
Hyun-gyu Kim, Michael Roberts and Arlan Brucal

University of Hawaii at Manoa

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Energy Efficiency Gap (EEG)?

- It is often asserted that consumers in the durable market have high discount rates for energy cost saving.
- Implicit Discount Rate: Capture how consumers trade off between operating cost and initial purchase price
  - Air Conditioner: 24.1%-26.4% (Hausman [1979])
  - Automobile: 30% (Beggs, Cardell, and Hausman [1981]); 9-12.6% (Train [1986])
  - Refrigerator: 40-300% (Gately [1980]); 60%-108% (Cole and Fuller [1980])
- Consumers and business often slow to invest in energy efficiency, called ”Energy Paradox” (Jaffe & Stavins, 1994)
Why the Energy Efficiency is Important?

- Mckinsey(2007) reports
  - "Energy Efficiency offers a vast, low-cost energy resource for the U.S. economy"
  - By investing $520 billion through 2020, the US can yield $1.2 trillion worth of gross energy savings
  - That will reduce end-use energy consumption by 23% of projected demand and abate 1.1 gigatons of greenhouse gases (GHG) annually
Why the Energy Efficiency is Important?

Figure: U.S. mid-range GHG Abatement Curve
Why do we need to revisit Energy Efficiency Gap?

- Previous literatures provide the evidence of EEG.
  - Cross-sectional
  - Unobservable characteristics
  - Does not meet modern standard credibility
    (Allcott and Greenstone [2012])
What is New in this Research?

- Employ the changes of interest rates and energy prices
  - Incentives to invest in energy efficiency change over time as energy prices and interest rates change
- Use the most recent panel data set (2003-2011)
  - Address potential bias from cross-sectional analysis
  - Take advantage of panel data (ex. fixed effects)
- Using Present value (PV) model
  - Present valued operating cost (PVOC)

\[
PVOC = \sum_{y=0}^{Y} (EC \times P_e)(1 + r)^{-y}
\]
Main Question

- Does demand for relatively energy efficient appliances change as interest rates and energy price change?
  - PV model says they should
  - how much provides as alternative way to estimate implicit discount rate
Contribution of this paper?

- Develops new approach to study energy efficiency gap in the appliance market
- Considers recent data that includes a near population of appliances
Bunching Energy Efficiency Rate

Energy efficiency rates of most individual appliances are bunching around minimum criteria of federal and energy star standard.

Figure: Refrigerator
Theoretical Analysis

- Consumers are assumed to choose the appliance which generates the highest level of utility

\[
\max_{j \in 1, \ldots, J} V(\Theta_1), \ldots, V(\Theta_J)
\]

- Utility of consumer i from purchasing j at time t is

\[
\max \quad U_{ijt}(ee_{jt}) \\
\text{s.t.} \quad W_t \geq PVOC_{jt} + P_{ee}ee_j
\]

F.O.C

\[
p_{ee} = -\frac{\partial PVOC_{jt}}{\partial ee_{jt}}
\]
Theoretical Analysis

- Holding all other attributes and tastes fixed, the PV model predicts that rational consumers would equally value the changes of energy efficiency price and discounted future energy cost saving when interest rates and electricity prices change.

\[ \Delta P_{ee} = \Delta PVOC \]
Theoretical Analysis

When the values of $\Delta P_{ee}$ and $\Delta PVOC$ are same, the demand curve of Estar over Non-Estar become flat with the assumption that consumers are homogeneous.

**Figure: Hedonic Equilibrium**

\[ P_{ES} - P_{NES} = PVOC_{NES} - PVOC_{ES} \]

All else the same, demand for energy efficiency is perfectly elastic, connected to present value of energy savings.
Theoretical Analysis

Discount rates and electricity prices shift demand curve of Estar over Non-estar

Figure: Hedonic Equilibrium
Results

- If all attributes of appliance are same except on energy efficiency, demand curve of ES over Non-ES becomes perfectly elastic.
- Demand curve shifts depending on the changes of interest rate and price of energy.
Empirical Estimation

\[ P_{gjt} = \beta PVOC_{gjt} + \delta_t + \alpha_j + \rho(\gamma_g \times d_t) + \varepsilon_{gjt} \]

- \( P_{gjt} \): price of \( g \) type product \( j \) at time \( t \)
- PVOC: function of present valued operating cost
- \( \delta_t \): time fixed effect
- \( \alpha_j \): model fixed effect
- \( \gamma_g \): group dummy variable, which is sorted by door type and energy star
- \( (\gamma_g \times d_t) \): interaction term of group and time dummy
- \( \beta \): valuation weight of present valued operating cost  
  \( (\beta < -1: \text{ overvaluation}, \beta > -1: \text{ undervaluation}) \)
How Much Consumers Implicitly Discount Future Energy Cost

\[ P_{gjt} = PVOC_{gjt}(ee_j, r_t, p^e, \bar{\eta}) + \delta_t + \alpha_j + \gamma_g + \rho(\gamma_g \times d_t) + \varepsilon_{gjt} \]

\[ PVOC_{gjt}(ee_j, r_t, p^e, \bar{\eta}) = OC(ee_j, p^e) \times \sum_{y=0.5}^{Y} \frac{1}{(1 + r_t + \bar{\eta})^y} \]

- \( \bar{\eta} \) reveals extra discount rates of future energy cost saving
- Everygody have fixed \( \bar{\eta} \) (homogeneous)
- Non-linear least squares with fixed effects
Data

- Point-of-sale data of individual model
  - Collected by NPD Group
  - Monthly total revenue and sales of product
  - Product characteristics
  - Price = Total revenue / Number of sales
  - Time Period: Jan 2003 - Dec 2011

- Federal Trade Commission (FTC)
  - Contain annual energy consumption and efficiency rate
Note: The solid line shows the difference in sales weighted demeaned average real price for energy star minus non-energy star, conditional on capacity and door-type group. The red dash line is the difference in sales weighted demeaned PVOC.
### Results

**Table: Estimated Relation Between Price and PVOC**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Whole</th>
<th>SSA</th>
<th>TFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVOC</td>
<td>-2.949*</td>
<td>-3.652*</td>
<td>0.318</td>
</tr>
<tr>
<td></td>
<td>(1.238)</td>
<td>(1.997)</td>
<td>(0.571)</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Time-by-group dummy</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Model fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sales weighted</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observation</td>
<td>25,372</td>
<td>16,897</td>
<td>8,475</td>
</tr>
</tbody>
</table>

Note: Observations are weighted by sales. Robust standard errors, clustered by model, are in parenthesis. *** p > 0.001, ** p > 0.05, * p > 0.1
Result of $\bar{\eta}$ Estimation

- Estimated $\bar{\eta}$: -0.173
- Consumers are add extra -17.3% of IDR on risk-free market rate
- Consumers tend to over-value future energy cost saving
When interest rate decreases, the change of relative price and market share of Estar would be smaller if consumers are heterogeneous compared to the case that consumers are homogeneous.
### Table: Estimated Relation Between PVOC and Market Share

<table>
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<tr>
<th>Variable</th>
<th>Whole</th>
<th>SSA</th>
<th>TFA</th>
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</thead>
<tbody>
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<td>(0.0058)</td>
<td>(0.0062)</td>
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<td>Time dummies</td>
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<td>Yes</td>
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</tr>
<tr>
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<td>25,372</td>
<td>16,897</td>
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</tbody>
</table>

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Change of Price Difference and Market Share

Figure: Predicted Price Change When Interest Rate Decreases by 1%

Note: In this figure, the type of refrigerator is fixed to SSA and 22 cu.ft. I used average electricity price (11 cents/kwh) and electricity consumer of ES is 571kwh and Non-ES is 668kwh.
Conclusion

- Consumers seem overvalue future energy cost saving.
- Consumers are indifferent between $1 of PVOC saving and $2.91 of extra upfront cost.
- Consumers in refrigerator market implicitly discount 17.3% less given the risk-free market rate.
Thank you!!!
Reference


