Smart Thermostats, Automation, and Time-Varying Pricing

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Motivation

- Time-varying pricing can help match electricity demand and supply in time and can help facilitate integration of renewables, but remains uncommon and unpopular
- Consumers are buying smart thermostats
  - Automation may complement economic incentives
  - May help correct consumer attentiveness and increase price sensitivity

- We ask:
  1.) When facing TOU prices, what are the thermal discomfort costs and monetary savings of thermostat automation?
  2.) Will consumers be willing to surrender control of their thermostat for small dollar savings?
What do we do?

- We partnered with ecobee during North American roll-out of “eco+” (includes automated TOU feature)

  - 2133 eligible households; 1319 randomly encouraged (with 80% activation rate)
  - Thermostats are already on the wall
  - Encouragement pushed via app or thermostat

- Data on HVAC compressor run-time, motion sensing, indoor/outdoor temperatures, setpoints, etc., at the thermostat-hour level

- TOU rates are default rate structure
Empirical framework

1. We estimate how compressor run-time and discomfort changes throughout the day for encouraged vs. not-encouraged households.
   • Discomfort = (observed temp. - preferred temp.) × whether motion is sensed within home.

2. We explore these changes for “often home,” “sometimes home,” and “rarely home” households.
   • Based on tercile of motion sensed in pre-treatment period.
Empirical results: Compressor run-time

- "Pre-cooling" effect from 6–7am & 10–11am
- Large decreases during peak-pricing periods
- No change in off-peak periods (aside from pre-cooling)
- → automated-TOU feature reduces hourly compressor run-time by ~62% for compliers when feature is running.

Notes: Coefficients are hourly ITT estimates for compressor run-time. 95% confidence intervals presented by the shaded area. TOU rate periods are denoted by the dashed lines.
Empirical results: Discomfort

- Majority of positive discomfort appears during on-peak times of day
- No change in discomfort in mid- or off-peak periods
- → a ~6 degree-min/hour increase in discomfort for typical peak hour when feature is running.

Notes: Coefficients are hourly ITT estimates for discomfort. 95% confidence intervals presented by the shaded area. TOU rate periods are denoted by the dashed lines.
Empirical results: “Hardly Home” households

Notes: Coefficients are hourly ITT estimates for compressor run-time (left) and discomfort (right). 95% confidence intervals presented by the shaded area. TOU rate periods are denoted by the dashed lines.
Empirical results: “Sometimes Home” households

**Comp. Run-time**

- ITT Effect on Comp. Run Time (Minutes per hour)
- Sometimes Home:
  - 7AM
  - 11AM
  - 5PM
  - 7PM

**Discomfort**

- ITT Effect on Discomfort (Degree-Minutes per hour)
- Sometimes Home:
  - 7AM
  - 11AM
  - 5PM
  - 7PM

Notes: Coefficients are hourly ITT estimates for compressor run-time (left) and discomfort (right). 95% confidence intervals presented by the shaded area. TOU rate periods are denoted by the dashed lines.
Empirical results: “Often Home” households

Notes: Coefficients are hourly ITT estimates for compressor run-time (left) and discomfort (right). 95% confidence intervals presented by the shaded area. TOU rate periods are denoted by the dashed lines.
Putting our results in context

- **Compressor run-time:**
  - All households see \( \sim C\$0.21 \) savings per day (or \( C\$4.41 \) per summer month)

- **Discomfort:**
  - 2/3 of households see a “win-win”: energy cost savings, with no changes in discomfort
  - “Always Home” households (1/3 of sample) see a small increase in discomfort
    - An average 0.75°F increase in hourly temperatures

- **Will these effects persist?**
  - Additional analysis suggests longer-run effectiveness of automation
  - Few customers turn feature off
    - “Always Home” group turns off at same rate as other groups
  - Treatment effects persist throughout experimental period
So what?

**Implications:**

- Smart thermostats are being adopted at scale (≈13% penetration in US)

- Automation can:
  - Deliver small savings with minimal discomfort costs
  - Be implemented at low marginal cost

- Per household dollar savings are small from automation, but energy savings can be nontrivial when aggregated
  - 0.56MW reduction in hourly peak demand in our experimental sample
  - 11.3MW reduction in hourly peak demand if scaled to Ecobee thermostats in California

- Automation may help lower price tag of electricity grid decarbonization
Find our working paper here:
https://www.rff.org/publications/working-papers/
smart-thermostats-automation-and-time-varying-prices/

thank you!

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