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Is There an Energy Efficiency Gap in China? Evidence from an Information Experiment

Abstract

We provide evidence of an energy efficiency gap in China. Using an incentivized field experiment, we document that providing information to consumers on the energy costs of lightbulbs significantly affects their willingness to pay for energy efficient bulbs. Unlike previous literature, we do not find evidence that this gap is driven by biased beliefs. Further our experimental design allows us to rule out that changes in willingness to pay are driven purely by the salience of the monetary or environmental costs of lightbulbs. We argue that the results are consistent with consumers being risk averse and uncertain about the benefits of more energy efficient appliances.

JEL-Codes: Q400, H230.

Keywords: energy-efficiency, lightbulbs, information experiment.

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1 Introduction

The overwhelming share of growth in global energy demand in coming years is expected to come from non-OECD countries. Wolfram et al. (2012) argue that household energy consumption will account for a significant proportion of this growth, so increasing the energy efficiency of appliances and motor vehicles may lead to significant welfare benefits. However, frictions or mental gaps may lead to households not accurately evaluating this tradeoff resulting in suboptimal consumption of energy efficient products – a concept that has been labeled the *energy efficiency gap* (Allcott and Greenstone, 2012). The possibility of this gap drives a raft of policy measures in the developed world including minimum standards, labeling, tax rebates and other incentive programs. However, there is substantial disagreement about the existence, magnitude, and underlying causes of the gap (Handel and Schwartzstein, 2018; Allcott and Greenstone, 2012; Gerarden et al., 2017) and a dearth of evidence outside the developed world (Fowlie and Meeks, 2020).

In this paper we report the results of a field experiment to estimate the magnitude of the gap in urban China. Our experiment combines an incentivized multiple price list elicitation of willingness to pay with an information intervention outlining the relative energy costs of lightbulbs over ten years. We further differentiate our treatments by deliberately priming a random subset of subjects to consider the environmental and energy costs of the lightbulbs.

We find that the energy efficiency gap in urban China is similar to previous estimates of the gap in the United States. Unlike previous studies, our results are not consistent with the hypothesis that biased beliefs about long term cost savings cause underconsumption of energy efficient products. The effect of energy efficiency information is positive even for those who were the most optimistic about the energy efficiency of LEDs before receiving information. We also find that asking subjects about these savings without providing them with information does not affect their willingness to pay, which is inconsistent with the hypothesis that the energy efficiency gap is caused by lack of salience.

We propose an alternative explanation for the energy efficiency gap based on uncertainty.

An information treatment that resolves uncertainty about the benefits of energy efficient technologies may increase willingness to pay for energy efficiency.

We provide the first experimental evidence of the energy efficiency gap in China. In doing so we contribute to the literature identifying energy efficiency gaps in lightbulbs (Allcott and Taubinsky, 2015), vehicles (Allcott and Knittel, 2019; Allcott and Wozny, 2014; Sallee et al., 2016; Grigolon et al., 2018), home heating (Myers, 2019) and appliances (Houde, 2018). To date this literature has focused on the developed world. Exceptions are Toledo (2016) who investigate take up of LED lightbulbs in in Brazil and Carranza and Meeks (2021) who identify the effect of energy efficiency on electric reliability in the Kyrgyz Republic.

More generally, our results point to an under-explored mechanism of information campaigns: the resolution of uncertainty regarding product attributes. Unlike previous literature, we find that subjects overestimate the savings of LED lightbulbs, but increase their willingness to pay for those bulbs when informed about actual cost savings. In contrast, Allcott and Taubinsky (2015) find evidence that information on energy efficiency operates at least partially through changes in average beliefs. While Allcott and Knittel (2019) find no systematic evidence of consumers underestimating vehicle efficiency they also find no evidence of an energy efficiency gap. Similarly, Allcott and Sweeney (2016) find some evidence that consumers over estimate energy savings but also do not find evidence of a significant energy efficiency gap.

2 Conceptual framework

Consumer i has a budget Z_i out of which they must purchase a durable necessity. She has two options: a conventional model (N), and an energy efficient model (E). The models have prices p_N and p_E respectively, where $p_N < p_E$.

The present value of the lifetime energy cost of the conventional model is c_N, which is known to the consumer. [1] The consumer has beliefs about the present value of the lifetime

[1]The assumption that the consumer knows the energy cost of the conventional good simplifies the anal-

costs which are distributed with mean $\overline{c_{i,E}}$ and variance $\sigma^2_{i,E}$.

The salience of the lifetime energy costs of the durable necessity is given by $\gamma_i \in [0,1]$ where a consumer with $\gamma_i = 0$ ignores the lifetime energy costs entirely and a consumer with $\gamma_i = 1$ fully considers them.

Consumer i receives utility from x, the money she has left over after buying and operating the durable necessity. She has a constant absolute risk aversion utility function $U_i(x) = -e^{-\rho x}$, so she maximizes the certainty equivalent $\mu_{i,x} - \frac{\rho\sigma^2_{i,x}}{2}$, where μ_x and σ^2_x are the mean and variance of her expectations over x and ρ is her coefficient of absolute risk aversion.[2]

Consumer i chooses to buy the conventional good if

$$\begin{aligned} Z_i - p_N - \gamma_i c_N &> Z_i - p_E - \gamma_i \overline{c_{i,E}} - \gamma_i \frac{\rho\sigma^2_{i,E}}{2} \\ p_N + \gamma_i c_N &< p_E + \gamma_i (\overline{c_{i,E}} + \frac{\rho\sigma^2_{i,E}}{2}) \end{aligned} \tag{1}$$

and chooses to buy the energy efficient good if

$$p_N + \gamma_i c_N > p_E + \gamma_i (\overline{c_{i,E}} + \frac{\rho\sigma^2_{i,E}}{2}) \tag{2}$$

If consumer i were fully informed and attentive, she would buy the conventional good if

$$p_N + c_N < p_E + c_E \tag{3}$$

and the energy efficient good if

$$p_N + c_N > p_E + c_E \tag{4}$$

An energy efficiency gap occurs if consumers choose not to buy the energy efficient product, but would if they were fully informed and attentive. Formally, this occurs if there are more

ysis, but it can be relaxed without altering the main results.

[2]The main results hold for any utility function that displays risk aversion.

consumers for whom both (1) and (4) hold than for whom both (2) and (3) hold. This can be caused by one or more of the following:

- Consumers' beliefs about c_E are biased upwards, so that $\overline{c_{i,E}} > c_E$.
- Consumers are more uncertain about c_E, so that $\sigma^2_{i,E}$ is larger.
- The lifetime costs are not sufficiently salient.

Providing consumers with information about the lifetime energy costs may reduce $\sigma^2_{i,E}$, increase γ_i, and, if $\overline{c_{i,E}} > c_E$, reduce $\overline{c_{i,E}}$. Observing that information increases consumption energy efficient products does not shed light on the underlying cause of the energy efficiency gap. Our experimental setup addresses this issue.

3 Experiment design and implementation

Our experiment consisted of 7 modules which are presented in different orders to a control group and 5 treatment groups.[3] The design of the experimented is illustrated in Figure 1.

Modules A and D elicited willingness to pay for an LED lightbulb relative to two incandescent lightbulbs. To incentivize truthful revelation, each participant was allocated a budget of 20 Yuan (approximately $2.85 US) and presented with a multiple price list for the two lightbulb packages: one 40W equivalent LED lightbulb or two 40W incandescent lightbulbs. The point at which participants switch between options reveals their willingness to pay. At the end of the experiment the enumerators used a random number generator to draw one decision from the two elicitations and participants received the associated lightbulb and any unspent budget in cash.

Module B (Cost Information) consisted of information on the cost of using LED and incandescent lightbulbs over a 10 year period. Participants received a handout detailing the differences in the expected costs of lighting using the bulbs over a 10 year period. Module

[3]The Supplementary Appendix contains a schematic of the experimental design and the materials for each module in Chinese and English.

C provided participants with placebo information on different lightbulb shapes. Module E (Cost Questions) consisted of questions about the lifetime costs. Module F (Environment Questions) asked about the environmental effect of energy use. Finally, Module G (Other Questions) collected demographic information.

Our experiment includes a control group and 5 treatment groups. The control group did not receive the information about lifetime costs; [4] the Information treatment group (Treatment I) did receive this treatment; the Cost Priming treatment group (Treatment II) did not receive the information and the Cost Questions were asked immediately after the first elicitation of willingness-to-pay; the Environmental Priming treatment group did not receive the information and the Environment questions (Treatment III) were asked after the first elicitation of willingness to pay; the Information + Cost Priming treatment group (Treatment IV) received the information and were asked the Cost Questions between the first elicitation and the information; and the Information + Environmental Priming treatment group (Treatment V) received the information and were asked the Environment Questions between the first elicitation and the information.

The purpose of the two priming treatments is to assess whether simply drawing attention to monetary or environmental costs affects relative willingness to pay. It also provides us with data about participant beliefs which allows us to assess the impact of the Information on beliefs.

Our experiment was implemented between April 11 and June 9, 2018 at four outdoor locations in Beijing.[5] We hired and trained experienced enumerators of a local survey company to field the experiment.[6]

To eliminate any bias that might arise from question order, we randomized whether the multiple price list consisted of increasing the incentive to choose the standard bulb or

[4] All groups that did not receive the information treatment received the placebo information (Module C)

[5] We selected one site within each of the four major districts in central Beijing.

[6] Enumerators were trained to adhere strictly to the script. Their training included several practice rounds with a member of the research team as well as several supervised practice surveys on members of the public. Two supervisors from the survey firm were at the research site at all times and a member of the research team was periodically present.

increasing the incentive to choose the energy efficient bulb.

We elicit relative willingness to pay for energy efficient bulbs using an incentive compatible multiple price list. We attempt to reduce two well-known limitations of the multiple price list methodology. Subjects who did not choose monotonically by switching between the bulbs more than once were prompted by the enumerators to choose again. 14% of participants continued to give this type of response and were excluded from the sample. A second well-known limitation of multiple price list experiments is censoring of willingness to pay. A relatively larger share (48% in the first elicitation, 63% in the second) of subjects always chose one bulb, regardless of the price. These subjects were asked a follow-up question: *How much must a [...] bulb cost for you to choose [alternative] bulb?* We assign all censored subjects the median value of willingness to pay among this group.[7]

Table 1 shows that the randomization of our treatments appears to have been successful as groups are balanced on collected observable characteristics as well as baseline relative WTP for the LED bulb.

4 Results

4.1 The energy efficiency gap

To estimate treatment effects, we use the following specification:

$$\text{DiffWTP}_i = \alpha + \beta_1 \text{Info}_i + \beta_2 \text{CostPriming}_i + \beta_3 \text{EnvPriming} + X_i\gamma + \epsilon_i \tag{5}$$

For each subject i, DiffWTP_i represents the difference in relative willingness to pay (how much more the subject was willing to pay for the energy efficient bulb) between the second elicitation and the first. Info_i, CostPriming_i, and EnvPriming are binary variables indicating whether or not a subject received each treatment. X_i is a vector of demographic variables

[7] In the Supplementary Appendix we present results where we drop censored responses from the analysis and when we assign each participant their stated willingness to pay.

including age, gender, children, income, education, and whether the subject is responsible for their own electricity bill.

Table 2 shows the results of versions of this specification where subjects who have a censored WTP are assigned the median stated response. In Columns (1) to (3) all subjects are included, while in Columns (4) to (6) subjects who had a censored WTP and did not provide a stated response are dropped. Columns (1) and (4) include no controls, Columns (2) and (5) add controls and Columns (3) and (6) include interview and location fixed effects. The Information treatment has a significant positive effect on willingness to pay across all specifications. The Environmental Priming treatment has an effect which is only significantly positive in some specifications, and the Cost Priming treatment has no significant effect on willingness to pay.[8]

The measure of WTP in Columns (1)-(3) is closest to the measure used by Allcott and Taubinsky (2015) and the magnitude of the effect of the information treatment (11.37 Yuan=$1.60) is not dissimilar to the $2.30 effect that they found. This suggests that the energy efficiency gap in urban China is similar in magnitude to the energy efficiency gap in the United States.

4.2 Beliefs, salience and uncertainty

All subjects were asked to estimate the lifetime cost savings that the energy efficient bulb provides. Some answered without seeing the Information treatment and others after receiving the Information treatment.

Figure 2 shows the distribution of beliefs of those with and without information. The distributions are bottom-coded and top-coded at -3000 and 3000. The Information treatment updated beliefs towards 215 Yuan, which was the value provided in the Information treatment. Beliefs of the uninformed group were overly optimistic, so the net effect of information

[8]In the Supplementary Appendix we report all coefficients including the controls and the results of treatment effects for each of the 5 treatment groups. We find no significant interaction between Priming and Information treatments. We also include results for alternative measures of WTP.

is to revise beliefs about the savings from an LED bulb downward.

If the only effect driving the energy efficiency gap is misinformed consumers the effect of the Information treatment should be a function of prior beliefs. Specifically, subjects who are initially too pessimistic about the lifetime cost savings should increase their willingness to pay after receiving information, while subjects who are initially too optimistic should decrease their willingness to pay. However, Figure 3 shows that even these optimists increase their willingness to pay in response to information.

A second possibility is that consumers underinvest in energy efficient products because the lifetime cost savings are not salient. Table 2 suggests that this is unlikely to be the dominant factor. The effect of the Cost Priming treatment is statistically indistinguishable from zero and we can reject the hypothesis that it is equal to the effect of the Information treatment. If the lack of salience of lifetime cost savings is an important factor in the energy efficiency gap it is reasonable to expect that drawing subjects' attention to savings should have a detectable effect on willingness to pay.

If salience was a major factor, we would also expect that subjects' willingness to pay would be less correlated with their estimates of the cost savings until their attention is drawn to these savings. However, as we show in the supplementary appendix, the difference in the relationships between willingness to pay and expected savings between those who have and have not received the Information treatment is small and statistically insignificant. This further argues that salience does not play a dominant role.

The remaining possibility is that a third factor, other than biased beliefs or lack of salience, is an important determinant of the energy efficiency gap. As we argue in Section 2, a good candidate for this is uncertainty about cost savings.

Although we do not test for uncertainty directly, the results of the experiment are consistent with uncertainty being the driving factor behind the energy efficiency gap in China. The significant effect of the Information treatment is consistent with uncertainty as this treatment should reduce uncertainty. The absence of an effect of the Cost Priming treatment is

consistent with uncertainty as this treatment does not reduce uncertainty.

Our experimental setup does not allow us to directly test for a reduction in within-subject uncertainty. However, as Figure 2 shows, the Information treatment reduced dispersion of beliefs considerably. Although the figure is a cross-section of subjects, it is suggestive of a reduction in within-subject uncertainty. Further, since subjects updated their prior beliefs substantially in response to new information, their priors cannot have been strongly held. Since it appears likely that the Information treatment reduced uncertainty considerably, it is plausible that this had a significant effect on willingness to pay.

Overall, the experiment shows a significant energy efficiency gap that is not primarily driven by biased beliefs or salience. An explanation that remains viable is that consumer uncertainty about the lifetime cost savings of energy efficient products is a major determinant of the energy efficiency gap. Consumers guess that energy efficient products will save them money and consider this when making purchasing decisions. However, because they are not confident in their guess they are unwilling to invest as much in energy efficient products.

5 Conclusion

We test for an energy efficiency gap in urban China by performing incentivized elicitations of relative willingness to pay for incandescent and energy efficient lightbulbs. We find results that are broadly consistent with previous measures in developed countries. However, our results point to a new mechanism behind the energy efficiency gap. We rule out that biased beliefs or salience drive the gap that we observe, suggesting that a third factor must be the primary cause. We present a simple model showing that a likely candidate is uncertainty about the long term cost savings from energy efficiency and show that our results are consistent with this hypothesis.

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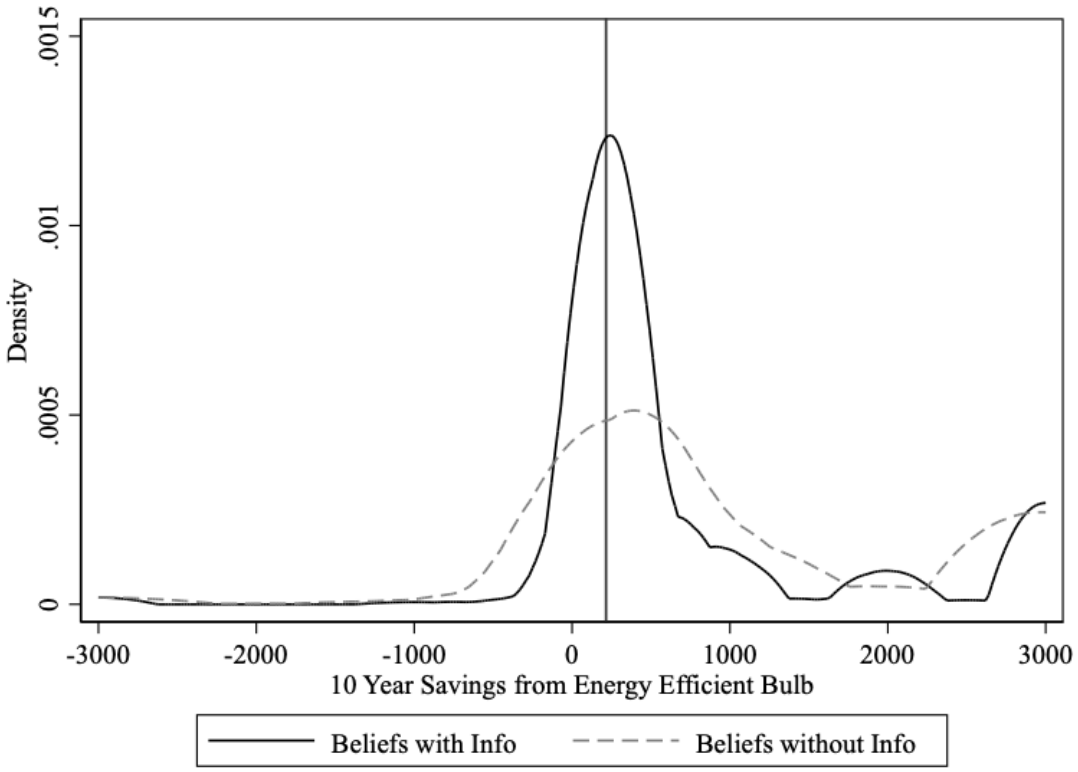
6 Figures and Tables

Figure 1: Experiment Design

		TREATMENT GROUPS					
		Control	Treatment I	Treatment II	Treatment III	Treatment IV	Treatment V
Modules	A: WTP Elicitation	1	1	1	1	1	1
	B: Cost Information	Not given	2	Not Given	Not Given	3	3
	C: Placebo Information	2	3	3	3	4	4
	D: WTP Elicitation	3	4	4	4	5	5
	E: Cost Questions	4	5	2	5	2	6
	F: Environment Questions	5	6	5	2	6	2
	G. Demographic Questions	6	7	6	6	7	7

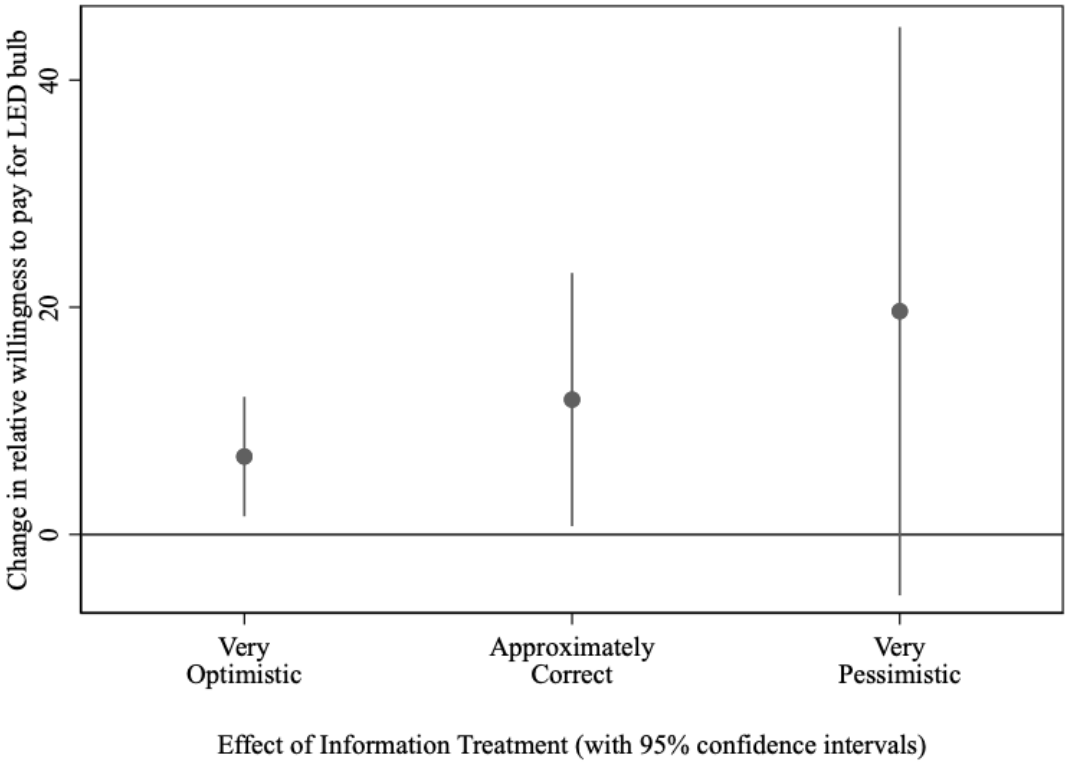
Figure outlines the order of the modules in the field experiment. For example, in the control group, Module A: WTP Elicitation is presented to subjects first, followed by Module C: Placebo Information. The shaded squares highlight the experimental treatments.

Figure 2: Beliefs about lifetime cost savings



Notes: Figure plots density of stated beliefs of respondents regarding the 10 year energy savings of LED bulbs for (1) participants who had not received the information treatment (dashed line) and (2) participants who had received the information treatment (solid line). Stated beliefs are censored at -3000,3000. The solid vertical line at 215 represents the information provided to the participants on the expected savings.

Figure 3: Effect of information treatment by initial beliefs



Notes: Figure plots estimated treatment effects of information by initial beliefs regarding the energy savings of LED lightbulbs. All respondents with censored WTP are assigned the median stated WTP across the censored group. Standard errors are robust.

Table 1: Balance of treatment groups

Variable	(1) Control N	(1) Control Mean/SD	(2) T1 N	(2) T1 Mean/SD	(3) T2 N	(3) T2 Mean/SD	(4) T3 N	(4) T3 Mean/SD	(5) T4 N	(5) T4 Mean/SD	(6) T5 N	(6) T5 Mean/SD
Baseline WTP	333	24.435	333	24.904	159	24.132	171	24.661	161	28.068	154	26.130
		(25.247)		(26.372)		(27.749)		(26.537)		(25.385)		(27.349)
Female	333	0.574	333	0.547	159	0.560	171	0.509	161	0.571	154	0.578
		(0.495)		(0.499)		(0.498)		(0.501)		(0.496)		(0.496)
Age	331	32.746	331	32.293	159	32.899	169	32.692	160	33.200	154	32.026
		(10.660)		(10.463)		(10.508)		(10.335)		(10.322)		(9.516)
Has Children	333	0.483	331	0.502	159	0.509	169	0.456	161	0.497	154	0.442
		(0.500)		(0.501)		(0.501)		(0.500)		(0.502)		(0.498)
HH Income $>$ 100,000 Y	324	0.265	328	0.271	155	0.271	168	0.268	159	0.201	150	0.273
		(0.442)		(0.445)		(0.446)		(0.444)		(0.402)		(0.447)
College or higher	333	0.571	333	0.529	159	0.491*	175	0.520	161	0.453**	154	0.571
		(0.496)		(0.500)		(0.501)		(0.501)		(0.499)		(0.496)
Pays own electricity bill	332	0.443	332	0.464	159	0.497	171	0.474	160	0.481	152	0.428
		(0.497)		(0.499)		(0.502)		(0.501)		(0.501)		(0.496)

Notes: For each covariate, Table reports observations, mean and standard deviation by group. Significance *** , **, and * indicate difference in mean between treatment group and control group is significant at the 1, 5, and 10 percent critical level. Treatment groups are defined in Section 3. Respondents with censored WTP are assigned the median stated WTP across the censored group. 100,000 Y is approximately $14,285.

Table 2: Treatment effects

	All Responses			Complete Responses		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES						
Information Treatment	11.372***	11.372***	11.390***	14.507***	14.016***	14.099***
	(1.144)	(1.169)	(1.177)	(1.611)	(1.609)	(1.624)
Cost Priming	-0.646	-0.427	0.008	-0.812	-0.338	-0.440
	(1.434)	(1.460)	(1.483)	(2.120)	(2.075)	(2.150)
Environmental Priming	2.895**	3.188**	4.010***	1.917	1.954	2.830
	(1.373)	(1.403)	(1.430)	(1.874)	(1.870)	(1.902)
Observations	1,311	1,273	1,273	736	725	723
R^2	0.074	0.081	0.099	0.109	0.115	0.136
Controls	No	Yes	Yes	No	Yes	Yes
Interviewer FE	No	No	Yes	No	No	Yes
Location FE	No	No	Yes	No	No	Yes
Mean dep var	6	6	6	7.9	7.8	7.8

Notes: Dependent variable is the within-subject difference in willingness to pay (WTP) for the LED lightbulb relative to the incandescent lightbulbs between the baseline and endline elicitations. Columns (1) - (3) assigns all subjects with censored WTP the median stated WTP across the censored group. Columns (4) - (6) assigns subjects with censored WTP the median stated WTP subjects the censored group and drops censored respondents who did not report a stated WTP. Standard errors are robust. Significance *** , **, and * indicate coefficient is significant at the 1, 5, and 10 percent critical level