Health awareness and the transition towards clean cooking fuels: evidence from Rajasthan

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Abstract: Ensuring affordable, reliable, sustainable and modern energy for all by 2030 is part of the internationally agreed Sustainable Development Goals (SDG7). With roughly 3 billion people still lacking access to clean cooking solutions in 2017, this remains an ambitious task. The use of solid biomass such as wood and cow dung for cooking causes household air pollution resulting in severe health hazards. In this context, the Indian government has set up a large program promoting the use of liquefied petroleum gas (LPG) in rural areas. While this has led millions of households to adopt LPG, a major fraction of them continues to rely heavily on solid biomass for their daily cooking. In this paper, we evaluate the effect of simple health messaging on the propensity of these households to use LPG more regularly. Our results from rural Rajasthan are encouraging. They show that health messaging increases the reported willingness to pay for LPG, and substantially increases actual consumption. We measure this based on a voucher, which can only be used if LPG consumption is doubled until a certain deadline. Households exposed to health messaging use the voucher about 30% more often than households exposed to a placebo treatment. We further show that the impact of our very brief, but concrete health messaging is close to the effect of a 10% price reduction for a new LPG cylinder. Finally, our study raises some interesting questions about gender-related effects that would be worth consideration in future research.

DOI: https://doi.org/10.1371/journal.pone.0231931

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S1 Appendix: Mathematical derivations for the theoretical model

In this paper, we proposed an illustrative model based on the Cobb-Douglas utility function:

$$U(g,x) = g^{\theta}x^{1\ \ \theta} \tag{1}$$

where g is the cooking gas LPG, x is a composite good that includes traditional biomass and other goods, and $\theta \in [0,1]$ is an indicator for the preference for LPG as compared to the composite good.

For an income B and prices p_g and p_x, the budget constraint is:

$$gp_g + xp_x \leq B \tag{2}$$

Maximizing (1) subject to (2) yields the Marshallian demand function for LPG:

$$g^*(p_g) = \frac{B}{p_g} \cdot \theta \tag{3}$$

Inverting this function we obtain the price a household is willing to pay for this quantity of LPG:

$$p_g(g^*) = \frac{B}{g^*} \cdot \theta. \tag{4}$$

Predictions related to WTP

Imagine we request the household to increase its consumption from g^* to $\bar{g} = 2g^*$ as we are interested in WTP for regular rather than very sporadic users. Assume that such a doubling of LPG consumption is feasible within the budget constraint (Assumption 1, see section Assumptions). To make this situation again optimal for the household, the new price must be 50% lower than the initial price:

$$p_g(\bar{g}) = \frac{B}{\bar{g}} \cdot \theta = \frac{1}{2} \cdot p_g(g^*). \tag{5}$$

While this exact relationship is directly related to the restrictive assumption underlying the Cobb-Douglas utility function that the price-elasticity of demand is equal to 1, even otherwise, we would clearly expect a reduction in WTP with an increase in the requested amount to be consumed.

More interesting in the context of our study, however, is the question to what extent health messaging can compensate some of this reduction in WTP. What is the change in WTP if we increase the decision maker's knowledge about the adverse health effects of cooking with traditional biomass?

Let us consider the preference for LPG θ as a linear function of health knowledge $h \in [0,1]$:

$$\theta = \bar{\theta} + h \cdot \gamma \tag{6}$$

where $\bar{\theta} \in [0,1]$ is basic preference (e.g., due to the convenience and time savings associated with LPG) and $\gamma \in [0,1]$ is a factor reflecting the salience of health information, notably due to gender.

We can then rewrite $p_g(\bar{g})$ as:

$$p_g(\bar{g}) = \frac{B}{\bar{g}} \cdot (\bar{\theta} + h \cdot \gamma) \tag{7}$$

The expected effect of health messaging on WTP is then given by:

$$\frac{\partial p_g}{\partial h} = \frac{B}{\bar{g}} \cdot \gamma > 0 \tag{8}$$

We are further interested to see if the impact of health messaging is affected by differences related to gender reflected by differences in the salience of the health information. To see this we need to take the cross-derivative with respect to h and γ. To do so, note that factors such as gender already influence the initial value of g^* and thus also $\bar{g}$. More formally, we can write:

$$\bar{g} = 2g^*(p_m, \bar{\bar{\theta}}) = 2\frac{B}{p_m} \cdot (\bar{\theta} + \bar{h} \cdot \gamma) \tag{9}$$

where p_m is the original market price and $\bar{\bar{\theta}} = \bar{\theta} + \bar{h} \cdot \gamma$ the initial preference for LPG. In other words, $\bar{g}$ is fixed as the double of the optimal consumption at the general market price and the initial preference for LPG $\bar{\bar{\theta}}$ that is based on the initial health knowledge and salience. We keep h fixed at this initial level $\bar{h}$ as its change due to the treatment does not influence g^*. In contrast, a greater salience of such health knowledge γ already influences the initial g^*. Hence, $\bar{g}$ needs to be considered as a function of γ but not of h when we take the derivatives. We assume that the treatment itself does not affect γ (Assumption 2, see section Assumptions), which is obvious if we think of it as reflecting the gender of the decision maker.

Inserting (9) in (8) and taking the derivative with respect to γ, we obtain:

$$\frac{\partial^2 p_g}{\partial h \partial \gamma} = \frac{\bar{\theta} p_m}{2(\bar{\theta} + \bar{h}\gamma)^2} > 0 \tag{10}$$

Predictions related to the propensity of voucher use

The propensity to use the voucher can be expressed as the difference in utility ΔU between a situation in which the voucher is used U_1 and a situation in which it is not used U_0. Taking into account the conditions for voucher use, namely doubling initial consumption and the discounted offer price p_d, we can specify U_1 as

$$U_1 = \bar{g}^{\theta} x^{1 \quad \theta} = \bar{g}^{\theta} (B \quad \bar{g} p_d)^{1 \quad \theta} \tag{11}$$

In contrast, the utility when the voucher is not used U_0 simply corresponds to Eq (1) evaluated at the optimal level of consumption given the market price p_m, without any discount but with the possibility to freely adjust all quantities to changes in θ:

$$U_0 = g^{*\theta} x^{*1 \quad \theta} \tag{12}$$

ΔU can thus be rewritten as

$$\Delta U = U_1 \quad U_0 = \bar{g}^{\theta} (B \quad \bar{g} p_d)^{1 \quad \theta} \quad g^{*\theta} x^{*1 \quad \theta}. \tag{13}$$

To facilitate the computation of the derivatives we simplify Eq (13) through a monotonous transformation using logs. This transformation will leave the sign of the derivatives unchanged.

$$\begin{aligned}\Delta u &= \ln U_1 \quad \ln U_0 \\ &= (1 \quad \theta)\ln\frac{B \quad 2g^*(p_m,\bar{\bar{\theta}})p_d}{B \quad g^*(p_m,\theta)p_m} + \theta\ln\frac{2g^*(p_m,\bar{\bar{\theta}})}{g^*(p_m,\theta)} \\ &= (1 \quad \theta)\ln(1 \quad 2\bar{\bar{\theta}}\frac{p_d}{p_m}) \quad (1 \quad \theta)\ln(1 \quad \theta) + \theta\ln(2\bar{\bar{\theta}}) \quad \theta\ln\theta\end{aligned} \tag{14}$$

Replacing θ by (6) and taking the derivative with respect to h yields:

$$\frac{\partial\Delta u}{\partial h} = \quad \gamma\ln\left(\frac{1 \quad 2\bar{\bar{\theta}}\frac{p_d}{p_m}}{2\bar{\bar{\theta}}}\right) + \gamma\ln\left(\frac{1 \quad \theta}{\theta}\right) > 0 \tag{15}$$

Note that this computation is again based on Assumption 1 (a doubling of consumption is feasible within the budget constraint), or else, we would take the log of a negative quantity in the first term. A further relevant assumption is that the requirement to double LPG consumption in order to use the voucher is a binding constraint (Assumption 3, see section Assumptions). For more extreme preferences for LPG, the model would suggest that the household would forego the voucher in order to be able to consume more LPG. This situation is irrelevant in practice, as the voucher can also be used any time before the deadline, and hence there is no constraint on the maximum use of LPG. For reasons of simplification, the model has not been designed to cover these obvious cases where the health treatment is extremely effective. Finally, remember that $0 < \frac{p_d}{p_m} \leq 1$ since p_d is the discounted price while p_m is the market price. Considering all these arguments, we obtain the sign of the derivative.

We now examine how the impact of h on Δu varies for different levels of salience of health information. We use (15) evaluated at the initial preferences for LPG $\theta = \bar{\bar{\theta}}$. Considering that $\bar{\bar{\theta}} = \bar{\theta} + \bar{h}\cdot\gamma$ we can take the derivative of $\frac{\partial\Delta u}{\partial h}$ with respect to γ to obtain the cross-derivative:

$$\frac{\partial^2\Delta u}{\partial \mathrm{h}\partial\gamma} = \ln\left(\frac{2(1 \quad \bar{\bar{\theta}})}{1 \quad 2\bar{\bar{\theta}}\frac{p_d}{p_m}}\right) + \gamma\frac{h\cdot(2\frac{p_d}{p_m} \quad 1)}{(1 \quad 2\bar{\bar{\theta}}\frac{p_d}{p_m})(1 \quad \bar{\bar{\theta}})} > 0 \tag{16}$$

This inequality holds under exactly the same conditions as the inequality in (15).

Before concluding this analysis, let us further examine the reaction of Δu to a change in the discounted offer price p_d. Since this price can be obtained only when the household effectively uses the voucher, a lower p_d makes voucher use more attractive:

$$\frac{\partial\Delta u}{\partial p_d} = \quad \frac{(1 \quad \theta)2\theta}{(1 \quad 2\theta)p_m} < 0 \tag{17}$$

This inequality only requires Assumption 1 (see section Assumptions). The negative relationship between WTP and the required consumption is thus also reflected in the lower propensity of voucher use (implying the doubling of consumption) for higher p_d.

Finally, note that—as opposed to WTP—the propensity of voucher use is unrelated to the budget B, since it enters in the same way in both U_1 and U_0 and hence cancels out:

$$\frac{\partial\Delta u}{\partial B} = 0 \tag{18}$$

Assumptions This section provides an overview of the three main assumptions referred to above:

1. Doubling LPG consumption (as imposed in the experiment) is theoretically possible, i.e., the consumption of other goods does not fall below 0 for all possible prices $p_d \in [0.5p_m, p_m]$ and θ. Formally,

$$B \quad 2g^*(p_m, \theta) \cdot p_d > 0, \forall p_d, \forall \theta$$

   Using Eq (3) this further implies: 1 $\quad 2\theta > 0, \forall \theta$.

2. The treatment $d \in [0, 1]$ does not alter γ directly, i.e., health messaging only affects health knowledge h, but not the salience of this knowledge:

$$\frac{\partial \gamma}{\partial d} = 0$$

   This is certainly true for the main variable we think of in this context, namely gender, but also smoke exposure more broadly, which cannot change immediately, i.e., prior to the household's reactions with respect to consumption or stated WTP that we are assessing here.

3. The preference increase for LPG as a result of the intervention is not so strong that the household would want to increase its LPG use by more than 100%. This implies that the requirement we impose on the household to *at least double* its LPG consumption can be treated in the model as a requirement to *double* consumption:

$$\bar{g} = \max\{2g^*(p_m, \bar{\bar{\theta}}), g^*(p_d, \theta)\} = 2g^*(p_m, \bar{\bar{\theta}}) \Rightarrow 2\bar{\bar{\theta}} > \theta$$

   The alternative case is of course possible, but including this option into the model would make the model more complex, while not changing anything substantially. This is because households willing to consume more than $2g^*(p_m, \bar{\bar{\theta}})$ will have an even higher propensity to use the vouchers.

S2 Appendix: Power calculation and sampling protocol

We determined our sample size based on the aim to detect an additional WTP for LPG associated with the intervention of 12 INR or larger. 12 INR corresponded to 2.5% of the regulated market rate for a standard size LPG cylinder when the field study started (= 480 INR). Assuming that the pooled standard deviation of WTP would be 60 INR (based on a pilot among 21 households), the price difference of 12 INR corresponded to a between-groups effect size of d=.2 (small). To obtain statistical power at the recommended 0.8 level with alpha set at 0.05 for a two-tailed test, a sample of 393 would be required. However, if the variance is higher, the required sample size increases substantially. We hence aimed at 500 usable observations for the experiment. Adding 10% to account for different kinds of data problems which may arise resulted in 550 planned interviews. We hence sampled 55 villages in Bikaner district with probability proportional to population size. Fig 1 shows this district, in the state of Rajasthan. The protocol in Fig 2 describes the sampling procedure in detail.

Fig 1. Study area of Bikaner district, Rajasthan, India.

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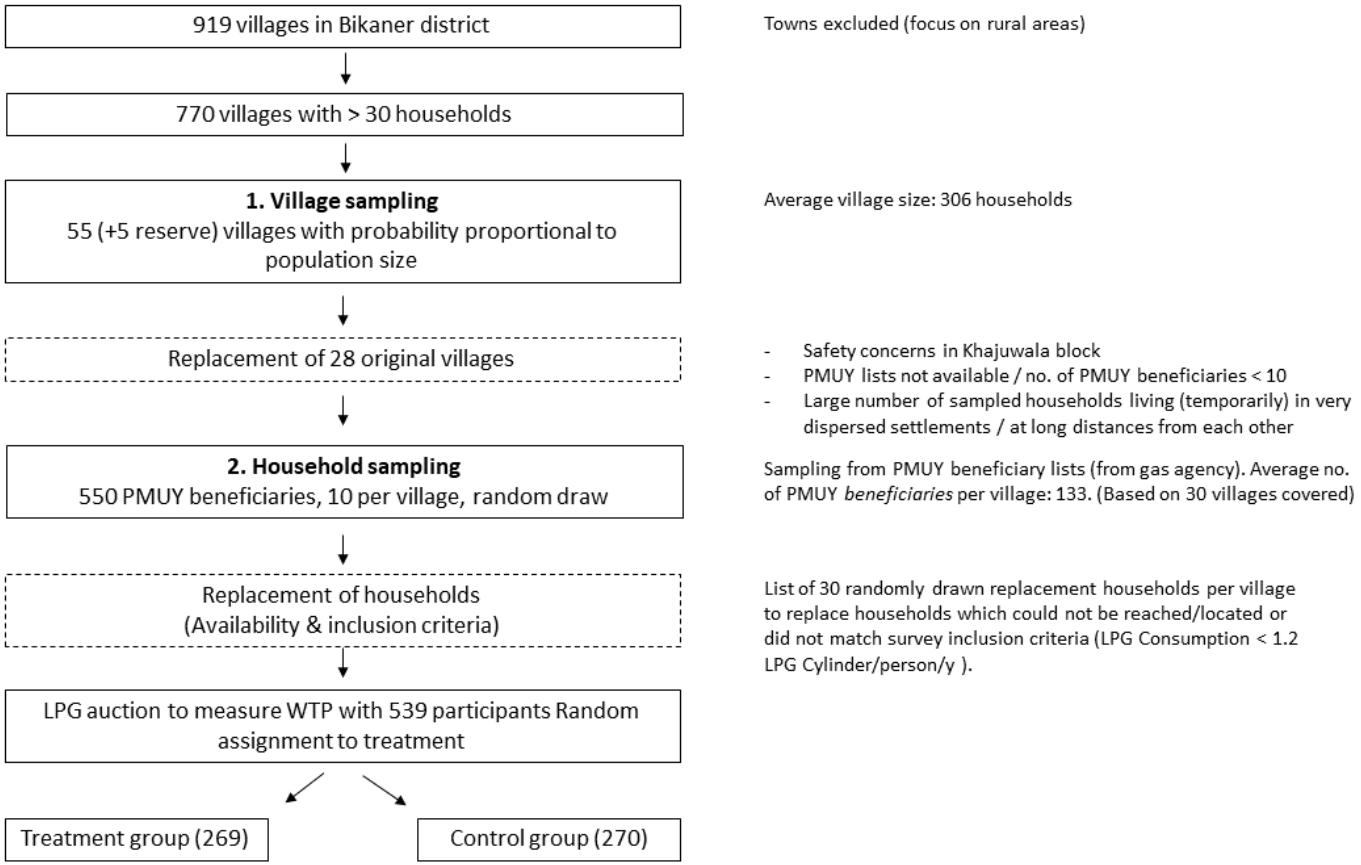
Fig 2. Sampling protocol.



S3 Appendix: Summary statistics and balance tests

Table 1. Means and tests of treatment-control covariate balance

	Total mean	Control mean	Treatment mean	Difference b	t
Male	0.08	0.09	0.07	0.01	(0.62)
Age	28.55	28.29	28.81	-0.52	(-0.73)
Education	1.50	1.57	1.43	0.14	(1.43)
Household size	6.00	5.85	6.15	-0.30	(-1.53)
Hindu	0.97	0.98	0.96	0.02	(1.24)
Muslim	0.03	0.02	0.04	-0.01	(-1.02)
BPL	0.60	0.57	0.63	-0.06	(-1.27)
Expenditures	6752.59	6740.38	6764.75	-24.37	(-0.07)
Land	0.66	0.63	0.68	-0.05	(-1.15)
Asset index	-0.01	-0.04	0.01	-0.05	(-0.38)
Refills	0.91	0.90	0.92	-0.02	(-0.88)
LPG consumption	0.24	0.23	0.25	-0.01	(-0.99)
Wood quantity	45.75	47.63	43.85	3.78	(1.17)
Dung quantity	52.47	51.78	53.17	-1.39	(-0.38)
Random price	339.94	336.41	343.48	-7.06	(-1.29)
Content	0.45	0.46	0.44	0.01	(0.53)
Voucher validity	21.05	21.34	20.75	0.59	(0.37)
Subsidy	0.15	0.13	0.17	-0.05	(-0.96)
LPG convenience	1.49	1.48	1.49	-0.01	(-0.20)
Distance	0.46	0.48	0.44	0.04	(0.91)
Refill cost	0.90	0.91	0.90	0.01	(0.31)
Fin. restriction	0.77	0.79	0.75	0.05	(1.26)
Food taste	0.57	0.57	0.56	0.02	(0.38)
Safety	0.24	0.24	0.23	0.01	(0.28)
N	539	270	269	539	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2. Means and tests of treatment-control covariate balance for voucher owners

	Total mean	Control mean	Treatment mean	Difference b	t
Male	0.10	0.12	0.07	0.05	(1.49)
Age	28.31	27.97	28.65	-0.67	(-0.73)
Education	1.52	1.55	1.50	0.05	(0.37)
Household size	5.89	5.75	6.03	-0.29	(-1.22)
Hindu	0.97	0.99	0.94	0.05***	(2.60)
Muslim	0.03	0.01	0.05	-0.05**	(-2.40)
BPL	0.57	0.58	0.57	0.01	(0.14)
Expenditures	6511.90	6405.41	6619.86	-214.46	(-0.44)
Land	0.66	0.67	0.65	0.01	(0.24)
Asset index	-0.09	-0.14	-0.04	-0.10	(-0.65)
Refills	0.91	0.89	0.93	-0.04	(-1.14)
LPG consumption	0.25	0.24	0.26	-0.02	(-1.09)
Wood quantity	46.15	47.54	44.72	2.82	(0.68)
Dung quantity	51.99	49.48	54.56	-5.07	(-1.08)
Random price	305.43	301.51	309.40	-7.89	(-1.51)
Content	0.43	0.42	0.44	-0.02	(-0.61)
Voucher validity	20.61	20.42	20.82	-0.40	(-0.20)
Subsidy	0.17	0.14	0.21	-0.08	(-1.14)
LPG convenience	1.50	1.53	1.47	0.06	(0.66)
Distance	0.47	0.44	0.50	-0.06	(-1.08)
Refill cost	0.88	0.87	0.90	-0.03	(-0.84)
Fin. restriction	0.74	0.75	0.72	0.03	(0.56)
Food taste	0.53	0.56	0.51	0.06	(0.97)
Safety	0.25	0.26	0.24	0.02	(0.43)
WTP for LPG	389.83	382.88	396.91	-14.03*	(-1.87)
Voucher value	174.64	178.59	170.60	7.99	(1.53)
N	303	153	150	303	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3. Variable definitions and summary statistics

Variable	Definition	Count	Mean	Std. Dev.	Min	Max
Dependent variables						
WTP	Willingness to pay for LPG	539	356.79	71.34	200.0	750.0
Voucher use	Dummy = 1 if individual used voucher before the household-specific expiry date	296	0.35	0.48	0.0	1.0
Key explanatory variable						
Health information	Dummy = 1 if individual is exposed to health information	539	0.50	0.50	0.0	1.0
Other variables						
Voucher	Dummy = 1 if individual received voucher	539	0.56	0.50	0.0	1.0
Voucher validity	Days until voucher expiry	538	21.05	18.22	3.5	172.0
Voucher value	Voucher value (INR)	303	174.64	45.44	5.0	235.0
Male	Dummy = 1 if individual is male	539	0.08	0.27	0.0	1.0
Age	Age of the individual	539	28.55	8.18	18.0	65.0
Education	Education(Categorical, levels 1-7)	539	1.50	1.16	1.0	7.0
Household size	Number of persons sharing one kitchen	538	6.00	2.31	2.0	20.0
Hindu	Dummy =1 if individual is Hindu	539	0.97	0.17	0.0	1.0
Muslim	Dummy =1 if individual is Muslim	539	0.03	0.17	0.0	1.0
BPL	Dummy = 1 if household holds a BPL card	508	0.60	0.49	0.0	1.0
Expenditures	Household consumption expenditures (INR/month)	521	6752.59	4184.69	400.0	50000.0
Land	Dummy = 1 if household owns land	539	0.66	0.48	0.0	1.0
Asset index	Weighted index of asset ownership	539	-0.01	1.42	-1.4	6.6
Refills	Dummy = 1 if household buys LPG refills	539	0.91	0.29	0.0	1.0
LPG consumption	Estimated LPG consumption HH (cylinder/month)	489	0.24	0.15	0.0	1.7
Wood quantity	Wood quantity used (kg/week)	536	45.75	37.29	0.0	350.0
Dung quantity	Dung quantity used (kg/week)	537	52.47	42.11	0.0	350.0
Content	Estimated content currently used cylinder (%)	468	0.45	0.25	0.0	1.0
Subsidy	Dummy = 1 if household buys					

	subsidized cylinders	232	0.15	0.35	0.0	1.0
LPG convenience	Convenience LPG vs. trad. cooking (1-Better, 2-Similar, 3-Worse)	539	1.49	0.74	1.0	4.0
Distance	Dummy = 1 if distance explains low LPG usage)	539	0.46	0.50	0.0	1.0
Refill cost	Dummy = 1 if refill costs explain low LPG)	539	0.90	0.30	0.0	1.0
Fin. restriction	Refill costs as main hindrance to regular LPG consumption (respondents share)	539	0.77	0.42	0.0	1.0
Food taste	Dummy = 1 if taste of food explains low LPG)	539	0.57	0.50	0.0	1.0
Safety	Dummy = 1 if safety explains low LPG)	539	0.24	0.42	0.0	1.0
Severe effects	Dummy = 1 if aware of severe effects from IAP	503	0.31	0.46	0.0	1.0
Slight effects	Dummy = 1 if aware of slight effects from IAP	503	0.53	0.50	0.0	1.0
No effects	Dummy = 1 if not aware of any effects from IAP	503	0.16	0.37	0.0	1.0
IAP diseases	Share of six IAP-related diseases correctly identified (in %)	539	0.34	0.28	0.0	1.0
All diseases	Share of ten diseases correctly identified as either IAP-related or not	539	0.51	0.15	0.1	0.9
Observations	539					

Sample restricted to respondents taking part in the WTP Experiment.

IAP = Indoor Air Pollution

S4 Appendix: Protocol and material for WTP elicitation and experiment

1 Protocols for WTP eliciting mechanisms and experiment

As explained in the main document, in order to ensure that survey participants would well understand the procedure leading to our measurement of WTP, we first ran the process with a relatively cheap item (a piece of soap) that respondents had to buy if their stated WTP was above a randomly drawn offer price. We then repeated the same procedure with a more expensive good (an LED bulb). This means that once the process was implemented for LPG, respondents had already gained significant experience with the procedure. In this Appendix we provide the protocol used for the WTP measurement of the piece of soap and the complete protocol for the LPG WTP experiment. The WTP measurement for the LED bulb was more or less identical to the one for soap, except for some reference to the experience the respondent already had with soap. It is therefore not shown here. The following questions and instructions were communicated verbally by the enumerator to the respondent. Occasional instructions in italics were directed to the enumerator. The enumerators carried these instructions on their mobile phone and the survey application of Qualtrics we had prepared took them automatically from one step to the next.

1.1 Protocol for measuring the willingness to pay for soap

1.1.1 Introduction

In this survey we will mainly ask you things about your energy use for cooking and lighting. In this context, we will also ask you to take a couple of decisions about real products. For this reason, before we start, we would like to go through a little exercise, so you can see how these decisions will work. I will now explain to you how it works.

In the following, you can purchase an item, as follows: First, you (participant) say the maximum amount you are ready to pay for it. The actual price will be unknown, but we will tell you the range of prices possible. We will then find out, at which price the good will be made available to you for purchase. To do so, we have prepared cards with prices within the possible range.

I will ask you to draw one card that will then show the relevant price. If this price is less than your originally stated maximum amount you would like to pay, then you will have to purchase the good at this price. If the price is higher than the amount you stated earlier, you cannot purchase it.

Maybe this procedure seems a bit complicated to you. But it makes sure that it is optimal for you to tell us your true willingness to pay. You cannot do better by stating a lower or higher price than you actually would be ready to pay.

Let us make an example for the procedure: You say you would be ready to pay up to 4 Rupees (INR), and the price on the card drawn is 7 INR The item will not be sold. If your price was 10 INR, the item is sold at 7 INR Note that if what you state is higher than the price drawn, this is an agreement to buy the good, and that if your stated amount is below the price, there will be no sale. Do you have any questions so far?

Let us now make the real run with a piece of soap. Are you willing to participate?

☐ Yes

☐ No

→ If *No* is selected, the survey ends at this point.

1.1.2 Bidding procedure

Here is a soap. The price at which it will be made available to you will be between 1 to 10 Rs, prices within this range are printed on the cards that you can see here. Now what is the maximum amount you are ready to pay to get it?

→ Participant states a price.

I would like to remind you that if you state an amount that is higher than the price which will be determined in a minute, this is an agreement to purchase the soap, and that if your amount is below the price there will be no sale. Would you like to adjust your amount now?
If YES, go back to last question and adjust amount
What is the maximum amount the participant is willing to pay? Please write down the price that was stated in INR

_____

We now determine the price at which the good is made available for you in a random manner. Please turn one of the cards upside.

→ The participant turns up one of the number cards in front of her. The cards show the numerical values 2, 4, ...10.

What is the actual price on the card? Please select the actual price on the card in the drop-down list

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→ The survey software calculates difference between bid (stated WTP) and offer price (randomly drawn price). Depending on the difference being positive or not, it redirects the enumerator to instruction A or B, with filled-in numerical values.

A THE RESPONDENT CANNOT BUY THE SOAP
Your **maximum amount** of [...] INR was lower than the actual price of [...] INR which you have drawn from the cards. This means the price you are ready to pay is not as high as the sales price we found here. Therefore you cannot buy the soap.

B THE RESPONDENT CAN BUY THE SOAP
You are ready to pay an amount of [...] INR This is higher than (or same) as the actual price of the soap, which you have drawn from the cards, which is [...] INR This means you will purchase the soap for the price of [...] INR now.

Did the participant agree to buy the soap?

☐ Yes

☐ No, because _____

1.2 Experimental Protocol to measure the effect of health messaging on the WTP for LPG

1.2.1 Introduction

Now we would now like to carry out an exercise on LPG, which is similar to the ones with the soap and LED carried out before. We would like you to bid for one cylinder of LPG. You will have the chance to buy a cylinder at a price somewhat below 480 INR Let us remind you that this is about a real purchase and that your decision will be truly implemented.

Do you agree to participate? In case you wish to consult with someone else in the family, you can do so.

Wait in case the respondent wants to call another person to participate for the rest of the question

☐ Yes

☐ No

→ If *No* is selected, survey software redirects enumerator to section "Exit questions experiment".

1.2.2 Conditions

Please listen carefully to the conditions: The mechanism is basically the same as for the soap and the LED bulb. But as you can imagine, we cannot carry the gas cylinders with us. Therefore we will work with vouchers.

Voucher: The current subsidized price for a cylinder of LPG (subsidy comes on your bank account) is about 480 INR If the price we draw is below that (480), we give you a voucher which will cover the difference.

Time period: There is another important difference to a normal order: you have to use the remaining LPG more intensively than before, such that you collect the new cylinder earlier than usual or than you might have planned. For your case this concretely means, that the cylinder that we offer you must be collected before [. . .] days

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→ We fixed a specific deadline for each household that would require this household to consume the remainder of the LPG in the cylinder currently in use twice as quickly than under normal circumstances. The deadline was determined by the survey tool based on the information about the family's existing LPG consumption and the remaining time for using up the current cylinder using the information provided at the outset in the screening questions. If this estimate could not be meaningfully interpreted (for instance, because the LPG connection was established only very recently), the household was directly asked to make a prediction on when they would need a refill and this prediction was halved to replace the estimate. The next working day after the end of this period constituted the deadline for the validity of the voucher.

1.2.3 Information intervention

Before we start, let me inform you that ...

→ Automated randomization through the survey app, directly displaying either the health frame or the alternative frame to the enumerator.

Present the information to the respondent and show the poster together with it.

→ The Enumerator presents the information (either of the frames) and shows the illustrating poster together with it. See all information material used for frames in section 2 of this Appendix.

1.2.4 Bidding procedure

Let us now turn to the bidding procedure. First let us find out what the maximum amount is that you are ready to pay for 1 cylinder of LPG, under the conditions I explained to you. Remember that it is optimal for you to tell us your true willingness to pay. You cannot do better by stating a lower or higher price than you actually would be ready to pay.

Now what is the maximum amount you are ready to pay for the cylinder?
Please note the price stated in INR

_____

I would like to remind you that if you bid above the price we will just determine, this is an agreement to buy an LPG cylinder, and that if your bid is below the price you cannot buy LPG at special conditions. Would you like to adjust your bid now?
If yes go back to last question.

We now determine the price at which the good is made available for you in a random manner. Please turn one of the cards upside.

→ The participant turns up one of the number cards in front of her. The cards represent numerical values between 240 and 480, at intervals of 10 (starting from 245).

Note actual price from the card in INR

_____

→ Survey software calculates difference between bid (stated WTP) and offer price (randomly drawn price). Depending on the difference being positive or not, it redirects the enumerator to instruction A or B, with filled-in numerical values.

A. LPG VOUCHER
You are ready to pay an amount of [...] Rs, this is higher than (or same) as the actual price, which you have drawn from the cards, which is [...] INR. This means you will be able to buy a cylinder of LPG at the price of [...] INR now.

We will make this possible by giving you a voucher, which covers the difference between this price and 480 [the normal subsidized cylinder price]. In your case this is 480 minus [offer price], equals [calculated voucher value] INR. For this we have an agreement with [name local distributor]. You can go there or order via phone/SMS and then use the voucher like cash. As we have explained before, there is a special condition of this voucher: You have to use the voucher to buy the next LPG cylinder before [calculated deadline] days.

Please take the voucher and fill it in:

- Name of interviewed person
- Her full address
- Voucher amount: (480 – [offer price] INR) , this is [calculated vouchervalue] INR
- Valid until: Today's date + [calculated time to used up current cylinder] days

Explain very clearly that they have to use the voucher until this date, because after this date it will not be valid anymore, the voucher will become useless.

Please enter the voucher number here:

_____

Please take a photo of the voucher.

B. NO LPG Voucher
The amount you are ready to pay for 1 cylinder [...] INR is lower than the actual price of [...] INR which you have drawn from the cards. This means what you would like to pay is not enough to buy a new cylinder under these special conditions. Therefore, you cannot buy the LPG cylinder now.

1.2.5 Exit questions

Q1
Considering the impact on health, compared to traditional cooking stoves, the LPG-based cooking is:

- ☐ Better (1)
- ☐ Similar (2)
- ☐ Worse (please specify) (3): _____
- ☐ Don't know (4)

→ Enumerator is directed to

Q2 if "Considering the impact on health, compared to traditional cooking stoves, the LPG-based cooking is" = Better (1)

Q3 if "Considering the impact on health, compared to traditional cooking stoves, the LPG-based cooking is" = Similar (2)

Q4 if "Considering the impact on health, compared to traditional cooking stoves, the LPG-based cooking is" = Don't know (4)

Q2
Let us talk a bit more about that. If cooking with firewood and/or dung affects the health, how severe is that? I will read out 2 statements now, please which one corresponds to your opinion:

- ☐ Cooking with dung cakes/firewood causes coughing and irritated eyes, but this health impact is not a severe problem.
- ☐ Cooking with firewood/dung cakes over a long time can cause very severe health problems.
- ☐ Other (please specify): _____

Q3
Let us talk a bit more about that. I read out 2 statements now, please tell me which one corresponds to your opinion:

- ☐ No, I do not think that cooking with firewood and/or dung cakes causes any health problems.
- ☐ Cooking with dung cakes/firewood causes coughing and irritated eyes, but this health impact is not a severe problem.

Q4
Let us talk a bit more about that. I read out 3 statements now, please tell me which statement corresponds to your opinion:

- ☐ No, I do not think that cooking with firewood and/or dung cakes causes any health problems.
- ☐ Cooking with dung cakes/firewood causes coughing and irritated eyes, but this health impact is not a severe problem.
- ☐ Cooking with firewood/dung cakes over a long time can cause very severe health problems.

Q5
I am going to name lot of different health problems now. Some of them have to do with the smoke from the chulha, others don't have anything to do with it at all. For each one, could you tell me whether you think that cooking from firewood or dung cakes can make it more likely to suffer from this disease?

Disease	Yes	No
Arthrosis / Jodbandi	○	○
Heart diseases	○	○
Lung Cancer	○	○
Osteoporosis (bone atrophy)	○	○
Cataract / Motyaabind	○	○
Pneumonia	○	○
Problems for physical child development	○	○
Dengue fever	○	○
Diarrhea / Haija	○	○
Stroke / Aaghaat	○	○

Q6
Do you feel any discomfort from cooking with firewood and/or dungcakes? Please select the statement which fits best.

- ☐ No, I do not feel any discomfort.
- ☐ Cooking with dung cakes/firewood causes me to caugh more and have irritated eyes, but it is not a problem for me.
- ☐ I feel discomfort in my lungs and eyes and I have already experienced severe health problems, which have to do with the smoke from the chulha.
- ☐ Don't know.

2 Information material used for frames

While this appendix contains English versions of the visualizing posters and texts, the material used in the field was in Hindi language.

2.1 Health frame (text for enumerator and poster)

Before we start let me inform you that LPG is very different from firewood and dung cake regarding the health effects of these fuels. You have certainly observed that when cooking with the chulha – especially indoors and with bad ventilation – there is a lot of pollution in the air (*show picture of cooking woman*). According to studies from different universities and research institutions, this pollution causes many more health problems than may be directly observable for the person who cooks and her family. As opposed to what one may think, the effects are not limited to temporary coughing, tearing eyes and throat ache, but also include several severe diseases:

- Generally, many people in India die much earlier than normal from disease which is caused by air pollution from cooking with solid fuels.
- A large number of people, for instance, die prematurely due to a stroke. This occurs when blood flow to an area of the brain is cut off. Every 4th case of death from stroke is due to breathing in the polluted air over a long period of time.
- Similarly, indoor air pollution increases the risk of developing lung cancer or heart disease significantly. It is like smoking a very large amount of cigarettes every day, you can see on the picture what can happen to the lung (*show pictures lung diseases and heart diseases*).
- It also increases the chances of getting a cataract/motyaabind (*show picture eye diseases*). If untreated, cataract/motyaabind can lead to blindness.
- And it can hinder the development of (the) children. Women and small children are the most affected by the pollution. When small children die from acute lower respiratory infections like pneumonia, this is due to indoor air pollution in more than half of the cases (*show picture development of child*). Of course, ventilation helps to reduce these risks. Having an open window and a chimney hood or cooking outside is therefore helpful. But according to available academic studies, the remaining risks are often considerable and should not be underestimated. When cooking on a chulha, the danger of being hit by the severe diseases mentioned above is usually still much higher than otherwise.

Fig 1. Visualizing poster health frame.

2.2 Alternative frame (text for enumerator and poster)

Before we start, let me give you some information about how liquefied petroleum gas or LPG, your cooking gas, is produced. LPG is a fossil fuel. Sometimes it is recovered naturally, directly from the ground. Another way of producing LPG is by refining it from crude oil. Crude oil is a thick and black liquid. It is a mixture of different chemicals which can be used as fuel because they burn well. Most crude oil is found by drilling down through rocks on land or off-shore at the bottom of the ocean.

- Look, we have a picture of an oil field off the coast of Mumbai. The oil gets pumped up from a deep hole in the ocean floor (*show picture of oil field off the coast of Mumbai*).
- Crude oil cannot be used as a fuel as it is. Therefore, the crude oil must be transported to a so-called oil refinery as a first step. This can best be done through a crude oil pipeline, which pumps the crude oil from the oil field to a refinery (*show picture of crude oil pipe*). This pipeline transports crude oil from the Barmer district, Rajasthan to Salaya, Gujarat.
- At the oil refinery, the crude oil is heated and then distilled to separate it into different petroleum products (*show picture of oil refinery*). These include gasoline for cars, ship fuel and the petroleum gas used for cooking.
- But gas takes up a lot of space. To make storage easier, the gas is liquefied by compressing with high pressure. This is why your cooking gas is called liquefied petroleum gas or LPG.
- Then the liquefied gas is transported to a bottling plant. There it gets filled into the cylinders that you know (*show picture of bottling plan*). They are small enough for relatively easy transport. Since the gas is still liquid, it does not take up too much room.
- As a last step, LPG distributors deliver the LPG cylinders to customers in local markets (*show picture of delivery*).
- In some major cities, households do not have to buy the LPG bottled up in cylinders, but instead receive gas through a pipeline in their kitchen (*show picture of woman with stove and gas pipeline*).
- If you release the liquid from the cylinder by turning on your appliance, it turns back into gas.

Fig 2. Visualizing poster alternative frame.

S5 Appendix: Offer price distribution and voucher use

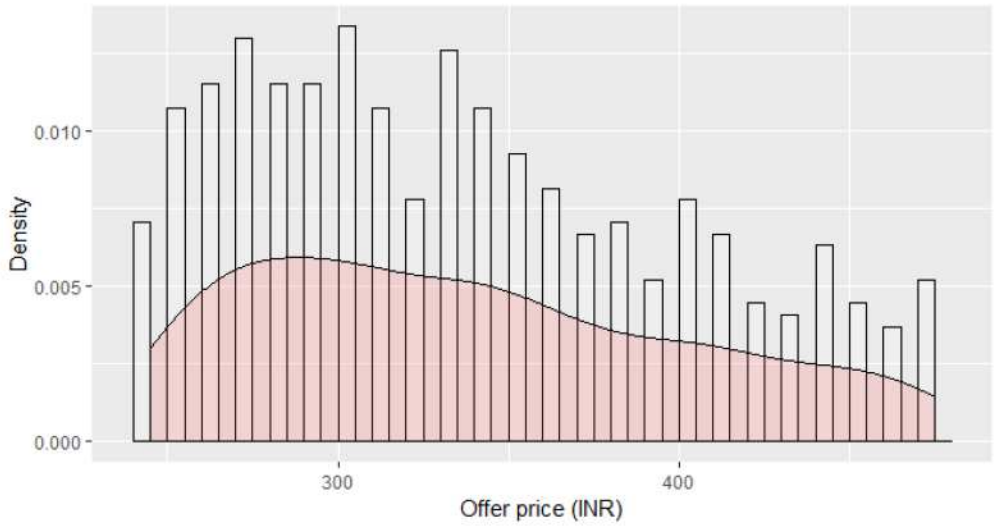
Offer Prices in the WTP eliciting mechanism

Enumerators determine the offer prices p_d used in the WTP eliciting mechanism by drawing a random piece from a set of price cards covering the range from 245 to 475 INR in steps of 5 INR.

The choice of the price range is based on the following reflection: Even if a household's currently used cylinder was full at the time of the survey and even if its demand for LPG was completely inelastic (i.e., it does not speed up consumption due to price reductions), it would be left with a maximum of 50% of the cylinder content (market value = 240 INR) at the expiry date of the voucher, i.e., when the cylinder is to be replaced by a full one. All households should thus accept to replace their currently used cylinder by a full one if they are given a compensation $C = 480 \quad 240 = 240$ INR, and a higher discount should not be necessary in our context.

Fig 1 shows the empirical distribution of the prices. While prices were drawn from the full range of possible values, their distribution is right-skewed. Offer prices below the mean (339) are more frequent than prices that are higher than this average. This is surprising as an approximately uniform distribution of offer prices should have been expected. A chi-square test comparing the observed frequencies to the expected frequencies under a discrete uniform distribution clearly rejects the null-hypothesis that these distributions are equal (p=0.000).

Fig 1. Distribution of offer prices.



Histogram with heights of the bars representing observed frequencies of offer prices and density curve as approximation of the proportion of values in certain price ranges.

This raises some doubts regarding the random selection of offer-prices. It cannot be excluded for instance that, in some cases, enumerators made the selection only among higher discount values in order to provide extra benefits to the household. However, since WTP is measured before offer prices are drawn, this should not affect our main results.

Offer Prices and voucher use probability

This section examines the effect of the randomly determined offer price in more detail. Table 1 shows the results of a logistic regression estimation that includes the voucher value, i.e., the offered price discount D ($= p_m \quad p_d$) as a continuous variable (odds ratios displayed).

Table 1. Joint effect of health information on voucher use.

	(1)	(2)	(3)	(4)
Health message	1.444*	1.724**	7.633**	11.421**
	(0.095)	(0.020)	(0.031)	(0.029)
Discount (per 20 INR)		1.360***	1.516***	1.564***
		(0.000)	(0.000)	(0.000)
Discount X Health message			0.843*	0.822
			(0.097)	(0.106)
Male				2.906**
				(0.023)
Content				0.548
				(0.407)
Voucher validity				0.996
				(0.680)
Asset index				1.122
				(0.219)
Land				1.221
				(0.481)
LPG distance				1.024*
				(0.050)
Fin. restriction				1.400
				(0.314)
Education				1.019
				(0.874)
Age				0.981
				(0.289)
Household size				0.889*
				(0.086)
Months since LPG adoption				1.024
				(0.181)
Constant	0.203***	0.017***	0.006***	0.007***
	(0.000)	(0.000)	(0.000)	(0.000)
N	532	531	531	449
Area under the ROC curve	55%	73%	73%	77%

Logit models with odds ratios,* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. p-values in parentheses. Lack of data on the additional variables included in Col. 2-4 leads to a reduction in the number of observations.

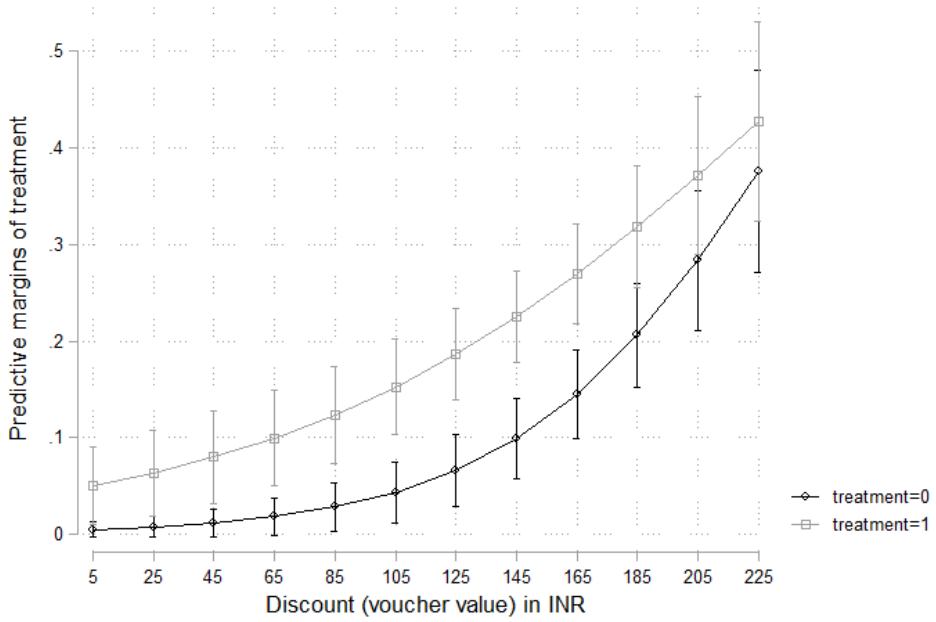
Col. 1 reports the odds ratio for the uncontrolled comparison between treatment and control group as a baseline (corresponding to Table 5, Col. 1 in the main part of the text). As discussed in the section "Joint effect of health messaging on voucher use", the estimate indicates that the odds of using the voucher are 1.44 times larger for a household that received the health messaging than for a household that did not. Col. 2 shows that the treatment effect is not much affected by the additional inclusion of the offer price. The odds ratio increases from 1.44 to 1.72. This corresponds to a change in the predicted probability of voucher use from 6 percentage points for the model in Col. 1 to 8 percentage points for the model in Col. 2. Furthermore, the estimate becomes more precise. Generally, the inclusion of prices substantially increases the precision of the model and its capacity to correctly predict the use or non-use of the voucher. The effect on the quality of the prediction is similar to the effect of the inclusion of price dummies in Table 5 of the main text.

The discount itself has a robust and also quite sizeable effect. On average, a price reduction of 20 INR increases the odds of using the voucher by a factor of 1.36. This corresponds to an increase in the predicted probability of using the voucher by 4 percentage points.

In Col. 3 and 4 we allow the price reduction to interact with the treatment effect and add further controls. Measured in terms of odds ratios, the interaction term is just at the border of significance. However, this is not very meaningful because, when the discount is close to zero, almost no respondent uses the voucher so that even a tiny absolute effect of health messaging appears like a huge effect in relative terms.

Rather than to interpret the interaction term in Table 1, we thus move to a graphical illustration of the probability of voucher use for different treatment conditions and different discount values. Using the regression in Col. 4, Fig 2 shows how the predicted probability of voucher use increases with rising discounts (depicted in steps of 20 INR) for both the treated and the untreated. Comparing the lines for these two groups, we find no systematic reduction in the distance between treated and non-treated for increasing voucher values. The marginal effect of the discount is also not changed by the treatment (p=66%, see Stata code in Appendix S6). On average, across all observed values in the sample, the effect of health messaging is about 10 percentage points. Differences are most clearly significant for intermediate voucher values.

Fig 2. Predicted Probability of voucher use.



Logistic regression model as estimated in Col. 4 of Table 1 and 90% CIs

Comparing the price effect and the treatment effect

Fig 2 also allows us to compare the change in the predicted probability of voucher use driven by the treatment to the change induced by different discount values. For very low voucher values (at the left of the graph) health messaging increases the probability of voucher use by about 5 percentage points. To reach the same effect size, the voucher value must be increased by 100 INR (from 5 to 105 INR). In the middle part of the graph, the treatment effect appears somewhat stronger, but the slope of the curve of the non-treated is steeper, implying that a further discount matters more, too. At a discount value of 125, for instance, the effect of the health treatment is almost 15 percentage points, but the same effect can be reached by increasing the discount by 60 INR, i.e., a lesser amount than before, from 125 to 185 INR. On average across the range of observed values in the sample, increasing the discount by 40 INR (=8.3% of the current subsidized price of a new cylinder) increases voucher use by about 10 percentage points, and thus corresponds to the effect size of health messaging within the same model (Table 1, Col. 4).

S6 Appendix: Replication data and code

The data and replication code can be downloaded here (ZIP):
https://doi.org/10.1371/journal.pone.0231931.s006