classes 2 and 3, respectively. Class 1 is omitted.

² The other controls include all of those from the complete model in Table 8 (e.g., the basic controls from Table 8 Column 3 plus those indicated in the notes below Table 8). Very few of these were found to be significantly related to purchase; as shown they did not alter the sign or significance of the main results shown here. Observations with missing values for these additional covariates are omitted from these regressions (Columns 2 and 4).