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Yuya Kudo*, Abu S. Shonchoy, Kazushi Takahashi

March 2015

Abstract

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Keywords: Bangladesh, clean and renewable energy, RCT, river islands, solar light

JEL classification: O13, O18, Q41

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March 12, 2015

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1 Introduction

Access to electricity is essential for modern living. Evidence to date suggests that electrification is linked to a wide range of improvements, including more income generating activities (Khandker et al. (2012, 2013)), greater female employment generation (Dinkelman (2011); Grogan and Sadanand (2013)), better productivity (Kirubi et al. (2009)), firm creation and industrial development (Peters et al. (2011); Rud (2012)), higher literacy rate (Kanagawa and Nakata (2008)), and increased study time and educational performance (Gustavsson (2007); Khandker et al. (2012); Furukawa (2014)).

However, despite efforts by governments and international donor agencies toward sustainable energy for all (United Nations (2010)), universal access to electricity has been challenging for many low-income countries, particularly in remote areas where costs of grid extension are prohibitively high, and thus provision of services is unfeasible and unattainable (Chaurey et al. (2004)). As of 2013, 1.3 billion people in developing countries lived without access to electricity, of which a majority resides in the rural areas (IEA (2013)). Over 80% of these "energy poor" households, who lack access to energy services, generally rely on firewood and kerosene-based traditional lighting sources, which are known to cause hazards, such as fire, explosion, and burns, as well as are detrimental to pulmonary and respiratory health by causing severe indoor air pollution (Lam et al. (2012)). Moreover, firewood and kerosene-based lighting products are expensive, often comprising approximately 10% of total household expenditures of the poor (Bacon et al. (2010); Maliti and Mnenwa (2011)).

Given the adverse impacts of biomass fuel-based lighting sources on environment, health, and household expenditure, it is crucial to introduce complimentary lighting devices to off-grid and poorly electrified areas, which are affordable, environment friendly, and portable. One of the most promising off-grid electricity systems that use a renewable source of energy is the large solar photovoltaic panel-based electricity, known as Solar Home Systems (SHSs). However, it is increasingly recognized that the SHSs are often too expensive for the poor, particularly those at the bottom of the pyramid (BoP) who need such a technology the most (Samad et al. (2013)). Moreover, the SHSs are characterized as a fixed utility where access to electricity is unavailable outside the installed place. Thus, it is sometimes infeasible to provide the SHSs for mobile population, such as pastoralists and nomads, as well as the geographically challenged residents, such as dwellers of river islands who are regularly affected by floods and forced to migrate during the rainy seasons. Therefore, although the SHSs still play an important role as useful alternative off-grid electricity, the lighting market that targets BoP has been shifting to a new arena that is being led by solar portable lights, such as solar lanterns (World Bank (2010)).[1]

In this study, we conduct a randomized controlled trial (RCT) to assess the effects of solar lanterns in the river islands of northern Bangladesh, which is locally known as "*Char*." These islands are prone to cyclical river erosion and floods, which frequently result in loss of economic activities, possessions, and homes disrupting families, livelihoods, and earnings. Unsurprisingly, the provision of electricity is almost non-existent in the *Char* areas, and the Rural Electrification Board (REB) of Bangladesh does not have any plan to expand the electricity in these sites due to their susceptible nature.

The main objective of this study is to rigorously evaluate the impact of solar lanterns on various welfare outcomes of households by providing this modern technology to a randomly selected subset of the population. Anecdotal evidence suggests that the use of solar lamps has substantial potentials to transform lives of the poor, including the reduction of incidences of fire burns and hazards, indoor air pollution, and household expenditures on biomass and kerosene, as well as increased study hours of children and working hours for adults' in the evening, boosting income and educational achievements. However, rigorous empirical studies to systematically understand the impact is still limited, and they are based on very small sample size: 155 in Uganda (Furukawa (2012, 2014)), 341 in rural Kenya (Hassan and Lucchino (2014)), 300 in rural Rwanda (Grimm et al. (2014)), and only 90 in Liberia (Smith (2014)), which suffers from a problem of low statistical power. Moreover, the scope of the aforementioned studies is rather limited to narrow household outcomes, and little is known about the variety of impacts of solar lamps that may involve both welfare and behavioral changes.

Using a unique panel data set collected from 852 households and children, and employing an RCT setup, this study attempts to identify short-term causal effects of access to solar lantern on various outcomes both at the individual and household levels. At the individual level, the impact assessment of solar lanterns is based on children's health, time use, school attendance, and educational attainment.

[1] There exist a number of solar lantern products manufactured by many companies (for example, see `http://www.lightingglobal.org/products/?view=grid`), and for this study, we used d.light solar lantern products, which are certified and recognized under the World Bank Lighting Global Project (`https://www.lightingglobal.org/`).

At the household level, it aims to estimate the impact on kerosene consumption, savings, household expenditure, asset accumulation, and willingness to pay for solar devices.

Our estimated results show that children who randomly received solar lanterns significantly increased their study hours, particularly at night, and relied more on solar lanterns products instead of kerosene lamps. In addition, their school attendance also increased for several months after the provision of solar products. However, these increases in educational inputs did not translate into improved educational attainment, measured by the school-based annual examination results. While we do not see any significant impact of solar lanterns on children's respiratory indicators measured in both objective and subjective manners, we see significant improvements in their eye problems, such as eye redness and irritation, 14 months after the distribution of solar lamps. Moreover, households that received solar lanterns relied less on kerosene-based lighting sources, which significantly contributed to the reduction of biomass fuel consumption in general and kerosene expenditure in particular, although its impacts on savings and asset accumulation were negligible. We also find some suggestive evidence that households that experienced solar lanterns were quite satisfied with the products, as their willingness to buy solar lamps was higher than households who continued to use kerosene-based lighting sources.

The rest of the paper is structured as follows. Section 2 explains the study setting, sampling framework, and detailed design of the RCT. Section 3 discusses summary statistics of the sample households. Section 4 outlines the estimation strategy, followed by discussions on the estimation results. Section 5 concludes the paper.

2 Survey and experimental design

2.1 Study setting

As mentioned previously, our study area is river islands located in northwest Bangladesh, which are formed by sediments and silt depositions. These islands are merely a few inches above the normal functioning 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. Every year, residents of *Chars* are often forced to evacuate to mainland to look for shelter during the flood. The major mode of transportation from *Char* to mainland is based on boat networks, which are poorly managed, unreliable, and prone to weather conditions. Therefore, living in *Char* is highly precarious, risky, and dangerous at times. The provision of national grid electricity is rare, and the REB of Bangladesh has hardly electrified any *Char* properly.

Some NGOs have tried to provide some small-scale SHSs[2]; however, such SHSs are generally expensive[3] and has some physical constraints, which are not appropriate for *Char* dwellers. As mentioned, living in *Char* is extremely vulnerable and requires frequent relocation and mobility, but the SHS is a fixed utility by which the access of electricity is only available at the installed place. During the time of flood or land erosions, when quick relocation is necessary, households find it difficult and expensive to move their SHS along with them. As a result, the use of SHS in the *Char* context is quite limited. Since there exists hardly any alternative source for electricity, most Char residents use kerosene-based lighting equipment, such as open wick lamp and covered wick lamp (known as "Hurricane"), for their main source of light at night. Some households use battery-powered flashlights to accommodate their emergency need. However, these flashlights (also known as "Torch" lights) have very limited power to perform any additional tasks, and the required batteries are expensive and often unavailable to *Char* dwellers.

2.2 Stylized consequences of traditional lighting sources

Traditional lighting sources that burn biomass energy create a staggering amount of indoor air pollution, whose scale is higher than the World Health Organization's (WHO) safe standards, and poses a serious threat to pulmonary health (Apple et al. (2010)). For instance, burning a liter of kerosene with open fire lamps emit enormous particulate matters (PM) with diameter less than 10 micrometers or microns (PM10) per hour, which is above the 24-hour mean standard of PM10 per cubic meter of WHO (World Bank (2008)). PM10 has been epidemiologically associated with cardiovascular and respiratory causes, such as frequent coughing, asthma, and chronic obstructive pulmonary disease (COPD), which could lead

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

[3]The minimum amount to be paid for a 10 watt panel with a 2/3 LED light or a 5 watt CFL is 9800 taka, which provides lights for only 4 hours. See `http://www.gshakti.org/index.php?option=com\_content\&view=article\&id=115\&Itemid=124`.

to bronchitis and tuberculosis (Anderson et al. (2012)). Moreover, these kerosene lamps often cause fire related hazards; for example, Mashreky et al. (2008) in their study demonstrated that kerosene lamps are causing approximately 23% and 11% burns of infant and children (aged 1-4), respectively, which is the third leading cause of illness among the children of that reference age. Other frequently cited self-reported adverse impact of kerosene lamps are concerning eye health in the form of eye irritation or itchiness (Baker and Alstone (2011)).

2.3 Solar devices

To improve accessibility to electricity and to study how the living of *Char* dwellers could be changed after the introduction of solar lanterns, we procured part of solar devices using social business funds that were raised in an online technology market operated by Kopernik, a non-profit organization aiming at distributing low-cost technologies to the underprivileged in less developed countries, and were financed by Daiwa Securities.[4] The remaining devices were available due to generous contributions from two NGOs, i.e., BRAC, one of the largest NGOs in the world and Gono Unnayan Kendra (GUK), an implementation partner of our research project based in *Char* areas. In total, we had 500 units of d.light S250 along with additional 300 units of the other two types of products called S10 and S2. The details of these products are as follows (see also Figure 1):

- S250: d.light S250 is their flagship product, which provides bright light for a maximum of 4 hours and illuminates a room equivalent to a 3-5 Watt compact fluorescent lamp (CFL). This unit also has the functionality of charging cellular phones. S250 has a separate lightweight solar panel, which needs to be used to recharge the unit.

- S10: d.light S10 is a portable solar light-emitting diode (LED) lamp, which provides bright light for a maximum of 4 hours. This unit does not possess the functionality to charge mobile phones. The solar panel of S10 is combined with the main unit.

- S2: d.light S2 is the simplest and highly efficient LED, which provides a focused light for a maximum of 4 hours. Illumination capacity of this unit is lower than the other two units. Like S10, this unit

[4] See `http://kopernik.info/` for more information on Kopernik.

also does not have the functionality to charge mobile phones. The solar panel of S2 is also combined with the core unit.

In terms of lighting capacity, S250 could provide on an average 110 lumens[5] of light based on the top brightness setting after a full day's solar charge,[6] whereas S10 and S2 could provide approximately 29 and 25 lumens of light, respectively.[7] In comparison with traditional lighting devices used in Bangladesh, kerosene-based open wick lamp and covered wick lamp ("Hurricane") produce on an average approximately 7.8 and 45 lumens of light (Mills and Jacobson (2008)).

[Here, Figure 1]

2.4 Sampling procedures

We selected children attending primary and secondary schools as a primary target population, because one of the best usages of solar lantern is to improve the study environment at night. More precisely, as very few variations in school performance or hours of study were expected at the elementary level, we focused on children who enrolled in 4^{th} to 5^{th} grades in the primary school, and 6^{th} to 8^{th} grades in the junior high school level. To select sample children (and their households) for this study, we listed all primary and secondary schools located in the *Chars* of Gaibandha and Kurigram districts and conducted quick initial inspection with teachers and School Management Committees (SMCs) of the respective schools to ask about their students' access to electricity, either through national grid or through SHS. After comprehensive interviews with teachers and SMCs, we realized that the provision of solar lights through SHS has been recently introduced by a local NGO in several *Chars* and non-negligible children and their families already have limited access to solar lights, even though they were only for supplementary use. To avoid contamination effects, out of 2795 children who belong to 4^{th} to 8^{th} grades in 28 schools in 8 *Chars* we listed, we selected 1292 children in 17 primary and secondary schools in two *Chars* that had received very limited SHS service from the NGO. Then, we interviewed children at their respective houses to further verify the list to make sure our selected sample does not have access to solar lights at

[5] Lumen is the measure of light emission.
[6] See `https://www.lightingglobal.org/products/dl-s300/`.
[7] See `https://www.lightingglobal.org/products/dl-s20/` and `https://www.lightingglobal.org/products/dl-s2/`.

home. Of the 1292 total children, it was found that 911 did not have any access to SHS at the time of our survey. Of those, 882 became effective sample households for this study; the rest were dropouts from schools due to marriage or other practical reasons (i.e., land erosion resulting in force migration) before the detailed baseline household survey. The detailed time-line for our surveys and interventions are illustrated in Figure 2.

During the baseline survey in July and August in 2013, we collected the detail data at the household level to understand the socio-economic conditions of the sample children and their households, which pertain to household demographic characteristics, health conditions of each household members, details of energy use and its sources, expenditures, various income generating activities, durable and nondurable assets, debt, savings, and credit. We also designed a set of questions to measure risk and time preferences as well as willingness to pay for solar lanterns.

[Here, Figure 2]

2.5 Experiments

Once we finished the baseline household survey, we organized a public lottery to randomly allocate the access to use solar lights for sixteen months (September 2013 to December 2014) to the eligible students in two different bundles of products. The first treatment bundle (Treatment A) contains each of all d.light solar products, i.e., S250 (solar lantern), S10 (general solar lantern with no cellular recharge facility), and S2 (simple solar lantern) containing approximately 164 lumens of lighting capacity at top brightness setting. The second treatment bundle (Treatment B) contains the S250 solar lantern only providing a lumen capacity of 110 at the maximum setting. By differentiating the treatment intensity, we seek to explore whether the provision of smaller lanterns has any additional impacts, such as facilitating the use of the main product (S250) to its intended users. For example, other household members of the treated households may want to use solar lanterns for their own activities, which may mitigate effects on the target children, but the provision of additional solar products may reduce the intensity of such sibling competition.

We held public lotteries at each sample school in the presence of parents, teachers, and village elites.

Students and their parents drew a lottery by themselves and, depending on the realized lottery, they were classified into one of the following three groups: (1) Treatment A, (2) Treatment B, and (3) control group that did not receive any solar lantern. After the public lottery, we ended up having Treatment A with 248 students, Treatment B with 198 students, and control group with 436 students. See Figure 3 for details.

During the time of the distribution of solar lanterns, we collected school attendance record, exam scores in the previous year, and health measures of sample children. These health measures included objective scores of lungs capacities, such as forced expiratory volume (FEV_1) and forced vital capacity (FVC) and subjective assessment, such as oxygen cost diagram (OCD) and breathing ability (see Appendix A.2 for the definition of these measures). A spirometer was used to check the FEV_1 and FVC. Furthermore, to collect accurate daily time use, we provided each student with a time-diary. To facilitate the time keeping, we gave both treated and controlled students a wall clock together with a set of batteries.

To recharge the solar products effectively, obstructions to sunlight (e.g., walls, trees) need to be avoided. Furthermore, the tilt angle of the panel is also important. To facilitate proper maintenance and correct recharge practice, a product manager of a local selling agency was invited to the study site who adequately trained our enumerators, who in turn instructed survey respondents and children. Moreover, to ensure that these set of instructions are readily available to our sample households, we provided a detailed pictorial manual to all households. This manual contained elaborated information on adequate use/maintenance and recharge techniques of the products. This manual also included a detailed time-diary to keep detailed record of each student's time use for various activities (e.g., hours of playtime outside schools, study time at home, etc.). School teachers were held responsible to regularly check these time diaries, which was periodically collected by our survey team.

To comply with ethical concerns, the access to solar lights was given for 16 months, which are subject to be withdrawn and re-distributed to our control households. To make sure that this process could go smoothly, we issued a legal documentation for each treatment households describing the conditions including information on proper use, product responsibility, prohibitive practices (e.g., renting or sub-leasing), and withdrawal requirement. In this contract, we made the households to take charge of the product loss (e.g., theft); however, in the case of product malfunctioning (e.g., defects), we replaced the product upon verification process by the sales unit. This process, we believe, has reduced the contamination possibility due to the misuse of the products.

However, it is theoretically still possible that the ways of obtaining a new technology (e.g., either through leasing, free distribution, or purchasing from the market) could affect its use and socio-economic impacts. Thus, the findings of the current research could therefore be limited only to its experimental design, and it should be taken with caution while considering the external validity of our findings.

[Here, Figure 3]

2.6 Follow-up surveys

After the implementation of the RCT, we periodically visited schools every two months to assess (both objective and subjective) health indicators of children, as well as collected their monthly time use diaries. Moreover, one year after the baseline survey, we implemented a follow-up study of the same children and their households to construct welfare and behavioral changes over one year. During the follow-up phase, we could trace 852 households and the rest was attrited due to reasons, such as relocation or marriage.

Furthermore, we implemented an independent "health camp" at each of our sample schools after 14 months of initial distribution of solar lanterns to access the impact of solar lanterns on respiratory and pulmonary health conditions. These "health camps" were administered with professional doctors and health practitioners, who did not know the treatment status of each child and performed an unbiased assessment of children's health conditions.

3 Data

3.1 Balance across treatment assignments

Table 1 provides a description of key baseline variables of the survey students (Panel A) and their households (Panel B) by the treatment arms. By design, one household includes only one experimented student in this study. To ensure that the randomization worked well, regression coefficients of these variables on the treatment arms were reported in Tables A.1, 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 finding mitigates the concern of the randomization failure.

[Here, Table 1]

3.2 Lighting products and their use at baseline

As indicated from the number of lighting products in Table 1, kerosene-based products were major light sources at baseline in the surveyed area. Almost all households owned at least one kerosene lamp or lantern ("Hurricane"), with approximately 23% equipped with kerosene lanterns, which were generally more expensive than the lamps. On an average, sample households used approximately 4.8 and 6.3 hours of kerosene devices in rainy and off-rainy seasons, respectively. Annual expenses 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 biomass-based fuel costs in the total budget.

Table 2 presents major activities with each light source. For example, approximately 98% of the households owning the kerosene lamps referred to both reading/studying and cooking/eating at night as the first or second most major activities for their use, followed by 68% of walking outside at night. Partially similar to the kerosene lamps, it appears that the kerosene lanterns were primarily used for reading/studying, but not for cooking/eating at night.

[Here, Table 2]

3.3 Willingness to pay for solar lanterns at baseline

This study implicitly assumes that a household knew of and (if possible) was willing to purchase/use solar products, which would in turn affect several outcomes of interest. Indeed, approximately 72% of the surveyed households had heard about major solar products (e.g,. SHS) before the baseline survey. Based on information collected in that survey, we also created an index for the respondents' willingness to pay for the solar lamps, with a large number (between zero and five) indicating more willingness to pay (see

Appendix for A.1 the details). As Table 1 reports, the mean value of the index is approximately four, suggesting the presence of the respondents' great interest in purchasing and/or using the solar products.

4 Empirical analysis

4.1 Empirical strategy

In order to identify causal impacts of the solar lantern, we estimate the following empirical model by OLS:

$$y_{ij} = \alpha_1 + \alpha_2 d_1 + \alpha_3 d_2 + \alpha_4 \mathbf{x_{ij}} + \beta_j + \epsilon_{ij}, \tag{1}$$

where y_{ij} is the outcome of interest at the follow-up survey for a household (or a student) i living in a village j; d_1 (d_2) is an indicator for treated households that received treatment A (treatment B); the vector $\mathbf{x_{ij}}$ contains several baseline characteristics of the respondent; β_j corresponds to village fixed effects; and ϵ_{ij} represents a stochastic error term. The successful randomization makes the variables d_1 and d_2 orthogonal to ε_{ij} while freeing the associated estimates from any endogeneity bias. In addition to checking the statistical significance of the treatment effects of α_2 and α_3, equality of those two coefficients are also tested and the p-values are reported in tables presented below.

Given the preceding observation that most individual or family characteristics are well balanced across the treatment conditions, it is expected that including the baseline controls would not affect the consistency of the treatment effects. However, this is true if all the baseline respondents were successfully contacted and the outcome values reported in the follow-up survey. In this study, 96% of the 882 original households were re-interviewed. While the rate of sample attrition is not so high in this research, it is still possible that the outcome data are missing during the follow-up if respondents failed to provide the information and/or a researcher estimates the logarithmic number of outcomes that include the zero value (e.g., expenditures on particular items, land size, loan amount). To mitigate potential sample selection bias, this study therefore exploits respondents' baseline characteristics as controls in the estimations (although exclusion of those controls almost unaffected the implications obtained from the regression analysis). The estimation results based on specifications excluding baseline controls are available from the authors upon request. This attrition issue will also be discussed in more detail in subsection 4.3 after reporting the main estimation results.

The controls used in the regressions included household size; the number of non-resident members, temporal migrants, and males in a household; heads' age, completed years of education, and gender; the number of owned flashlights, kerosene lanterns, and kerosene lamps; per-day hours of using light sources in rainy seasons as well as those in dry seasons; annual expenditures; values of productive asset, livestock, and non-land asset; land size; an indicator, equal to one if a household has tried and succeeded in borrowing in the last 12 months; loan and savings amount; and indexes representing a household's willingness to pay for solar lamps, risk preferences, and time preferences (see Appendix A.1 for the details of these indexes). Furthermore, when estimating a student's time use, school attendance, examination results, and health status, the baseline controls also contained his/her age; years of completed education; a literacy dummy; a gender dummy; and a set of indicators for self-reported health-related problems in the last three months.[8] For brevity, we suppress coefficients on these baseline controls when reporting the estimation results. However, coefficients on those suppressed controls are also available upon request.

Finally, for all the outcomes whose baseline information is available in the data set, we also estimated the first difference of those variables without exploiting the aforementioned controls. The implications obtained from this differences-in-differences estimation were quite similar to those reported below, and the results can also be obtained from the authors upon request.

4.2 Main estimation results

This subsection reports the main estimation results. The information on the time use analyzed in the Table 3, school attendance in Table 4, examination results in Table 5, and health outcomes in Table 6 and Table 7 were collected from our targeted school-age child in each household. In contrast, the unit of observation is a household from Table 8 to Table 10.

[8]The respondents evaluated several health-related items, such as diarrhea, fever, headache, cough, sore throat, gastritis, nasal mucus/runny nose, phlegm/sputum, dizziness, burning, breath-related problems, eye-related problems, throat-related problems, skin diseases, and jaundice.

4.2.1 Time use

By estimating equation (1), this study first reports impacts of solar products on time use in Table 3. The data on total hours that the respondent child spent from September 2013 to April 2014 (eight months) was sourced from a time diary that the research team asked each household to record every day. Exploiting the information based on such a diary would increase the reliability of the analysis.

Based on the results in Table 3, receiving solar products significantly reallocated the time use for home study, reducing daytime study hours, while increasing it during the night. The net effect on study hours at home was significantly positive. As the results also suggest, a treated student substituted solar lamps for kerosene lamps/lanterns to enjoy more nighttime study. Moreover, due to this crucial substitution, treated children had significantly less hours of air pollution exposure compared with control groups. Notably, there was no significant difference in these impacts between children that received three solar products (Treatment A) and those that received only one (Treatment B). Figures A.1 (Treatment A) and A.2 (Treatment B) plot the estimated monthly treatment effects (with a 5% confidence interval) on time use during the eight months. The hours studied primarily increased before December 2013, which is an annual examination season in Bangladesh.

4.2.2 School attendance

The research team visited the studied schools in February, April, and September in 2014, without letting them know the visit in advance, and checked children's school attendance. The estimated results on school attendance are reported in Table 4, which reveals that receiving solar lamps initially encouraged students to attend school more strongly as we see more positive and statistically significant attendance records for our treated students (mainly for those students who received all three products). However, this initial enthusiasm of school attendance due to receiving solar lanterns tended to disappear for later months of attendance records. This could be due to the fact that initial enthusiasm was not supported by better learning inputs provided by the schools, and therefore, treated students lost their interest in attending schools in the end. Alternatively, students might have attended regularly in the initial months, expecting that they may get some additional treatments in the future if they show high presence records.

Then, it is possible that it took several months for them to realize that no additional support was coming from our counterpart NGO, and they corrected their expectation and eventually behaved similarly to other children who belong to the control group.

[Here, Table 4]

4.2.3 Examination results

We also examined whether these increases in study time at home and the initial higher rate of school attendance resulted in better schooling outcomes, measured by the results of annual school examinations held in December in 2013 and 2014.

Courses and subjects of these annual examinations varied across schools and grades to some extent. As a result, the analysis presented here focused on core subjects and estimated the grade point average (GPA, ranges from zero to five) of those subjects, which was constructed based on the Bangladesh Ministry of Education's prescribed method.[9] For some schools, the language examination (Bengali and English) consisted of two parts. In such cases, for the sake of comparison, we calculated the average GPA between those two parts of the same language examination as the GPA score of these subjects. For students that failed to attend an examination of one or more subjects, the GPA score of those subjects was assumed to take the value of zero.

Based on academic rules in Bangladesh, students can proceed to the next grade if they take the examination of all the necessary subjects and get a GPA score equal to or greater than one in all those subjects. Accordingly, this study also constructed and estimated an indicator that hypothetically measured whether students could have progressed to the next grade, if the entire assessment had been made only based on the examination results of core subjects. However, note that this hypothetically measured pass/fail indicator is not necessarily the true annual examination passing grade of our sample students, whose information was not available to us.

The estimation results were reported in columns (1a) to (1g) for the 2013 examination and in columns (2a) to (2g) for 2014 in Table 5, respectively. In 2014, one school did not hold the annual examination on one of the core subjects, namely Bangladesh general studies (BG), for students enrolled to grade five

[9] See `http://www.educationboard.gov.bd/dhaka/rules_business.php`.

(24 observations). In the analysis, it was assumed that those students got the GPA value of zero in this subject, and thus failed to proceed to the next grade. Instead, the estimations additionally included an indicator for these students ("No BG exam held") in columns (2a) and (2g) (although excluding this variable hardly affected the obtained implications).

As the results show, there is no evidence supporting that receiving solar lamps improved educational attainment. The impacts were insignificantly different from zero, or if there is any significance, negative. Notably, based on the hypothetically measured pass/fail indicator, students that received three solar products revealed a lower tendency to proceed to the next grade in 2014, compared to all other groups. While the mechanisms are not clearly discernible, at the very least, it appears that solar products did not significantly improve children's educational attainment during the period of investigation. The result is in line with Furukawa (2014), which found no improvement of school exams despite the increased study time induced by the provision of solar lanterns. In all likelihood, solar lamps were expected to remove one factor discouraging children's human capital acquisition, i.e., the lack of nighttime light, but it does not necessarily lead to the improved performance, as growing empirical studies suggest that relaxing only one constraint may not result in children's better school outcomes in the developing world (e.g., Glewwe et al. (2004); Glewwe et al. (2009); Mo et al. (2013)).

[Here, Table 5]

4.2.4 Health

The analysis in Table 6 estimates health-related information based on a student's subjective evaluation. The information on abilities to read OCD and breathing ability was collected in April 2014, whereas the data on the other outcomes were drawn from a standard module of the follow-up survey.[10] In addition to this subjective information, the research team also asked medical doctors to conduct health checks at schools in September 2014. Health-related outcomes based on doctors' evaluation were estimated, which are presented in Table 7. Since the doctors were unaware of the treatment status of the sample students, their beliefs about effectiveness of solar products are less likely to affect their diagnosis in a

[10] The information on abilities to read oxygen cost diagram (OCD) and breathing ability was collected every third month following the baseline survey, and this study reports the estimation results based on the most recent information available (i.e., April 2014).

systematic manner. Appendix A.2 provides detailed descriptions about the definition of several health-related outcomes exploited in all these tables.

The estimation results reported in Table 6 provided no strong support for the view that solar products improved a respondent's subjective health condition. However, as the results show in Table 7, providing solar products significantly reduced the cases of red eyes, eye irritation, and tearful eyes based on doctors' diagnosis, although no significant improvements were found for the other outcomes.

Two lessons can be obtained from these health consequences. First, a subjective health assessment may be less effective to detect (at least, subtle) health improvements, compared to an assessment based on more objective methods, such as professional medical checks. This is an important caution for any research that relies on a respondent's subjective evaluation for investigating short-term health improvements.

Second, the marginal health changes may provide several implications about health development. For instance, the duration of this research might have been too short to achieve significant health improvements, as respiratory improvements progress very slowly, or providing solar products for school-aged children might have been too late or too early to expect any significant and noticeable health improvement. Alternatively, the findings may suggest that kerosene lamps are not the only source of indoor air pollution, which would also be associated with burning of other biomass fuels, such as wood and cow dung. Only replacing kerosene lamps/lanterns with solar products might not have been effective enough to considerably improve health conditions such as respiratory function.[11]

[Here, Table 6 and Table 7]

4.2.5 Light sources

Table 8 reports the estimation results for several outcomes related to light sources. It appears that the provision of solar products significantly reduced the number of kerosene products in a household and actively used as well as its time to use those products. While statistical significance was somewhat weaker compared to the case of kerosene products, similar implications can also be obtained for flashlights. The

[11]For instance, one of the direct impacts of substituting kerosene-based lighting sources with solar lights is less exposure to the PM (both PM2.5 and PM10). However, this substitution may not be adequate to eliminate all the possible sources of exposure to PM. Children could get exposed to PM through traditional cook stoves or through diesel engines that regularly provide mechanical power to operate irrigation pumps and engine boats for transportation linkage, or even by the free-flowing dust in the *Chars*, which is a common feature due to the vulnerable nature of such silt based land formation.

estimation results also suggest that these impacts were much stronger for households that received all solar products than those that received only one.

[Here, Table 8]

4.2.6 Expenditures and investment

The impacts of have access to solar lantern on a household's expenditures and investment are reported in Table 9. Most clearly, those that received three (one) solar products reduced kerosene expenditures in the last 12 months by approximately 75% (50%). As explained in subsection 4.3, compared to controlled households, treated households showed less tendency to provide information on kerosene expenditures at follow-up, probably due to substitution of solar lamps for kerosene products. Then, assuming that the treatment group that reported the amount of kerosene expenditures at follow-up includes a greater proportion of households that are more likely to use kerosene products than the corresponding control group, the true treatment effects on kerosene expenditures may be even more negative. While its mechanism is not clearly identified from the current study, the estimations in columns (a) and (e) also show that households having access to three solar products also significantly decreased expenditures on food and some non-food items. Consequently, all these impacts contributed to a decline in the total expenditures of treated households by 2%-7%. This decline may be associated with a weakly significant increase in the amount of family savings implied in column (i).

Apparently, providing solar products also increased the likelihood that a household aimed at and succeeded in obtaining a loan (although the statistical significance may not be strong enough for this finding to be conclusive). However, such positive effects were not found for the amount of loan based on the results in column (h), which may be due to the small number of observations exploited in the analysis in that column. Finally, this study found no statistically significant impacts on major household assets.

[Here, Table 9]

4.2.7 Willingness to buy

In Table 10, it was attempted to assess the treatment effects on a household's willingness to buy solar products, which is surveyed at follow-up. The dependent variable takes one if the respondent is willing to buy each solar lantern. The variable is considered as a measure of subjective satisfaction. As the result in column (a) shows, treated households became more willing to buy solar lamps than did those in a control group.

For both treated and controlled households that showed an interest in purchasing solar products, this study also estimated their willingness to buy a particular product in columns (b)-(d). Notably, treated households revealed their willingness to purchase mainly for products that they used during the experiment. Namely, those that received only one product (S250) primarily felt inclined to purchase S250, whereas three-product users showed their willingness to buy all those products.

In the remaining columns, it was also examined how treated households benefited from solar products during the experiment. Based on the comparison between three-product and one-product users, the former group more evidently enjoyed solar lamps using them for household chores (other than direct use), compared to the latter.

[Here, Table 10]

4.3 Bounds on treatment effects

While the number of households that attrited in the follow-up survey is small (and exploiting baseline controls in the analysis left the results almost unaffected), sample selection associated with missing outcome data is still an empirical concern. One possible way to solve this problem is to use a selection correction methodology by explicitly modeling the selection process. However, this approach cannot be taken in the current research due to difficulty in precisely modeling selection mechanisms and the lack of good instruments that explain the selection but not the outcomes.

Alternatively, this study attempted to show bounds on treatment effects based on Lee (2009)'s methodology. However, it is acknowledged that this approach also has limitations. First, it has to be assumed that treatment assignment monotonically affects the selection, which cannot clearly be tested. Second, the estimates are treatment effects on the sub-population that would always be observed regardless of the treatment assignment, which may not always be a main interest. Nevertheless, it is still useful to assess the previously identified estimates based on this approach.

First of all, Lee (2009) demonstrated that in randomized experimental settings, if sample attrition rates are similar between treatment and control groups, a simple comparison between those groups that are successfully contacted can still be interpreted as a valid average treatment effect on the aforementioned local population. With controls of baseline family characteristics and village-fixed effects, Table 11 reports impacts of solar products on non-attrition probability (one if the outcome data are not missing at follow-up) for all the outcomes estimated above. Based on the results, for example, treatment groups are less likely to provide information on kerosene expenditures at follow-up than control groups, probably because of their replacement of kerosene lamps/lanterns with solar products. However, in many cases, the results show no effects of treatment assignment on the non-attrition probability.

Pooling two treatment groups into one, Tables 12 (health outcomes) and 13 (non-health outcomes) also present 5% confidence intervals of the treatment effects based on Lee (2009)'s approach. Since no controls are exploited in this analysis, the confidence intervals are quite wide. Nevertheless, it appears that the results provide similar implications as obtained from the previous analysis.

[Here, Table 11, Table 12, and Table 13]

5 Conclusion

There is a growing public interest in the diffusion of affordable modern off-grid solar lighting to help the destitute in less developed countries. While anecdote evidence that emphasizes the potential of such modern technology is accumulating, rigorous empirical evidence is still scant. This study aimed at providing one of few rigorous evaluations on the short-term effects of solar products on a household's decision-making in less advanced economies. To meet this research objective, we conducted a randomized field experiment in river islands ($Chars$) having no access to an electrical grid in northern Bangladesh.

Several findings were obtained. First, providing solar products decreased study hours of school-age children at home in the daytime while increasing hours of study in the night. Consequently, treated children also increased their total study hours at home during the first 8 months of investigation (from September 2013 to April 2014). This increase in study hours was more evident before an examination season. However, daytime activities that those children alternatively engaged in, by substituting their study hours, was not clearly identified in the current study. Second, the rate of school attendance also increased as a result of our experiment for the initial several months following the provision of solar lanterns. Third, despite these increases in study hours and school attendance, there was no evidence supporting that children that received solar lamps achieved higher scores at examination than those that did not. Fourth, although the changes were not so remarkable for 14 months of investigation, this study still provides some evidence suggesting health improvements of those treated children, especially for their eye related problems. The relevant findings also highlighted the effectiveness of professional health checks for the purpose of assessing health conditions, compared to a respondent's subjective evaluation. Fifth, households that received solar lamps substituted the modern technology for traditional light sources, such as kerosene lamps/lanterns. This behavioral change resulted in a significant decrease in annual kerosene expenditures, which in turn reduced the total household expenditures for 12 months. However, it is not clearly identified from the current research how the saved money was exploited, because the amount of savings and households assets did not show significant increases. After the experimental phase, finally, treated households also revealed a greater willingness to purchase solar products than those in a control group.

These results together suggest that despite the apparent improvement in the reduction of household expenditure on biomass fuels and increased children's nighttime study due to the introduction of solar lanterns, no sizable impacts on educational performance, health outcomes, and household welfare emerge by simply providing those products in an experimental setting. The portable and affordable lanterns would be a welcoming addition to the ongoing fight to reduce "energy poverty" in the geographically challenged areas, but better technological enhancement to provide brighter lights for long hours may be required to bring about the substantial benefits to those "energy poor."

In this study, we pay considerable attention to establish the internal validity of our findings. We implement an RCT to infer causality and further investigate bounds for the treatment effects based on

Lee (2009)'s approach, which suggests that the above findings are less likely to be attributed to estimated bias stemming from missing outcome data and the associated sample selection. While interpreting the bounds requires the monotonicity assumption that is not always testable, this exercise provides some confidence about the findings of the current research. That said, we also acknowledge that our results are contingent on and specific to the area and the period studied and are not presently generalizable. Further research and evidence are needed before asserting more concrete, generalizable conclusions.

A Appendix: Variable descriptions

This section provides supplementary information on variables exploited in this study.

A.1 Preferences

Risk preferences: 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. The current study calculated the sum of the respondents' choices of lottery B that ranged from zero (risk averse) to five (risk loving) and used it as a measure that reflects the degree of risk aversion.

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, first, they must always choose lottery B when the lower amount of the gambling game is 300 BDT. This response is expected because in that case, lottery B guarantees that the respondents receive 300 BDT, equal to the amount given by lottery A. In fact, only less than 1% of the respondents selected lottery A in face of the choice. Second, given the presumption that the respondents are risk-averse, they are likely to choose lottery B when the lower amount of the gambling game is large enough. The positive relationship between the selection of lottery B and the lower amount of the gambling game is confirmed in Figure A.3 (left-hand panel) that plotted the proportion of the respondents that selected lottery B against the lower amount of the gambling game. Given that the majority selected lottery B when the lower amount of the gamble is 300 BDT, the (likely) risk-averse respondents would eventually choose lottery A when the lower amount of the gambling game goes below a certain level. This suggests that a switch from selecting lottery A to lottery B is unlikely to occur when the lower amount of the gamble decreases. In the survey that allowed the respondents to make any choices (to avoid potential response bias), only less than two percent of the respondents revealed such an unlikely switch.

Time preferences: To measure the respondents' time preferences, the respondent households were required to choose between receiving 250 BDT the next day (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.

To check if the measure was meaningful, two exercises were performed. First, it appears that the respondents that are less patient due to several factors (e.g., credit constraint) prefer option A to option B when the amount provided in option B is small. However, increasing the reward of option B may raise the likelihood that the respondents choose option B. This relationship is indeed observed in Figure A.3 (right-hand panel), whereby the fraction of the respondents that selected option B was depicted against the amount presented in that option. Second, given the observation that the respondents are likely to select option B when the amount offered in that option is large enough, it is expected that a switch from selecting option B to option A is unlikely when the reward of 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 option B ranged from 265 to 280, 300, 330, and 375. As before, the sum of the respondents' responses selecting 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 option B and the reward of that option was again confirmed in Figure A.3 (right-hand panel). Furthermore, only two percent of the respondent households revealed an unlikely switch from selecting option B to option A when the reward of option B increases.

Willingness to pay: To measures the respondents' willingness to pay for solar products at baseline, the survey team hypothetically asked the respondent households to select free offers between receiving traditional kerosene lamps and fuels for one year (option A) and leasing solar lamps for a certain period (option B). The respondents assessed all five different lease periods (months) that ranged from twelve to nine, six, three, and one. For example, it is expected that some respondents always select option B irrespective of the length of the lease periods, showing their strong preference to use solar products. On the other hand, respondents that show no interest in using solar lamps would always prefer option A that surely enables them to reduce expenditures associated with the use of kerosene lamps. The remaining respondents are likely to choose option B for relatively long lease periods, but option A for short trial periods. Therefore, summing the respondents' responses selecting option B yielded an index for willingness to pay for the solar lamps, with a large number (between zero and five) indicating more willingness to pay.

Two exercises were performed to check whether the respondents provided reasonable responses to these questions. First, Figure A.4 provides a representation of the relationship between the proportion of the respondents choosing option B and the lease period of that option. The proportion increases in the length of the lease period, which is an intuitive finding. Second, given the tendency that the respondents prefer option B to option A when the length of the lease period is long enough, it is unlikely that they change the responses from option A to option B when the lease period decreases. Only less than 0.4 percent of the respondent households gave such an unreasonable response.

As Table 1 reports, the mean value of the index is approximately four, suggesting the presence of the respondents' great interest in purchasing and/or using the solar products at baseline.

In addition to this index, in the baseline survey, we also asked how much the respondents were willing to pay as monthly installments (that lasted three years) if they were to purchase solar lanterns. This information was elicited as a free-answer question. When collecting this information, the respondent households were split into two groups by a coin flip, with one receiving basic information on our "d.light" product specifications and the other group with additional information on the possible impact of using solar lights on pollution, cost saving, and health improvements. While providing the information, the same product picture was presented to both these groups.[12]

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

A The d.light S250, which is a solar lantern developed in the 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 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.

A.2 Health outcomes

Oxygen cost diagram (OCD) reading: Based on diagram A.5, the respondents were asked to make a mark on a 10 cm line at the point before which they became breathless. This measure takes the values that range from zero to ten.

Breathing ability: This measure is a subjective evaluation of breathing ability, taking any of the following five values.

1. Not troubled by breathlessness except on strenuous exercise.
2. Short of breath when hurrying or walking up a slight hill.
3. Walks slower than contemporaries on level ground because of breathlessness, or has to stop for breath when walking at own pace.
4. Stops for breath after walking at own pace.
5. Too breathless to leave the house, or breathless when dressing or undressing.

FEV$_1$ (forced expiratory volume): Volume of air exhaled under forced conditions in the first second.

FVC (forced vital capacity): Determination of the vital capacity from a maximally forced expiratory effort.

B The d.light S250, which is a solar lantern developed in the 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. 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.

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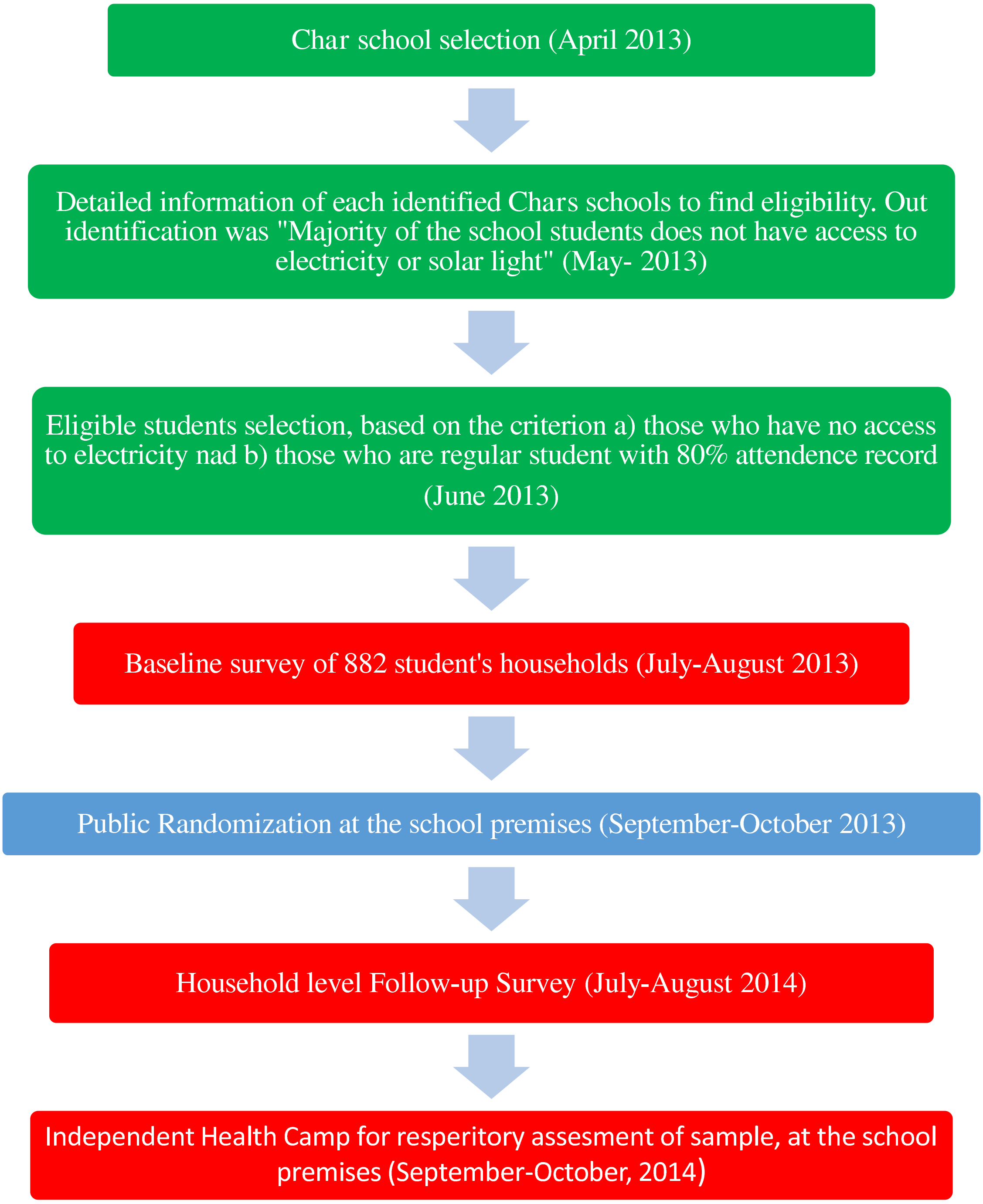
Figure 1: Product pictures

Note: The s250, s10, and s2 are displayed in order from the left.



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: Timeline of interventions and surveys

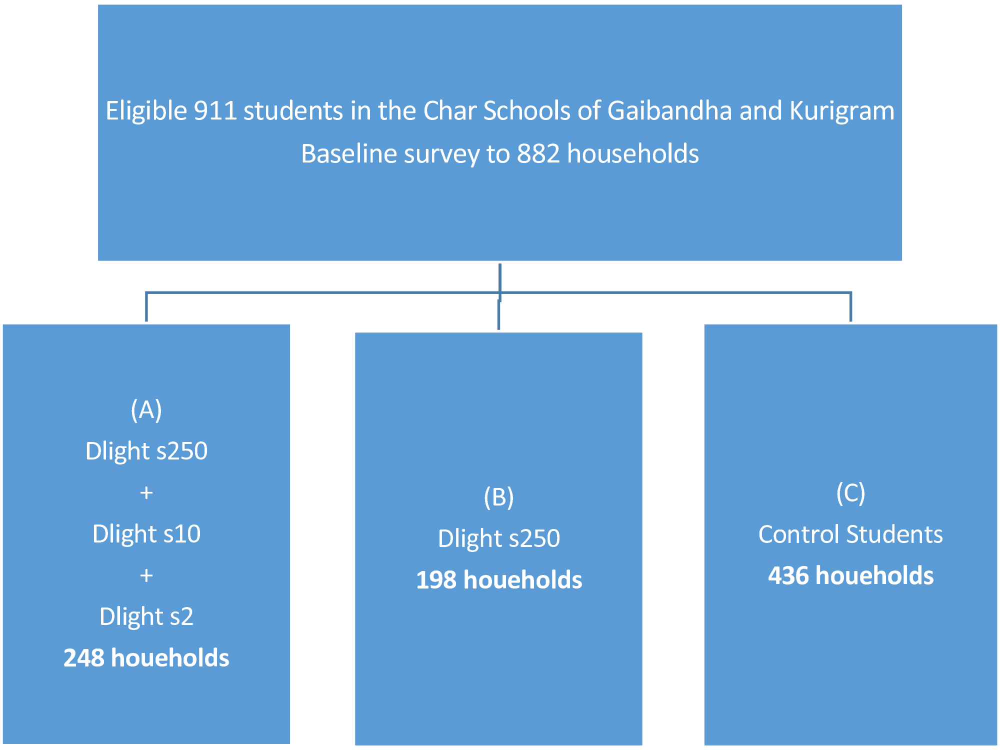


Figure 3: Randomization design

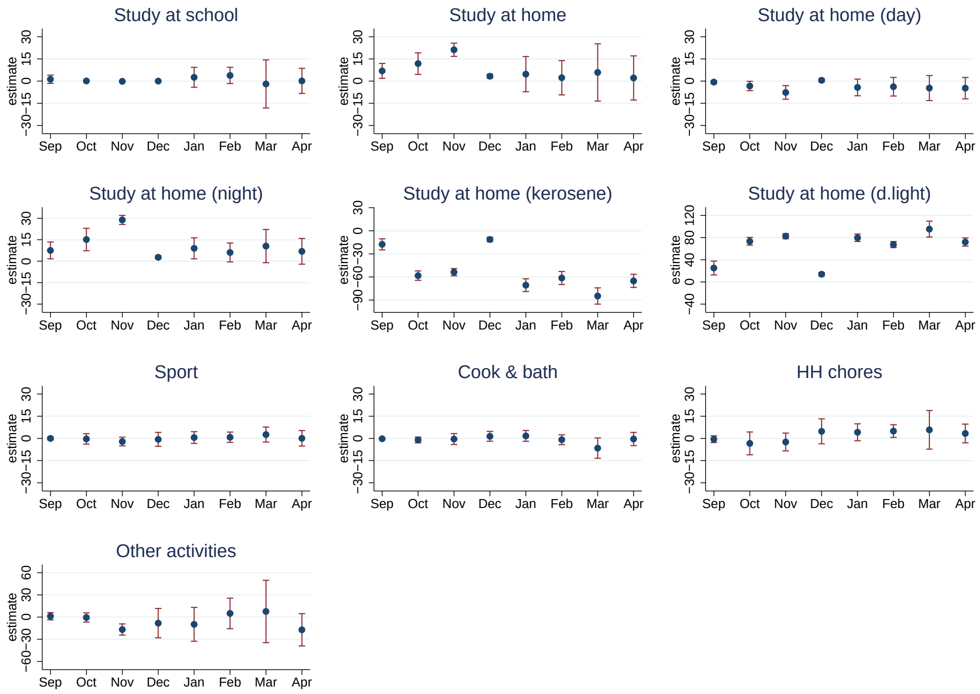


Figure A.1: Impacts on children's time use: all products

Note: Standard errors are robust to heteroskedasticity and clustered residuals within each school.

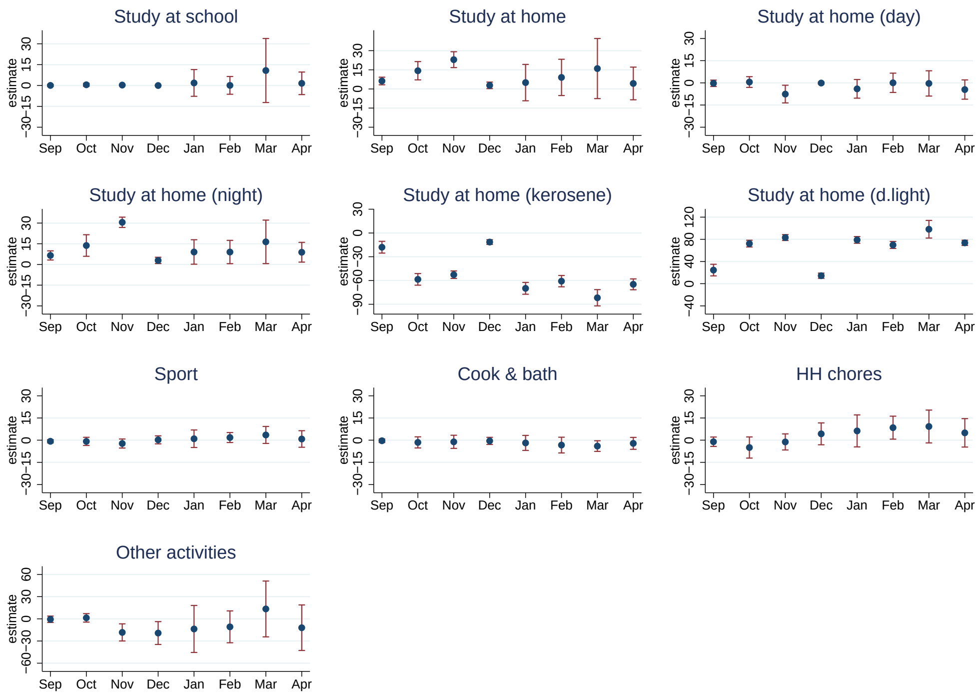


Figure A.2: Impacts on children's time use: one product

Note: Standard errors are robust to heteroskedasticity and clustered residuals within each school.

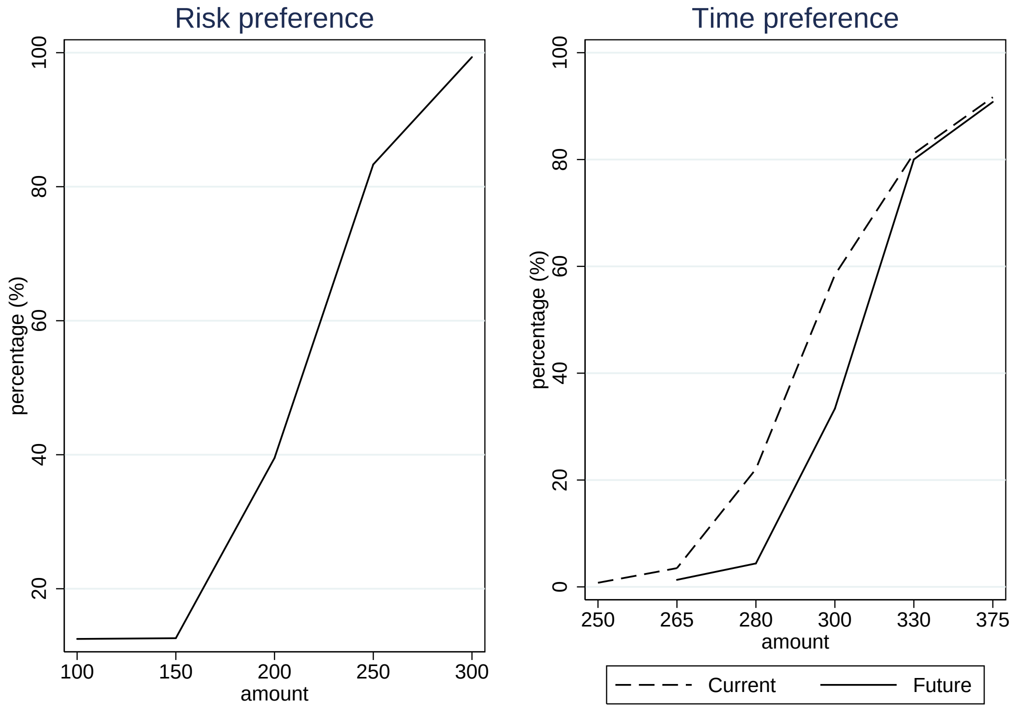


Figure A.3: Risk and time preferences

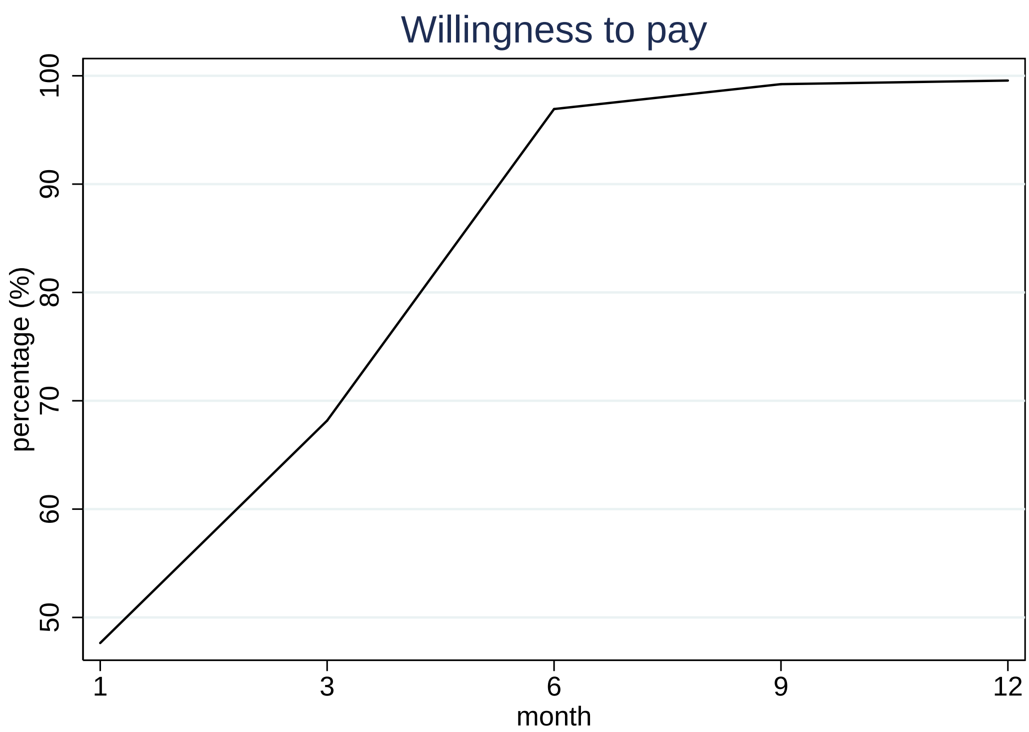


Figure A.4: Willingness to pay for solar lamps

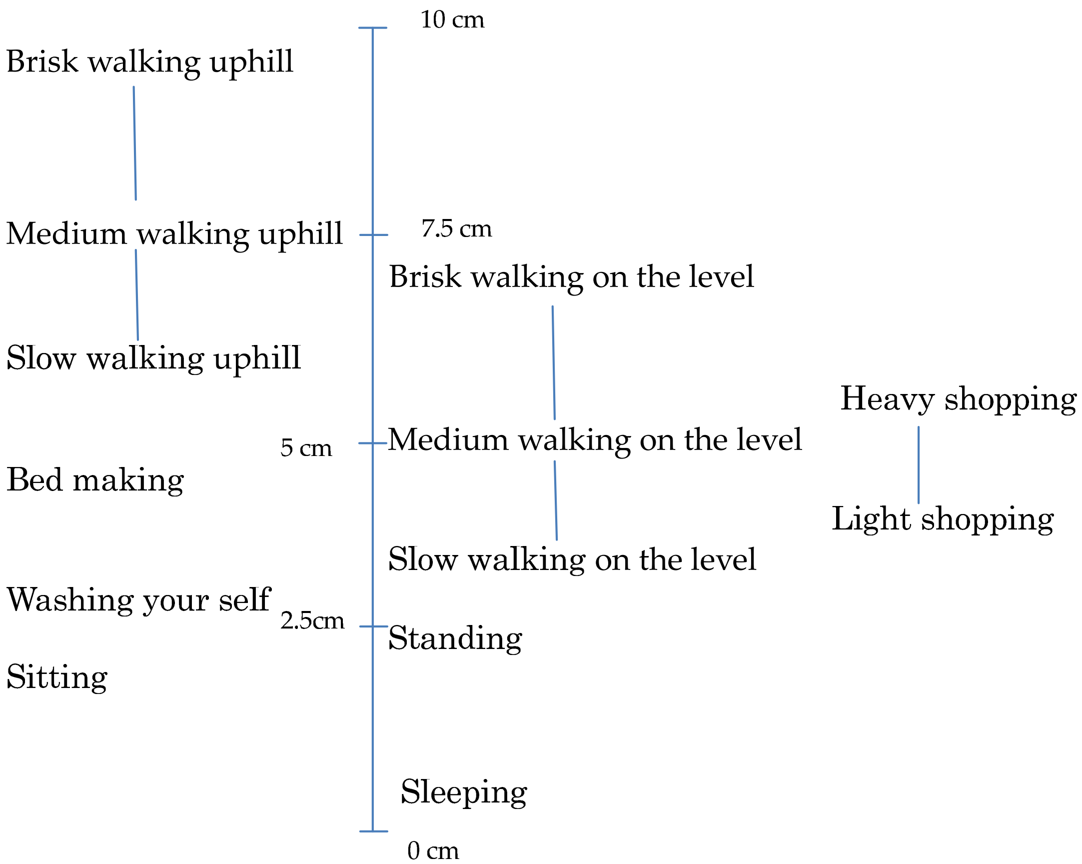


Figure A.5: Oxygen cost diagram

Table 1: Summary statistics (baseline)

	Treatment A (248 households)		Treatment B (198 households)		Control (436 households)		All	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Panel A: Student-level variables (one school-age child for one household)								
Age (years)	12.34	1.55	12.46	1.61	12.36	1.46	12.38	1.52
Male (dummy)	0.41	0.49	0.42	0.49	0.45	0.49	0.43	0.49
Education (years)	4.64	1.38	4.63	1.42	4.59	1.39	4.61	1.39
Literate (dummy, read & write)	0.99	0.06	0.99	0.07	1.00	-	0.99	0.04
Health problem in the last 3 months (dummy)								
Diarrhea	0.01	0.12	0.00†	0.07	0.01	0.13	0.01	0.12
Fever	0.37	0.48	0.35†	0.47	0.31	0.46	0.34	0.47
Headache	0.26	0.44	0.26†	0.44	0.21	0.41	0.24	0.42
Cough	0.11	0.32	0.10†	0.30	0.08	0.28	0.09	0.30
Sore throat	0.00	0.06	0.02†	0.14	0.01	0.11	0.01	0.11
Gastritis	0.01	0.12	0.01†	0.12	0.01	0.13	0.01	0.12
Nasal mucus/runny nose	0.23	0.42	0.23†	0.42	0.17	0.38	0.20	0.40
Phlegm/sputum	0.02	0.16	0.02†	0.15	0.04	0.19	0.03	0.18
Dizziness	0.00	0.06	0.00†	-	0.00	0.06	0.03	0.05
Breath-related problems	0.00	0.08	0.00†	-	0.00	-	0.00	0.04
Throat-related problems	0.00	-	0.00†	-	0.00	-	0.00	-
Skin diseases	0.00	0.06	0.01†	0.10	0.01	0.10	0.00	0.09
Jaundice	0.00	-	0.00†	0.07	0.00	0.06	0.00	0.05
Panel B: Household-level variables								
Household size	4.94	1.37	4.78	1.10	4.94	1.30	4.90	1.28
No. of non-resident members	0.08	0.46	0.05	0.34	0.06	0.41	0.06	0.41
No. of temporal migrants (12 mth)	0.29	0.48	0.30	0.48	0.28	0.49	0.29	0.48
No. of males	2.40	1.14	2.30	0.98	2.49	1.12	2.42	1.10
Head age (years)	41.84	9.19	41.98	8.10	41.67	8.49	41.79	8.60
Head education (years)	1.18	2.66	1.19	2.79	1.34	2.94	1.26	2.83
Head male (dummy)	0.91	0.27	0.92	0.25	0.91	0.28	0.91	0.27
No. of light sources								
Flashlight	0.08	0.31	0.11	0.31	0.12	0.35	0.11	0.33
Kerosene lanterns	0.24	0.47	0.25	0.49	0.24	0.44	0.24	0.46
Kerosene lamps	1.72	0.62	1.66	0.54	1.64	0.57	1.67	0.58
Per-day hours using light sources (sum of all owned & zero if not own)								
Flashlight (rainy season)	0.22	0.79	0.31	0.90	0.32	0.92	0.29	0.88
Flashlight (off-rainy season)	0.32	1.17	0.41	1.22	0.46	1.30	0.41	1.24
Kerosene lanterns (rainy season)	0.69	1.42	0.66	1.39	0.57	1.15	0.62	1.28
Kerosene lanterns (off-rainy season)	0.85	1.73	0.82	1.74	0.72	1.46	0.78	1.60
Kerosene lamps (rainy season)	4.19	1.81	4.23	1.76	4.04	1.78	4.13	1.78
Kerosene lamps (off-rainy season)	5.48	2.43	5.58	2.42	5.25	2.39	5.39	2.41
Expenditures (BDT)								
Food (12 mth)	62009.58	27463.06	59819.72	30648.68	58617.44	22753.63	59841.14	26061.42
School fees (6 mth)	2610.28	1620.37	2573.40	1579.37	2521.84	1690.14	2558.28	1644.94
Medical fees (12 mth)	2119.18	1651.87	2206.11	1887.91	2188.26	1996.33	2172.84	1879.09
Kerosene (12 mth)	1543.79	700.05	1553.39	735.16	1694.93	1709.81	1620.66	1306.58
Other non-food (12 mth)	11151.97	3816.90	10713.38	2716.02	11030.61	3554.57	10993.52	3463.82
Total	79434.81	30044.97	76866.01	31985.23	76053.10	24863.77	77186.45	28092.25
Productive asset (BDT)	1687.17	8578.34	844.39	3592.65	825.09	3138.21	1071.82	5341.21
Non-land asset (BDT)	2336.65	1822.51	2653.18	3837.07	2603.77	3137.47	2539.75	3016.69
Total land (decimal)	10.32	34.58	10.47	21.02	9.82	22.12	10.11	25.99
Livestock value (BDT)	19503.81	21130.79	16791.41	17559.84	18168.42	18356.85	18234.78	19011.62
Borrow dummy (try & success, 12mth)	0.12	0.32	0.14	0.35	0.14	0.35	0.14	0.34
Loan (BDT)	1280.24	4479.27	1197.72	5107.86	1814.22	5935.95	1525.68	5379.52
Saving (BDT)	1941.66	4883.18	1634.13	3491.74	1738.00	3299.33	1771.95	3847.01
Willingness to pay (0 to 5)	4.12	0.97	4.08	0.91	4.12	0.96	4.11	0.95
Risk loving (0 to 5)	2.55	1.08	2.42	1.06	2.46	1.14	2.48	1.11
Patience A (0 to 6)	2.61	1.19	2.54	1.15	2.56	1.23	2.57	1.20
Patience B (0 to 5)	2.07	0.96	2.07	0.86	2.14	0.89	2.10	0.90

†: No. of observations is 197.

Table 2: Major activities by light sources (baseline)

	Flashlight	Kerosene lanterns	Kerosene lamps
Reading/studying	0.04	0.98	0.98
Social interaction	0.13	0.17	0.22
Cooking/eating at night	0.01	0.15	0.98
Walking outside at night	0.86	0.48	0.68
Tending livestock	0.08	0.05	0.13
Income generating activities	0.02	0.00	0.00
Nighttime light for security	0.72	0.23	0.30
No. of households	95	202	875

Table 3: Impacts on children's time use (OLS)

Dependent variables:	Hours spent on from September 2013 to April 2014:				
	Study at school	Study at home (c) + (d)	Study at home (day)	Study at home (night) (e) + (f)	Study at home (kerosene)
	(a)	(b)	(c)	(d)	(e)
All products	8.119	58.993**	-23.483*	82.476***	-424.696***
	(12.025)	(26.209)	(12.863)	(16.633)	(15.775)
One product	17.586	82.971**	-16.249	99.220***	-419.969***
	(15.073)	(28.570)	(11.372)	(18.886)	(14.144)
Base cntrl. (Ind)	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES
School FE	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES
All = one (p-values)	0.581	0.237	0.420	0.226	0.593
R-squared	0.214	0.245	0.274	0.293	0.838
No. of obs.	620	620	620	620	620
	Study at home (d.light)	Sport	Cook & bath	HH chores	Other activities
	(f)	(g)	(h)	(i)	(j)
All products	507.172***	3.361	-6.731	21.449	-37.292
	(13.073)	(8.472)	(7.044)	(13.674)	(50.780)
One product	519.189***	2.132	-12.415	30.665	-64.769
	(15.652)	(8.528)	(7.746)	(18.915)	(54.329)
Base cntrl. (Ind)	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES
School FE	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES
All = one (p-values)	0.411	0.916	0.481	0.586	0.542
R-squared	0.846	0.310	0.325	0.244	0.443
No. of obs.	620	620	620	620	620

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 school. (3) Individual baseline controls include age (years); education (years); literacy (dummy); gender (dummy); and dummies for health-related problems in the last three months (diarrhea, fever, headache, cough, sore throat, gastritis, nasal mucus/runny nose, phlegm/sputum, dizziness, burning, breath-related problems, eye-related problems, throat-related problems, skin diseases, jaundice). (4) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 4: Impacts on children's school attendance (OLS)

Dependent var.	One if attend		
Month of visit in 2014:	Feb	April	Sep
	(a)	(b)	(c)
All products	0.103**	0.103***	0.023
	(0.042)	(0.028)	(0.036)
One product	0.032	0.088	-0.006
	(0.046)	(0.052)	(0.033)
Base cntrl. (Ind)	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES
School FE	YES	YES	YES
Village FE	YES	YES	YES
All = one (p-values)	0.125	0.749	0.430
R-squared	0.280	0.262	0.298
No. of obs.	880	880	880

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 school. (3) Individual baseline controls include age (years); education (years); literacy (dummy); gender (dummy); and dummies for health-related problems in the last three months (diarrhea, fever, headache, cough, sore throat, gastritis, nasal mucus/runny nose, phlegm/sputum, dizziness, burning, breath-related problems, eye-related problems, throat-related problems, skin diseases, jaundice). (4) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 5: Impacts on children's examination results

Dependent var.	Pass (estimates)	Bengali	English	Math	General science	Islam studies	Bangladesh general (BG) studies
	(1a)	(1b)	(1c)	(1d)	(1e)	(1f)	(1g)
December in 2013							
All products	0.026	-0.015	-0.036	-0.029	0.092	0.066	0.095
	(0.035)	(0.118)	(0.091)	(0.098)	(0.115)	(0.111)	(0.092)
One product	0.001	0.028	-0.148*	-0.136	0.022	-0.021	0.136
	(0.018)	(0.101)	(0.085)	(0.102)	(0.085)	(0.103)	(0.127)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES
School FE	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.514	0.706	0.324	0.439	0.586	0.538	0.787
R-squared	0.353	0.295	0.287	0.420	0.330	0.305	0.301
No. of obs.	849	849	849	849	849	849	849
	(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	(2g)
December in 2014							
All products	-0.090**	-0.138	-0.044	-0.229	-0.167	-0.108	-0.213
	(0.039)	(0.101)	(0.086)	(0.160)	(0.101)	(0.147)	(0.139)
One product	-0.048	0.050	0.043	0.007	-0.134	0.017	-0.064
	(0.039)	(0.126)	(0.113)	(0.153)	(0.116)	(0.148)	(0.139)
No BG exam held	-0.677***	-	-	-	-	-	-2.098***
	(0.065)						(0.164)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES
School FE	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.252	0.073	0.364	0.138	0.698	0.224	0.278
R-squared	0.219	0.171	0.158	0.214	0.212	0.167	0.204
No. of obs.	845	845	845	845	845	845	845

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 school. (3) Individual baseline controls include age (years); education (years); literacy (dummy); gender (dummy); and dummies for health-related problems in the last three months (diarrhea, fever, headache, cough, sore throat, gastritis, nasal mucus/runny nose, phlegm/sputum, dizziness, burning, breath-related problems, eye-related problems, throat-related problems, skin diseases, jaundice). (4) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 6: Impacts on children's health based on own evaluation (OLS)

Dependent var.	OCD reading (0 to 10)	Breathing ability (1 to 5)	One if have health problems in the last 3 months: Diarrhea	Fever	Headache	Cough	Sore throat
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
All products	-0.164	0.025	0.000	-0.042	-0.037	0.015	0.003
	(0.176)	(0.054)	(0.010)	(0.042)	(0.036)	(0.043)	(0.014)
One product	-0.184	-0.010	-0.010**	-0.035	-0.044	-0.045	-0.009
	(0.190)	(0.085)	(0.005)	(0.047)	(0.041)	(0.031)	(0.010)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES
Data collection	Apr. 2014	Apr. 2014	follow-up	follow-up	follow-up	follow-up	follow-up
All = one (p-values)	0.880	0.599	0.117	0.847	0.857	0.046	0.448
R-squared	0.169	0.145	0.075	0.144	0.137	0.105	0.140
No. of obs.	669	669	816	816	816	816	816

Dependent var.	One if have health problems in the last 3 months: Gastritis	Nasal mucus/ runny nose	Phlegm/ sputum	Dizziness	Breath -related problems	Throat -related problems	Skin diseases	Jaundice
	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
All products	-0.008	-0.029	-0.004	-0.001	-0.002	0.003	0.010*	-0.003
	(0.012)	(0.047)	(0.004)	(0.001)	(0.002)	(0.003)	(0.006)	(0.003)
One product	-0.021**	-0.036	-0.003	0.004	-0.000	-0.000	0.000	-0.004
	(0.009)	(0.038)	(0.002)	(0.004)	(0.002)	(0.001)	(0.001)	(0.004)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES
Data collection	follow-up	follow-up	follow-up	follow-up	follow-up	follow-up	follow-up	follow-up
All = one (p-values)	0.126	0.813	0.526	0.336	0.337	0.295	0.068	0.396
R-squared	0.086	0.105	0.070	0.071	0.328	0.105	0.044	0.078
No. of obs.	816	816	816	816	816	816	816	816

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 school. (3) Individual baseline controls include age (years); education (years); literacy (dummy); gender (dummy); and dummies for health-related problems in the last three months (diarrhea, fever, headache, cough, sore throat, gastritis, nasal mucus/runny nose, phlegm/sputum, dizziness, burning, breath-related problems, eye-related problems, throat-related problems, skin diseases, jaundice). (4) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 7: Impacts on children's health based on doctors' diagnosis (OLS)

Dependent var.	FEV_1	FVC	Eye redness (dummy)	Eye irritation (dummy)	Tearful eyers (dummy)	Dimness of vision (dummy)	Breathing at rest (min)	Breathing after light walk (per min)	Breathing after heavy walk (per min)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
All products	-0.022	-0.005	-0.146**	-0.146***	-0.036	0.003	-0.481	-0.468	-0.737
	(0.046)	(0.077)	(0.054)	(0.051)	(0.025)	(0.004)	(0.708)	(0.695)	(0.684)
One product	-0.011	-0.017	-0.130**	-0.110**	-0.044**	0.002	0.223	0.131	-0.094
	(0.050)	(0.060)	(0.049)	(0.044)	(0.017)	(0.013)	(0.604)	(0.614)	(0.538)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.862	0.873	0.738	0.381	0.678	0.902	0.271	0.339	0.385
R-squared	0.288	0.258	0.216	0.234	0.104	0.147	0.355	0.341	0.303
No. of obs.	752	752	525	525	525	525	525	524	525
Dependent var.	Heart beat after light walk (per min)	Heart beat after brisk walk (per min)	Heart beat after short run (per min)	Lung noise with stethoscope (dummy)	Pneumonia (duumy)	Postnasal drip/ mucus (dummy)	Frequent/ chronic cough (dummy)	Time to hold breath (sec)	Shortness of breath (dummy)
	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)
All products	-1.648*	-0.428	-0.355	0.010	-0.011	-0.004	-0.051	-1.120	-0.001
	(0.963)	(0.760)	(0.795)	(0.012)	(0.012)	(0.020)	(0.039)	(0.985)	(0.004)
One product	-2.311*	0.205	0.020	0.006	-0.015	-0.042	0.004	-1.805	0.005
	(1.334)	(0.660)	(0.689)	(0.010)	(0.010)	(0.031)	(0.038)	(1.231)	(0.010)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.574	0.216	0.548	0.325	0.615	0.167	0.308	0.310	0.386
R-squared	0.229	0.271	0.266	0.183	0.141	0.147	0.231	0.301	0.074
No. of obs.	525	525	525	525	525	525	525	525	525
Dependent var.	Size of chest at rest (cm)	Size of chest at expansion (cm)	Visible burns (dumm)	Visible burns (no)	Frequent headache (dummy)	Hearing problem (dummy)	Insomnia (dummy)	Gastro/ intestinal problem (dummy)	Fatigue (dummy)
	(s)	(t)	(u)	(v)	(w)	(x)	(y)	(z)	(aa)
All products	-0.072	-0.124	-0.041	-0.056	0.009	-0.002	-0.021	0.030	-0.010
	(0.278)	(0.293)	(0.028)	(0.033)	(0.021)	(0.010)	(0.021)	(0.020)	(0.009)
One product	0.057	-0.007	0.007	-0.010	0.019	-0.002	-0.009	0.011	-0.023
	(0.399)	(0.358)	(0.040)	(0.035)	(0.035)	(0.013)	(0.025)	(0.016)	(0.016)
Base cntrl. (Ind)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.694	0.701	0.062	0.128	0.781	0.995	0.326	0.423	0.513
R-squared	0.292	0.266	0.131	0.177	0.217	0.108	0.229	0.278	0.180
No. of obs.	525	525	525	479	525	525	525	525	525

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 school. (3) Individual baseline controls include age (years); education (years); literacy (dummy); gender (dummy); and dummies for health-related problems in the last three months (diarrhea, fever, headache, cough, sore throat, gastritis, nasal mucus/runny nose, phlegm/sputum, dizziness, burning, breath-related problems, eye-related problems, throat-related problems, skin diseases, jaundice). (4) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 8: Impacts on households' light sources (OLS)

Dependent var.	No. of actively used light sources		
	Flashlight	Kerosene lanterns	Kerosene lamps
	(a)	(b)	(c)
All products	-0.054*	-0.246***	-1.406***
	(0.027)	(0.029)	(0.096)
One product	0.004	-0.192***	-0.554***
	(0.031)	(0.028)	(0.068)
Base cntrl. (HH)	YES	YES	YES
Village FE	YES	YES	YES
All = one (p-values)	0.056	0.055	0.000
R-squared	0.355	0.398	0.473
No. of obs.	847	847	847

Dependent var.	Per-day hours using light sources (sum of all owned & zero if not own)					
	Flashlight (rainy)	Flashlight (dry)	Kerosene lanterns (rainy)	Kerosene lanterns (dry)	Kerosene lamps (rainy)	Kerosen lamps (dry)
	(d)	(e)	(f)	(g)	(h)	(i)
All products	-0.144**	-0.203**	-0.671***	-0.884***	-3.825***	-4.597***
	(0.063)	(0.098)	(0.090)	(0.092)	(0.180)	(0.236)
One product	-0.025	0.020	-0.522***	-0.694***	-1.602***	-1.687***
	(0.082)	(0.113)	(0.084)	(0.095)	(0.180)	(0.203)
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.096	0.022	0.048	0.039	0.000	0.000
R-squared	0.328	0.330	0.389	0.381	0.535	0.516
No. of obs.	847	847	847	847	847	847

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. (3) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 9: Impacts on households' expenditures and investment (OLS)

Dependent var.	Log of expenditures						
	Food	Non-food				Total	
		School fees	Medical fees	Keosene	Other non-food		
	(a)	(b)	(c)	(d)	(e)	(f)	
All products	-0.052***	-0.012	-0.090*	-1.327***	-0.039**	-0.073***	
	(0.014)	(0.034)	(0.049)	(0.142)	(0.016)	(0.012)	
One product	-0.012	0.005	0.003	-0.686***	0.016	-0.019	
	(0.020)	(0.035)	(0.040)	(0.069)	(0.022)	(0.017)	
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	
Village FE	YES	YES	YES	YES	YES	YES	
All = one (p-values)	0.092	0.688	0.108	0.000	0.025	0.006	
R-squared	0.475	0.411	0.246	0.461	0.476	0.525	
No. of obs.	847	842	847	631	847	847	
Dependent var.	Borrow dummy (try & success , 12mth)	Log of					
		loan (BDT)	savings (BDT)	productive asset (BDT)	non-land asset (BDT)	total land (decimal)	livestock value (BDT)
	(g)	(h)	(i)	(j)	(k)	(l)	(m)
All products	0.071*	-0.061	0.020	-0.077	0.079	-0.038	-0.157
	(0.038)	(0.154)	(0.099)	(0.064)	(0.082)	(0.072)	(0.132)
One product	0.039	0.069	0.127*	-0.051	-0.069	0.074	-0.109
	(0.029)	(0.168)	(0.069)	(0.078)	(0.093)	(0.089)	(0.100)
Base cntrl. (HH)	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES
All = one (p-values)	0.481	0.393	0.272	0.712	0.217	0.158	0.710
R-squared	0.149	0.401	0.250	0.370	0.310	0.386	0.392
No. of obs.	846	228	832	844	840	631	769

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. (3) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 10: Impacts on households' willingness to buy solar products (OLS)

Dependent var.	One if willing to buy			
	any solar products	s2	s10	s250
Sample:	all	Those that were willing to buy		
	(a)	(b)	(c)	(d)
All products	0.425***	0.209***	0.161***	0.086**
	(0.064)	(0.052)	(0.051)	(0.041)
One product	0.375***	0.062	0.049	0.090**
	(0.071)	(0.058)	(0.059)	(0.037)
Base cntrl. (HH)	YES	YES	YES	YES
Village FE	YES	YES	YES	YES
All = one (p-values)	0.236	0.004	0.015	0.797
R-squared	0.281	0.235	0.227	0.127
No. of obs.	847	492	492	492

Dependent var.	One if the first benefit (other than direct use) of solar products is				
	mobile charging	business use	HH chores	social interaction	security
Sample:	Treated households				
	(e)	(f)	(g)	(h)	(i)
All products	-0.028	0.004	0.119**	-0.019	-0.071
	(0.052)	(0.009)	(0.055)	(0.018)	(0.047)
One product	-	-	-	-	-
Base cntrl. (HH)	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES
All = one (p-values)	-	-	-	-	-
R-squared	0.259	0.174	0.227	0.098	0.223
No. of obs.	413	413	413	413	413

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. (3) Household baseline controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 11: Estimating non-attrition probability (OLS)

	All products		One product		R-sqd.	No. of obs	No. of obs. having non-missing values at follow-up
	Coefficient	Std. errors	Coefficient	Std. errors			
Outcomes of interest:							
Time use	0.010	(0.033)	-0.002	(0.040)	0.106	882	620
Examination results (2013)	0.013	(0.011)	0.022	(0.017)	0.111	882	850
Examination results (2014)	0.011	(0.014)	0.027*	(0.015)	0.099	882	846
Health (own, April 2014)	0.069***	(0.025)	0.009	(0.034)	0.118	882	669
Health (own, follow-up)	0.006	(0.019)	-0.002	(0.023)	0.084	882	816
Health (medical, FEV & FVC)	0.012	(0.013)	0.018	(0.017)	0.108	882	753
Health (medical, visible burns)	0.012	(0.013)	0.018	(0.017)	0.108	882	479
Health (medical, other)	0.008	(0.014)	0.028	(0.019)	0.109	882	525
Light sources	0.012	(0.013)	0.018	(0.017)	0.108	882	847
Food expenditures	-0.698***	(0.058)	-0.052**	(0.024)	0.518	882	847
School fees	0.012	(0.013)	0.018	(0.017)	0.108	882	842
Medical fees	0.012	(0.013)	0.018	(0.017)	0.108	882	847
Kerosene expenditures	0.009	(0.014)	0.019	(0.017)	0.105	882	631
Other non-food	0.068*	(0.039)	0.044	(0.027)	0.137	882	847
Total expenditures	0.019	(0.013)	0.021	(0.018)	0.085	882	847
Borrow	0.013	(0.013)	0.023	(0.017)	0.104	882	846
Loan	0.020	(0.013)	0.005	(0.018)	0.103	882	228
Savings	0.007	(0.044)	-0.010	(0.037)	0.157	882	832
Productive asset	0.038*	(0.022)	0.006	(0.024)	0.135	882	844
Non-land asset	0.012	(0.013)	0.018	(0.017)	0.108	882	840
Total land	0.006	(0.026)	0.006	(0.026)	0.086	882	631
Livestock value	0.032	(0.039)	0.015	(0.027)	0.182	882	769
Willingness to buy	0.013	(0.045)	-0.008	(0.039)	0.145	882	847

Notes: (1) A dependent variable is one if the outcome data are not missing at follow-up and zero otherwise. (2) Figures ( ) are standard errors. *** denotes significance at 1%, ** at 5%, and * at 10%. (3) Standard errors are robust to heteroskedasticity and clustered residuals within each village. (4) The estimations include household controls and village-fixed effects. (5) Household controls include household size; no. of non-resident members; no. of temporal migrants; no. of males; head age (years); head education (years); head gender (dummy); no. of flashlights; no. of kerosene lanterns; no. of kerosene lamps; per-day hours using light sources in rainy seasons (flashlights, kerosene lanterns, kerosene lamps); per-day hours using light sources in dry seasons (flashlights, kerosene lanterns, kerosene lamps); natural number of expenditures (food, school fees, medical fees, kerosene expenditures, other non-food expenditures); productive asset values (natural number); non-land asset values (natural number); land size (natural number); livestock values (natural number); borrow (dummy, try & success in the last 12 months); loan (natural number); savings (natural number); willingness to pay (0 to 5); risk preferences (0 to 5); and time preferences (0 to 5, now and future).

Table 12: Lee (2009)'s confidence intervals (5%) of the treatment effects on health outcomes

	Confidence interval		No. of obs.
	Lower bound	Upper bound	having non-missing values at follow-up
Based on own evaluation			
Diagram reading (0 to 10)	-0.828	0.155	669
Breathing ability (1 to 5)	-0.148	0.219	669
Diarrhea (dummy)	-0.018	0.005	816
Fever (dummy)	-0.101	0.039	816
Headache (dummy)	-0.087	0.051	816
Cough (dummy)	-0.061	0.044	816
Sore throat (dummy)	-0.056	0.015	816
Gastritis (dummy)	-0.054	0.004	816
Nasal mucus/runny nose (dummy)	-0.100	0.013	816
Phelgm/sputum (dummy)	-0.011	0.001	816
Dizziness (dummy)	-		
Breath-related problems (dummy)	-0.006	0.005	816
Throat-related problems (dummy)	-		
Skin disease (dummy)	-		
Jaundice (dummy)	-0.007	0.002	816
Based on doctors' diagnosis			
FEV_1	-0.130	0.071	753
FVC	-0.195	0.123	753
Eye redness (dummy)	-0.281	-0.065	525
Eye irritation (dummy)	-0.261	-0.048	525
Tear (dummy)	-0.065	-0.002	525
Dimness of vision (dummy)	-0.010	0.015	525
Breathing at rest (per min)	-3.378	1.335	525
Breathing after light walk (per min)	-3.507	1.283	524
Breathing after heavy walk (per min)	-3.622	1.116	525
Heart beat after light walk (per min)	-6.445	1.138	525
Heat beat after brisk walk (per min)	-3.115	1.192	525
Heat beat after short run (per min)	-3.316	1.425	525
Lung noise with stethoscope (dummy)	-0.010	0.020	525
Pneumonia (dummy)	-0.025	0.010	525
Postnatal drip/mucus (dummy)	-0.173	0.017	525
Frequent chronic cough (dummy)	-0.178	0.020	525
Time to hold breath (sec)	-4.901	1.090	525
Shortness of breath (dummy)	-0.010	0.009	525
Size of chest at rest (cm)	-0.775	0.759	525
Size of chest at expansion (cm)	-0.908	0.695	525
Visible burns (dummy)	-0.169	0.020	525
Visible burns (no)	-0.130	0.024	479
Frequent headache (dummy)	-0.157	0.039	525
Hearing problem (dummy)	-0.029	0.008	525
Insomnia (dummy)	-0.069	0.007	525
Gastro/intestinal problem (dummy)	-0.039	0.054	525
Fatigue (dummy)	-0.033	0.017	525

Note: A confidence interval of a few outcomes is missing due to computational difficulty.

Table 13: Lee (2009)'s confidence intervals (5%) of the treatment effects on non-health outcomes

	Confidence interval		No. of obs.
	Lower bound	Upper bound	having non-missing values at follow-up
Hours spent on from September 2013 to April 2014			
Study at school	-32.585	37.279	620
Study at home	-5.370	101.205	620
Study at home (day)	-64.567	-8.905	620
Study at home (night)	48.098	118.923	620
Study at home (kerosene)	-461.023	-411.944	620
Study at home (d.light)	477.336	548.982	620
Sport	-34.486	20.300	620
Cook & bath	-33.094	11.463	620
HH chores	-32.443	61.175	620
Other activities	-157.535	94.497	620
Examination results (2013)			
Pass	-0.033	0.096	850
Bengali	-0.140	0.240	850
English	-0.242	0.159	850
Math	-0.287	0.224	850
General science	-0.108	0.319	850
Islamic studies	-0.084	0.341	850
Bangladesh general (BG) studies	-0.028	0.382	850
Examination results (2014)			
Pass	-0.127	0.014	846
Bengali	-0.301	0.151	846
English	-0.267	0.163	846
Math	-0.389	0.153	846
General science	-0.409	0.076	846
Islamic studies	-0.318	0.190	846
Bangladesh general (BG) studies	-0.433	0.075	846
No. of flashlights	-0.109	-0.0141	847
No. of kerosene lanterns	-0.301	-0.1851	847
No. of kerosene lamps	-1.123	-0.8829	847
Per-day hours using light sources			
Flashlight (rainy)	-0.319	-0.054	847
Flashlight (dry)	-0.442	-0.061	847
Kerosene lanterns (rainy)	-0.850	-0.503	847
Kerosene lanterns (dry)	-1.070	-0.657	847
Kerosene lamps (rainy)	-3.072	-2.450	847
Kerosene lamps (dry)	-3.645	-2.845	847
Log of expenditures			
Food	-0.084	0.022	847
School fees	-0.088	0.119	842
Medical fees	-0.157	0.036	847
Kerosene	-1.207	-0.626	631
Other non-food	-0.056	0.051	847
Total	-0.092	0.006	847
Borrow dummy (try & success, 12mth)	-0.031	0.096	846
Log of loan (BDT)	-0.614	0.404	228
Log of savings (BDT)	-0.185	0.254	832
Log of productive asset (BDT)	-0.200	0.141	844
Log of non-land asset (BDT)	-0.172	0.161	840
Log of total land (decimal)	-0.299	0.242	631
Log of livestock value (BDT)	-0.386	0.226	769
Willingness to buy	0.330	0.462	847

Table A.1: Balance test across treatment conditions

Dependent variables:	Treatment A Coefficient	Treatment A Std. errors	Treatment B Coefficient	Treatment B Std. errors	R-sqd.	No. of obs.
Panel A: Student-level variables (one experimented student for one household)						
Age (years)	-0.020	(0.121)	0.098	(0.134)	0.002	882
Male (dummy)	-0.045	(0.039)	-0.027	(0.043)	0.000	882
Education (years)	0.051	(0.111)	0.037	(0.121)	0.002	882
Literate (dummy, read & write)	-0.004	(0.004)	-0.005	(0.005)	0.002	882
Health problem in the last 3 months (dummy)						
Diarrhea	-0.002	(0.010)	-0.013	(0.008)	0.002	881
Fever	0.061	(0.038)	0.041	(0.041)	0.003	881
Headache	0.051	(0.034)	0.048	(0.037)	0.003	881
Cough	0.030	(0.025)	0.019	(0.026)	0.002	881
Sore throat	-0.010	(0.007)	0.007	(0.012)	0.003	881
Gastritis	-0.002	(0.010)	-0.003	(0.011)	0.000	881
Nasal mucus/runny nose	0.059*	(0.033)	0.060*	(0.036)	0.005	881
Phlegm/sputum	-0.013	(0.014)	-0.016	(0.015)	0.002	881
Dizziness	-0.001	(0.005)	-0.005	(0.003)	0.001	881
Breath-related problems	0.008	(0.006)	0.000**	(0.000)	0.006	881
Eye-related problems	-0.001	(0.005)	-0.005	(0.003)	0.001	881
Skin diseases	-0.007	(0.007)	-0.001	(0.009)	0.001	881
Jaundice	-0.005	(0.003)	0.000	(0.006)	0.001	881
Panel B: Household-level variables						
Household size	0.007	(0.088)	-0.152**	(0.061)	0.003	882
No. of non-resident members	0.016	(0.023)	-0.014	(0.019)	0.001	882
No. of temporal migrants (12 mth)	0.012	(0.032)	0.016	(0.041)	0.000	882
No. of males	-0.084	(0.069)	-0.183**	(0.076)	0.004	882
Head age (years)	0.175	(0.690)	0.318	(0.699)	0.000	882
Head education (years)	-0.159	(0.242)	-0.147	(0.222)	0.001	882
Head male (dummy)	0.005	(0.028)	0.019	(0.023)	0.001	882
No. of light sources						
Flashlight	-0.040*	(0.020)	-0.017	(0.018)	0.003	882
Kerosene lanterns	0.001	(0.031)	0.012	(0.046)	0.000	882
Kerosene lamps	0.081*	(0.044)	0.017	(0.045)	0.004	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)	0.002	882
Flashlight (dry season)	-0.134	(0.081)	-0.048	(0.071)	0.002	882
Kerosene lanterns (rain)	0.116	(0.094)	0.094	(0.109)	0.002	882
Kerosene lanterns (dry)	0.128	(0.103)	0.101	(0.136)	0.001	882
Kerosene lamps (rain)	0.152	(0.120)	0.190	(0.179)	0.002	882
Kerosene lamps (dry)	0.228	(0.177)	0.335	(0.236)	0.003	882
Expenditures (BDT)						
Food (12 mth)	3392.136*	(1767.952)	1202.277	(1699.036)	0.003	882
School fees (6 mth)	88.441	(93.956)	51.567	(126.334)	0.001	882
Medical fees (12 mth)	-69.083	(132.390)	17.843	(133.091)	0.000	882
Kerosene (12 mth)	-151.141*	(81.734)	-141.537	(95.089)	0.003	882
Other non-food (12 mth)	121.357	(303.357)	-317.236**	(149.378)	0.002	882
Total	3381.710*	(1973.045)	812.914	(1725.075)	0.003	882
Productive asset (BDT)	862.086	(583.284)	19.302	(289.049)	0.005	882
Non-land asset (BDT)	-267.120*	(146.512)	49.409	(277.152)	0.002	882
Total land (decimal)	0.495	(2.781)	0.647	(1.837)	0.000	882
Livestock value (BDT)	1335.393	(1767.869)	-1377.003	(1449.068)	0.003	882
Borrow dummy (try & success, 12mth)	-0.028	(0.022)	-0.003	(0.024)	0.001	882
Loan (BDT)	-533.978*	(279.999)	-616.493	(402.984)	0.003	882
Saving (BDT)	203.657	(353.130)	-103.873	(240.940)	0.001	882
Willingness to pay (0 to 5)	-0.001	(0.072)	-0.045	(0.072)	0.000	882
Risk loving (0 to 5)	0.091	(0.079)	-0.041	(0.083)	0.002	882
Patience A (0 to 6)	0.053	(0.105)	-0.019	(0.132)	0.001	882
Patience B (0 to 5)	-0.074	(0.073)	-0.071	(0.095)	0.002	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.