

Demand for Solar Energy Products Among the Poor: Evidence from India

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Outline

1 Introduction

- Motivation

2 Research

- Research setting
- Research question

3 Methodology

- Solar lanterns
- Solar home systems

4 Results

- Solar lanterns
- Solar home system

5 Going forward

Motivation

- How to improve energy access and renewable energy use simultaneously
- Off-grid electrification - an immediate solution to increase access to electricity
- Decreases in costs of solar technologies [▶ Solar cost](#)
- Determinants of commercial success in the rural energy market

"very fundamental scale-up and replication challenges will have to be addressed if the sector is to achieve its potential" (World Bank IFC, 2012)

Contribution

- Solar market potential in India
 - Technology adoption & informational barriers (Foster and Rosenzweig, 1995; Mainali and Silveira, 2011).
 - Possible reasons for non-adoption of solar products.
 - Worried about low quality and risk of malfunctioning product (Dercon and Christiaensen, 2011; Levine et al., 2012; Guiteras et al., 2013).
 - Barriers to a healthy Solar Home System (SHS) market
 - Lack of awareness (Rebane and Barham, 2011)
 - Lack of info about where to purchase solar products or ask for O&M services (Friebe, von Flotow, and Taübe, 2013)
- Willingness to pay (WTP) for solar lanterns
- Patterns of demand for solar home systems (SHS)

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Research setting

- Rajiv Gandhi Grameen Vidyutikaran Yojana rural electrification program established in 2005
- 43.2% of rural hh depend on kerosene for lighting (Census of India, 2011)
- In UP, grid electricity available for 4-8 h a day
- 59% of villages in the Unnao district electrified (Census of India, 2011)

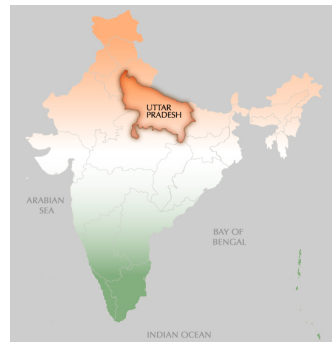


Figure 1: Map of Uttar Pradesh from IPTU European Regional Development Fund

Research setting

- Average intensity of solar radiation - $20 \text{ MW}/\text{km}^2$ (Indian Renewable Energy Development Agency)
 - If 10% of India covered, 8 million MW per year
- Jawaharlal Nehru National Solar Mission - 30% capital subsidy for rooftop solar systems up to 100W



Figure 2: Solar lantern and 40W SHS sold by BOOND

Research question

Willingness to pay (WTP) for solar lanterns

- Does a trial period have an impact on WTP?
- Does the trial period with postponed payment have an impact on WTP?

Patterns of Demand for solar home systems (SHS)

- Does the respondent know what a SHS is?
- Has the respondent seen SHS before?
- Does the respondent know someone with SHS?
- How much would they be willing to pay for a 40-watt SHS that provides enough power to charge a mobile phone and run 3–4 lights?

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Methodology - lanterns

- 1008 randomly selected poor households from villages below median population (898 without grid access)
- Three treatment groups
 - control, trial, delay
- Becker-DeGroot-Marshak (BDM) mechanism to obtain maximum WTP (3x)
- Random ball drawn
 - 0-480 rupees (\$0-8)
 - Price on ball $>$ WTP: fail to purchase
 - Price on ball \leq WTP: can purchase

Methodology - lanterns

$$WTP_{i,v} = \alpha + \beta_1 Trial_{i,v} + \beta_2 Delay_{i,v} + \gamma x'_{i,v} + \nu + \epsilon_{i,v} \quad (1)$$

- i : household in village v
- $Trial$ and $Delay$: indicators for the immediate payment and postponed payment treatments
- x_i : non-experimental covariates
- $\epsilon_{i,v}$: error term
- ν : village fixed effects

Baseline survey - SHS

- 76 largest villages in the central subdistrict of Unnao district in UP from 2011 Census of India
- Cooperation with MORSEL, local survey company
- 10 household heads residing near the center of each village surveyed
 - SHS usually marketed in central locations
- 20-min survey
 - socio-economic characteristics, knowledge on solar technology, views about politics and solar technology

Methodology - SHS

$$\text{Logit}(Y_i) = \alpha + \beta \mathbf{X} + \epsilon_i, \quad (2)$$

$$Z_i = \alpha + \beta \mathbf{X} + \epsilon_i. \quad (3)$$

- Y_i : binary dependent variable about SHS awareness
- Z_i : willingness to pay for SHS
- β : coefficients of interest
- \mathbf{X} : explanatory variables
- ϵ_i : error term clustered at village-level
- For logit, village random or fixed effects

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Solar lanterns

- Significant difference in the bid price between delayed payment and control group (6.32 rupees) ▶ Bid price
- Low effect of trial period across all treatment groups ▶ WTP
- Effect of trial period and postponed payment positive but insignificant in quantile regressions
- 110 households purchased solar lanterns
 - All households thought solar lantern would reduce monthly energy expenditure
 - 83% of households in the trial group purchased
 - 71% of only trial, 92% of trial and postponed payment

Solar home system

① High awareness of SHS

- 64% know SHS, 89% has seen SHS, 75% know someone with SHS [▶ Know SHS](#)
- Predictors of awareness: household expenditure, education level, young age

② Average estimate for SHS price

- 7526 rupees (\$120) < real price 13,000 rupees (\$208)

③ Willingness to pay for SHS

- 4209 rupees (\$67), much smaller even if 30% govt subsidy is considered [▶ WTP](#)
- Predictors of WTP: grid electricity, high income, kerosene expenditure, high levels of education

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Take away and next steps

- Low demand for solar lanterns
 - (40.5 rupees < 480 rupees)
- In year 2014, sold 211 SHS in catchment area
 - 100-watt system more popular - more lights, small fan, TV
- Positive effect of rural electrification on SHS
 - complementary between solar and grid electricity
- Dynamic pricing scheme & solar pico-grid
 - The number of hours each household member uses electricity
 - The primary reason for using solar
 - Whether households respond do differential prices

Take away and next steps

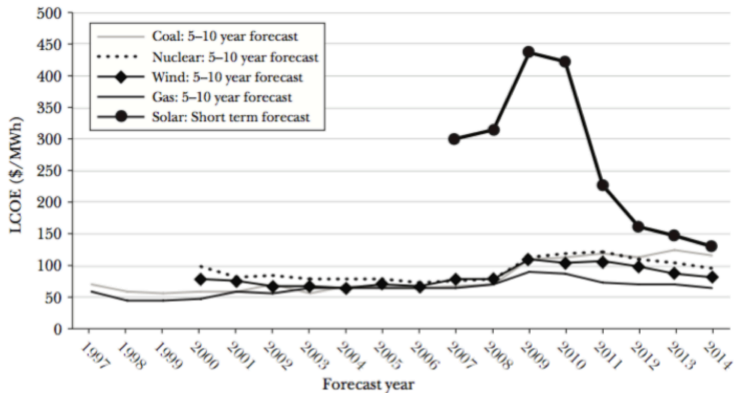
Thank you for listening!



Info requested from villagers

Type of information	Specific Issues
SHS equipment	What are the size and life of the battery? What are the capacity and backup of 40w, 100w, 200w panels? Can one use a TV, fan, fridge, and/or water motor? Will SHS work in the rainy season? What is the warranty of the battery and the panel? Is an inverter included with a 200w system?
SHS maintenance	How quickly will the SHS service be provided? Is the SHS maintenance service free or of charge?
Solar subsidy	What is the subsidy percentage provided by the bank? How much of the total cost is the subsidy?
Partnership w/ bank	What is the margin of the money to deposit into the bank? What are the formalities to purchase SHS through the bank? What is the interest rate of the bank?
Products of Boond	What is the wattage of CFL and LED bulbs? What other products does BOOND sell besides SHS?

Decreasing levelized cost of solar energy from US EIA



Source: EIA Annual Energy Outlook reports from 1997 to 2014.

Solar lantern - final bid price

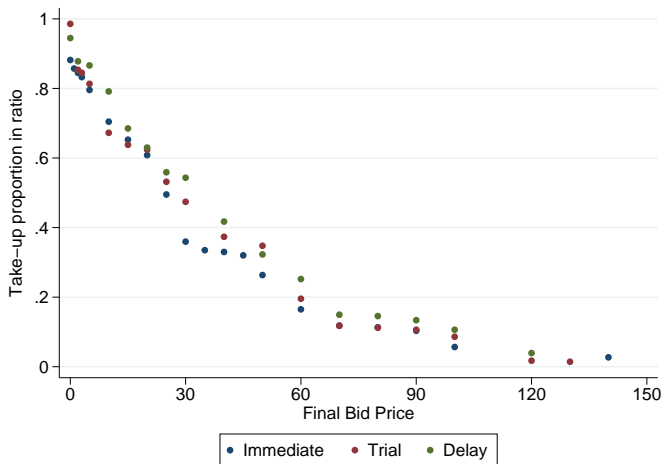


Figure 3: Final bid distribution of three treatment groups, excluding a handful of outlier observations above 150 rupees.

Solar lantern - means of the final bid price

	Immediate	Trial	Delay
Mean final bid price	34.2	35.4	40.5

	Trial-Immediate	Delay-Trial	Delay-Immediate
Final bid price	1.25 (0.49)	5.07 (1.66)	6.32 (2.12)

The t -statistics are in parentheses.

WTP for solar lanterns

	(1)	(2)	(3)	(4)	(5)	(6)
Trial	1.25 (2.20)	1.32 (2.24)	0.42 (2.10)	0.64 (2.10)	0.78 (2.16)	0.80 (2.29)
Trial with Delay	6.32* (3.19)	4.12 (3.57)	4.51 (3.60)	6.20** (2.99)	4.37 (3.50)	4.00 (3.57)
Female household heads			6.39** (2.69)	2.30 (3.33)	2.19 (2.90)	2.87 (3.16)
Years of Education			0.94*** (0.26)	1.21*** (0.30)	0.95*** (0.29)	0.89** (0.33)
Log Income			7.21*** (1.57)	10.03*** (2.33)	7.42*** (1.83)	7.34*** (1.99)
Own Land			-6.87*** (2.21)	-6.98*** (1.78)	-6.82*** (2.18)	-7.85*** (2.42)
Household size						-0.05 (0.74)
Have electricity						1.99 (4.23)
Age of household head						0.04 (0.11)
Constant	34.19*** (2.56)	38.62*** (3.54)	-17.69 (13.18)	-40.46** (19.01)	-19.99 (16.21)	-18.08 (19.02)
Enumerator FE	No	Yes	No	Yes	Yes	Yes
Village FE	No	Yes	Yes	No	Yes	Yes
Observations	1008	1008	994	994	994	920
R ²	0.00	0.14	0.16	0.08	0.18	0.17

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1: Regression of final bid on covariates and treatment groups.

WTP for SHS

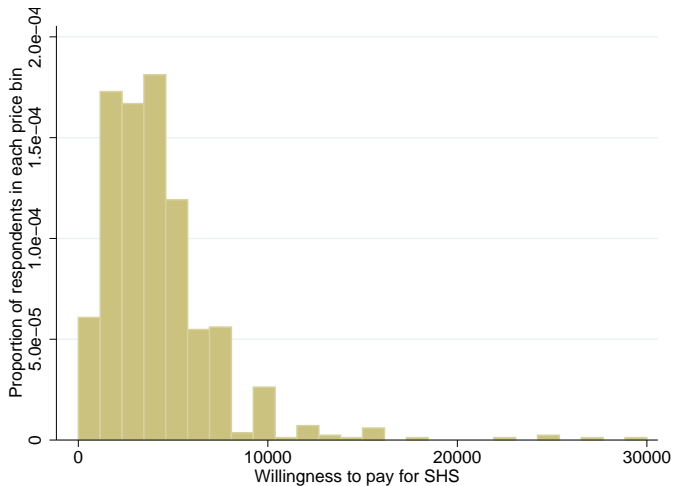


Figure 4: Histogram of the willingness to pay. Outlier observations with values higher than 30,000 rupees are excluded.

WTP for SHS

	(1) RE	(2) FE	(3) FE	(4) FE	(5) FE
Electricity	1113.56*** (415.56)	1085.24** (454.36)	1172.95*** (389.72)	1178.41*** (392.88)	1128.63*** (390.51)
Monthly kerosene spending	-0.31 (2.77)	-0.93 (2.87)	-5.71** (2.49)	-5.87** (2.50)	-6.24** (2.49)
Monthly household expenditure	0.21*** (0.05)	0.16*** (0.05)	0.12*** (0.04)	0.12*** (0.04)	0.11** (0.04)
School completed	570.81*** (124.87)	571.56*** (128.83)	445.24*** (110.60)	438.36*** (114.70)	374.44*** (115.75)
Female	-913.21 (767.67)	-1021.01 (789.80)	-903.79 (675.64)	-903.78 (678.24)	-739.57 (675.66)
Household size	-55.40 (66.96)	-27.09 (68.71)	19.18 (59.05)	19.65 (59.23)	21.35 (58.82)
Birth year	10.14 (13.34)	8.39 (13.74)	10.79 (11.77)	10.96 (11.84)	6.95 (11.82)
Scheduled Caste				-225.28 (533.89)	-249.89 (530.29)
Scheduled Tribe				-931.19 (1587.19)	-719.93 (1577.79)
Other Backward Caste				174.97 (413.45)	269.43 (411.74)
Knows SHS					1202.27*** (386.51)
Constant	-15644.97 (26277.04)	-11987.32 (27063.56)	-16086.02 (23183.44)	-16408.25 (23278.68)	-8983.56 (23242.18)
Observations	717	717	713	713	713
R ²		0.09	0.09	0.09	0.11

Summary stats for SHS

	Mean	Stan Dev	Min	Max	N
Electricity	0.44	0.50	0	1	760
Monthly kerosene spending	99.5	68.4	0	500	760
Monthly HH expenditure	5882.8	4138.2	1000	40000	760
Female	0.063	0.24	0	1	760
Household size	6.53	3.04	1	25	760
Birth year	1970.1	14.0	1934	1996	760
Forward Caste	0.43	0.50	0	1	760
Scheduled Caste	0.15	0.36	0	1	760
Scheduled Tribe	0.021	0.14	0	1	760
Other Backward Caste	0.39	0.49	0	1	760
No Formal Education	0.16	0.37	0	1	760
Primary school	0.19	0.39	0	1	760
Secondary school	0.26	0.44	0	1	760
High school	0.15	0.36	0	1	760
Intermediate	0.11	0.31	0	1	760
Graduate	0.13	0.34	0	1	760

For values in rupees (kerosene spending, monthly expenditure)
the exchange rate to USD is 62.555.

Table 2: Summary statistics for household characteristics.

Awareness of SHS

	mean	sd
Knows SHS	0.64	0.48
Has seen SHS	0.89	0.31
Knows a person with SHS	0.75	0.43
Knows nearest energy center	0.37	0.48

	mean	sd
Qualify for SHS subsidy	0.85	0.35
SHS is low maintenance	0.35	0.48
SHS would be quickly fixed	0.76	0.42