Do Consumers Respond to Marginal or Average Price?
Evidence from Nonlinear Electricity Pricing

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Nonlinear pricing is widely used in many important economic policies

- **Example 1: Income taxation**

  ![Marginal income tax rates (%)](image-url) in 2010 in the US
Nonlinear pricing is widely used in many important economic policies

- Example 2: Electricity, cell phone, natural gas, and water pricing

Electricity prices (cents per kWh) in Southern California Edison in 2007
Research question: How do consumers respond to nonlinear price schedules?


2. Laboratory experiments find: Many individuals respond to Average Price.

Economic theory and laboratory evidence provide different predictions.
Research question: How do consumers respond to nonlinear price schedules?

1. Standard economic theory predicts:
   - Consumers respond to **Marginal Price**

2. Laboratory experiments find:
   - Many individuals respond to **Average Price**

- **Demand Curve**
- **Marginal Price (MP)**

- **Monthly Consumption**
- **Marginal Price (cents per kWh)**
Research question: How do consumers respond to nonlinear price schedules?

1. Standard economic theory predicts:
   - Consumers respond to **Marginal Price**

2. Laboratory experiments find:
   - Many individuals respond to **Average Price** = (Total payment / Quantity)

⇒ Standard theory and laboratory evidence provide different predictions
Why do we care about “Marginal price” vs. “Average price”?

- It will change welfare implications of nonlinear taxation/pricing

![Demand Curve with Marginal Price (MP) and Average Price (AP)]

- Existing literature analyzes welfare based on “marginal price response”
  - Optimal taxation (Mirrlees 1971)
  - Electricity pricing (Reiss and White 2005)
  - Water pricing (Olmstead, Hanemann, and Stavins 2007)
Why do we care about “Marginal price” vs. “Average price”?  

- The mystery of “no bunching”  
  - Bunching should be found if consumers/taxpayers respond to marginal price  
  - Exception: Chetty, Friedman, Olsen, and Pistaferri (2011)
Why do we care about “Marginal price” vs. “Average price”?

“No bunching” implies two possibilities:

- Elasticity is nearly zero, or
- Consumers respond to other perception of price rather than marginal price
I exploit a nearly ideal research environment in electricity markets in California

**Edison** (Southern California Edison) provides electricity for the north side

**San Diego** (San Diego Gas & Electric) provides electricity for the south side
Households experience substantially different nonlinear pricing

- **Edison** and **San Diego**: Cents per kWh in 2002

![Graph showing monthly consumption](image-url)
My research design addresses two challenges in previous studies

(1) Lack of clean counterfactual groups

- Comparable individuals usually face exactly the same tax/price schedule
- Difficult to find a clean control group ⇒ **Identification problems**
- This study: **Nearly identical households experience different price schedules**
My research design addresses two challenges in previous studies

(2) Lack of sufficient exogenous price variation

- MP and AP are highly collinear in a typical nonlinear price schedule
- Multicollinearity problem ⇒ Inconclusive results
  - Liebman and Zeckhauser (2004), Borenstein (2009)

- This study: Rich cross-sectional & time-series price variation
My estimation results provide several key findings

1. Consumers respond to average price rather than marginal price
2. Consumers respond to lagged price rather than contemporaneous price
3. Short-run price elasticity wrt one-month lagged average price: -0.14
4. This average price response changes welfare implications in two ways
   - It makes nonlinear pricing less successful in energy conservation
   - It changes the efficiency costs of nonlinear pricing
The cap-and-trade program proposed in 2009:

- 30% of permits will be given to electric utilities for free
- Concern: lowering electricity price may discourage conservation
- Existing proposal: distribute **a fixed credit to electricity bills**
- Rationale behind: a fixed credit does not change marginal price

However, if consumers respond to average price,

- The fixed credit may also discourage conservation because consumers see it as a price decline in average price (Burtraw 2009)
I begin with an overview of the research design

Road map

1. Introduction
2. Research Design
3. Estimation
4. Welfare Analysis
5. Conclusion
Research Design

Three key components:

1. The territory border of two electric utilities lies within city boundaries
2. I specifically focus on households within one mile of the utility border
3. The two utilities independently change their price schedules

Nearly identical households experience different nonlinear price schedules
The territory border lies within several city boundaries in Orange County, CA.

**Edison** (Southern California Edison) provides electricity for the north side.

San Diego (San Diego Gas & Electric) provides electricity for the south side.
Why is the territory border here?

- It is because of the history of transmission line development.
- In 1940’s, Edison’s and San Diego’s transmission lines were connected here:
  - Crawford and Society (1991)
  - Myers (1983)
- Most city boundaries in this area were established around 1980’s.
I focus on households within 1 mile of the utility territory border

**Edison** (Southern California Edison) provides electricity for the north side

**San Diego** (San Diego Gas & Electric) provides electricity for the south side
Data: A panel data set of household-level monthly billing records

- **Main data:** Panel data of household-level monthly electricity billing records
  - January 1999 to December 2008 (10 years)

1. Customer ID
2. Nine-digit ZIP code (e.g. 94720-5180)
3. Price schedules
4. Billing period (e.g. May15-Jun14)
5. Electricity consumption (kWh) during the billing period

- **Additional data:** Demographic variables from Census 2000
Within 1 mile of the border, household characteristics are nearly identical

<table>
<thead>
<tr>
<th>Household characteristic</th>
<th>SCE side</th>
<th>SDG&amp;E side</th>
<th>T-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household size</td>
<td>2.69</td>
<td>2.75</td>
<td>-0.48</td>
</tr>
<tr>
<td>Per capita income</td>
<td>38809</td>
<td>39690</td>
<td>-0.67</td>
</tr>
<tr>
<td>%Households with annual income below 20k</td>
<td>6.85</td>
<td>6.37</td>
<td>0.48</td>
</tr>
<tr>
<td>20-40k</td>
<td>13.37</td>
<td>12.65</td>
<td>0.84</td>
</tr>
<tr>
<td>40-60k</td>
<td>15.53</td>
<td>14.97</td>
<td>0.35</td>
</tr>
<tr>
<td>60-100k</td>
<td>29.62</td>
<td>28.72</td>
<td>0.42</td>
</tr>
<tr>
<td>over 100k</td>
<td>34.52</td>
<td>37.38</td>
<td>-1.01</td>
</tr>
<tr>
<td>Median home value</td>
<td>364143</td>
<td>375987</td>
<td>-0.84</td>
</tr>
<tr>
<td>Median monthly rent</td>
<td>1388</td>
<td>1411</td>
<td>-0.19</td>
</tr>
<tr>
<td>Ave. daily electricity use (kWh) in Aug 1999:</td>
<td>21.88</td>
<td>21.89</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

- Each variable shows the mean value on each side of the utility border
In contrast, households experience substantially different nonlinear pricing.
In contrast, they experience substantially different nonlinear pricing.

- **Edison** and **San Diego**: Cents per kWh in 2002

![Graph showing nonlinear pricing for Edison and San Diego]
In particular, they experience different MP and AP

- Marginal price (solid) and average price (dashed): Cents per kWh
In tier 3, MP is similar, but AP is higher in SDG&E

- Marginal price (solid) and average price (dashed): Cents per kWh
In tier 4, MP is lower but AP is higher in SDG&E

- Marginal price (solid) and average price (dashed): Cents per kWh
I first explain my identification strategy and then present results.

Road Map

1. Introduction
2. Research Design

3. Estimation
   1. Identification strategy
   2. Results

4. Welfare Analysis
5. Conclusion
Four steps to explain my identification strategy

1. Price is a function of consumption $\Rightarrow$ OLS estimates will be biased
2. Changes in price schedules can be used to estimate demand
3. Several studies show that identifying assumptions are violated in a conventional method
4. I use a spatial discontinuity to address this challenge
1) Price is a function of consumption ⇒ OLS estimates will be biased

\[ \ln x_{it} = \alpha + \beta \ln p_{ut}(x_{it}) + \varepsilon_{it} \]

- \( x_{it} \): consumption of household \( i \) at time \( t \)
- \( p_{ut} \): price schedule in electric utility \( u \) at time \( t \)
2) Changes in price schedules can be used to estimate demand
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2) Changes in price schedules can be used to estimate demand.

![Diagram showing price schedules for Household A and Household B]
2) Changes in price schedules can be used to estimate demand.
2) Changes in price schedules can be used to estimate demand

\[ \Delta \ln x_{it} = \alpha + \beta \Delta \ln p_{ut}(x_{it}) + \varepsilon_{it} \]

- Previous studies use simulated instruments (policy-induced price changes):
  \[ \Delta \ln p_{ut}^{PI}(x_{it}) = \ln p_{ut}(x_{it_0}) - \ln p_{ut_0}(x_{it_0}) \]

- Typically, the first stage is very strong
- An identification assumption: a parallel trend between A and B
3) Several studies show that the parallel trend assumption is likely to be violated

- Reason (1) Mean reversion in consumption
  - Saez, Slemrod, and Giertz (2009)
3) Several studies show that the parallel trend assumption is likely to be violated

- Reason (2) Changes in the distribution of consumption
4) I use a spatial discontinuity in electricity service areas to address this challenge.
4) I use a spatial discontinuity in electricity service areas to address this challenge.

- **Electric utility A**
  - At time $t = 0$, prices are constant across regions A and B.
  - At time $t = 1$, prices increase for customers in region B.

- **Electric utility B**
  - At time $t = 0$, prices are constant across regions A' and B'.
  - At time $t = 1$, prices remain the same for customers in regions A' and B'.

**Parallel trend assumptions:** between A and A', and between B and B'

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Econometric estimation

- Control mean-reversion in a non-parametric way
- Make small bins of $x_{i,t_0}$

$$G_g = 1\{g < x_{i,t_0} \leq g + k\}$$

- Estimate 2SLS:

$$\Delta \ln x_{i,t} = \beta \Delta \ln p_{i,t} + \lambda_{t,g} + \mu_{u,g} + \gamma Z_{i,t} + \varepsilon_{it}$$

- using the policy-induced price change as an instrument:

$$\Delta \ln p_{u,t}^{PI}(x_{it}) = \ln p_{u,t}(x_{i,t_0}) - \ln p_{u,t_0}(x_{i,t_0})$$

- Zip-level time dummy $\gamma_{zip,t}$ and weather variables: CDD, CDD$^2$, HDD, HDD$^2$

- Identification assumption:
  - In the absence of price change, $E[\Delta \ln x_{i,t} | x_{i,t_0}]$ should have parallel trends between households within 1 mile of the service area are border
  - This is an untestable assumption, but I can look at $E[\Delta \ln x_{i,t} | x_{i,t_0}]$ for the time when there was no different price change between the two electric utilities
Now I present results

Road Map

1. Introduction
2. Research Design
3. Estimation
   1. Identification strategy
   2. Results
4. Welfare Analysis
5. Conclusion
I find no bunching at any point of the monthly billing data

  - Elasticity wrt marginal price can be estimated by estimating bunching
- My estimation based on this method leads to nearly zero elasticity
  - Then, consumers do not respond to electricity price at all?
  - The next analysis shows that consumers “do” respond to electricity price
The difference-in-differences analysis

Electric utility A

Electric utility B

A

B

A'

B'

Q

Q

Price

Price

t = 0

t = 1
The difference-in-differences analysis: Consumers respond to price changes

- For example, this figure shows the DD for from 1999 to 2000

\[ DD = \frac{\triangle \ln x_{i,t}^{SDG&E}}{\triangle \ln x_{i,t}^{SCE}} \]

- Relative changes for SDG&E customers relative to SCE customers.
- Parallel trend assumptions hold from January to May 2000
Relative changes for SDG&E customers relative to SCE customers.

Panel A. Consumers whose previous year’s consumption is on tier 4
Relative changes for SDG&E customers relative to SCE customers.

January billing months

Panel A. Consumers whose previous year’s consumption is on tier 4
Relative changes for SDG&E customers relative to SCE customers.

January billing months

Panel A. Consumers whose previous year’s consumption is on tier 4
Relative changes for SDG&E customers relative to SCE customers.

January billing months

Panel A: Consumers whose previous year’s consumption was at tier 4

![Graph showing changes in price and consumption from 1998 to 2008.](image)
Panel A: Consumers whose previous year’s consumption was at tier 4
Relative changes for SDG&E customers relative to SCE customers.

January billing months

Panel B. Consumers whose previous year’s consumption was at tier 3

![Graph showing changes in price and consumption from 1998 to 2008. The x-axis represents years from 1998 to 2008, and the y-axis represents differences in price and consumption as a percentage. The graph includes lines for Marginal Price, Average Price, and Consumption.]
1. Marginal price vs average price:
2. Contemporaneous price vs lagged prices
3. Heterogeneous price elasticities by income level
4. Heterogeneous price elasticity by consumption level
5. A more general way of identifying consumers’ perceived price
Estimation results: Marginal Price v.s. Average Price (Contemporaneous price)

\[ \Delta \ln x_{i,t} = \beta_1 \Delta \ln mp_{i,t} + \beta_2 \Delta \ln ap_{i,t} + \lambda_{t,g} + \mu_{u,g} + \gamma Z_{i,t} + \varepsilon_{it} \]

- An encompassing test between marginal price and average price

**2SLS Estimates: Marginal Price vs. Average Price**

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dln(MP)</td>
<td>-0.074</td>
<td></td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.008)</td>
<td></td>
</tr>
<tr>
<td>dln(AP)</td>
<td></td>
<td>-0.105</td>
<td>-0.115</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>6,513,600</td>
<td></td>
</tr>
</tbody>
</table>

- Dependent variable: dln(Electricity consumption)
- Standard errors are clustered at the household level to account for serial correlation
2SLS Estimates: Marginal Price vs. Average Price

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dln(MP_{t-1})</td>
<td>-0.103</td>
<td></td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td></td>
<td>(0.013)</td>
</tr>
<tr>
<td>dln(AP_{t-1})</td>
<td></td>
<td>-0.143</td>
<td>-0.152</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>5,807,960</td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable: dln(Electricity consumption)

Standard errors are clustered at the household level to account for serial correlation
Estimation Results

1. Marginal price vs average price:
2. Contemporaneous price vs lagged prices
3. Heterogeneous price elasticities by income level
4. Heterogeneous price elasticity by consumption level
5. A more general way of identifying consumers’ perceived price
### Estimation results: Contemporaneous Average Price v.s. Lagged Average Prices

#### 2SLS Estimates: Average Price vs. Lagged Average Price

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δln(AP)</td>
<td>-0.105</td>
<td>0.013</td>
<td>0.010</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.007)</td>
<td></td>
</tr>
<tr>
<td>Δln(AP\textsubscript{t-1})</td>
<td>-0.139</td>
<td>-0.123</td>
<td>-0.119</td>
<td>-0.115</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>Δln(AP\textsubscript{t-2})</td>
<td></td>
<td></td>
<td></td>
<td>-0.011</td>
<td>-0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.008)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Δln(AP\textsubscript{t-3})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>N</td>
<td>5,862,240</td>
<td>5,807,960</td>
<td>5,807,960</td>
<td>5,753,680</td>
<td>5,699,400</td>
</tr>
</tbody>
</table>

- Dependent variable: dln(Electricity consumption)
- Standard errors are clustered at the household level to account for serial correlation
Marginal price vs average price:
Contemporaneous price vs lagged prices
Heterogeneous price elasticities by income level
Heterogeneous price elasticity by consumption level
A more general way of identifying consumers’ perceived price
Heterogeneous Price Elasticity by Income Level

<table>
<thead>
<tr>
<th>Income level</th>
<th>Lower</th>
<th>Higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>d\ln(\text{AP}_{t-1})</td>
<td>-0.157</td>
<td>-0.114</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>N</td>
<td>2,903,980</td>
<td></td>
</tr>
</tbody>
</table>

- Dependent variable: d\ln(\text{Electricity consumption})
- Standard errors are clustered at the household level to account for serial correlation
Heterogeneous Price Elasticity by Consumption Level

<table>
<thead>
<tr>
<th>Consumption level</th>
<th>Lower</th>
<th>Higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>dln(AP_{t-1})</td>
<td>-0.140</td>
<td>-0.146</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.009)</td>
</tr>
</tbody>
</table>

N = 2,903,980

- Dependent variable: dln(Electricity consumption)
- Standard errors are clustered at the household level to account for serial correlation
Estimation Results

1. Marginal price vs average price:
2. Contemporaneous price vs lagged prices
3. Heterogeneous price elasticities by income level
4. Heterogeneous price elasticity by consumption level
5. A more general way of identifying consumers’ perceived price
Is average price the price that consumers respond to?

- I provide evidence that consumers respond to average rather than marginal.
- However, it does not exclude other possibilities.
  - e.g. Consumers may respond to **Expected Marginal Price** (Saez 1999).

![Diagram](image-url)
## Estimation results: Expected Marginal Price vs. Average Price

### 2SLS Estimates: Expected Marginal Price vs. Average Price

<table>
<thead>
<tr>
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<th>(1)</th>
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<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \ln(\text{EMP}) )</td>
<td>-0.081</td>
<td></td>
<td>-0.020</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td></td>
<td>(0.021)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta \ln(\text{AP}) )</td>
<td></td>
<td>-0.105</td>
<td>-0.110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.026)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta \ln(\text{EMP}_{t-1}) )</td>
<td></td>
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<td></td>
<td>-0.113</td>
<td>-0.026</td>
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<td>(0.004)</td>
<td>(0.021)</td>
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<td>-0.139</td>
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<td>(0.025)</td>
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<tr>
<td>N</td>
<td>5,862,240</td>
<td>5,862,240</td>
<td>5,862,240</td>
<td>5,807,960</td>
<td>5,807,960</td>
<td>5,807,960</td>
</tr>
</tbody>
</table>
More generally, price perception can be modeled in the following way

- Consider consumer $i$ with consumption $y_{it}$
- Consider that the consumer’s perceived price can be modeled as a weighted average of possible marginal prices for this consumer
- Consumer $i$ constructs her perceived price based on her weight distribution
More generally, price perception can be modeled in the following way

- Perceived price = AP when the weight distribution is uniform [0, \( y_{it} \)]
More generally, price perception can be modeled in the following way:

- **Perceived price** = MP when the weight distribution is truncated locally around $y_{it}$.
More generally, price perception can be modeled in the following way:

- Perceived price = Expected MP when the weight distribution is symmetric and surrounded broadly around $y_{it}$
More generally, price perception can be modeled in the following way

- The goal is to estimate the weight distribution
- One way to do is to examine the goodness of fit with different prices
  - Start with a regression with the local marginal price at $y_{it}$
  - Gradually add surrounding marginal prices to construct a new perceived price
  - Run the regression with a new price to see how the goodness of fit changes
How does the goodness of fit change?

- $R^2$ changes from 0.31 to 0.32 as the percentage change from actual consumption varies from -100 to 100.

![Graph showing the change in $R^2$](image-url)
Marginal gain in the goodness of fit

-0.002
-0.001
0
0.001
0.002

Marginal gain in $R^2$

-100
-80
-60
-40
-20
0

% change from actual consumption

-0.002
-0.001
0
0.001
0.002

Marginal gain in $R^2$

0
20
40
60
80
100

% change from actual consumption
Joint estimation of price elasticity and price perception weighting parameters

\[ \Delta \ln x_{i,t} = \beta \Delta \ln p(\theta_1, \theta_2)_{i,t} + \lambda_{t,g} + \mu_{u,g} + \gamma Z_{i,t} + \varepsilon_{it} \]

- Assume an asymmetric triangular distribution with slopes \( \theta_1, \theta_2 \)
- Find \( \theta_1, \theta_2 \) that minimizes the sum of squared residuals
- Results: \( \theta_1^* = 93.54, \theta_2^* = 4.37 \)
Does the sub-optimal response change welfare implications of nonlinear pricing?

Road Map

1. Introduction
2. Research Design
3. Estimation

Welfare Analysis

4. The effects on energy conservation
   1. The effects on efficiency costs of nonlinear pricing

5. Conclusion
Welfare implication 1: The effects on energy conservation

- Many electric utilities introduce nonlinear pricing to reduce GHG emissions
- “Flat rate tariff” vs “Nonlinear tariff” for energy conservation
Welfare implication 1: The effects on energy conservation

Results: Compared to a flat rate design, the existing five-tier nonlinear pricing

1. Reduces total consumption if consumers respond to Marginal Price
2. Slightly increases total consumption if consumers respond to Average Price

<table>
<thead>
<tr>
<th></th>
<th>Flat rate tariff</th>
<th>Five-tier Tariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption (Gwh)</td>
<td>20501</td>
<td>19413</td>
</tr>
<tr>
<td>%Change from Flat Rate Tariff</td>
<td>-5.31%</td>
<td>0.54%</td>
</tr>
<tr>
<td>Standard Errors by Delta Method</td>
<td>(0.88%)</td>
<td>(0.09%)</td>
</tr>
</tbody>
</table>
Welfare implication 1: The effects on energy conservation

**Results:** Compared to a flat rate design, the existing five-tier nonlinear pricing

1. Reduces total consumption if consumers respond to **Marginal Price**
2. Slightly increases total consumption if consumers respond to **Average Price**

<table>
<thead>
<tr>
<th></th>
<th>Flat rate tariff</th>
<th>Five-tier Tariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption (Gwh)</td>
<td>20501</td>
<td>19413</td>
</tr>
<tr>
<td>%Change from Flat Rate Tariff</td>
<td>-5.31%</td>
<td>0.54%</td>
</tr>
<tr>
<td>Standard Errors by Delta Method</td>
<td>(0.88%)</td>
<td>(0.09%)</td>
</tr>
</tbody>
</table>
Welfare implication 2: The effect on the efficiency costs of nonlinear pricing

Road Map

1. Introduction
2. Research Design
3. Estimation
4. Welfare Analysis
   4.1 The effects on total consumption
   4.2 The effects on efficiency costs of nonlinear pricing
5. Conclusion
Welfare implication 2: The effect on the efficiency costs of nonlinear pricing

- Suppose that the MC of electricity:
  - Does not depend on the *level* of an individual household’s monthly consumption
  - Minimum efficiency cost if $P = MC$

![Graph showing the relationship between marginal cost and demand. The marginal cost is a horizontal line at 15 cents per kWh, and the demand curve is a downward sloping curve.](image-url)

Marginal Cost

Demand

Monthly Consumption as Percent of Baseline (%) 0 100 200 300 400 500

Cents Per kWh 0 10 15 20 25 30 35

Marginal Price

Average Price
Welfare implication 2: The effect on the efficiency costs of nonlinear pricing

- Suppose that the MC of electricity:
  - Does not depend on the level of an individual household’s monthly consumption
  - Nonlinear pricing creates efficiency costs
The sub-optimal response reduces the DWL if the social MC

Results: Average price response →

1. Reduces the DWL when the social MC of electricity ≤ 21.13 kWh
2. Increases the DWL when the social MC of electricity > 21.13 kWh

![Graph showing deadweight loss (DWL) vs. social marginal cost of electricity (cents/kWh).]
I conclude by summarizing the results

Road Map

1. Introduction
2. Research Design
3. Data
4. Estimation
5. Welfare Analysis
6. Conclusion
I conclude by summarizing the results

This paper examines how consumers respond to nonlinear pricing:

- Exploit price variation across the territory border of two electric utilities

Key findings:

1. Consumers respond to average price rather than marginal price
2. Consumers respond to lagged price rather than contemporaneous price
3. Short-run price elasticity wrt one-month lagged average price: - 0.14
4. This average price response changes welfare implications in two ways
   - It makes nonlinear pricing less successful in energy conservation
   - It changes the efficiency costs of nonlinear pricing
Discussion and Future Research

**Why do consumers respond to average price?**
- Information costs are probably larger than the utility gain

**Can information provision change consumer behavior?**
- Chetty and Saez (2009): Teaching tax codes
- Similar research on residential electricity can help us to understand how to effectively inform consumers about economic incentives
One of my ongoing projects

- **Randomized field experiments for residential electricity customers**

1. **Dynamic pricing and information provision**
   - Dynamic electricity prices (day-ahead announcement)
   - Info group 1: In-home display to provide information
   - Info group 2: Smart-phone to provide “how to” information

2. **Investigate the reason for “energy efficiency gap” of durable goods purchases**
   - Hausman (1979) “Very high imputed discount rates”
   - Randomized field experiments to investigate the reasons
   - In-person consulting to inform about gains from replacements
   - Providing a rebate to help up-front investment
Thank you for your attention!