Adoption and Short-term Impacts of Improved Cookstoves in Rural India

A Masters Project

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Abstract

Half of the world's population (2.7 billion people), of which 95 percent is in 'poor' countries, rely on solid fuels including biomass fuels like wood, dung, agricultural residue and coal, to meet most of their energy needs. Cooking and heating with simple biomass fuels lead to more early deaths (4.3 million) in the world than AIDS, TB, and malaria combined, with women and children being disproportionately affected. Improved cookstoves (ICS) technologies are seen as one of the ways to enable transitions to cleaner cooking behaviour. This study reports on the results of an intervention conducted in Rajasthan, India, in which 600 households were randomly assigned to participate in a program promoting and distributing improved cookstoves and 300 more households were matched on village level characteristics and the historical presence of the implementing NGO in the village. We find that 46% of households in the treatment group adopted the improved cookstove. The results for short term impacts of adopting an improved cookstove are mixed on time savings while cooking and preparing fuel. Interestingly however, we find that households that adopted the ICS spend more fuel while cooking and reported a higher cost of treating illnesses than households in the non-treatment groups. Despite the mixed results on the short term impact of adopting an ICS, we find that households with an ICS had a higher perception of the impact of an ICS on the welfare of their household members. 90% of the households that adopted the ICS repoted to be satisfied with their purchase.

Key Words: Indoor air pollution, improved cookstoves, biomass, traditional cookstoves, rural India

Table of Contents

1. Introduction

Half of the world's population (2.7 billion people), of which 95 percent is in 'poor' countries, rely on solid fuels including biomass fuels like wood, dung, agricultural residue and coal, to meet most of their energy needs (Duflo, 2008; Lewis et al., 2012 and 2015). Globally, cooking and heating with simple biomass fuels leads to more premature deaths (4.3 million per year) than AIDS, TB, and malaria combined, with women and children being disproportionately affected (Lim etal., 2012; WHO, 2012).

The health impacts of household air pollution include heightened risks of lung cancer, cardiovascular and chronic pulmonary diseases, strokes, eye diseases and burns (Reid et al.2012; West et al. 2013). Some studies suggest that early exposure to household air pollution can have neurological and developmental impacts on young children (McCracken et al. 2012; WHO 2014). This is due to unhealthy emissions from traditional cookstoves that contain fine particulate matter, PM 2.5, carbon monoxide, and a variety of polyaromatic hydrocarbons (Rosenthal, 2015).

To address these and other harms from traditional cooking, there is increasing momentum to promote and disseminate improved cookstoves (ICS). Promotional strategies include increased funding through small-scale credit operations and carbon credits programs like the Gold Standard and Carbon Development Mechanism. The formation of the Global Alliance for Clean Cookstoves (GACC, 2011) points towards the growing attention on the issue of household air pollution. The GACC aims to increase ICS adoption by 100 million homes. The implementation of government policies like the National Biomass Cookstoves Initiative in India reflects a growing political will to address the issue and donors and local implementers have worked to develop programs dedicated to the promotion and adoption of clean cookstoves.

This paper looks at the adoption and impact of improved cookstoves in rural Udaipur, India. The data for this analysis was collected from 900 households in 60 villages that form three different groups of villages as a part of a phased roll-out of an improved cookstove intervention. The results from this paper add to the literature on the short term impacts of improved cookstoves in rural India and part of the uniqueness of this analysis lies in the intervention design which aims to discourage stove stacking, i.e., use of a combination of traditional and improved stoves while cooking. The analysis also includes an extensive set of robustness checks that help to demonstrate the stability of results.

2. Background

The basic theory of technology adoption – applied to environmental health behaviors – suggests that factors like information campaigns, supply chain support, trust between the supplier and consumer apart from household socio-economic characteristics determine household choice (Pattanayak and Pfaff 2009; Jeuland et al. 2015). Adoption of efficient and clean cooking technologies has proven to be challenging, however, with programs showing modest or low adoption rates for clean cookstoves or fuel (Lewis et al.,2012). In a study conducted in Uttarakhand (Jeuland and Pattanayak, 2014) it was found that significant preference barriers exist to adoption of clean cookstoves even after intensive promotion campaigns for households that are ‘uninterested’ in the technology from the start.

Demand-sensitive promotion strategies can be successful if they respond to the heterogeneity of preferences exhibited by households (Jeuland and Pattanayak, 2014). While the health benefits of improved cookstoves have been significant in laboratory settings, these benefits or best averted expenses like the reduced cost of illness may not be as salient to households as the daily cost of fuel purchase or time spent using the stove (Jeuland and Pattanayak, 2012; Lewis et al., 2016).

A study of three ICS pilots in India involving social marketing with a focus on promotion, product, price, and place argued that time savings, not emission reduction, was the most valued attribute among households contemplating adoption of a cleaner cooking technology (Lewis et al.,2015). Price was identified as the most significant barrier to adoption by households. While some ICS pilots have proven to be successful with differential pricing schemes allowing households to pay in installments or have subsidies (Uttar Pradesh, Uttarakhand; 2012), there were modest adoption patterns in some cases where fuel subsidies were vulnerable to capture by wealthier households who already owned improved cookstoves (Bailis et al., 2009).

Household characteristics can play a very important role in determining the use of new technology. Multiple fuel users can constitute a crucial and untapped market niche for improved cookstoves (Masera, 2006). Mixed-fuel users usually adopt new cookstoves faster than exclusive fuelwood users due to greater understanding and openness to new technology (Masera, 2005). The impacts on fuel use and health benefits may however be far more diluted in these households due to ‘stove stacking’.

A study in rural Mexico (Pine et al., 2011) found that a bi-level selection process which included both community and household characteristics, selected households that are likely to be early adopters. Early adopters can serve as ‘opinion leaders’ in communities. This can facilitate diffusion of a new innovation throughout the social system. Additionally, the adoption decisions of early adopters tend to be more robust in that this group is less likely to reverse its initial decision to adopt (Rogers, 2003).

Apart from potential health impacts, inefficient cooking through traditional methods has been shown to pull female labor and time away from education, agriculture and productive activities (Pitt et al., 2006; Poddar, 2016). Using improved cookstoves (ICS) has the potential to reduce time spent collecting fuel, amount of fuel gathered and cooking time. These effects could in turn improve productivity, thereby increasing household wealth (Lewis et al., 2012). Apart from direct benefits to households through adoption of ICS technologies, cooking efficiency can benefit the local and global environment by reducing fuelwood harvesting and particulate emissions (Brooks et al, 2015. Using affordable and efficient biomass cookstoves can enable incremental but necessary energy transitions when behaviors are ‘sticky’ or difficult to change (Rosenthal, 2015).

3. Stove Selection and Intervention

This study uses learnings and methods from the papers identified above to inform the analysis and contextual understanding of the research question. In collaboration with an Udaipur based non-governmental organization, Udaipur Urja c/o Seva Mandir, a stove promotion intervention was conducted in a large number of villages in rural Udaipur District in 2016. The technology was chosen after a period of testing in households wherein different types of ICS technology were given to the households on a trial and rotational basis and their preferences were recorded. The stoves most preferred by households were the Greenway Smart Stove and the Greenway Jumbo Stove. Focus group discussions conducted prior to the intervention revealed that most households use more than one stove for cooking. The intervention thus offered all households the option to obtain a package of two stoves (Greenway Smart and Greenway Jumbo stove) for purchase.

The Greenway Smart and Jumbo Stoves are single burner high efficiency cookstoves that deliver fuel savings of up to 65 percent in lab settings, minimize harmful emissions of CO, CO_2 and Particulate Matter (PM) and deliver convenient cooking without any requirement of fuel processing or change in cooking habits. They thus help address health, environment and fuel collection burdens that come with traditional stoves. The stove can operate on all solid fuels, including wood, agro-waste, etc. and does not require any refurbishing or recurring cost. The combustion mechanism in these stoves can adjust according to the operator's requirements and the technology is advertised to be user-friendly. The stoves are expected to last for up to five years (Greenway Grameen Infra. Pvt. Ltd).

As a part of the intervention, Udaipur Urja launched promotional campaigns in the treatment villages through wall paintings, community meetings, stove demonstrations and household level visits by Udaipur Urja professionals. Locals from the village were recruited to sell the package of two cookstoves at a highly subsidized rate of 7.5 dollars (500 rupees), down from a market rate of 60.2 dollars (4000 rupees).

The messages used in the promotional campaigns advertised qualities like faster cooking time, low fuel use and low emissions from the stove. Due to the carbon finance mechanism that helped to subsidize the stove costs, households agreeing to buy the stoves were required to enter into a contractual agreement with Udaipur Urja, which entailed a full transition to the improved cookstove and dismantling of traditional cookstoves used previously. Locals in each target community were recruited to be 'monitors', who would sell the cookstoves, visit households every month to register complaints, and monitor the use of the stoves.

4. Data and Analysis

The data for this survey comes from the baseline and midline survey conducted in collaboration with Seva Mandir and Udaipur Urja across 900 households in 60 villages between August to September 2013 and 2016 in the district of Udaipur in Rajasthan, India. The intervention zones and villages were not randomly selected. 40 villages in the sample come from the intervention area, with the remaining 20 being in control areas. An experimental design was nonetheless adopted whereby the 40 villages in the intervention area were randomly assigned to an 'early' intervention group and 20 villages to a 'late' intervention group which would be targeted about 6 months after the first ICS dissemination.

The third "control group" was identified using propensity score matching of the selected early phase intervention villages with villages outside the intervention area. This procedure ensured that the full sample was balanced on a series of characteristics recorded in the Census. In the baseline for 900 households, results from 38 were dropped due to incomplete surveys. Fourteen of the total of 900 households at baseline were replaced during the midline survey, mostly due to the household moving out of the village. This study primarily analyzes data from baseline and follow-up surveys conducted following the first phase of promotion, using the sample of 40 early and late phase villages. In robustness checks, we add the remaining 20 matched control villages to the sample. The key identification assumptions in those robustness checks vary, depending on the analytical strategy that is utilized, as discussed further below.

The questions included in the main survey pertained to household composition and demo- graphics, daily time use by each household's primary cook, perceptions about environmental risks, prevalence and costs incurred due to diarrheal and ARI diseases, fuel and water sources, stove use and preferences, water treatment, storage and hygiene behavior.

4.1. Factors driving adoption of improved cookstoves

We first aim to understand adoption of the improved cookstoves. Adoption for the purposes of this study simply means that the household possessed at least one of the marketed improved cookstoves as verified by an enumerator during household surveys. This dichotomous outcome for ownership is analyzed using a logit model which also allows consideration of the factors that drive the adoption of the ICS technology in a household. *We cluster standard errors at the village level for all the estimations discussed in this paper. We also use fixed effects for all models with controls except the 2sls estimations.*

The model specification is as follows;

$$Y_i = \beta_0 + \beta_1 treatment_j + \beta_n \boldsymbol{X}_n + \beta_n \boldsymbol{Z}_n + \epsilon_{i,j}. \quad (1)$$

In equation (1), Y_i represents whether the household (i) adopted the improved cookstove; *treatment* is an indicator variable for whether a village (j) is in the treatment group and received the option of buying the improved cookstoves; ***X*** is a vector of socio-economic characteristics for households like a) number of children under five in the house, b) minimum years of education of the primary cook and household head, c) whether the caste of the household is SC/ST/OBC/NT, d) reported value of the house and land on which the house is built, e) number of rooms in the house f) whether the household had taken a loan in the past year, g) self-reported monthly expenditure of the household, h) the acres of reported agricultural land owned by the household and i) number of hours of electricity the household reports to receive daily; ***Z*** is a vector of baseline level characteristics that are controlled for like a) hours spent cooking daily, b) time spent preparing fuel, c) amount of wood used while cooking, d) number of members that were sick in the past week, e) money spent on diseases in the past week f) perception of the impact of an improved cookstove, g) time spent collecting wood (per day). Finally, $\epsilon_{i,j}$ represents the error term of the logit (extreme value distribution) model.

In the models above, the coefficient on the treatment variable can be considered to provide an estimate of the causal impact of the promotion effort on adoption, when the sample of 40 phase 1 and phase 2 villages is used, since the randomization approach should have eliminated all unobserved differences between treated and untreated households. In the complete sample of 60 villages, this causal interpretation depends on an assumption that there are no unobserved differences between the matched control villages and the early phase villages, that could also be correlated with improved stove adoption.

4.2. Impact of Adoption of Improved Cookstoves

I run an intent-to-treat estimate, a difference-in-difference and an instrumental variables regression for studying the impact of adoption on a number of expected outcomes. All the models have clustered standard errors at the village level and village fixed effects. The list of outcomes estimated in this analysis is as follows;

a) *Time spent cooking*: Self-reported number of hours spent by the household cooking on stoves used regularly (daily or more than twice a week).[1]
b) *Time spent preparing wood for cooking*: Self-reported time spent by the household preparing the wood usually by cutting it into smaller pieces – for daily cooking.
c) *Amount of wood use*: Self-reported amount of wood in kg used for daily cooking.
d) *Sick Members:* Number of household members reported to be sick from cough, cold or diarrhea in the past week.
e) *Cost of Sickness:* Cost incurred by the household in treating the members of the household who fell sick in the past week.
f) *Perception of Impact of Improved Cookstove*: Categorical variable – the answer to the question to 'on a scale of 1 to 5 do you believe that use of an ICS and clean fuel can improve health and environment?'.

[1] There are two measures of this amount of time, one that is specific to different stoves, and the other in the form of entries in time use diaries for the primary household cook. We prefer the latter measure because it is less likely to be affected by social desirability bias, since treatment households may otherwise tend to overstate their use of cleaner stoves.

The detailed results for all outcomes are given in the appendix. The following are the estimating equations for all specifications;

4.2.1. Intent – to – treat estimation

$$Y_i = \beta_0 + \beta_1 treatment_j + \beta_n \boldsymbol{X}_n + \beta_n \boldsymbol{Z}_n + \epsilon_{i,j}. \quad (2)$$

This model is estimated using ordinary least squares. In equation (2), Y_i represents outcome variables as discussed in section 1.2 in 2016; *treatment* is an indicator variable for whether a village is in the early phase treatment group and therefore received the option of buying the improved cookstoves; $\boldsymbol{X}$ is a vector of socio-economic characteristics for households as discussed in section 1.1; $\boldsymbol{Z}$ is a vector of baseline level characteristics as discussed in section 1.1 and $\epsilon_{i,j}$ represents a normally-distributed error term. The coefficient β_1 again indicates the causal impact of the stove promotion campaign on the outcome of interest when the sample only includes phase 1 and phase 2 villages. When all villages are included, this interpretation relies on unobserved differences between matched control and early phase villages being unrelated to the outcome of interest.

4.2.2. Difference – in – Difference intention to treat estimation

$$Y_i = \beta_0 + \beta_1 treatment_j + \beta_2 year2016 + \beta_3 (treatment_j \times year2016) + \beta_n \boldsymbol{X}_n + \epsilon_{i,j}. \quad (3)$$

This model is again estimated using ordinary least squares. In equation (3), Y_i represents the outcome variable; *treatment* is an indicator variable for whether a village (j) is in the treatment group and received the option of buying the improved cookstoves; *year2016* is an indicator variable that equals one if the household was interviewed in 2016; *treatmentXyear2016* is an interaction variable for households in the treatment villages for year 2016; $\boldsymbol{X}$ is a vector of socio-economic characteristics and $\epsilon_{i,j}$ represents a normally-distributed error term. In contrast to the previous ITT model, in this case, the coefficient β_3 indicates the causal impact of the stove promotion effort on the outcome of interest when the sample only includes phase 1 and phase 2 villages. When all villages are included, the identification assumption is a bit weaker than in model (2) above. Specifically, causal interpretation relies on unobserved and time-varying differences between matched control and early phase villages being unrelated to the outcome of interest. This is because time-invariant differences are netted out in the difference-in-difference model.

4.2.3. Instrumental variables estimation

Only 46% of the households in the Phase 1 group chose to buy an improved cookstove and this results in the ITT model identifying a causal impact that averages compliers and non-compliers together. Being in the treatment group only gave the households an option to buy the improved cookstove. Since actual adoption of the ICS was not randomly assigned, we cannot simply naively compare outcomes among adopters and non-adopters in trying to understand the effects of adoption on other variables of interest. We thus use the 2SLS approach to predict adoption of the improved cookstove employing the treatment status as an instrumental variable. The first stage of the instrumental variables model is the same as the probit estimation given in equation (1). I will predict the value of adoption in each household and use the predicted values in my second stage estimation as given below.

$$Y_i = \beta_0 + \beta_1 \widehat{haveICS}_i + \beta_n \boldsymbol{X}_n + \beta_n \boldsymbol{Z}_n + \epsilon_{i,j}. \tag{4}$$

In equation (4), Y_i represents the change in the outcome variable from 2013 to 2016; $\widehat{haveICS}$ is the predicted value of adoption in household (i); $\boldsymbol{X}$ is a vector of socio-economic characteristics and $\epsilon_{i,j}$ represents a normally distributed error term.

In this model, the coefficient β_1 indicates the causal impact of improved cookstove ownership on the outcome of interest when the sample only includes phase 1 and phase 2 villages. When all villages are included, this interpretation relies on unobserved differences between matched control and early phase villages being unrelated to the outcome of interest.

All outcomes were tested on different sample combinations to check the robustness of estimates. The main analysis is done on the subsample of 40 villages from early phase villages and late phase villages which were randomly selected. The same models were then run on the full sample of 60 villages which included the 20 villages identified through matching on village level characteristics and NGO relationship. An additional robustness check was done through running the models on a subsample of early phase intervention villages and the control villages which were matched.

The main analysis of this paper is based upon the causal impacts identified through the randomized sample of villages in Phase 1 and Phase 2 i.e. the early and late intervention villages. However, these robustness checks enable us to test the senstitivity of the estimates we get. It should be noted however that since the control group was not randomized, the full sample analysis in the robustness checks may introduce bias on unobservable characteristics. We control for observable characteristics that were unbalanced at baseline in all the models.

5. Results

5.1. Descriptive Statistics

We check whether the households in the three subsample groups – Phase 1, Phase 2 and Phase 3 are balanced i.e. have no statistically significant differences on socio-economic characteristics and baseline outcome levels. We compare the means of all these characteristics and report the p-values for their differences.

As can be seen from Table 1 given below, the Phase 1 and Phase 2 groups are balanced on most characteristics, as expected because inclusion in these groups was randomized. The Phase 1 and Control groups are unbalanced on many characteristics, however. This is because the matching algorithm only used a limited set of village characteristics from the Census, supplemented by a few institutional variables from the partner NGO, such as the strength of relationship with the implementing NGO and the number of years they have worked in the village.

As discussed before, for the purposes of this analysis we focus on the subsample of two groups namely, Phase 1 and Phase 2 where the villages in the Phase 1 group received the treatment, because the identification of causal impacts depends less on assumptions of unconfoundedness by unobserved differences between groups. There is one variable where on an average the means of the two groups are statistically different from each other. At baseline, households in the phase 1 group were spending more time preparing fuel before cooking than households in the phase 2 group.

When we compare the means between the phase 1 group and the rest of the sample (Phase 2 and Control), we find that nine variables are unbalanced at baseline. Most of these variables are also unbalanced when we compare the means of phase 1 villages with control villages. The variables that are unbalanced are aspiration, household head education, whether the household was below the poverty line, the number of rooms in the house, log of monthly expenditure, log of agricultural land, number of hours of electrification, time spent preparing fuel before cooking, and cost of sickness.

I use log-transformed variables for monthly expenditure of households, acres of land, time spent preparing fuel and value of house. This is because these variables in absolute values show a highly skewed distribution. In the subsequent analysis, the unbalanced characteristics are added as controls to account for these initial differences between the Phase 1 and Phase 2 groups. The last column in table 1 describes these variables and gives a brief description on how they were measured and calculated.

Table 1: Descriptive Statistics

Variables	Mean/(Observations)				p-value			Description
	Phase 1	Phase 2	Control	Total	Phase 1 vs Control	Phase 1 vs Phase 2	Phase 1 vs Phase 2 + Control	
hhsize	5.753	5.63	5.51	5.631	0.285	0.441	0.233	Number of members in the household.
	-300	-300	-300	-900				
aspiration	0.997	0.976	0.895	0.956	**0.003**	0.475	**0.026**	Calculated from self reported answers to question on where they see themselves in terms of wealth on a scale of 1 to 6 in the future.
	-299	-294	-296	-889				
childunder5	0.477	0.523	0.463	0.488	0.829	0.408	0.736	Number of children under the age of 5.
	-300	-300	-300	-900				
pcedu	2.363	2.48	1.24	2.028	**0.004**	0.810	0.193	Years of Education for the primary cook.
	-300	-300	-300	-900				
hhheadedu	8.08	8.2	4.533	6.938	**0.000**	0.807	**0.002**	Years of Education for the head of the household.
	-300	-300	-300	-900				
caste	0.967	0.89	0.93	0.929	0.410	0.215	0.171	Caste=1 if from SC/ST/NT/OBC.
	-300	-300	-300	-900				
bpl	0.833	0.783	0.72	0.779	**0.034**	0.278	**0.049**	BPL=1 the household has a below poverty line ration card.
	-300	-300	-300	-900				
lnvaluehouse	284116.6	239033.1	159311.6	227487.1	**0.007**	0.959	0.121	The self reported value of the house and the land on which it is built.
	-300	-300	-300	-900				
rooms	3.473	3.373	2.627	3.158	**0.000**	0.485	**0.002**	Number of rooms in the house.
	-300	-300	-300	-900				
lnmonthlyexp	6947.6	6019.4	5368	6111.7	**0.000**	0.083	**0.002**	The total self reported monthly expenditure in the household.
	-300	-300	-300	-900				
lnagrland	1.61	1.377	1.64	1.543	0.069	0.076	**0.035**	The self reported acres of agricultural land that the household has.
	-300	-300	-300	-900				

	Mean/(Observations)				p-value			Description
Variables	**Phase 1**	**Phase 2**	**Control**	**Total**	**Phase 1 vs Control**	**Phase 1 vs Phase 2**	**Phase 1 vs Phase 2 + Control**	
hrselectrified	4.557	3.963	2.8	3.773	**0.007**	0.317	**0.023**	Number of hours the house gets electricity.
	-300	-300	-300	-900				
tothrscooking	3.18	3.152	2.894	3.075	**0.014**	0.780	0.077	Total number of hours spent cooking in a day by a household.
	-300	-300	-300	-900				
lntotfuelpreptime	40.02	33.24	33.38	35.55	**0.000**	**0.003**	**0.000**	Total time spent preparing fuel daily
	-300	-300	-300	-900				
woodusekg	8.013	7.549	11.08	8.901	0.061	0.413	0.362	Total kg of wood used daily for cooking.
	-294	-289	-299	-882				
sickmem	1.667	1.593	1.31	1.523	**0.011**	0.580	0.068	Number of sick members in the past two weeks.
	-300	-300	-300	-900				
costsickness	554.4	524.2	271.4	450	**0.001**	0.097	**0.005**	Cost incurred by household in health care in the past two weeks.
	-300	-300	-300	-900				
percimpICS	2.303	2.324	1.933	2.187	**0.003**	0.833	0.076	On a scale of 1 to 5 whether the HH believes that use of an ICS and clean fuel can improve health and environment.
	-300	-299	-299	-898				
collectwood	1.821	1.654	2.19	1.891	0.078	0.362	0.524	Hours spent collecting wood (per day)
	-297	-292	-300	-889				
Observations								**900**

mean coefficients; count in parentheses

* p<0.05 *** p<0.001 ** p<0.01

5.2. Adoption of Improved Cookstoves

The estimating equation (1) from section 1.1 was used to run a logit with odds ratios on the full sample of 60 villages which includes Phase 1, Phase 2 and control reported in Column 1, Table 2. The same model was run on the subsample of the randomized Phase 1 and Phase 2 villages reported in Column 2, Table 2. Column 3 reports the estimates for within the treatment group (Phase 1) analysis to identify the characteristics of households in the treatment group who adopted the improved cookstove. We also ran the logit model on Phase 1 and Phase 2 villages to identify the characteristics of households that use traditional cookstoves.

We find that the households in treatment villages were 4.631 times more likely (Table 2, Column 3) than households in the Phase 2 villages that did not receive the treatment to adopt an improved cookstove. The full sample analysis estimate is slightly higher at 4.960; i.e. households in the Phase 1 villages were 4.96 times more likely to adopt an ICS in comparison to the households in Phase 2 and control villages. Within the villages that received the treatment, an average of 46 percent households adopted the improved cookstoves.

We find that within the treatment group (Phase 1), at a significance level of 0.05, head of households with a higher education level were more likely to adopt an improved cookstove (Table 2, Column 2). This number holds up to the full sample analysis at a significance level of 0.10. This result is also consistent when we run the logit on just the adopters of the ICS suggesting that household head education is a driver of adoption within the sample. At a significance level of 0.10 households that reported a lower value of their house were more likely to adopt an improved cookstove.

When we run the logit on the outcome of whether the household used a traditional cookstove in the past week, we find that with a higher education level of the household head, households in the treatment group are less likely to use a mud or three stone stove (Table 2, Column 4). This is consistent with the results we found before on the outcome for adoption of an improved cookstove. We also find that households with bigger agricultural land were more likely to use a traditional stove and have a lower baseline perception of the impact of an improved cookstove on the welfare of their family members. At a significance level of 0.10 we find that households that spent less time preparing fuel at baseline were more likely to be using a traditional cookstove. The coefficient for this is very small in magnitude.

Table 2: Adoption of ICS - Logit

Variables	haveICS Full Sample b/se	haveICS Phase 1 vs Phase 2 b/se	haveICS Within Phase 1 b/se	tradstove Phase 1 vs Phase 2 b/se
main				
treatment	**4.960*****	**4.631*****		**-2.304*****
	(0.74)	(0.87)		(0.42)
hhsize	-0.003	-0.012	-0.017	0.121
	(0.10)	(0.11)	(0.11)	(0.08)
aspiration	-0.105	-0.110	-0.165	0.152
	(0.16)	(0.16)	(0.18)	(0.17)
childunder5	0.123	0.149	0.206	0.021
	(0.18)	(0.18)	(0.19)	(0.15)
pcedu	0.002	0.004	0.010	-0.014
	(0.03)	(0.03)	(0.03)	(0.03)
hhheadedu	0.042+	**0.045***	**0.048***	**-0.043***
	(0.02)	(0.02)	(0.02)	(0.02)
caste	-1.259	-1.349	-1.755+	0.711
	(0.85)	(0.86)	(1.02)	(0.45)
bpl	0.393	0.478	0.587	0.105
	(0.37)	(0.37)	(0.38)	(0.31)
rooms	-0.021	-0.031	-0.092	-0.155
	(0.14)	(0.14)	(0.15)	(0.11)
lnmonthlyexp	-0.270	-0.206	-0.197	0.063
	(0.19)	(0.16)	(0.17)	(0.16)
lnagrland	0.092	0.044	0.023	**0.185***
	(0.16)	(0.15)	(0.16)	(0.08)
lnvaluehouse	-0.334+	-0.338+	-0.355+	0.193
	(0.19)	(0.19)	(0.20)	(0.16)
hrselectrified	0.008	0.006	0.009	-0.018
	(0.02)	(0.02)	(0.02)	(0.01)
basetothrscooking	0.046	0.048	0.038	0.052
	(0.07)	(0.07)	(0.08)	(0.10)
basetotfuelpreptime	0.000	0.000	0.000	-0.009+
	(0.01)	(0.01)	(0.01)	(0.00)
basewoodusekg	-0.004	-0.003	-0.005	-0.000
	(0.01)	(0.01)	(0.02)	(0.01)
basepercimpICS	0.139	0.116	0.103	**-0.237***
	(0.12)	(0.12)	(0.13)	(0.12)
basecollectwood	0.009	0.015	0.029	0.005
	(0.07)	(0.07)	(0.08)	(0.06)
basecostsickness	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
basesickmem	0.028	0.021	0.033	-0.024
	(0.07)	(0.07)	(0.07)	(0.06)
constant	1.558	1.486	6.758*	-0.336
	(2.87)	(2.87)	(3.22)	(2.70)
N	871.0	578.0	295.0	578.0

+ $p<0.10$ * $p<0.05$ ** $p<0.01$ *** $p<0.001$

5.3. Total Hours Spent Cooking Daily

This variable was calculated using two different reporting measures in the survey. We ask the primary cook in the household (if present) to recount all of her activities from the start of the morning until the time she goes to sleep. In short, this is a time diary for the primary cook. The number of hours spent cooking is calculated from the time reported in this time diary. For the households where the primary cook was not present at the time of the survey, we analyze the reported number of hours spent cooking on the primary stove by the respondent present in the household.

Table 3 gives the results from the intention to treat (equation 2), difference-in-difference intention to treat (equation 3) and the instrumental approach (equation 4) estimations. Columns 1 and 2 show the intent to treat estimations with and without controls respectively, Columns 3 and 4 show the difference-in-different intention to treat estimations with and without controls respectively, Columns 5 and 6 look at the impact of adopting an improved cookstove within the treatment (Phase 1) subsample and Columns 7 and 8 show us the instrumental approach estimations with and without controls respectively. This order of columns for reporting results will be followed in all the subsequent outcomes as well.

In Table 3, we find no statistically significant results except for households within the treatment group. The direction of the relationship between being in the treatment group and the hours spent cooking daily remains negative for all the models tested, although statistically insignificant. Within the treatment group, we find that households that adopted an improved cookstove were spending less time cooking daily. In particular, households that adopted the improved cookstove spent 40 minutes less time cooking daily than the households that did not adopt the ICS. This estimate however suffers from selection bias. Households who chose to buy the improved cookstove may be different on unobservable characteristics from the households that did not adopt the ICS.

The difference-in-difference intention to treat estimation in columns 3 and 4 reveal that while the coefficient is still a negative value (indicating a reduction in time spent cooking from baseline), these results are not statistically significant. We use the instrumental variable approach to tackle the problem of selection bias highlighted above. The 2sls estimates are not statistically significant. Column 8 of Table 3 shows that households that adopt an improved cookstove spend 17 minutes less time cooking in comparison to the households in Phase 2.

In conclusion, our results show that there seem to be no statistically significant short term impacts on the time spent cooking by a household that adopts an improved cookstove. This may be because the cooking behavior of a household takes a longer time period to change and this survey was administered only after a few months of the intervention.

Table 3: Total Time Spent Cooking (Phase 1 vs Phase 2)

	ITT	ITT+ Controls+FE	DiD	DiD+ Controls+FE	WTG	WTG+ Controls+FE	2SLS	2SLS+ Controls
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
treatyear2016			-0.136	-0.107				
			-0.12	-0.13				
year2016			-0.773***	-0.903***				
			-0.09	-0.1				
haveICS					**-0.472*****	**-0.662*****	-0.238	-0.278
					-0.11	-0.13	-0.17	-0.2
treatment	-0.108	-0.069	0.028	-0.214*				
	-0.08	-0.09	-0.1	-0.08				
basetothrscooking		0.059+				0.048		0.061*
		-0.03				-0.03		-0.03
basetotfuelpreptime		0.001				-0.002		0.001
		0				0		0
basewoodusekg		-0.002				0.002		-0.001
		-0.01				-0.01		-0.01
basepercimpICS		-0.106*				-0.079+		-0.061
		-0.05				-0.04		-0.05
basecollectwood		0.022				0.042		0.024+
		-0.02				-0.03		-0.01
basecostsickness		0				0		0
		0				0		0
basesickmem		0.032				0.087*		0.023
		-0.03				-0.04		-0.03
SES Controls	No	Yes	No	Yes	No	Yes	No	
Village FE	No	Yes	No	Yes	No	Yes	No	No
constant	2.379***	1.990*	3.152***	0.941	2.489***	2.780**	2.381***	1.490*
	-0.05	-0.8	-0.08	-0.65	-0.08	-0.89	-0.06	-0.75
R-sqr	0.004	0.176	0.13	0.277	0.078	0.361	0.028	0.124
dfres	39	39	39	39	19	19		
N	598	578	1198	1191	299	295	598	578

="+ p<0.10 * p<0.05 *** p<0.001"

5.3.1. Robustness Checks:

The analysis above was conducted on a subsample of all the households for which data was collected. In particular, while the analysis was conducted on Phase 1 and Phase 2 groups of villages which were randomly selected, I ran the same models on the full sample of all 900 households to check the sensitivity of these estimates. The tables for these checks are given in the Appendix.

While the comparison between Phase 1 and Phase 2 villages gave us statistically insignificant results on the time savings from cooking, in the full sample analysis, we find that there are statistically significant time savings on cooking that are robust to all the models. Specifically, in the basic intention-to-treat model, we find that households in Phase 1 save around 20 minutes in time spent cooking daily in comparison to households in Phase 2 and Control. When we add controls to the model we see that this coefficient increases to an hour of time savings. In the difference-in-difference intention to treat estimation we find that households spend around 50 minutes less time cooking daily in comparison to households in the Phase 2 and control villages from before. This result is robust but smaller in magnitude in the difference in difference estimation with controls. Households in Phase 1 save 30 minutes in daily cooking time in 2016 from 2013 in comparison to Phase 2 and Control. The 2sls estimation with controls gives us time savings of 45 minutes for households that adopted the improved cookstove in comparison to Phase 2 and Control.

Table 4: Total Time Spent Cooking - Robustness Check

Models	Phase 1 vs Phase 2	Full Sample	Phase 1 vs Control
ITT	-0.108	-0.336**	-0.564**
ITT+Controls+FE	-0.069	-1.002***	-0.931***
DID	-0.136	-0.494**	-0.851***
DID+Controls+FE	-0.107	-0.498**	-0.835**
2SLS	-0.238	-0.740**	-1.232**
2SLS+Controls+FE	-0.278	-0.673***	-1.049***

+ p<0.10   * p<0.05   ** p<0.01   *** p<0.001

It should be noted that the villages in the control group were not randomized and instead were identified through matching on Census village characteristics and institutional variables like the number of years that the NGO spent working in the village and the strength of their relationship with the village members. A comparison of these two groups should thus give us estimates that are not influenced by the historical relationship that the NGO shares with the village and specific village level characteristics like distance of the village from a *pukka* road, no. of development programs implemented in the village, no. of tubewells, handpumps and wells, no. of marginal and main workers, total area and spread of the village etc as these characteristics were specifically balanced between the two groups through propensity score matching.

Trying to parse out the impact of using an improved cookstove without the influence of the intervening NGO and other village characteristics will be helpful to gauge whether interventions like these will work in other contexts irrespective of the strength of the supplier relationship with the village. Many of the household level socio-economic characteristics however were not balanced at baseline between Phase 1 and Control (Table 1). Though we control for all those characteristics in our regressions, unobserved differences may still influence the results.

We find that households that adopted the ICS in Phase 1 villages were spending 1 hour and 3 minutes less time cooking daily in comparison to the control group. These time savings results are statistically significant in all the models. All estimates in this subsample analysis are robust to all models we ran.

5.4. Total Time Spent Preparing Fuel

The variable for time spent preparing fuel was a self-reported measure given by the respondent (household head or primary cook) during the survey. This is seen as the amount of time it takes for a household using a traditional cookstove to prepare the wood i.e. cut it into smaller pieces, before cooking daily.

As before, Table 4 gives us the intention-to-treat in 2016, difference-in-difference, within treatment group analysis and instrumental variable approach estimations. The results for time savings from preparing fuel are somewhat inconclusive. The intention-to-treat estimation after adding controls shows that households in the treatment group in 2016 spent 5 minutes more time preparing fuel in comparison to the Phase 2 group (Table 4, Column 2).

The difference-in-difference estimation reveals that households in the treatment group spent 7 minutes less time from 2013 to 2016 preparing fuel in comparison to the Phase 2 group (Table 4, Column 3 & 4). This result stays statistically significant even after adding controls. Upon analyzing just the subsample for Phase 1 villages where households received the treatment, we find that households that adopted the improved cookstove spent 3 minutes less time preparing fuel in comparison to Phase 2 villages. However, this result is only statistically significant without controls at 90 percent confidence level.

The instrumental variable approach overcomes the challenge of non-compliance in the treatment group i.e. not all households that were in the Phase 1 group ended up buying the improved cookstove. We find that the estimates in the 2sls to be statistically insignificant.

It is important to note here that at baseline treatment households were spending more time preparing fuel than control villages. In light of that, these time savings for ICS households may be underestimated. One of the promotional messages for the adoption of the ICS given by the implementing NGO, Udaipur Urja, was the reduction in effort and time taken to prepare fuel. Traditionally, households spend time cutting large chunks of wood into smaller pieces before cooking. The implementing NGO promoted the idea of using lighter wood like branches and shrubs for cooking. These promotional messages were given at the village level wherein even non-adopters within the treatment group were exposed. This could explain why the estimates are inconclusive for the subsample of within the treatment group and statistically insignificant for the 2sls estimation. Cooking behavior may have changed for both adopters and non-adopters within the treatment group.

Table 5: Time Spent Prepping Fuel (Phase 1 vs Phase 2)

	ITT	**ITT+ Controls+FE**	**DiD**	**DiD+ Controls+FE**	**WTG**	**WTG+ Controls+FE**	**2SLS**	**2SLS+Controls**
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
treatyear2016			**-7.379****	**-7.409****				
			-2.63	-2.6				
year2016			-13.942***	-15.956***				
			-1.18	-1.11				
haveICS					**-3.230***	-2.862+	-1.333	-2.276
					-1.44	-1.45	-2.38	-2.75
treatment	-0.602	5.491***	6.777**	11.901***				
	-1.11	-1.35	-2.27	-1.71				
basetothrscooking		0.567				-0.564		0.302
		-0.46				-0.73		-0.43
basetotfuelpreptime		0.039				0.077*		0.029
		-0.04				-0.03		-0.03
basewoodusekg		-0.033				-0.039		-0.061
		-0.08				-0.12		-0.08
basepercimpICS		-0.795				-0.396		-0.833
		-0.7				-0.84		-0.67
basecollectwood		-0.099				-0.464		0.112
		-0.39				-0.52		-0.33
basecostsickness		0				0.001		0
		0				0		0
basesickmem		-0.452				-0.256		-0.379
		-0.46				-0.49		-0.43
SES Controls	No	Yes	No	Yes	No	Yes	No	Yes
Village FE	No	Yes	No	Yes	No	Yes	No	No
constant	19.298***	-13.003	33.240***	-6.722	20.186***	9.206	19.311***	-3.372
	-0.84	-13.96	-1.12	-13.66	-0.87	-17.11	-0.84	-12.89
R-sqr	0	0.113	0.208	0.278	0.019	0.185	0.005	0.041
dfres	39	39	39	39	19	19		
N	598	578	1198	1191	299	295	598	578

="+ p<0.10 * p<0.05 *** p<0.001"

5.4.1. Robustness Checks

In the full sample analysis, we find that there are statistically significant time savings on fuel preparations before cooking for only the diffirence-in-difference estimations. Specifically, in the intention-to-treat model with controls, we find that households in Phase 1 spend 4 more minutes in time spent preparing fuel before cooking daily in comparison to households in Phase 2 and Control. This result is not statistically significant. In the difference-in-difference estimation with controls, households in Phase 1 save 15 minutes in fuel prep in 2016 from 2013 in comparison to Phase 2 and Control. The 2sls estimation with controls gives us time savings of 14 minutes for households that adopted the improved cookstove in comparison to Phase 2 and Control, however this results is statistically insignificant.

Table 6: Time Spent Prepping Fuel - Robustness Check

Models	Phase 1 vs Phase 2	Full Sample	Phase 1 vs Control
ITT	-0.602	-8.172	-15.718
ITT+Controls+FE	5.491***	3.567	10.335
DID	-7.379**	-14.879*	-22.354
DID+Controls+FE	-7.409**	-14.954*	-21.380
2SLS	-1.333	-17.967	-34.303
2SLS+Controls	-2.276	-14.066	-26.319
*** p<0.05**	** p<0.01	*** p<0.001	*** p<0.001

When we look at the subsample of Phase 1 and Control groups, we find that only the difference-in-difference estimates are statistically significant. In the difference-in-difference estimation with controls we find that households in Phase 1 villages were spending 21 minutes less time preparing fuel daily in comparison to the control group. The 2sls estimations are statistically insignificant. It should be noted that the estimates for the full sample and Phase 1 vs Control analysis are much larger than the Phase 1 vs Phase 2 estimates, albeit statistically insignificant.

5.5. Amount of Wood Used for Cooking

The amount of wood used for cooking, like the other outcome variables discussed before, is also a self-reported measure given by the respondent present in the household during the survey. The variable is measured in kg per day and signifies the amount of fuel a household consumes in a day solely while cooking. As can be seen from Table 5, all the estimations show a statistically significant result for changes in the amount of wood used for cooking except the difference in difference estimation.

From the intention to treat estimation with controls, we see that households in the Phase 1 group use around 1.6 kgs more of wood than households in the Phase 2 group. The estimates while still positive are statistically insignificant for the difference in difference estimation. When we look at the estimates within the treatment group we find that adopters of the ICS were infact using less fuel than non-adopters. As discussed before however, this estimation suffers from bias. The 2sls estimations show statistically significant increases in the amount of fuel used per day.

The result for fuel use may be driven by the fact that this survey was conducted only a couple of months after the intervention. Households could have been reporting their historic use of fuel instead of their current use of wood. Alternatively, given that the greater fuel use is concentrated among non-adopting households (as shown in the within treatment group regressions), this could be due to reduced fuel acquisition costs in villages where promotion occurred, due to reduced pressure from adopting households.

Table 7: Amount of Wood Use (in kg) - PHASE 1 vs PHASE 2

	Amount of Wood Used Daily – Phase 1 vs Phase 2							
	ITT	**ITT+ Controls+FE**	**DiD**	**DiD+ Controls+FE**	**WTG**	**WTG+ Controls+FE**	**2SLS**	**2SLS**
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
treatyear2016			0.449	0.56				
			-0.66	-0.68				
year2016			-3.113***	-3.407***				
			-0.56	-0.59				
haveICS					**-1.244***	**-1.916****	**2.059****	**1.728***
					-0.44	-0.63	-0.69	-0.82
treatment	**0.930*****	**1.617*****	0.48	0.128				
	-0.26	-0.34	-0.58	-0.37				
basetothrscooking		0.021				-0.057		0.006
		-0.12				-0.12		-0.11
basetotfuelpreptime		0.012+				0.007		0.013*
		-0.01				-0.01		-0.01
basewoodusekg		0.008				-0.006		0.004
		-0.02				-0.04		-0.02
basepercimpICS		0.008				-0.092		-0.009
		-0.17				-0.28		-0.16
basecollectwood		0.022				0.224		0.066
		-0.11				-0.14		-0.1
basecostsickness		0				0		0
		0				0		0
basesickmem		0.124				0.014		0.055
		-0.14				-0.14		-0.13
SES Controls	No	Yes	No	Yes	No	Yes	No	Yes
Village FE	No	Yes	No	Yes	No	Yes	No	No
constant	4.360***	1.854	7.473***	-2.059	5.863***	6.916+	4.339***	1.48
	-0.18	-2.74	-0.48	-3.22	-0.24	-3.47	-0.19	-2.47
R-sqr	0.021	0.165	0.067	0.133	0.036	0.212	.	0.005
dfres	39	39	39	39	19	19		
N	598	578	1198	1191	299	295	598	578

="+ p<0.10 * p<0.05 *** p<0.001"

5.5.1. Robustness Checks

In the full sample analysis, we find that in the intention-to-treat estimation with controls, households in Phase 1 use 2.24 kgs of less wood while cooking in comparison to the households in Phase 1 and Phase 2. This result, however, is not robust through any of the later models we ran. We find no statistically significant changes in the amount of fuel used by households that adopted the improved cookstoves (2sls estimation) in comparison to households in Phase 2 and Control.

Table 8: Amount of Fuel Used - Robustness Check

Models	Phase 1 vs Phase 2	Full Sample	Phase 1 vs Control
ITT	0.930***	0.057	-0.812*
ITT+Controls+FE	1.617***	-2.247***	-1.806***
DID	0.449	0.571	0.695
DID+Controls+FE	0.560	0.699	0.914
2SLS	2.059**	0.126	-1.773*
2SLS+Controls	1.728*	0.357	-1.242*

+ p<0.10 * p<0.05 ** p<0.01 *** p<0.001

From the subsample of Phase and Control groups we find different results. The intention to treat estimates tell us that households in Phase 1 villages were spending 1.8 kgs of less wood than the households in the control group. The difference-in-difference estimations show positive but statistically insignificant results. The 2sls with controls estimations reveal households that adopted the ICS were using 1.2 kgs less wood than the control group. The results for the amount of wood used seem to be very mixed and inconclusive indicating that the reporting bias discussed earlier may be influencing the estimations here.

5.6. Perception of the Impact of Improved Cookstoves

The variable for perception of the impact of improved cookstoves was calculated from a question asked in the survey to both Phase 1 and Phase 2 groups. The respondents were asked to scale their perception of the impact of adopting an ICS technology on their family's health and well-being. The scale went from 0 to 5 where 5 signified the most positive impact on the household and 0 signified the least.

As can be seen from Table 9 the results from this analysis hold up under most of our estimations. The intention-to-treat estimates with controls show that households in the treatment group in 2016 move up 0.941 units higher in their perceptions than the households in Phase 2 (Table 9, Column 2). The difference-in-difference estimation shows that households move up by 0.408 units from 2013 to 2016 in comparison to the Phase 2 group (Table 9, Columns 4). These results do not seem to hold up in our analysis of the subsample Phase 1 households (Table 9, Columns 5 & 6). This could be because the promotion of improved cookstoves was conducted in the villages as a whole and the perception of the impact of adopting an improved cookstove within the treatment group (Phase 1) could have changed for the village as a whole. In other words, these results could be driven by the fact that villages as a whole received information about the improved cookstove by the implementing NGO.

The instrumental variable approach in Columns 7 & 8 confirm our intention-to-treat analysis in columns 1 to 4. Households that adopted the improved cookstove moved 0.88 units higher in their perception of the impact of adopting an improved cookstove in comparison to the Phase 2 households. These results hold up even after adding controls.

Our results in perception of the impact of improved cookstove is interesting in light of our analysis on outcomes discussed before. It seems that even though the short term impacts of adopting an improved cookstove are somewhat limited, households that adopted the ICS have a high perceived impact of adopting the cookstove. Upon analyzing the satisfaction levels of households that adopted the ICS we find that around 90% of the households that adopted the improved cookstoves were satisfied by their purchase.

Table 9: Perception of ICS Impact - PHASE 1 vs PHASE 2

	Perception of ICS Impact - Phase 1 vs Phase 2							
	ITT	**ITT+ Controls+FE**	**DiD**	**DiD+ Controls+FE**	**WTG**	**WTG+ Controls+FE**	**2SLS**	**2SLS+Controls**
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
treatyear2016			**0.418****	**0.408****				
			-0.13	-0.12				
year2016			0.181+	0.148				
			-0.09	-0.1				
haveICS					0.046	0.187	**0.881*****	**0.778*****
					-0.1	-0.15	-0.26	-0.23
treatment	**0.397*****	**0.941*****	-0.021	0.546***				
	-0.09	-0.09	-0.1	-0.06				
basetothrscooking		0.023				-0.037		-0.002
		-0.03				-0.04		-0.03
basetotfuelpreptime		0				0.002		0.001
		0				0		0
basewoodusekg		0				-0.008		-0.004
		0				-0.01		0
basepercimpICS		0.055				0.017		0.042
		-0.04				-0.06		-0.03
basecollectwood		0.009				-0.013		0.013
		-0.03				-0.04		-0.02
basecostsickness		0				0		0
		0				0		0
basesickmem		-0.014				-0.036		-0.033+
		-0.02				-0.03		-0.02
SES Controls	No	Yes	No	Yes	No	Yes	No	Yes
Village FE	No	Yes	No	Yes	No	Yes	No	No
constant	2.505***	-0.519	2.324***	-1.286*	2.881***	3.285*	2.496***	-0.922
	-0.08	-1.01	-0.07	-0.56	-0.08	-1.17	-0.08	-0.9
R-sqr	0.053	0.198	0.066	0.188	0.001	0.139	.	0.027
dfres	39	39	39	39	19	19		
N	596	576	1195	1188	297	293	596	576

="+ p<0.10 * p<0.05 *** p<0.001"

5.6.1. Robustness Checks

We find that the results from Phase 1 vs Phase 2 analysis is not robust to the different sample combinations. In the full sample analysis, we find that in the intention-to-treat estimation, households in Phase 1 have a perception of lower impact of ICS in comparison to the Phase 2 and Control group. This result is not statistically significant however and the direction of relationship is not robust to the later models we ran on the full sample. The difference-in-difference estimation shows that households perceived the impact of an improved cookstove to be higher in 2016 than in 2013 in comparison to Phase 1 and Control group households at an alpha of 0.10. The 2sls estimation shows that at an alpha of 0.05, the housholds that adopted the ICS in 2016 perceived the impact of the ICS on their household health and welfare to be higher than the households in Phase 2 and Control.

Table 10: Perception of ICS Impact - Robustness Check

Models	Phase 1 vs Phase 2	Full Sample	Phase 1 vs Control
ITT	0.397***	0.384***	0.370***
ITT+Controls+FE	0.941***	0.219*	0.282**
DID	0.418**	0.209+	-0.000
DID+Controls+FE	0.408**	0.222*	0.055
2SLS	0.881***	0.844***	0.808***
2SLS+Controls	0.778***	0.691***	0.642**

+ p<0.10 * p<0.05 ** p<0.01 *** p<0.001

When we look at the subsample of Phase 1 and Control groups, the intention to treat estimates tell us that households in Phase 1 villages have a higher perception of the impact of ICS than households in Phase 2 and Control. This estimate is not robust to any of the models we ran later. The estimates are much smaller on the subsample analysis of Phase 1 and control villages. Specifically, none of the models other than the simple ITT analysis show statitistically significant results on perception of ICS impact. This is an interesting result; however since the control group was not identified through randomization the results on perception could be driven by unobservable characteristics biasing the estimates.

5.7. Health Impacts

We also tested whether there were any short term health impacts upon adopting an improved cookstove. Tables 11 and 12 look at the cost incurred by a household in the past week for treating an illness and the number of household members who fell sick in the past week respectively. We find that there are in fact statistically significant increases in the cost of sickness for households that adopted the ICS. This is contrary to most literature which would suggest better health outcomes. This survey was administered a short while after the cookstove was distributed in the villages. It is possible that these health outcomes would differ in the long run. The 2sls estimation shows that households that adopted the improved cookstove saw statistically significant increases in the cost of treating illnesses in the past week. Similar to the amount of fuel used estimations, the within treatment group estimations show a negative (but statistically insignificant) relationship between households that adopted the ICS and those that did not.

Table 11: Cost of Sickness (Phase 1 vs Phase 2)

	Cost of Sickness – Phase 1 vs Phase 2							
	ITT	**ITT+ Controls+FE**	**DiD**	**DiD+ Controls+FE**	**DiD+ Controls+FE**	**WTG+ Controls+FE**	**2SLS**	**2SLS+ Controls**
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
treatyear2016			5.26	26.371				
			-95.18	-90.91				
year2016			-335.851***	-382.479***				
			-64.9	-71.24				
haveICS					-91.504	-146.195	**338.852****	**426.614******
					-78.3	-111.48	-140.84	-127.5
treatment	**152.993****	**449.608******	147.733+	-195.619**				
	-57.02	-78	-86.81	-67.24				
basetothrscooking		9.737				13.846		-2.476
		-25.04				-43.46		-23.47
basetotfuelpreptime		2.222				1.345		1.612
		-1.72				-1.92		-1.62
basewoodusekg		-0.715				-12.050+		-2.376
		-5.32				-6.86		-4.87
basepercimpICS		47.412				56.105		32.605
		-35.77				-56.39		-29.86
basecollectwood		-37.306*				-36.791		-34.011*
		-18.01				-23.53		-15.18
basecostsickness		0.048				0.108+		0.051
		-0.04				-0.05		-0.03
basesickmem		3.187				40.307		-1.564
		-18.8				-28.04		-17.23
SES Controls	No	Yes	No	Yes	No	Yes	No	Yes
Village FE	No	Yes	No	Yes	No	Yes	No	No
constant	291.662***	-109.18	627.513***	-261.654	486.888***	402.468	288.262***	-484.414
	-42.76	-910.65	-54.08	-625.82	-41.35	-1361.54	-43.79	-738.91
R-sqr	0.012	0.14	0.047	0.107	0.004	0.158	.	0.015
dfres	39	39	39	39	19	19		
N	598	578	1198	1191	299	295	598	578

="+ p<0.10 * p<0.05 *** p<0.001"

As can be seen from the table below, consistent with the cost of sickness outcome, there are statistically significant increases in the number of members who were sick in the past week for households that adopted the improved cookstove (table 13, Column 8). The results from short term reported health outcomes show the same sort of inconsistency as we saw for reported use of fuel for cooking. The within group estimates show a negative relationship between the adoption of an improved cookstove and the number of members who were sick in the past week at a significance level of 0.10. The inconsistency in these health outcomes in the short run may due to some sort of reporting bias. An analysis of outcomes like height and weight of the child in the households over the long run may give us more insight into the impact of the adopting the ICS.

Table 12: No. of Sick Members (Phase 1 vs Phase 2)

	No of Members who were sick in the past week - Phase 1 vs Phase 2							
	ITT	**ITT+ Controls+FE**	**DiD**	**DiD+ Controls+FE**	**WTG**	**WTG+ Controls**	**2SLS**	**2SLS Controls**
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
treatyear2016			0.201	0.177				
			-0.14	-0.15				
year2016			-0.821***	-0.906***				
			-0.1	-0.11				
haveICS					-0.154	-0.389+	**0.607***	**0.583****
					-0.18	-0.2	-0.24	-0.21
treatment	**0.274***	0.052	0.073	-0.164				
	-0.1	-0.13	-0.13	-0.11				
basetothrscooking		0.004				0.091		-0.001
		-0.05				-0.07		-0.04
basetotfuelpreptime		0.004				0.005		0.003
		0				0		0
basewoodusekg		-0.001				-0.008		-0.005
		-0.01				-0.01		-0.01
basepercimpICS		0.053				0.106		-0.004
		-0.05				-0.08		-0.04
basecollectwood		-0.048+				-0.044		-0.042+
		-0.02				-0.04		-0.02
basecostsickness		0				0		0
		0				0		0
basesickmem		0.069+				0.084		0.078+
		-0.04				-0.06		-0.04
SES Controls	No	Yes	No	Yes	No	Yes	No	Yes
Village FE	No	Yes	No	Yes	No	Yes	No	No
constant	0.773***	0.826	1.593***	1.197	1.118***	1.061	0.766***	-0.09
	-0.07	-1.13	-0.09	-0.82	-0.12	-1.31	-0.07	-1.18
R-sqr	0.014	0.169	0.078	0.186	0.003	0.246	.	0.057
dfres	39	39	39	39	19	19		
N	598	578	1198	1191	299	295	598	578

="+ p<0.10 * p<0.05 *** p<0.001"

5.7.1. Robustness Checks

The full sample analysis for the cost of sickness shows no statistically significant results on the intention to treat estimates with controls. The difference in difference estimation, interestingly, shows a negative but statistically insignificant relationship between cost of sicknesss and treatment status. The 2sls estimation reveals that households that adopted the improved cookstove reported to have spent 245 rupees more than households in the Phase 2 and Control groups. The Phase 1 vs control difference-in-difference estimation however gives us statistically significant decreases in the cost of treating illnesses for a household in the treatment group. This result is not robust to the 2sls estimation we run later.

Table 13: Cost of Sickness - Robustness Check

Models	Phase 1 vs Phase 2	Full Sample	Phase 1 vs Control
ITT	152.993*	101.347*	49.872
ITT+Controls	449.608***	48.681	76.096
DID	5.260	-120.233	-245.554**
DID+Controls	26.371	-110.909	-236.528*
2SLS	338.852*	222.808+	108.842
2SLS+Controls	426.614***	244.963*	29.775

+ p<0.10 * p<0.05 ** p<0.01 *** p<0.001

Table 14: No. of Sick Members - Robustness Check

Models	Phase 1 vs Phase 2	Full Sample	Phase 1 vs Control
ITT	0.274*	0.132	-0.010
ITT+Controls	0.052	-0.105	-0.039
DID	0.201	-0.083	-0.367**
DID+Controls	0.177	-0.092	-0.361*
2SLS	0.607*	0.290	-0.021
2SLS+Controls	0.583**	0.360+	0.041

+ p<0.10 * p<0.05 ** p<0.01 *** p<0.001

The full sample analysis for the number of members who were sick in the past week shows no statistically significant results on any of the models we run. Consistent with the DiD estimation from the cost of treating illnesses, in the Phase 1 vs Control analysis, we find that households in the treatment group had fewer members who were sick in the past week. The inconsistency in the results for these health outcomes shows that there may in fact be some sort of reporting bias driving these results.

6. Discussion

We can see from these results that even in the short run there are a number of impacts of using improved cookstoves promoted among rural households in Udaipur. This analysis finds that while the households in the Phase 1 group were exposed to the same kind of promotional messages at the village level from the Udaipur Urja, the rate of adoption in the group was 46 percent and other than treatment status, households that adopted the improved cookstove had heads of households with a higher education level than non adopters. Households that used a traditional stove in the past week were more likely to have a larger agricultural land holding, a lower education level for the head of the household and a lower baseline perception of the impact of an improved cookstove on the welfare of their household members.

The impact of the improved cookstove was evaluated for outcomes like times spent cooking, preparing fuel, amount of fuel used, perception of ICS impact and health status in the past week. The models used were; intention-to-treat, difference-in-difference and a 2sls estimation along with the same intention-to-treat estimation on a subsample of just the Phase 1 group. We found mixed results on the Phase 1 vs Phase 2 analysis wherein there were no statistically significant time savings for cooking and fuel preparation on the 2sls estimation.

While we don't find statistically significant impacts on time saved for fuel preparation before cooking, interestingly, we see an increase in the amount of fuel used for cooking. The within treatment group analysis of this outcome reveals that the households that adopted the improved cookstove were using less fuel for cooking than households that did not adopt. This directs us to a possible reporting bias by household and suggests that the results we see on the 2sls may be driven by non-adopters. The discrepancy in the results for the different models run for this outcome may also suggest that households were reporting the amount they used historically and may not have adjusted their estimated amount of fuel use according to their current needs. A better measure of that outcome variable would have been to weigh the amount of fuel used for cooking.

In the Phase 1 vs Phase 2 analysis, we find that households tend to have a positive and statistically significant perception of the impact of improved cookstoves on their household health and welfare. This result does not hold up in our robustness check with the subsample for Phase 1 and Control which was identified through matching on characteristics like number of years the NGO worked in the village and the strength of their relationship with the village members.

Interestingly we find that the cost of treating illnesses and the number of members who were sick in the week of the survey went up for households that adopted the improved cookstove in the 2sls estimation. However, we find that this result has the same discrepancy in the within treatment group analysis discussed above. A deeper analysis into reporting biases while administering surveys like these could be valuable in unpacking these results.

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