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On the Welfare Impact of Solar Lantern in Northern Bangladesh: A Progress Report

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Abstract: This progress report explains the motivation behind a newly launched research project on the impacts of solar lantern provision in northern Bangladesh, its sampling strategy, experimental design and summary statistics.

Keywords: Solar lantern, Randomized controlled trial, Impact Evaluation, Bangladesh

1. Motivation

Access to electricity is an essential tool of modern days that can bring substantial improvements to the standard of living and could bring a series of direct and indirect benefits to the households. Once a household gets access to electricity, a direct benefit is the higher level of lighting which helps the children to have more hours of studying and adults to have more active hours, which could be useful for completing household chores and being engaged in productive activities, for example, keeping the home-based businesses remain open for longer hours or producing more outputs or being active with other production or income generating activities. The indirect impact of electricity is, by enabling households to be able to access modern equipment, households can have better heating and cooking facilities, mechanical power, and reliable transport and telecommunications services. As such, "Energy Poverty", a terminology used by international agencies to express the lack of access to energy services, hampers billions of people's lives on a daily basis who typically depend on traditional biomass fuels, which is inefficient as well as alarmingly detrimental to pulmonary health by causing severe indoor air pollution (IAP). As of 2013, there are 1.3 billion people who live without access to electricity in developing countries (IEA 2013), out of which a majority resides in the rural areas. Over 80 percent of these "energy poor" households in developing world have been accessing lights in the nights using kerosene-based candles, lamps or lanterns. For instance, in Bangladesh, kerosene based simple open-fire wick lamps are the most widespread and popular device to have access to light in the night at non-electrified areas. A kerosene lamp typically consist of two parts, the bottom is a small tin based containers that holds the kerosene while the upper part has uncovered wick which is dipped in kerosene to provide light by burning. Solar lamps are the only few available lighting options for the poor, however, these lights are really inefficient in terms of providing lights. Moreover, by burning bio-mass energy, these lights emit a staggering amount of IAP, whose scale is higher than the international standards and poses a serious health and fire related hazard risks (Apple, Vicente et al. (2010)).

Given the widespread use of biomass fuels for the source of lighting and its adverse impact of environment and pulmonary health, governments, policy makers and international donors have now started to pay more attention to the energy poverty and the need to provide access to electricity in the rural areas. A large body of literature discusses many direct and indirect benefits of electricity in the rural context of developing countries.[1] However, despite the willingness and effort to increase the electricity access, one particular challenge for any government and technology provider is to extend the grid electricity service to remote and geographically challenged areas where costs of grid extension is very high and usually extending the service to these areas are unfeasible and unsustainable. One particular example of such an area is the river islands of the North West part of Bangladesh. River islands, which are locally known as "Char'', are areas of land that are formed regularly by silt sediments and are eroded periodically by major rivers of Bangladesh. These islands are just a few inches above the normal active river water level and are extremely vulnerable to flooding during the wet season as monsoon precipitation coupled with excessive glacier melting of the Himalayas usually overflows the major river channels of Bangladesh. Floods frequently result in loss of economic activity, possessions and homes disrupting families, livelihoods and earnings. Erosion of large *Char* areas due to floods is typical and not limited to Northern Bangladesh. In every year, some of *Char* population is forced to evacuate to mainland to look for shelters after the flood. Transportation and communication with *Char*s from the mainland are also major impediments to development. Major mode of transportation with Char islands is by boat which is poorly managed, unreliable and prone to weather conditions. Therefore, living in *Char* is highly precarious, risky and dangerous in times, however, according to the statistics of the DFID funded recent initiative of Char Livelihood Program (CLP), approximately one million people resides in the *chars* of the Jamuna rivers (Conroy 2010).

Unsurprisingly, the provision of electricity is almost non-existence in the *char* areas and the Rural Electrification Board of Bangladesh does not have any plan to expand the electricity in the *char* areas due to the vulnerability nature of the *char*. Some NGOs have tried to provide some small scale Solar Home System (SHS)[2]; however, such SHS is quite expensive[3] and has some physical constraints which are not appropriate for the *Char* scenario. As mentioned

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[1] For example see Peters *et. al.* 2011, Khandker *et. al.* 2009, Khandker *et. al.* 2009; Lipscomb *et. al.* 2013, Dinkleman, 2011.

[2] For example see Grameen Shakti, http://www.gshakti.org/index.php?option=com_content&view=article&id=58&Itemid=62

[3] the minimum one has to pay for a 10 watt panel with a 2/3 LED light or a 5 watt CFL is 9800 taka which provides light for only 4 hours, http://www.gshakti.org/index.php?option=com_content&view=article&id=115&Itemid=124

above, *Char* living is extremely vulnerable which requires flexibility to allow frequent relocation and mobility. Unfortunately, the SHS is a fixed and immobile utility where the access of electricity is only available at the installed place. SHS system does not allow users to use the light in the night go out of the house or to use in the night to access toilets. Moreover, during the time of flood or land erosion, when quick relocation is necessary, households find it extremely difficult and expensive to move their SHS system along with them. As a result the use of SHS in *char* context is very limited. Since there is hardly any alternative source for electricity in the Char, most of the people prefer to use kerosene-based lamp for their only source of light at the night. Some households use battery powered torch lights to accommodate their emergency use, however, these lights have very limited power to do any additional tasks and also the cost of battery is quiet expensive and these batteries are not always available by the char dwellers.

D.light design, a social enterprise in California, has recently designed a series of low cost and light weight solar lights[4] which are durable, weather resistant and has the capacity to produce bright white light, through LED bulbs. Top of their product range is the Dlight Solar lantern (s250 or s300) which has the dual functionality to use a cell phone charger as well as a solar light. Dlight claims that their solar lantern products (s250 or s300) could brighten-up a middle sized room as much as a 5 Watt CFL lamp can and capable of providing up to 10 times more light than a traditional kerosene lantern and reduces the health risks posed by the kerosene fume[5]. The price of such a product is 2600 taka per unit which is about one-fourth of the available SHS system in Bangladesh. This product has the potential to be an ideal low-cost light source, alternative to the typical kerosene lamps for the people living in *chars*. The best feature of this product at the *char* context is its mobility; once charged, users can take the unit wherever they want which could be extremely useful for the *char* dwellers who could use the unit for a range of purposes, from productive activities as well as in need of emergency. Moreover, such lanterns could enhance the learning of the children who typically use kerosene-based lighting for their school based home-works and study requirements. School going children of *Chars*, lacking access to reliable energy, are depending on dim kerosene lamps as their main source of lighting, which inhibits their study through dimness, indoor air pollution, fire hazards and high marginal

[4] http://www.dlightdesign.com/

[5] kopernik.info/technology/dlight-s250-solar-lantern

cost of usage that makes poor parents unwilling to provide ample kerosene in the night to continue the study.

However, promoting and marketing such products with health and welfare benefits to the poor population has been always a big challenge for the technology providers, as the take-up rate of the technology has been disappointingly low. Quite a few explanations have been pointed-out by researchers through analyzing the low adoption rates of technology in developing countries, which are liquidity or credit constraint (Gine et al., 2008; Cohen & Dupas, 2010; Cole et al., 2010; Dupas & Robinson, 2011), inability to realize adoption benefits (Feder & Slade, 1984; Conley & Udry, 2001; Gine & Yang, 2009), self-control problems (Banerjee & Mullainathan, 2010; Duflo et al., 2011), benefits are external to the households (Kremer & Miguel, 2007), risk-averse to experimentation (Foster & Rosenzweig, 1995; Conley & Udry, 2010; Bryan et al., 2013) or household bargaining and decision problem (Miller and Mushfiq 2013), to name a few. However, recently there has been a growing number of researches which focus on innovative ways to improve the uptake-rate of welfare enhancing technology for the poor and we have started to see some success, for example see BenYisay (2013), which provides evidence of complex market and decision making process of the poor households in the developing countries that requires further research.

2. Objective of this Study

The aim of this research is to assess the impacts of new technology for low-cost yet mobile off-grid electricity provision at the *char* areas in Bangladesh. So far there has been only one small scale Randomized Controlled Trial (RCT) that has accessed the health and study impact of small solar lamps in Uganda (Furukawa, 2012 and 2013) and the paper found rather negative impact of solar lamp on exam scores of the treated children and a diminutive improvement in health outcomes. Also Furukawa (2013) found that only 30% of the free distributed solar lamps were in active use, after one year of the intervention, which creates a puzzle of actual adaptation and use of such products at the rural context. Employing an RCT set-up, our research objective is to improve our understanding of the direct causal impact of access to solar lantern on various outcomes both at the household level and at the individual level. At the household level, we aim to estimate the impact of solar lanterns on kerosene consumption as well as savings and income improvements. At the individual level, the impact assessment of solar lanterns will be based on children's health, education performance and time use. Once the direct benefit of such product is achieved, on the second half of this project, we will emphasize on the likely channels to improve the uptake rate of the product and will try to bridge the knowledge gap of promoting the adoption and up-take rate of new technology in the developing countries.

3. Sampling Procedure:

To select our sample households for this study, we listed up all primary and secondary schools located in the *Chars* of Gaibandha and Kurigram districts and did initial quick inspection with School Management Committees (SMCs) and teachers to ask whether their students have any access to electricity, through national grid or through SHS. Please note that, we targeted schools rather than villages as a sampling cluster because the main outcome of our interests includes the impacts of solar lamps on educational attainment. Because few variations in attendance or hours of study were expected in the elementary level, we focused on children who belong to 4th to 5th grades in the primary school, and 6th to 8th grades in the junior high school. Through interview with teachers and SMCs, we realized that the provision of solar lights through SHS has been recently introduced by an NGO in several *Chars* and non-negligible children and their families had already some access to solar lights, even though they are only for supplementary use. In order to avoid contamination effects, out of 2795 children in 28 schools in 8 *Chars* we listed, we selected 1292 children who belong to 4th to 8th grades in 17 primary or secondary schools in two Chars where provision of SHS have not been so common. Then, we made direct interviews with children to list up those who have not used solar lamps in those schools. Of 1292 total children, 911 were found not to have any access to SHS by the time of survey. Of those, 882 became effective sample households for this study; the rest were drop-out from schools before the detailed household survey due to marriage or other reasons. The detailed time schedule is illustrated in Figure 1.

4. Household Survey

The baseline survey was implemented in July-August 2013 for 882 children and their households. In the survey, we collected the detail data to understand the socio-economic conditions of the sample children and their households, which pertain to household demographic characteristics, health conditions of each household member, details of energy use and its sources, expenditures, various income generating activities, durable and non-durable asset, debt, savings and credit. We have also designed a set of questions on risk and time preferences as well as willingness to pay for solar lanterns. The brief description of each module is as follows.

Household Composition: This section captures basic demographic information on the household including members' names, age, gender, relation to the household head, marital status, literacy, and main occupations.

Child Education: This section applies only to children aged between 5 to 18 years old and asks current enrolment of school, days of absent from school, and school fees.

Health: This section asks subjective health conditions of each household member (ranging from very poor to very good), using a vignette method as well as the detail of illnesses household members suffered and associated medical expenditures within a year.

Energy Use: This section collects information on light sources, major purpose for the use, the average time used as well as fuel expenditures.

Housing and willingness to pay solar lamps: This section asks conditions of housing and kitchen separately in the rainy and dry season. Also, it asks how much a household is willing to pay for solar lamps, after explaining functions of solar lamps.

Expenditure: This section records the actual consumption of food items over the past week, and typical non-food items consumed in the last month and last year.

Farm activities: This section asks details of land ownership, land use, agricultural production, use of fertilizer, herbicides, pesticides, agricultural machinery, and hired labor, separately for Aus, Aman, and Boro seasons, which help derive annual farm income.

Livestock: This section asks the number of livestock and poultry, the value of their production, self-consumption and inputs, including livestock- and poultry-related production, such as milk and eggs. This covers not only those owned by the household, but also those leasing-in.

Wage Income: This section asks activities and income of wage employment, including permanent and temporary one.

Self-employed income: This section collects information on self-employment pertaining to number of days in business, gross revenue, expenses for raw materials, fuels and hired labor if any.

Transfer income: This section asks non-labor earnings, including remittance, pension, scholarship, and other governmental and non-governmental assistances.

Durables: The ownership and present values of durables, such as radio, bicycle, television, and mobile phones, is asked in this section.

Productive asset: This section asks ownership and present values of assets related to agricultural and non-agricultural production, such as tractor, tiller, fishing net, and rickshaw.

Borrowing: This section asks whether a household has tried to borrow, and if so whether and how much it can borrow from any source.

Savings: This section asks the amount of savings in banks, NGOs, and at home.

Preferences: This section asks household's risk and time preferences. The structure is similar to the ones used by Michal Bauer & Julie Chytilova & Jonathan Morduch, 2012. "Behavioral Foundations of Microcredit: Experimental and Survey Evidence from Rural India," *American Economic Review*, vol. 102(2), pages 1118-39.

5. Research Financing:

In association with Kopernik[6], with the generous funding provided from Daiwa Securities, and BRAC, one of the largest NGOs of the world, our implementation partner NGO, Gono Unnayan Kendra (GUK) has been donated with 500 units of D.light designed S250 along with additional 300 units of other two types of products (s10 and s2) from BRAC to do the impact study of such an innovative product in the Char areas of Northern Bangladesh. GUK helped us to choose schools located at the *Chars* in Northern Bangladesh.

The details of these products are as follows:

- S250: Dlight designed s250 is their flagship products, which has the capacity to provide maximum bright light for 4 hours. This unit also has the functionality of charging cellular phones. S250 has a separate light weight solar panel which needs to be used to recharging the unit. For details see http://kopernik.info/technology/dlight-s250-solar-lantern
- S10: Dlight designed s10 is a general solar lantern, which has the capacity to provide maximum bright light for 4 hours, however, this unit does not have the functionality to charge mobile phones. The solar panel of S10 is combined with the main unit. For details, see http://kopernik.info/technology/dlight-s10-solar-lantern
- S2: Dlight designed s2 is the simplest solar lantern, which has the capacity to provide maximum bright light for 4 hours, the illumination capacity of this unit is lower than the other two units. Like s10, this unit also does not have the functionality to charge mobile phones. The solar panel of S2 is also combined with the main unit. For details, see http://kopernik.info/technology/dlight-s2-solar-lantern

6. Experimental design:

Once we have finished the baseline survey, we organized a public lottery to randomly allocate the access to use solar lights for one and half year (up to December 2014) to the eligible students in two different bundles of products. The first treatment bundle (B1) contains the s250 solar lantern only whereas second treatment bundle (B2) contains one of each dlight solar products, which are s250 (solar lantern), s10 (general solar lantern with no cellular recharge facility) and s2 (simple solar lantern). The reason for separate bundling was to avoid the multiple

[6] An on-line technology market place for the developing world, for more information, see http://kopernik.info/

use of the same unit, which might show a negative effect of solar lantern on educational outcome. It might be possible that parents of the treated children use solar lantern for their productive activities or other household chores while reducing the energy allocation of kerosene, which might have adverse effect on the educational outcome of the treated children. There is also a possibility of siblings' rivalry where siblings of the treated children may fight for their own personal use of the solar lantern. If case any of these mentioned incidents occur then our impact study may pick a wrong impact of solar lantern, which could be misleading.

We hold public lottery at each school to distribute the solar lanterns to the students, at the presence of parents, school teachers and village elites. During the time of the distribution, we have collected pervious years school exam scores as well as baselines health measures. To collect accurate time use with solar lights and to make sure the leased solar lanterns are well maintained and properly re-charged, we also provided each student with a time-diary and pictorial manual that contains detailed information on the adequate use and recharge techniques. To facilitate the time keeping, we have given a wall clock with a set of battery to each student, irrespective of treatment groups.

After the public lottery, we ended up distributing bundle two (B2) to 248 students and bundle one (B1) to 198 students, while keeping 436 in the control group (C), see Figure 2 for details.

7. Summary statistics

To meet the research objectives, in the present study, two treatment and one control groups were created as in Figure 2. The treatments were randomly assigned across households. Consequently, one group of the respondent households received three different types of solar lamps (treatment A) in contrast to another group that received only one solar lamp (treatment B), with the other receiving nothing (control group).

By these treatment arms, Tables 1 and 3 provide a description of key variables at the levels of individuals and households, respectively. Most variable are self-speaking. To assess if the randomization worked well, regression coefficients of several individual- and household-level variables on the treatment arms were also reported in Tables 2 and 4, respectively, whereby the control arm was a reference group.

While only a few variables show statistically significant differences across the treatment conditions, most variables are well-balanced. This mitigates the concern of the randomization failure. Below, a few additional remarks will be made about the data.

7.1 Lighting

Sources

As seen in Table 3, in the surveyed area, kerosene-based products were major light sources. Almost all households owned kerosene lamps, with approximately 23% having kerosene lanterns. This difference in the commonality within the kerosene-based products may be due to the fact that the kerosene lanterns were more expensive than the lamps.

Table 5 present major activities for each light source to be used that the respondent households reported. For example, about 96% of the households owing the kerosene lamps referred to cooking and eating at night as the first or second most major activities for the lamps to be used, followed by 88% of reading/studying as well as 58% of walking outside at night. Unlike the kerosene lamps, it appears that the kerosene lanterns were primarily used for the latter two activities, not for cooking/eating at night.

It is also shown from Table 3 that annual expenditure on kerosene corresponded to approximately 15% of non-food expenditures (exclusive of school fees, medical fees and expenditures on other energy), suggesting the significance of the fuel costs.

Willingness to pay for solar lanterns

Approximately 72% of the surveyed households have heard about solar lanterns before. Two methods were exploited to evaluate their willingness to pay for the solar lamps.

Firstly, their assessment about a monthly instalment that lasted three years for the purchase of the solar lanterns was directly asked. When collecting this information, the respondent households were split into two groups by a coin flip, with one receiving basic product information on the specifications and the other that was given additional information. When providing the information, the same product picture was applied to both the groups. The issues included in the additional information emphasized that the solar lanterns could completely replace the kerosene lamps that contributed to generating indoor air pollution and the associated health problems. [7]

The mean value of the willingness to pay of the households that received the additional information was 76.00 (std. 42.67), in contrast to 81.95 (std. 244.99) of those that did not. While these mean values were not different between the groups at any conventional level of statistical significance, the apparent difference in the standard deviation might suggest that the additional information reduced uncertainty about the benefits of the products.

Secondly and more indirectly, the survey team asked the respondent households to select between receiving kerosene lamps and the fuels for one year (option A) and leasing solar lamps for a certain period (option B), both of which were free due to a subsidy provided by the government. Five different lease periods (month) that ranged from 12 to 9, 6, 3 and 1 were assessed by the respondents. Summing the respondents' responses selecting the option B yielded an index for the willingness to pay for the solar lamps, with the large number (between zero and five) indicating more willing to pay. As seen in Table 3, the mean value of the index is approximately four, suggesting the presence of the respondents' great interest in purchasing and/or using the products.

The current study performed two exercises to check that the respondents provided a reasonable response to the question. Firstly, Figure 3 provides a representation of the relationship between the proportion of the respondents choosing the option B and the lease period of that option. The proportion increases in the length of the lease period, which is an intuitive finding.

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[7] In the survey, the following instructions were applied to those two groups, respectively.

- The d.light S300, which is a solar lantern developed in US, provides bright white light at a wide angle, enabling the illumination of an entire room. A USB port provides the ability to charge smart phones. Lightweight (350g), it comes with an ergonomically designed handle and top strap, which offers maximum flexibility for use in the home, workplace, or outdoor environments.
- The d.light S300, which is a solar lantern developed in US, provides bright white light at a wide angle, enabling the illumination of a(n entire room. A USB port provides the ability to charge smart phones. Lightweight (350g), it comes with an ergonomically designed handle and top strap, which offers maximum flexibility for use in the home, workplace, or outdoor environments. By using d.light lanterns, you can completely eliminate the need for kerosene lanterns in households. Also, Kerosene lamps are a key contributor to indoor air pollution, which is documented to have disastrous health effects, ranging from tuberculosis to cancer, but d.light lanterns are extremely safe and use super-bright LEDs that do not emit any pollutants.

Secondly, given the tendency that the respondents prefer the option B to the option A when the length of the lease period is long enough, it is unlikely that they change the responses from the option A to the option B when the lease period considered decreases. Only less than 0.4 percent of the respondent households gave such an unreasonable response.

7.2 Preferences

Risk preferences

The information on both the risk and time preferences was collected. To measure the risk preferences, the respondent households were asked to choose between receiving 300 BDT with certainty (lottery A) and playing a simple gambling game (lottery B). In the gambling game, the respondents could gain either 450 BDT or a certain amount of money less than 450 BDT with equal probability. Altering the lower amount from 300 to 250, 200, 150 and 100, the respondents were required to give their responses to all the five lottery choices. As a measure that reflects the degree of risk aversion, the current study uses the sum of the respondents' choices of the lottery B that ranges from zero (risk averse) to five (risk loving).

Three informal checks were performed to make sure that the respondents' misunderstanding of the question did not make this measure useless. Assuming that the respondents' utility is increasing in the money received, firstly, they must always choose the lottery B when the lower amount of the gambling game is 300 BDT. This response is expected because in that case, the lottery B guarantees that the respondents receive 300 BDT given by the lottery A. As a matter of fact, only less than 1% of the respondents selected the lottery A in face of the choice. Secondly, given the presumption that the respondents are risk-averse, they are likely to choose the lottery B when the lower amount of the gambling game is large enough. The positive relationship between the selection of the lottery B and the lower amount of the gambling game is confirmed in Figure 4 (left-hand panel) that plotted the proportion of the respondents that selected the lottery B against the lower amount of the gambling game. Given the risk averseness as well as the fact that the majority selected the lottery B when the lower amount of the gamble is 300 BDT, finally, the respondents may eventually choose the lottery A when the lower amount of the gambling game goes below a certain level. This suggests that a switch from selecting the lottery A to the lottery B is unlikely when the lower amount of the gamble decreases. In the survey that to avoid potential response bias, allowed the respondents to make any choices, only less than two percent of the respondents revealed such an unlikely switch.

Time preferences

This study took a similar approach to evaluate the respondents' time preferences to that used for measuring the risk preferences. The respondent households were required to choose between receiving 250 BDT tomorrow (option A) and receiving a certain amount of money equal to or more than 250 BDT three months later (option B). The respondents gave their responses to all the six choices, where the amount received three months later ranged from 250 to 265, 280, 300, 330 and 375. The sum of the respondents' responses selecting the option B was exploited as a measure of their time preferences, with the larger number (between zero and six) meaning more patient.

In order to check that the measure was reasonably understood, two exercises were made. Firstly, it appears that the respondents that are less patient due to several factors (e.g., credit constraint) prefer the option A to the option B when the amount received in the option B is small. However, increasing the reward of the option B may raise the likelihood that the respondents choose the option B. This relationship is indeed observed in Figure 4 (right-hand panel), whereby the fraction of the respondents that selected the option B was depicted against the amount received in that option. Secondly, given the observation that the respondents are likely to select the option B when the amount received in that option is large enough, it is expected that a switch from selecting the option B to the option A is unlikely when the reward of the option B increases. Such an unreasonable switch was observed only for less than two percent of the respondent households.

To assess dynamic consistency of the time preferences, the respondent households were also asked to select between receiving 250 BDT one year later (option A) and receiving a certain amount of money more than 250 BDT 15 months later (option B). The reward of the option B ranged from 265 to 280, 300, 330, and 375, yielding five choices that the respondents considered. As before, the sum of the respondents' responses selecting the option B was exploited to evaluate their time preferences with the score ranging from zero (less patient) to five (more patient). The positive relationship between the likelihood of selecting the option B and the reward of that option was again confirmed in Figure 4 (right-hand panel). In addition, only two percent of the respondent households revealed an unlikely switch from selecting the option B to the option A when the reward of the option B increases.

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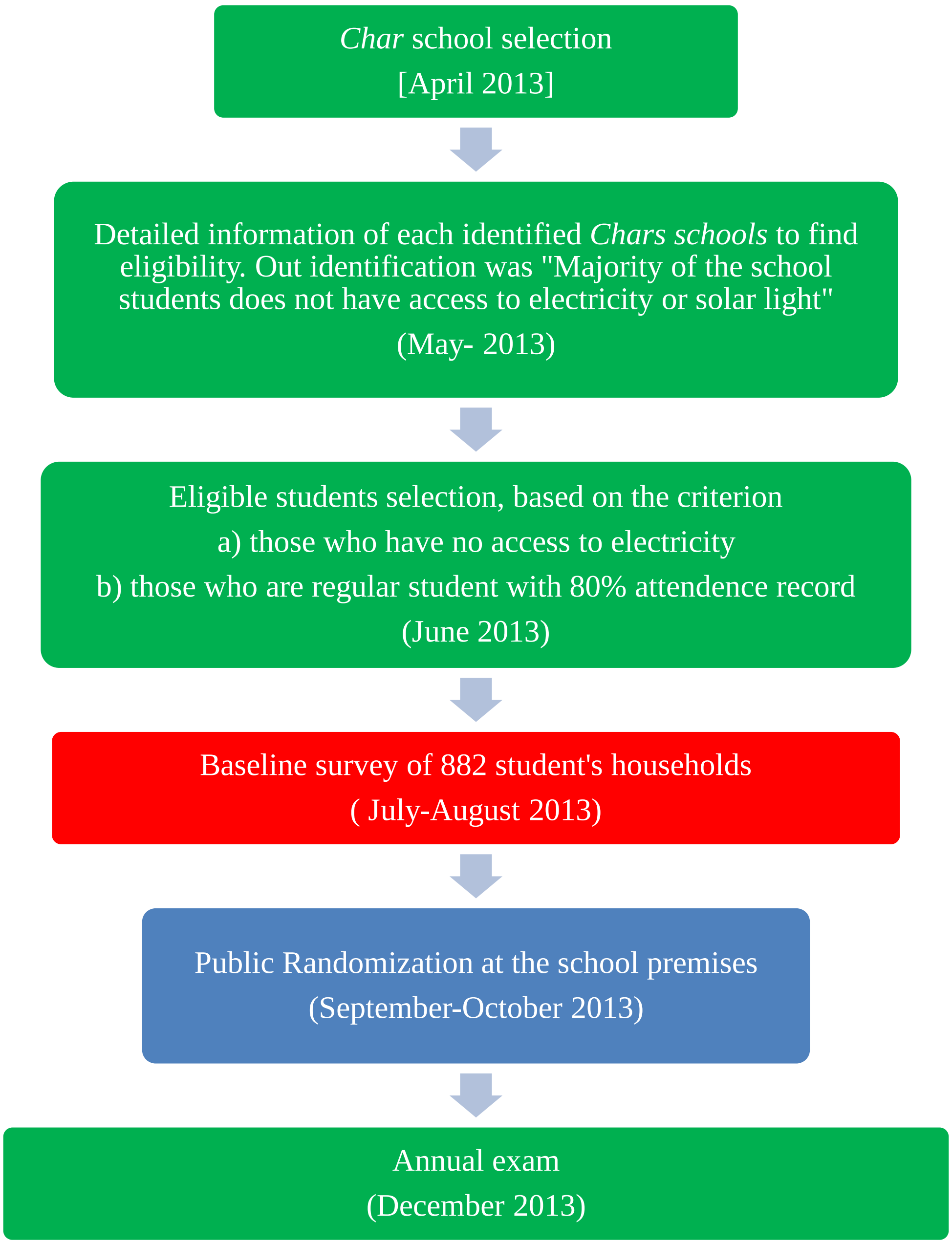
Figure 1: Timeline of Interventions and Surveys



Source: Prepared by the authors. The blue panels show events regarding interventions, red panels show events regarding surveys and the green panels show events regarding sample selection .

Figure 2: Randomization design

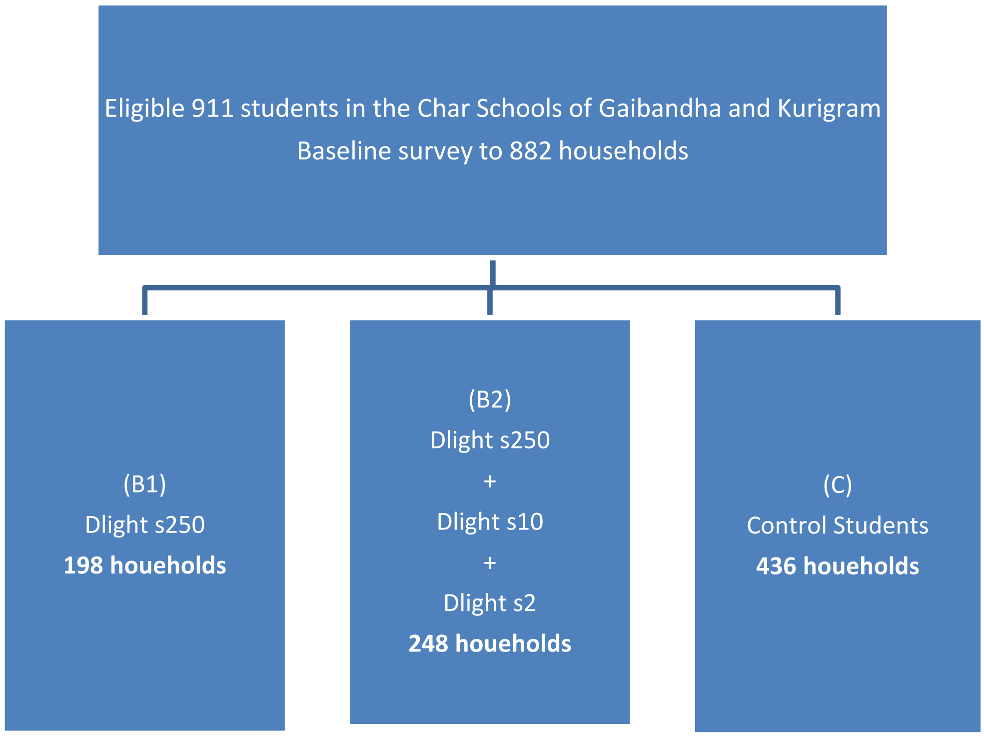


Figure 3: Willingness to pay for solar lamps

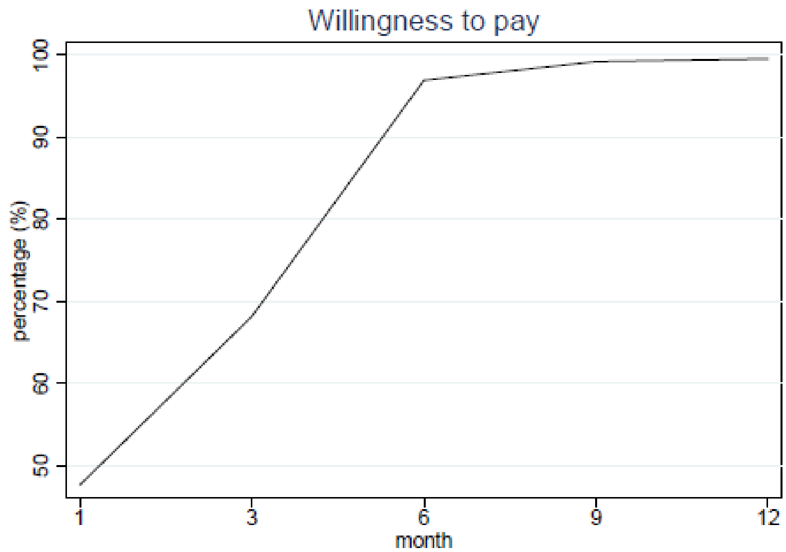


Figure 4: Risk and time preference

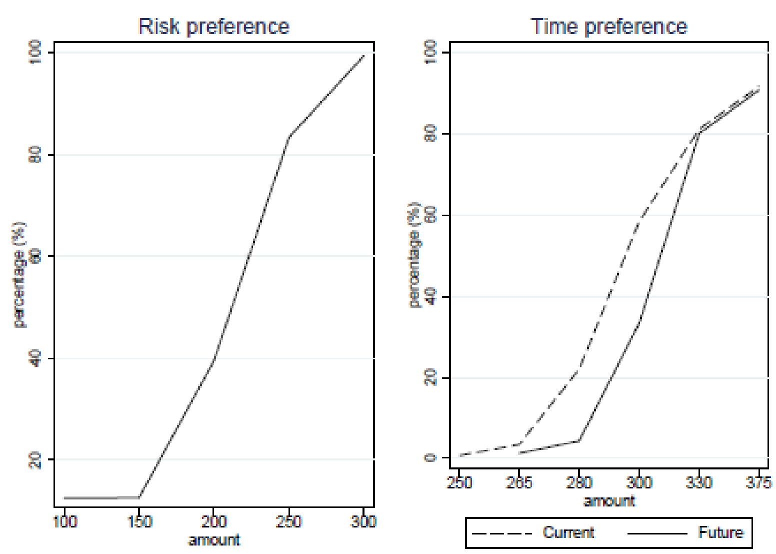


Table 1. Summary statistics: individual-level variables

	Treatment A			Treatment B			Control		
	Mean	Std.	No. of obs.	Mean	Std.	No. of obs.	Mean	Std.	No. of obs.
Age (years)	23.57	16.64	1227	23.77	16.48	948	23.35	16.58	2154
Male (dummy)	0.48	0.50	1227	0.48	0.49	948	0.50	0.50	2154
Married (dummy)	0.40	0.59	1227	0.41	0.49	948	0.50	0.49	2154
Education (years)	2.55	3.16	1227	2.50	3.12	948	2.56	3.19	2154
Literate (dummy, read & write)	0.52	0.49	1227	0.54	0.49	948	0.54	0.49	2154
School fees (BDT, 6 mth)	1293.25	954.52	501	1234.67	865.64	414	1224.44	1034.70	911
Medical fees (BDT, 12mth)	428.98	560.43	1225	460.77	767.26	948	443.50	766.34	2151
Health problem in the last 3 months (dummy)									
Diarrhea	0.01	0.13	1225	0.02	0.15	948	0.02	0.16	2151
Fever	0.34	0.47	1225	0.33	0.47	948	0.33	0.47	2151
Headache	0.24	0.43	1225	0.23	0.42	948	0.23	0.42	2151
Cough	0.13	0.34	1225	0.09	0.29	948	0.09	0.29	2151
Sore throat	0.02	0.14	1225	0.01	0.12	948	0.02	0.14	2151
Gastritis	0.10	0.30	1225	0.09	0.29	948	0.09	0.29	2151
Nasal mucus/Runny nose	0.19	0.39	1225	0.19	0.39	948	0.19	0.39	2151
Phlegm/Sputum	0.02	0.16	1225	0.02	0.15	948	0.03	0.17	2151
Dizziness	0.00	0.06	1225	0.00	0.06	948	0.00	0.07	2151
Burning	0.00	-	1225	0.00	-	948	0.00	0.02	2151
Breath-related problems	0.00	0.08	1225	0.00	0.07	948	0.00	0.08	2151
Eye-related problems	0.00	0.07	1225	0.00	0.05	948	0.01	0.10	2151
Throat-related problems	0.00	0.02	1225	0.00	0.04	948	0.00	0.05	2151
Skin diseases	0.00	0.08	1225	0.00	0.09	948	0.01	0.10	2151
Jaundice	0.00	0.04	1225	0.00	0.05	948	0.00	0.06	2151

Table 2. Balance test across treatment conditions: individual-level variables

	Treatment A		Treatment B		No.
Dependent variables:	Coefficient	Std. errors	Coefficient	Std. errors	of obs.
Age (years)	0.215	[0.438]	0.413	[0.483]	4329
Male (dummy)	-0.018	[0.014]	-0.022	[0.015]	4329
Married (dummy)	-0.004	[0.011]	0.012	[0.011]	4329
Education (years)	-0.014	[0.123]	-0.060	[0.137]	4329
Literate (dummy, read & write)	-0.021	[0.015]	-0.004	[0.015]	4329
School fees (BDT, 6 mth)	68.810	[57.050]	10.230	[56.244]	1826
Medical fees (BDT, 12mth)	-14.522	[27.106]	17.262	[33.622]	4324
Health problem in the last 3 months (dummy)					
Diarrhea	-0.008	[0.006]	-0.004	[0.006]	4324
Fever	0.008	[0.017]	0.003	[0.020]	4324
Headache	0.008	[0.017]	0.000	[0.018]	4324
Cough	0.042***	[0.014]	0.003	[0.013]	4324
Sore throat	0.001	[0.005]	-0.004	[0.005]	4324
Gastritis	0.009	[0.012]	0.001	[0.012]	4324
Nasal mucus/Runny nose	0.000	[0.017]	0.006	[0.018]	4324
Phlegm/Sputum	-0.007	[0.007]	-0.009	[0.008]	4324
Dizziness	-0.001	[0.003]	-0.001	[0.003]	4324
Burning	0.000	[0.000]	0.000	[0.000]	4324
Breath-related problems	0.001	[0.003]	-0.001	[0.003]	4324
Eye-related problems	-0.005	[0.003]	-0.007**	[0.003]	4324
Throat-related problems	-0.002	[0.001]	-0.001	[0.002]	4324
Skin diseases	-0.003	[0.004]	-0.002	[0.004]	4324
Jaundice	-0.002	[0.002]	-0.001	[0.002]	4324

Notes: (1) Figures [ ] are standard errors. *** denotes significance at 1%, ** at 5%, and * at 10%. (2) Standard errors are robust to heteroskedasticity and clustered residuals within each village.

Table 3. Summary statistics: household-level variables

	Treatment A (248		Treatment B (198		Control (436	
	Mean	Std.	Mean	Std.	Mean	Std.
Household size	4.94	1.37	4.78	1.1	4.94	1.3
No. of males	2.4	1.14	2.3	0.98	2.49	1.12
Head age (years)	41.84	9.19	41.98	8.1	41.67	8.49
Head education (years)	1.18	2.55	1.19	2.79	1.34	2.94
Head male (dummy)	0.91	0.27	0.92	0.25	0.91	0.28
Light sources (dummy)						
Flashlight	0.08	0.27	0.11	0.31	0.12	0.32
Kerosene lanterns	0.22	0.41	0.23	0.42	0.23	0.42
Kerosene lamps	0.98	0.1	1	-	0.99	0.09
No. of light sources						
Flashlight	0.08	0.31	0.11	0.31	0.12	0.35
Kerosene lanterns	0.24	0.47	0.25	0.49	0.24	0.44
Kerosene lamps	1.72	0.62	1.66	0.54	1.64	0.57
Per-day hours using light sources (sum of all owned & zero if not own)						
Flashlight (rainy season)	0.22	0.79	0.31	0.9	0.32	0.92
Flashlight (dry season)	0.32	1.17	0.41	1.22	0.46	1.3
Kerosene lanterns (rain)	0.69	1.42	0.66	1.39	0.57	1.15
Kerosene lanterns (dry)	0.85	1.73	0.82	1.74	0.72	1.46
Kerosene lamps (rain)	4.19	1.81	4.23	1.76	4.04	1.78
Kerosene lamps (dry)	5.48	2.43	5.58	2.42	5.25	2.39
Expenditures (BDT)						
School fees (6 mth)	2610.28	1620.37	2573.4	1579.37	2521.84	1690.14
Medical fees (12 mth)	2119.18	1651.87	2206.11	1887.91	2188.26	1996.33
Kerosene (12 mth)	1543.79	700.05	1553.39	735.16	1694.93	1709.81
Other energy (12 mth)	13.81	60.41	22.63	83.75	26.11	123.92
Food (12 mth)	76345.64	29850.64	73561.37	32353.91	72698.94	25006.37
Non-food (12 mth)	11138.16	3803.22	10690.74	2702.5	11004.5	3527.97
Total	93770.87	32708.79	90607.67	33828.45	90134.6	27211.53
Income (BDT, 12 mth)						
Agriculture	1353.55	11514.56	799.14	3578.46	610.23	5768.08
Wage	51260.89	33872.58	52617.17	30424.61	52743.81	33162.44
Non-farm self-employed	14652.98	41646.82	18114.04	111697.2	11374.15	35028.47
Livestock	1707.46	4101.51	1417.21	3345.14	1967.04	6254.43
Support from others	11555.5	17040.58	10487.68	20146.72	11339.59	21225.69
Rental	274.19	2587.22	0	-	169.72	2917.81
Total	80804.58	44451.14	83435.25	109715.7	78204.55	39893.31
Productive asset (BDT)	1687.17	8578.34	844.39	3592.65	825.09	3138.21
Asset (BDT)	2336.65	1822.51	2653.18	3837.07	2603.77	3137.47
Borrow dummy (try, 12 mth)	0.43	0.49	0.42	0.49	0.44	0.49
Borrow dummy (success, 12mth)	0.12	0.32	0.14	0.35	0.14	0.35
Loan (BDT)	1280.24	4479.27	1197.72	5107.86	1814.22	5935.95
Saving (BDT)	1941.66	4883.18	1634.13	3491.74	1738	3299.33
Willingness to pay (0 to 5)	4.12	0.97	4.08	0.91	4.12	0.96
Risk loving (0 to 5)	2.55	1.08	2.42	1.06	2.46	1.14
Patience A (0 to 6)	2.61	1.19	2.54	1.15	2.56	1.23
Patience B (0 to 5)	2.07	0.96	2.07	0.86	2.14	0.89

Table 4. Balance test across treatment conditions: household-level variables

	Treatment A		Treatment B		No.
Dependent variables:	Coefficient	Std. errors	Coefficient	Std. errors	of obs.
Household size	0.007	[0.088]	-0.152**	[0.061]	882
No. of males	-0.084	[0.069]	-0.183**	[0.076]	882
Head age (years)	0.175	[0.690]	0.318	[0.699]	882
Head education (years)	-0.159	[0.242]	-0.147	[0.222]	882
Head male (dummy)	0.005	[0.028]	0.019	[0.023]	882
Light sources (dummy)					
Flashlight	-0.041*	[0.021]	-0.01	[0.018]	882
Kerosene lanterns	-0.01	[0.030]	0.001	[0.040]	882
Kerosene lamps	-0.003	[0.008]	0.009*	[0.005]	882
No. of light sources					
Flashlight	-0.040*	[0.020]	-0.017	[0.018]	882
Kerosene lanterns	0.001	[0.031]	0.012	[0.046]	882
Kerosene lamps	0.081*	[0.044]	0.017	[0.045]	882
Per-day hours using light sources (sum of all owned & zero if not own)					
Flashlight (rainy season)	-0.101*	[0.059]	-0.014	[0.052]	882
Flashlight (dry season)	-0.134	[0.081]	-0.048	[0.071]	882
Kerosene lanterns (rain)	0.116	[0.094]	0.094	[0.109]	882
Kerosene lanterns (dry)	0.128	[0.103]	0.101	[0.136]	882
Kerosene lamps (rain)	0.152	[0.120]	0.19	[0.179]	882
Kerosene lamps (dry)	0.228	[0.177]	0.335	[0.236]	882
Expenditures (BDT)					
School fees (6 mth)	88.441	[93.956]	51.567	[126.334]	882
Medical fees (12 mth)	-69.083	[132.390]	17.843	[133.091]	882
Kerosene (12 mth)	-151.141*	[81.734]	-141.537	[95.089]	882
Other energy (12 mth)	-12.300***	[4.540]	-3.478	[5.216]	882
Food (12 mth)	3646.696*	[2002.783]	862.429	[1766.671]	882
Non-food (12 mth)	133.657	[302.001]	-313.758**	[148.430]	882
Total	3636..27	[2204.477]	473.066	[1793.309]	882
Income (BDT, 12 mth)					
Agriculture	743.328	[942.726]	188.91	[234.885]	882
Wage	-1482.92	[2361.696]	-126.636	[1938.853]	882
Non-farm self-employed	3278.832	[2968.052]	6739.889	[6958.118]	882
Livestock	-259.588	[385.564]	-549.831	[377.688]	882
Support from others	215.908	[1185.483]	-851.915	[1499.313]	882
Rental	104.469	[95.013]	-169.725	[128.899]	882
Total	2600.029	[2950.728]	5230.692	[7530.028]	882
Productive asset (BDT)	862.086	[583.284]	19.302	[289.049]	882
Asset (BDT)	-267.120*	[146.512]	49.409	[277.152]	882
Borrow dummy (try, 12 mth)	-0.011	[0.042]	-0.018	[0.047]	882
Borrow dummy (success, 12mth)	-0.028	[0.022]	-0.003	[0.024]	882
Loan (BDT)	-533.978*	[279.999]	-616.493	[402.984]	882
Saving (BDT)	203.657	[353.130]	-103.873	[240.940]	882
Willingness to pay (0 to 5)	-0.001	[0.072]	-0.045	[0.072]	882
Risk loving (0 to 5)	0.091	[0.079]	-0.041	[0.083]	882
Patience A (0 to 6)	0.053	[0.105]	-0.019	[0.132]	882
Patience B (0 to 5)	-0.074	[0.073]	-0.071	[0.095]	882

Notes: (1) Figures [ ] are standard errors. *** denotes significance at 1%, ** at 5%, and * at 10%. (2) Standard errors are robust to heteroskedasticity and clustered residuals within each village.

Table 5. Major activities by light sources

	Flashlight	Kerosene lanterns	Kerosene lamps
Reading/studying	0.03	0.94	0.88
Social interaction	0.13	0.17	0.22
Cooking/eating at night	0.01	0.16	0.96
Walking outside at night	0.86	0.46	0.58
Tending livestock	0.08	0.05	0.13
Income generating activities	0.02	0	0.01
Nightlight for security	0.73	0.23	0.29
No. of households	97	211	904