A Field Experiment on Dynamic Electricity Pricing in Los Alamos

Opt-in Versus Opt-out

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Research on Smart Grid Economics in Ida Lab

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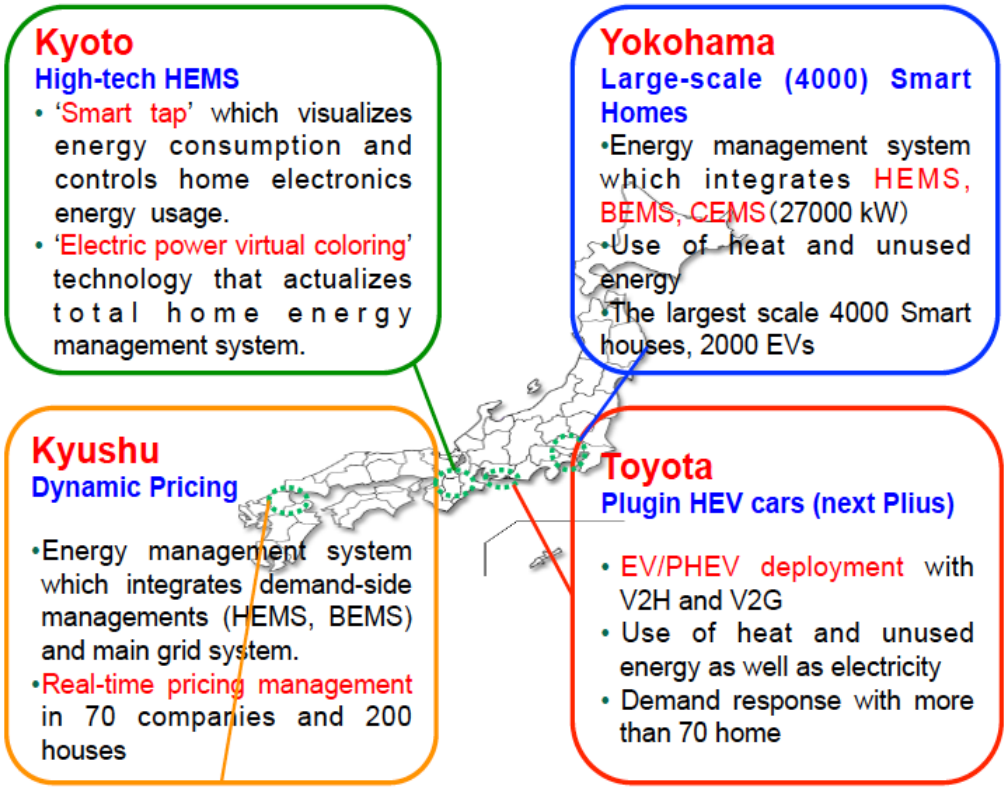
He also manages METI's social experiment programs on smart grid economics, which have been conducted in four cities (2011-2014): Yokohama, Toyota, Kyoto and Kyushu.



Demand Response Experiment in Los Alamos County

- The main objective of the Mesa Smart Meter Study is to evaluate **Peak-Cut Effects** under distinct combinations of dynamic electricity pricing programs (**Critical Peak Pricing/Peak Time Rebate**) and customer enrollment procedures (**Opt-in/Opt-out**).

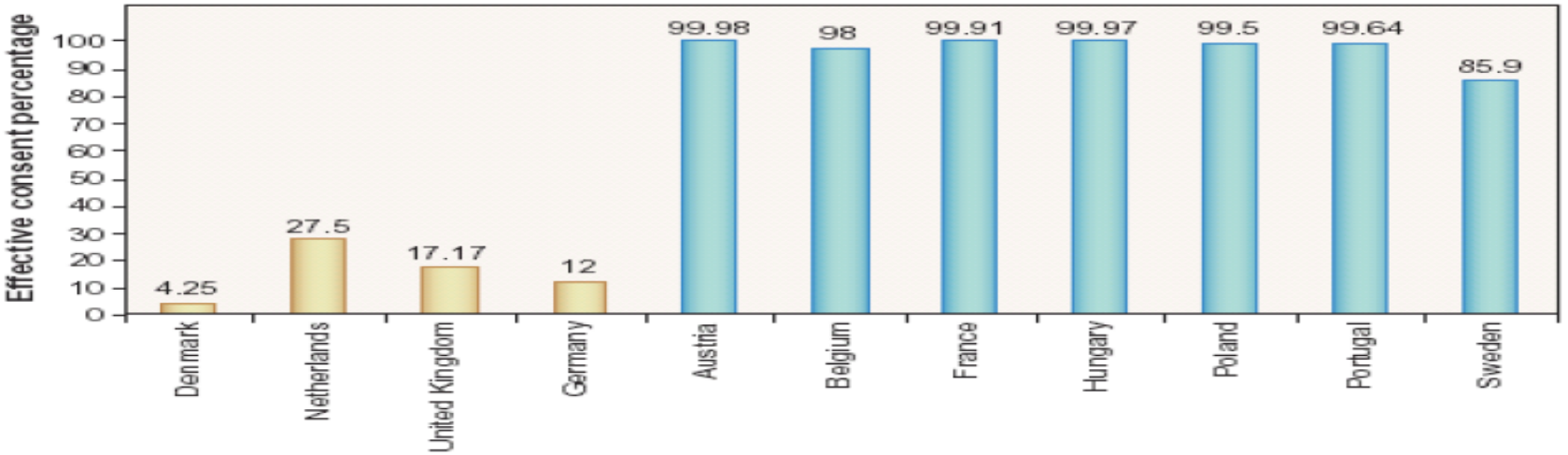
- The CPP tariff can be considered as incentive framed as **"loss"**, while the PTR tariff can be considered as incentive framed as **"gain"**. Studies in Behavioral Economics point out that "loss" always looms much larger than "gain".

- On-peak period is set to be **4pm – 7pm of weekdays**; Maximum 15 days of event days for summer and also 15 for winter.

- To ensure high reliability of results, we implement the experiment using **Randomized Control Trial (RCT)** with 3 treatment groups and 1 control group.

Decisions by Default: Opt-in Versus Opt-out

- The Los Alamos experiment is **1st in the world** to test the relative effectiveness of distinct combinations of default options **(opt-in versus opt-out)** and framing of economic incentive **(gain versus loss)**.
- Decisions by defaults have recently become an important issue in many fields (insurance, finance, marketing, medicine, energy, etc.). Individuals often have a strong tendency to choose the default option (i.e., the option assigned to them).
- Example: **Organ Donation in Europe,** explicit-consent (opt-in) countries vs. presumed-consent (opt-out) countries.



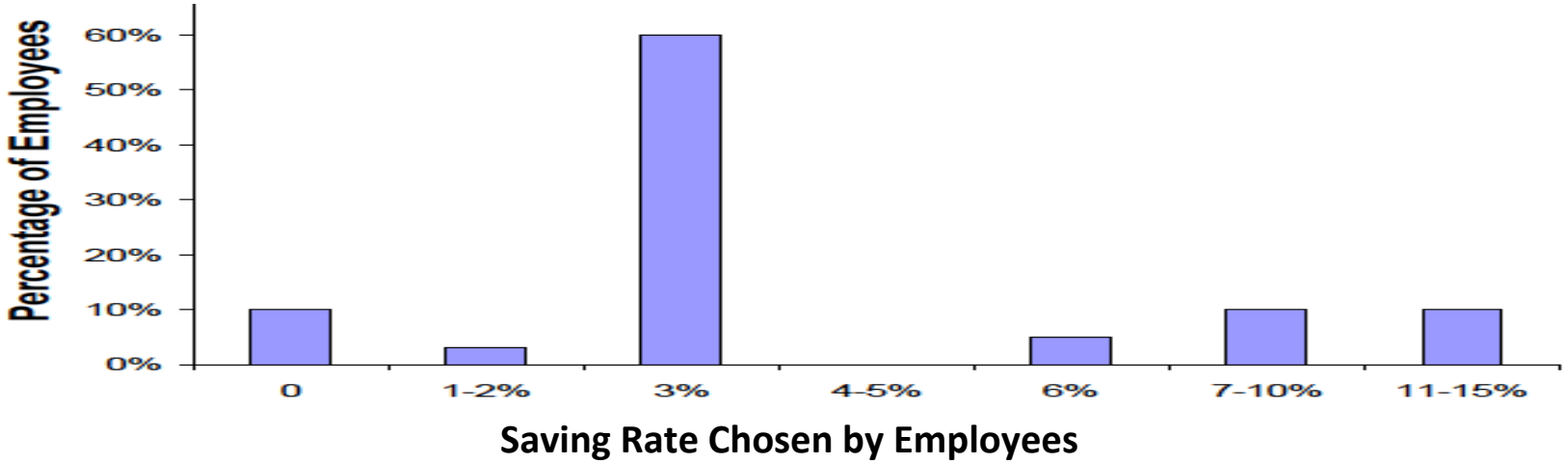
Johnson and Goldstein (2003): "Do defaults save lives?", SCIENCE, 302(5649), pp.1338-1339

Decisions by Default: Opt-in Versus Opt-out

Famous example in U.S.: **401(k) retirement saving plan**. When employees must **opt-in** the plan, less than **50%** enrolled. When they are automatically enrolled, very few **opt-out**, resulting in nearly **100%** enrollment.

However, using opt-out procedure may generate **customer inertia**: employees stick with the default saving rate (3%) of the opt-out program, leading to dramatic decrease in the number of people who choose to save more than 3%.

The problem of "default effects" can become even more complicated when **incentive can be offered either as gain or as loss**.



Madrian and Shea (2001):"The power of suggestion: inertia in 401(k) participation and savings behavior", QUARTERLY JOURNAL OF ECONOMICS, 116(4), pp.1149-1187

Insights from the Los Alamos Experiment

- **Very high customer acceptance rate** can be achieved even **under opt-in enrollment procedure**, which can be largely attributable to LAC customers' **high education levels and technology related experiences**.

- **Peak-cut Effects can be achieved** even in regions with rather **Mild Climates** (avg.max.temperature 77.2°F in summer).

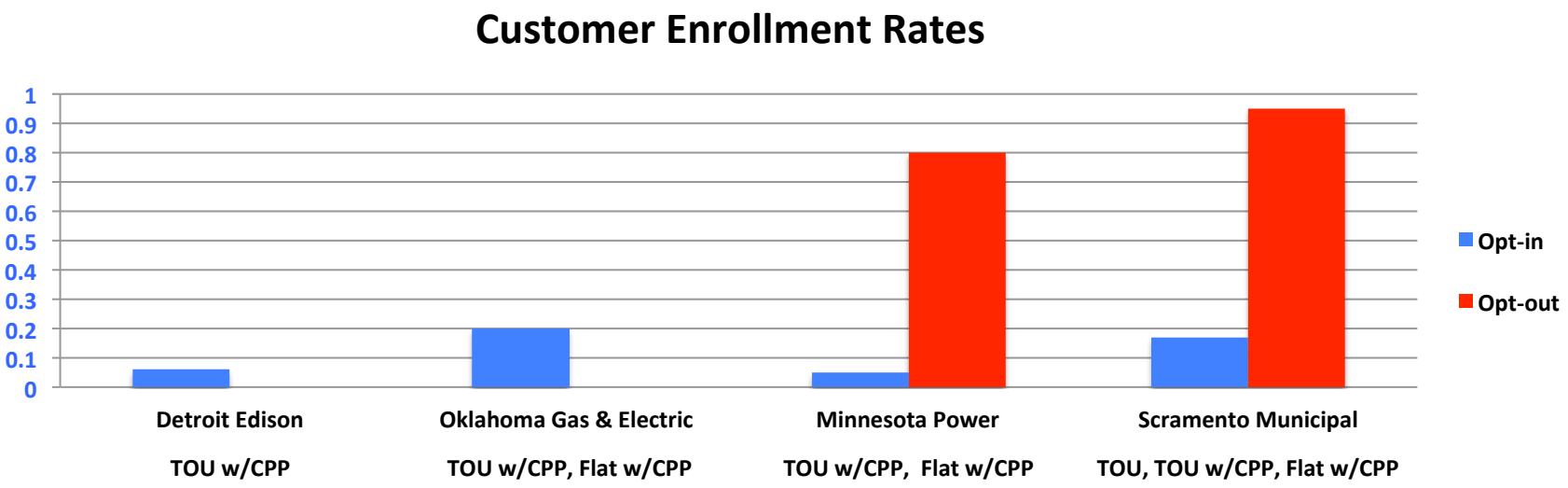
- Average Peak-cut Effects in LAC :
  - **Opt-in CPP > Opt-out CPP > Opt-out PTR**
- i.e., Opt-in x "Loss" > Opt-out x "Loss" > Opt-out x "Gain"

- Customer Welfare & Bill Impact: saving of the **opt-in CPP group dominates** that of the opt-out CPP group.

Opt-in Versus Opt-out in Dynamic Electricity Pricing

Customer enrollment rates can be quite low for opt-in pricing programs, while those for opt-out programs are extremely high.

Example: enrollment rates of several demand-response pilots conducted in U.S.: Detroit Edison (opt-in), Oklahoma Gas & Electric (opt-in), Minnesota Power (opt-in & opt-out), and Sacramento Municipal (opt-in & opt-out).



-"Smart Grid Investment Grant: Consumer Behavior Studies", U.S. Department of Energy

Existing Concerns for Dynamic Pricing Programs

There are other issues/concerns in the demand-response literature:

- **Opt-in CPP:**
- Those who choose to "opt-in" may disproportionately be **"structural winners" or "free riders":** customers who have low on-peak consumption, and thus save money under CPP rate even without changing behavior ; e.g., Borenstein (2013).

➔ **Low aggregate demand reduction impact**

- **Opt-out CPP:**
- However, it is not offered on a voluntary basis, thus can be **politically difficult** for utilities to implement in practice (less acceptable to customers/policy makers); e.g., Wolak (2010).

➔ **Less likely to be implemented in practice**

- **Opt-out PTR:**
- It can be seen as **Incentive framed as "gains"**, thus probably less effective than CPP (incentive frames as "loss"); e.g., Wolak (2010, 2011b).

➔ **"Loss Aversion" effect**: e.g., the incentive of PTR customers to save energy on very hot/cold days may be rather low, etc. We will discuss this issue further.

Customer Enrollment Rate of Opt-in CPP group

- Customer Enrollment Rates in the **Smart Pricing Option (SPO) Pilot of Sacramento Municipal Utility District:**

Opt-in CPP: 16% ~ 18% vs. **Opt-out CPP**: 93% ~ 98%

In their experiment, opt-out CPP group has generated much larger aggregate peak reduction. Indeed, opt-in CPP customers need to generate **6 times** the peak-cut effects of their opt-out counterparts to have similar aggregate impact.

- In contrast, Customer Enrollment Rate in the LAC experiment:

Opt-in CPP: 63% vs. **Opt-out CPP**: 97%

* **The conventional wisdom that "because of extremely high customer enrollment rate, peak reduction of opt-out CPP will be much larger than opt-in CPP" has been challenged by the Los Alamos experiment.**

- What factors may have led to low opt-in enrollment rate in existing studies?
- **Status quo bias, Inexperience to the related technology, Procrastination, etc.**

Customer Enrollment Rate of Opt-in CPP group

What factors may led to high Opt-in CPP enrollment rate in LAC?

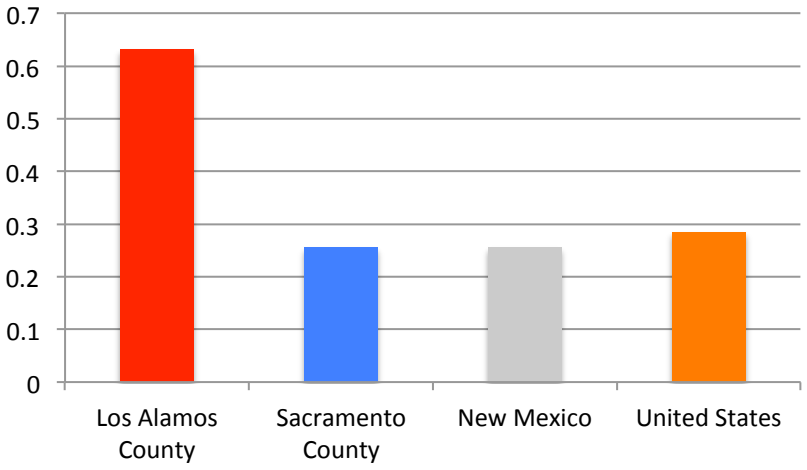
1. Bill protection

2. Education level/Experience: one of the highest education levels in U.S.; many hold Ph.D. degrees and/or work as scientists/engineers at LANL.

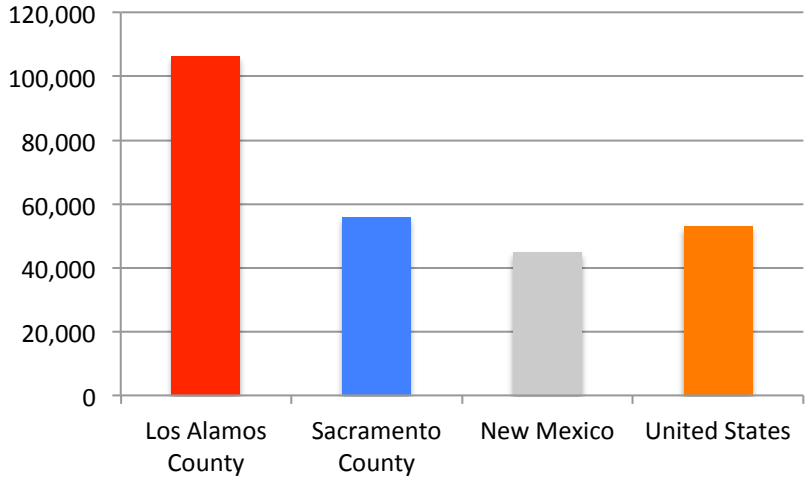
➔More open to/familiar with smart grid technologies/dynamic pricing programs;

➔More rational decision making.

Bachelor's degree or higher, percent of persons age 25+ (2008-2012)



Median household income (US$, 2008-2012)



-"State and County Quick Facts", U.S. Census Bureau

Peak-cut Impact in Regions with Mild Climates

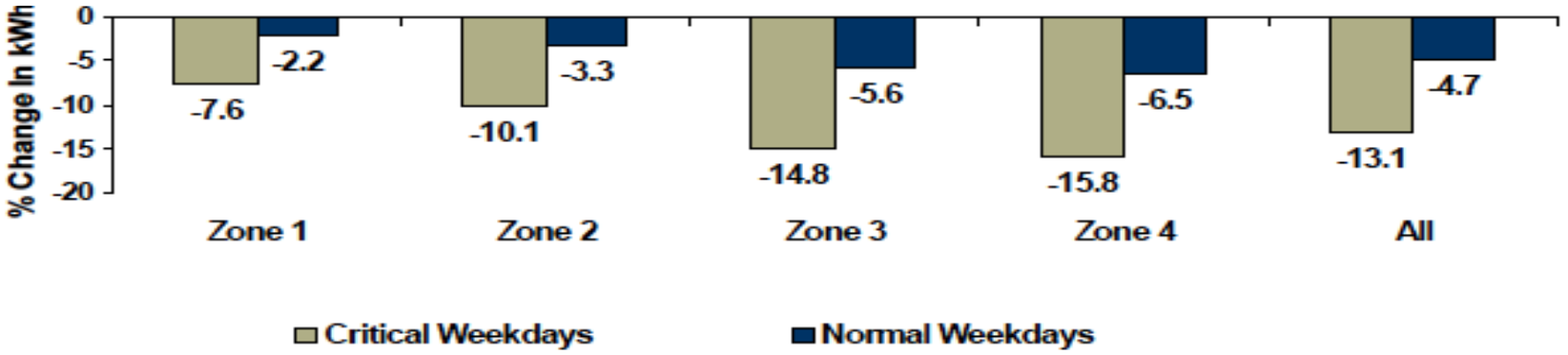
Some Characteristics of the **Los Alamos Experiment**:

1. **Mild climate**: 65.9°F (avg., Jul.-Sep.); 77.2°F (avg.max., Jul.-Sep.).
2. **Low Central Air Conditioner (CAC) saturation:** lower than 10% of households.

Almost all existing studies have been conducted in regions with hot climates. One exception is California's **Statewide Pricing Pilot (SPP).**

Avg. Temperature (Jul.-Sep.): Zone 1: 73.5°F, Zone 2: 79.4°F, Zone 3: 88.6°F, Zone 4: 98.8°F; Statewide Avg. CAC saturation: 43%.

(Net) CPP Peak-cut Effects of Zone 1-Zone 4:



City Examples for Each Climate Zone:

Zone 1: Santa Cruz; Zone 2: Long Beach; Zone 3: Sacramento; Zone 4: Lancaster.

- "Impact Evaluation of the California Statewide Pricing Pilot, Final Report", Charles River Associates

Who participate into the experiment?
&
Who choose Opt-in CPP?

- Estimation results suggest that customers with **high average daily consumption** are more likely to participate in our experiment, and among customers assigned to the opt-in CPP group, those with **high on-peak usage** are more likely to choose CPP rate, very different from standard prediction.

- Therefore, in the Los Alamos experiment, not only **"structural winners"**, but also **"structural losers"** (i.e., customers with high on-peak consumption) also choose to opt-into CPP rate. This could be very important for the success of an "opt-in" based dynamic pricing program.

- **This suggest that it is desirable to use customer tools such as Bill Protection, at least in the beginning year of the dynamic pricing program.**

*Note: we use Binary Choice model here:

- $\mathbf{Pr(y_i = 1 \mid X) = F(X'_i b)}$

- Let y=1 if "I" participates in the experiment and y=0 otherwise. "X" denotes household characteristics, e.g., average daily consumption, on-peak/off-peak ratio. F is normal distribution function. Similar specification for the analysis on opt-in CPP customers.

Estimation Results (Summer 2013)

Treatment Groups	Gross Peak-cut (Intent-to-treat)	Net Peak-cut (Treatment-on-treated)
Opt-in CPP	-6.8%*** (0.016)	-10.4%*** (0.025)
Opt-out CPP	-4.5%** (0.020)	-4.7%** (0.020)
Opt-out PTR	-3.9%** (0.020)	-4.0%** (0.021)

Gross Peak-cut: the effects of those who are offered certain treatment; important for the analysis of the **aggregate load impact**.

Net Peak-cut: the effects of those who are not only offered but also actually accepted the treatment; important for the **analysis of customer behaviors**.

Test of Equality of Average Treatment Effects

Probability(Opt-in CPP = Opt-out PTR): 10%* for Gross., 1%* for Net.**

Probability(Opt-out CPP = Opt-out PTR): 77% for Gross., 78% for Net.

Probability(Opt-in CPP = Opt-out CPP): 20% for Gross., 1%* for Net.**

Estimation Results (Winter 2013)

Treatment Groups	Gross Peak-cut (Intent-to-treat)	Net Peak-cut (Treatment-on-treated)
Opt-in CPP	-4.6%*** (0.013)	-6.9%*** (0.019)
Opt-out CPP	-4.1%*** (0.015)	-4.3%*** (0.016)
Opt-out PTR	-3.0%** (0.015)	-3.1%** (0.015)

Test of Equality of Average Treatment Effects

Probability(Opt-in CPP = Opt-out PTR): 31% for Gross., 5% for Net.**

Probability(Opt-out CPP = Opt-out PTR): 52% for Gross., 52% for Net.

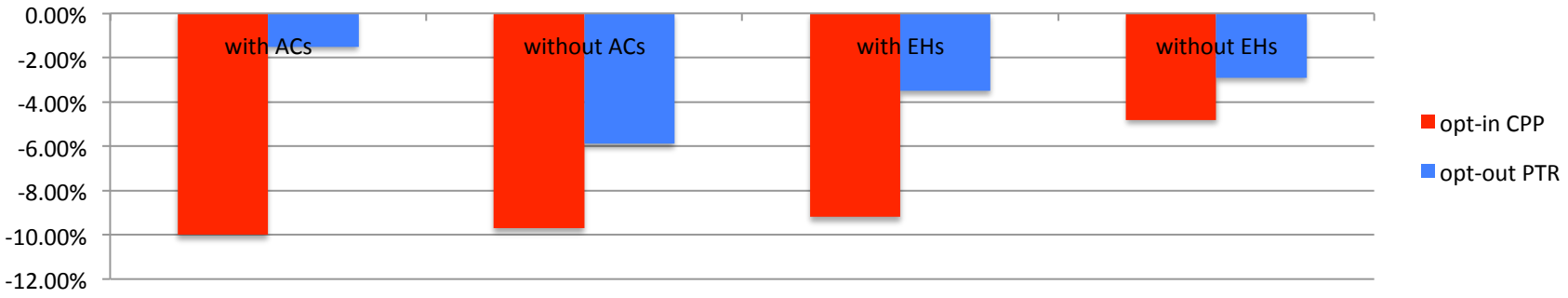
Probability(Opt-in CPP = Opt-out CPP): 77% for Gross., 19% for Net.

*Note 1: Similar to most results in the literature, the Peak-cut effects for winter are relatively lower compared with those for summer.

*Note 2: For the estimation of peak-cut effects (summer & winter), we implemented panel data regression controlling time/household fixed effects.

Subgroup Analysis with Customer Characteristics (Air Conditioners/Electric Heaters)

We separate sample into subgroups of customers with/without ACs for summer (with/without EHs for winter), and estimate (Net) Effects for each subgroup.



Remark: Opt-in CPP performs much better than opt-out PTR among households who have ACs/EHs. These results suggest there is **"loss aversion" effect** in opt-out PTR group.

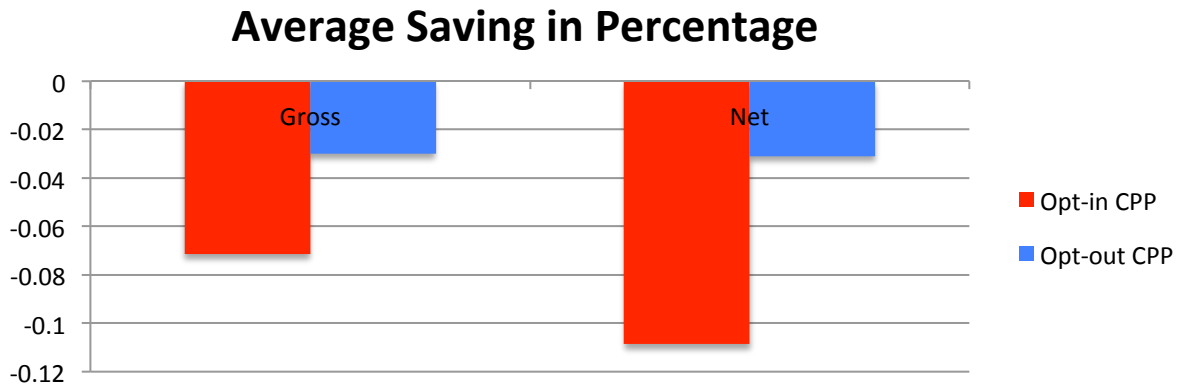
CPP: incentive framed as "Loss"; PTR: incentive framed as "Gain".

Suppose that on certain CPP/PTR event day, the weather is very hot. CPP customers with ACs still have strong incentive to adjust ACs since they face **"punishment" of high price ($0.75/kwh)**. But PTR customers do not have such strong incentive; they may choose to abandon the rebate and pay **the standard flat rate ($0.077/kwh)**.

Bill Impact and Customer Welfare

Bill saving of opt-in CPP group dominates opt-out CPP group:

1) Compared with the electricity bills of the control group, opt-in CPP customers **save 4% more (Gross Effect)** than opt-out CPP customers, and opt-in CPP customers who actually took the CPP treatment **save 7% more (Net Effect).**



2) We also observe **Polarization Effect:** customers at the tails of the distribution of electricity usage (i.e., left tail: lowest usage customers, right tail: highest usage customers) are saving more.

* **Possible reasons:** low-usage customers may be **more motivational** and high usage customers may have **more available means** to reduce peak-time usage.

THANK YOU
FOR
YOUR ATTENTION!!