Moral Suasion and Economic Incentives: Field Experimental Evidence from Energy Demand

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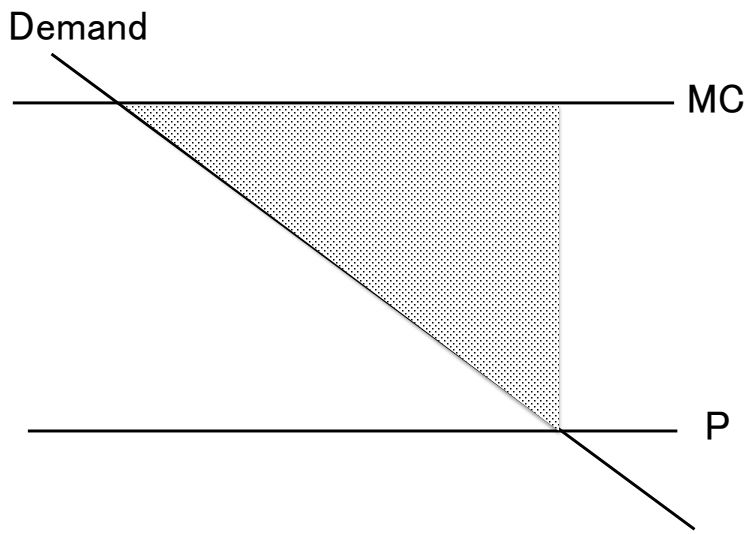
Motivation: Inefficiency in electricity markets

- Marginal cost of electricity supply is time-varying
  - Cost is particularly high in critical peak hours (example: 1pm - 4pm of a very hot summer day)
- However, consumers usually face time-invariant incentives
  - Price does not reflect MC $\rightarrow$ DWL



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    - Standard economic theory
    - p = mc should solve the inefficiency

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   - Request voluntary energy conservation
   - More popular policies in history (US, Brazil, Japan, etc.)

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   - Request voluntary energy conservation
   - More popular policies in history (US, Brazil, Japan, etc.)
   - Widely used in environmental policies (water, air pollution etc.)

Dynamic responses to these two policy instruments

- A key question for policymakers and economists is:
  - Can we generate **persistent effects** by appealing to intrinsic and extrinsic motivations? (Gneezy, Meier and Rey-Biel, 2011)

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  1. Moral suasion and economic incentives for energy conservation

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  2. Use high-frequency consumption data (each 30-min)
  3. Repeat interventions to test habituation and dishabituation
  4. Collect data after final interventions to test habit formation

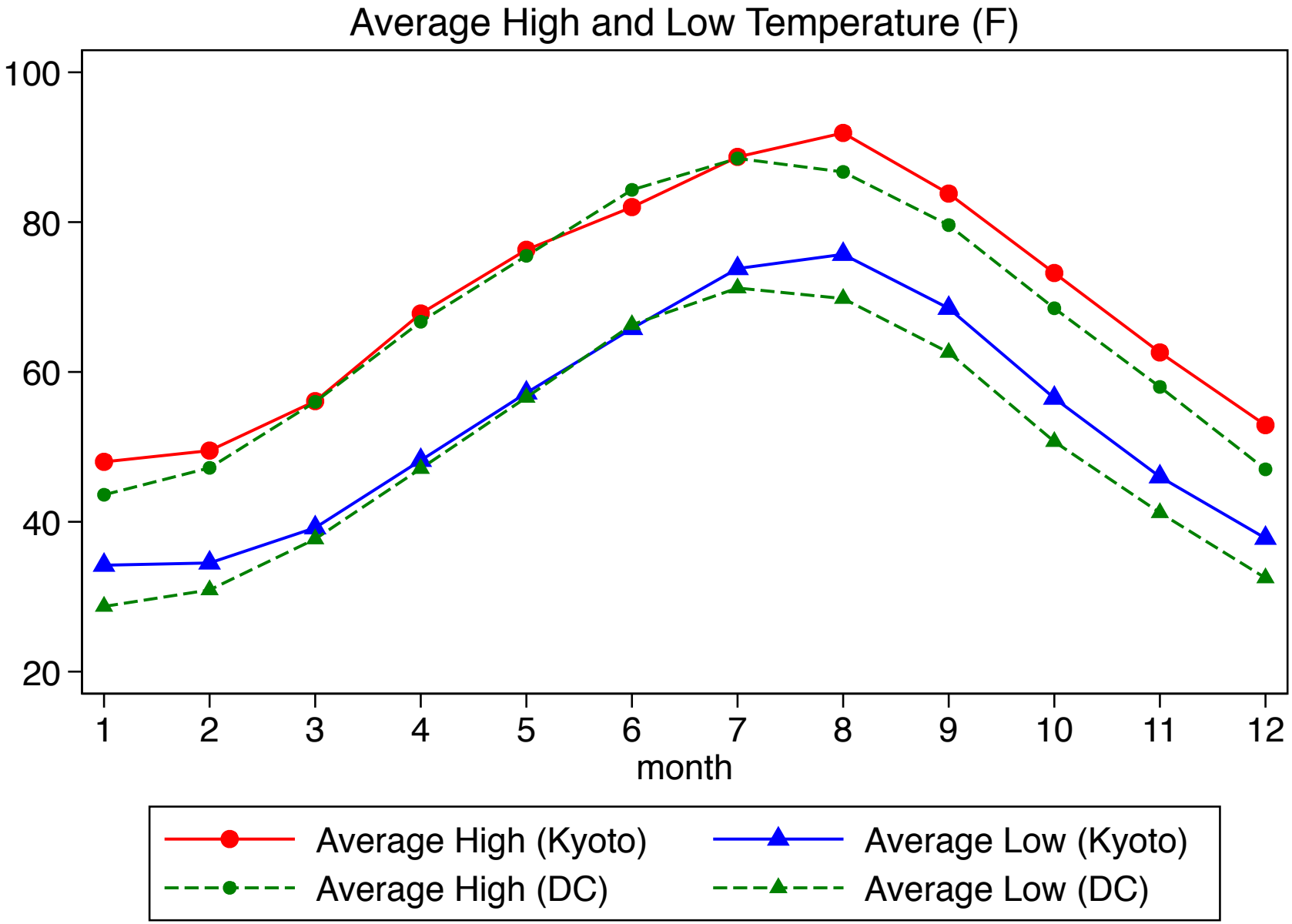
Outline of the talk

1. Introduction
2. **Experimental Design, Data, and Hypotheses**
3. Estimation and Results
4. Mechanisms Behind the Results
5. Welfare Implications
6. Conclusion

A field experiment in Kyoto, Japan

- In collaboration with the Japanese government and firms
- One of our 4 field experiments on "smart electricity grid"

Temperatures in Kyoto compared to Washington D.C.



Data

1. High-frequency household-level electricity usage data
   - Usage in each 30-minute interval
   - Pre-experiment, during experiment, and after final intervention

2. Pre-experiment survey data
   - Demographic and housing information

3. Follow-up survey data
   - Durable goods investments and lifestyle changes

Experimental design

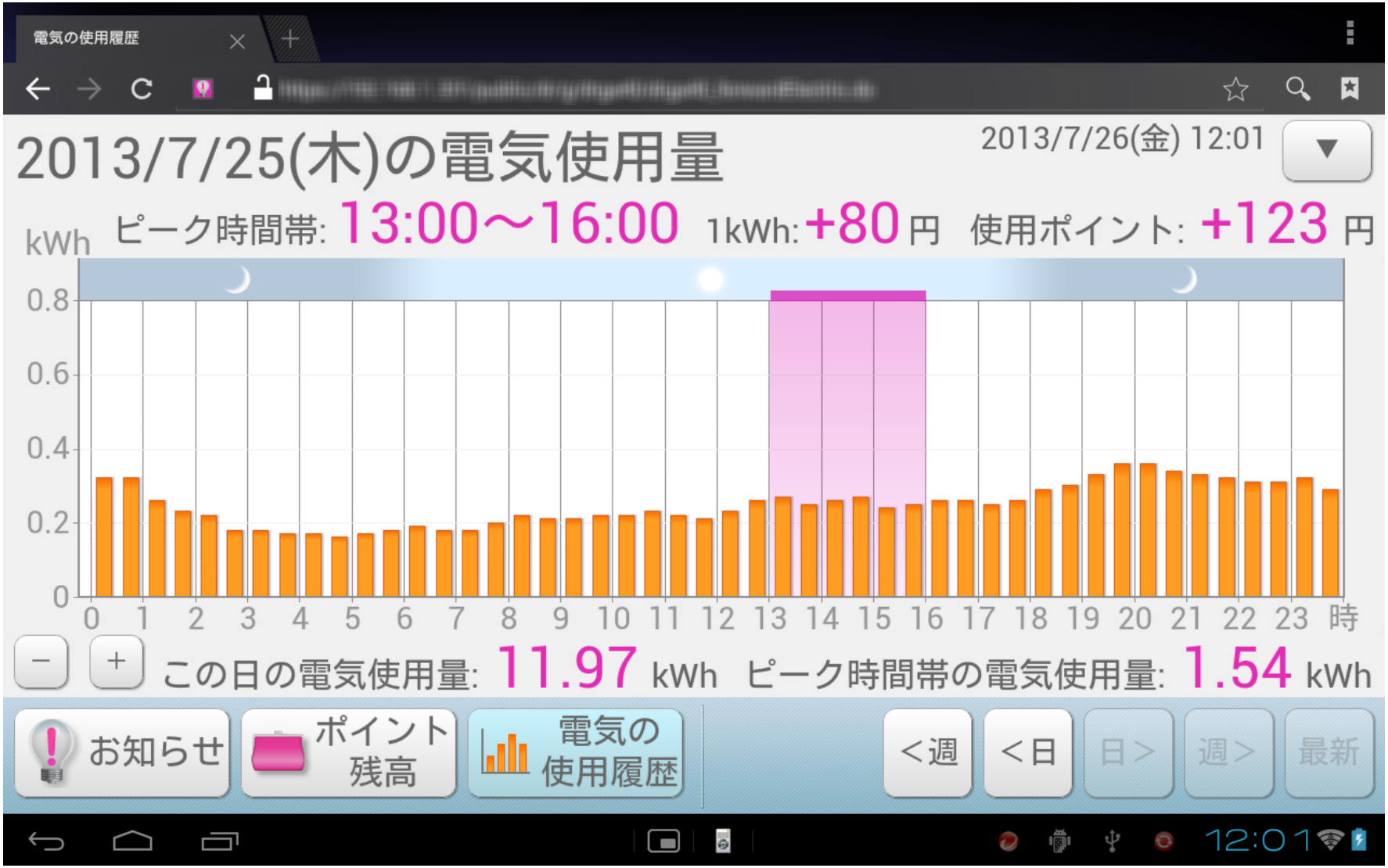
- We randomly assigned 691 participants to 3 groups
  1. Control group (153)
  2. Moral suasion group (154)
  3. Economic incentive group (384)

- All groups received participation reward ($240) and display
  - The next slide shows a screenshot of the monitor

- Randomization $\rightarrow$ Internal validity is guaranteed.

- External validity is still an important issue to investigate
  - For this purpose, we collected data of non-participants as well

All groups get in-home displays: real-time usage and price



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Summary statistics for sample in our experiment

	Sample in the Field Experiment		
	Moral Suasion (M)	Economic Incentive (E)	Control Group (C)
Electricity use (kWh/day)	15.14	15.76	15.92
	(6.91)	(8.49)	(8.47)
Household income (1,000USD)	66.74	66.59	67.06
	(31.49)	(31.34)	(31.01)
Square meter of the house	121.49	113.08	122.15
	(57.54)	(46.92)	(46.52)
Number of AC	3.46	3.50	3.68
	(1.93)	(1.67)	(1.64)
Mean age of the household	42.26	42.22	40.31
	(17.67)	(19.07)	(17.38)
Age of building (years)	13.83	13.39	13.12
	(8.25)	(7.54)	(8.20)
Household Size	3.21	3.14	3.32
	(1.18)	(1.23)	(1.25)

1. Observables are balanced by treatment group b/c of randomization

Our sample compared to a random sample of population

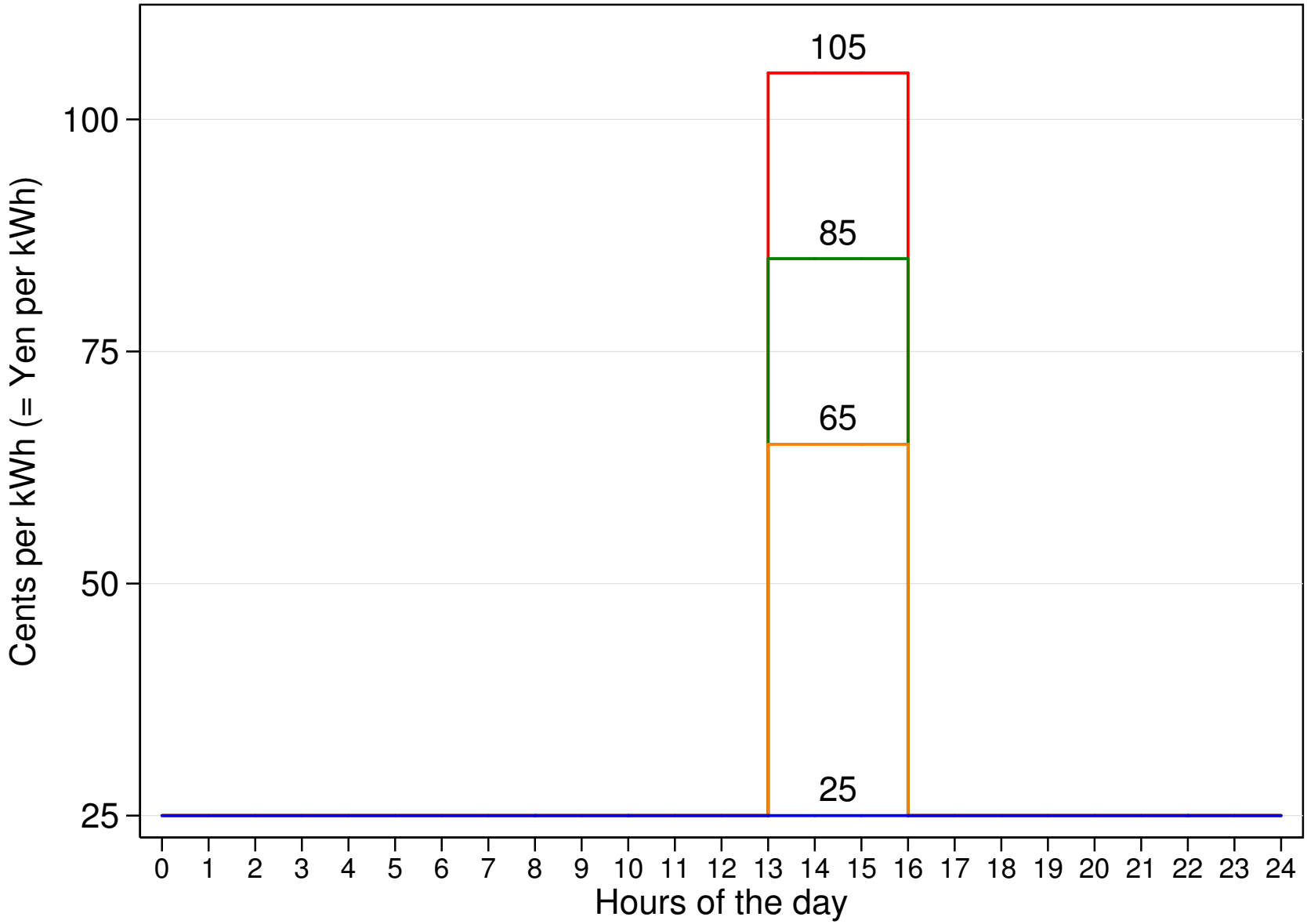
	Sample in the Field Experiment (C)	Random Sample of Population (P)	Difference [S.E.] (C)−(P)
Electricity use (kWh/day)	15.92 (8.47)	16.23 (7.97)	-0.31 [0.86]
Household income (1,000USD)	67.06 (31.01)	66.83 (41.81)	0.22 [3.93]
Square meter of the house	122.15 (46.52)	125.90 (59.65)	-3.75 [5.41]
Number of AC	3.68 (1.64)	3.95 (1.71)	-0.28 [0.16]
Mean age of the household	40.31 (17.38)	41.91 (16.76)	-1.60 [1.56]
Age of building (years)	13.12 (8.20)	15.05 (8.11)	-1.92 [0.75]
Household Size	3.32 (1.25)	2.98 (1.41)	0.34 [0.13]

1. Most observables are statistically similar
2. There's still a concern for differences in unobservables
3. "Site selection bias" (Allcott 2014) is another important issue

Treatment 1) Economic incentive

- Objective: influence extrinsic motivation for conservation
- Customers were informed:
  - "You will be charged high electricity prices during the critical peak demand hours on peak demand days. The critical peak price will be either 65, 85, or 105 cents per kWh." (note: baseline price = 25)
- Critical peak demand hours
  - 1-4pm (summer) and 6-9pm (winter) on "treatment days"
  - Treatment days were defined by day-ahead weather forecasts
- They received day-ahed and same-day notices of treatment
  - Via text message and on in-home-display

Treatment 1) Economic incentive



Procedures

- Treatment day = weekday satisfying the following condition
  - Summer: max temperature $\geq 31^{\circ}\mathrm{C}$ ($88^{\circ}\mathrm{F}$)
  - Winter: max temperature $\leq 14^{\circ}\mathrm{C}$ ($57^{\circ}\mathrm{F}$)
- Stratified randomization for three critical-peak prices
  - We define "cycle", which includes 3 treatment days
  - In each cycle, three prices (65, 85, 105) were randomized
- Total treatment days
  - 15 treatment days (5 cycles) for summer
  - 21 treatment days (7 cycles) for winter

Treatment 2) Moral suasion

- Objective: influence intrinsic motivation for conservation
- Customers were informed:
  - "Energy conservation will be required for the society during the critical peak demand hours on peak demand days, in which electricity supply would be very limited relative to demand. Please reduce your electricity usage during the critical peak hours."
- Critical peak demand hours
  - Defined exactly in the same way as economic incentive group
- They received day-ahed and same-day notices of treatment
  - Via text message and on in-home-display

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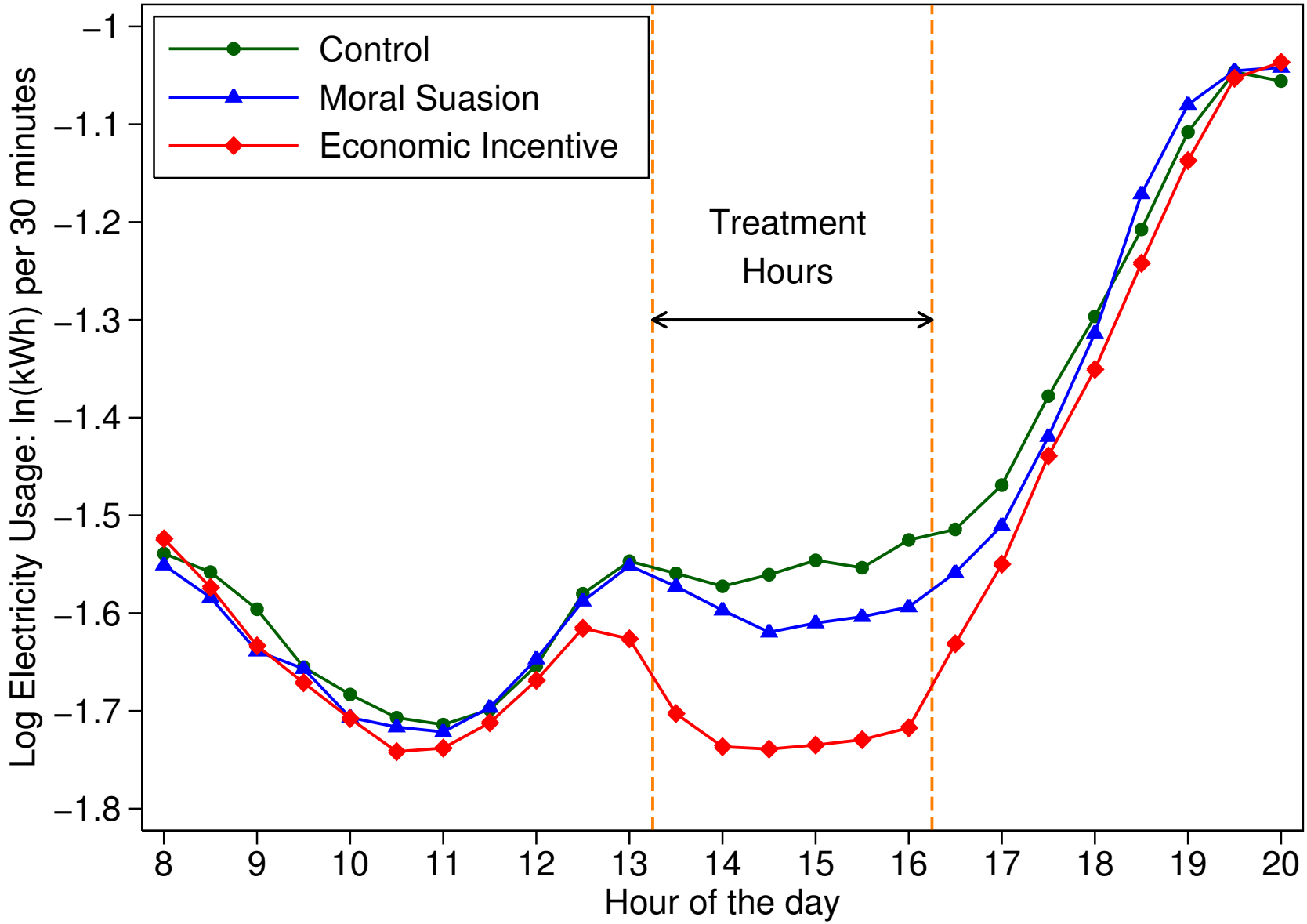
Hypotheses

1. Predictions from standard economic theory
   - Economic incentive group $\rightarrow$ reduces usage based on elasticity
   - Moral suasion group $\rightarrow$ consumes similarly to control group

2. Predictions from theory of habituation and dishabituation
   - Treatment effects may change through repeated interventions

3. Predictions from theory of habit formation
   - Our treatments could act as a trigger to change a bad habit and form a good habit of energy-efficient lifestyles

Mean ln(usage) for 30-min intervals on treatment days



1) Overall effects for all treatment days

- What were the overall effects for all treatment days?

$$\ln y_{it} = \alpha M_{it} + \beta E_{it} + \theta_i + \lambda_t + \eta_{it}$$

  - y_{it}: electricity usage for household i at 30-min interval t
  - $M_{it} = 1$ if i receives moral suasion at t
  - $E_{it} = 1$ if i receives economic incentive at t
  - θ_i, λ_t: fixed effects
  - S.E. clustered at the household level

- All treatment days (15 days for summer, 21 days for winter)
- Focus on treatment hours (summer 1-4pm, winter 6-9pm)

1) All Treatment Days: $\ln y_{it} = \alpha M_{it} + \beta E_{it} + \theta_i + \lambda_t + \eta_{it}$

	Summer		Winter	
	(1)	(2)	(3)	(4)
Moral suasion	-0.031			
	(0.014)			
Economic incentive	-0.167			
	(0.021)			
Economic incentive (price = 65)				
Economic incentive (price = 85)				
Economic incentive (price = 105)				
Observations	123106	123106	244891	244891

1. Moral suasion $= -3\%$, Economic incentive $= -15\%$
2. Price elasticity: -0.136 (summer), -0.141 (winter)
3. (Price = 65) and (Price = 105) statistically different at the 5% level

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	(0.021)		(0.022)	
Economic incentive (price = 65)		-0.151		-0.163
		(0.022)		(0.024)
Economic incentive (price = 85)		-0.167		-0.164
		(0.023)		(0.023)
Economic incentive (price = 105)		-0.182		-0.189
		(0.024)		(0.024)
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2) Repeated interventions, habituation, and dishabituation

- Were the effects persistent throughout repeated interventions?

$$\ln y_{it} = \sum(\alpha_c M_{ict} + \beta_c E_{ict}) + \theta_i + \lambda_t + \eta_{it}$$

- We divide our treatment days into cycles
- Each cycle includes 3 treatment days
- c: cycle $=$ 1 to 5 (summer), 1 to 7 (winter)

Repeated Interventions: $\ln y_{it} = \sum(\alpha_c M_{ict} + \beta_c E_{ict}) + \theta_i + \lambda_t + \eta_{it}$

	Summer		Winter	
	Moral Suasion	Economic Incentive	Moral Suasion	Economic Incentive
1st cycle	-0.083 (0.024)			
2nd cycle	-0.033 (0.025)			
3rd cycle	-0.005 (0.029)			
4th cycle	-0.015 (0.028)			
5th cycle	-0.003 (0.028)			
6th cycle				
7th cycle				

1. Moral suasion $\rightarrow$ quickly diminish.

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3rd cycle	-0.005 (0.029)		0.003 (0.029)	
4th cycle	-0.015 (0.028)		-0.033 (0.029)	
5th cycle	-0.003 (0.028)		-0.011 (0.026)	
6th cycle			-0.016 (0.030)	
7th cycle			-0.011 (0.031)	

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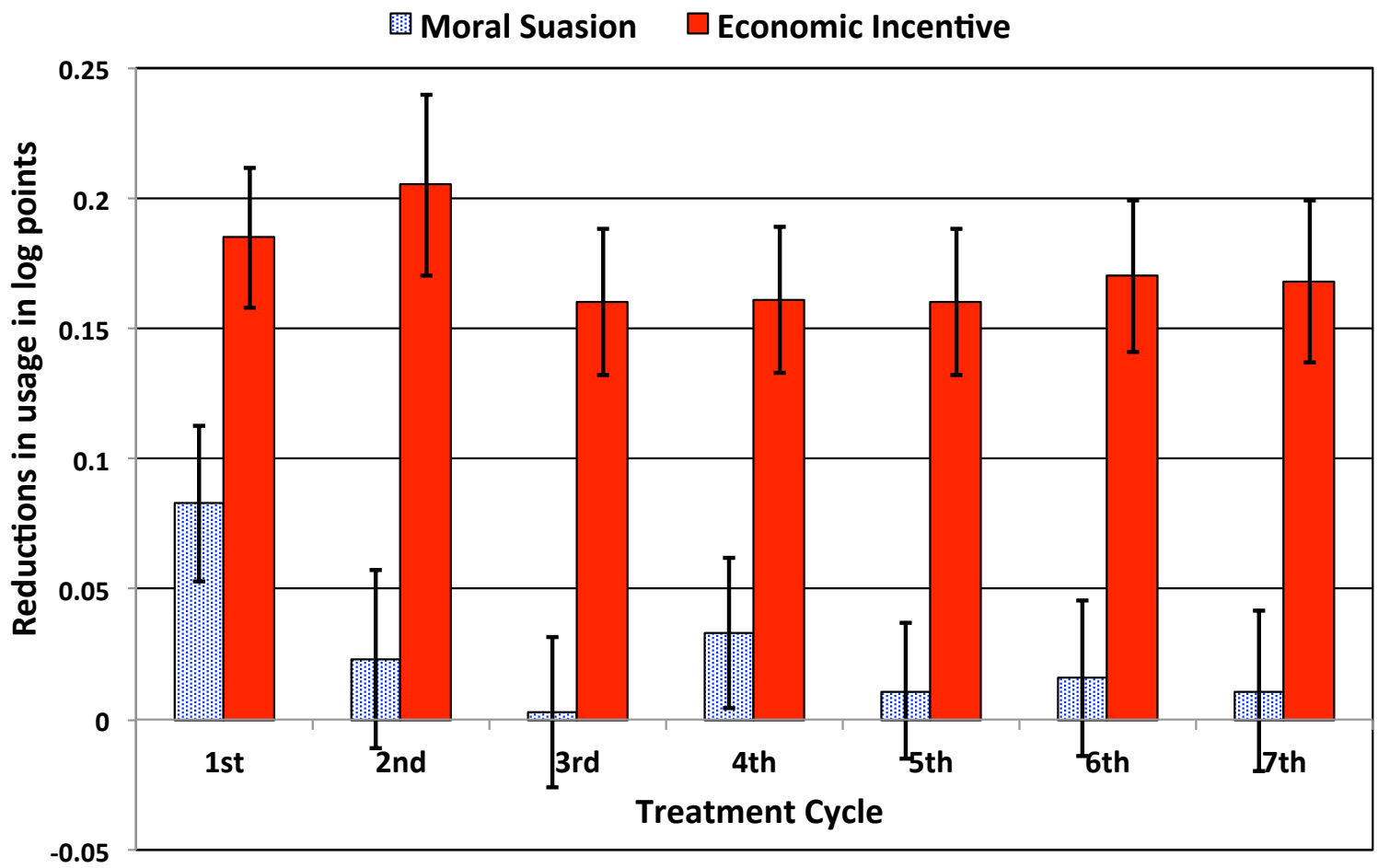
	Summer		Winter	
	Moral Suasion	Economic Incentive	Moral Suasion	Economic Incentive
1st cycle	-0.083 (0.024)	-0.184 (0.023)	-0.083 (0.030)	-0.185 (0.027)
2nd cycle	-0.033 (0.025)	-0.198 (0.027)	-0.023 (0.034)	-0.205 (0.035)
3rd cycle	-0.005 (0.029)	-0.174 (0.028)	0.003 (0.029)	-0.160 (0.028)
4th cycle	-0.015 (0.028)	-0.154 (0.029)	-0.033 (0.029)	-0.161 (0.028)
5th cycle	-0.003 (0.028)	-0.127 (0.031)	-0.011 (0.026)	-0.160 (0.028)
6th cycle			-0.016 (0.030)	-0.170 (0.029)
7th cycle			-0.011 (0.031)	-0.168 (0.031)

1. Moral suasion → quickly diminish. Economic incentive → persistent


Moral Suasion
Economic Incentive
0.25
0.2
0.15
0.1
0.05
0
-0.05
Reductions in usage in log points
1st
2nd
3rd
4th
5th
6th
7th
Treatment Cycle

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3) Spillover effects for non-treatment hours

- Were there spillover effects on usage in non-treatment hours?

$$\ln y_{it} = \alpha M_{it} + \beta E_{it} + \theta_i + \lambda_t + \eta_{it}$$

- Two hypotheses:

1. Changes in relative price $\rightarrow$ off-peak usage may increase
2. Fixed cost of lifestyle change $\rightarrow$ off-peak usage may decrease

- An important question for environmental externalities
  - Total emissions could increase (Holland and Mansur 2008)

3) Spillover effects for non-treatment hours

	Summer		
	Treatment Hours (1pm-4pm)	Shoulder Hours (10am-1pm, 4pm-7pm)	Other Hours
	(1)	(2)	(3)
Moral suasion	-0.031	-0.010	-0.008
	(0.014)	(0.010)	(0.005)
Economic incentive	-0.167	-0.060	-0.022
	(0.021)	(0.015)	(0.010)
Observations	123106	248621	634387

1. Moral suasion $\rightarrow$ small reductions, although statistically insignificant
2. Economic incentive $\rightarrow$ significant reductions in non-treatment hours
3. Robust results for the winter

- Implication: customers may have a fixed adjustment cost of lifestyle change, which can be triggered by our treatment

4) Habit formation after the treatment was removed

- Did the effects remain after we removed the tratements?

$$\ln y_{it} = \alpha M_{it} + \beta E_{it} + \theta_i + \lambda_t + \eta_{it}$$

- Usage in three-month periods after the final interventions
- Hypotheses:

1. No habit formation $\rightarrow$ usage will be similar to control group
2. Habit formation $\rightarrow$ usage will be different from control group

4) Habit formation after we removed the treatment

Table : Habit Formation After the Treatments Were Withdrawn

	After Summer Experiment (1)	After Winter Experiment (2)
Moral suasion	0.006	0.021
	(0.028)	(0.026)
Economic incentive	-0.077	-0.069
	(0.034)	(0.022)
Observations	426770	478605

1. Moral suasion $\rightarrow$ no evidence of habit formation
2. Economic incentive $\rightarrow$ usage reductions remained after interventions

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What are mechanisms behind our findings?

Results from the experiment:

- Economic incentives resulted in larger and persistent effects

Two hypotheses:

1. Treatment may have triggered durable goods investments
   - Survey durable goods investments

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1. Treatment may have triggered durable goods investments
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2. Treatment may have triggered behavioral changes in lifestyle
   - Survey lifestyle changes in terms of energy efficiency

1) Durable goods investments

	Dependent variable: binary choice				
	Room AC	Refrigerator	Washer	Electric fan	Light bulb
	(1)	(2)	(3)	(4)	(5)
Moral suasion	0.08	0.01	0.01	-0.00	0.03
	(0.04)	(0.03)	(0.03)	(0.05)	(0.05)
Economic incentive	0.09	-0.01	0.01	-0.01	-0.03
	(0.03)	(0.03)	(0.02)	(0.04)	(0.04)
Constant	0.06	0.08	0.05	0.23	0.29
	(0.03)	(0.02)	(0.02)	(0.03)	(0.04)
Observations	640	640	640	640	640

1. DepVar = 1 if the household purchased an energy-efficient appliance
2. Room AC: Moral suasion $\rightarrow$ increased by 8 percentage points
3. Room AC: Economic incentive $\rightarrow$ increased by 9 percentage points
4. This evidence does not fully explain our findings from experiment

2) Behavioral changes in lifestyle

	Energy-efficient lifestyle	Energy-efficient use of appliances (Dependent variable: binary choice)				
	(Degree: 1 to 5)	AC	Heater	PC	Washer	Cleaner
	(1)	(2)	(3)	(4)	(5)	(6)
Moral suasion	0.13	-0.00	0.08	0.01	-0.03	-0.03
	(0.08)	(0.06)	(0.06)	(0.05)	(0.04)	(0.04)
Economic incentive	0.40	0.13	0.15	0.09	0.08	0.12
	(0.07)	(0.05)	(0.05)	(0.04)	(0.03)	(0.04)
Constant	3.03	0.61	0.53	0.11	0.08	0.07
	(0.06)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)
Observations	626	626	626	626	626	626

1. Do you try to use energy at home energy-efficiently? (score 1 to 5)
2. Do you try to use energy for each appliance energy-efficiently?
3. Economic incentive $\rightarrow$ significant effects on lifestyle changes

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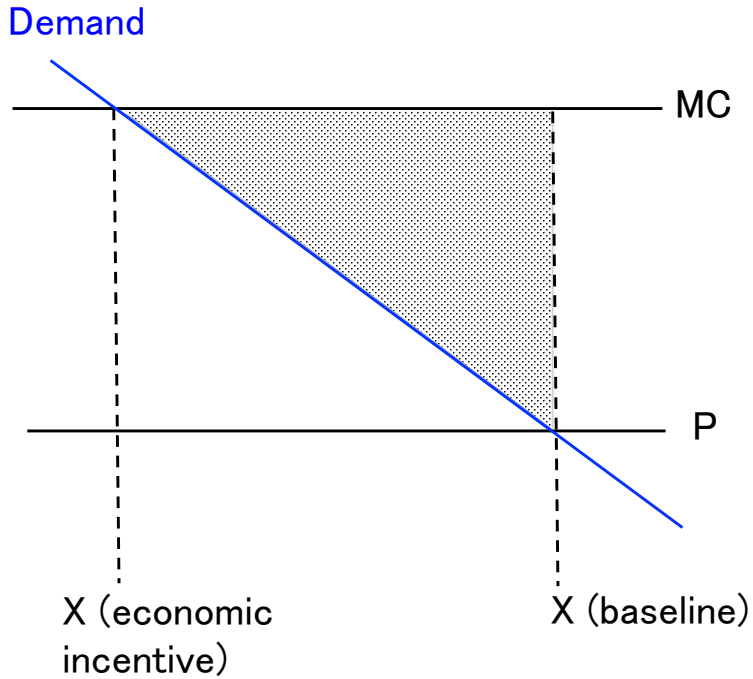
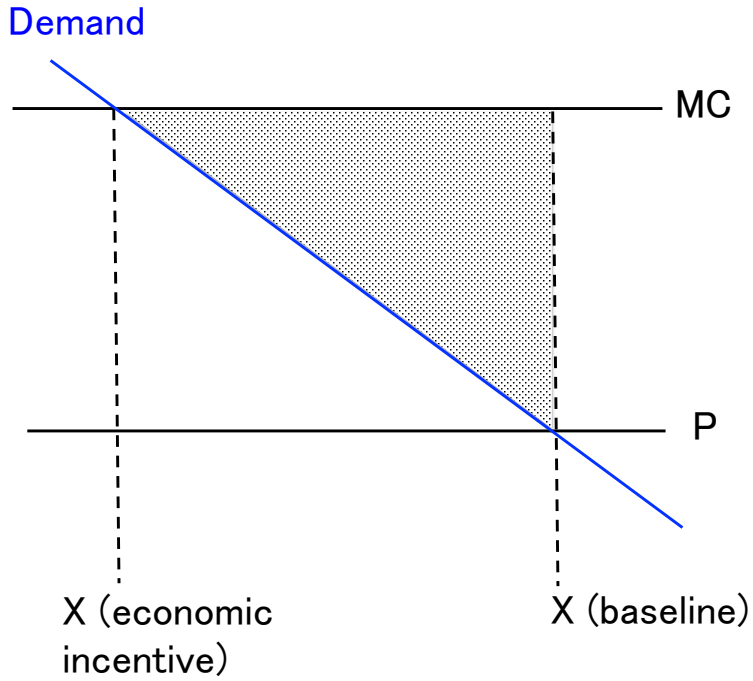
1) Welfare gains from economic incentives



- Estimate welfare gains for the Japanese electricity market
  - Peak residential demand = 46,800 MWh
  - Consider MC = 65 cents/kWh (more results in Appendix)
  - Baseline price = 25 cents, new price = 65 cents
  - Use price elasticity that is obtained from our experiment

1) Welfare gains from economic incentives



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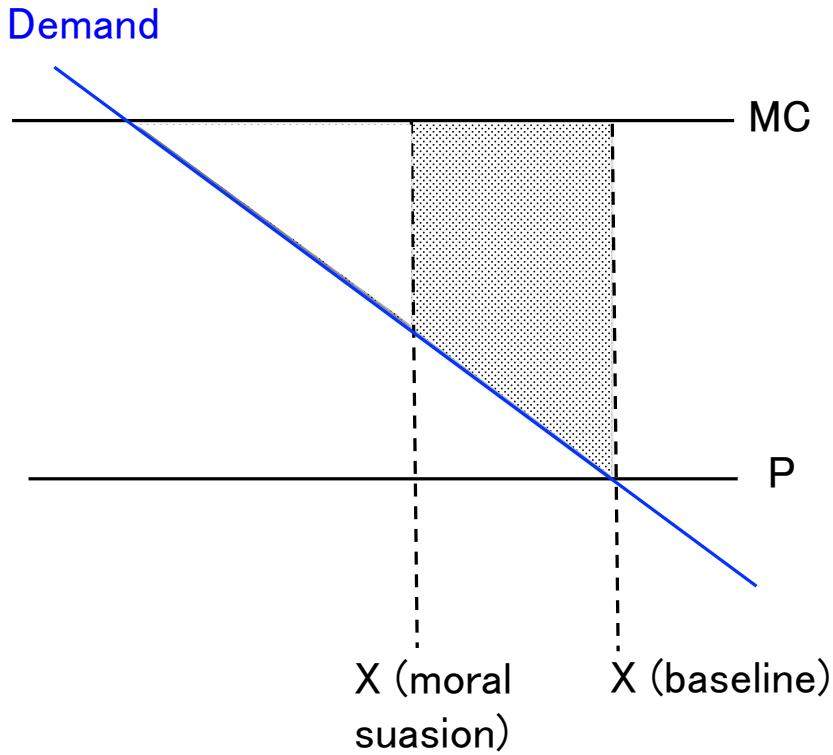
  - Peak residential demand = 46,800 MWh
  - Consider MC = 65 cents/kWh (more results in Appendix)
  - Baseline price = 25 cents, new price = 65 cents
  - Use price elasticity that is obtained from our experiment

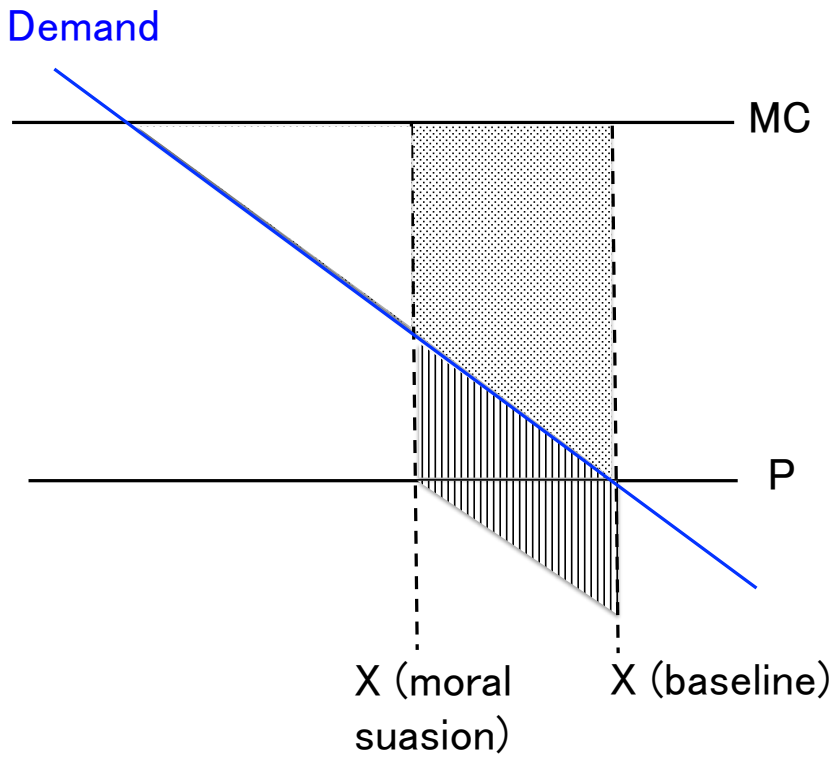
- Calculate welfare gains for two scenarios
  - Short-time policy (3 treatment days)
  - Repeated policy (15 treatment days)

2) Welfare gains from moral suasion



- 1) Efficiency gain
  - Because consumption is more closer to optimal level

2) Welfare gains from moral suasion



- 2) If consumers obtain warm-glow for the conservation
  - The upper triangle = "lower bound" of warm-glow
  - This triangle = loss in consumer surplus
  - With demand function: $\ln x = a + \alpha D_{moral} + \epsilon \ln p$, warm-glow is the parallelogram

Welfare gains from two policies

	Economic incentive	Moral suasion	
	Efficiency Gain ($M)	Efficiency Gain ($M)	Efficiency Gain + Warm Glow ($M)
Short-Run Treatments (3 days)	16.84 (1.99)	11.37 (2.55)	15.02 (4.62)
Repeated Treatments (15 days)	76.55 (9.04)	24.40 (9.92)	27.32 (12.38)

1. For the short-run, both policies provide substantial welfare gains
2. Repeated treatments: Moral suasion $\rightarrow$ small additional gain
3. Repeated treatments: Economic incentive $\rightarrow$ large additional gain

Conclusion

- **Field experiment on household electricity demand**
  - Use 30-minute interval usage data to observe lifestyle changes

- **Results from the experiment**
  1. Moral suasion $\rightarrow$ effective in short-run
  2. Moral suasion $\rightarrow$ diminish quickly after repeated interventions
  3. Economic incentive $\rightarrow$ larger, persistent, habit formation

- **Mechanism**
  1. Durable goods investments did not fully explain our findings
  2. Behavioral changes in lifestyle were likely to be a main channel

- **Welfare implications**
  - For short-run, both policies provide substantial welfare gains
  - Repeated treatments $\rightarrow$ policy implications differ substantially

What's next? An ongoing field experiment on tariff choice

- **How to get customers into "efficient" electricity tariff?**
  - Mandatory dynamic pricing is politically infeasible
  - Realistically, many policymakers have to rely on "opt-in" policy

- **Randomly assigned 3 opt-in policies for dynamic pricing**
  1. Control group
  2. Opt-in
  3. Opt-in + "Counterfactual Bill"
  4. Opt-in + "Counterfactual Bill" + "Upfront Cash Incentive"

- **Several interesting questions**
  1. Which policy can maximize "opt-in"?
  2. Which policy can obtain "price-elastic" customers?
  3. Which policy can generate largest total usage reductions?

Thank you!

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