The Efficiency Consequences of Heterogeneous Behavioral Responses to Energy Fiscal Policies

Presentation

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Efficiency Consequences of Heterogeneous Behavioral Responses to Energy Fiscal Policies

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Motivation: Inside the Ivory Tower

Recent literature in behavioral public finance

1. Documented various phenomena that impact behavioral responses to taxes and subsidies
   - Salience (Chetty et al. 2009)
   - Hassle costs (Currie, 2004)
   - Information frictions (Handel and Kolstad, 2015)
2. Investigate the optimal design of policies in presence of behavioral biases
   - Allcott et al. (2014) Pigouvian policies with misperceptions
   - Farhi and Gabaix (2015), revisit most classic results in optimal tax theory with behavioral agents (sparsity-based model of bounded rationality, Gabaix 2014)

Motivation: Outside the Ivory Tower

Overlapping fiscal instruments are commonly used to achieve a single policy goal in the energy context.

- e.g., Carbon tax with consumer rebates and R&D subsidies

Why Overlapping Fiscal Instruments?

1. Trade-off between economic efficiency and distributional concerns
2. Interacting market failures
3. Pre-existing tax distortions
4. Heterogeneous externalities
5. **Heterogeneous micro-frictions: combining instruments can be more efficient**

What We Do

1. **Theory**
   - Unifying framework to study behavioral responses to fiscal policies using the concept of **micro-frictions**.
   - Investigate the design of optimal Pigouvian policies.
2. **Empirics**
   - Estimate heterogeneous behavioral responses to energy fiscal instruments and quantify micro-frictions.
   - Empirical settings: U.S. appliance market.
3. **Policy Analysis**
   - Use the estimated model to investigate optimal energy fiscal policies with heterogeneous micro-frictions using applied behavioral welfare economics.

Definition: Micro-Frictions

Definition 1:
Any phenomena impacting the response to a fiscal instrument such that a one dollar variation induced by the fiscal instrument does not have the same effect than a dollar variation in relative prices.

Definition 2 (more general):
Any phenomena impacting the response to a price change such that the marginal effect of the price change is not equal to the marginal utility of income.

Examples: Micro-Frictions

Behavioral Biases (*Internalities*)

- misperception
- present bias
- salience
- inattention (rational or not)

Transaction Costs

- hassle costs to claim a rebate
- time and effort to fil a tax return
- cost of hiring a tax specialist

Overview of Main Results: Theory

1. **Optimal Pigouvian Taxation with Micro-Frictions**
    1. Although behavioral biases and transaction costs can be observationally equivalent, they lead to different policy prescription:
        - Transaction cost $\rightarrow$ Pigou holds.
    2. Modest behavioral biases can lead to large adjustment of a Pigouvian tax.
    3. Heterogeneity across consumers and instruments matters.
    4. Unobserved heterogeneity in biases complicates the design of the optimal Pigouvian tax.

Overview of Main Results: Empirics

In the U.S. appliance market:

1. Substantial heterogeneity across income groups and policy instruments.
2. Micro-frictions are important for all types of energy fiscal policies we investigate.
3. Larger behavioral biases, but smaller transaction costs for lower income households relative to higher income households.

Overview of Main Results: Policy Analysis

1. Rarely optimal to combine tax and subsidies in practice.
2. Large adjustment to the Pigouvian tax could be justified by behavioral biases.
3. Energy labels interact in perverse ways with energy fiscal policies.
4. Energy fiscal instruments should target the investment margin.

Road Map for Today

1. Optimal Pigouvian Instruments with Micro-Frictions
2. Empirical Setting and Data
3. Empirical Strategy
4. Results
5. Policy Analysis

Optimal Pigouvian Instruments with Micro-Frictions

Optimal Taxation with Behavioral Biases

Nascent, but rapidly growing literature

- Chetty, Kroft, and Looney (2009)
- Allcott, Mullainathan, Taubinsky (2014)
  - Internalities $\rightarrow$ Pigouvian tax should be above the marginal damage.
  - Internalities $\rightarrow$ Pigouvian tax with a subsidy more efficient than a tax alone.
  - Heterogeneity $\rightarrow$ average internality is not a sufficient statistics.
- Farhi and Gabaix (2015)
  - Heterogeneity $\rightarrow$ the targeting principle does not hold.
  - Heterogeneity $\rightarrow$ a quantity instrument might dominate a price instrument.
  - If (endogeneous) attention costs are included in welfare $\rightarrow$ lower optimal behavioral tax.
- Taubinsky and Rees-Jones (2016)
  - The DWL of taxation is proportional to the variance of the internality in the population.

Workhorse Model in the Literature: Chetty et al.

Model with misperception to tax:
Rational consumer:

$$\max_c U(c) - (p + \tau)c$$

Behavioral consumer:

$$\max_c U(c) - (p + m\tau)c$$

where $m \leq 1$ (typically)

Misperception $\rightarrow$ Pigou Doesn't Hold

Externality: ϕ marginal damage of consuming c
Planing Problem:

$$\max_{c} U(c) - (p + \phi)c$$

Rational consumer:

$$\max_{c} U(c) - (p + \tau)c$$

$\tau = \phi$
Behavioral consumer:

$$\max_{c} U(c) - (p + m\tau)c$$

$\tau = \phi/m \geq \phi$ if $m \leq 1$

Transaction Cost Model

Consumers must pay a **true economic** cost k to learn τ
Behavioral consumer:

$$\max_{R=\{0,1\}} (1-R)\cdot\left[\max_c U(c) - p\cdot c\right] + R\cdot\left[\max_c U(c) - (p+\tau)c - k\right]$$

Transaction Cost Model Observationally Equivalent to Misperception Model

If $k \sim F(\cdot)$: only a fraction of the consumers will respond to the tax.

Lemma 1 *The transaction cost (TC) model is observationally equivalent to a misperception (MP) model if* $m < 1$.

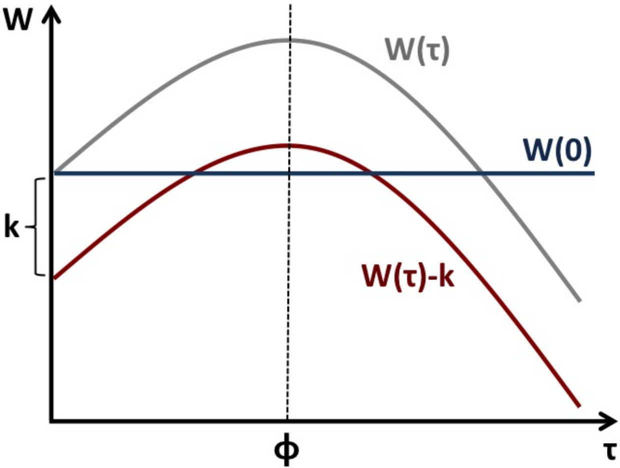
We don't know if only a fraction of the consumers responded to the tax, all of them responded, but misperceived the tax, or both.

Transaction Cost $\rightarrow$ Pigou Holds

Proposition 1 *With the TC Model Pigou holds*
For any distribution $k \sim F(\cdot)$, with $F'(0) = f(0) > 0$,
$\tau = \phi$ if consumers are subject to transaction costs k.

Transaction Cost → Pigou Holds

Proof For a given k:



Optimal Pigouvian Instruments and Behavioral Biases in Energy Operating Costs

Our framework:

- Discrete choice model with several different goods where the adjustment to a Pigouvian tax is on the extensive margin (i.e., choosing among J technologies):
- Micro-frictions (behavioral biases) to process energy operating costs
- Energy tax impacts energy operating costs

Optimal Pigouvian Instruments and Observed Heterogeneity

- Suppose we can segment the population in R types
- Estimate misperceptions for each type r: m_r

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For each type r:

$$\tau_r = \frac{\phi}{m_r} + P_{energy} \frac{(1 - m_r)}{m_r}$$

Optimal Pigouvian Instruments and Observed Heterogeneity

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For each type r:

$$\tau_r = \frac{\phi}{m_r} + P_{energy}\frac{(1 - m_r)}{m_r}$$

Example:

- ϕ=0.02 \$/kWh
- P_{energy}=0.11 \$/kWh
- m_r=0.5
- τ_r=0.15 \$/kWh

Optimal Pigouvian Instruments and Observed Heterogeneity Across Consumers

If no targeting possible:

$$\tau = \frac{\phi}{1 - \frac{\sum_r \alpha_r (1-m_r) \Delta_r^{\tau, energy}}{\sum_r \alpha_r \Delta_r^{\tau, energy}}} + P_{energy} \frac{\frac{\sum_r \alpha_r (1-m_r) \Delta_r^{\tau, energy}}{\sum_r \alpha_r \Delta_r^{\tau, energy}}}{1 - \frac{\sum_r \alpha_r (1-m_r) \Delta_r^{\tau, energy}}{\sum_r \alpha_r \Delta_r^{\tau, energy}}}$$

where

- α_r: share of consumers of type r
- $\Delta_r^{\tau, energy}$: net change in energy consumption due to a small τ

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Proposition 2

- *If* $m_r \leq 1$ *for all* r
- $\Delta_r^{\tau, energy} \leq 0$ *for all* r
- $\tau \geq \phi$

Optimal Pigouvian Instruments and Observed Heterogeneity Across Instruments

Consider that an ad valorem sales tax is also levied, denoted T^s, on the price of each technology and consumers' response to T^s is scaled by d, which may capture the lack of tax salience or other biases.

$$\tau = \frac{\phi}{m} + P^e \cdot \frac{(1-m)}{m} - T^s \cdot \frac{d}{m} \cdot \frac{\sum_j \frac{\partial \sigma_{kj}}{\partial \tau}}{\sum_j \frac{\partial e_j}{\partial \tau}}.$$

Optimal Pigouvian Instruments and Unobserved Heterogeneity

- Suppose we segment the population in R types
- Estimate misperceptions for each type r, but misperceptions vary across J products: m_{jr}
- Why $m_{jr} = m_r$:
  - Sorting not taken into account by the segmentation
  - Heterogeneous response to information (e.g. certification, fuel economy advertising)

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For a given type r

$$\tau_r = \phi \frac{\sum_j \sigma^{\tau}_{jr} energy_j}{\sum_j m_{jr} \sigma^{\tau}_{jr} energy_j} + P_{energy} \frac{\sum_j (1 - m_{jr}) \sigma^{\tau}_{jr} energy_j}{\sum_j m_{jr} \sigma^{\tau}_{jr} energy_j}$$

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Proposition 3

- *If $m_r \leq 1$ for all r*
- $\tau \lesseqgtr \phi$

Take Aways

1. If not clearly empirically identified, need to take a stand on the source of micro-frictions.

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2. Behavioral biases in processing energy operating costs:
    - $\tau \neq$ externality cost
    - Pigouvian tax is fifth best.
        - τ and P_{energy} misperceived
        - Heterogeneity across types
        - Heterogeneity across goods
        - Heterogeneity across P_{energy}

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1. If not clearly empirically identified, need to take a stand on the source of micro-frictions.
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     - τ and P_{energy} misperceived
     - Heterogeneity across types
     - Heterogeneity across goods
     - Heterogeneity across P_{energy}
3. Observed and unobserved heterogeneity in behavioral biases are rationales—on **efficiency** grounds—for combining multiple fiscal instruments.

Empirical Setting and Data

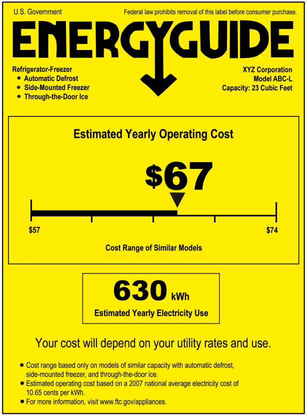
U.S. Fiscal Policies to Promote Energy Efficient Durables (Appliances)

- **Subsidies**
  - Rebates
    - Utility Rebates (≈ County level)
    - Government Rebates "Cash for Appliances" (C4A), akin to "Cash for Clunkers" (C4C) (State level)
  - Sales tax holidays and exemptions (State level)
  - Manufacturers' tax credit (Federal level)
  - Consumers' tax credit (Federal level)

- **Pricing Externalities in the U.S. Electricity Sector**
  - Local pollutants: Acid Rain Program (1990 Clean Air Act)
  - CO_2: Regional cap-and-trade programs

Decision Environment: Readily Available Energy Information

(a) Energy Star



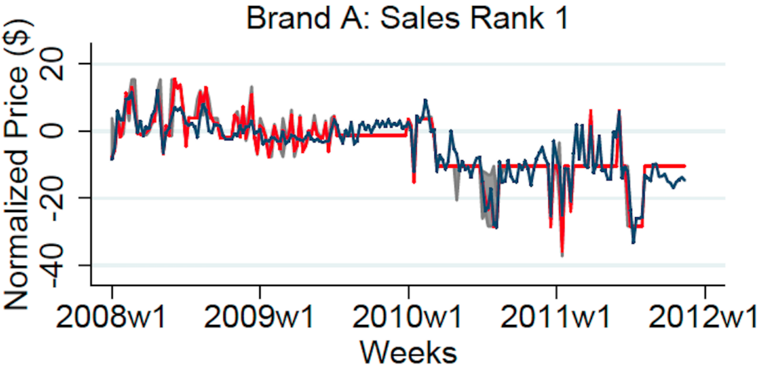
(b) EnergyGuide

Data

- Transaction-level data over 2008-2012 from a large U.S. appliance retailer
- Focus on refrigerators
  - Manufacturer model number matched to attribute information
    - kWh/year, size, ES certification, options, brand
  - Unique household identifier matched (56%) with Acxiom demographic information
    - income, education, family structure, age, homeownership, housing type, political affiliation
  - MSRP, price paid, sales tax paid
  - Location of the store
- Utility rebates at county level (DSIRE): amounts
- C4A rebates (state): amounts, timing, other parameters
- Local (**state** or county) average electricity prices (EIA-861)
- Sales tax rates at the zip code-week level

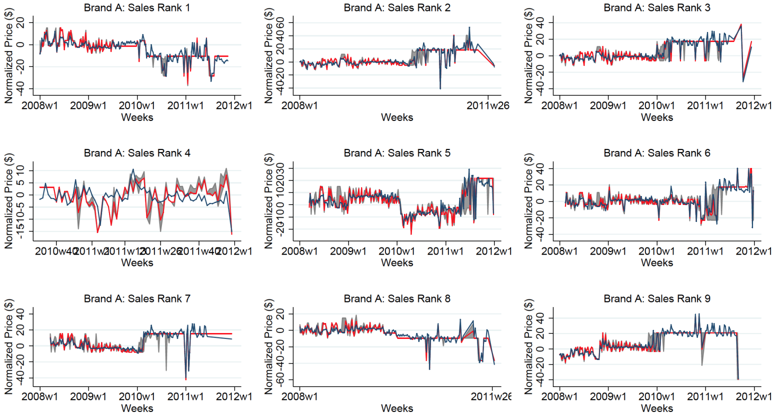
Identifying Source of Variation

Prices: National Pricing Strategy

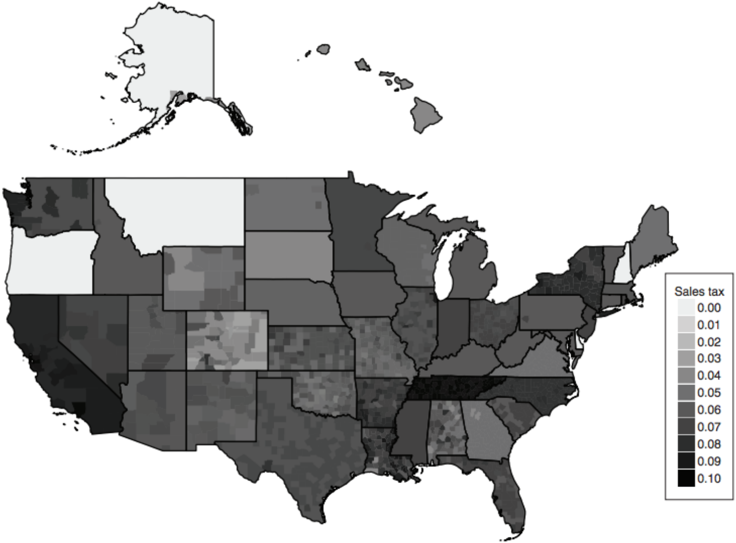


Prices

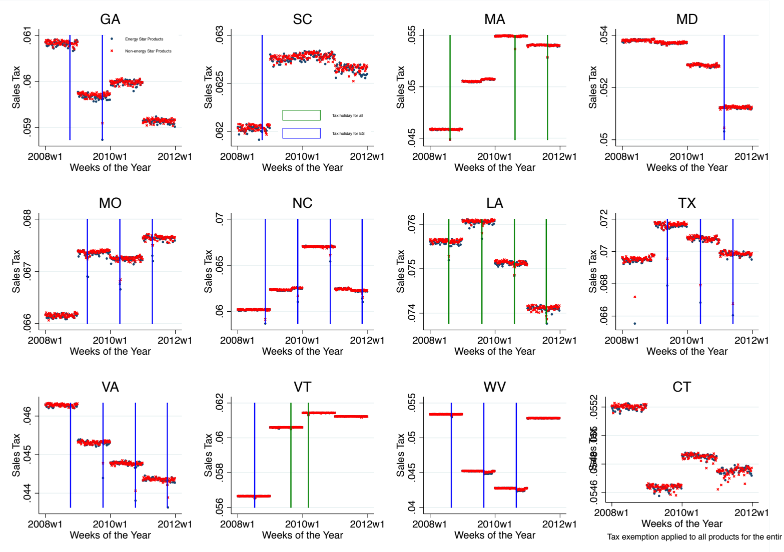
A lot of model-specific idiosyncratic variation:



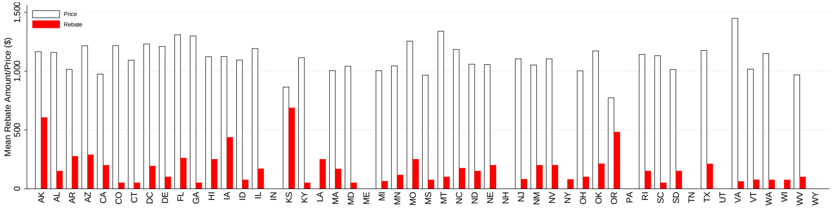
Sales Taxes



Sales Taxes


GA
SC
MA
MD
MO
NC
LA
TX
VA
VT
WV
CT
Sales Tax
Weeks of the Year
2008w1
2010w1
2012w1
Energy Star Products
Non-energy Star Products
Tax holiday for all
Tax holiday for ES
.061
.06
.059
.063
.0625
.062
.055
.05
.045
.054
.052
.05
.068
.067
.066
.07
.065
.06
.076
.075
.074
.072
.07
.068
.066
.046
.045
.044
.062
.06
.058
.056
.055
.05
.045
.04
.0552
.0546
Tax exemption applied to all products for the entir

C4A Rebates: Variation Rebate Amount



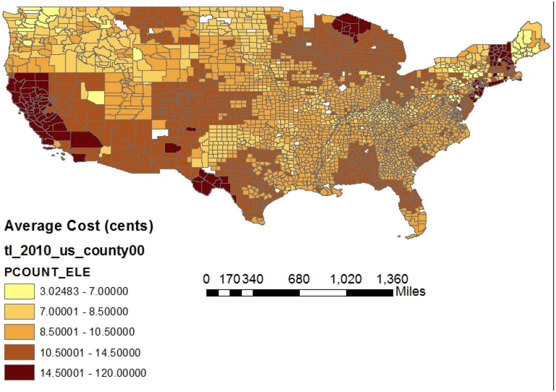
C4A Rebates: Variation Timing

Utility Rebates

- 80-150 electric utilities/year offered rebates for ES refrigerators
- Rebate coverage vary from year to year
- Rebate amount also vary over time

Electricity Costs

2010 Average County Electricity Prices



Empirical Strategy

Preferred Specification

Conditional logit with observed heterogeneity:

$$
\begin{aligned}
U_{ijtr} = & -\eta_i Price_{jrt} \\
& -\alpha_i SalesTax_{jrt} - \beta_i SalesTax_{jrt} \times DHoliday_{rt} \\
& +\psi_i Rebate_{rt}^{Utility} \times ES_{jt} \\
& +\phi_i During_{rt}^{C4A} \times ES_{jt} + \zeta_i Before_{rt}^{C4A} \times ES_{jt} + \xi_i After_{rt}^{C4A} \times ES_{jt} \\
& -\theta_i ElecCost_{jrt} - \rho_i ElecCost_{jrt} \times ES_{jt} \\
& +\gamma_j + ES_{jt} \times State_r + BrandMonthFE_{jt} \\
& +Demo_i \times Attributes_j + \epsilon_{ijtr}
\end{aligned}
$$

- No outside option: static model of choice in a particular store
- Consumer-specific consideration set based on size purchased.

Estimation

- Infeasible to estimate this ML model with millions of transactions
- For each of the 6 income groups, draw about 55,000 households
- Estimate the model by maximum likelihood

Results

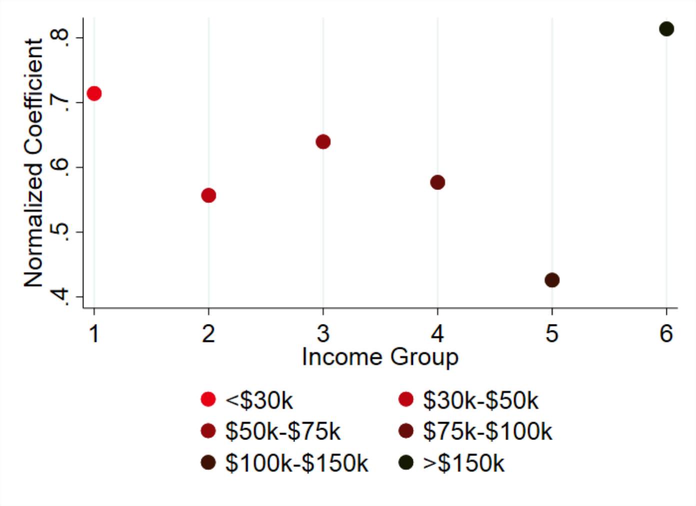
Interpretation of Behavioral Parameters

- η_i: **Marginal utility of income**
  - Key parameter to interpret the relative magnitude of other behavioral parameters.

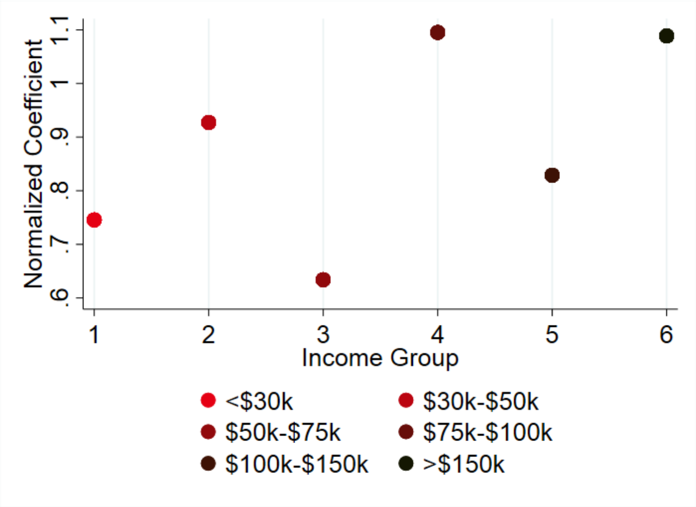
Interpretation of Behavioral Parameters

- η_i: **Marginal utility of income**
  - Key parameter to interpret the relative magnitude of other behavioral parameters.
- α_i/η_i: **Sales tax salience and lack of information about local taxes**
  - $\alpha_i/\eta_i < 1$: Behavioral biases play a role.

Interpretation: Sales Tax



Interpretation: Sales Tax Holidays



Interpretation of Behavioral Parameters, Contd.

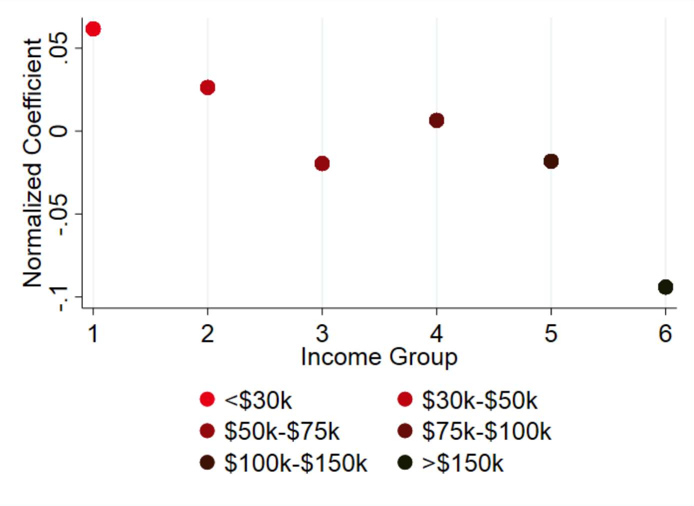
- ψ_i/η_i: **Probability to Claim Utility Rebates**
- ϕ_i/η_i: **Probability to Claim C4A Rebates**

Interpretation of Behavioral Parameters, Contd.

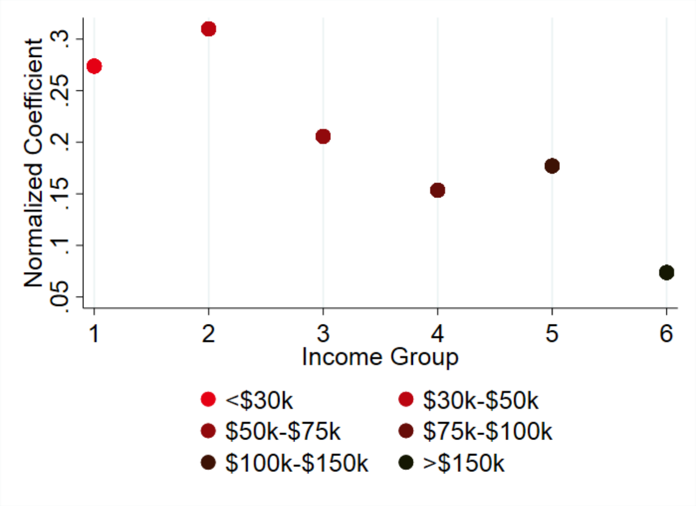
- ψ_i/η_i: **Probability to Claim Utility Rebates**
- ϕ_i/η_i: **Probability to Claim C4A Rebates**

- $\psi_i/\eta_i < 1$, $\phi_i/\eta_i < 1$: **"Transaction/Hassle costs" to claim rebates play a role.**

Interpretation: Utility Rebates



Interpretation: CFA Rebates



Interpretation of Behavioral Parameters, Contd.

- With θ_i and η_i we can solve for an **implied discount rate**

Interpretation of Behavioral Parameters, Contd.

- With θ_i and η_i we can solve for an **implied discount rate**

- If consumers form time-invariant expectations about the yearly operating electricity cost
- No depreciation

Lifetime energy operating cost (LC_j) for the durable j is given by

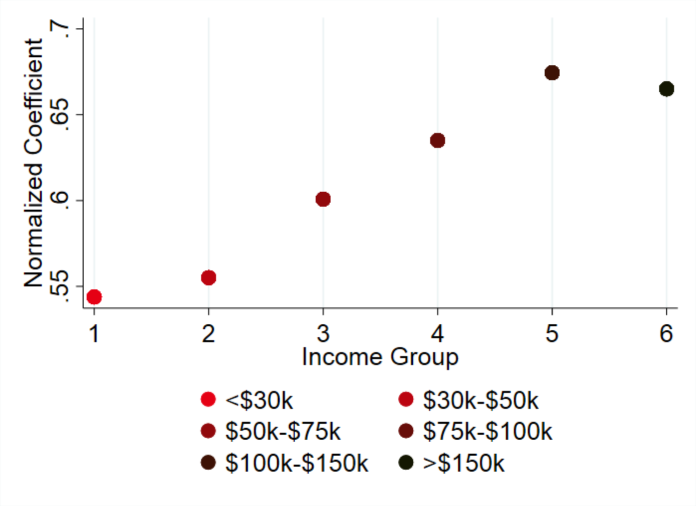
$$LC_{ij} = \sum_{t=1}^{L} \rho_i^t C_{ij} = \rho_i \cdot \frac{1-\rho_i^L}{1-\rho_i} \cdot C_j,$$

Therefore, we have:

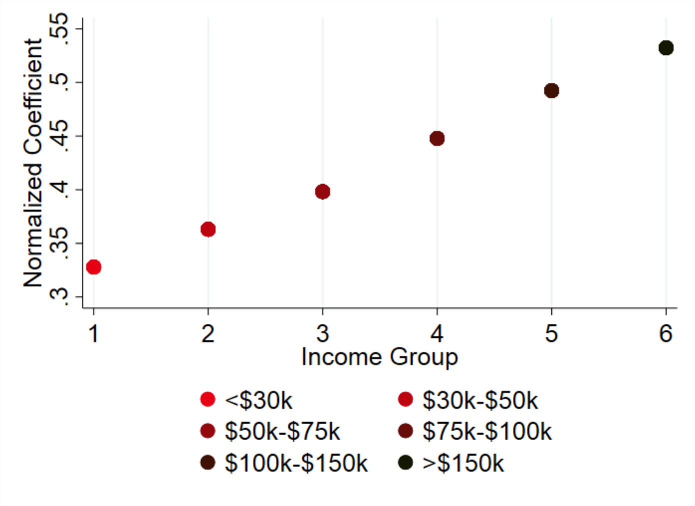
$$\theta_i = \eta_i \cdot \rho_i \cdot \frac{1-\rho_i^L}{1-\rho_i},$$

where $\rho_i = 1/(1+r_i)$.
$\theta_i / \left(\eta_i \cdot \rho_i(5\%) \cdot \frac{1-\rho_i(5\%)^L}{1-\rho_i(5\%)}\right) < 1$ Behavioral biases play a role.

Interpretation: Elec. Costs at $r = 5\%$



Interpretation: Elec. Costs X ES at $r = 5\%$



Take Aways Empirics

- For all energy fiscal instruments, large micro-frictions
- Low income HDs subject to larger behavioral biases (energy costs, sales taxes)
- Higher income HDs subject to larger transaction costs (rebates)
- Energy Star magnifies the biases on the perception of energy costs

Policy Analysis

Welfare Measure

- We have a model of decision utility
- We have to take a stand and interpret the discrepancy between the coefficient on price and the other coefficients capturing the behavioral responses to costs and subsidies

Welfare Measure

- We have a model of decision utility
- We have to take a stand and interpret the discrepancy between the coefficient on price and the other coefficients capturing the behavioral responses to costs and subsidies

- Is there a discrepancy between decision and experienced utility?
  - All consumers ultimately pay the sales tax and future electricity costs. Do the "muted" behavioral responses reflect a lack of information?

  - Not all consumers take advantage of rebates. The coefficient on rebates reflects the fact that the probability of taking rebates is less than one due to various hassle costs.

Our Assumptions

Assumption 1:
Under perfect information, the behavioral responses to sales taxes and sales tax holidays should be the same as for prices.

Assumption 2:
Under perfect information, the coefficient on electricity cost should imply a discount rate in line with other investment/borrowing decisions. We assume $r = 5\%$.

Assumption 3:
Under perfect information, the ES certification should not impact how consumers perceive electricity costs.

Welfare Measure

- Leggett (2002) developed a framework to compute welfare with uninformed consumers in a discrete choice setting.
- Allcott (2013), Kuminoff et al. (2015), and Dubois et al. (2016) rediscovered and applied it.
- Other recent applications: Houde (2017), Kuminoff et al. (2016), Reynaert and Sallee (2016), and Allcott and Knittle (2017).

Welfare Measure with Leggett's Correction

CS for a policy change $\mathcal{P} \rightarrow \tilde{\mathcal{P}}$:

$$CS_{itr} = \frac{1}{\eta_i} \cdot \left[ln \sum_{j}^{J} exp(\tilde{U}_{ijtr}) + \sum_{j}^{J} \tilde{P}_{ijtr}(\tilde{U}^{E}_{ijtr} - \tilde{U}_{ijtr}) \right] - \frac{1}{\eta_i} \cdot \left[ln \sum_{j}^{J} exp(U_{ijtr}) + \sum_{j}^{J} P_{ijtr}(U^{E}_{ijtr} - U_{ijtr}) \right]$$

where

$$U^{E}_{ijtr} = -\eta_i P_{jrt} - \eta_i Tax_{jrt} - \eta_i \rho_i \frac{1-\rho^{L}_i}{1-\rho_i} Elec_{jrt} + \psi_i R^{Utility}_{rt} \times ES_{jt} + \phi_i R^{CFA}_{rt} \times ES_{jt} + \gamma_{ij} + \tau_i ES_{jt} + \epsilon_{ijtr}$$

Welfare Measure with Leggett's Correction

Standard welfare measure:

$$CS_{itr} = \frac{1}{\eta_i} \cdot \left[ln \sum_{j}^{J} exp(\tilde{U}_{ijtr}) - ln \sum_{j}^{J} exp(U_{ijtr}) \right]$$

Leggett's correction:

$$CS_{itr} = \frac{1}{\eta_i} \cdot \left[\sum_{j}^{J} \tilde{P}_{ijtr}(\tilde{U}^{E}_{ijtr} - \tilde{U}_{ijtr}) - \sum_{j}^{J} P_{ijtr}(U^{E}_{ijtr} - U_{ijtr}) \right]$$

Optimal Pigouvian Tax

- Externality cost: $\phi =$0.02 \$/kWh ($\approx$ \$100 carbon tax)
- Electricity price: 0.11 \$/kWh
- No rebates and sales tax

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- Transaction cost model:
  $\tau =$0.02 \$/kWh

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- Electricity price: 0.11 \$/kWh
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- Transaction cost model:
  $\tau =$0.02 \$/kWh
- Behavioral bias energy costs:
  $\tau =$0.104 \$/kWh

Optimal Pigouvian Tax

- Externality cost: $\phi =$0.02 \$/kWh ($\approx$ \$100 carbon tax)
- Electricity price: 0.11 \$/kWh
- No rebates and sales tax

- Transaction cost model:
  $\tau =$0.02 \$/kWh
- Behavioral bias energy costs:
  $\tau =$0.104 \$/kWh
- Differentiated bias-adjusted tax:
  $\tau_k = [0.129, 0.124, 0.106, 0.095, 0.083, 0.085]$ \$/kWh

Comparison of Energy Fiscal Instruments

Policy Scenario	Optimal Policy	Social Welfare ($/consumer)
Pigou tax: no adjustment	$\tau = 0.020$ $/kWh	1.791
Bias-adjusted Pigou tax	$\tau = 0.104$ $/kWh	5.049
CFA rebate	S^{CFA}=$50	0.047
Mean-tested CFA rebate	S^{CFA}=[$32, $42, $61, $74, $57, $36]	0.050
ES Sales tax	T^s_{ES}= 4.62%, T^s_{nonES}= 6.43%	0.575
Pigouvian tax with CFA rebate	τ =0.104 $/kWh, S^{CFA} =$1	5.049
Pigou tax with ES sales tax	τ =0.104$/kWh, T^s_{ES}= -0.01%, T^s_{nonES}= -0.08%	5.049
Pigou tax with mean-tested CFA rebate	τ=0.104$/kWh, S^{CFA}=$0	5.049

When Should We Combine an Energy Tax with Subsidies?

- The 'gradient' of the behavioral responses to energy costs is increasing with income.
- The bias-adjusted tax is too low for lower income HDs and too high for higher income HDs.
- Subsidies are not socially desirable for high income HDs.
- Here the trade-off between low and high income implies that no subsidy is optimal.

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What if the level and gradient of the behavioral responses to subsidies were different?

When Should We Combine an Energy Tax with Subsidies?

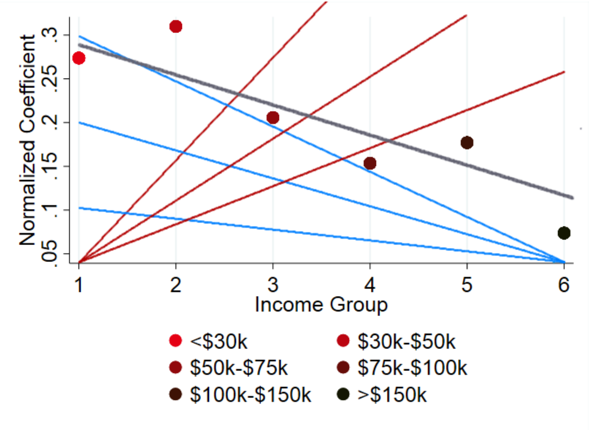

Figure: Varying the Gradient and Level of the Behavioral Responses to CFA rebate

When Should We Combine an Energy Tax with Subsidies?

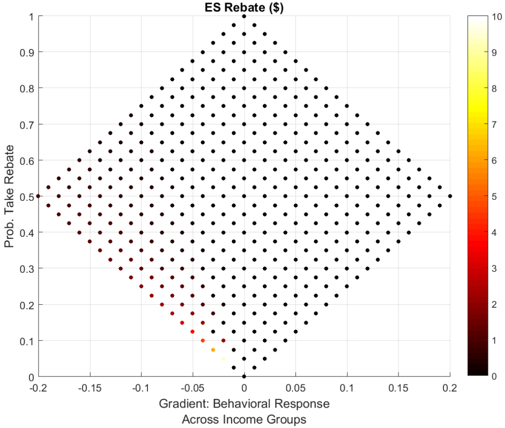

Figure: Sensitivity with Respect to Behavioral Responses to CFA rebate

The Unintended Effect of the Energy Star (ES) Certification

Remember

- The interaction of ES and energy costs leads to a lower behavioral response
- We have also find a large WTP for the ES label: \$101, \$103, \$131, \$168, \$174, \$136,
- Are those behavioral responses to the label preferences or biases?

- Adjustment cost model:
  $\tau =$0.02 \$/kWh
- Behavioral bias energy costs and no Energy Star bias:
  $\tau =$0.104 \$/kWh
- Behavioral bias energy costs and with Energy Star bias:
  $\tau =$-0.004 \$/kWh

If Energy Star (ES) Acts as a Bias

Policy Scenario	Optimal Policy	Social Welfare ($/consumer)
Welfare definition: ES$\times$ElecCost$\neq 0$ and WTP for ES acts as a bias		
Pigou tax: no adjustment	$\tau =$ 0.020 $/kWh	-2.513
Bias-adjusted Pigou tax	$\tau =$ -0.072 $/kWh	4.483
CFA rebate	S^{CFA}=$0	0
ES Sales tax	T^s_{ES}= 25.15%, T^s_{nonES}= -1.41%	19.044
Pigouvian tax with CFA rebate	$\tau =$-0.072$/kWh, S^{CFA} =$0	4.483
Pigou tax with ES sales tax	$\tau =$0.033, T^s_{ES}= 27.08%, T^s_{nonES}=-4.12%	19.606

Conclusions

Thank you!

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Identification

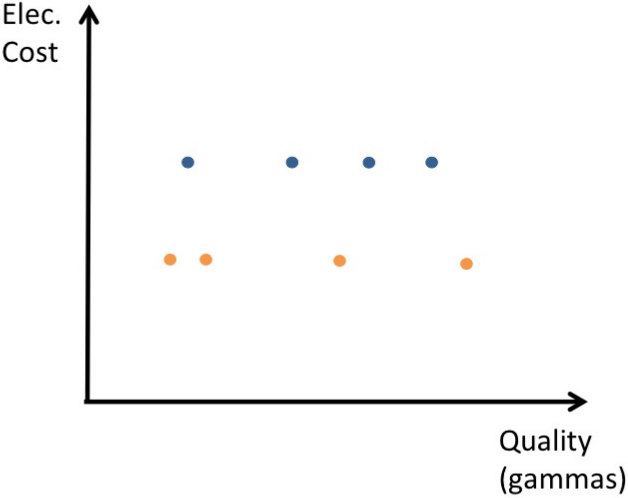

Figure: High Electricity Price State

Identification

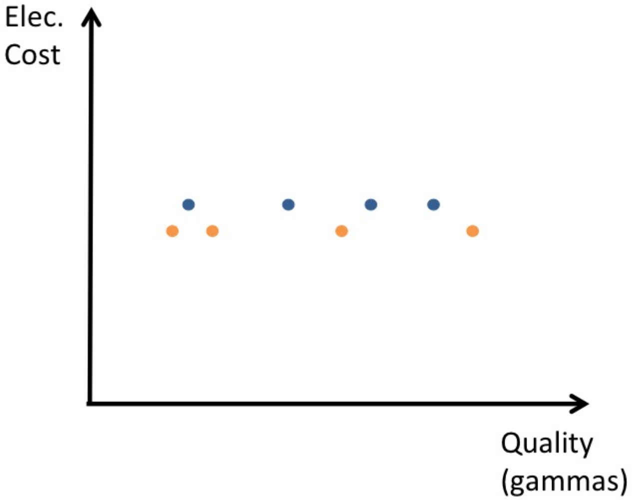

Figure: Low Electricity Price State

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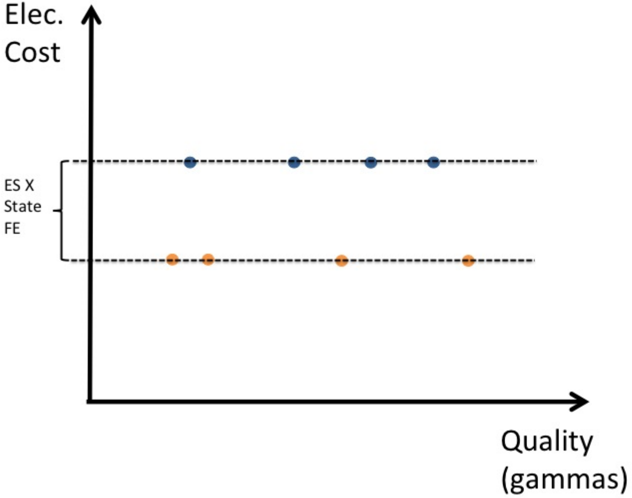

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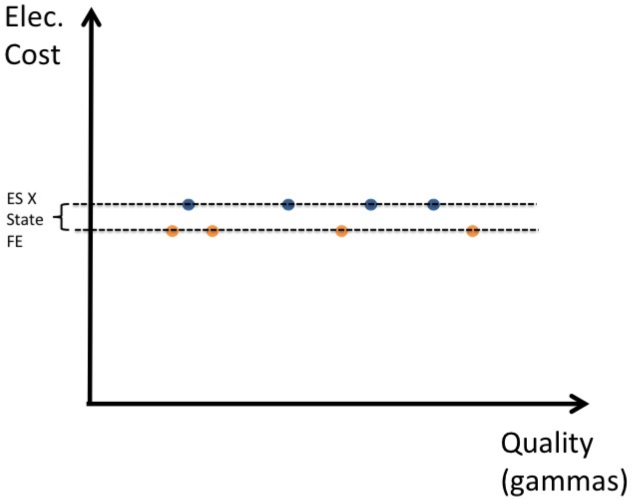

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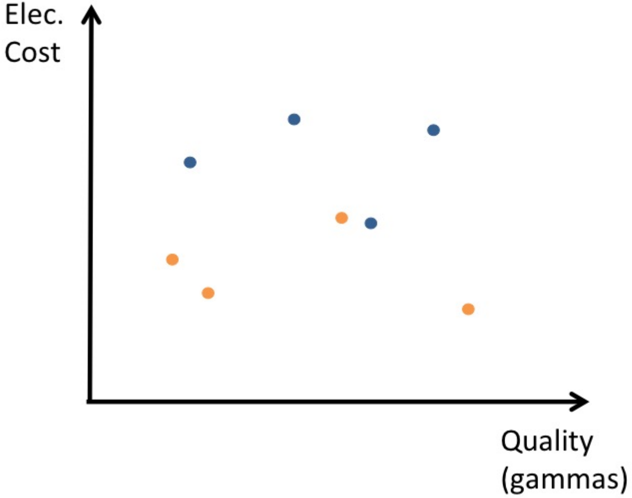

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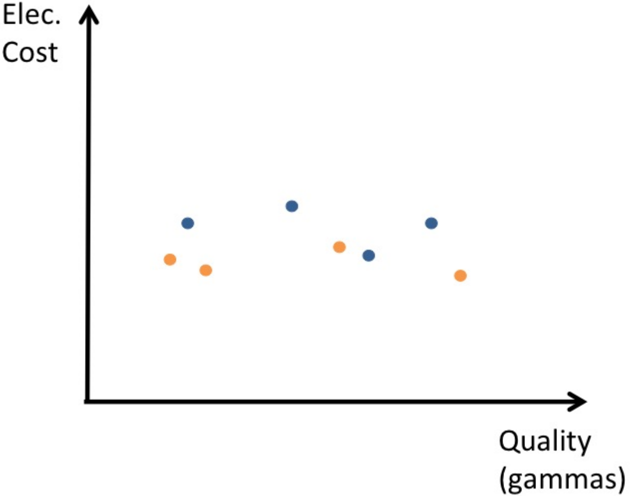

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