Energy efficiency behavior: The role of information and discounting


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Energy efficiency: the economic decision problem

\[
\text{Minimize} \quad \text{Total Cost} = K(E) + O(E, P_E) \times D(r, T) + \text{other costs}
\]

- **Objective**: annual operating cost, price of energy, discount rate
- **Equipment purchase cost**, annual energy use, present value factor, time horizon
The “energy paradox” or “energy efficiency gap”

• Apparent reality that energy-efficient products that would pay off for adopters … are nonetheless *not* adopted
  – “Rationalizing” observed choices can require implicit discount rates much higher than market rates
  – 30+ year debate (e.g., Hausman 1979; Shama 1983; Dubin & McFadden 1984; Jaffe & Stavins 1994; Gillingham, Newell, and Palmer 2011; Alcott and Greenstone 2012)

• Explanations
  – Market failure explanations
  – Behavioral explanations
  – Model and measurement explanations
Explanations for the energy efficiency gap

• Market failure explanations
  – information problems (lack of information)
  – split incentives (e.g., renter/landlord, capital/operating budgets)
  – liquidity constraints (purchaser cannot finance more up-front cost)
  – prices don’t include externalities or are set too low through regulation

• Behavioral explanations
  – inattentiveness/salience issues
  – bounded rationality, heuristic decisionmaking
  – prospect theory (losses matter more than gains)
  – myopia (excessive weight on the near term)

• Model and measurement explanations
  – unobserved costs of adoption
  – heterogeneity: product attributes; characteristics of adopters
Study goals

• Evaluate alternative labeling approaches in the context of households’ preferences for energy efficiency
  – systematic research lacking on whether/how existing labels affect choices
  – does information content and complexity matter?
  – what are the effects of multiple labels?

• Disentangle effects of different factors influencing energy efficiency decisions
  – different factors separately evaluated by many studies; here we seek to jointly evaluate the relative importance of different factors
  – discount rates (elicited in the survey through choice and market data)
  – individual heterogeneity (personal/household situation)
  – commonly unobserved factors, such as cost and availability of credit, likelihood of moving, income, education, and others
U.S. labeling to address information problems

Energy Guide (information rich)

Energy Star (“endorsement” without detailed information)
Energy labels internationally

Canada

Mexico

European Union

Example of an EnerGuide label for an ENERGY STAR qualified appliance.

Energy consumption / Consommation énergétique

200 kWh

per year / par anneau

Mexico

EFICIENCIA ENERGÉTICA
Relación de Eficiencia Energética (REE) determinada como se establece en la NOM-021-ENER/SCFI/ECOL-2000

REE = Efecto neto de enfriamiento (W)

Potencia eléctrica (W)

Marca: SUPER-UHS

Modelo: TOI034R200B

Potencia eléctrica 600 W

Efecto neto de enfriamiento 17 000 W

REE establecida en la norma en (W/W)

2,49

REE de este aparato en (W/W)

2,75

Ahorro de energía de este aparato

10%

IMPORTANTE
Este aparato cumple con los requisitos de seguridad al usuario y no daña las capas de ozono.

La etiqueta no debe retirarse del aparato hasta que haya sido adquirido por el consumidor final.

European Union

Energy consumption kWh/ year (Based on standard test results for 24h)

More efficient

A

B

C

D

E

F

G

Less efficient

Energy consumption kWh/year

325

Fresh food volume

190

126

Frozen food volume

Noise (dB(A) re 1 pW)

Further information is contained in product brochures

Richard Newell, Sept. 7, 2015, Tsinghua University
More international labels

Source: Energy Efficient Strategies (EES)
Study approach

• Household survey (responses from 1,217 single-family households), includes detailed demographic information

• Evaluate immediate water heater replacement decision

• Elicit choices between different water heater alternatives

• Different alternatives randomly (but realistically) varied by price and energy use

• State-of-the-art choice experiment design
  – fully computerized survey instrument, customized as each respondent progresses through
  – labeling approach randomly varied by respondent (~100 per label)

• Use choices to estimate households’ valuation of energy efficiency under different labeling treatments

• Also elicit data on discount rates, credit situation, likelihood of moving, etc.

• Choice experiment data estimated in combination with random utility and multinomial logit models, controlling for heterogeneity
Labeling alternatives evaluated (12 treatments)

Variations on Energy Guide label
1. Current label: Energy Guide w/ Annual Operating Cost, Range, & Energy Use (kWh, therms)
2. Energy Guide, w/ only Annual Operating Cost & Range
3. Energy Guide, w/ only Annual Energy Use (kWh, therms)
4. Annual Operating Cost & Range
5. Annual Operating Cost

Energy Star logo
7. Energy Star + Annual Operating Cost & Range
8. Energy Star Only

CO₂ information
9. CO₂ Emissions + Energy Guide w/ Annual Operating Cost & Range
10. CO₂ Emissions + Annual Operating Cost & Range
11. CO₂ Emissions Only

Efficiency grade
12. EU-style Efficiency Grade + Annual Operating Cost
Consider choosing between the following three water heater options. Please think that these are the only options available to you and you have to make the purchase.

### Water Heater Decision 1

<table>
<thead>
<tr>
<th></th>
<th>Water Heater A</th>
<th>Water Heater B</th>
<th>Water Heater C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price</td>
<td>$400</td>
<td>$650</td>
<td>$550</td>
</tr>
<tr>
<td>Energy Use</td>
<td><img src="image1" alt="Energy Guide A" /></td>
<td><img src="image2" alt="Energy Guide B" /></td>
<td><img src="image3" alt="Energy Guide C" /></td>
</tr>
<tr>
<td></td>
<td>$357/yr</td>
<td>$265/yr</td>
<td>$288/yr</td>
</tr>
<tr>
<td></td>
<td>294 therms</td>
<td>218 therms</td>
<td>237 therms</td>
</tr>
</tbody>
</table>

**Your choice from these options?**

- [ ] A
- [ ] B
- [ ] C
Consider choosing between the following three water heater options. Please think that these are the only options available to you and you have to make the purchase.

**Water Heater Decision 1**

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</tr>
<tr>
<td><strong>Energy Use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More efficient</td>
<td>More efficient</td>
<td>More efficient</td>
</tr>
<tr>
<td>Estimated Yearly Operating Cost</td>
<td><strong>357</strong></td>
<td><strong>$265</strong></td>
</tr>
</tbody>
</table>

Your choice from these options? □ A □ B □ C
Eliciting individual-specific discount rates

• Cash-over-time choice approach similar to prior work
  – e.g., “Eliciting Individual Discount Rates,” M Coller, M Williams, *Experimental Economics, 1999*

• Elicit choices between two cash payment alternatives
  – Payment A is delivered in one month
  – Payment B is delivered in 12 months
  – Both tax-free, certain; only difference is delivery date and payment amount

• Payment A always equals $1000; Payment B is greater

• Sequence of questions that vary Payment B
  – Payment B has increasing values ($1019-$2500) equal to $1000 present value at discount rates of 2% up to 100%
  – Stop when the respondent switches to the 12-month option

• Individual discount rate implicit in the choices
## Cash-over-time choice problem

<table>
<thead>
<tr>
<th>Payment A (in 1 month)</th>
<th>vs.</th>
<th>Payment B (in 1 year)</th>
<th>Discount rate for PV of Payment A and B to be equal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,019</td>
<td>2%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,037</td>
<td>4%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,057</td>
<td>6%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,076</td>
<td>8%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,096</td>
<td>10%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,116</td>
<td>12%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,137</td>
<td>14%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,158</td>
<td>16%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,179</td>
<td>18%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,201</td>
<td>20%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,258</td>
<td>25%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,317</td>
<td>30%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,443</td>
<td>40%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,581</td>
<td>50%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,733</td>
<td>60%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,989</td>
<td>75%</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$2,501</td>
<td>100%</td>
</tr>
</tbody>
</table>
What individual discount rates are revealed by the cash-over-time choice task?

Individual Discount Rates, Percentage Distribution by Category (n=1217)

Median 11%, Mean 20%
Estimating impact of information on WTP for EE

• Predict the probability of elicited choices as a function $U = f(\cdot)$ of the attributes of each alternative
  – discrete choice, random utility model, maximum likelihood
  – normalize coefficients to allow WTP interpretation

• $U = \lambda [ Price + \gamma_j Discounted Energy Cost + \eta_j X ]$
  – $\lambda$ estimates the effect of purchase price
  – $\gamma_j$ estimates $\$ WTP per $ saved in discounted energy operating costs, conditional on information treatment $j$
    • cost-minimizing behavior would imply $\gamma_j = 1$
  – $\eta_j$ estimates $\$ WTP associated with other attributes

• Discounted energy costs computed in two ways
  (1) individually-elicited rates; (2) uniform 5% rate
Structuring estimation and interpretation by representing labels as information composites

• Rather than directly estimate the impact of 12 different treatments, we express labels in terms of their key information elements
  – More intuitive and allows more structurally-sensible specification

• Information elements (interacted with discounted energy cost)
  – Any operating cost information included (yes/no)
  – Continuous operating cost information included (yes/no)
  – Energy Guide image included (yes/no)
  – Energy Star logo included (yes/no)
  – Physical energy info. (therms, kWh) included (yes/no)
  – CO2 emissions information included (yes/no)
  – Relative energy efficiency grade information included (EU-style label) (yes/no)

• Also include separate terms for energy use, CO$_2$, Energy Star
Six composite treatments that capture key information attributes (money, physical energy, CO₂, endorsement)
WTP for $1 reduction in discounted operating costs, by label

A. Simple operating cost information

B. Relative operating cost and Energy Guide added to Label A

C. CO₂ information added to Label B

D. The current Energy Guide: Physical energy information added to Label B

E. Energy Star added to Label D

F. EU style relative grade

WTP based on individual discount rates

WTP based on 5% discount rate
Main findings on the influence of information

- Willingness to pay for energy efficiency is significantly affected by the information available for decisions
  - monetary operating cost information is most important
  - information on physical energy and CO\textsubscript{2} emissions have additional, but lesser impact on choices

- Whether you use individual discount rates, or a lower assumed rate, has a significant implication for the degree of labeling “nudge” and/or support for other efficiency policies
  - using \textit{individual discount rates}, current US Energy Guide label yields roughly cost-efficient WTP for energy efficiency
  - using a \textit{lower 5\% discount rate}, the more suggestive Energy Star logo or EU-style efficiency grade appear to induce more cost-efficient behavior
Role of time preference in energy efficiency choices

- Prior studies have also not considered the role of individual time preference in evaluating the degree to which there is an energy-efficiency “gap” or “paradox”
- Instead, the standard approach is to either:
  - assume observed choices are cost-minimizing, and compute an average “implicit discount rate” (e.g., Hausman 1979)
  - or assume a particular discount rate and then judge the degree to which observed choices are “rational” (i.e., cost-minimizing) (e.g., Alcott and Wozny 2014)
- Surprising, given the central importance of individual time preferences to the profitability of energy efficiency choices
- Importance of individual discount rates is further heightened by experimental findings that elicited time preferences are quite heterogeneous (e.g., Frederick, Loewenstein, O'donoghue 2002)
Closer examination of individual time preferences and energy efficiency

• What influence do individual discount rates have on indicators of household preferences for energy efficiency?
  – choices about energy operating costs of products
  – required payback periods
  – tax credits for energy efficient products

• What are the most important determinants of individual discount rate heterogeneity?
  – demographics (eg, education, household size, race)
  – financial situation (eg, credit score, income)
Time preferences and energy efficiency choices

• Estimate energy efficiency choices as a function of individual discount rates, controlling for characteristics of respondent/their household/home
  – WTP for energy efficiency based on product choice experiment, using random utility/multinomial logit model
  – WTP for energy efficiency based on separate question that directly asked maximum WTP for $10 reduction in annual energy costs, using OLS
  – Payback period required to recover energy efficiency investments, using OLS
  – Energy efficiency tax credit claims, using OLS
What *payback period* do these consumers use?

How quickly should a more energy-efficient alternative recover its additional purchase cost? (n=1217)

- Median and mean = 3 to 4 years
- Don't know
Estimated coefficient on individual discount rate when predicting preferences for energy efficiency

<table>
<thead>
<tr>
<th>Model</th>
<th>Choice-based WTP for $1 annual energy savings</th>
<th>Stated WTP for $10 annual energy savings</th>
<th>Payback Period Required for EE</th>
<th>Federal EE Tax Credit Claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1 (simple)</td>
<td>-0.017***</td>
<td>-0.100***</td>
<td>-0.076***</td>
<td>-0.028*</td>
</tr>
<tr>
<td>Model 2 (incl. income)</td>
<td>-0.016**</td>
<td>-0.100***</td>
<td>-0.075***</td>
<td>-0.024*</td>
</tr>
<tr>
<td>Model 3 (incl. income, credit score)</td>
<td>-0.016***</td>
<td>-0.080**</td>
<td>-0.061***</td>
<td>-0.019</td>
</tr>
<tr>
<td>Model 4 (incl. many controls)</td>
<td>-0.016***</td>
<td>-0.079**</td>
<td>-0.046*</td>
<td>-0.017</td>
</tr>
</tbody>
</table>

Significant at the 1***, 5**, and 10* percent levels.
Influence of characteristics of respondent and their household on their time preferences

- OLS prediction of individual elicited discount rates to understand factors influencing heterogeneity
- Education matters greatly for discount rates
  - some college (8-9% lower) and bachelors or more (13-14% lower) than no college (24%), ceteris paribus
- Black, non-hispanic respondents had higher discount rates, as did larger households
- Income has a distinct association, but not always statistically significant
  - results suggests discount rates may spike at low incomes (<$10K annually)
- Lower credit scores are associated with significantly higher individual discount rates
Main findings regarding the influence of time preferences on energy efficiency choices

- Individual willingness to invest in energy efficiency is systematically lower for those with higher discount rates, controlling for other attributes.
- Individual discount rates are quite heterogeneous, and systematically depend on education, financial status, and other demographic factors.
- Overall, findings imply that individual discount rates are critical for understanding energy efficiency investments, the energy efficiency gap/paradox, and for guiding energy efficiency policy.
For more information

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