The Effect of Information and Subsidy on Adoption of Solar Lanterns: An Application of the BDM Bidding Mechanism in Rural Ethiopia

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Abstract

The transition to solar energy to provide clean lighting for rural households in developing countries has been slow. Using a Becker-Degroot-Marschak (BDM) bidding mechanism in a randomized field experiment, this study investigated the effect of information and subsidy policy instruments on the uptake of solar lanterns. The BDM approach used provides a more comprehensive and more transparent approach for eliciting willingness to pay (WTP), as our random draw is from a wide range of uniformly distributed prices, drawn in front of the subjects. We found that an increase in subsidy level increases the adoption rate. Provision of information about private and public benefits of the solar lantern generally did not have a significant effect on adoption rate and willingness to pay. Households with access to grid electricity have a lower WTP for the solar lantern and are thus less likely to adopt, while those using kerosene for lighting are more likely to adopt. We also find that access to credit increases WTP for the lantern. The results suggest that the Sustainable Energy for All and UN Sustainable Development Goals related to universal electricity and clean energy access may not be achieved without subsidizing household-level solar lighting.

Key words: Ethiopia, information, market-based policy instruments, non-market policy instruments, renewable energy, solar lanterns

JEL Codes: D1, D4

1. Introduction

About 620 million people in sub-Saharan Africa do not have access to grid electricity services. Because grid electricity is capital intensive and takes more time and resources to reach rural households, especially for dispersed settlements, off-grid electricity alternatives such as solar lanterns can reach the rural poor living in remote areas, helping to achieve goals of universal electrification.

Households' reliance on kerosene and biomass for lighting adds to health risks from indoor air pollution, and kerosene purchases impose a significant economic burden (Rom and Gunther, 2018). These patterns of household fuel use also increase the global accumulation of greenhouse gas emissions through forest degradation, fossil fuel combustion with the use of kerosene, and black carbon emissions. Beyond these spillover effects, battery-powered lighting provides a much higher quality of light (steadier, brighter illumination) per unit of energy input than kerosene (Barnes and Floor, 1996).

However, while use of solar lighting is growing, it remains limited. Recent studies in rural Africa have found that while household-scale off-grid solar is an economically sound option to reach mass electrification of household lighting, poor households' willingness to pay for this energy source is less than the level of price needed to cover costs (Grimm et al., 2020). Accordingly, subsidies would be needed to achieve widespread use of solar lighting by rural, off-grid households.

In Ethiopia, where this study is conducted, the use of renewable energy in urban areas (which constitute about 20% of the total population) is increasing, but the overwhelming majority of rural households continue to rely on biomass and kerosene as fuel sources for lighting.[1] While urbanization is rapidly increasing, the majority of Ethiopians will remain in rural areas for some time to come. This pattern of energy consumption in Ethiopia is similar to most sub-Saharan African countries.

Households face costs in shifting to solar energy sources, including the need to acquire and become familiar with the use of different equipment. Monetary costs can impede adoption

[1] The importance of kerosene as a source of lighting in rural Ethiopia is shown by a 2013 Lighting Africa Market Intelligence report which found that over 85% of rural households rely on fuel-based light sources, predominantly kerosene. Lighting Africa https://www.lightingafrica.org/country/ethiopia/

by low-income households even when the individual household benefits are fully understood. Households may not fully internalize private benefits in their purchase decisions, perhaps because of lack of information about such benefits, and they do not fully account for global externalities such as climate change. They also may face liquidity constraints in the purchase of the equipment.

To promote the uptake and usage of solar lighting, policy makers can provide potential purchasers with more information about the benefits of the technology, and they can use subsidies for the purchase of the equipment. Policies to provide monetary incentives are expensive from a budgetary perspective, and they may not assure the actual uptake of the technology by targeted households if there is behavioral inertia due to customs and traditions, as well as informational constraints (Ang et al., 2020).

Non-price motivations have played an increasingly important role during the last decade in efforts to accelerate adoption of renewable energy technologies. Experiments with non-market-based instruments have focused mainly on information provision, with a focus on individuals becoming more aware not only of the more direct and immediate benefits of the adoption of a given good (or technology or behavior), but also of indirect economic and environmental consequences of their actions. Especially in rural areas of low-income countries like Ethiopia where information on relatively new products such as solar lanterns may not be widespread and the level of education of recipients of such information is low, it may be important to examine the role of information on the benefits of such products. Non-price information-based instruments can be used in combination with market-based instruments to increase the adoption of solar lighting technologies. However, as noted in our literature review, the number and range of such investigations in developing countries remains limited.

Using a randomized experiment and Becker-Degroot-Marschak (BDM) willingness to pay (WTP) elicitation methods,[2] this study aims at investigating the effectiveness of both information provision and subsidies for adoption of and willingness to pay for solar lanterns for residential lighting in rural Ethiopia. The BDM bidding mechanism involves the actual purchase of the good in an incentive compatible way. It thus helps elicit the true willingness to

[2] For details please see the discussion in the section on experimental design.

pay of subjects in an experiment because subjects will not benefit by overstating or understating their willingness to pay.

Our study contributes to the literature in several ways. It adds to a still limited literature on the impacts of price and information policies for adoption of renewable energy technologies in developing countries. The experimental design includes provision of information (including information about monetary and time savings, health benefits and environmental benefits), such that we can assess the impact of the information provision on incentives to adopt the solar lantern. This responds to a finding in a recent systematic review of research on non-monetary energy-sector incentives by Liebe et al. (2018), which found that despite the growing importance of non-monetary incentives, studies of their impacts are limited in developing countries.[3]

Moreover, unlike previous papers on adoption of solar technologies that used the BDM method for WTP elicitation, this study uses a wide range of uniformly distributed prices that are truly randomly chosen. In addition to providing continuous data on prices at which the solar lantern is sold as part of the experiment, this provides flexibility for the empirical analysis where different categories of prices and implied subsidy levels can be used. In addition, the random price draw was done in front of the subjects, which increases the transparency of the process.

As expected, an increase in the subsidy increases the adoption rate. However, provision of information about the private and public benefits of the solar lantern alone did not have a significant effect on adoption rate and willingness to pay. Combining information with subsidies increases adoption only when the subsidy levels are between 50% and 75%. Most of the households would purchase the solar lantern in our study only if it were subsidized. This has important implications for achieving the UN Sustainable Development Goal (SDG7) and the related Sustainable Energy for All (SE4All) goal of universal electricity access and access to clean energy. We also found that a household's connection to the grid decreases adoption of and willingness to pay for the solar lantern, suggesting that grid electricity is a preferred source of lighting. Conversely, the use of kerosene for lighting

[3] We may note that respondents of the current study are from rural areas most of them living quite some distance away from the nearest towns where products such as solar lanterns are sold.

increases adoption of the solar lantern, suggesting kerosene is a less preferred lighting source. Access to credit increases willingness to pay perhaps suggesting that the potential to borrow when the need arises makes these respondents pay more.

The rest of the paper is organized as follows. Section 2 provides a brief review of the literature on the role of market-based and information-based policy instruments to influence pro-environmental behavior such as adoption of renewable energy technologies. In section 3, we discuss data, sampling strategy, experimental design and empirical strategy. In sections 4 and 5, we present a discussion of the descriptive and econometric results, respectively. Section 6 presents the main conclusions and policy recommendations.

2. Review of Literature

In this section, we present a review of studies on the roles of information and market-based policy instruments in addressing environmental problems.

2.1 Information Provision as a Policy Instrument: Energy Conservation

In the last couple of decades, there has been a growing trend in the use of information provision as an environmental policy instrument (Sterner and Coria, 2012; van den Bergh et al., 2021). Information provision attempts to influence people through provision of information, communication of reasoned arguments, and moral suasion to achieve a policy goal (Vedung and van der Doelen, 1998).

Numerous studies have shown that non-price incentives for energy conservation behavior can generate moderate but notable effects on energy consumption through providing individuals with various types of information including energy savings tips, historical usage, real time energy usage, and peer comparisons (Asensio and Delmas, 2015; Ito et al., 2015; Allcott and Rogers, 2014; Costa and Kahn, 2013; Ayres et al., 2013; Mizobuchi and Takeuchi, 2012; Allcott, 2011; Allcott and Mullainathan, 2010; Fischer, 2008; Abrahamse et al., 2005). Most of this research has been carried out in developed countries. A recent systematic review of research on non-monetary incentives in the energy sector by Liebe et al. (2018) finds that there are few studies in developing countries and none in Africa and South America (work by Sudarshan, 2017 in India is a notable example of a developing-country application).

Evidence also suggests that people exhibit heterogeneous responses when they are provided with information, with changes in behavior driven by observable characteristics such as ideology (Costa and Kahn, 2013). In addition, people react differently to the content of information they have been provided (Asensio and Delmas, 2015). There is also evidence of rebound effects in non-price information interventions because, as pointed out by Byrne et al. (2014), consumers underestimated their baseline energy consumption.

2.2 Information Measures and Willingness to Pay for Solar Lighting

Our study adds to a still-small literature exploring determinants of the willingness to pay for relatively low-cost solar lighting in developing countries. Rom and Gunther (2019) carried out a randomized field experiment in Kenya in which households received differing degrees of discount on a solar lamp, and subsequent use of the lamp was remotely monitored, in order to assess both willingness to pay and the potential reduction in kerosene use for lighting.

Two other papers use the BDM mechanism. Alem and Dugoua (2021) investigate the effects of information and social networks on the acquisition of solar lanterns in a non-electrified part of Uttar Pradesh, India. The program consisted of giving solar lanterns to randomly selected "seed" households, and then offering friends of these households the chance to purchase the lantern after some of the friends were given presentations on the lanterns by the seed households. Willingness to pay for the lantern was increased by virtue of contact with a seed household, but it was higher still with the information treatment. Meriggi et al. (2021) study the potential impacts of short-term subsidies for solar lamps on longer-term willingness to pay for the lamps in Cameroon. They find that the subsidies not only stimulate uptake but also increase longer-term willingness to pay.

3. Methodology

3.1 Baseline Data

Baseline data was collected from a survey of a stratified random sample of 810 rural households from 45 study sites in Ethiopia. Sites were purposely selected from the three largest regional states of Ethiopia (Amhara, Oromia, and Southern Nations, Nationalities and Peoples (SNNP) regional states) to maintain heterogeneity in site characteristics while also targeting sites that are not connected to the grid and not targeted by governmental and non-governmental organizations for dissemination of solar lanterns. In the rural areas we targeted, the level of education is low and information on relatively new products such as solar lanterns may not be very widespread.[4]

There were 18 randomly selected households in each of the 45 sites. As noted in the experimental design section below, all 810 households were subjected to the randomized field experiment. All households that were randomly selected and invited agreed to participate in the study.

To gather information about observable characteristics of our sample households, the baseline survey included questions about: (1) socioeconomic characteristics (including demographic characteristics and wealth), (2) fuel used by households for lighting and the corresponding equipment, (3) knowledge and perceptions of the environmental, health and other effects of using biomass and solar lanterns, and (4) social networks. As the survey was applied to a random sample of households in our study sites, interviewed households will be regarded as our experimental population. Respondents were household heads.

3.2 Experimental Design

After we collected data on baseline characteristics of households, we conducted an information provision experiment to promote the adoption of solar lanterns. This was followed by elicitation of the respondents' WTP using the BDM bidding method. The following is a summary of our experimental design; see also Figure 1.

First, we provided information as follows. Interviewed individuals in each village were randomly divided into two groups (treatment and control groups) and placed in two separate rooms. Each group consisted of 9 respondents. The treatment group was provided

[4] Respondents in this study are from rural areas quite some distance away from the nearest towns where products such as solar lanterns are sold. In addition, our data show that the average level of education of the respondents is less than 3 years. As noted in the experimental design section of this paper, information on private and public (environmental) benefits of the solar lantern used in the experiment is provided to treated respondents. While an attempt has been made in designing the treatment to focus on information that may not be provided by retailers of solar lanterns, the main idea is to assess the importance of the information provided to the treatment group compared to the control group that receives none of the information.

information on the private and environmental benefits of the solar lantern (see Appendix 4).[5] The information on private benefits included monetary savings for households who repeatedly buy lighting fuels such as kerosene; time saved to collect lighting fuel sources such as fuelwood and for trips to buy kerosene from the nearest market; a three times brighter light provided by the solar lantern, covering a wider area compared with using kerosene (and thus benefitting children studying in the evenings); and individual health and safety benefits when shifting from other energy sources such as kerosene and wood to solar lanterns.[6] The public (environmental) benefits of adopting solar lanterns included outdoor air pollution reduction, forest conservation and availability of fuelwood for future generations due to reduced use of fuelwood for lighting, and reducing battery waste.

The control group did not receive information on private and environmental benefits of the solar lantern. Each group also received general information on how the solar lantern is operated and charged and other facts about the product – the type of information expected to be obtained from retailers if a person decides to buy the item from the market.

The solar lantern we used for the study is the "Sun-king Pico" with a built-in solar panel (Figure 2). This solar lantern has three light modes (turbo mode with 25 lumens for 6 hours, normal mode with 13 lumens for 12 hours, and low power mode with 2 lumens for 72 hours). It is handheld and hangable with 360 degrees tilt; 3 times brighter than a kerosene lamp, with 5 years of battery life and 2 years warranty. The selling price of the solar lantern at the time of the survey was Birr 245 (about USD 8.75).

Figure 2 about here

[5] While our initial idea was to use separate treatments to examine the roles of information on private benefits and environmental benefits, we decided to combine the two given our sample size. Note that actual retailers in the market might or might not provide the private and environmental benefit information shown in Appendix 4, depending on factors that include the retailers' own knowledge, interest and ability to communicate. Moreover, the information provided to all the treated respondents is expected to be the same because it was provided in a room with treated households and communicated by the same group of fieldworkers trained and employed to conduct the study.

[6] The health and safety benefit information included a reduction in the risk of pulmonary and heart diseases from indoor air pollution associated with use of kerosene and wood for lighting, and reduction in fire hazards associated with use of kerosene lamps.

Second, after the information provision, in each room we elicited WTP using the BDM bidding method. Before respondents stated their maximum WTP for the solar lantern, we informed them about the decision mechanism underlying the BDM bidding method. Participants were told the range of prices used (i.e., the minimum and the maximum) in the experiment and were taken aside separately and asked by an interviewer to state verbally their maximum willingness to pay for the solar lantern. At the end, both groups (treatment and control) were gathered in one place and a random purchase price was selected from a bucket containing 24 possible prices ranging from 20 Birr to 250 Birr with an interval of 10 Birr between each price.[7] The highest possible price in the BDM experiment, 250 Birr, was 5 Birr (or 2%) higher than the market price of the solar lantern at the time of the survey. The lowest price was 8% of the market price. All prices except the highest price reflected a subsidy relative to the market price, but the fact that the price list included a subsidy was not announced to the participants. The purchasers of the solar lantern would pay the randomly drawn purchase price, not their WTP. We believed that allowing for a wide range of purchase prices across the separate BDM experiments would allow flexibility for the empirical analysis. In particular, we could consider outcomes for a number of randomly chosen prices, in contrast with previous studies in which only less than five different predetermined prices were used for all study sites.[8]

Under the above procedures, it would be in the best interest of the participants to bid according to their actual valuation of the solar lantern. This was explained to the respondents until we made sure it was understood. If a respondent's stated WTP was below their actual WTP and a price higher than their stated WTP but not more than their actual WTP was drawn, they would not be allowed to buy the solar lantern, even if they wanted to buy it at this

[7] The exchange rate at the time of the survey was 1 USD = 28 Birr. This implies that the range of 20 to 250 Birr is about 0.7 to 8.9 USD. The price interval of 10 Birr (about 36 US cents) is quite small. The 10 Birr interval was chosen because respondents' WTP was expected to typically be in multiples of ten. This is also confirmed by the distribution of WTP data we collected from this study, in which all respondents provided their responses in multiples of ten, except 7 of the 808 respondents, whose WTP was in multiples of 5. We also note that, while the maximum price of 250 in the range is more or less the same as the market price of the solar lantern, the minimum price of 20 Birr was chosen with the expectation that households may typically have a WTP of 20 or more; this is also confirmed by the results of the study, which show that only 5 of the 808 respondents had WTP of less than 20.

[8] We conjectured that using a price interval of 10 Birr includes most of the possible prices that the respondents would state, and that individuals may be inclined to think in terms of tens in formulating bids. Carrying out the random draw in front of all the subjects at the study site increased the transparency of the process. We thank Fredrik Carlsson and Francisco Alpízar for suggesting this approach in the design.

randomly drawn price. On the other hand, if their stated WTP was higher than their actual WTP and the randomly drawn price was higher than their actual WTP and not more than their stated WTP, they would be expected to buy the solar lantern even if they did not want to do so. Neither of these outcomes is in the best interest of the respondent. Individuals were also informed that if their stated willingness to pay was greater than or equal to the randomly drawn price, they would be given the opportunity to purchase the solar lantern at the randomly drawn price. The incentive-compatibility of the method leads us to believe that participants' stated WTPs are very good approximations of their actual WTPs.

Payment could be made immediately or after about a month. In cases where a household decided to purchase the solar lantern immediately, the household paid for and received the solar lantern at the end of the experiment. Individuals who wanted to pay later were visited after about a month, and the solar lantern was delivered immediately after the individuals made the payment.

After each member of the treatment and control groups was asked to state his/her WTP for the solar lantern, the two groups came together in one room where a purchase price was randomly drawn. Prior to that point, communication among participants between groups was prohibited: a member the treatment group would not know what happened with members of the control group and vice versa. The randomly drawn price was the same for all households in a study site, which is also in line with the practice in previous studies (eg, Grimm et al., 2020; Meriggi et al., 2021).[9] The communication prohibitions and use of a single price for all participants in a study site are important elements of the experimental design. Since the good is essentially a homogeneous private good with some spillover benefits, a single price would be expected by purchasers. Moreover, some of the households were willing to make the payment and receive the solar lantern after about a month; if prices differed in a site, communication among the households during this period could have spillover effects affecting the decisions of households, raising ethical issues as well as confusion.

3.3 Empirical Strategy

[9] There may be peer effects due to use of a single price for a site, such as a fear of missing out which may increase WTP, but also a possible desire not to bid too high and be seen as a fool which may decrease WTP. We cannot test these opposing effects from our data. Moreover, we believe the stated reason for using a single price for a site outweighs the potential disadvantages of such peer effects.

In line with previous studies that analyze decisions to adopt using BDM (as well as other methods such as CVM and DCE), we specify adoption of the solar lantern as the dependent variable in equation 1 which takes a value of one if the household (respondent) purchased the solar lantern based on the BDM bidding method and takes a value of zero otherwise. Adoption is based on the randomly selected purchase price of the solar lantern in the BDM experiment, which is why the selected purchase price is a right hand side variable in the adoption equation. This is also in line with previous studies including CVM studies where prices in the form of bids are used to explain adoption. Because the BDM mechanism generates different values of purchase prices at different villages, all drawn from the same uniform distribution, the effect of these prices on adoption is the same as a village-level random allocation of the prices.

We expect that informed (treated) households would be more likely to adopt for a given purchase price in the BDM procedure than uninformed (control group) households. To capture the combined effect of information and prices, we introduced an interaction term in our regression as in Equation 1.

$$Adoption_{ij} = \alpha + \beta_1 inf_i + \beta_2 Price_j + \beta_3 (inf_i \, x \, Price_j) + X_{ij}\lambda + \varepsilon_{ij} \quad (1)$$

where *inf* is a dummy variable taking a value of one if the respondent *i* is part of the information treatment group and zero otherwise, and price is a continuous variable which represents the randomly drawn price of the solar lantern in site/village j. As noted, the purchase prices in the BDM method are randomly drawn from a uniform distribution which is unknown to the participants (buyers). However, buyers do know the maximum and minimum possible purchase prices before the fact. Finally, X_{ij} is socio-economic characteristics of household i in site j, and ε_{ij} is the error term.

The presence of a continuous price variable in our study may provide an advantage of flexibility over a limited number of prices used in similar other studies (eg, Grimm et al., 2020; Meriggi et al., 2021). We take advantage of this flexibility and express the subsidy as a percentage of the market price of the solar lantern. We then use these to generate dummy variables representing different ranges of subsidy/price levels or subsidy as percentage of the full price. In our study, we generate three binary prices (i.e., price with 25% subsidy or less, price with subsidy between 25% and 50% and price with subsidy between 50% and 75%) and investigate whether the effect of these three price categories is different by comparing with a base category of subsidy higher than 75%.[10] This also allows us to evaluate whether effects of the different price ranges differ between individuals who received information and those who did not (by introducing interaction terms between the dummy variables representing price ranges and information treatment). This is shown in Equation 2.

$$Adoption_{ij} = \alpha + \beta_1 inf_i + \beta_2 P_{<25\%} + \beta_3 P_{25-50\%} + \beta_4 P_{50-75\%} + \beta_5 (inf_i\, xP_{<25\%}) + \beta_6 (inf_i\, xP_{25-50\%}) + \beta_7 (inf_i\, xP_{50-75\%}) + X_{ij}\lambda + \varepsilon_{ij}$$

(2)

where $P_{<25\%}$ is a dummy variable taking the value 1 if the price of the solar lantern in the village is with 25% subsidy or less including full price and 0 otherwise, $P_{25-50\%}$ is a dummy variable taking the value 1 if the price of the solar lantern in the village is between 25% and 50% subsidy and $P_{50-75\%}$ is 1 if the price is between 50% and 75% subsidy. This classification of price categories is necessitated by the nature of the experimental design where we considered a range of 24 different prices. As noted, this is unlike most previous studies which use only three or four different prices from which a price is randomly drawn for a site; these previous studies often refer to a particular subsidy level in their analysis, such as 25% subsidy, because the probability that this price will be picked from a range of three or four different prices is very high (e.g., 33.3% if only three prices are used). In these studies, the decision on which site receives which price is made before the fieldworkers go to the sites to conduct the study. However, in our case the approach we followed would typically give us a very small percentage of subjects for whom a particular price is randomly picked, considering that the probability of this happening is very low due to a wide range of different prices considered (about 1 in 24 or less than 5%). The rest of the variables in Equation 2 are as defined in Equation 1.

[10] Unlike other studies, such as Merggi et al. (2021), who could include only two dummy variables representing two price/subsidy levels with a third one as the base category, we also could have defined these dummy variables based on another categorization of these dummy variables, for example, a total of five different dummy variables with an interval of 20% instead of the 25% interval used here. It may also be noted that the different dummy variables we used to represent subsidy percentages can also be interpreted as dummy variables for ranges of prices or subsidy levels with higher subsidy percentages representing lower prices or higher subsidy levels.

In addition to the effect of information and subsidy on adoption of the solar lantern, we also study the effect of information on households' WTP for the solar lantern obtained from the BDM process. This can be analyzed using Equation 3.

$$WTP_{ij} = \delta + \theta inf_i + X_{ij}\gamma + v_{ij} \qquad (3)$$

where WTP is willingness to pay obtained from the BDM, X is socio-economic characteristics of the household and v_{ij} is the error term.

In Equations 1 and 2 above, the parameters $\beta's$ capture the effect of information provision and/or prices on adoption of the solar lantern. We expect the coefficients of the information variable in each model to be positive because households may not adopt this product partly because of limited awareness of the full benefits (i.e., both the private and environmental benefits) of the solar lantern. We expect the coefficients of price variables in both equations to be negative because households are less likely to buy if the purchase price in the BDM procedure is larger). Likewise, the parameter θ in Equation 3 captures the effect of information on individuals' stated WTP, and it is expected to be positive because those who got information on private and environmental benefits of the solar lantern are expected to value the product more and be willing to pay a higher price. Moreover, parameters λ and γ capture the effect of socio-economic variables on adoption of, and WTP for, the solar lantern, respectively; and α and δ are constant terms.

Because the dependent variable in Equations 1 and 2 is binary, non-linear models such as logit and probit are the most commonly used methods of estimation. However, when one or more interaction terms are involved in these models, computation of marginal effects from these non-linear models involves practical difficulty and cannot be interpreted easily.[11] Instead, we used a linear probability model (LPM) because the coefficients are easy to interpret and marginal effects are easy to compute. In fact, Angrist and Pischke (2009) and Wooldridge (2019) note that OLS estimates of LPM produce coefficients that are mostly statistically indistinguishable from the marginal effects of the probit model especially when the average values of the variables are considered. To address heteroskedasticity that arises when using OLS to estimate LPM with dummy dependent variables, we estimate robust

[11]Although there is an "inteff" Stata command to estimate the "marginal effect" of interaction effects, this command does not produce the marginal effect of the main variables taking the interaction into account.

standard errors (Wooldridge 2019). Moreover, because our measure of the individuals' WTP is non-negative continuous variable and only three respondents stated a zero willingness to pay, we use the OLS method to estimate the effect of information provision on WTP that was gathered through the BDM bidding method.

4. Descriptive Statistics

This section discusses the descriptive statistics of the outcome variables, treatment variables and key socio-economic characteristics of the households in our study. Table 1 presents descriptive statistics of key socio-economic characteristics of the households considered in our study for the overall sample as well as for treatment and control groups.

As shown in Table 1, on average about 61% and 58% of the information treatment and control households, respectively, used kerosene as the main source of light in their house. These figures mean that the percentage of households using kerosene in the treatment and control groups is somewhat lower than the national estimate of 85% mentioned previously. In terms of use of clean lighting energy sources, about 11% and 12% of the treatment and control households, respectively, used solar, and 2.7% and 1.5% of the treatment and control households are connected to grid electricity. This is consistent with the World Bank's MTF survey for Ethiopia, which finds that about 11% of households get electricity access through off-grid electricity sources and those are mainly through solar technologies (MoWIE, 2019). The data also show that about 84% of the respondents used rechargeable lump battery for lighting.[12]

Table 1 about here

On average, treatment household heads were about 47 years old, and had about 3 years of education; about 92% were married and 92% were male. Likewise, the control household heads were about 48 years old, and had about 2.6 years of education; about 92% were married

[12] These rechargeable batteries typically require access to electricity to be recharged. Consequently, they are typically not used frequently as recharging them would be costly in terms of time spent to travel to where electricity is available for recharging and possible payments for recharging services.

and 94% were male. The treatment households had on average 5.8 household members and about 86,000 Birr worth of assets; 98% of them owned houses with an average of 2.4 rooms and spent about 288 Birr per month for lighting. Similarly, the control households had on average 5.8 household members and about 93,000 Birr worth of assets; 98% of them owned houses with an average of 2.4 rooms and spent about 270 Birr per month for lighting.

We conducted a balancing test to evaluate the similarity of control and treatment households using both simple mean difference and regression analysis. Table 1 shows the mean difference between control and treatment units on key socio-economic characteristics, and Table 2 presents regression results of the balancing test. In both Tables 1 and 2, the treatment and control households are similar for most of the variables at the baseline, except the variables gender, age and education of the household head. In particular, control household heads were slightly older and slightly less educated, although the assignment of respondents to the two groups was random (Table 1). The regression for the balance test also shows that there were fewer male-headed households in the information treatment group (which was weakly significant). This implies we need to include these variables in our regression to analyze adoption and WTP.

Table 2 about here

We also find that about 59% and 57% of treatment and control households, respectively, adopted the solar lantern in the experiment. A simple mean difference test shows that there is no statistically significant difference in the number of adopters between the two groups, which means that the information we provided did not make a significant difference in promoting the adoption of the solar lantern. The results also show that the mean of the treatment households' WTP is slightly higher than control households, but this difference is only weakly significant at 10% level. Nonetheless, this weakly significant difference did not result in a significant difference in the number of adopters between the two groups.

The randomly picked BDM price ranged from 20 Birr to 250 Birr with a mean of 122 Birr. For about 50% of the respondents, the randomly picked price was 130 Birr or less (which is about half of the market price of the solar lantern). On the other hand, the maximum willingness to pay of the respondents was on average 147 Birr and ranged from 0 to 2000

Birr.[13] About 50% of the respondents were willing to pay more than 50% of the market price of the solar lantern. About 15% of the subjects were willing to pay more than the full price of the solar lantern. However, about two-thirds of those who were willing to pay more than the full price were willing to pay only 5 Birr more than the full price.

Figure 3 shows the percentage of actual adopters at different levels of price. The percentages are computed from sites that had the corresponding prices. We note from Figure 3 that the percentage of adopters increases when the BDM purchase price is lower. Specifically, for sites where the price drawn was less than 10 percent of the market price, 100% of the respondents in those sites adopted the solar lantern. With a price no larger than 25 percent of the market price, the percentage of respondents adopting drops by only 5 percent (to 95 percent). The percentage adopting decreases to 69 percent in sites where the BDM price is at least 75 percent of the market price.[14] Given that our sample is made up of low-income rural households, our findings indicate that although the solar lantern under study is not very expensive (with a full price of less than 9 USD), and most of them were sold in our experiments at much less than the market price, most of the households in the study area will only purchase the solar lantern at less than the market price. Our experiment does not reveal a reason for this other than the cost relative to WTP, but it also could be partly due to previous negative experiences or the spread of information about low-quality solar lanterns in the market. Large quantities of solar lanterns are dumped into the market through illegal channels, which is likely to affect the sustainability of the market in the absence of well-established higher-quality brands.[15]

Figure 3 about here

[13] Considering that there were high extreme values (some of which were about 8 times more than the market price of the solar lantern under study), in the econometric analysis we tried to examine whether removal of such extreme values changes the results.

[14] As noted, this is an advantage of our experimental design; unlike most previous studies, the fieldworkers actually did the random draw of the prices from the full list of 24 uniformly distributed prices in each of the 45 villages covered by the study. Because we use over 20 different subsidy levels, our approach provides flexibility, for example, in terms of being able to pick a wide range of subsidy levels and examining their implications; our approach also involves transparency, as the prices are drawn at random in front of the subjects.

[15]Please see the following website about the diffusion of bad quality solar lanterns in Ethiopia: https://www.greentechmedia.com/articles/read/unlocking-an-energy-revolution-in-ethiopia-with-lessons-from-the-black-mark#gs.22joj9

As discussed in the experimental design section, households were also given the opportunity to pay later (after a month). About 34% of the households who were willing to buy at the randomly drawn prices made the payment after a month, while 66% made the payment and received the solar lantern at the time of the experiment. Respondents who chose to pay later could have different reasons, including the fact that they were not ready to pay. In the context of the study area, the only way they could pay immediately was in cash. Not having the required cash at the moment and not being able to borrow from people they know from the sample households would preclude paying immediately. It is possible that some of the respondents who chose to pay a month later did so partly to benefit from the time delay due to the time value of money. This would in turn imply that the willingness to pay of these respondents would have been smaller if they paid immediately, due to discounting.

However, considering that the difference in the date of payment is only one month and that the full price is less than 9 US dollars, with most of the respondents in the experiments paying significantly subsidized prices, the difference in cost between those who paid immediately and those who paid after about a month was not very large. Moreover, those who paid immediately would be compensated by the benefit from use of the solar lantern immediately. In the econometric analysis, we examine whether the results differ if the WTP of those who paid a month later is discounted at 1% to calculate the present value.

Households whose WTP was less than the randomly drawn price were not given the opportunity to buy the technology even if they changed their mind for some reason, including cases where a very low price was drawn which is only slightly higher than their WTP. Of 340 respondents who did not adopt the solar lantern, 22 (which is less than 3 percent of the total sample) changed their mind and decided not to buy the solar lantern although their WTP was equal to or greater than the price drawn (referred to as decliners). We may also note that households were provided a show-up fee of 50 Birr. Because of this, one may expect that these households might have changed their mind if their WTP was less than the randomly drawn price of 50 Birr or less. In 11 out of the 45 villages (about 24% of the villages under study), the randomly drawn price was 50 Birr or less. However, only 1 of the 22 respondents who changed their mind (less than 5%) was from a village where the randomly drawn price was 50 Birr or less.[16]

Figure 4 depicts the demand curve for the solar lantern, showing willingness to pay and the corresponding percentage of respondents after excluding decliners. We note from the figure that, unlike the findings of Grimm et al. (2020), we do not observe anchoring at the lower bound of the price range announced to the respondents (20 Birr). A possible reason is that we considered a wide range of prices relative to the market price—a range covering almost all possible prices, with the lowest price being only about 8 percent of the market price. We also see that willingness to pay appears to cumulate around multiples of 50, starting from 50 and ending with 250.

Figure 4 about here

One of the key conclusions of the descriptive analysis is that, similar to the findings of Grimm et al. (2020) for Rwanda, most of the subjects would purchase the solar lantern only if it is subsidized. Grimm et al. (2020) also find that providing solar lanterns on credit may not address the problem either. Thus, meeting the UN's SDG7 and the SEforAll objective of universal electricity access would be possible only if some form of subsidy is introduced for a portion of the population.

5. Econometric Results

As discussed in the empirical strategy section, we estimate the effect of information and prices on households' adoption and WTP for the solar lantern.

5.1. Analysis of Adoption

[16] We may also note that less than 2% of respondents of villages where the randomly picked price was 50 Birr or less did not buy the solar lantern, suggesting that the take-up was high in villages where the randomly picked price was low combined with the show-up fee of 50 Birr that was given to each respondent.

Tables 3 and 4 present regression results showing the effect of information and prices/subsidy on the adoption of the solar lantern at continuous and dummy prices, respectively. Regression results are presented with and without controls.

Table 3 about here

As shown in Table 3, the price variable has a negative sign and is statistically significant at the 1% level, indicating that lower solar lantern prices increase incentives for rural households to adopt the solar lantern. The demand is inelastic: a one percent decrease in the price of the solar lantern increases the rate of adoption by 0.4 percentage points. This is consistent with the descriptive results, which show that at full price there were only 5 households that adopted the solar device and that, when the subsidy changes to 25% of the price or less, only 38 households adopted the solar lantern. The number of adopters reached 53% only when the subsidy reached 90% of the price or less.

Table 4 shows the effect on lantern adoption of the different price/subsidy levels. We define three dummy prices in Table 4 as less than 25% subsidy, 25% to 50% subsidy and 50% to 75% subsidy, while subsidy of 75% or more is the reference category. Considering that these three dummy prices represent higher prices compared with the reference category, estimated coefficients are expected to be negative. Regression results are presented with and without controls. The coefficients are interpreted relative to more than 75% subsidy, which is the reference category. The coefficients of the three subsidy variables are negative and statistically significant at the 1% level, showing that adoption is lower when subsidy as a percentage of the full price is lower. The magnitude of the coefficients shows that the effect is stronger at higher prices or lower subsidy levels.

Table 4 about here

Consistent with the descriptive results above, provision of information about the private and public benefits of the solar lantern did not make a significant difference in the rate of adoption (see Tables 3 and 4). Further, a combination of price incentives and information (i.e., their interaction) also did not have a significant effect on adoption, except in the case where a subsidy level of 50% to 75% of the full price is interacted with information, which was significant at the 5% level.

In Tables 3 and 4, we also considered the effect of control variables on adoption. The results show that households that are connected to grid electricity are less likely to adopt the solar lantern, suggesting that the former is a preferred substitute for lighting. We also find that at the village level, villages that are connected to the grid are more likely to have a higher adoption rate, but the coefficient is only weakly significant. In contrast, households that used kerosene for lighting were more likely to adopt the solar lantern, consistent with the widely understood view that solar is a preferred substitute. Households that lived farther away from the market were more likely to adopt the solar lantern, most likely reflecting the higher burden for them of travel to purchase kerosene; but this is only weakly significant.

5.2 Analysis of WTP

Table 5 presents the effect of information provision on individuals' WTP for the solar lantern. We find that the information treatment does not have a significant effect on WTP. Similarly to the results for adoption, households that are connected to the grid have a lower willingness to pay in the BDM procedure compared with those not connected, which is expected. Moreover, households that have better access to credit have a higher willingness to pay for the solar lantern, perhaps suggesting that possible access to credit when there is a need to borrow makes respondents pay more.[17] Households that used fuel wood for lighting and are farther away from the market have a higher willingness to pay which is consistent with the

[17] It should be noted that in the BDM procedure we allowed respondents to pay a month later and one may argue that this is related to credit access. However, our credit access variable represents the possibility to borrow Birr 400 or more when the need arises. We also see from the data that while about 80 percent of the sample households (646 in number) have access to credit, only 158 respondents that purchased the solar lantern wanted to pay a month later (and over 80 percent of the latter reported having access to credit). As noted elsewhere in the paper, one main reason for this being interested in purchasing the solar lantern after a month may be that they did not have the cash to pay immediately.

higher cost they have for purchasing wood and the much higher quality of lantern light relative to lighting from fuel wood. However, these results are weakly significant.

Table 5 about here

We also briefly discuss below the sensitivity of the analysis of WTP to the following three issues: the effect of extremely large WTP in the sample; the effect of differences in stated WTP between those who collected the solar lantern after paying immediately, and those who paid and collected the solar lantern a month later; and the effect of removing respondents who did not purchase the solar lantern although they were eligible to do so in the BDM process (decliners).

We noted that there are some extremely large WTP values among our sample of participants, including some that are much higher than the maximum price of the solar lantern. Since we informed participants about the price range (the minimum and the maximum) and explained the nature of the bidding mechanism we used, for a respondent to ensure eligibility to buy the solar lantern, it would be enough to state a WTP equal to the highest price in the range. Some subjects' WTPs were quite high; the most extreme case was 8 times the market price of the solar lantern. Values this high may reflect a misunderstanding of the mechanism. We ran a regression excluding these very large values, and the main results are robust to their removal (Appendix 1).

To examine the possible effects of differences in WTP between those who paid and collected the solar lantern a month later compared to those who immediately paid and collected the solar lantern, we discounted the WTP of respondents who paid about a month later at the rate of 1 percent per month. The results of the regression analysis also are robust to this change (Appendix 2). The results are robust as well to exclusion of respondents who declined to purchase the solar lantern in spite of stating a willingness to pay larger than or equal to the randomly drawn price (Appendix 3).[18]

[18] We also combined these three cases and the results (not reported here) are also robust to these changes.

6. Summary and Conclusion

About 620 million people in sub-Saharan Africa do not have access to grid electricity services. Off-grid electricity sources such as solar lantern are options, especially for reaching the rural poor living in remote and dispersed settlements for whom the cost of grid-electricity supply is quite high. However, penetration of off-grid electricity is also very limited. In Ethiopia, only 11% of rural households use off-grid electricity sources. The majority of rural households continue to rely on biomass and kerosene as fuel sources for lighting.

This study examined the role of information and price discounts as policy instruments to increase the willingness of potential purchasers in rural Ethiopia to pay for solar lanterns, and to augment their adoption. We use the BDM method to analyze preferences of rural households towards solar lanterns. Our sample included 810 subjects from 45 sites. The experimental design involved dividing households in each site into two randomly selected groups, with one receiving an information treatment while the other did not, followed by the execution of the BDM procedure that led to selling the solar lantern to those whose willingness to buy was higher than the randomly chosen price and were willing to buy it.

Our results indicate that as would be expected, a decrease in price increases the rate of adoption, though the adoption decision is price-inelastic. Provision of information about the private and public benefits of the solar lantern generally did not make a significant difference in the rate of adoption, except in cases where a subsidy of 50% to 75% of the full price is combined with information provision. In spite of the information provided to respondents about the quality of the solar lantern and the different benefits it provides, these results may have been influenced by previous information that respondents had about the benefits of the solar lantern used in the experiment or other low quality solar lanterns they may have heard about or experienced. Consistent with intuition, our results also show that households who use kerosene for lighting are more likely to adopt the solar lantern, while households that are connected to the grid are less likely to adopt it. Households with access to credit have a higher WTP.

In our study, similar to the findings of Grimm et al. (2020), most of the subjects would purchase the solar lantern only if they can obtain it for less than the market price – for some subjects, substantially less. The results imply that meeting the UN SDG7 and the related SEforAll goal of universal electricity access will be possible only if some form of subsidy is introduced for a portion of the population. As Grimm et al. (2020) note, providing solar lanterns on credit may not address the problem either.

Accordingly, to achieve its goal of 100% electrification, where 35% of the goal is to be achieved via off-grid solutions such as solar technologies (MEFCC and SNV 2018), the Ethiopian government needs to devise effective policy instruments. Our results indicate that simply providing information about the lantern technology has very limited effect. The real constraint to high adoption is the price of the technology relative to willingness to pay for many low-income households. This is however true of some other important household consumption goods as well. Because solar lanterns already are available in markets, one possibility for broader adoption is reduction in cost from competition and innovation while also addressing any issues with quality of the products through effective monitoring.

Appendices

Appendix 1. Effect of Information on WTP for Solar Lantern with Controls (excluding extreme values of WTP)

Variables	**Coef**	**Se**
Information	9.489	5.765
Gender of household head (1=Male, 0=Female)	1.566	20.409
Marital status (1 if married, 0 otherwise)	0.824	17.303
Education of household head in years	1.576	1.003
Age of the household head in years	-0.274	0.241
Household size	0.254	1.573
Value of total assets in Birr	0.000	0.000
Number of rooms in the house	2.569	3.765
Household connected to grid (1 if yes, 0 otherwise)	-56.504***	14.270
Household uses solar light (1 if yes, 0 otherwise)	3.095	10.672
Household uses kerosene for lighting (1 if yes, 0 otherwise)	7.609	6.669
Household uses fuel wood for lighting (1 if yes, 0 otherwise)	24.177*	13.318
Access to credit (1 if access to 400 Birr or more, 0 otherwise)	12.234*	6.741
Distance to the market	0.788	0.521
Distance to the nearest road	0.012	0.030
Distance to the nearest town	0.318	0.244
Village has access to grid (1 if yes, 0 otherwise)	7.367	8.675
Constant	101.011***	20.979
Observations	800	
R-squared	0.06	

Note: *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is amount respondents are willing to pay in Birr (obtained from the BDM mechanism).

Appendix 2. Effect of Information on WTP for Solar Lantern with Controls (with late payments discounted)

Variables	Coef	Se
Information	14.479	8.903
Gender of household head (1=Male, 0=Female)	31.295	30.671
Marital status (1 if married, 0 otherwise)	-17.737	30.276
Education of household head in years	-0.263	1.325
Age of the household head in years	-0.263	0.315
Household size	-1.328	2.415
Value of total assets in Birr	0.000	0.000
Number of rooms in the house	2.659	5.424
Household connected to grid (1 if yes, 0 otherwise)	-55.364***	14.830
Household uses solar light (1 if yes, 0 otherwise)	-3.318	11.200
Household uses kerosene for lighting (1 if yes, 0 otherwise)	12.710	10.690
Household uses fuel wood for lighting (1 if yes, 0 otherwise)	30.342*	15.889
Access to credit (1 if access to 400 Birr or more, 0 otherwise)	16.417**	7.957
Distance to the market	1.518*	0.902
Distance to the nearest road	0.031	0.040
Distance to the nearest town	0.048	0.284
Village has access to grid (1 if yes, 0 otherwise)	5.168	9.237
Constant	94.837***	33.320
Observations	806	
R-squared	0.042	

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Dependent variable is amount respondents are willing to pay in Birr (obtained from the BDM mechanism).

Appendix 3. Effect of Information on WTP for Solar Lantern with Controls (with decliners excluded)

Variables	Coef	Se
Information	14.137	9.184
Gender of household head (1=Male, 0=Female)	30.219	30.660
Marital status (1 if married, 0 otherwise)	-17.783	30.255
Education of household head in years	-0.239	1.367
Age of the household head in years	-0.281	0.322
Household size	-1.206	2.476
Value of total assets in Birr	0.000	0.000
Number of rooms in the house	2.808	5.592
Household connected to grid (1 if yes, 0 otherwise)	-57.504***	16.600
Household uses solar light (1 if yes, 0 otherwise)	-4.123	11.574
Household uses kerosene for lighting (1 if yes, 0 otherwise)	11.477	11.065
Household uses fuel wood for lighting (1 if yes, 0 otherwise)	29.106*	16.652
Access to credit (1 if access to 400 Birr or more, 0 otherwise)	17.337**	8.131
Distance to the market	1.470	0.914
Distance to the nearest road	0.031	0.041
Distance to the nearest town	0.032	0.292
Village has access to grid (1 if yes, 0 otherwise)	3.225	9.498
Constant	98.522***	33.975
Observations	784	
R-squared	0.041	

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Dependent variable is amount respondents are willing to pay in Birr (obtained from the BDM mechanism).

Appendix 4. Information treatment

INSTRUCTIONS TO BE READ BY THE INTERVIEWER TO MEMBERS OF THE GROUP THAT RECEIVES THE INFORMATION TREATMENT

Interviewer: Record which version of the instrument is used: 1. Including the information presented below on private and public benefits of the solar lantern. 2. Not including the information on private and public benefits of solar lanterns.
The following is a description of the information provided to treated respondents on the private and public (environmental) benefits of the solar lantern. After this description discussion is held with respondents as a group including responses to questions from the respondents.

Private benefits of adopting the solar lantern are:
1, Savings on fuel expenditure such as kerosene and diesel that you use for lighting (reduction in energy expenditure per lumen);
2. Three times brighter light covering larger area compared with kerosene or diesel lamps. This is expected to especially help students who study in the evening;
3. Savings in time spent to purchase kerosene and diesel with repeated trips to towns and collecting fuelwood that you may use for lighting;
4. Reduction in the risk of suffering from pulmonary and heart diseases from indoor air pollution associated with use of kerosene and wood for lighting; and
5. Reduction in fire hazards associated with use of kerosene lamps and

Public (environmental) benefits of adopting the solar lantern include:
1. Outdoor air pollution reduction due to reduced use of fuelwood and kerosene;
2. Forest conservation and availability of fuelwood for future generations made possible by reduction in use of fuelwood for lighting, and
3. Reduction in battery waste due to reduced use of batteries for lighting which helps reduce environmental degradation.

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Figure 1. Experimental Design

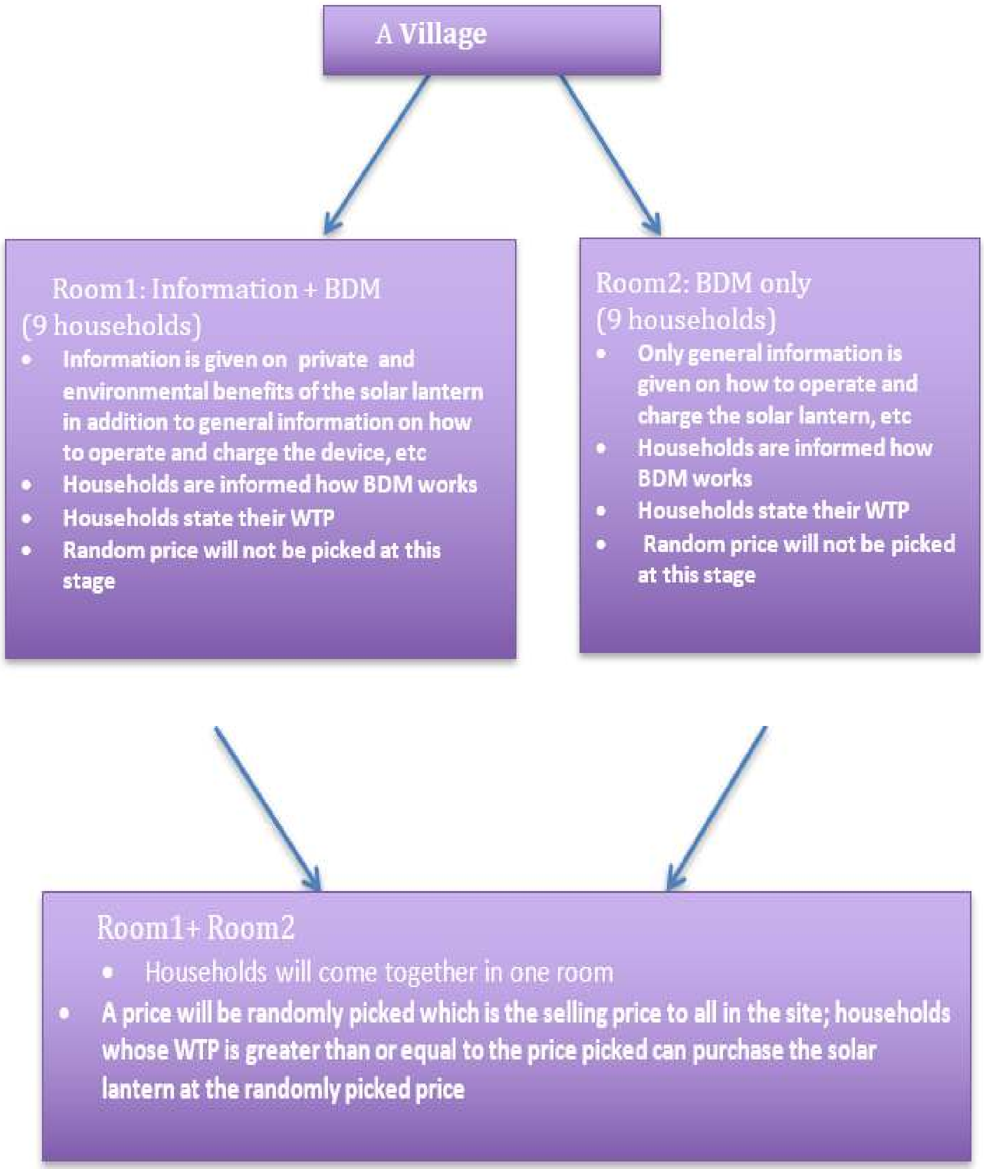
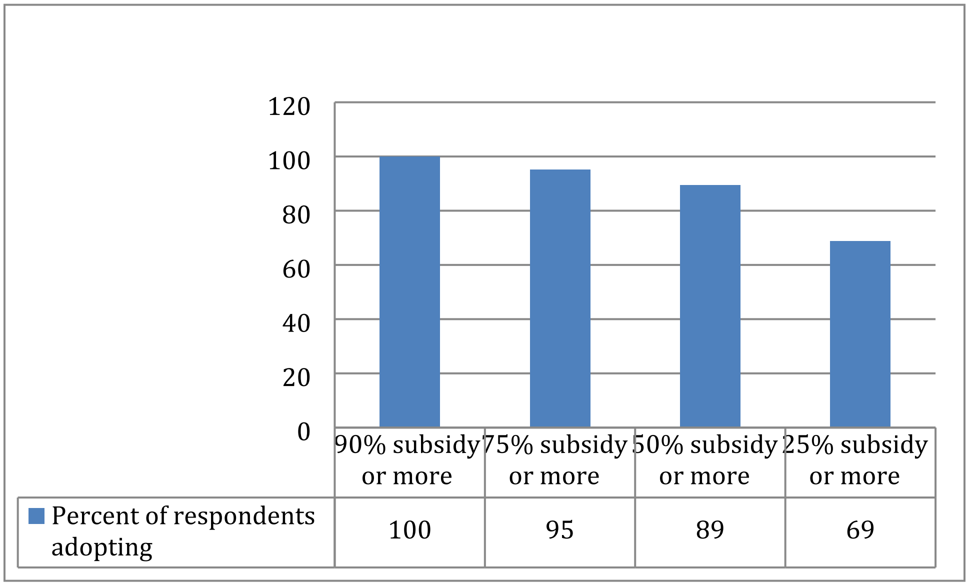


Figure 2. The Solar Lantern used (Sun-king Pico)

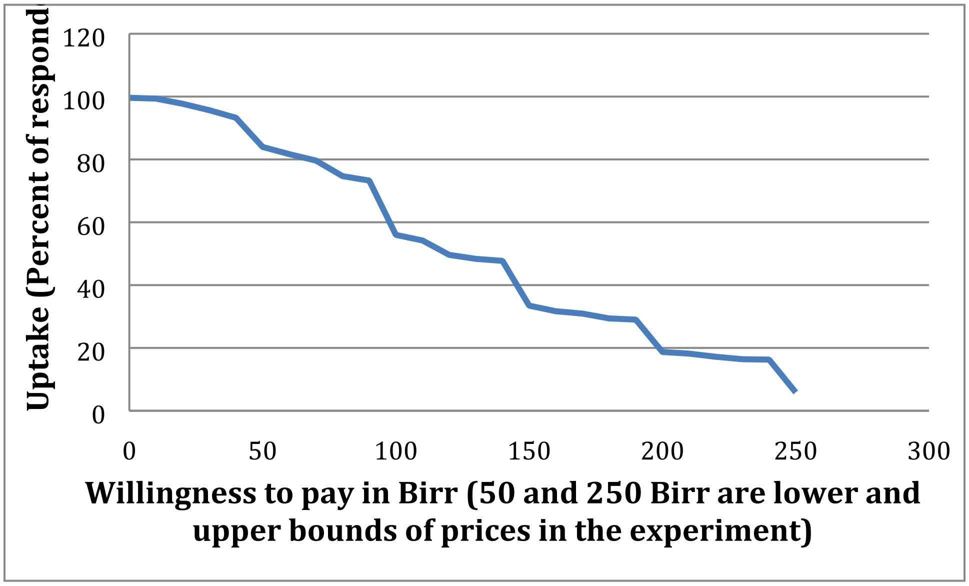
Note: Front view (left) and back view (right)

Figure 3. Percent of Respondents Adopting by Subsidy Level



*The percentage of respondents adopting is calculated for sites where the subsidies actually applied based on the price drawn.

Figure 4. Demand for Solar Lantern



*WTP in this figure does not include decliners (who are less than 3% of the total sample). The uptake as shown by the percentage of respondents assumes that all subjects would purchase the solar lantern if their WTP is greater than the corresponding price drawn.

Table 1. Summary Statistics[a]

Variables	Description	Overall mean	Treatment Group (1)	Control group (2)	Difference (1) - (2)	p-value
Household characteristics						
Age	Age of household head in years	46.866 (0.460)	45.800 (0.650)	48.094 (0.656)	-2.294 (0.923)	0.013
Gender of head	Sex of head (1if male)	0.931 (0.009)	0.923 (0.013)	0.938 (0.012)	-0.015 (0.018)	0.407
Education	Education level of head in years	2.855 (0.112)	3.099 (0.167)	2.610 (0.148)	0.488 (0.223)	0.029
Household size	Household size	5.781 (0.071)	5.768 (0.100)	5.794 (0.102)	-0.026 (0.143)	0.855
Wealth measures						
Asset Value	Total asset value in 000 Birr	90 (59.882)	86 (54.909)	93 (10.139)	-7 (11.713)	0.518
House ownership	Own house (1 if yes)	0.998 (0.002)	0.995 (0.003)	1.000 (0.000)	-0.005 (0.003)	0.157
Rooms	Number of rooms in the house	2.388 (0.027)	2.404 (0.037)	2.368 (0.039)	0.037 (0.054)	0.500
Separate kitchen	Separate kitchen (1 if yes)	0.764 (0.015)	0.764 (0.021)	0.760 (0.021)	0.004 (0.030)	0.900
Thatched roof	House has thatched roof (1 if yes)	0.226 (0.015)	0.222 (0.021)	0.232 (0.021)	-0.010 (0.029)	0.738
Galvanized iron roof	House has galvanized iron roof (1 if yes)	0.755 (0.015)	0.756 (0.021)	0.753 (0.021)	0.002 (0.030)	0.935
Energy features						
Rechargeable lump battery	Use of rechargeable lump battery for lighting	0.837 (0.013)	0.827 (0.019)	0.846 (0.018)	-0.019 (0.026)	0.466
Kerosene	Use of kerosene for lighting (1 if yes)	0.594 (0.491)	0.612 (0.024)	0.576 (0.024)	0.0370 (0.035)	0.29
Solar energy	Use of solar panel for lighting (1 if yes)	0.121 (0.011)	0.114 (0.016)	0.129 (0.017)	-0.015 (0.023)	0.502
Village grid access	Village access to grid (1 if yes)	0.178 (0.013)	0.175 (0.019)	0.180 (0.019)	-0.005 (0.027)	0.854
Connected to grid	Household connected to grid (1 if yes)	0.020 (0.005)	0.027 (0.008)	0.015 (0.006)	0.012 (0.010)	0.221
Expenditure for lighting	Monthly expenditure for lighting in Birr	279.471 (13.299)	288.144 (18.721)	270.754 (18.908)	17.390 (26.608)	0.514
N	Total number of households	808	405	403	808	

[a] Standard deviations are in parentheses.

Table 2. Balance Test Results (OLS regression)

Dependent variable: 1 if Information received; 0 otherwise		
Variables	**Coef.**	**se**
Gender of household head (1=Male, 0=Female)	-0.204*	0.108
Marital status (1 if married, 0 otherwise)	0.140	0.096
Education of household head in years	0.010	0.006
Age of household head in years	-0.002	0.002
Household size	-0.003	0.010
Value of total assets in Birr	-0.000	0.000
Number of rooms in the house	0.013	0.025
Household connected to grid (1 if yes, 0 otherwise)	0.192	0.128
Household uses solar light (1 if yes, 0 otherwise)	-0.021	0.057
Household uses kerosene for lighting (1 if yes, 0 otherwise)	0.033	0.040
Household uses fuel wood for lighting (1 if yes, 0 otherwise)	0.016	0.073
Access to credit (1 if access to more than 400 Birr)	0.028	0.046
Distance to market	0.001	0.003
Distance to nearest road	0.000	0.000
Distance to nearest town	-0.001	0.002
Village has access to grid (1 if yes, 0 otherwise)	-0.024	0.051
Constant	0.571***	0.129
Observations	806	
R-squared	0.021	

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 3. OLS Regression of the Effect of Information and a continuous Price on Adoption of Solar Lantern

	Without control		With controls	
Variables	**Coef.**	**se**	**Coef.**	**se**
Randomly drawn price	-0.004***	0.000	-0.004***	0.000
Information treatment	-0.005	0.037	-0.008	0.039
Information treatment X Randomly drawn price	0.000	0.000	0.000	0.000
Gender of household head (1=Male, 0=Female)			0.112	0.095
Marital status (1 if married, 0 otherwise)			-0.111	0.087
Education of the household head in years			0.005	0.005
Age of household head in years			-0.001	0.001
Household size			-0.003	0.007
Value of total assets in Birr			0.000	0.000
Number of rooms in the house			0.013	0.019
Household connected to grid (1 if yes, 0 otherwise)			-0.246***	0.068
Household uses solar light (1 if yes, 0 otherwise)			0.016	0.041
Household uses kerosene for lighting (1 if yes, 0 otherwise)			0.076**	0.033
Household uses fuel wood for lighting (1 if yes, 0 otherwise)			0.063	0.063
Access to credit (1 if access to 400 Birr or more, 0 otherwise)			0.030	0.033
Distance to market			0.004*	0.002
Distance to nearest road			0.000	0.000
Distance to nearest town			-0.000	0.001
Village has access to grid (1 if yes, 0 otherwise)			0.072*	0.039
Constant	1.109***	0.026	1.010***	0.100
Observations	808		806	
R-squared	0.399		0.423	

Note: *** p<0.01, ** p<0.05, * p<0.1; Adoption =1 if household purchased at randomly drawn price and =0 otherwise

Table 4. OLS Regression of the Effect of Information and Dummy Prices on Adoption of Solar Lantern

	Without control		With control	
Variables	**Coef.**	**Se.**	**Coef.**	**Se.**
Less than 25% subsidy	-0.772***	0.045	-0.786***	0.049
25% to 50% subsidy	-0.656***	0.045	-0.649***	0.047
50% to 75% subsidy	-0.312***	0.067	-0.313***	0.071
Information	-0.041	0.025	-0.038	0.028
Information X Less than 25% subsidy	0.059	0.066	0.067	0.067
Information X 25% to 50% subsidy	0.082	0.067	0.063	0.069
Information X 50% to 75% subsidy	0.196**	0.088	0.176**	0.087
Gender of household head (1=Male, 0=Female)			0.116	0.092
Marital status (1 if married, 0 otherwise)			-0.105	0.086
Education of household head in years			0.002	0.005
Age of household head in years			-0.001	0.001
Household Size			0.000	0.007
Value of total assets in Birr			0.000	0.000
Number of rooms in the house			0.013	0.018
Household connected to grid (1 if yes, 0 otherwise)			-0.221***	0.070
Household uses solar light (1 if yes, 0 otherwise)			-0.034	0.042
Household uses kerosene for lighting (1 if yes, 0 otherwise)			0.078**	0.032
Household uses fuel wood for lighting (1 if yes, 0 otherwise)			0.070	0.064
Access to credit (1 if access to 400 Birr or more, 0 otherwise)			0.020	0.032
Distance to the market			0.003	0.002
Distance to the nearest road			0.000	0.000
Distance to the nearest town			0.000	0.001
Village has access to grid (1 if yes, 0 otherwise)			0.067	0.041
Constant	0.972***	0.014	0.839***	0.096
Observations	808		806	
R-squared	0.416		0.436	

Note: *** p<0.01, ** p<0.05, * p<0.1; Adoption =1 if household purchased at the randomly drawn price and =0 otherwise

Table 5. Effect of Information on WTP for Solar Lantern with Controls

Variables	Coef	Se
Information	14.391	8.962
Gender of household head (1=Male, 0=Female)	31.321	30.748
Marital status (1 if married, 0 otherwise)	-17.784	30.317
Education of household head in years	-0.259	1.331
Age of the household head in years	-0.262	0.317
Household size	-1.347	2.435
Value of total assets in Birr	0.000	0.000
Number of rooms in the house	2.667	5.462
Household connected to grid (1 if yes, 0 otherwise)	-55.462***	14.882
Household uses solar light (1 if yes, 0 otherwise)	-3.121	11.250
Household uses kerosene for lighting (1 if yes, 0 otherwise)	12.906	10.755
Household uses fuel wood for lighting (1 if yes, 0 otherwise)	30.371*	15.979
Access to credit (1 if access to 400 Birr or more, 0 otherwise)	16.523**	7.992
Distance to the market	1.524*	0.909
Distance to the nearest road	0.032	0.041
Distance to the nearest town	0.052	0.286
Village has access to grid (1 if yes, 0 otherwise)	5.231	9.287
Constant	94.889***	33.550
Observations	806	
R-squared	0.042	

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Dependent variable is amount respondents are willing to pay in Birr (obtained from the BDM mechanism).

The Effect of Information and Subsidy on Adoption of Solar Lanterns: An Application of the BDM Bidding Mechanism in Rural Ethiopia

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