The impact of improved clean cookstoves on households in Southern Haiti

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Abstract

The present paper evaluates the effects of the use of improved cookstoves (ICSs) on household fuel expenditure in Southern Haiti. It takes advantage of the fact that approximately 80 households received ICSs, a novel technology, in the aftermath of the 2010 Haitian earthquake. Survey work in 2014 permits a comparison of fuel expenditures between ICS-using households and non-using households. The effect of ICS use on fuel expenditure is estimated using a simple t-test and propensity score matching methods. Ultimately, understanding the effect of ICS use on fuel expenditures will help promoters of ICSs to improve their marketing plans and increase adoption.

Keywords: technology adoption, improved cookstoves, propensity score matching

Introduction

Improved cookstoves were developed primarily for their potential to improve household health, local environmental quality, and for regional climate benefits. Compared to traditional stoves, ICSs improve cooking efficiency and can reduce the amount of fuel required, time and effort spent gathering fuel, and cooking times – all of which have the potential to improve health and increase household welfare (Lewis & Pattanayak, 2012). Thus, the two essential benefits of most improved stoves programs are their environmental, health, as well as socioeconomic impacts. To justify programs promoting ICSs, sponsors have cited the alleviation of the pressure on the natural resource base, the use of energy in a cost-effective and efficient way, and the provision of a mean for the poor to decrease their high expenditures on energy (Barnes, Openshaw, Smith, and van der Plas, 1994).

Deforestation issues in Haiti became more alarming the past decade. In 2013, less than 1.5% of natural forest still remains in Haiti (KONPAY, 2013). Due to important and urgent health and environmental issue in Haiti, a local Haitian NGO has developed an improved model of stove that can be combined with a sustainable alternative to charcoal for a more efficient and cleaner cooking. The improved stove is composed of two main parts: a circular pot-opening part on the top of a cylindrical combustion chamber featuring a clay layer in between two metal sheets insulation allowing the stove to conserve heat and burn more efficiently.

The current paper estimates the effects of the use of improved cookstoves (ICSs) on household fuel expenditure in Southern Haiti. Ultimately, understanding the effect of ICS use on fuel expenditures will help promoters of ICSs to improve their marketing plans and increase adoption.

Background and previous studies

Development of improved stoves is not a recent phenomenon. Over the past one hundred years, middle and upper-income families have adopted different type of stoves, especially when access to petroleum-based fuels was a problem. Among the industrialized countries, enclosed wood or charcoal stoves were used both to cut down on indoor air pollution and to facilitate cooking. Several designs were developed largely by trial and error. Efficiency was not an important factor of stoves models due to the relative abundance of woodfuels. However, the increase of urban population, difficulties in woodfuel supply, and increase in market prices induced efforts to design more fuel-efficient models (Barnes *et al.* 1994).

The recent spate of improved stove programs focusing on energy efficiency began in the 1970s after the huge rise in oil prices. In addition to a desire to rationalize the continuing reliance on biomass fuels, a desire to prevent or mitigate deforestation contributed to the growth of stove programs. With higher oil prices, increasing deforestation, and talk of an impending "fuelwood crisis," governments, donors, and nongovernmental organizations (NGOs) started to finance and develop stove programs (Barnes *et al.* 1994).

In general, women and middle and lower-income families are the main beneficiaries of ICSs programs (Eckholm, 1982). Commonly, in rural areas, people collect rather than purchase fuelwood, and using more efficient stoves has the potential to reduce the time allocated to collection, which is especially significant for women. Furthermore, estimated economic and environmental impacts of adopting improved stoves can be quite significant for communities.

A large number of empirical studies identify different benefits as well as costs associated with a household's decision to use improved cookstoves and fuels. From the users' perspective, benefits include reduced air pollution, time saved from collecting fuels, and fuel cost savings, as well as aesthetic gains and improved social standing (Malla and Timilsina, 2014). The literature on cookstove adoption reveals that initially, households respond most – with a high rate of adoption – to fuel savings (when fuel is very scarce or monetized), to the speed of cooking, convenience, compatibility with local cooking practices, and level of advancement/modernity of the technology, and relatively less so to indoor-air-pollution-related issues (Ruiz-Mercado, Masera, Zamora, & Smith, 2011).

In a broader frame, literature on technology adoption is currently moving in three directions according to Doss (2006). These directions include i) innovative econometric and modeling methodologies to understand adoption decisions; ii) examinations of the process of learning and social networks in adoption decisions; iii) and micro-level studies based on local data collection intended to shed light on adoption decisions in specific contexts for policy purposes. Our study fits in this last category. According to Lewis and Pattanayak (2012) empirical (quantitative) studies of adoption studies remain "narrow, thin and scattered." Quality of improved stoves and clean fuel adoption research varies very much in terms of stove design, measurement approaches, statistical analysis methods, and sample sizes.

Methodology

This study estimates the effects of the use of improved cookstoves (ICSs) on household fuel expenditure in Southern Haiti. It takes advantage of the fact that approximately 80 households received ICSs, a novel technology, in the aftermath of the 2010 Haitian earthquake. Crucially, the stove distribution effort--which took place in a temporary camp--purportedly did not target specific household types. Survey work tracking down these recipient households in 2014 permits a comparison of fuel expenditures between ICS-using households and non-using households (i.e. those that never received stoves). The effect of ICS use on fuel expenditure is estimated using a simple t-test and propensity score matching methods.

To estimate the effect of the use of the improved stove, treatment evaluation methods are applied. The sample is comprised of two groups: households that received the stoves and effectively used them between the time of distribution and the survey (16.44% of the sample), and households that did not receive the stove or stopped using it before the time of the survey (83.56% of the sample). The first group is our treatment group; the second is our control group. In total, our sample comprises 146 households. Within each household, the member in charge of food preparation was interviewed. In our context, this means that the majority of survey respondents were women, as is clear in our summary statistics (Table 1).

Our variable of interest is fuel expenditure. In the survey, respondents were asked questions about the type(s) of fuel they use and how much they spend weekly on each type to estimate their cooking cost. Respondents were also asked questions about their average cooking time per day and other household socio-demographic information such as the household size, the income, the level of education, etc.

As a first step, a simple t-test is used to compare the mean fuel expenditure over the past year of households that used the stove and households that did not. Based on a statistically significant result of a mean comparison, we can conclude that fuel expenditure of households that used the stove differ from fuel expenditure of households that did not use the stove. However, a t-test simply compares the means of the two groups and does not account for any potential sample selection; nor does it inform us of other household characteristics that may also affect ICS use. Sample selection could pose a problem, despite the fact that the distribution of stoves was purportedly random. Two factors could introduce selection problems: Not all stove recipients could be tracked down (e.g. if the household had moved away from the region), and a portion of stove recipients effectively 'disadopted' the stove during the four years between time of receipt and the time of the survey. The main reason stated for dis-adoption is that the stove had broken (stated by 54.28% of the dis-adopters). People also stopped using the technology because they gave it to a relative (14.29% of the dis-adopters), typically a relative living in an urban area or who is financially better off. In addition, as an unintended consequence of the fact that recipients were advised during the distribution program to use the stove with an alternative charcoal, 14.29% of the dis-adopters stopped using their improved stoves when the accompanying briquettes ran out. Other reasons for dis-adoption are that the stove was too slow to heat, it did not match user's pans, it got rusted and these were respectively stated by 5.71%, 5.71% and 6% of the recipients. The dis-adoption was prevalent in the sense that, despite 42% of the sample having at one point owned the improved stove, only 16% of the sample effectively used it over the one-year period of the survey. 26% stopped using their stove sometime between 2012 and the time of the survey. These represent the majority (63.31%) of those who possessed the improved stove at one point. Our small sample size does not permit the separate treatment of these dis-adopters – they are therefore lumped in together with households that never received the stove. For these reasons, we follow the t-test with propensity score matching techniques, using as covariates household cooking characteristics and demographic information such as education and income. The average treatment effect on the treated is estimated using several matching methods.

The propensity score is defined by Rosenbaum and Rubin (1983) as the conditional probability of receiving a treatment given pretreatment characteristics:

$$p(\mathrm{X}) \equiv \Pr(\mathrm{D} = 1|\mathrm{X}) = \mathrm{E}(\mathrm{D}|\mathrm{X})$$

where D = 1 indicates the household having received and effectively used the stove since the distribution program. (D=0 otherwise X is the multidimensional vector of pretreatment characteristics. The probability of using the stove can be rewritten as:

$$p(\mathrm{X}) = \Pr(\mathrm{D} = 1|\mathrm{X}) = F\,(X'\beta) \qquad (1)$$

β denotes the vector of the model parameters to be estimated and F is a cumulative density function. F can be the standard normal cumulative distribution or the logistic cumulative distribution. In case of a standard normal distribution, a Probit model is fitted and equation (1) becomes

$$p(\mathrm{X}) = \Pr(\mathrm{D} = 1|\mathrm{X}) = F\,(X'\beta) = \int_{-\infty}^{X'\beta} \emptyset(z)dz$$

with $\emptyset(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$ representing the density function of the standard normal distribution.

In case of a logistic distribution, a logit model is estimated and equation (1) can be rewritten as

$$p(\mathrm{X}) = \Pr(\mathrm{D} = 1|\mathrm{X}) = F\,(X'\beta) = \frac{\exp(X'\beta)}{1 + \exp(X'\beta)}.$$

In both cases, the models are estimated by maximizing the log-likelihood function and the resulting coefficient estimates permit the calculation of average effects of treatment on the treated.

Data

For the purpose of the study, a survey was conducted during the course of March 2014 across two districts in Southern Haiti: Jacmel and Les Cayes. In these two districts, improved cookstoves production units exist, but the purchase and use of ICSs is rare. A total of 150 participants were randomly selected and interviewed. Sampling was such that approximately half of the interviewees had received a cookstove in the aftermath of the 2010 earthquake as part of a pilot trial program.

The outcome of interest is the average household fuel expenditure over the one-year period preceding the survey, measured in dollars per day. Fuel expenditures are the average daily amount of money spent to purchase cooking fuel (charcoal, woodfuel or kerosene). Wood freely collected or other fuel freely obtained is not counted. The key explanatory variable is a dummy variable indicating regular use of an ICS over the one-year period from March 2013 to March 2014.

Treatment and control groups are distinguished by whether the household effectively used the improved cookstove over the past year. The control group comprises households that never received the stove (85 households) and households that received the stove but stopped using it regularly for whatever reason (38 households). This self-selection out of the treatment group and into the control group introduces the possibility of selection bias. It is therefore important to examine interviewee and household demographics as well. Table 1 presents summary statistics of these variables by group.

Table 1: Summary statistics by groups

		Treatment group (N=24)		Control group (N=122)	
Variable	**Description**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
COOKPLACE	Whether cooks Indoor (=1) or Outdoor (=0)	0.292	0.464	0.131	0.339
AGE	Age in years	41.208	12.573	39.057	13.189
SEX	Gender: Male(=1) or Female (=0)	0.292	0.464	0.270	0.446
MARITAL	Marital status: Married (=1) or Single (=0)	0.708	0.464	0.779	0.417
EDUCATION	Education level: Below high school (=0) or Above high school (=1)	0.417	0.504	0.467	0.501
HHSIZE	Household size (number of members)	6.042	3.000	4.861	2.062
INCOME	Average daily income per capita in US dollar	1.275	1.035	1.964	2.163
BENEFITORNOT	Whether received the stove (=1) or not (=0)	1.000	0.000	0.320	0.468
USED	Whether used the stove for at least year (=1) or not (=0)	1.000	0.000	0.000	0.000
FUELEXPDTRE	Average daily fuel expenditure in US dollar	0.844	0.736	1.006	0.982
COOKTIME	Average daily cooking time in hours	3.333	1.204	3.043	1.153
INDWORK	Independent worker	0.333	0.482	0.467	0.501
FARMER	Farmer	0.167	0.381	0.098	0.299
SALARY	Employee (salaried)	0.083	0.282	0.164	0.372

Judging by the demographic characteristics, households in the treated group do not significantly differ from households in the control group. In other words, observationally, the population that received the stoves and used them is not different from the population who did not receive them or received and then stopped using them.

Results

Results of the t-test are summarized in Table 2. Fuel expenditure for households that used the stoves appears lower than those of households that did not use them. Judging only by the means, households that used the improved cookstove reduce their fuel expenditure by 16.1

cents/day (the average fuel expenditure is 97.9 cents/day). However, this difference is not statistically significant. Following this preliminary step, propensity score matching is used to control for any possible systematic selection into the groups.

Table 2: Difference in mean tests summary

Variables	Description	Mean All	Mean for Control group	Mean for Treatment group	Difference	p-Value
FUELEXPDTRE	Fuel expenditure/day (US $)	0.979	1.005	0.844	-0.161	0.447

A propensity score model (probit model) is estimated and the balancing property is satisfied. Propensity score model results are presented in Table 3. Most of the coefficients are not significant except for the variables COOKPLACE and HHSIZE. These results suggest that bigger households are more likely to use the improved stove, as well as households with indoor kitchens.

Table 3: Probit model estimation

	Probit model	
Variables	**Coefficient**	**Std. Err**
AGE	0.006	(0.012)
SEX	0.049	(0.366)
COOKPLACE	0.783**	(0.348)
EDUCATION	-0.005	(0.323)
COOKTIME	0.054	(0.120)
HHSIZE	0.103*	(0.059)
INCOME	-0.102	(0.129)
MARITAL	-0.078	(0.328)
INDWORK	-0.347	(0.340)
FARMER	-0.025	(0.527)
SALARY	-0.520	(0.605)
Constant	-1.632**	(0.702)

Note: *** Significant at 1%; **significant at 5%, * significant at 10%

Average treatment effect on the treated estimation

Table 4 reports the average treatment effect on the treated using several matching methods. After matching treated and control households, we estimate that using the improved cookstove lowers the fuel expenditure by about 14.6 cents/day to 23.6 cents/day. In other words, households that use the improved stove have lower fuel expenditure than households that did not use one. Given the average fuel expenditure (97.9 Cents/day), this reduction is significant for households in Haiti. However, this difference is not statistically significant at the 5% level for any of the matching methods.

Table 4: Average treatment effect on the treated

Estimation method	Differences in Fuel expenditure ($/day)
T-test	- 0.161
ATE nearest neighbor	- 0.253
ATE four nearest neighbor	- 0.281*
ATE radius matching	- 0.146
ATE kernel	- 0.236*

Conclusions

Commonly, in rural areas, people collect rather than purchase fuelwood, and using more efficient stoves has the potential to reduce the time allocated to collection, which can be particularly burdensome for women (Barnes *et al.* 1994). In Haiti, where less than 1.5% of natural forest remains, the clean cookstove program intends to simultaneously address issues of energy, environmental protection, climate, health and gender. This research helps measure tangible benefits for the users of the improved cookstove. The research uses propensity score matching methods to estimate the fuel cost-saving effects of the use of the improved cookstove for households. The treatment group consists of households that received the stoves during the distribution and used them over the past year, while the control group is the set of households that did not use the stove over the past year. Results show that the use of the improved stove significantly reduces household fuel expenditure by about 14.6 cents/day to 23.6 cents/day.

During the interviews, respondents acknowledge that the stove is efficient, cooks faster, and retains the heat of the fuel longer than conventional or traditional stoves found in the community. However, they complain about the fact that the cost of the technology prevents them from buying a replacement when the stove is damaged. Cash is therefore an important constraint that limits both the adoption and the continued use of the stove. Further studies on the production side of this technology may offer valuable insights to better match demand and supply.

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