Online Appendix

Evaluating Behaviorally-Motivated Policy: Experimental Evidence from the Lightbulb Market

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A Details of TESS Experiment

Introductory Screen

In appreciation for your participation in this study, we are giving you a $10 shopping budget. During the study, we will ask you to make 30 decisions between pairs of light bulbs using that $10 shopping budget. There will be a first set of 15 decisions, then a break, and then a second set of 15 decisions.

After you finish with all 30 decisions, one of them will be randomly selected as your “official purchase.” In approximately four to six weeks, GfK will send you the light bulbs you chose in that official purchase. After your official purchase has been paid for from the $10 shopping budget we are giving you, any money left over will be provided to you in the form of **bonus points awarded to your account.** This means that after the study is completed, you will receive 1) the light bulbs you selected in the decision that is randomly selected to be your “official purchase” and 2) an amount between zero and 10000 bonus points, corresponding to whatever money is left in your shopping budget after the purchase.

Light bulbs are frequently shipped in the mail. There is not much risk of breakage, but if anything does happen, GfK will just ship you a replacement. Even if you don’t need light bulbs right now, remember that you can store them and use them in the future.

Since each of your decisions has a chance of being your official purchase, you should think about each decision carefully.

Next

Baseline Choices (Top of Screen)

We have given you a $10 shopping budget to purchase a package of light bulbs. Your first 15 purchase decisions will concern the two packages of light bulbs shown below.

Choice A Philips 60-Watt-Equivalent Compact Fluorescent Light Bulb, 1-Pack	Choice B Philips 60-Watt Incandescent Light Bulbs, 4-Pack
	

Click for detailed product information

Between the 15 decisions, the only thing that varies is the price. Each of these decisions has a chance of being the one choice (out of 30) that will become your official purchase, so you should think about each purchase carefully. Whatever money you do not spend on the light bulbs, you get to keep: any remaining money will be provided to you as cash-equivalent bonus points. Please think about each decision carefully.

Here is an example of how this might work. After you make all your decisions, suppose that Decision Number 6 from the set below were selected as your official purchase.

- If you had chosen Choice A, you would pay $2 from your $10 shopping budget. You would receive the Choice A light bulb package in the mail within 4-6 weeks, as well as the remaining $10-$2=$8 in your shopping budget (You would receive that $8 in the form of 8000 bonus points credited to your account.)
- If you had chosen Choice B, you would pay $4 from your $10 shopping budget. You would receive the Choice B light bulb package in the mail within 4-6 weeks, as well as the remaining $10-$4=$6 in your shopping budget. (You would receive that $6 in the form of 6000 bonus points credited to your account.)

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

Detailed Product Information Window

Detailed Product Information

Choice:	A	B
Manufacturer:	Philips	Philips
Type:	Compact Fluorescent (CFL)	Incandescent
Number of Bulbs:	1	4
Light Output:	60 Watt-equivalent	60 Watts
Light Output:	900 Lumens	840 Lumens
Color Temperature:	2700K	2700K
Energy Use:	13 Watts	60 Watts
Manufacturer's Home Country:	USA	USA

Back to Questionnaire

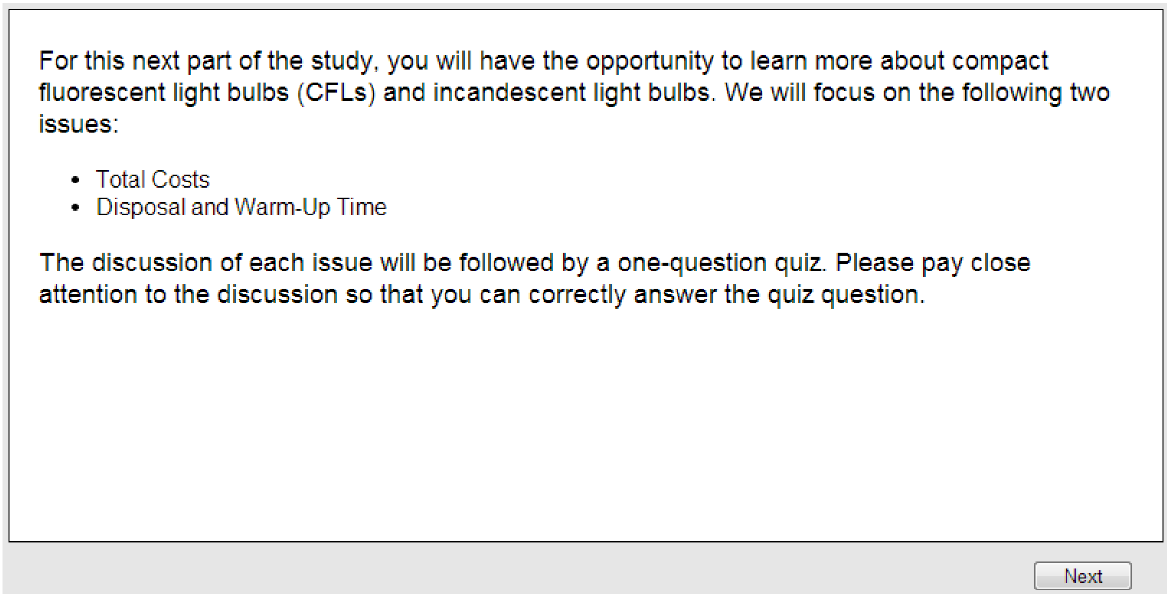
Baseline Choices (Bottom of Screen)

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
	Purchase **Choice A for free**	Purchase **Choice B for $10**
1)	○	○
	Purchase **Choice A for free**	Purchase **Choice B for $8**
2)	○	○
	Purchase **Choice A for free**	Purchase **Choice B for $6**
3)	○	○
	Purchase **Choice A for free**	Purchase **Choice B for $4**
4)	○	○
	Purchase **Choice A for $1**	Purchase **Choice B for $4**
5)	○	○
	Purchase **Choice A for $2**	Purchase **Choice B for $4**
6)	○	○
	Purchase **Choice A for $3**	Purchase **Choice B for $4**
7)	○	○
	Purchase **Choice A for $4**	Purchase **Choice B for $4**
8)	○	○

Note: This does not show all of the 15 Decision Numbers.

Balanced Treatment Introductory Screen


For this next part of the study, you will have the opportunity to learn more about compact fluorescent light bulbs (CFLs) and incandescent light bulbs. We will focus on the following two issues:

- Total Costs
- Disposal and Warm-Up Time

The discussion of each issue will be followed by a one-question quiz. Please pay close attention to the discussion so that you can correctly answer the quiz question.

Next

Treatment Information Screen

CFLs last longer than incandescents. At average usage:

- Incandescents burn out and have to be replaced every year.
- CFLs burn out and have to be replaced every eight years.

If one incandescent bulb costs $1 and one CFL costs $4, this means that the total purchase prices for eight years of light are:

- $8 for incandescents
- $4 for CFLs

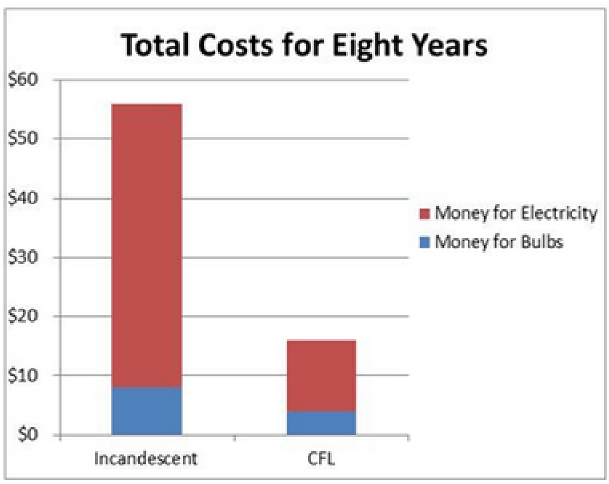
Also, CFLs use less electricity than incandescents. At national average usage and electricity prices:

- A standard (60-Watt) incandescent uses $6 in electricity each year.
- An equivalent CFL uses $1.50 in electricity each year.

Thus, for eight years of light, the total costs to purchase bulbs and electricity would be:

- $56 for incandescents: $8 for the bulbs plus $48 for electricity
- $16 for a CFL: $4 for the bulbs plus $12 for electricity

The graph below illustrates this:



Negative Information Screen

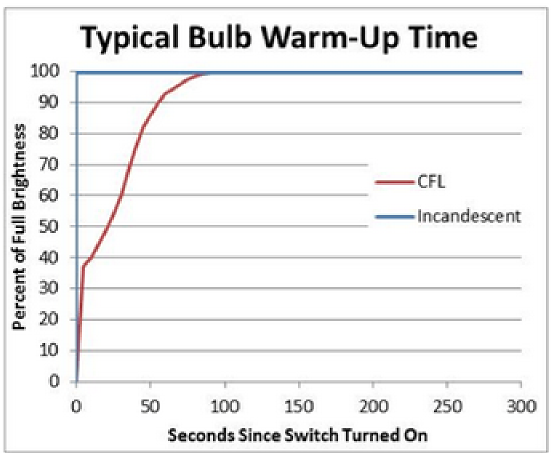
After they burn out, CFLs need proper disposal:

- Because CFLs contain mercury, it is recommended that they be properly recycled, and not simply disposed of in regular household trash. CFLs can be recycled through:
  - Local waste collection sites
  - Mail-back services that you can find online
  - Local retailers, including Ace Hardware, IKEA, Home Depot, and Lowe's, as well as other retailers.
- No special precautions need to be taken to dispose of an incandescent light bulb. Incandescents can be disposed of in regular household trash.

After the light switch is turned on, CFLs take longer to warm up than incandescents:

- An incandescent reaches full brightness immediately.
- A typical CFL can take 60 to 90 seconds to reach its full brightness.

The graph below illustrates this:

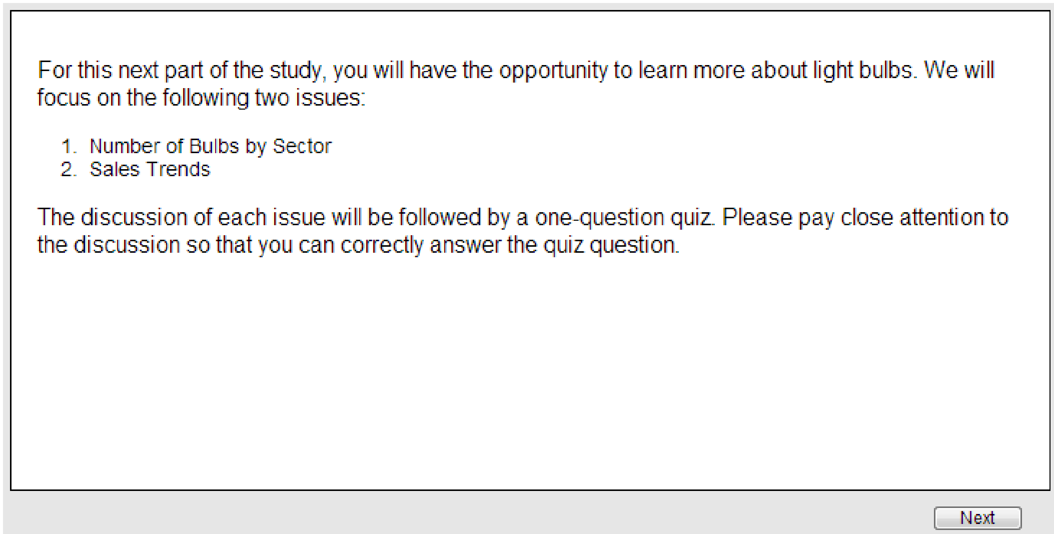


Question: About how much longer does it take a typical CFL to reach full brightness, as compared to an incandescent?

Type your answer below.

[ ] to [ ] seconds

Control Introductory Screen



For this next part of the study, you will have the opportunity to learn more about light bulbs. We will focus on the following two issues:

1. Number of Bulbs by Sector
2. Sales Trends

The discussion of each issue will be followed by a one-question quiz. Please pay close attention to the discussion so that you can correctly answer the quiz question.

Next

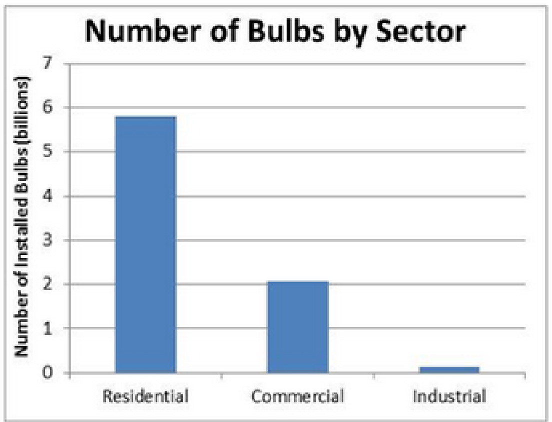
Number of Bulbs Screen

According to official estimates, there are slightly more than eight billion light bulbs installed in the United States.

The US economy can be divided into three major sectors: residential, commercial, and industrial. Each sector has a different number of light bulbs:

- There are about 5.8 billion light bulbs installed in residential buildings in the U.S.
- There are about 2.1 billion light bulbs installed in commercial buildings in the U.S.
- There are about 0.14 billion light bulbs installed in industrial buildings in the U.S.

The graph below illustrates this:



Question: About how many more light bulbs are installed in residential buildings compared to commercial buildings in the U.S.?

To answer this question, you can enter whole numbers and/or decimals.

Type your answer below.

[   ] billion

Sales Trends Screen

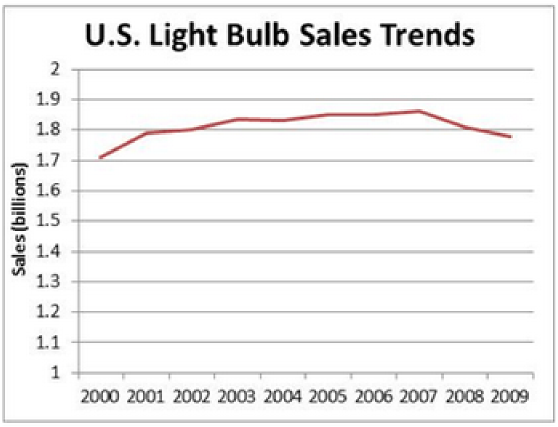
According to official sales data, sales of light bulbs in the United States have had the following trend:

- Sales increased in each year between 2000 and 2007.
- Sales decreased slightly in 2008 and 2009.

Total light bulb sales were different at the end of the decade compared to the beginning:

- Sales in 2000 were just over 1.7 billion bulbs.
- Sales in 2009 were just under 1.8 billion bulbs.

The graph below illustrates this:



<u>Question</u>: About how many light bulbs were sold in the United States in 2009?

To answer this question, you can enter whole numbers and/or decimals.

Type your answer below.

[ ] billion

Endline Choices (Top of Screen)

Remember, we have given you a $10 shopping budget to purchase a package of light bulbs. Your second 15 purchase decisions will concern the two packages of light bulbs shown below.

Choice A	Choice B
Philips 60-Watt-Equivalent Compact Fluorescent Light Bulb, 1-Pack	**Philips 60-Watt Incandescent Light Bulbs, 4-Pack**
	

Click for detailed product information

Between the 15 decisions, the only thing that varies is the price. Each of these decisions has a chance of being the one choice (out of 30) that will become your official purchase, so you should think about each purchase carefully. Whatever money you do not spend on the light bulbs, you get to keep: any remaining money will be provided to you as cash-equivalent bonus points. Please think about each decision carefully.

Here is an example of how this might work. After you make all your decisions, suppose that Decision Number 21 from the set below were selected as your official purchase.

- If you had chosen Choice A, you would pay $2 from your $10 shopping budget. You would receive the Choice A light bulb package in the mail within 4-6 weeks, as well as the remaining $10-$2=$8 in your shopping budget (You would receive that $8 in the form of 8000 bonus points credited to your account)
- If you had chosen Choice B, you would pay $4 from your $10 shopping budget. You would receive the Choice B light bulb package in the mail within 4-6 weeks, as well as the remaining $10-$4=$6 in your shopping budget (You would receive that $6 in the form of 6000 bonus points credited to your account.)

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

Endline Choices (Bottom of Screen)

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
16)	Purchase **Choice A for free**	Purchase **Choice B for $10**
17)	Purchase **Choice A for free**	Purchase **Choice B for $8**
18)	Purchase **Choice A for free**	Purchase **Choice B for $6**
19)	Purchase **Choice A for free**	Purchase **Choice B for $4**
20)	Purchase **Choice A for $1**	Purchase **Choice B for $4**
21)	Purchase **Choice A for $2**	Purchase **Choice B for $4**
22)	Purchase **Choice A for $3**	Purchase **Choice B for $4**
23)	Purchase **Choice A for $4**	Purchase **Choice B for $4**
	Purchase **Choice A for $4**	Purchase **Choice B for $3**

Note: This does not show all of the 15 Decision Numbers.

Post-Experiment Survey Questions

Question 1. *How important were the following factors in your purchase decision? [Rate from 1-10]*

1. *Energy use*
2. *Time required for the bulb to reach full brightness after it is turned on*
3. *Bulb lifetime*
4. *Mercury content and protocols for proper disposal*
5. *Purchase Price*

Question 2. *Do you think that the intent of the study was to ...*
Select all answers that apply

1. *Understand the effect of price changes on purchasing patterns*
2. *Measure whether people make consistent purchases in similar situations*
3. *Understand why people buy incandescents vs. CFLs*
4. *Test how well people are able to quantify energy costs*
5. *Test whether ability to quantify energy costs affects purchases of incandescents vs. CFLs*
6. *Test whether the number of bulbs in a package affects purchasing patterns*
7. *Test whether consumer education affects purchases of incandescents vs. CFLs*
8. *Understand what features of lightbulbs are most important to people*
9. *Predict the future popularity of incandescents vs. CFLs*
10. *None of the above*

Question 3. Part A: *The typical CFL lasts 8000 hours, or about eight years at typical usage rates. Do you think it costs more or less to buy electricity for that 8000 hours of light from compact fluorescent light bulbs (CFLs) compared to incandescent light bulbs?*

- More
- Less

Part B: *At national average electricity prices, how much [more/less] does it cost to buy electricity for that 8000 hours of light from compact fluorescent light bulbs (CFLs) compared to incandescent light bulbs? Just give your best guess.*

Question 4. *Some states and local areas have rebates, low-interest loans, or other incentives available for energy efficiency. These might include rebates for Energy Star appliances or energy efficient light bulbs, low-interest loans for energy-saving home improvements, government-funded weatherization, and other programs. Are any such programs available in your area?*

1. *Yes*
2. *I think so, but I'm not sure*
3. *I'm not sure at all*
4. *I think not, but I'm not sure*
5. *No*

Question 5. *This question is about hypothetical choices and does not affect your earnings in this study.*

Suppose that you could get the amount under "Option A" (i.e. \$100), or the amount under "Option B" a year later. Assume it's no more work for you to receive the money under Option A than under Option B, and that you would receive the money for sure, regardless of when you choose to receive it. Which would you prefer?

This question is about hypothetical choices and does not affect your earnings in this study. Suppose that you could get the amount under "Option A" (i.e. $100), or the amount under "Option B" a year later. Assume it's no more work for you to receive the money under Option A than under Option B, and that you would receive the money for sure, regardless of when you choose to receive it. Which would you prefer?

For each row, please choose whether you would prefer the payment under "Option A" or under "Option B".

	Option A	Option B
1)	$100 today	$50 in one year
2)	$100 today	$90 in one year
3)	$100 today	$100 in one year
4)	$100 today	$110 in one year
5)	$100 today	$130 in one year
6)	$100 today	$150 in one year
7)	$100 today	$170 in one year
8)	$100 today	$200 in one year
9)	$100 today	$250 in one year
10)	$100 in one year	$50 in two years
11)	$100 in one year	$90 in two years

Notes: This does not show all of the 18 choices. Participants were randomly assigned to receive either this table or another table that was identical except that the bottom half and top half were switched, so that the one year vs. two year tradeoffs were presented first.

Question 6. *Please indicate how much you agree or disagree with the following statements:*

Select one answer from each row in the grid

[Strongly Agree Agree Neutral Disagree Strongly Disagree]

1. *It's important to me to fit in with the group I'm with.*
2. *My behavior often depends on how I feel others wish me to behave.*
3. *My powers of intuition are quite good when it comes to understanding others' emotions and motives.*
4. *My behavior is usually an expression of my true inner feelings, attitudes, and beliefs.*
5. *Once I know what the situation calls for, it's easy for me to regulate my actions accordingly.*
6. *I would NOT change my opinions (or the way I do things) in order to please someone else or win their favor.*

B Additional TESS Results

B.A Descriptive Statistics and Baseline Willingness-to-Pay

Column 1 of Table A.1 presents descriptive statistics. All statistics for baseline relative WTP necessarily exclude the Endline-Only group. Liberal is self-reported political ideology, originally on a seven-point scale, normalized to mean zero and standard deviation one, with larger numbers indicating more liberal. Party is self-reported political affiliation, similarly normalized from an original seven-point scale, with larger numbers indicating more strongly Democratic. Environmentalist measures the consumer's answer to the question, "Would you describe yourself as an environmentalist?" Conserve Energy is an indicator for whether the consumer reports having taken steps to conserve energy in the past twelve months. Homeowner is a binary indicator variable for whether the consumer owns his or her home instead of rents. Except for baseline WTP, these variables were recorded when the consumer first entered the TESS panel, not as part of our experiment.

Column 2 presents the difference in means between all Treatment groups vs. Control. Column 3 presents the difference in means between the Positive and Balanced Treatment groups. All 20 t-tests fail to reject equality, as do the joint F-tests of all characteristics.

Table A.2 shows the association between baseline WTP and the individual characteristics in Table A.1. Column 1 shows that men, Democrats, and those who report having taken steps to conserve energy have higher demand for CFLs. Columns 2-5 separately test individual variables of environmentalism and political ideology which are correlated, providing additional evidence that liberals tend to have higher WTP. These correlations conform to our priors and build further confidence that the WTP measurements are meaningful.

The table also provides suggestive evidence on two distortions other than imperfect information and inattention which might justify subsidies and standards. The first is that renters might have lower CFL demand because they might leave the CFLs in the house's light sockets when they move and be unable to capitalize on their investment. Lacking random or quasi-random assignment in renter vs. homeowner status, Davis (2012) and Gillingham, Harding, and Rapson (2012) correlate durable good ownership with homeowner status conditional on observables. Columns 1 and 6 replicate their approach in the TESS data, showing that homeowners do not have higher WTP for CFLs. However, additional (unreported) regressions with market share at market prices as the dependent variable show that we cannot reject the Davis (2012) result that homeowners are five percent more likely to prefer CFLs.

The second potential distortion considered in Table A.2 is present bias. In the post-experiment survey, we estimate the β and δ of a quasi-hyperbolic model through a menu of hypothetical intertemporal choices at two different time horizons: \$100 now vs. \$$m^1$ in one year, and \$100 in one year vs. \$$m^2$ in two years. Denoting $\bar{m}_i^1$ and $\bar{m}_i^2$ as the midpoint between the values at which participant i switches from preferring money sooner to later, the long run discount factor is $\delta_i = 100/\bar{m}_i^2$, and the present bias parameter is $\beta_i = \bar{m}_i^2/\bar{m}_i^1$. We dropped non-monotonic responses and top-coded and bottom-coded $\bar{m}_i^1$ and $\bar{m}_i^2$ at \$300 and \$40, respectively. The median δ is 5/7, meaning that the median consumer prefers \$100 in one year to \$130 in two years but prefers \$150 in two years to \$100 in one year. A slight majority of consumers (52 percent) have $\beta = 1$, meaning that they are not present or future biased by this measure, and the median β is also 1.

If there is a distribution of β and δ, consumers with higher β and δ should be more likely to purchase CFLs. Column 1 shows that there is a conditional correlation between δ and baseline WTP, suggesting that people who are more patient may be more likely to purchase CFLs. However, there is no statistically significant correlation between β and WTP. Column 7 repeats the estimates without any conditioning variables, and the coefficients are comparable. The results in column 1 rule out with 90 percent confidence that a one standard deviation increase in β increases WTP for the CFL by more than \$0.47.[33]

B.B Estimating the Equivalent Price Metric in the TESS Experiment

The TESS experiment allows us to directly estimate the conditional average treatment effect on WTP for consumers marginal between points on the multiple price list. Figure 4 shows the 11 intervals over which we calculate CATEs, which are bounded by $-\infty, -3, -2, -1, 0, 1, 2, 3, 4, 6, 8, \infty$. In this section, we calculate EPMs over the same intervals and compare them to the CATEs. We exclude the highest and lowest intervals, because it is not possible to calculate a demand slope on an interval bounded by an infinite price.

To estimate $EPM[p_l, p_h]$, we reshape the TESS data so that there are two purchase observations per consumer, one at p_l and one at p_h. Denoting S_p as an indicator for whether this observation is at the lower price, we then estimate the following equation in a linear probability model:

$$1(\text{Purchase CFL})_{ip} = \tau T_i + \eta S_p + \alpha T_i S_p + \varepsilon_{ip} \tag{8}$$

Because there are multiple observations per consumer, we cluster standard errors by consumer.

Coefficients from this regression can be inserted into Equation (5) to approximate $EPM[p_l, p_h]$:

$$EPM[p_l, p_h] \approx \frac{(\Delta Q(p_l) + \Delta Q(p_h)) \cdot \frac{1}{2}}{(D_N(p_l) - D_N(p_h))\,/\Delta p} = \frac{\hat{\tau} + \hat{\alpha}/2}{(\hat{\eta} + \hat{\alpha})/\Delta p} \tag{9}$$

Standard errors are calculated using the Delta method.

Table A.3 presents results for each of the nine relative price intervals. Column 1 gives the numerator of Equation (9), column 2 gives the denominator, and column 3 gives the ratio of columns 1 and 2. Column 4 presents the CATE estimates, which are from Figure 4. Column 5 presents the p-value of the difference between the EPM and CATE on WTP, while column 6 presents the absolute value of the difference divided by the CATE. In four of the nine price intervals, the EPM and CATE differ with greater than 90 percent confidence, and on average, the two quantities differ by 49 percent.

B.C Self-Monitoring Scale

If demand effects are present, they should differentially affect people who are more able to detect the intent of the study and are more willing to change their choices given the experimenter's intent. One existing measure of these issues is the Self-Monitoring Scale, a battery of personality questions developed by Snyder (1974). Snyder writes that the scale is designed to identify individuals who "tend to express what they think and feel, rather than mold and tailor their self-presentations and social behavior to fit the situation."

From the set of standard Self-Monitoring Scale statements, we took the most relevant six:

- It's important to me to fit in with the group I'm with.

[33] This may not be surprising. Present bias over *cash flows* might cause consumers to buy an incandescent to reduce current expenditures, but as Andreoni and Sprenger (2012) and many others have pointed out, agents in most models would be present biased over *consumption*, and most American consumers have enough liquidity that paying the incremental few dollars for a CFL does not immediately affect consumption. Present bias could induce people to procrastinate in buying and installing CFLs, but this would play no role in the TESS experiment because we forced consumers to make an active choice.

- My behavior often depends on how I feel others wish me to behave.
- My powers of intuition are quite good when it comes to understanding others' emotions and motives.
- My behavior is usually an expression of my true inner feelings, attitudes, and beliefs.
- Once I know what the situation calls for, it's easy for me to regulate my actions accordingly.
- I would NOT change my opinions (or the way I do things) in order to please someone else or win their favor.

At the very end of the post-experiment survey, we asked consumers to respond to each of these six statements on a five-point Likert scale from "Agree" to "Disagree." We normalize responses to each question to mean zero, standard deviation one, and interact each with the treatment indicator while also controlling for lower-order interactions. Table A.5 presents results. While the six Self-Monitoring Scale variables are correlated with each other, none is correlated with endline CFL demand or with the treatment effect, nor is a composite of the six.

B.D Effects on Purchase Priorities

The post-experiment survey also asks consumers to rate on a scale of 1-10 the importance of price, energy use, bulb lifetime, warm-up time, and mercury and disposal in their purchase decisions. Table A.6 presents how the treatments affected these ratings. Both Positive and Balanced treatments decreased the stated importance of purchase prices, consistent with consumers re-orienting away from purchase price as a measure of total cost. Point estimates suggest that both the Positive and Balanced treatments increased the importance of energy use and that the Positive treatment also increased the importance of bulb lifetimes. These are the only estimates in the entire analysis whose significance level is affected by the weighting: they are not significant in Table A.6, but (unreported) regressions show that they are statistically significant when weighting all observations equally. The Positive Treatment group and Control group do not differ on the importance of warm-up time or mercury and disposal, which is to be expected because neither group received information on these two issues. Interestingly, the Balanced treatment decreased the importance of warm-up time. One potential explanation is that consumers had previously believed that CFL warm-up times were longer, and the treatment reduced the importance of this difference between CFLs and incandescents.

Appendix B Tables

Table A.1: **Descriptive Statistics and Balance for the TESS Experiment**

	(1)	(2)	(3)
Individual Characteristics	Population Mean	Treatment - Control Difference	Positive - Balanced Treatment Difference
Baseline Relative Willingness-to-Pay	2.9	0.20	-0.25
for CFL ($)	(7.1)	(0.52)	(0.70)
Household Income ($000s)	70.9	-2.86	-3.79
	(51.8)	(3.92)	(3.86)
Education (Years)	13.8	-0.04	0.18
	(2.5)	(0.18)	(0.21)
Age	46.7	0.26	0.22
	(16.9)	(1.26)	(1.45)
Male	0.48	-0.007	-0.009
	(0.50)	(0.035)	(0.040)
Liberal	0.00	0.056	-0.005
	(1.00)	(0.076)	(0.084)
Party	0.00	0.080	0.078
	(1.00)	(0.072)	(0.082)
Environmentalist	0.30	-0.024	0.019
	(0.32)	(0.023)	(0.026)
Conserve Energy	0.55	0.008	0.032
	(0.50)	(0.036)	(0.041)
Homeowner	0.70	0.022	-0.012
	(0.46)	(0.035)	(0.038)
F-Test p-Value		0.848	0.983

Notes: Column 1 presents means of individual characteristics in the TESS experiment population, with standard deviations in parenthesis. Column 2 presents differences in means between the Treatment and Control groups. Column 3 presents differences in means between Positive and Balanced treatment groups. Comparisons of baseline WTP and F-tests for all covariates necessarily exclude the Endline-Only group. Columns 2 and 3 have robust standard errors in parenthesis. Observations are weighted for national representativeness.

Table A.2: **Association Between Individual Characteristics and Baseline CFL Demand**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Income (000s)	0.005						
	(0.006)						
Education (Years)	0.010						
	(0.148)						
Age	0.003						
	(0.018)						
Male	0.931						
	(0.533)*						
Liberal	0.091	0.374					
	(0.389)	(0.285)					
Party	0.573		0.562				
	(0.344)*		(0.266)**				
Environmentalist	0.682			1.429			
	(0.791)			(0.804)*			
Conserve Energy	0.970				0.863		
	(0.525)*				(0.545)		
Homeowner	0.047					0.116	
	(0.716)					(0.616)	
Present Bias β	0.281						0.144
	(0.298)						(0.284)
Discount Factor δ	1.215						0.962
	(0.620)*						(0.605)
R2	0.03	0.00	0.01	0.00	0.00	0.00	0.01
N	1,163	1,226	1,229	1,221	1,219	1,229	1,178

Notes: The left-hand-side variable is baseline relative WTP for the CFL. *, **, ***: Statistically significant with 90, 95, and 99 percent confidence, respectively. Observations are weighted for national representativeness.

Table A.3: **Equivalent Price Metric vs. Conditional Average Treatment Effects on WTP**

	(1)	(2)	(3)	(4)	(5)	(6)
Range of Relative WTP ($/package)	Treatment Effect on Market Share	Demand Slope (Market Share/$)	Equivalent Price Metric ($/package)	Conditional Average Treatment Effect ($/package)	p-value of Difference	Absolute Value of Difference (Percent of CATE)
6 to 8	0.17	0.02	7.03 (1.79)	5.35 (1.36)	0.46	31
4 to 6	0.19	0.02	7.96 (1.9)	4.05 (1.03)	0.07	96
3 to 4	0.22	0.11	1.97 (0.36)	4.11 (1.06)	0.06	52
2 to 3	0.24	0.08	3.13 (0.64)	5.14 (1.12)	0.12	39
1 to 2	0.21	0.10	2.02 (0.41)	3.82 (0.91)	0.07	47
0 to 1	0.14	0.05	2.64 (0.81)	2.39 (0.91)	0.83	11
-1 to 0	0.10	0.10	0.94 (0.33)	2.11 (0.51)	0.05	56
-2 to -1	0.05	0.03	1.46 (0.82)	2.16 (1.4)	0.66	33
-3 to -2	0.01	0.01	0.75 (1.67)	3.41 (1.77)	0.28	78

Notes: This table calculates the equivalent price metric for comparison to the conditional average treatment effect on WTP on every bounded interval in the TESS multiple price list. Standard errors are in parentheses. Standard errors in column (3) are calculated by applying the Delta method to Equation (9) using the covariance matrix from estimates of Equation (8). See Appendix B.B for details.

Table A.4: **Perceived Intent of TESS Study**

	(1)	(2)	(3)
Do you think that the intent of the study was to . . .	Control	Balanced Treatment	Positive Treatment
Understand the effect of price changes on purchasing patterns	0.44	0.34	0.37
Measure whether people make consistent purchases in similar situations	0.31	0.25	0.26
Understand why people buy incandescents vs. CFLs	0.31	0.48	0.47
Test how well people are able to quantify energy costs	0.27	0.38	0.46
Test whether ability to quantify energy costs affects purchases of incandescents vs. CFLs	0.33	0.50	0.54
Test whether the number of bulbs in a package affects purchasing patterns	0.37	0.22	0.26
Test whether consumer education affects purchases of incandescents vs. CFLs	0.41	0.60	0.64
Understand what features of lightbulbs are most important to people	0.30	0.41	0.34
Predict the future popularity of incandescents vs. CFLs	0.30	0.34	0.34
None of the above	0.05	0.08	0.05
Number of Respondents	461	545	519

Notes: This table presents the share of consumers in each group who responded that the intent of the study was as listed in the leftmost column. Observations are weighted for national representativeness.

Table A.5: **Association of Treatment Effects with Self-Monitoring Scale**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Important to fit in	0.209						
	(0.396)						
Behave as others wish		0.413					
		(0.391)					
Good intuition for others' motives			0.312				
			(0.306)				
(-1)*Behavior expresses true feelings				-0.544			
				(0.341)			
Regulate my actions					-0.268		
					(0.322)		
(-1)*NOT change opinions to please someone						-0.212	
						(0.378)	
Self-Monitoring Mean							-0.009
							(0.008)
R2	0.57	0.58	0.57	0.57	0.57	0.57	0.58
N	1,185	1,184	1,184	1,184	1,184	1,184	1,188

Notes: This table presents estimates of Equation (6) with the addition of Self-Monitoring Scale variables and the interaction of these variables with the Treatment indicator. The coefficients presented are these interaction terms. The outcome variable is endline willingness-to-pay for the CFL. Robust standard errors in parenthesis. *, **, ***: Statistically significant with 90, 95, and 99 percent confidence, respectively. Observations are weighted for national representativeness.

Table A.6: **Effects on Important Factors in Purchase Decision**

	(1)	(2)	(3)	(4)	(5)
	Price	Energy Use	Bulb Lifetime	Warm-Up Time	Mercury and Disposal
1(Balanced Treatment)	-0.86	0.15	0.02	-0.94	-0.29
	(0.21)***	(0.21)	(0.20)	(0.24)***	(0.25)
1(Positive Treatment)	-0.55	0.20	0.25	0.04	-0.09
	(0.22)**	(0.21)	(0.19)	(0.23)	(0.24)
Constant	7.75	7.43	7.76	5.41	6.03
	(0.13)***	(0.15)***	(0.13)***	(0.17)***	(0.18)***
R2	0.02	0.00	0.00	0.02	0.00
N	1,533	1,478	1,512	1,506	1,518

Notes: This table reports treatment effects on self-reported importance of different factors in purchase decisions. Robust standard errors in parenthesis. *, **, ***: Statistically significant with 90, 95, and 99 percent confidence, respectively. Observations are weighted for national representativeness.

Table A.7: **Additional Estimates of TESS Average Treatment Effects**

	(1)	(2)	(3)	(4)
1(Treatment)	2.39	3.07	1.98	2.83
	(0.38)***	(0.50)***	(0.30)***	(0.48)***
1(Treatment & Fail Info Quiz)	-1.06			
	(1.24)			
1(Treatment & Incorrect Survey Beliefs)		-1.17		
		(0.56)**		
R2	0.58	0.58	0.58	0.57
N	1,188	1,188	1,188	1,188
Assumed Censored Mean WTP	15	15	12	20

Notes: This table presents alternative estimates of Equation (6). The outcome variable is endline willingness-to-pay for the CFL. 1(Treatment) pools all information sub-treatments. Robust standard errors in parenthesis. *, **, ***: Statistically significant with 90, 95, and 99 percent confidence, respectively. Observations are weighted for national representativeness.

C iPad Total Cost Comparison Screen

Notes: This is the information screen presented to Treatment group consumers in the in-store experiment. Numbers in this screen shot represent a consumer buying one CFL at typical purchase prices and national average electricity prices.

D Appendix to Theoretical Framework

D.A Proof of Proposition 1

Computing $W'(s)$:

First note that for $p = c - s$,

$$\begin{aligned} W(s) &= Z(s) + v_I - p_I + \int 1_{v-b \geq c-s}(v-p)dF(v)dG(b|v) \quad (10) \\ &= Z + v_I - p_I + \int 1_{v-b \geq c-s}(v-c)dF(v)dG(b|v) \quad (11) \\ &= Z + v_I - p_I + \int 1_{x \geq c-s}E(v-c|\hat{v}=x)dH_p(x) \\ &= Z + v_I - p_I - \int 1_{x \geq c-s}E(v-c|\hat{v}=x)D'_B(x) \end{aligned}$$

where as before, H is the distribution of perceived valuations $\hat{v} = v - b$, and $D_B(p) = 1 - H(p)$ is the market demand. The equivalence between (10) and (11) follows from noting that $Z(s) = Z - \int 1_{v-b\geq c-s} s dF(v)dG(b|v)$ and thus that $\int 1_{v-b\geq c-s}(v-c)dF(v)dG(b|v) = \int 1_{v-b\geq c-s}(v-p)dF(v)dG(b|v) - \int 1_{v-b\geq c-s} s dF(v)dG(b|v)$. The expectation $E(v|\hat{v})$ is computed with respect to the induced joint distribution over $(v, \hat{v})$.[34] From this it follows that for $p = c - s$,

$$\begin{aligned} W'(s) &= -E(v-c|v-b=p)D'_B(p) \\ &= -E(p+b-c|v-b=p)D'_B(p) \\ &= E(s-b|v-b=p)D'_B(p) \\ &= (s-B(p))D'_B(p) \end{aligned}$$

Intuitively, the average true value of consumers who change their choices from I to E as a consequence of increasing the subsidy by some very small amount ds is

$$E_G(v|v-b=p) = E_G(v-b|v-b=p) + E_G(b|v-b=p) = p + B(p).$$

The social cost of transferring an additional unit of product E to a consumer is c. Thus the social efficiency gain from inducing all marginal consumers to purchase E instead of I is given by $(p + B(p)) - c = B(p) - s$. The total increase in demand is $-D'_B(p)ds$ by definition, and thus the total change in welfare is $W(s+ds) - W(s) = (s - B(p))D'_B(p)ds$, from which it follows that $W'(s) = (s - B(p))D'_B(p)$.

Computing $W(s + \Delta s) - W(s)$:

To compute $W(s + \Delta s) - W(s)$, notice that at $p = c - s$,

[34] So if, with some abuse of notation, $F(v|\hat{v})$ is the conditional distribution of true values v given perceived values $\hat{v}$, then $E(v|\hat{v}=x) = \int v dF(v|x)dx)$

$$\begin{aligned}
W(s+\Delta s)-W(s) &= \int_{x=s}^{x=s+\Delta s} W'(x)dx \\
&= \int_{x=s}^{x=s+\Delta s} xD_B'(c-x)dx - \int_{x=s}^{x=s+\Delta s} B(p)D_B'(c-x)dx \\
&= \int_{x=s}^{x=s+\Delta s} xD_B'(c-x)dx + (D_B(p-\Delta s)-D_B(p))\int_{x=p-\Delta s}^{x=p} \frac{B(p)}{D_B(p-\Delta s)-D_B(p)}dH(x) \\
&= \int_{x=s}^{x=s+\Delta s} xD_B'(c-x)dx + (D_B(p-\Delta s)-D_B(p))E_H\left[B(x)|p-\Delta s\le x\le p\right]
\end{aligned}$$

where as before, H is the CDF of perceived valuations $\hat{v}$.[35]

Suppose now that D_B is locally linear, so that $D_B''(p)\approx 0$. Now as in Harberger (1964), the first term becomes

$$\int_{s}^{s+\Delta s} xD_B'(c-x)dx \approx (\Delta s)sD_B'(p)+\frac{(\Delta s)^2}{2}D_B'(p).$$

The second term becomes

$$(D_B(p-\Delta s)-D_B(p))E_H\left[B(x)|p-\Delta s\le x\le p\right]\approx -\Delta sD_B'E_H\left[B(x)|p-\Delta s\le x\le p\right].$$

Combining the expressions for the first and second terms yields equation (2).

An additional approximation:

Note that in our TESS experiment, we compute $E_H[B(x)|p-\Delta s\le x\le p]$ directly. However, when that is not possible, an additional approximation that may be useful is that if in addition to D being locally linear B is also locally linear on $[p-\Delta s,p]$ (i.e., $B''(x)\approx 0$ on the interval), then

$$\begin{aligned}
\int_{x=s}^{x=s+\Delta s} B(p)D_B'(c-x)dx &\approx D_B'(x-s)\int_{x=s}^{x=s+\Delta s}(B(c-s)-B'(c-s)(x-s))dx \\
&= \Delta sD_B'(p)B(p)-\frac{(s+\Delta s)^2-s^2}{2}D_B'(p)B'(p)-s\Delta sD_B'(p) \\
&= \Delta sD_B'(p)B(p)-\frac{\Delta s^2}{2}D_B'(p)B'(p)
\end{aligned}$$

This yields $W(s+\Delta s)-W(s)=\Delta s(s-B(p))D_B'(p)+\frac{\Delta s^2}{2}(1+B'(p))D_B'(p)$. This second approximation is a second order approximation of $W(s+\Delta s)-W(s)$. The initial approximation we derive is slightly more precise than second order, since we do not rely on $B''(p)\approx 0$.

D.B Comparing the equivalent price metric to the average marginal bias

D.B.1 A two-type example

Suppose that conditional on a perceived value of $\hat{v}$, there are only two possible values of bias: a *high* value $b_H(\hat{v})$ and a *low* value $b_L(\hat{v})\le b_H(\hat{v})$. That is, if a consumer's perceived valuation is $\hat{v}$ then his true valuation

[35] Which implies that $D(p)=1-H(p)$, a relationship we use in the computations above.

is either $\hat{v}+b_L(\hat{v})$ or $\hat{v}+b_H(\hat{v})$. Assume that b_L and b_H are differentiable and let $D_{B,L}$ and $D_{B,H}$ correspond to the demand curves of agents corresponding to the low and high values, respectively. Let $D_{N,L}$ and $D_{N,H}$ correspond to the demand curves that would be obtained if these consumers were debiased. That is, $D_{N,k}$ is the demand curve that would be obtained if all type k consumers were debiased. The relationship between D_N and D_B is now given simply by $D_{B,k}(p) = D_{N,k}(p + b_k(p))$ for $k = L, H$.

By definition,

$$B(p) = \frac{D'_{B,L}(p)b_L(p) + D'_{B,H}(p)b_H(p)}{D'_B(p)},$$

while to a first order approximation,

$$\begin{aligned} EPM(p) &= \frac{D_B(p) - D_N(p)}{D'_N(p)} = \frac{D_{B,L}(p) - D_{N,L}(p) + D_{B,H}(p) - D_{N,H}(p)}{D'_N(p)} \\ &= \frac{D_{N,L}(p + b_L(p)) - D_{N,L}(p) + D_{N,H}(p + b_H(p)) - D_{N,H}(p)}{D'_N(p)} \\ &\approx \frac{D'_{N,L}(p)b_L(p) + D'_{N,H}(p)b_H(p)}{D'_N(p)}. \end{aligned}$$

It thus follows that when demand curves are linear, the EPM correctly approximates $B(p)$ if and only if

$$\frac{D'_{B,L}(p)}{D'_{N,L}(p)} = \frac{D'_{B,H}(p)}{D'_{N,H}(p)} \tag{12}$$

Note, however, that $D'_{B,k}(p) = (1 + b'_k(p))D'_{N,k}(p)$, and so it is not generally true that the condition in Equation (12) holds. The condition holds if $b'_L(p) = b'_H(p)$.[36] When consumers with higher bias are relatively more likely to be on the margin in their biased state–i.e., $D'_{B,H}/D'_{N,H} > D'_{B,L}/D'_{N,L}$ because $b'_H > b'_L$–the EPM will underestimate $B(p)$. Conversely, when consumers with higher bias are relatively less likely to be on the margin, the EPM will overestimate $B(p)$. This same principle is what underlies our example with normal distributions in Section II: consumers with high b are relatively less likely to be on the margin at high prices p, and relatively more likely to be on the margin at low prices p.

Notice also that having D'_B instead of D'_N in the denominator of the EPM does not broaden the set of cases in which the EPM is a first-order approximation to $B(p)$. In fact, having D'_B instead of D'_N in the denominator narrows the set of cases in which the EPM is a first-order approximation to $B(p)$. When $b_L(p) = b_H(p)$ for all p, so that bias is homogeneous, the EPM with D'_N in the denominator constitutes a first-order approximation to $B(p)$. However, moving $D'_B \neq D'_N$ in the denominator will introduce a bias in the approximation whenever $b'_L(p) = b'_H(p) \neq 0$.

D.B.2 Conditions for exact equivalence

With a slight abuse of notation, we now let $F(\cdot|b)$ denote the CDF of v conditional on a value of b and we let $G(\cdot)$ denote the unconditional CDF of b. To ease notation and exposition, we will restrict here to the case where $F(\cdot|b)$ and G continuously differentiable, with respective density functions $f(\cdot|b)$ and g. The argument for finite or mixture distributions would follow almost identically.

[36]This is a special condition generalizing the homogeneous bias assumption under which Mullainathan, Schwartzstein, and Congdon (2012) show that the EPM correctly approximates $B(p)$.

Proposition 2 *For all generic distributions G, $EPM(p) = B(p)$ if and only if $\frac{f(p+b|p)}{D'_B(p)} = \frac{F(p+b|b)-F(p|b)}{bD'_N(p+b)}$ for all b.*

The condition in the proof is slightly more general than the condition that $f(v|b)$ is linear on $v \in [p, p+b]$. And the linearity condition, in turn, is roughly equivalent to requiring that D_N is linear and that b is independent of v in a neighborhood of $v = p + b$.

Proof.

By definition,

$$B(p) = \frac{\int bf(p+b|b)g(b)db}{\int f(p+b|b)g(b)db}$$

and

$$\begin{aligned} EPM(p) &= \frac{\int [(1-F(p|b) - (1-F(p+b|b))]\, g(b)}{\int f(p|b)g(b)db} \\ &= \frac{\int (F(p+b|b) - F(p|b))\, g(b)}{\int f(p|b)g(b)db} \end{aligned}$$

Now $D'_B(p) = \int f(p+b|b)g(b)db$ and $D'_N(p) = \int f(p|b)g(b)db$ and thus comparing the equations for B and EPM shows that these two equations will hold for all generic density weights $g(b)$ if and only if the condition in the Proposition holds for all b. ■

D.B.3 Quantifying possible deviations between the equivalent price metric and the average marginal bias

Here we will restrict to a simpler scenario in which we can partition consumers into finitely many types θ such that a consumer with WTP $\hat{v}$ has a true value of $\hat{v} + \tau_\theta(\hat{v})$. Clearly, the divergence between $B(p)$ and $EPM(p)$ can only be higher in the slightly more general set up. We now show that even under fairly restrictive regularity conditions, the difference between $B(p)$ and $EPM(p)$ can be quite large.

Proposition 3 *Suppose that $\tau_\theta(p) \in [\underline{\tau}, \bar{\tau}]$. For $p_1 < p_2$, suppose $D_N(p_1)$, $D_N(p_2)$, $D_B(p_1)$, $D_B(p_2)$ are all measured, and that the following additional restrictions are known to apply:*

1. *For each pair θ_1, θ_2, $D_{N,\theta_1}(p)/D_{N,\theta_2}(p)$ is constant on $[p_1, p_2]$.*
2. *$D_{B,\theta}$ and $D_{N,\theta}$ are linear on $[p_1, p_2]$ for all θ.*

Then $((B(p_1) + B(p_2))/2 - (EPM(p_1) + EPM(p_2))/2$, the difference between the average B and the average EPM over the range $[p_1,p_2]$, can be as high as:

$$\frac{D'_N}{2D'_B} \min\left[\bar{\tau} - EPM(p_2), -D_B(p_2)/D'_N - EPM(p_2)\right] \cdot max\left[\frac{D'_B}{D'_N}, \frac{EPM(p_1) - \underline{\tau}}{p_2 - p_1}\right] \tag{13}$$

and as low as:

$$-\frac{D'_N}{2D'_B}(EPM(p_1) - \underline{\tau}) max\left[\frac{D'_B}{D'_N}, \frac{\bar{\tau} - EPM(p_1)}{p_2 - p_1}\right] \tag{14}$$

Proposition 3 shows that $B(p)$ and $EPM(p)$ can differ significantly even under the following restrictions: demand curves are linear, treatment effects are uncorrelated with the slopes of the unbiased demand curves $D_{N,\theta}$, and treatment effects are restricted to lie in a reasonably narrow range. A consequence of Proposition 3 is that even when information has no effect on demand, the conditional average treatment effect on WTP can still be substantial. Suppose, for example, that 40 percent of consumers purchase E at baseline prices, that a \$1 subsidy move demand by 10 percentage points, that information provision has no effect on demand at subsidized and unsubsidized prices. This roughly corresponds to the estimates in the in-store experiment. Finally, suppose that the treatment effect on any one consumer's WTP cannot be any greater than \$5 or smaller than -\$5. Proposition 3 then shows that despite there being absolutely no treatment effect on quantity purchased, and despite the very restrictive regularity conditions, the CATE on WTP for consumers who are marginal to the \$1 subsidy can still be as high as \$2 and as low as -\$2.50. This generalizes our normal distributions example in Section II to the case of biases with narrow support and more restrictive distributional assumptions.

It is important to note that Proposition 3 does not compute the maximum possible divergence between $B(p)$ and the EPM. Rather, it only provides a sense of how much the two can diverge. We have not yet been able to compute the maximum possible divergence between these two measures, though we conjecture that the quantities in Proposition 3 do, indeed, correspond to the maximum possible divergence.

D.B.4 Proof of Proposition 3

Consider two types, $\theta = 1, 2$ and let $\gamma = D'_{N,1}(p)/D'_{N,2}(p)$. Note that restriction 2 guarantees that $D'_{N,1}(p)/D'_{N,2}(p)$ is constant in p.

We consider how large or small we can make the quantity

$$\begin{aligned} B(p) &= \frac{1}{D'_B(p)}\left(\gamma\tau_1(p)D'_{B,1}(p) + (1-\gamma)\tau_2(p)D'_{B,2}(p)\right) && (15) \\ &= \frac{D'_N(p)}{D'_B(p)}\left(\gamma\tau'_1(p)\tau_1(p) + (1-\gamma)\tau'_2(p)\tau_2(p)\right) && (16) \end{aligned}$$

where equation (16) follows from (15) due to restrictions 1 and 2 in the proposition.

Part 1: Maximizing $B(p) - EPM(p)$

Now set $\tau_1(p_1) = \tau_2(p_1) = EPM(p_1)$ and let $\tau'_1 = m_1$ and $\tau'_2 = m_2$, with $m_1 > m_2$ By definition, we must have

$$\gamma\tau(p) + (1-\gamma)\tau_2(p) = EPM(p)$$

from which it follows that

$$\gamma m_1 + (1-\gamma)m_2 = \frac{D'_B - D'_N}{D'_N} \equiv \tilde{m}$$

and thus

$$\gamma = \frac{\tilde{m} - m_2}{m_1 - m_2}.$$

We now have

$$\begin{aligned}
B(p) - EPM(p) &= \left[\gamma m_1^2 + (1-\gamma)m_2^2 - \tilde{m}^2\right](p - p_1) \\
&= \left[\gamma(m_1^2 - m_2^2) + m_2^2 - \tilde{m}^2\right](p - p_1) \\
&= \left[(m_1 + m_2)(\tilde{m} - m_2) + m_2^2 - \tilde{m}^2\right](p - p_1) \\
&= \left[(m_1 + m_2)\tilde{m} - m_1 m_2 - \tilde{m}^2\right](p - p_1) \\
&= (m_1 - \tilde{m})(\tilde{m} - m_2)(p - p_1). \qquad (17)
\end{aligned}$$

The last equation above shows that to maximize $B(p) - EPM(p)$ optimal to have m_1 as high as possible and m_2 as low as possible.[37] So the final step is to determine these bounds for m_1 and m_2.

To this end, note that we must have $EPM(p_1) + m_1(p_2 - p_1) \leq \bar{\tau}$. This implies that $m_1 \leq \frac{\bar{\tau} - EPM(p_1)}{p_2 - p_1}$.

Additionally, since we are requiring linearity of demand curves in the region of interest, we must have $D_N(p_2 + \tau_1(p_2)) \geq 0$; or $D_N(p_2) + D'_N \tau_1(p_2) \geq 0$. From which it follows that $\tau_1(p_2) \leq -D_N(p_2)/D'_N$. This similarly implies that $m_1 \leq \frac{-D_N(p_2)/D'_N - EPM(p_1)}{p_2 - p_1}$

Similarly, $EPM(p_1) + m_2(p_2 - p_1) \geq \underline{\tau}$, and thus $m_2 \geq \frac{\underline{\tau} - EPM(p_1)}{p_2 - p_1}$. Additionally, demand must be downward sloping, which implies that $m_2 > -1$.

Altogether, we thus want to set

$$\begin{aligned}
m_1 &= \frac{min(\bar{\tau}, -D_N(p_2)/D'_N) - EPM(p_1)}{p_2 - p_1} \\
m_2 &= max(-1, \frac{\underline{\tau} - EPM(p_1)}{p_2 - p_1})
\end{aligned}$$

But now $EPM(p_2) = \tilde{m}(p_2 - p_1) + EPM(p_1)$, from which it follows that

$$m_1 - \tilde{m} = \frac{min(\bar{\tau}, -D_N(p_2)/D'_N) - EPM(p_2)}{p_2 - p_1}$$

The first part of the proposition now follows by combining (17) with the bounds we computed for m_1 and m_2.

Part 2: Minimizing $B(p) - EPM(p)$

This other part follows analogously. Set $\tau_1(p_2) = \tau_2(p) = EPM(p_2)$. Then as in (17) we analogously get that

$$B(p) - EPM(p) = -(m_1 - \tilde{m})(\tilde{m} - m_2)(p - p_1). \qquad (18)$$

Again, for $m_1 > m_2$ we similarly want m_1 as high as possible and m_2 as low as possible; that is, we want the low bias types to be the ones who are most elastic.

Analogously to the preceding computations, we must have $EPM(p_2) - m_2(p_2 - p_1) \leq \bar{\tau}$ from which it follows that $m_2 \geq -\frac{\bar{\tau} - EPM(p_2)}{p_2 - p_1}$. And as before, $m_2 > -1$ to generate downward-sloping demands.

Similarly, $EPM(p_2) - m_1(p_2 - p_1) \geq \underline{\tau}$ from which it follows that $m_1 \leq \frac{EPM(p_2) - \underline{\tau}}{p_2 - p_1}$.

[37] Just consider a perturbation where m_1 is increased by ϵ and m_2 is decreased by $\beta/(1-\beta)\epsilon$

D.C A more general framework and the comparing demand responses approach

To analyze other strategies for quantifying consumer bias, we now propose a more general framework that will allow us to compare product subsidies to energy taxes. The framework will formally encompass an extension of our energy efficiency model, as well as the salience models of Chetty, Looney, and Kroft (2009) and Goldin and Homonoff (2013). The framework is also applicable to other situations in which there may be opaque attributes, such as the work by Hossain and Morgan (2006) on shipping charges, the work by Abaluck and Gruber (2011) on out-of-pocket insurance costs, and the work by Lacetera, Pope, and Sydnor (2013) on left-digit bias.

As before, we will continue working with the somewhat simpler setup in which we can partition consumers into finitely many types θ, where each type is a correspondence between true and perceived valuations. True demand curves are given by $D_{N,\theta}(p)$, while biased demand curves are given by $D_{B,\theta}(p)= D_{N,\theta}(p+\tau_\theta(t_1,t_2))$, where $p = c+t_1+t_2$ is the total price after taxes t_1 and t_2. For energy durables applications, t_1 can correspond to product prices while t_2 can correspond to the tax on energy costs. For tax salience applications, t_1 can correspond to the tax included in prices while t_2 can correspond to the tax not included in prices; for this application, if consumers weight t_2 by $\sigma \leq 1$, then $\tau_\theta(t_1,t_2) = -(1-\sigma)t_2$.

In this more general framework, the welfare impact of increasing t_i depends on the marginal bias with respect to t_i:

$$B_i(t_1,t_2) = \sum \zeta^{t_i}_{D,\theta}(t_1,t_2)\tau_\theta(t_1,t_2)$$

where, $\zeta^{t_i}_{D,\theta} = \frac{D^{t_i}_{B,\theta}(t_1,t_2)}{\sum_\theta D^{t_i}_{B,\theta}(t_1,t_2)}$ is the portion of consumers who are type θ out of all those consumers who respond to a marginal increase in the tax t_i; and $D^{t_i}_{B,\theta}(t_1,t_2)$ denotes the derivative of $D_{B,\theta}$ with respect to t_i evaluated at (t_1,t_2). Following the derivations in Proposition 1, it easy to show that at $p = c + t_1 + t_2$,

$$\frac{d}{dt_i}W(t_1,t_2) = -(t_1 + t_2 + B_i(p))D^{t_i}_B(t_1,t_2)$$

where $D^{t_i}_B$ is the derivative of D_B with respect to t_i.

When consumers are debiased, changes in t_1 and t_2 should have identical impacts on demand, and thus we let $D'_N(p)$ denote the derivative of D_N with respect to either t_1 or t_2 at $p = c + t_1 + t_2$. Analogously to Section 2, we define

$$EPM(t_1,t_2) = \frac{D_B(t_1,t_2) - D_N(t_1,t_2)}{D'_N}.$$

D.C.1 The EPM and the average marginal bias in a more general setting

As before, the EPM and the average marginal bias will typically not be the same. Notice also that as long as $B_1 \neq B_2$, it will always be true that the EPM is an imperfect approximation to either B_1 or B_2 (and possibly both). And as we show below, $B_1 \neq B_2$ for very simple and natural examples of this framework.[38] We now show how the EPM can fail to provide the necessary sufficient statistic even for very simple models of bias, as long as bias is heterogeneous.

[38] This issue of $B_1 \neq B_2$ is also central to Allcott, Mullainathan and Taubinsky's (2014) derivation of the optimal combination of product and energy taxes. The crucial quantity for determining the optimal subsidy in that framework is $B_1 - B_2$.

First, consider the simple case in which type θ consumers underweight energy costs by θ, and consider their choice of the relatively less efficient appliance I. Suppose that $c = c_1 + c_2$, where c_1 is the relative cost of producing the energy using appliance and c_2 is the relative energy cost associated with utilization. Then $\tau_\theta(t_1,t_2) = -(1-\theta)(c_2 + t_2)$, where t_2 are the additional energy costs due to taxation. In this model, $D^{t_1}_{N,\theta}(t_1, t_2) = D^{t_1}_{B,\theta}(t_1, t_2)$ and therefore $EPM \approx B_1$. But the same time, $D^{t_2}_{B,\theta}(t_1, t_2) = \theta D^{t_2}_{N,\theta}(t_1, t_2)$, and thus $EPM \neq B_2$. To see this concretely, note that to a first order approximation,

$$EPM \approx \frac{\sum_\theta D'_{N,\theta}\tau_\theta}{\sum_\theta D'_{N,\theta}} \tag{19}$$

whereas

$$B_2 = \frac{\sum_\theta D^{t_2}_{B,\theta}\tau_\theta}{\sum_\theta D^{t_2}_{B,\theta}} = \frac{\sum_\theta \theta D'_N \tau_\theta}{\sum_\theta D'_{N,\theta}} \tag{20}$$

In fact, it is easy to see that as long as θ is heterogeneous, $|EPM| > |B_2|$ because the most biased types are also the least elastic to the energy tax.[39] Assuming homogenous bias and then using the EPM to calculate a sufficient statistic for the optimal energy tax would thus produce a number that is too high.

The implications of the EPM for the tax salience frameworks of Chetty, Looney, and Kroft (2009) and Goldin and Homonoff (2013) are identical. To obtain these frameworks, let t_2 be the sales tax not included in price, and let $\tau_\theta(t_1,t_2) = (1-\theta)t_2$. Then proceed as above for the energy cost salience framework. Again, the conclusion here will be that in the presence of heterogeneity, $|EPM| > |B_2|$. Thus assuming a representative agent framework and using the EPM as a sufficient statistic for B_2 would lead one to underestimate the excess burden of increasing t_2.

D.C.2 The comparing demand responses approach with homogeneous consumer bias

Another common approach for measuring bias is the "comparing demand responses" approach, as summarized by DellaVigna (2009), and used by Allcott and Wozny (2014), Busse, Knittel, and Zettelmeyer (2013), and Sallee, West, and Fan (2015) to study undervaluation of energy costs, and by Chetty, Looney, and Kroft (2009) to study tax salience. Variations of this approach have also been used by Hossain and Morgan (2006), Abaluck and Gruber (2011), and Lacetera, Pope, and Sydnor (2014).

The idea of this approach is as follows: Suppose consumers underweight future energy costs. Then they should also react less to changes in energy costs than to changes in the upfront prices of energy-using appliances. The approach then is to use the ratio $\frac{D^{t_2}_B(t_1,t_2)}{D^{t_1}_B(t_1,t_2)}$ as a measure of bias.

With a homogeneous consumer who underweights energy costs by θ, the comparing elasticity approach is simple. In this model, all consumers are homogeneous and have bias $\tau(t_1,t_2) = -(1-\theta)(c_2 + t_2)$. Thus$D^{t_1}_B(t_1, t_2) = \theta D^{t_2}_N(t_1, t_2)$, from which it follows that $\theta = \frac{D^{t_2}_B(t_1,t_2)}{D^{t_1}_B(t_1,t_2)}$.

Notice, however, that the success of this derivation depends on the fact that the bias $\tau_\theta = -(1-\theta)(c_2+t_2)$ is linear in t_2 and constant in t_1. More generally, $\frac{D^{t_2}_B(t_1,t_2)}{D^{t_1}_B(t_1,t_2)} = \frac{1+\frac{d}{dt_2}\tau}{1+\frac{d}{dt_1}\tau}$, a quantity that without a number of additional structural assumptions is not generically related to the representative consumer's *level of bias* τ. Depending on how τ changes with t_1 or t_2, the comparing demand responses approach will either over- or

[39] Alternative versions of the EPM that place $D^{t_1}_B$ or $D^{t_2}_B$ in the denominator do not do any better here either. The simply scale up the EPM by the ratio $\frac{D'_N}{D^{t_i}_B}$, which does not fix the fact that (19) and (20) are two very different weighted averages.

under-estimate the level of the bias. This is in contrast to the EPM, which always provides an accurate first order approximation when bias is homogenous.

In particular, the comparing demand responses approach does not generate a statistic that can be used to approximate the bias when $\frac{d}{dt_1}\tau$ is is non-zero and $\frac{d}{dt_2}\tau$ is not constant, both of which are conditions that are likely in practice. In the context of energy-using durables, $\frac{d}{dt_2}\tau$ is likely to be non-constant because attention is endogenous and thus θ is increasing in t_2. And similarly, a higher product tax might make a consumer more likely to consider the alternative seriously. The second reason is that bias is likely to depend on true valuations. Depending on the model of attention, the bias could be increasing or decreasing with the true valuation. Consumers who value the energy efficient product the most, for example, are the most likely to be "Green" consumers who are very attentive to energy costs. But because the true valuation of marginal consumers depends on the price p, this leads the bias to depend on the price p.

D.C.3 The comparing demand responses approach with heterogeneous consumer bias

So far, we've shown that when consumer bias is homogeneous, the success of the comparing demand responses approach depends critically on the elasticity of consumer bias with respect to t_1 and t_2. This is contrast to the EPM which (under the full debiasing assumption) always provides an accurate first-order approximation to consumer bias. How does the comparing demand responses approach compare to the EPM or $B(p)$ under heterogeneity?

Consider again the simple setting in which consumers underweight energy-related costs by θ, so that $\tau_\theta(t_1,t_2) = -(1-\theta)(c_2+t_2)$. Then the comparing demand responses approach gives

$$\begin{aligned}
\rho := \frac{D_B^{t_2}}{D_B^{t_1}} &= \frac{\sum_\theta D_{B,\theta}^{t_2}}{\sum_\theta D_{B,\theta}^{t_1}} \\
&= \frac{\sum_\theta \theta D_{B,\theta}^{t_1}}{\sum_\theta D_{B,\theta}^{t_1}} \\
&= \frac{\sum_\theta D_{N,\theta}^{t_2}\tau_\theta}{(c_2+t_2)\sum_\theta D_{N,\theta}^{t_2}} + 1 \\
&\approx \frac{EPM}{c_2+t_2} + 1
\end{aligned}$$

where the last line is a consequence of (19). Thus to a first order approximation, the comparing demand responses approach allows us to back out the same statistic as the one given to us by the EPM. The analysis in section D.B thus shows that just like the EPM, the comparing demand responses approach can be used to produce a consistent estimate of B_1, but not of B_2.

However, our TESS experiment suggests that the conditions under which the EPM produces an accurate estimate of B_1 do not hold, which implies that $\frac{d}{dt_1}\tau_\theta \neq 0$ in this framework. Under these kinds of more general conditions, the comparing demand responses approach cannot provide an accurate estimate of B_1 either. Indeed, more generally we have that

$$\rho := \frac{D_B^{t_2}(p)}{D_B^{t_1}(p)} = \frac{\sum_\theta D_{B,\theta}^{t_2}(p)}{\sum_\theta D_{B,\theta}^{t_1}(p)}$$
$$= \frac{\sum_\theta (1 + \frac{d}{dt_2}\tau_\theta) D_{N,\theta}^{t_2}(p + \tau_\theta)}{\sum_\theta (1 + \frac{d}{dt_1}\tau_\theta) D_{N,\theta}^{t_1}(p + \tau_\theta)}$$

Under these more general conditions, ρ is the ratio of two weighted averages of "bias response" functions $1 + \frac{d}{dt_i}\tau_\theta$. Without various special assumptions, this difficult to interpret quantity is not closely related to the EPM, B_1, or B_2. Again, $\frac{d}{dt_i}\tau_\theta$ is likely to be a complicated function because of endogenous attention or because bias depends on true valuations.

References

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