Evaluating Behaviorally Motivated Policy

Experimental Evidence from the Lightbulb Market

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About Researchers

- **Hunt Allcott**
  - Professor of Global Environmental Policy and of Economics, Stanford
  - An applied microeconomist working at the intersection of behavioral, public, and environmental/energy economics.
- **Dmitry Taubinsky**
  - Associate Professor of Economics, UC Berkeley
  - Use a combination of theory, field experiments, surveys and quasi-experiments to study topics such as: inattention to and misunderstanding of complex tax incentives.

Motivations

- **Consumer Bias**
  - Consumers' choices may not maximize their own welfare.
  - "Energy Paradox" (Jaffe & Stavins, 1994): the low adoption of energy-efficient technologies despite apparently large cost savings.
  - Consumers may be imperfectly informed about or inattentive to energy costs when they buy energy-using durables. (Internalities)
- **Lightbulb Market**
  - Standard incandescent or compact fluorescent lightbulb (CFL)?
  - Compared to standard incandescent, a CFL lasts much longer and uses 4 times less electricity, so a 60-watt equivalent CFL saves about $5 per year on average.
  - Only 28% of residential sockets that could hold CFLs actually had them. (US Department of Energy, 2010)
  - More information or Subsidize CFLs (equal to ban traditional incandescents)?

- **Questions**
  - Is the CFL's low market share simply an expression of well-informed preferences, or are consumers unaware of or inattentive to how much money they could save?
  - Preference (psychology) vs. Information (economics)
    - How much does information provision affect demand for CFLs?
    - If powerful information provision is costly or infeasible, does a CFL subsidy or a ban on incandescent increase welfare as a second-best solution to imperfect information and inattention?
- **Strategy: carry out an experiment specifically designed**
  - Estimate the effects of information.
  - Derive "sufficient statistic" formulas for welfare effects.

- Use two real-stakes randomized experiments to study how energy cost information affects choices of energy-using durables.
- Provide a theoretically grounded empirical analysis of the "behavioral" motivation and test for undervaluation using randomized experiments.
- Instead of estimating the equivalent price metric (EPM) statistic, the paper directly measures the Average Marginal Bias.

Consumer Choice

- **Two Choices:** E (CFL) and I (incandescent)
- **Utility**: $v_j + (Z - p_j)$
  - budget: Z, price: p
  - relative price of E: $p = p_E - p_I$
  - relative utility of E: $v = v_E - v_I$
  - optimization: when $v > p$, choose E
  - misoptimization: $\hat{v} = v - b > p$ (b is a bias)
- **Demand Function**: $D_B(p) = 1 - H(p)$, $D_N(p) = 1 - F(p)$
  - F: cumulative density function (CDF) of v
  - H: the CDF of perceived valuations $\hat{v}$

Optimal Policy

- **Two Policies:** subsidy s for good E or a ban on I
- **lump-sum recycling:** purely corrective
  - A subsidy for E = a tax on I
  - A ban on one choice = a mandate for the other.
- **Welfare Impact of Subsidy**
  - $W(s) = Z(s) + v_I - p_I + \int_{v-b \geq p}(v-p)dFdG$
  - $p = c - s$ (competitive economy, relative cost $c = c_E - c_I$)
- **FOC**: $\frac{\partial W(s)}{\partial s} = W'(s) = (s - B(p))D'_B(p) = 0$
  - F: cumulative density function (CDF) of v
  - H: the CDF of perceived valuations $\hat{v}$
  - average marginal bias at price p: $B(p) = E_G(b|v - b = p)$
  - optimal subsidy: $s^* = B(c - s^*)$

Compute $B(p)$

- **First**, elicit each consumer's perceived value $\hat{v}$, get the distribution $H(\hat{v})$.
- **Second**, apply the pure nudge.
  - clear information while minimizing demand effects and confounds.
- **Third**, observe each consumer's new valuation (true v).
- Compute the average change in valuation for each level of $\hat{v}$:
  - $E_G[v - \hat{v} \mid \hat{v} = p] = E_G[b \mid \hat{v} = p] = B(p)$

Another expression: EPM

- **Equivalent Price Metric:** $EPM(p) = \frac{D_B(p) - D_N(p)}{D'_N(p)}$
- **Advantage:** easy to be implemented
  - 2-by-2 experimental design that varies nudges and prices.
  - Chetty, Looney and Kroft (AER, 2009) used EPM to estimate how labels with total tax-inclusive prices affect market shares and compare this to the price elasticity of demand.
- **Shortcoming:** not always equal to the $B(p)$
  - EPM is a coarse statistic that cannot identify whether the most biased consumers are relatively more or less elastic to the subsidy.

Example

If all consumers who undervalue E are so strongly biased against it that they all prefer I over E by at least \$2.
For the subsidy of \$1, $B(p) = 0$, but a debiasing nudge would increase the demand, $EPM(p) > 0$.

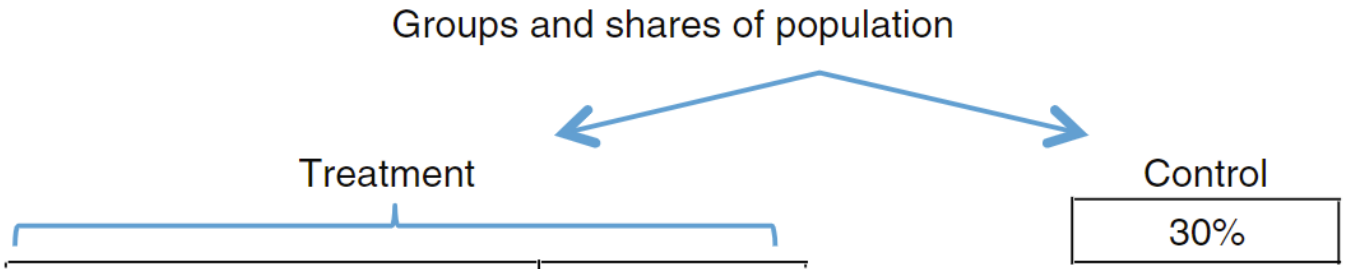
Four Types of Biases

- **Biased beliefs:** consumers may know CFLs use less energy but misestimate the cost savings.
- **Exogenous inattention to energy:** consider energy as an add-on cost.
- **Costly information acquisition:** in the absence of that information, consumers will assume that different goods have the same energy.
- **"Noisy" and costly thinking:** thinking allows a more precise representation (cognitive constraint or explicit thinking cost efficiency).

Generalization of $W'(s)$

- $W'(s) = (s - B(p) - A(p) - \phi(p))D'_B(p)$
  - $A(p)$: average marginal bias from other biases not addressed by information provision.
  - $\phi(p)$: average marginal uninternalized externality.

- Potential TESS participants are randomly selected from the US Postal Service Delivery Sequence File and recruited through an extensive series of mailings and telephone calls. About 10 percent of invitees actually become participants.



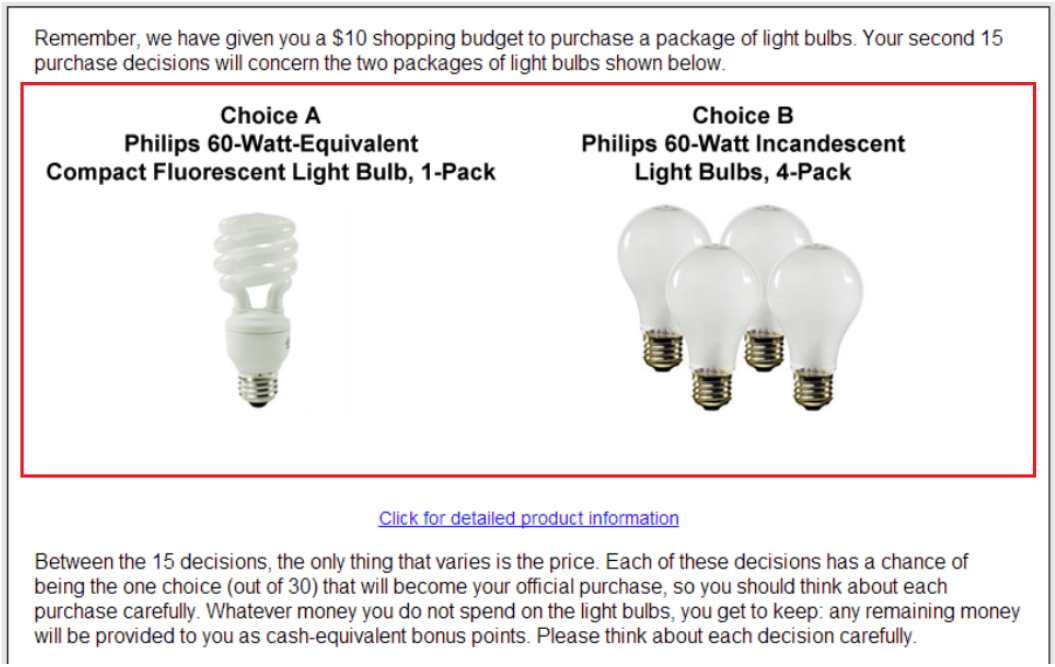
	Baseline & endline	Endline-only
Positive	27.5%	7.5%
Balanced	27.5%	7.5%

Process

1. Baseline choices (multiple price list)
2. Information provision (two screens, content varies by group)
3. Endline choices (multiple price list)
4. Post-experiment survey (beliefs, time preferences, etc.)

FIGURE 1. TESS EXPERIMENTAL DESIGN

- The study had four parts: baseline lightbulb choices, information provision screens, endline lightbulb choices, and a post-experiment survey.
  - **Baseline & Endline lightbulb choices**
    - Consumers chose between two lightbulb packages



Now please make your decisions for each of the 15 choices below.

Decision Number	Choice A 60-Watt-Equivalent Compact Fluorescent Light Bulb, 1-Pack	Choice B 60-Watt Incandescent Light Bulbs, 4-Pack
1)	Purchase **Choice A for free**	Purchase **Choice B for $10**
2)	Purchase **Choice A for free**	Purchase **Choice B for $8**
3)	Purchase **Choice A for free**	Purchase **Choice B for $6**
4)	Purchase **Choice A for free**	Purchase **Choice B for $4**
5)	Purchase **Choice A for $1**	Purchase **Choice B for $4**
6)	Purchase **Choice A for $2**	Purchase **Choice B for $4**
7)	Purchase **Choice A for $3**	Purchase **Choice B for $4**
8)	Purchase **Choice A for $4**	Purchase **Choice B for $4**

- The study had four parts: baseline lightbulb choices, information provision screens, endline lightbulb choices, and a post-experiment survey.
  - **Information provision screens**
    - **Treatment information:** Incandescents should be replaced per year, (CFLs, per 8 years).
    - **Negative information:** CFLs need proper disposal and recycle (containing mercury).
    - **Number of bulbs:** 5.8, 2.1 and 0.14 million (Residential, Commercial and Industrial)
    - **Sales trends:** 1.7 billion (2000), 1.8 (2009)
  - **A post-experiment survey**
    - Beliefs
    - Time preference

Quantity Effects

- The Treatment information increased average WTP.

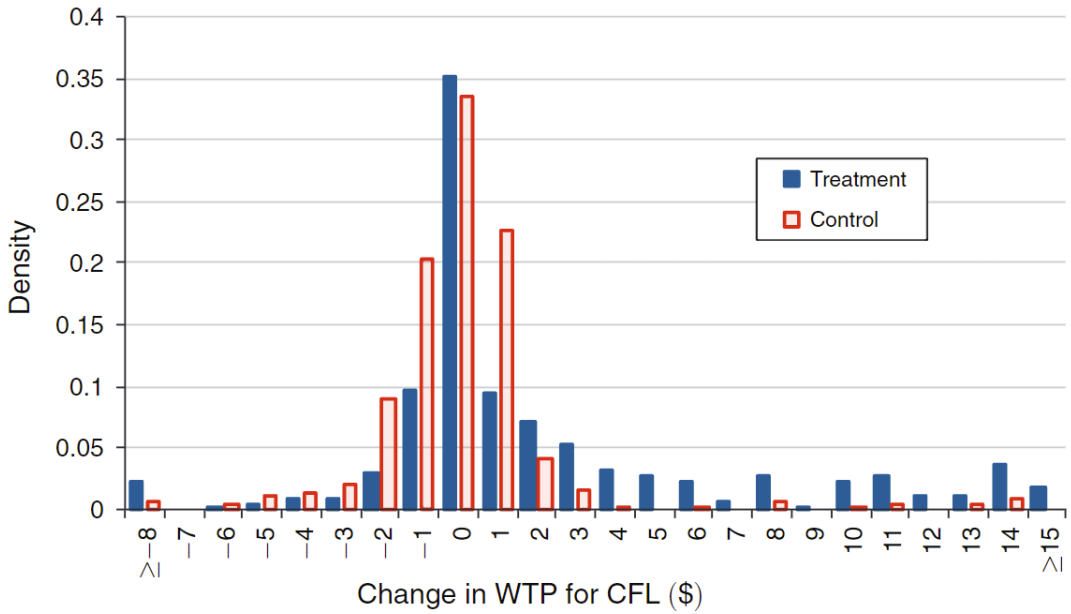


FIGURE 2. HISTOGRAM OF RELATIVE WTP CHANGES

Quantity Effects

- Demand is highly price-responsive near market prices.

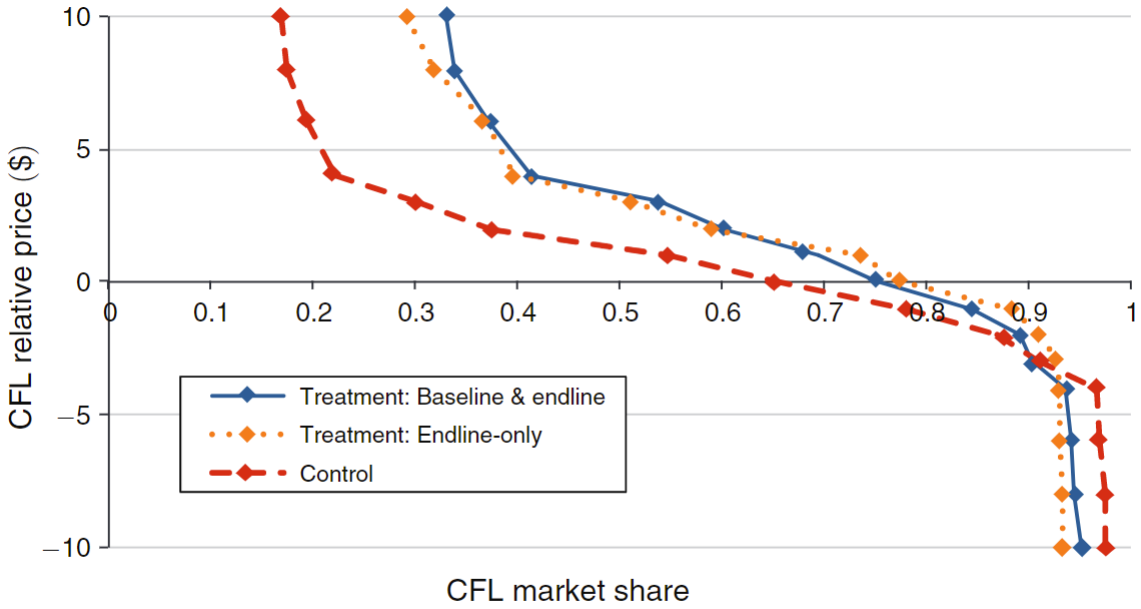


FIGURE 3. ENDLINE CFL DEMAND CURVES

Quantity Effects

- The average EPM just below the market price denoted $EPM[-1, 0]$, can be calculated using numbers in the past few paragraphs: $EPM[-1, 0] \approx ((0.07 + 0.12)/2)/0.1 \approx \$0.94$. On this interval, information affects CFL market share about as much as a \$0.94 price reduction.

Conditional Average Treatment Effects

- The CATE on the interval $p\,[-1, 0]$ is \$2.11, which is more than twice the \$0.94 EPM.

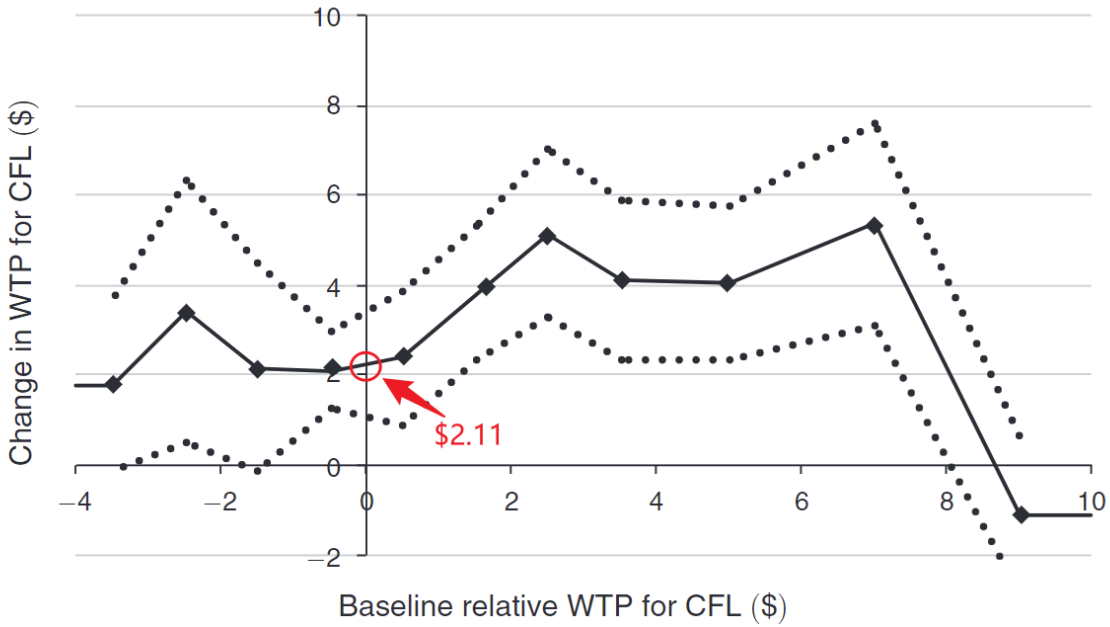


FIGURE 4. CONDITIONAL AVERAGE TREATMENT EFFECTS BY LEVEL OF BASELINE WTP

Conditional Average Treatment Effects

- We also compare the EPM and CATE at all nine price intervals where both can be calculated. Four of the nine differ with more than 90% confidence, and on average, the EPM differs from the CATE by 49%.

Average Treatment Effects

- OLS: $\mathrm{w_i^1} = \tau \mathrm{T_i} + \gamma \mathrm{X_i} + \mu_\mathrm{i} + \varepsilon_\mathrm{i}$
- Let T_i be an indicator for whether the consumer is in the Treatment group, denote X_i as consumer i's vector of individual characteristics, and denote μ_i as a vector of indicator variables for each level of baseline WTP.

Average Treatment Effects

- In column 3, information increased relative WTP for the CFL by an average of $2.30.

TABLE 1—EFFECTS OF TESS INFORMATION TREATMENT

	(1)	(2)	(3)	(4)	(5)	(6)
1(Treatment)	2.54 (0.55)***	2.28 (0.36)***	2.30 (0.37)***	3.16 (0.37)***	2.29 (0.54)***	2.14 (0.50)***
1(Endline-only)					−0.44 (0.76)	
1(Positive treatment)						0.35 (0.56)
R^2	0.03	0.57	0.58	0.33	0.04	0.58
Observations	1,203	1,203	1,188	919	1,449	1,188
Baseline WTP dummies μ	No	Yes	Yes	Yes	No	Yes
Individual characteristics	No	No	Yes	Yes	Yes	Yes
Exclude max./min. baseline WTP	No	No	No	Yes	No	No
Include Endline-only group	No	No	No	No	Yes	No

Demand Effects

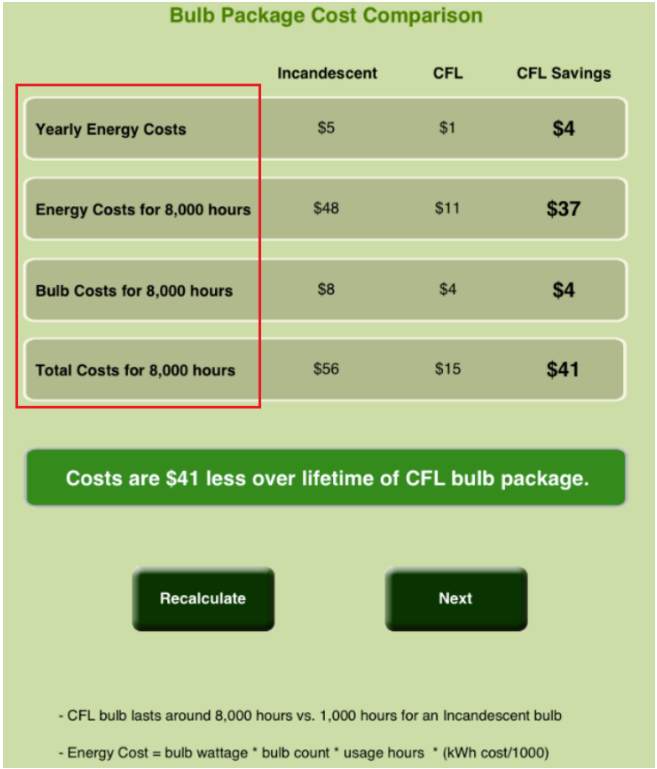
- Reasons
  - If participants identify the intent of the study, demand effects may cause consumers to comply with the study's perceived intent.
  - If consumers are willing to change their choices given the experimenter's intent: self-monitoring scale.
- Results
  - Estimates show that the Endline-only group's WTP is not statistically different from the Control group's endline WTP.
  - Because the effects do not differ between the Balanced and Positive Treatment groups, it confirms the result that internal consistency does not bias the estimates.

Effects on Beliefs

- The information treatment do act through belief updating.
- Because of the wide dispersion, however, the average treatment effect on beliefs is statistically indistinguishable from zero and very imprecisely estimated.

- Three research assistants worked in four large "big box" stores
- The research assistants approached customers in the stores' "general purpose lighting" areas
- They invited customers to have a brief survey via iPad
- In the survey, they collected
  - The most important factors in their lightbulb purchase decision.
  - The wattage and number of bulbs consumers planned to buy.
  - The amount of time each day consumers expected these lightbulbs to be turned on each day.
- Not mention electricity costs or discuss any differences between incandescents and CFLs.

- The iPad randomized customers into information Treatment and Control groups with equal probability.
  - The Treatment group received information intervention while Control group didn't receive this.



- Not mention electricity costs or discuss any differences between incandescents and CFLs.

- After the survey, the RAs gave customers a coupon.
- The iPad randomized respondents into
  - **The Standard Coupon group:** a coupon for 10 percent off all lightbulbs purchased.
  - **The Rebate Coupon group:** the same 10 percent coupon plus a second coupon valid for 30 percent off all CFLs purchased.
- If consumers use the coupons, the researchers can match the iPad data to purchases.
- The RAs would then record additional visually observable information on the customer, including approximate age, gender, and ethnicity.

Strengths and weaknesses

- Strengths
  - Consumers naturally participated in a standard marketplace.
  - Evaluate the effects of information on demand.
- Weaknesses
  - Can't identify the average marginal bias.

- Don't observe the possible purchases of the 23 percent of consumers in the iPad.
- The difference of the total duration between Treatment and Control group in means (medians) is 3.17 (3.0) minutes.
- 77 percent of interview respondents purchased any lightbulb with a coupon, and 73 percent of survey respondents purchased a substitutable lightbulb.
- Regression sample: the set of consumers that purchase a "substitutable lightbulb".
- Information didn't affect whether or not customers purchase a substitutable lightbulb.

Regression

- Linear probability model (LPM)
  - $\mathbb{1}(\text{Purchase CFL})_i = \tau T_i + \eta S_i + \gamma \mathbf{X}_i + \varepsilon_i$
    - T_i and S_i as indicator variables for whether customer i is in the Treatment and Rebate Coupon groups, respectively.
    - X_i is the vector of individual-level covariates.

Regression

TABLE 5—EFFECTS OF IN-STORE INFORMATION TREATMENT

	(1)	(2)	(3)
1(Treatment)	−0.002	0.004	−0.022
	(0.035)	(0.033)	(0.045)
1(Rebate)	0.094	0.105	0.078
	(0.035)***	(0.033)***	(0.047)*
1(Rebate and Treatment)			0.054
			(0.066)
R^2	0.01	0.16	0.16
Observations	794	793	793
Individual characteristics	No	Yes	Yes

Notes: This table presents estimates of equation (7), a linear probability model with outcome variable 1(Purchased CFL). The dependent variable has mean 0.38. Robust standard errors in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

- The rebate increased CFL market share by about 10% points.
- The standard errors rule out with 90% confidence that information provision had more than the effect of a $\$0.28$ CFL subsidy
  - $EPM[Rebate, Standard] \approx \frac{(0.032+-0.022)/2}{0.21} \approx \$0.02$
  - Using the delta method, the 90 percent confidence interval is $[-\$0.24, \$0.28]$.

Comparation of Two Experiments

- The effects near market prices ($p = 0$ in the TESS experiment and with the Standard Coupon in the in-store experiment) : **statistically different (p-value = 0.015)**
- At a small discount ($p = -1$ in TESS and with the \$0.63 average discount of the Rebate Coupon) : **statistically indistinguishable (p-value = 0.44)**
- While we only have two experiments, this pair is relatively useful because they differ markedly on the three key dimensions:
  - **Consumer populations:** National Local.
  - **Choice environments:** Simple & Controlled Complex & Additional Information displayed.
  - **Treatments:** Recorded audio and graphs online A live person without graphs.

Conclusions and Contributions

- Conclusions
  - Moderate CFL subsidies may be optimal.
  - Imperfect information and inattention alone cannot justify a ban on incandescents.
- Contributions
  - Large shares of consumers still prefer incandescents even after being powerfully informed.
  - More careful thought is needed about why incandescent lightbulb bans might increase welfare.

Discussions

- More psychological theory can be applied in the theoretical model. (such as detailed nudge theory from Richard Thaler).
- the average treatment effect on beliefs is not exactly estimated in the paper, further research can focus on the role beliefs play in the change of choices and pay attention to other methods to persuade consumers to make better decisions.

Push the Boundaries...

- **Green** Nudge (including pure nudge and moral nudge): an Environmental Policy Instrument. (Carlsson et al.,2021)

	How? *Type of Intervention*	
Why? *Reason for Intervention*	Conventional Economics	Behavioral Economics
Conventional Economic Problem (externalities, public goods, common-pool resources, asymmetric information)	A. Externality-correcting taxes, tradeable permits, command and control, information	C. Green nudge: pure and moral
Behavioral Economic Problem (internalities, bounded rationality)	B. Internality-correcting taxes, regulation, Information	D. Self-focused nudge: pure and moral

Figure 1 Overview of interventions by reason and type.

Thanks!