Evaluation of Peak Pricing on Single-Family Residential Water Consumption in Seattle

David Hsu

University of Washington, Seattle

February 4, 2009
Motivation

Urban water supply is of growing concern worldwide:

- climate change
- urbanization
- economic development

Reasons to manage urban supply, demand, and infrastructure:

- fixed supplies from protected watersheds
- no substitutes
- competing uses for water
On a per capita basis, total consumption -35%, billed consumption -25%. This trend is also occurring in other major cities: Boston, NY, LA. Why?
Hypotheses

Various disciplines have focused on different policy options:

- engineers $\Rightarrow$ technical conservation
- planners $\Rightarrow$ urban form, density, building codes
- psychologists $\Rightarrow$ behavior and attitudes
- economists $\Rightarrow$ pricing policies

I focus on price for the following reasons:

- cheap to deliver
- can target specific users
- can signal the environmental cost of supply
- good rate design is fundamental for other policies as well
Research Question

*What was the impact of new price structure in Seattle in 2001?*

- previous two-tier inclined-block price structure
- third tier ('shock rate') applied only to summer peak
- only above 18 ccf, or 13,500 gallons per month
- a nonlinear price structure
(L) number of customers by tier; (R) quantities consumed by tier.
Modeling Approach

A discrete-continuous choice model was used to model nonlinear prices, and control for weather and physical characteristics. Steps:

1. **discrete choice**
   - calculate the probability of landing in each tier
   - allows estimation of effect of different prices on tier choice

2. **continuous choice**
   - linear regressions within each tier
   - calculate the effect of appropriate marginal price in each tier

3. **use model to simulate results statistically**
   - calculate effect of changing prices and other variables
Data

Seattle Public Utilities billing databases:

- panel data structure
- single-family residential household only
- bimonthly billing
- random sample from this database for eight census tracts

Outcome variable: household water consumption

Predictors used:

- average temperature, total precipitation (National Weather Service)
- marginal price history (Seattle Public Utilities)
- lot size and house value (King County tax assessor, 2007 only)

Removed 1992 and 2001 data, because of drought restrictions.
Individual Household Data

A Household in Sand Point

Time
Avg Daily Consumption (CCF)
1991 1993 1995 1997 1999 2001 2003 2005 2007
0.0 0.5 1.0 1.5 2.0

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## Discrete Choice

Estimated coefficients for ordered categorical fit to center-normalized data:

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<th>Std Error</th>
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$R^2$ equivalent: 36%
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The choice probability of tier 3 is influenced first by temperature; then price; then physical characteristics. Precipitation seems relatively unimportant.
Continuous Choice within Tier 3

Estimated coefficients for log-linear fit to center-normalized data:

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Once you’re in tier 3, housing best explains quantity of water used.
Elasticity of Water Demand

Elasticity of demand measures the effect of price on consumption:

$$\varepsilon_d = \frac{\Delta Q/Q}{\Delta P/P} = \frac{\Delta Q}{\Delta P} \frac{P}{Q}$$

A1: If we change our third tier price by $1:
- Change in probability of tier 3: $-8\%$
- Change in quantity in tier 3: $-5.4\%$

A2: If we change our third tier price by 250%:
- Change in probability of tier 3: $-26\%$
- Change in quantity in tier 3: $-14\%$
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Distribution of Consumption in Tiers

(L) number of customers by tier; (R) quantities consumed by tier.
Conclusions

Preliminary conclusions:

1. applied discrete-continuous choice model to water demand
2. price reduced number of people in third tier by 26%
3. price reduced quantity consumed in third tier by 14%
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Ongoing research:

1. establish causal inference
2. investigate seasonal and geographic variation
3. identify effects of other conservation policies
Thank you

Questions?

Comments: dhsu2@u.washington.edu