NEURAL INFORMATION PROCESSING SYSTEMS

NeurIPS 2022 Workshop

Climate Change AI

Tackling Climate Change with Machine Learning

Analyzing Micro-Level Rebound Effects of Energy Efficient Technologies

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Introduction

- ↑ energy efficiency of appliances ⇒ energy saved
- Evidence suggest otherwise
- Reason is the presence of the following in consumer behaviour:
  - Jevons Paradox (JP) - Decrease in cost ⇒ Increase in demand ⇒ Reduced impact
  - Optimism Bias (OB) - Underestimation of negative events by human's actions
- More simply stated, consumers limit their electricity consumption because of:
  - Monetary cost of electricity
  - Environmental impact
- With ↑ energy efficiency, both of the aforementioned factors ↓ ⇒ relatively ↑ energy consumption

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Dataset

- 14^{th} iteration of the residential energy consumption survey (RECS) program, 2015
- Publicly available and feature rich 'microdata'
- Data from more than 5600 randomly sampled households across USA
- For i^{th} appliance, energy consumption data (KWH^i) and energy rating (ESQ^i)
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- Since the impact of JP and OB might be different for different households, household characteristics are required as control variables

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Pre-Processing

- Households with missing data were not considered
- Omission done separately for each appliance - to maximize data availability
- List of appliances that were considered, along with the number of households (hh) that remain eligible:
  - Clothes Dryer (CD) – 4, 101 hh
  - Clothes Washer (CW) – 4, 172 hh
  - Dish Washer (DW) – 3, 501 hh
  - Freezer (FZ) – 1, 700 hh
  - Refrigerator (RF) – 4, 717 hh
  - Light Bulbs (LB) – 4, 738 hh
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Objective

- Aims to visualize behavioral shifts in consumers when they use energy efficient appliances
- Hence, we model appliances-wise energy consumption over the energy efficiency of those appliances
- If JP and OB exist:
  - Consumers using an energy efficient appliance will consume more power than their counterparts.

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Methods

- Normalize the electricity consumption data (KWH^i) for each appliance $\Rightarrow$ $nKWH^i$
- $nKWH^i$ $\Rightarrow$ target dependent variable
  Energy star qualified flag (ESQ^i) $\Rightarrow$ independent variable
- Use $hhCh_n, \forall n \in \{\text{hh characteristics}\}$ as controls
- For easy interpretation, series of multi-variate linear regressions are performed as:

$$nKWH^i = \alpha^i \cdot ESQ^i + \sum_{n=1}^{15} \beta_n^i \cdot hhCh_n + \gamma^i \quad (1)$$

- Impact of ESQ over KWH is determined from the model as:

$$\frac{\partial nKWH^i}{\partial ESQ^i} = \alpha^i \quad (2)$$

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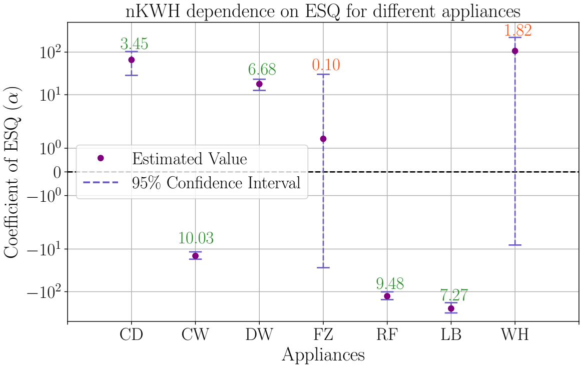

Plot showing normalized KWH dependence on ESQ for different appliances. Estimated value of the dependence parameter (α)), its 95% confidence interval and the absolute value of t-statistic are reported for each appliance. If $\alpha > 0$, appliance consumes more electricity, in general, when it is energy star qualified.

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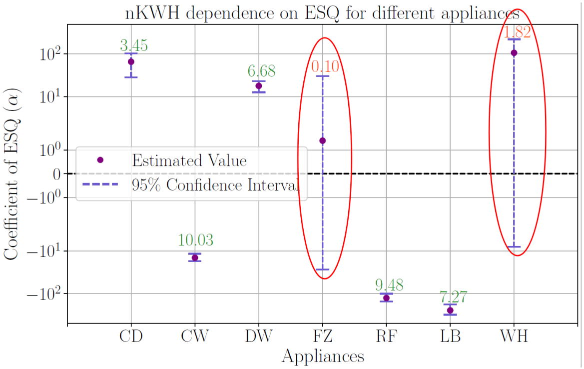

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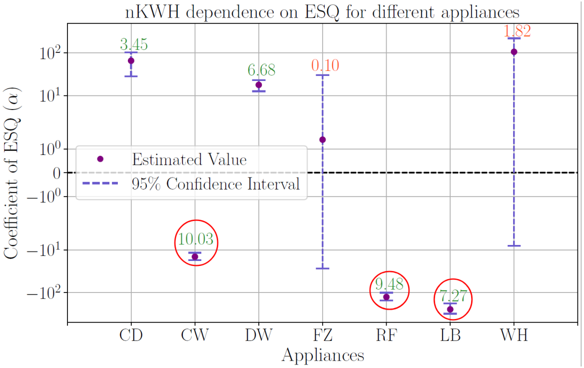

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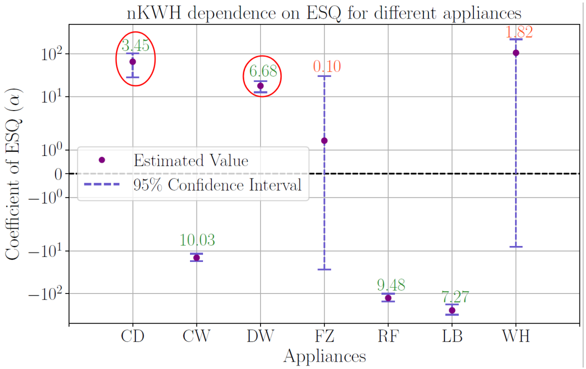

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Analysis

- **Improving energy efficiency of substitutable appliances tends to result in overall increased electricity consumption**

Varying impact of JP and OB over households

- RECS 2015 'microdata' also provides usage frequency of appliances
- Frequency trends for CW and CD are similar
- Assumption: Both CW & CD are used together
- Difference in energy consumption yet could come from the degree of drying capacity for CD
- $\therefore$ ${}^{KWH_{CD}}/_{KWH_{CW}}$ for an individual household will represent the impact of JP and OB over that household

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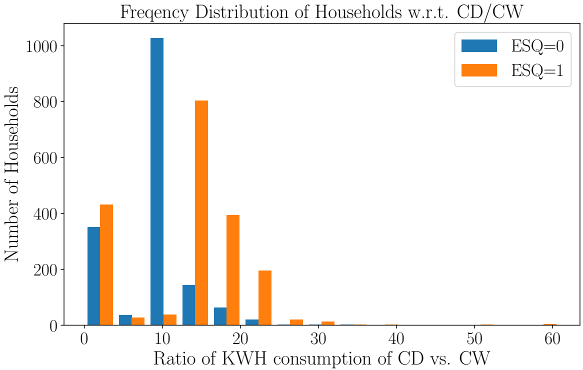

Frequency distribution of households that have both CD and CW, with respect to $^{KWH_{CD}}/_{KWH_{CW}}$. Blue bars: set of households whose both CD and CW are not energy efficient ($ESQ = 0$); Orange bars: set of households whose both CD and CW are energy efficient ($ESQ = 1$).

Conclusion

- A micro level analysis is performed to identify the reason behind individual consumer responses upon increasing efficiency of any appliance
- The paper identifies that the degree of rebound effect varies across the individuals and can only be seen in appliances which are substitutable
- Proposed an index to estimate the influence of the behavioral shifts (subject to further validation)
- In future, recommend to model target audience's behavioural shifts $\longrightarrow$ help make policy decisions
- Suggests focused policy interventions for substitutable appliances

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Thank You

https://github.com/jain15mayank/Behavioural-Study-Indicative-Tests