Learning from Unincentivized and Incentivized Communication: A Randomized Controlled Trial in India*

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Abstract

Interactions among peers of the same social network play significant roles in facilitating the adoption and diffusion of modern technologies in poor communities. We conduct a large-scale randomized controlled trial in rural India to identify the impact of information from friends on willingness to pay (WTP) for high-quality and multi-purpose solar lanterns. We offered solar lanterns to seed households from 200 non-electrified villages and randomly assigned three of their friends to two communication treatments (unincentivized and incentivized) that led them to different exposure to their seed friend. We also introduce a second treatment to investigate whether the seed's gender identity impacts the magnitude of peer effects. We show that, unincentivized communication increases WTP for solar lanterns by 90% and incentivized communication by 145%, but gender doesn't seem to matter. We also show that learning from others is the mechanism that drives the increase in WTP. Our findings have significant implications for policies that aim at promoting the diffusion of new technologies in developing countries.

JEL: O33, D83, Q21, Q42
Keywords: Technology Adoption; Peer Effects; Information Flow; Solar Lantern

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1 Introduction

Theories of economic growth hold technological progress as the main engine of economic development. In particular, endogenous growth models highlight the important role of social learning in technology diffusion: profit- or utility-maximizing agents invest, learn by doing and learn from each other through knowledge spillovers (Romer 1986; Lucas 1988; Aghion and Howitt 1998; Barro and SalaiMartin 2004; Acemoglu 2009). This phenomenon has been especially documented for the diffusion of agricultural technologies in developing countries (Foster and Rosenzweig 1995; Bandiera and Rasul 2006; Bardhan and Udry 1999; Conley and Udry 2010). But peers, or broadly speaking of one's social network, also influence a host of other individual outcomes such as those related to education (Hoxby 2000; Sacerdote 2001; Angrist and Lang 2002; Zimmerman 2003; Figlio 2005), health (e.g., Munshi 2003; Kling and Liebman 2007), political participation (e.g., Fafchamps and Vicente 2013; Fafchamps, Vaz, and Vicente 2020; Nickerson 2008), labor productivity and consumption (e.g., Mobius, Niehaus, and Rosenblat 2005; Mas and Moretti 2009).

In this paper, we conduct a randomized controlled trial to investigate and quantify the magnitude of peer effects on willingness-to-pay (WTP) for a new solar-powered lantern in Uttar Pradesh, India. The solar lanterns are durable, multi-purpose, and convenient to use. They sold for Indian rupees (INR) 1,200 (USD 18.5) in Lucknow, the capital of the state of Uttar Pradesh, at the time of fieldwork. The lanterns also have a phone-charging feature, which makes them appealing. The study area was still non-electrified, and households did not know about solar lanterns before the study. We randomly selected 200 "seed" individuals, to whom we offered a solar lantern to participate in the study. Each seed household gave three names of close peers (friends or relatives) with whom they regularly interact and we randomly assigned these friends to three groups: a control group, an "unincentivized" communication treatment, and an "incentivized" communication treatment. We interviewed and elicited willingness to pay for the solar lanterns using the Becker-Degroot-Marschak (BDM) method (Becker, DeGroot, and Marschak 1964) from all three friends, but at different points in time. We elicited WTP from the control group immediately after interviewing the seed household. This allows us to capture WTP when there is no prior knowledge of what lanterns are and how to use them. We elicited WTP for both the unincentivized and incentivized groups thirty days after the seed received the lantern. Friends in the incentivized group, however, were invited to a "tea meeting," during which the seed presented the solar lantern and shared his or her experience. We elicited WTP from this group right after the tea meeting.

Our experimental design exploits the time lags to instrument for the possibility that peers exchange information about solar lanterns. Within thirty days, peers in the "unincentivized" treatment group have likely talked to their seed friend, who may have mentioned or even demonstrated the lantern's use. We also introduce a second treatment to instrument the peer's identity, specifically the gender of the original seed: out of the 200 individuals, half are male and half female. Recent empirical research has documented that the social identity of the person who carries and diffuses information can have a critical influence on how such information is understood or interpreted. In the context of technology adoption, this means that potential adopters are more susceptible to information and advice from some communicators rather than others (BenYishay and Mobarak 2019). A key determinant seems to be whether communicators and receivers share a common group identity. In India, gender roles structure a large part of social life (OECD 2020; Deininger, Goyal, and Nagarajan 2013; Roy 2015; Kandpal and Baylis 2019). Therefore, we investigate whether women may be less effective communicators, especially when it comes to transmitting information about new technologies. Before fieldwork, the research project was approved by the Internal Review Board (IRB) of Columbia University, and a complete pre-analysis plan, describing the main hypotheses to be tested, the experimental set-up and the identification strategy was posted in a public registry.

The results suggest that both the "unincentivized" an "incentivized" treatments have large effects on WTP for solar lanterns. In contrast, the gender treatment is not statistically significant at conventional levels (although the point estimate is negative). Specifically, we find that the unincentivized treatment group is willing to pay INR 120 more than the control group. The incentivized group, on the other hand, is willing to pay INR 190 more than the control group. These treatment effects correspond to 90% and 145% increases, respectively. It is notable that the unincentivized treatment almost doubled WTP, whereas the incentivized treatment added another 55 percentage points.

This paper contributes to the development economics literature on the role of communication and social learning in adoption and diffusion of new technologies. Important research in this strand of literature uses theories of social-learning to model adoption and diffusion of mostly agricultural technologies (Foster and Rosenzweig 1995; Bardhan and Udry 1999; Bandiera and Rasul 2006; Conley and Udry 2010).[1] A particularly important observation in this literature is that modern agricultural technologies significantly improve agricultural output and welfare, but their adoption or uptake rate has been disappointingly low. It demonstrates that farmers engage in learning-by-doing and learning from others. Indeed, adoption by one farmer generates knowledge to all her peers and increases their expected yield (Foster and Rosenzweig

1. The only exceptions to this are the studies by Oster and Thornton (2012) and Jain and Kapoor (2015), which investigate the impact of peers on adoption of menstrual cups by school girls in Nepal and academic achievement by university students in India, respectively.

1995; Bardhan and Udry 1999). The adoption of new agricultural technologies, therefore, is a social process. More recently, BenYishay and Mobarak (2019) extended this fundamental theory of social learning and show that farmers are more likely to adopt new technologies if they share the social identity of the person who communicates information about the new technology. Using a randomized controlled trial in Malawi, they investigated whether the provision of performance-based rewards to those who communicate about the technology results in increased diffusion of the technology. They found that technology adoption was much more likely when the information was provided by "peer" farmers (i.e., farmers with characteristics similar to those of the respondents), as opposed to government-employed extension workers or "lead" farmers (i.e., farmers with high income or running larger-scale farming operations).

We build on BenYishay and Mobarak (2019) and use a novel technology (a solar lantern) to disentangle the impact of learning through incentivized and well-targeted communication from learning through unincentivized and regular communication of peers on adoption and willingness-to-pay for the technology. A solar lantern is a superior lighting technology, which has the potential to improve the welfare of all members of the household. Unlike agricultural technologies, which involve significant uncertainty, are sensitive to specific agro-ecological conditions, and require a long time to capture their payoff, the solar lanterns we consider are easy to operate, and users quickly learn about their benefits. Our design also allows us to aggregate revealed WTP, a figure important for policymakers and other stakeholders to design optimal subsidy and cost reduction strategies to encourage the diffusion of the technology in cases when average WTP is lower than average cost.

The major challenge in identifying the impact of information from social network members on the adoption of new technologies, even after tackling identification issues through a randomized assignment, is understanding the mechanisms that drive the observed results. It may be that neighbors like to imitate each other rather than learn from each other about the benefits of the new technology or about how to operate it (Oster and Thornton 2012). We collected detailed information about respondents' perceptions of the solar lanterns as well as gender norms. In particular, we find evidence that the increase in WTP is driven both by learning how to operate the technology and learning about its benefits. We also document that households in our sample appeared to give women some say in purchasing decisions or when it comes to using new products. In particular, most respondents thought that women were as able as men to use new technologies. Consequently, despite their lower overall social status, women may still be perceived as legitimate communicators when it comes to demonstrating the pros and cons of household durables such as solar lanterns.

The paper also speaks to the emerging literature on electrification and energy transition in developing countries (Dinkelman 2011; Dugoua and Urpelainen 2014; Furukawa 2014; Grimm et al. 2016; Lee, Brewer, et al. 2016; Lee, Miguel, and Wolfram 2016). The current level of electrification in developing regions, such as Sub-Saharan Africa, South Asia, and Latin America remains low (International Energy Agency 2014).[2] Extending the grid to all rural areas requires high levels of investment that are often difficult to secure by governments. Households in poor communities regularly use kerosene lamps to meet lighting needs. In rural India, this is the case for about half of the population (Jain et al. 2018).

Yet, kerosene lamps generate indoor air pollution, which adversely affects health outcomes, pose risk of burns and fires, and require rural households to regularly travel long distances to buy fuel (Lam et al. 2012). We conduct a cost-benefit analysis and show that, if households adopt the solar lantern, they could save about INR 576 per year on kerosene spending and they could amortize the full cost of the lantern in just over two years. Kerosene lamps also emit harmful greenhouse gasses. UNEP (2013) estimated that the substitution of solar lighting for all traditional lighting in India would save about 34 million tonnes of carbon dioxide annually. In the Indian context, kerosene use also has a significant impact on public finances due to the long history of generous subsidies. Every consumer switching from kerosene to solar lanterns would save the government about INR 600 per year (Jain and Ramji 2016). Solar-powered lighting equipment, therefore, holds the promise of reducing indoor air pollution and greenhouse gas emissions, while improving household and public finances. Given the mounting pressures from the international community to see progress on climate action, transition to solar technologies offers exciting opportunities. From a public policy point of view, this paper offers insights on how to facilitate this transition.

The rest of the paper is organized as follows. Section 2 lays out the conceptual framework and the key hypotheses about willingness to pay for solar lanterns. Section 3 describes the design and experimental procedure, including randomization checks. Section 4 presents the empirical results, mechanism and cost-benefit analysis. Section 5 discusses the key experimental design related issues, and section 6 concludes the paper.

2 Conceptual Framework

Drawing on the key papers on social learning in development economics (Foster and Rosenzweig 1995; Bardhan and Udry 1999; Bandiera and Rasul 2006; Conley and Udry 2010; BenYishay and Mobarak 2019), we lay out a brief motivating framework for interpreting the main results of our randomized controlled trial. We begin by defining the following treatments:

2. It is estimated that around 1 billion people live without electricity access and many more without reliable electricity. See "https://www.iea.org/energyaccess/database/" for details.

- In the *unincentivized* group, subjects observe the new technology being used by their peers without incentivized communication. Learning from others is the result of natural interactions through social networks and the seed household.

- In the *incentivized* group, subjects observe the new technology being used by their peers, and are directly informed about its properties just before WTP is elicited. Thus, learning from others is the result of both the natural and incentivized interactions with the seed household.

In the context of agricultural technologies, previous studies have used the "target-input" model proposed by Wilson (1975) and Jovanovic and Nyarko (1994) to test for the presence of social learning. According to this model, farmers know the basic form of the new technology with certainty (e.g., an improved seed), but do not know precisely how to use it (e.g., the quantity of seeds or the amount of fertilizer to use). Farmers learn about the new technology over time through learning-by-doing. They try different levels of input and observe the realized output. Farmers can also learn from each other if they belong to the same social network and share information (or costlessly observe each other's input choice). In this model, the diffusion of new technologies is a social process because adoption by an individual generates information that spillovers to all her peers and which increases their expected welfare in the future (Bardhan and Udry 1999).

Solar lanterns are much simpler to use than agricultural technologies, but the primary mechanism remains that users learn about the product through learning-by-doing and through learning-from-others. When users first see solar lanterns, they quickly understand that it needs solar exposure to generate light. However, several aspects of the product will be uncertain, such as how long it takes to charge and the duration of the batteries. Lighting quality will also be difficult to ascertain before prolonged usage. A critical aspect is whether luminosity remains stable over time, especially relative to kerosene lamps, which are the default lamps used by households in the region. Scope for misuse also exists on how to position the lantern in the sun for optimal charging and how to maintain the photovoltaic panels over time. Regular cleaning of the panels is essential to ensure that dirt, grime, bird droppings, and debris do not block the sun while avoiding any abrasive contact not to scratch the glass accidentally.

We model the diffusion of solar lanterns using the social learning framework. Peers learn about the service provided by the lanterns and update their beliefs about its quality through their interactions with the seed households. Our hypothesis is that they become more willing to pay for lanterns as a result. The experimental design leaves one month for information to diffuse, that is, for households in the unincentivized group to learn about the solar lantern.[3] In our context, one month seems sufficient because, 1) the technology is easily

3. Allowing for longer than a month would increase the probability of other confounders.

observable, and 2) we offer the technology to one of their closest friends whom they interact with regularly. We will show later that, indeed, all households in the "unincentivized" treatment group report knowing what a solar lantern is, indicating that one month was sufficient to ensure respondents in the treatment groups were exposed to solar lanterns through their friend. Hence, we formulate Hypothesis 1 as follows:

Hypothesis 1. *The unincentivized treatment increases willingness to pay.*

An appealing extension of the "target-input" model, developed by BenYishay and Mobarak (2019), accounts for how information travels through social networks, specifically focusing on the role of "communicators" (the members of the social network who communicate information about the new technology). Only communicators know the optimal level of the technology and it is costly to transfer such knowledge to others. Technology diffusion may occur faster if communicators are rewarded for each new person adopting the technology due to their efforts. In our case, we asked seed households to invite their randomly selected peer for tea, after about one month of using the solar lantern. We expect tea meetings to increase the salience of the product and provide more accurate information than in the case of unincentivized regular interactions. Consequently, we hypothesize that the peers who attend a tea meeting are more willing to pay for the lanterns than the peers who do not attend a tea meeting. We formulate Hypothesis 2 as follows:

Hypothesis 2. *The incentivized communication treatment increases willingness to pay more than the unincentivized communication treatment.*

Finally, BenYishay and Mobarak (2019) show that, when it comes to adopting new technologies, farmers appear most convinced by communicators with whom they share a group identity. In our study, the social identity we focus on is gender because gender norms in India assign women to a remarkably low social status. Peers may, therefore, capture the knowledge that women generate through their experience with solar lanterns less effectively. Previous studies have documented that women are less influential than men. For example, although in a context very different from ours, Aral and Walker (2012) use randomized experiments on 1.3 million Facebook users to show that men are more influential than women and that women influence men more than they influence other women.

In India, women's lower social status is apparent in the lower educational attainment levels and lower labor market participation. Gender inequalities are also pervasive inside the household, where women display lower bargaining power over many household decisions, such as wealth inheritance or the purchase of durable goods (Deininger et al. 2013; Roy 2015; Kandpal and Baylis 2019). In similar contexts, studies have shown that improved cookstoves are adopted less than optimally, because women have low decision-making power

(Miller and Mobarak 2013; Alem, Hassen, and Köhlin 2017). Hence, inside or outside the household, women lack social prestige. We, therefore, hypothesize that, when they communicate about a new technology, receivers of the information are likely to pay less attention or to discount the information they receive. This implies that the effect of our communication treatments on WTP would be weaker when the seed is female. This leads to our third hypothesis:

Hypothesis 3. *Learning through male social networks increases willingness to pay by a greater amount than learning through female social networks.*

The objective of this paper is to quantify the impact of unincentivized and incentivized communication regarding a new technology on WTP by peers.[4] Although the treatment effects have significant implications on social learning and the adoption of new technologies throughout networks, our scope is limited to identifying learning about the technology by close members in the social network. Nonetheless, we attempt to draw on theories of social learning to explain some of the mechanisms behind our results in Section 4.

3 Experimental Design

3.1 Product, Sampling and Treatments

To test our hypotheses, we collaborated with a local organization known as MORSEL India to distribute solar lanterns and conduct a randomized controlled experiment[5] in 200 non-electrified habitations[6] in rural India. We chose the Gonda district in the state of Uttar Pradesh to draw our sample of habitations. Uttar Pradesh is located in the Northern part of the country and is the most populous and the fourth largest state of India in terms of land area.[7]. At the time of the experiment, the study area was still non-electrified, and

4. When analyzing the diffusion of information, it is often valuable to understand how information spreads across large distances within the network. The two notable models used in the literature to explain learning within social networks are the Bayesian model and the non-Bayesian types of models, which mainly constitute the DeGroot model (DeGroot 1974). Bayesian learning assumes agents update their beliefs about the different states of the world using Bayes' rule. In contrast, in the Degroot model, each agent receives a noisy independent signal from a true state of the world and repeatedly transmits information to other agents. To update their own belief, DeGroot-type agents evaluate the weighted average of their neighbor's opinions. More recently, Li and Tan (2020) and Chandrasekhar, Larreguy, and Xandri (2020) proposed new models of social learning. Li and Tan (2020) propose a variant of the Bayesian model of learning from local networks consisting of the agent's neighbors and the links among them. The agent is assumed to believe that her local network is the entire network. Then, the authors formulate a tractable learning rule to demonstrate what they call "locally Bayesian learning", under which new information is extracted by each agent using the full history of observed reports in the agent's local network. Chandrasekhar et al. (2020) on the other hand consider a model of incomplete information where members can be either Bayesian or Degroot, and where members have information about the proportion of the two types. The authors validate their model using experiments and find that the percentage of Bayesian members in a network varies substantially with the empirical context.

5. Before implementation, the experiment was approved on the 8th of April 2015 by the internal review board (IRB) of Columbia University (IRB-AAAP2110). We also listed all our research hypotheses and key empirical specifications in a pre-analysis plan (PAP), which we registered at the "Evidence in Governance and Politics" website.

6. Habitations (also called sub-villages or hamlets) are the lowest administrative units in India. The average size of the habitations in the study area is around 300 people (53 households), which is a bit lower than the state average of 700 people (122 households).

7. See https://knowindia.gov.in/states-uts/uttar-pradesh.php for a description of the state

households did not know about solar lanterns. This fact offered the required setting to implement our solar lantern interventions.

Solar lanterns are small lamps (about 35 centimeters or 1.15 feet high) powered by a battery that charges when exposed to solar radiation. The solar lanterns we used sold for INR 1,200 in Lucknow, the capital of Uttar Pradesh state.[8] Notably, these lanterns had a USB-port feature, which allowed users to charge a mobile phone. In our sample, households spent on average about INR 42 on lighting needs per month per lamp (typically on kerosene), corresponding to about INR 500 per year. If households purchased the lantern at the market price of INR 1,200, they would amortize it in about two and a half years. We chose the product based on a review of solar lanterns available among Uttar Pradesh distributors. The survey team confirmed that the lanterns performed well regarding lighting quality, duration, and charging power by using them for about a week. This way, we selected the model to be durable, multi-purpose, and convenient to use.

The data collection began with a mapping of 200 primary habitations and 25 replacement habitations around Gonda city. The enumerators approached the habitations in expanding circles, with habitations near Gonda city visited first and those farther away visited later. If a habitation was excluded because of safety concerns or because it had access to grid electricity, a randomly drawn replacement habitation was used instead. Overall, we had to exclude and replace five habitations only. The map of the study area depicting the sample habitations is presented in Figure 1.

Within each habitation, the enumerators approached a randomly chosen seed household.[9] Depending on the treatment, they interviewed either a male or female household member.[10] We gave all seed households a solar lantern and INR 100 (USD 1.54) in exchange for taking part in the survey and inviting one of the three friends for a tea meeting. The seed was requested to provide the names of three friends with whom he or she interacts regularly. The three friends were then randomly assigned to three groups: control, unincentivized, and incentivized communication.[11] The control group was interviewed immediately after the seed household provided names. This procedure ensured that there was no time for information about the lantern to diffuse to the friends in the control group. The unincentivized and incentivized groups were interviewed approximately 30 days after the seed. We surveyed these two groups at the same time to avoid

8. This was equivalent to about USD 18.5 at the time of the fieldwork (Fall, 2015). The solar lantern had a 3-watt solar panel, a 6V 4.5Ah battery, a 3-watt, 24-piece surface-mounted-device LED, and a phone-charging socket. See Fig. 4 of the online appendix for a photo.

9. The enumerators would walk through the habitations and interview the household of first adult they meet.

10. We used a random number generator in Excel to generate a random number between 0 and 100 for each habitation. If the number was strictly higher than 50, we assigned the habitation to the female seed treatment.

11. We used a random number generator in Excel to generate a random number for each of the friends' names. We assigned the name with the highest number to the control group, the second to the unincentivized group, and the third to the incentivized group.

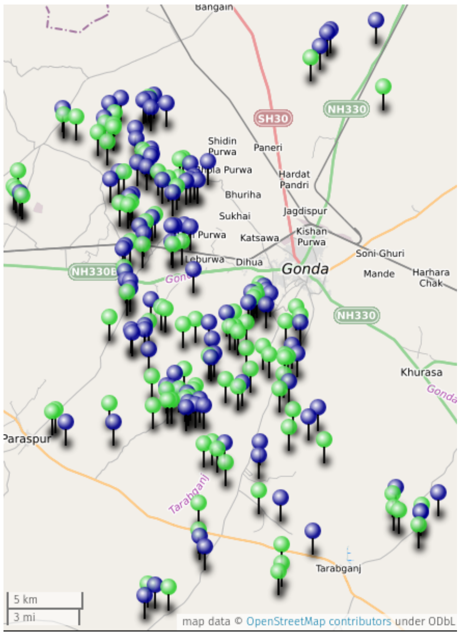


Figure 1: Map of study area around Gonda city. Green dots indicate the habitations with female seeds and blue dots habitations with male seeds.

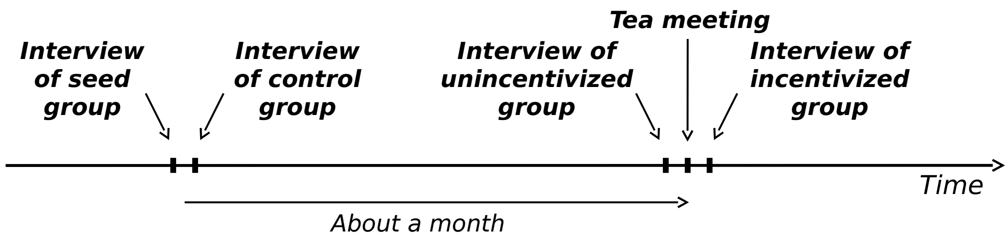


Figure 2: Timeline of the experiment

treatment spillovers. Unlike previous studies (e.g., BenYishay and Mobarak 2019; Vasilaky and Leonard 2018), our design holds the seed constant but introduces variation in the seeds' incentive to communicate information about the new technology. This enables us to identify the effects of both unincentivized and incentivized communications on WTP. This feature very likely rules out other mechanisms for information spread. The experiment began with sampling and the control group's interviews in July-August 2015 and was completed in October 2015. The timeline of the experiment is summarized in Figure 2.

We waited only 30 days because solar lanterns are products simple enough to learn about in a short time. Thirty days appeared to be reasonably long enough for information about the lantern to flow from the seed

Table 1: Summary statistics on the size of the treatment groups

	Total number of habitations		
	Control	**Unincentivized**	**Incentivized**
Male Seed	98	98	98
Female Seed	99	99	99

Notes: In all treatments, we interviewed the household head. We randomized the gender treatment across habitations, and the other treatments within habitations.

to the two treatment groups.[12] If the chosen friend was not the household head, we interviewed the head of the household to which that friend belonged.[13] Households in the three groups were all offered the possibility of buying a solar lantern through a Becker-Degroot-Marchak (BDM) game, which we present in detail in subsection 3.2. Before playing the BDM game with the households in the incentivized treatment group, we asked the seed to invite his/her "incentivized" friend over for a tea meeting to discuss his/her experience of the lantern. Table 1 summarizes the size of the different treatment groups. We visited a total of 197 habitations, 98 assigned to the male seed treatment, and 99 to the female seed treatment. We dropped three habitations because the unincentivized and incentivized friends had moved out of the village and could no longer be tracked and surveyed. Furthermore, the willingness to pay data is missing for six respondents for unexplained reasons. The final number of observations in the main regressions is, therefore, 585.

The male-female treatment was randomized at the habitation level. One of the co-authors drew a random number for each habitation and assigned the highest 100 numbers to the female treatment. Our survey team attended all tea meetings which the seed households organized for their "incentivized" friend. The enumerators, who all spoke the local dialect, told the seed respondents to share stories about their experience and the performance of the lanterns during the tea meeting. They specifically said that the goal was not to convince their friend to buy a lantern.

3.2 Outcome Variable

The outcome variable is the subject's WTP measured in the BDM game. As Becker et al. (1964) show, the BDM game recovers the subject's true preference by removing incentives to misrepresent WTP. During the game, the player first announces how much he is willing to pay for the item. Then, a price is drawn from a random distribution. If the drawn price is below the stated WTP, the subject pays the *randomly drawn price*, not the stated WTP.[14] The subject, therefore, has no incentive to understate WTP to obtain a

12. We document this in the "Mechanisms" section of this paper.
13. The person playing the game needs to be able to make a purchasing decision. That is why we always chose to interview and play the BDM game with the household head.
14. In fact, it is plausible to argue that the game sets up a real purchasing experience. In that sense, our WTP elicitation is captured through revealed preferences.

better bargain. This method has been widely applied in development economics to measure WTP because it is incentive-compatible and provides a continuous demand curve, as opposed to demand estimates for a discrete number of price points (as is the case in typical randomized-price WTP elicitation methods) (e.g., Hoffmann 2009; Levine et al. 2012; Guiteras et al. 2013).[15]

The game was played in the field as follows. We asked households to announce their maximal willingness-to-pay on a 0-1,200 scale (in INR). Then, the actual price is determined by a random draw from a bag that contains 21 balls, each one of them with a number written on it. The number ranges from INR 0 to INR 1,200 in increments of INR 100.[16] The respondent first makes a bid and then randomly draws a ball. If the price on the ball is higher than the bid, the respondent is not allowed to purchase the lantern. If the price on the ball is lower than the bid, the respondent pays the price on the ball. As a result, when the respondent makes a bid, she/he must make sure to have access to money. The respondent has only one chance to play, and she/he cannot change her/his bid after drawing a ball. Before playing for *real*, we conducted a practice round with a bar of soap to make sure the respondents fully understood the rules.

Figure 3 displays the bids' distribution: we see that most subjects made a positive bid, but no respondent offered the full market price of the lantern. We also note that WTP displays substantial variation across individuals, spanning 0 to 1200, with mean 239 and standard deviation 266. In the end, a total of 160 respondents ended up purchasing the lantern because their bid was higher than or equal to their draw (42 in the control group, 55 in the unincentivized group, and 63 in the incentivized group).

In implementing the BDM game, we carefully trained enumerators to ensure that they were able to explain the rules clearly and to emphasize the importance of the practice round with soap. Based on our field observations, the respondents seemed to understand the rules quickly. No subject complained afterward or refused to pay when they won the solar lantern. Some respondents were disappointed not to win the lantern, but in that case, they also did not have to pay any money.

3.3 Covariate Balance and Power Analysis

We present summary statistics of key baseline variables and statistical tests of balance for covariates in Table 2. We note that the treatment groups are balanced across most covariates, with a few exceptions: gender of the respondent, savings, and indebtedness[17]. The control group has significantly more female-headed households, and about INR 450 fewer savings than other groups. This is a potential source for concern

15. In practice, prices are drawn from a distribution of discrete numbers, so the demand curve is defined on these numbers only.
16. The game is, therefore, incentive-compatible across increments of INR 100.
17. The groups are also not balanced with respect to the timing of the interview by design. We discuss this issue further in Section 5.

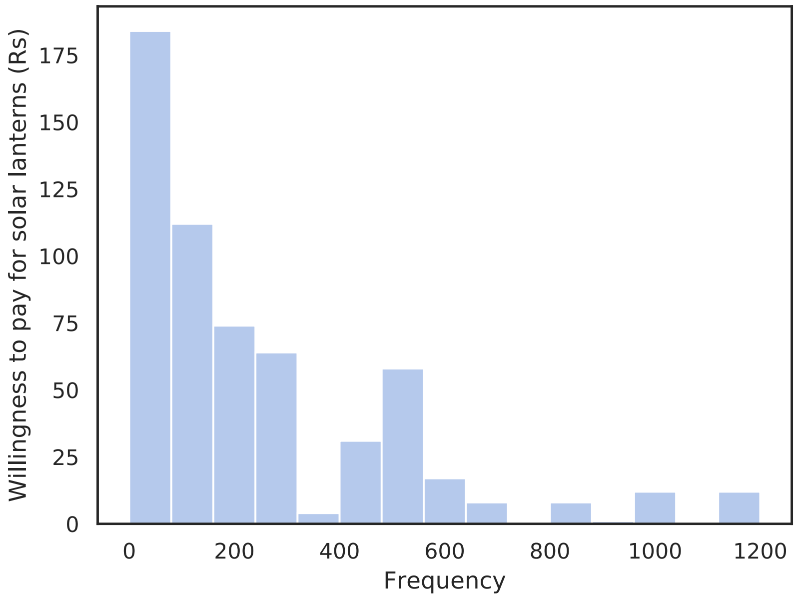


Figure 3: Histogram of bids for solar lanterns. Summary statistics are as follows: minimum = INR 0; maximum = INR 1200; mean = INR 239; standard deviation = INR 266.

given households with more savings would be in a better position to bid higher prices. In Section 4, we perform different robustness checks and control for these covariates in additional regressions to re-estimate the treatment effects.

In Table 3, we present the statistical test of covariate balance across treatments and the gender of the seed. As expected, households referred by female seeds are more likely to be headed by a female, while households referred by male seeds are usually headed by a male. It follows that the groups display significant differences in variables such as education, consumption expenses, and literacy.

Standard power analysis shows that the experiment can identify plausible treatment effects. Using the control group's mean and standard deviation (134 and 181 respectively), a standard deviation's uniform increase (to 315, with a standard deviation of 362) would be detected with a probability of $\alpha = 0.95$ if the control and treatment group each had at least 65 participants. In our setting, each group has 200 subjects, which exceeds the minimum number of habitations required by a large margin and enables us to detect realistic treatment effects.

Table 2: Baseline summary statistics and test of balance for covariates

Variable	(1) Control	(2) Unincentivized	(3) Incentivized	(4) Control vs Unincen.	(5) Control vs Incent.	(6) Unincen. vs Incent.	(7) Joint
Female respondent	0.36	0.20	0.25	0.16***	0.10**	-0.06	6.48***
	(0.48)	(0.40)	(0.44)	(0.04)	(0.05)	(0.04)	
Age	42.91	43.15	44.26	-0.24	-1.35	-1.11	0.52
	(14.76)	(14.24)	(12.91)	(1.46)	(1.40)	(1.37)	
Education	1.94	2.04	1.89	-0.10	0.05	0.15	0.60
	(1.35)	(1.44)	(1.26)	(0.14)	(0.13)	(0.14)	
Monthly Expenses	4176.65	4376.65	4530.46	-200.00	-353.81	-153.81	0.74
	(2334.32)	(3412.50)	(2810.66)	(294.57)	(260.31)	(314.98)	
Amount of Savings	223.35	682.23	661.42	-458.88***	-438.07***	20.81	17.15***
	(673.75)	(884.06)	(1038.31)	(79.19)	(88.19)	(97.16)	
In debt	0.47	0.61	0.48	-0.14***	-0.01	0.13***	5.02***
	(0.50)	(0.49)	(0.50)	(0.05)	(0.05)	(0.05)	
Household size	7.31	7.18	7.29	0.13	0.02	-0.11	0.07
	(3.92)	(3.38)	(3.37)	(0.37)	(0.37)	(0.34)	
Reads hindi	0.48	0.49	0.48	-0.01	-0.01	0.01	0.02
	(0.50)	(0.50)	(0.50)	(0.05)	(0.05)	(0.05)	
Land (acres)	1.31	1.44	1.42	-0.13	-0.11	0.03	0.31
	(1.89)	(1.94)	(1.43)	(0.19)	(0.17)	(0.17)	
Has a phone	0.85	0.84	0.87	0.02	-0.02	-0.03	0.36
	(0.36)	(0.37)	(0.34)	(0.04)	(0.03)	(0.04)	
Number of kerosene lamps	2.38	2.42	2.40	-0.05	-0.03	0.02	0.07
	(1.27)	(1.23)	(1.04)	(0.13)	(0.12)	(0.11)	
Hours of lighting	5.18	4.78	5.03	0.40*	0.14	-0.25	1.97*
	(2.37)	(1.81)	(1.77)	(0.21)	(0.21)	(0.18)	
Monthly spending per lamp	39.65	43.85	43.78	-4.20	-4.12	0.07	1.32***
	(26.72)	(23.50)	(34.85)	(2.59)	(3.17)	(3.06)	
Observations for WTP	197	194	194	–	–	–	–

Notes: Columns 1-3 of this table report summary statistics of baseline variables for the control and treatment groups. Columns 4-6 report statistical (t-test) results on mean differences between the control and the two treatment groups. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10% levels, respectively. We also performed a rank-sum (Wilcoxon-Mann-Whitney) test for the variables that do not approximate a normal distribution. Rank-sum tests and t-tests differed only for the variable "Hours of lighting": the mean difference between the unincentivized and incentivized groups is significant at the 10% level. Column 7 shows the F-statistic for a test of the joint equality of the means across the three groups using a one-way analysis-of-variance (ANOVA). We also ran a non-parametric test of joint equality of the means across the three groups (Kruskal-Wallis). Results differed only for the variables "Hours of lighting" and "Monthly spending per lamp": the means across the three groups are significantly different for at least two groups at the 10% and 1% level, respectively.

Table 3: Baseline summary statistics and test of balance for variables across treatments and seed gender

	Control			Unincentivized			Incentivized		
Variable	Male	Female	Male vs Female	Male	Female	Male vs Female	Male	Female	Male vs Female
Female respondent	0.15	0.56	0.40***	0.10	0.29	0.19***	0.15	0.35	0.20***
	(0.36)	(0.50)	(0.06)	(0.30)	(0.46)	(0.06)	(0.36)	(0.48)	(0.06)
Age	43.68	42.15	-1.53	43.42	42.89	-0.53	45.29	43.24	-2.04
	(15.89)	(13.58)	(2.11)	(15.06)	(13.44)	(2.03)	(12.82)	(12.97)	(1.84)
Education	2.05	1.84	-0.21	2.27	1.82	-0.45**	1.98	1.81	-0.17
	(1.36)	(1.35)	(0.19)	(1.54)	(1.29)	(0.20)	(1.28)	(1.23)	(0.18)
Monthly Expenses	3898.98	4451.52	552.54*	4844.90	3913.13	-931.77*	4940.82	4124.24	-816.57**
	(2240.88)	(2402.99)	(331.13)	(4403.35)	(1913.73)	(482.92)	(3206.43)	(2299.60)	(397.25)
Amount of Savings	278.57	168.69	-109.88	717.35	647.47	-69.87	672.45	650.51	-21.94
	(776.23)	(552.66)	(95.93)	(914.49)	(856.11)	(126.20)	(740.27)	(1270.25)	(148.33)
In debt	0.48	0.45	-0.03	0.58	0.64	0.05	0.48	0.47	-0.00
	(0.50)	(0.50)	(0.07)	(0.50)	(0.48)	(0.07)	(0.50)	(0.50)	(0.07)
Household size	7.36	7.26	-0.09	7.77	6.61	-1.16**	7.94	6.65	-1.29***
	(3.95)	(3.91)	(0.56)	(3.71)	(2.93)	(0.48)	(3.47)	(3.16)	(0.47)
Reads hindi	0.54	0.41	-0.13*	0.59	0.38	-0.21***	0.49	0.47	-0.02
	(0.50)	(0.50)	(0.07)	(0.49)	(0.49)	(0.07)	(0.50)	(0.50)	(0.07)
Land (acres)	1.20	1.42	0.23	1.43	1.46	0.02	1.60	1.23	-0.38*
	(1.16)	(2.40)	(0.27)	(1.68)	(2.17)	(0.28)	(1.64)	(1.16)	(0.20)
Has a phone	0.82	0.89	0.07	0.81	0.87	0.06	0.91	0.83	-0.08*
	(0.39)	(0.32)	(0.05)	(0.40)	(0.34)	(0.05)	(0.29)	(0.38)	(0.05)
Number of kerosene lamps	2.23	2.52	0.28	2.44	2.40	-0.03	2.54	2.26	-0.28*
	(1.25)	(1.27)	(0.18)	(1.33)	(1.12)	(0.18)	(1.14)	(0.92)	(0.15)
Hours of lighting	5.08	5.27	0.19	4.81	4.76	-0.05	5.01	5.06	0.06
	(2.22)	(2.51)	(0.34)	(1.89)	(1.74)	(0.26)	(1.71)	(1.83)	(0.25)
Monthly spending per lamp	38.79	40.48	1.69	44.92	42.84	-2.09	42.30	45.25	2.95
	(22.00)	(30.64)	(3.88)	(21.72)	(25.13)	(3.44)	(21.83)	(44.27)	(5.01)
Observations for WTP	98	99	–	97	97	–	95	99	–

Notes: "Male" and "Female" columns report summary statistics of baseline variables by gender of the seed. "Male vs Female" columns report statistical (t-test) results on mean differences between Male and Female groups. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10% levels, respectively. We also performed a rank-sum (Wilcoxon-Mann-Whitney) test for the variables that do not approximate a normal distribution. The only differences with the t-tests are as follows: 1) The difference in the level of education is significant at the 10% in the control group, 2) The difference in household expenses is not significant in the unincentivized group, 3) The difference in savings of the seeds is significant at the 10% level in the incentivized group, 4) The difference in irrigated land is not significant in the incentivized group, 5) The difference in the number of kerosene lamps is not significant in the incentivized group.

4 Results

4.1 Empirical Strategy

Given randomization, we can identify the impact of our “unincentivized” and ”incentivized” communication treatments on WTP for solar lanterns by the mean difference between treatment and control groups in a regression. We specify the regression equation as follows:

$$WTP_{ij} = \alpha + \beta_1 U_i + \beta_2 U_i F_i + \gamma_1 I_i + \gamma_2 I_i F_i + \mu_j + \epsilon_{ij}, \quad (1)$$

where WTP_{ij} is the willingness to pay by household i in habitation j for a solar lantern (our key outcome variable of interest); U_i is a dummy variable coding for whether household i is in the unincentivized group; F_i is a dummy variable coding for whether the lantern was offered to a female (i.e., it equals one if household i is a friend of a female seed); I_i is a dummy variable coding for whether the household is in the incentivized group (i.e., household i attended a tea meeting with the seed); μ_j is a vector of habitation fixed effects ($N = 200$); ϵ_{ij} is an idiosyncratic random error term with the standard distributional assumptions. A term for F_i does not appear in the equation because, by design, habitation fixed effects account for it. Our objective is to estimate $\beta_1, \beta_2, \gamma_1$, and γ_2. Throughout, we cluster standard errors at the habitation level. In this empirical framework, Hypothesis 1 is equivalent to $\beta_1 > 0$ and $\beta_1 + \beta_2 > 0$. On the other hand, Hypothesis 2 corresponds to $\gamma_1 > 0$ and $\gamma_1 + \gamma_2 > 0$ and Hypothesis 3 to $\beta_2 < 0$ and $\gamma_2 < 0$.

4.2 Treatment Effects

We begin by reporting the distribution of bids across treatment groups in Figure 4. We note that there are noticeable differences across groups. In particular, the treatment groups’ distributions display fatter right tails. This likely indicates that our treatments have positive effect on WTP. On the other hand, we hardly notice any differences when comparing the distribution across male and female seeds, which suggests that our gender treatment possibly had no impact.

Mean comparisons do not control for unobserved heterogeneity across habitations or correlation between observations within the same habitation. We, therefore, proceed to using regressions with fixed effects. The main results are shown in Table 4. In all regressions, the standard errors are clustered at the habitation level. In the second column, we do not include the “Female Seed” variable without interaction because it was randomized across habitations, and the regression contains habitation fixed effects. Results show that the unincentivized treatment increased WTP by almost INR 120 compared to the control group. Given

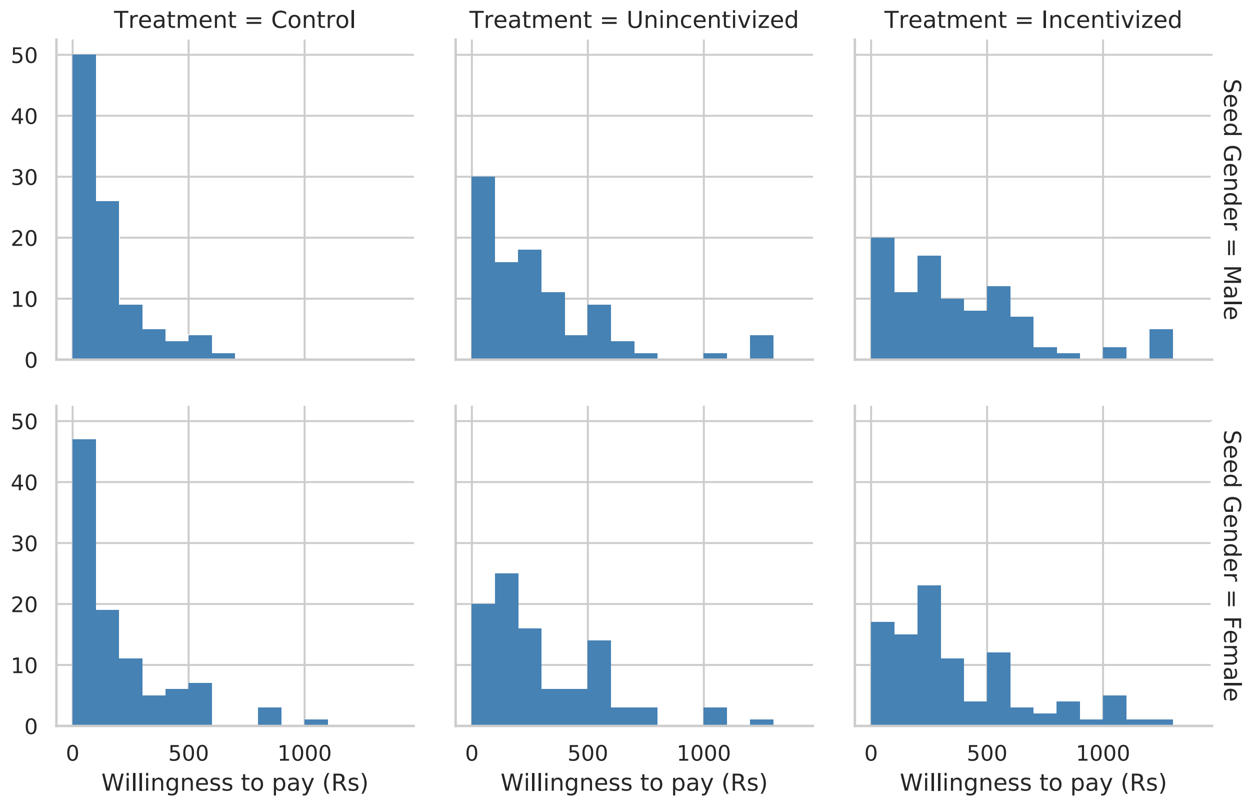


Figure 4: Faceted histogram of bids for solar lanterns across treatment groups

that the mean WTP in the control group was INR 134,[18] this corresponds to a 90% increase. Compared to the control group, the incentivized treatment increased WTP by INR 195, which corresponds to a 145% increase. The coefficients for both the communication treatments are also statistically significant at the 1% level. The finding from the incentivized communication treatment is consistent with BenYishay and Mobarak (2019), who showed that providing incentives to communicate with other farmers regarding a new agricultural technology promoted adoption. Our design further enables us to compare the magnitude of unincentivized and incentivized communication in terms of WTP for the new technology.

On the other hand, as shown in column 2 of Table 4, the gender treatment is not statistically significant. The point estimates are negative and correspond to minus INR 34 for the unincentivized group and minus INR 58 for the incentivized group. Some of the friends chosen by the female seeds were, in fact, female household heads. If women identify other women as belonging to the same social identity, then possibly the gender effect that we hypothesized is stronger within the subsample of male household heads. In other words, we expect that the communicator's female identity leads to more discounting of the information by males than by females. In column 3 of Table 4, we run a regression specification similar to column 2 but excluding households headed by women. Although the point estimate is indeed negative, the effect is not statistically significant. We, therefore, exclude the possibility of not observing a gender impact due to a composition effect. Instead, our results indicate that the mechanism we hypothesized and discussed earlier might not be in place.

Finally, we investigate whether there is an "homophily" effect at play, i.e., whether WTP increases more for seeds and friends with the same gender. We created a variable labeled "Same Gender" that equals one if the seed and the household head playing the BDM share the same gender. In column 4 of Table 4, we interact the variable with our two treatments. The coefficient on the interaction with the unincentivized treatment is small in magnitude and statistically insignificant. The coefficient for the interaction with the incentivized treatment is larger, yet, statistically insignificant. Hence, our results do not provide evidence for "homophily".

4.3 Robustness Checks

We perform several robustness checks to probe our results further. First, we control for monthly savings (one of the imbalanced covariates) and estimate the treatment effects. Column 1 of Table 5 shows that the coefficients slightly decrease from INR 120 to 108 for the unincentivized group and from INR 195 to 184 for the incentivized group. Yet, they remain statistically significant at the 1% level. The coefficient for monthly

18. Similarly, the value of the intercept in model 1 of Table 4 is INR 134.5.

Table 4: The impact of unincentivized and incentivized communication on WTP

	(1)	(2)	(3)	(4)
Unincentivized	119.88***	136.99***	134.59***	122.29***
	(22.11)	(30.85)	(35.01)	(43.87)
	[0.00]	[0.00]	[0.00]	[0.01]
Incentivized	195.08***	224.42***	224.80***	162.18***
	(22.93)	(32.09)	(36.44)	(44.11)
	[0.00]	[0.00]	[0.00]	[0.00]
Unincentivized x Female Seed		-34.07	-10.59	
		(44.23)	(62.97)	
		[0.44]	[0.87]	
Incentivized x Female Seed		-57.75	-63.89	
		(45.74)	(65.97)	
		[0.21]	[0.33]	
Unincentivized x Same Gender				-3.07
				(57.17)
				[0.96]
Incentivized x Same Gender				56.53
				(56.99)
				[0.32]
Same Gender				5.92
				(42.36)
				[0.89]
Constant	134.53***	134.55***	139.15***	130.39***
	(12.46)	(12.44)	(19.07)	(32.93)
	[0.00]	[0.00]	[0.00]	[0.00]
Incentivized vs. Unincentivized	75.19***	87.43**	90.22**	39.89
	(24.83)	(36.93)	(40.25)	(41.88)
	[0.00]	[0.02]	[0.03]	[0.34]
Incentivized vs. Unincentivized x Female Seed		-23.68	-53.31	
		(49.78)	(59.64)	
		[0.63]	[0.37]	
Incentivized vs. Unincentivized x Same Gender				59.60
				(56.92)
				[0.30]
Habitation fixed effects	Yes	Yes	Yes	Yes
R-squared	0.16	0.16	0.17	0.16
Observations	585	585	426	585
Control group mean	133.50	133.50	133.50	133.50

Notes: This table shows the main regression results for the impact of both the unincentivized and incentivized communication treatments on WTP for solar lanterns. Column 1 shows the main treatment effects without interactions. Column 2 shows the treatment effects with an interaction term for the gender of the seed. Column 3 reports similar treatment effects as column 2, excluding the sample of households headed by women. Column 4 presents the treatment effects with an interaction term for whether the seed and the household head playing the BDM game share the same gender. Standard errors clustered at the habitation level are in parentheses. P-values are in square brackets. ***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

savings is significant at the 5% level, but the magnitude is small: every additional Indian Rupee in savings correlates with a WTP increase of INR 0.026. Given the imbalance of savings across treatment groups,[19] this represents an average contribution to WTP of about INR 6 in the control group and about INR 17 to INR 18 in the unincentivized and incentivized groups, respectively. The contribution of savings to the WTP is, therefore, an order of magnitude lower than the contribution of our information treatments. In fact, those with the highest amount of savings are not those who revealed the highest WTP: the raw correlation coefficient between WTP and savings is only 0.15.[20]

In column 2, we interact monthly savings with the treatment dummies. The coefficient for the interaction term with the incentivized treatment is, in fact, significant at the 10% level, indicating that savings and WTP correlate in this treatment group. But the coefficient is negative, indicating that, overall, more savings is not associated with higher WTP. We also run a regression using monthly savings in logs instead of levels in column 3 and find similar results. Specifically, we note that the estimated treatment effect decreases slightly, from INR 120 to 103 in the unincentivized group and from INR 195 to 177 in the incentivized group. But, overall, the effects remain large and significant at the 1% level. Finally, column 5 reports the treatment effects for the sub-sample of respondents who declared having zero savings, which constitute more than half of our observations. We see that the treatment effects in this subsample are very similar to those found for the whole sample. Taken together, these robustness checks confirm that monthly savings are unlikely to drive our treatment effects.

Second, we ran the regressions by controlling for the date when the BDM experiment was conducted and other baseline control variables and report the results in Table 6. Column 2 reports the treatment effects controlling for the date of interview. The variable is correlated with our treatments, because WTP was elicited from the control group earlier than the two treatments by design. Consequently, the treatment coefficients and the standard errors for this specification are much larger. Nevertheless, the exercise remains useful to investigate the robustness of our treatment effects to a possible "income effect." Indeed, harvesting of maize and rice in the study area started at the end of September and early October, respectively, and about 20% of our treated households were interviewed after September 25. Hence, harvesting partly coincided with our survey of the unincentivized and incentivized groups.[21] If those sampled households began selling their

19. On average, the unincentivized (incentivized) group has INR 459 more (INR 438 more) in savings than the control group.

20. The correlation between WTP and the amount of savings can also be seen on a scatterplot in Online Appendix Figure A2.

21. The Rice Knowledge Management Portal, maintained by the Indian Council of Agricultural Research (http://www.rkmp.co.in/content/rice-growing-seasons-of-uttar-pradesh), indicates that, in Uttar Pradesh, summer rice is harvested in April-May and Kharif rice in November-December. On the other hand, wheat is harvested around March-April in the eastern part of Uttar Pradesh and around mid-April in the western part (see http://www.archive.india.gov.in/citizen/agriculture/index.php?id=11). Our local team indicated that a reasonable estimate for the first day of harvest in the region around Gonda city was September 25 for maize and October 5 for rice. We use these

Table 5: The impact of unincentivized and incentivized communications on WTP controlling for savings

	(1)	(2)	(3)	(4)	(5)
Unincentivized	107.56***	114.83***	103.16***	119.74***	117.94***
	(22.73)	(28.72)	(25.97)	(33.84)	(36.07)
Incentivized	183.53***	201.24***	177.30***	229.66***	214.38***
	(23.90)	(25.51)	(27.38)	(39.68)	(43.53)
Amount of savings (in Rupees)	0.03**	0.07**			
	(0.01)	(0.03)			
Unincentivized x Savings		-0.04			
		(0.04)			
Incentivized x Savings		-0.05*			
		(0.03)			
Savings (log)			5.69	19.35**	
			(4.34)	(7.48)	
Unincentivized x log Savings				-14.01	
				(8.86)	
Incentivized x log Savings				-22.41**	
				(9.47)	
Constant	128.62***	119.88***	128.26***	113.05***	119.59***
	(12.60)	(13.72)	(12.91)	(14.46)	(13.88)
Incentivized vs. Unincentivized	75.97***	86.41**	74.14***	109.92**	96.44*
	(24.78)	(33.60)	(24.95)	(49.86)	(53.65)
Habitation fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.16	0.17	0.16	0.17	0.18
Observations	585	585	585	585	315
Control group mean	133.50	133.50	133.50	133.50	133.50

Notes: This table shows the regression results controlling for savings. Columns 1 and 3 show the main treatment effects controlling for savings and the log of savings, respectively. Columns 2 and 4 show the treatment effects with an interaction term for savings and the log of savings, respectively. Column 5 reports the treatment effects for the sample of households who reported zero savings. Standard errors clustered at the habitation level are in parentheses. ***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

harvest, they would likely have been able to afford greater expenditures, and consequently, reveal higher WTP for the solar lanterns. The variable "Interview date" is the month and day of the month in which we interviewed the respondent. If there is an income effect from harvest sales, the coefficient for "Interview date" should be positive. Column 2 shows that the coefficient is not significant and leans toward negative values.[22] This indicates that respondents interviewed last were no more likely to bid higher amounts and provides supporting evidence against an income effect from the harvest season.

Whether the household head was female or male was another unbalanced variable. We control for it in column 3 of Table 6. Treatment effects for both the unincentivized and incentivized groups change little. In column 4, we control both for whether the household head is female and for the amount of monthly savings. The main treatment effects are slightly reduced but remain large and significant at the 1% level.

In columns 5 and 6, our main results remain robust to the inclusion of several additional control variables. Most variables, such as the level of education, expenditures, whether or not the respondent is in debt, household size, and the number of kerosene lamps display coefficients that are small and statistically insignificant.[23] As a further robustness check, we also implement a least absolute shrinkage and selection operator (LASSO) algorithm to select the variables in column 5 with the most predictive power. None of the variables are selected, but we report the full LASSO results in Online Appendix Table A12.[24]

4.4 Mechanisms

In this section, we investigate the mechanisms that possibly drive our treatment effects. To do so, we collected detailed data on variables related to knowledge about and the use of solar lanterns, gender norms, and women's status in the area. Table 7 displays regression results on the impact of our treatments on some of these variables. Columns 1 and 2 indicate that treated respondents are much more likely to have seen a solar lantern before compared to control respondents. They are also much more likely to know someone who owns a lantern. This is fully consistent with our experimental design and provides evidence that our treatments were implemented properly.

Columns 3 and 4 provide some insights as to why WTP has increased in the two treatment groups. Contrary to the control group, most respondents in the unincentivized and incentivized groups believe that

more conservative dates for our robustness checks.

22. Standard errors and coefficients are very large in this case due to the collinearity between our treatment dummies and the "Interview date" variable.

23. We also estimated the treatment effects after dropping the households who reported that someone in their household already owned a solar lantern (8 in total). Our results remained unchanged. See Online Appendix, Table A9 for regression results and Section 5 for the discussion related to households who owned solar lanterns before the treatments were implemented.

24. Our survey team also checked for other possible campaigns promoting solar lanterns in all the sampled habitations, which are likely to be correlated with our treatments. There were none.

Table 6: The impact of unincentivized and incentivized communications on WTP controlling for more covariates

	(1)	(2)	(3)	(4)	(5)	(6)
Unincentivized	115.14***	368.85*	110.00***	98.20***	104.07***	405.72**
	(22.21)	(191.16)	(22.52)	(23.11)	(23.26)	(191.16)
Incentivized	195.46***	449.00**	192.27***	181.13***	181.39***	482.62**
	(23.48)	(191.88)	(23.64)	(24.62)	(25.46)	(190.60)
Interview date		-6.72				-8.02
		(5.08)				(5.10)
Female Head			-32.74	-29.44	-23.12	-24.36
			(27.23)	(26.73)	(29.25)	(29.27)
Amount of savings (in Rupees)				0.03**	0.02*	0.03**
				(0.01)	(0.01)	(0.01)
Education					7.06	7.08
					(11.51)	(11.52)
Monthly Expenses					-0.00	-0.00
					(0.00)	(0.00)
In debt					-24.20	-24.57
					(26.09)	(26.01)
Household size					-2.37	-2.46
					(3.97)	(3.98)
Number of children in school					11.36	11.67
					(7.44)	(7.50)
Number of kerosene lamps					18.41	18.48
					(11.83)	(11.92)
Hours of lighting					1.00	1.40
					(6.50)	(6.53)
Monthly spending on lighting					-0.13	-0.14
					(0.26)	(0.27)
Constant	136.28***	136705.96	148.08***	141.42***	118.99**	162946.85
	(12.72)	(103092.88)	(15.95)	(15.83)	(49.23)	(103505.56)
Incentivized vs. Unincentivized	75.19***	76.81***	76.81***	77.39***	73.02***	73.02***
	(24.83)	(24.84)	(24.84)	(24.77)	(24.82)	(24.82)
Habitation fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.16	0.16	0.16	0.17	0.18	0.19
Observations	573	573	573	573	573	573
Control group mean	133.50	133.50	133.50	133.50	133.50	133.50

Notes: This table shows the main regression results for the impact of both the unincentivized and incentivized communication treatments on WTP for solar lanterns controlling for savings, the date of the interview, and other covariates. Column 1 shows the main treatment effects. Column 2 shows the treatment effects controlling for the date of the interview. Column 3 shows the treatment effects controlling for the gender of the household head. Control 4 controls both for the gender of the household head and savings. Column 5 shows treatment effects controlling for seven additional baseline variables. Column 6 reports similar treatment effects as column 5 and controlling for the date of the interview. There are fewer observations (573) than in the regressions for the main results reported in Table 4 (585) due to missing values for some of the baseline variables. Standard errors clustered at the habitation level are in parentheses. ***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

maintenance is important for a solar lantern to function properly. They also estimate the cost of a solar lantern at a higher level than the control group. At first, this might seem counter-intuitive. But, perception of higher costs and maintenance are both consistent with a higher appreciation of the product's technical properties. It supports the hypothesis that, through interactions with peers, respondents discover how sophisticated the product really is. In the beginning, villagers might expect that solar lanterns are nothing more than basic lamps, like kerosene lamps. They then observe their friend taking care of it. They take notice of the photo-voltaic panel connected to the lamp, allowing the battery to be charged. They also discover the phone-charging feature of the solar lantern. As a result, they perceive the product as a sophisticated item that requires careful maintenance and they become willing to pay a higher price for it.

Finally, columns 5 - 7 report regression results on the impact of the treatments on additional key variables constructed from survey questions for which the responses are coded from "definitely not" (1) to "definitely" (5). We note that almost all respondents thought solar lanterns were definitely innovative products, definitely superior to kerosene lamps, and that they would "definitely" recommend it to others over kerosene lamps. Here, there are no noticeable differences across treatments as the responses to the survey questions are already concentrated at the highest level ("definitely").

To investigate the possible mechanisms further, we follow Acharya, Blackwell, and Sen (2016) and estimate the Average Control Direct Effect (ACDE). In the context of experiments, the Control Direct Effect (CDE) is the causal effect of an intervention (or treatment) when the mediator is kept constant at a particular level.[25] In our setup, we investigate the following variables as possible mediators: whether the respondent has seen a solar lantern before; whether the respondent knows someone with a solar lantern; whether the respondent believes maintenance is important; the amount of Rupees spent on kerosene every month; and the number of hours of lighting used every day.

Unfortunately, there is little variation in these variables due to the response scales used in the survey questions. Nevertheless, the regression results presented in Table 8 reveal interesting insights. Column 1 reports the average total effect (ATE), which is equivalent to our main regression results. Columns 2 to 6 present the Average Control Direct Effects estimated using the sequential g-estimation described in Acharya et al. (2016). Each of the ACDE columns in the table shows the ACDE of the two treatment legs for a different mediator variable. We note that the ACDEs are similar to the average total effect. The mediator variable that seems to contribute the most is whether the respondent "knows someone with a solar lantern" (column 3). In this case, the treatment effect decreased from 120 to 95 for the unincentivized group. For

25. We thank an anonymous reviewer for guiding us on how to estimate the Average Control Direct Effect.

Table 7: Effect of treatments on variables highlighting possible mechanisms

	If has seen a solar lantern before	Knows someone with a solar lantern	Believes maintenance is important	Estimated cost of the solar lantern	Believes it is innovative	Believes it is superior to kerosene lamps	Would recommend over ker. lamp
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Unincentivized	0.69***	0.79***	0.48***	211.59***	0.04	-0.02	-0.02
	(0.03)	(0.03)	(0.04)	(53.73)	(0.03)	(0.01)	(0.01)
Incentivized	0.71***	0.81***	0.44***	109.54**	0.03	-0.01	-0.05*
	(0.03)	(0.03)	(0.04)	(53.99)	(0.03)	(0.01)	(0.03)
Constant	0.24***	0.13***	0.47***	627.09***	4.94***	4.99***	4.99***
	(0.02)	(0.02)	(0.02)	(30.32)	(0.02)	(0.01)	(0.01)
Incentivized vs. Unincentivized	0.02	0.02	-0.04	-102.05*	-0.01	0.01	-0.03
	(0.02)	(0.02)	(0.03)	(57.70)	(0.02)	(0.02)	(0.03)
Habitation fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.64	0.73	0.37	0.04	0.01	0.00	0.01
Observations	591	591	591	591	590	590	591

Notes: This table presents regression results on the effect of the treatments on the variables listed in the top of each column. The dependent variables in columns 1 - 4 are binary. The dependent variables in columns 5 - 7 are ordered (coded from 1 to 5 in the following way: Definitely not, Not really, Neutral, Somewhat, Definitely). The exact phrasing of the questions are shown in Online Appendix Table A3. Standard errors clustered at the habitation level are in parenthesis. ***, **, and * denote significance at the 1, 5, and 10% levels.

the incentivized group, the treatment effect decreased from 195 to 169 (13%).

Although our paper focuses on the impact experienced by only close members of the social network, our findings speak to the basic Bayesian theory of social learning. First, peers likely form their beliefs about the functioning of the solar lantern technology and how to operate it through the information they acquire via their regular interactions with the seed. Then, they update their beliefs about the technology after the seed's detailed presentation of the technology at the tea meeting, which in turn likely increased their willingness to pay for the lantern.

Finally, we attempt to explain why female seeds seem to act as equally effective communicators in our setting, contrary to our hypothesis. Our survey included a series of questions about gender norms in the sample villages. We report indicators of women's status in Table 9. The first set of questions reveal gender attitudes consistent with women holding lower social status. For example, we asked respondents whether they believed a woman should ask permission from her husband or a family member before going out. Almost all household heads said that women should ask for permission to go to the health center, visit a friend or

Table 8: Mediation Analysis

	(1) ATE	(2) ACDE	(3) ACDE	(4) ACDE	(5) ACDE	(6) ACDE
Unincentivized	119.88***	107.82**	94.65	95.72***	119.75***	120.40***
	(22.11)	(49.90)	(59.68)	(34.35)	(28.40)	(28.23)
Incentivized	195.08***	182.70***	169.18***	173.11***	195.01***	195.34***
	(22.93)	(52.21)	(62.14)	(29.77)	(27.00)	(26.87)
Constant	134.53***	130.25***	130.30***	111.43***	133.89***	127.19***
	(12.46)	(20.40)	(17.43)	(27.18)	(34.52)	(43.73)
Incentivized vs. Unincentivized	75.19***	74.70***	74.45***	77.09***	76.91***	74.79***
	(24.83)	(25.91)	(26.19)	(26.89)	(26.40)	(26.29)
Mediator	None	Seen One	Know Owner	Maintenance	Kerosene	Lighting
Habitation fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
SE Bootstrapped	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.16	0.14	0.12	0.13	0.16	0.16
Observations	585	585	585	585	585	585

Notes: This table presents Average Control Direct Effects (ACDE) estimated using the sequential g-estimation method. Column 1 reports the main treatment effects reported in Table 4 for comparison. Columns 2 - 4 report the estimated ACDE of the two treatments for the mediator variables coded as binary: "Seen a solar lantern before", "Knows someone with a solar lantern", and "Believes maintenance is important". Columns 5-6 present the estimated ACDE of the two treatments for the mediator variables "Monthly kerosene expenditure in INR", and the "Number of hours of lighting the respondent uses every day". Standard errors clustered at the habitation level are in parenthesis. ***, **, and * denote significance at the 1, 5, and 10% levels.

Table 9: Summary statistics on the status of women

Variable	(1) Male Seed Friends	(2) Female Seed Friends	(3) Difference
1. Should ask permission to go the health center	0.96	0.96	0.00
	(0.19)	(0.19)	(0.02)
2. Should ask permission to go visit a friend	0.98	0.97	-0.01
	(0.14)	(0.16)	(0.01)
3. Should ask permission to go to the market	0.98	0.98	0.00
	(0.14)	(0.13)	(0.01)
4. Talk about what to spend money on with spouse	1.59	1.61	0.03
	(0.60)	(0.58)	(0.05)
5. Women should have a say on how to spend income	0.98	0.97	-0.01
	(0.17)	(0.20)	(0.02)
6. It is importnat that girls go to school	4.98	4.97	-0.01
	(0.16)	(0.22)	(0.02)
7. Women should work outside home or own a business	3.52	3.80	0.28**
	(1.79)	(1.65)	(0.14)
8. Beating justified if she goes out without telling	0.50	0.56	0.06
	(0.50)	(0.50)	(0.04)
9. Beating justified if she argues with husband	0.59	0.67	0.08**
	(0.49)	(0.47)	(0.04)
10. Beating justified if suspected of adultery	0.76	0.75	-0.00
	(0.43)	(0.43)	(0.04)
11. Men are better able to use new technologies than women	3.30	3.13	-0.17
	(1.71)	(1.71)	(0.14)
Observations with WTP	290	295	–

Notes: Columns 1 - 2 of this table show summary statistics on the status of women from the made and female seed friends sample respectively. Column 3 shows statistical (t-test) results on mean differences between the two samples. ***, **, and * denote significance at the 1, 5, and 10% levels. Most of the variables are binary variables where 0 codes for no, and 1 for yes. Responses to question 4 are coded from 0 to 2 as follows: "Never," "Sometimes," "Often." Responses to questions 6, 7, and 11 are coded from 1 to 5 as follows: "Definitely not," "Not really," "Neutral," "Somewhat," "Definitely."

go to the market.

On the other hand, answers to other questions reflect more egalitarian views. Only about 5% of the sample said that they never talked with their spouse about what to spend income on, and about two-thirds said they often had such discussions. In addition, virtually all households thought that women should have a say in how income is spent. Most respondents thought that it was *definitely* important that girls go to school. They further expressed the view that beating a woman was rarely justified. Finally, most respondents thought that women were as able as men to use new technologies. Hence, gender norms in our context appear to give women some say in purchasing decisions, as well as when it comes to using new products. Possibly, gender identity does not matter when it comes to communicating information about lanterns because women are perceived as rightful users of the products, holding legitimate opinions about such household goods. This may help to explain why overall, our gender treatment has little effect on willingness to pay.

4.5 Implications for Solar Subsidies

Our study helps draw useful implications for policies that aim at promoting the diffusion of new technologies in developing countries. The adoption of technologies by a household typically generates positive externalities for neighbors. Thus, subsidies are often advocated by development economists to foster the process, especially when the adoption rate is lower than the socially optimal rate (Kremer and Miguel 2007; Cohen and Dupas 2010; Miller and Mobarak 2013). We can use the willingness-to-pay data generated from this experiment to predict the adoption rate under various subsidy rates. Such analysis is useful to governments and other stakeholders interested in fostering the adoption of solar lanterns in non-electrified low-income communities.

Figure 5 illustrates that starting from a baseline slate where no household knows about solar lanterns (i.e., our control group), covering 20% of the population would require a subsidy of about INR 950 per lantern. But once information has started diffusing (for example, through early adopters), a lower subsidy is required: covering 20% of the population would require an INR 700 subsidy (unincentivized treatment). Finally, assuming a scheme that incentivizes communication about the lanterns, the subsidy could decrease to INR 600 per lantern. This is about the same amount as what the Indian government is currently spending per household on kerosene subsidies, albeit per year (Garg et al. 2017).

India currently subsidizes the retail price of kerosene. The unsubsidized retailed price is INR 35 per liter, but eligible households are allowed to purchase 3 liters per month at a subsidized price of INR 19 per liter. Such subsidy is equivalent to INR 576 per year per eligible household, and one may wonder about switching kerosene subsidies to solar lanterns subsidies. According to Jain et al. (2018), entry-level lanterns typically provide 6 hours of lighting and substitute for two liters of kerosene per month. Mid and high-end

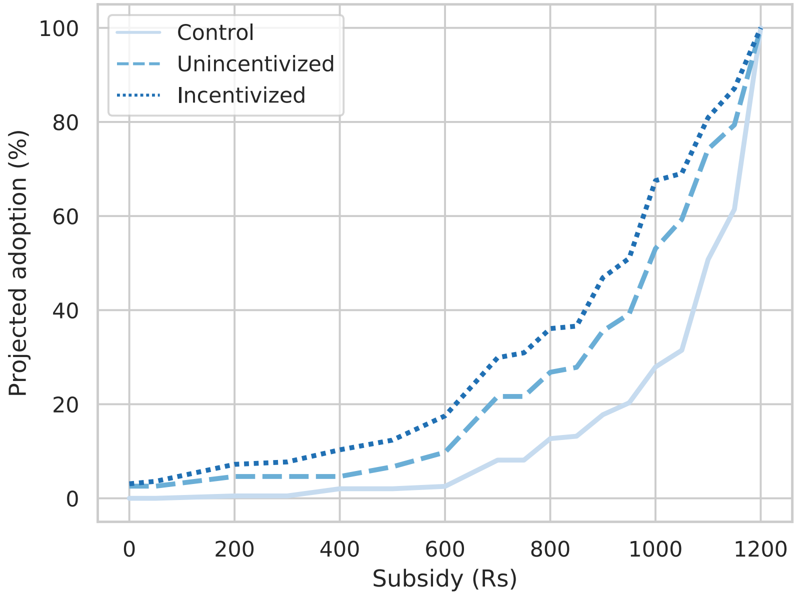


Figure 5: Projected adoption rate of solar lanterns as a function of offered subsidy

lanterns, such as those used in this experiment, provide 9 hours of lighting and substitute for about 3 liters of kerosene per month. Households could, therefore, save about INR 684 per year from kerosene spending if they adopted a solar lantern. The full cost of the solar lantern (INR 1200) would be amortized in just under two years. Since the product is fairly robust and a market for repairs is emerging, the lantern could continue to serve for several years, making the cost-benefit analysis all the more in favor of solar lanterns. Beyond the potential for monetary savings in kerosene spending, solar lanterns also offer attractive health benefits compared to kerosene lamps (no risk of burns, fires or poisoning, and lower indoor air pollution).

Last but not least, by adopting solar lanterns, households would save the government INR 576 worth of kerosene subsidy per year. In fact, the government may consider a scheme where households eligible to kerosene subsidies would instead be offered an equivalent subsidy to purchase a solar lantern. This will undoubtedly provide triple dividends by improving the welfare of poor households, while reducing the pressure on public resources and promoting sustainability.

5 Discussion

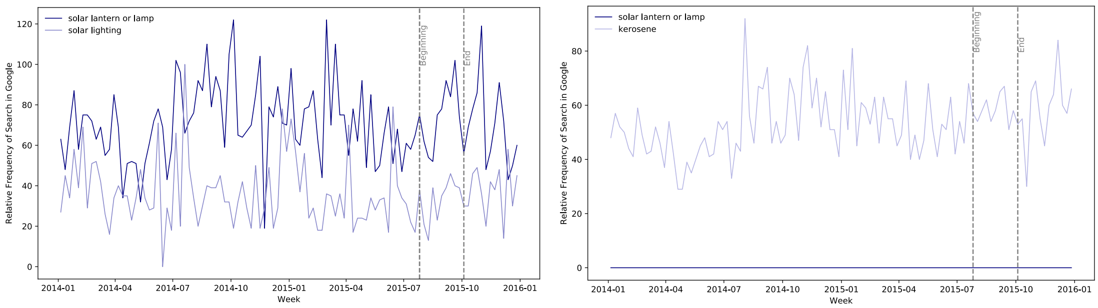
We designed a field experiment to spell out the impact of unincentivized and incentivized communication by peer households on willingness-to-pay for a solar lantern - a new household technology. We asked seeds to provide the names of three friends with whom they regularly interact, and we randomly assigned the friends to a control group, an "unincentivized" communication treatment, and an "incentivized" communication treatment. It is reasonable to assume that the three friends also knew each other, either as friends or neighbors. In particular, some of the control friends will have won a lantern during our BDM game, and they may have talked about it with the other treated respondents. Consistent with the "complex contagions" social network model by Centola and Macy (2007), information about the solar lanterns could have likely flowed from the control group to the two treatment groups during the 30 days treatment period.

Our treatment effects therefore likely capture both a network amplification effect and the more direct effect of information flowing from seeds to treated households. The magnitude of the network amplification effect, however, is likely small. We find that our results change little when we excluded those habitations where the control respondents won a solar lantern (see column 3 in Online Appendix Table A9). In other words, treated respondents did not systematically reveal a higher WTP when they had two lantern owners in their habitation (the seed and the control). Although this analysis relies on correlation rather than causal inference, it indicates that increased ownership of solar lanterns in one's social network did not amplify the WTP effect. Unfortunately, one cannot determine to what extent network amplification played a role without using more treatment arms and detailed network data, which we could not implement due to the significant resource implications.[26] Nevertheless, we argue that the treatment effects are driven, to a greater extent, by the direct communication of the treatment groups with the seed. Most importantly, the difference in WTP between the unincentivized and incentivized treatments is due to the quality of the information communicated by the seed. This is indeed one of our key findings.

We elicited WTP for solar lanterns from treatment groups one month after seed households received solar lanterns and one month after eliciting WTP from the control group. Doing so raises the concern of time as a possible confounder. In particular, other solar-related initiatives or the natural diffusion of the solar lanterns may bias our results. However, given the local context, we argue that this is very unlikely.

We asked enumerators to collect information regarding any other solar-related initiatives in the study

26. We asked respondents how many friends they had in the village. The mean response was 8 friends (with a standard deviation of 9) for seeds and 6 friends (with a standard deviation of 5) for peers. We also asked people how often they interacted with their friends. Almost all responded that they interacted daily. Therefore, it is reasonable to assume that people are friends with most people living in their habitation.



(a) Relative to “solar lighting”

(b) Relative to “kerosene’

Figure 6: Weekly Frequency of Google Searches in India

Note: The frequencies are relative to the highest point on the chart. A value of 100 represents the peak level of popularity for the term. A value of 50 implies that the term is half as popular. A score of 0 indicates there was not enough data for the term.

area during our fieldwork, and it appears that there were none. To provide more concrete evidence, we compiled “Google Trends” statistics from trends.google.com/trends/ for India overall. We looked for the frequency at which the terms “solar lantern” or “solar lamp” were searched on Google between 2014 and 2016 and present the results in Figure 6. The figures display the frequency of the terms over time. The signal before and during the experiment looks very similar. The data is noisy due to the low frequencies of the terms. Indeed, when compared to searches made for the term “kerosene”, we see that the signal is effectively reduced to zero. The fact that there are no particular increases in the number of searches for solar lanterns strongly supports our claim that no solar lantern campaigns that could have biased our results took place during the treatment period.

Another potential concern is that solar technologies may be naturally diffusing during our fieldwork. In fact, when interviewing seed and control households in July 2015, we asked whether they had already seen a solar lantern (before our visit). About 25% of seed respondents and 24% of control respondents said “yes”. We further asked where they had seen solar lanterns, and most responded “in town” or at a household in another village. A significant increase in awareness of solar lanterns within the one-month delay of our design would be a potential concern. We argue that this is very unlikely for the following reasons. First, our study focuses on an innovative design that offers superior benefits, not only in durability but also in functionality (USB-port). However, the idea of a lantern running on battery power and charging via solar exposure is not new. Basic designs of solar lamps have been available for sale in urban areas of India for many years before our experiment. Therefore, it is reasonable to assume that respondents’ awareness of solar lanterns was in a steady state.

Second, our data show that the control and treatment respondents did not differ in terms of solar ownership, implying that the one-month delay did not make a difference. Specifically, before eliciting WTP, we asked respondents whether someone in their household already owned a solar lantern. Only eight peer households answered "yes": 2 in the control group and 3 in each treatment group. The difference in WTP between these groups is not statistically significant.[27] Finally, the villages in our sample are far from urban centers where diffusion is more likely to occur. Respondents don't have access to electricity (and therefore do not own a television), and only about 12% of them owned a radio. Consequently, it is relatively difficult for them to keep track of what is going on in cities. These facts suggest that, during the one-month treatment period, other solar-related initiatives, or the natural diffusion of the solar lanterns are unlikely to play any significant role.

We acknowledge that other experimental designs could have helped to better establish that time was not a confounder. We attempt to discuss the pros and cons of these alternative designs. One option could have been to create a control group by conducting the BDM game at the same time as the treatment group with another friend of the seed from the village whom the seed doesn't communicate for a month. Although this is an attractive option, it would be practically challenging because it is difficult to enforce non-communication between the friend and the seed for a month. Another issue here is that it is likely that the treatment would contaminate the control group even in the absence of communication with the seed, merely through interactions with other villagers that know the seed. Villages are relatively small, and as a result, the whole habitation (and possibly the whole village) should be considered as treated once the lantern is seeded with one inhabitant.

A second alternative would have been to construct a control group by eliciting WTP from a random non-friend respondent in the village at the same time as our treatment groups. Here again, contamination would likely happen and invalidate the use of respondents from the same village as control units. Finally, a third alternative would have been to construct a control group by eliciting WTP from respondents in other random villages at the same time as our treatment groups. In addition to significantly increasing the field budget, this design would have caused other identification challenges, in particular, ensuring that villages are comparable enough to conduct a meaningful analysis. Treatment effects would have to be calculated as differences across villages, which could be problematic, especially with small sample sizes, as the differences in WTP could then be driven by observable or unobservable factors. The design we finally settled on attempted to avoid this problem, albeit, at the cost of introducing a one month delay.[28]

27. We also estimated the treatment effects after dropping the households who reported that someone in their household already owned a solar lantern (eight in total). Our results remained unchanged (see Online Appendix Table A9).

28. We thank an anonymous reviewer for encouraging us to discuss these alternative designs.

A key feature of our experimental design involves compensating seed households for taking part in the study and for inviting one of their friends for tea to share their solar lantern experience. To minimize the likelihood that seeds felt unfairly privileged from receiving a solar lantern plus INR 100, we phrased the experiment to them as a lottery. We informed them that they won a lottery, which awarded a solar lantern and INR 100 in exchange for answering survey questions and arranging another meeting with the survey team in the presence of one of their three best friends. We told them that their friends would also participate in a lottery but without more information about the nature of the lottery. Hence, the seeds did not know *ex-ante* that they would be getting INR 100 more than their friends, and the friends did not know that either. The seeds also did not know that their friends would play a BDM game. In this context, seed households likely felt no more lucky and privileged than their friends for participating in a lottery. This setting helps us rule out the possibility that seeds might have shared some of the INR 100 they received with their "incentivized" friend and this contributed to the group's higher WTP.

Other elements in our context also contribute to making sharing the INR 100 unlikely. First, the amount is small compared to the seeds' overall savings (about INR 1700) and monthly spending (about INR 4700). The INR 100 represents only 6% and 2% of savings and monthly spending respectively. The payment is, therefore, unlikely to have drawn much attention from the friends. Second, assuming seed households did share the payment with their friends, a plausible assumption is that those with higher savings transferred more money. We checked for this possibility by estimating the treatment effects while controlling for the seeds' savings and an interaction term between the treatments and savings. The results show that this is not the case: the seed's amount of savings does not correlate with our treatment effects (see Online Appendix Table A10).

6 Conclusions

The adoption of new technologies is crucial to improve the livelihood of poor communities, and information sharing through social networks can accelerate it. Technology adoption is inherently a social process because one individual's adoption creates positive information externalities that spillover to peers and increase their expected welfare (Bardhan and Udry 1999). Does rewarding individuals who make a conscious effort to communicate information about new technologies raise WTP by members of a social network? What are the mechanisms that explain the increase in WTP? Which member of the household matters for information about new technologies to flow more effectively through social networks? In this paper, we attempted to answer these questions by crafting a randomized controlled trial where we distributed solar lanterns under unincentivized and incentivized communication treatments to households in 200 non-electrified villages in rural India. Compared to previous studies, the design enables us to identify the magnitudes of the unincentivized and incentivized communication and propose subsidy options that offer triple dividends - improving the welfare of poor households, reducing the pressure on public resources, and promoting sustainability.

We find that learning about the technology via peers can significantly increase WTP. The unincentivized communications treatment group is willing to pay INR 120 more than the control group. This effect implies that having peers using solar lanterns in one's social network makes one willing to pay more for them. Typically, diffusion of new technology begins with a few early adopters trying out the product. These first adopters generate knowledge externalities, "learning-by-using," which the next generation of adopters can use to update their beliefs regarding the costs and benefits of the technology. Therefore, the unincentivized treatment effect may be understood as capturing the magnitude of the knowledge spillovers from one wave of adopters to the next. Even though the absolute magnitude is relatively small, it represents a WTP of almost double the initial WTP (about a 90% increase).

The incentivized communication treatment, on the other hand, investigates the way of increasing the intensity of information exchanges about solar lanterns. The key idea here is to leverage some actors to take a more active role in the diffusion of information within their social network. We find that attending a demonstration session led by a peer who experienced the technology increases WTP by INR 195, a 145% increase compared to the control group, and a further 55 percentage point increase compared to the unincentivized treatment group. We also investigated whether potential adopters respond to information more intensively when communicators are male rather than female. We found that the gender identity of the communicator did not matter. Finally, we showed that the treatment effects on WTP revealed by our interventions provide helpful insights into how to use scarce public resources to promote adoption and diffusion of new household technologies in general and solar technologies in particular. Future research might be able to use richer designs which deal with the role of time as a confounder, test the robustness of our findings, and shed more light on these issues.

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