



Behavioral and Econometric Lessons from Urban Water Demand under Extreme Drought: Focus on Aurora, Colorado

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Overview

- Partnership with Aurora, Colorado
- Highlighted Areas of the Study
 - Water Smart Readers
 - Outdoor Water Restrictions
- Methodology
- Results
- Conclusions

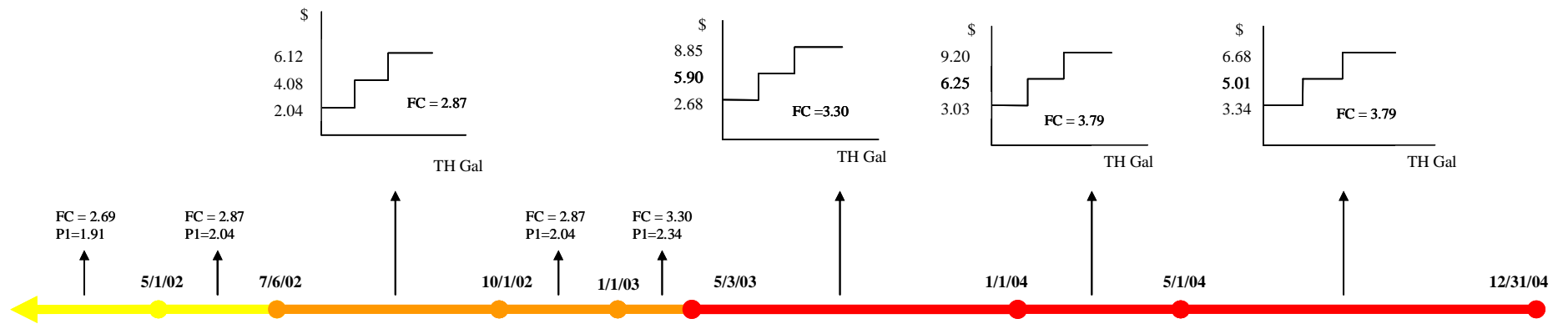
“...one way or another, we know that drought will return. The longer we go without drought, the more likely we will be ill-prepared when drought makes its inevitable next visit to Colorado. Are we ready?”

A History of Drought in Colorado: Lessons Learned and What Lies Ahead

McKee et al., Feb 2000

Aurora, Colorado

- *Rapidly* Growing Suburb of Denver
 - Aurora Water provides service to approx 300,000 Residents
 - 70-80% of Deliveries to Residential Customers
- Response to Drought of 2002
 - Major price and rate structure changes
 - Imposed mandatory restrictions
 - Variety of indoor/outdoor rebate programs
 - Total annual deliveries decreased by 8% in 2002 and 26% in 2003
 - Vast majority of cutbacks came from the residential sector
- Overview of Partnership Objectives
 - Analyze residential water demand to determine “what happened”
 - What information can we use to better prepare for next-time?
 - Billing and rebate participation records



Single Rate
 Households face a fixed service cost (FC) plus a uniform per unit charge (P1); all prices are shown per thousand gallons (TH Gal)

Inc. Block Rate
 In addition to FC, households face an increasing block rate structure for all units consumed. Block widths are standardized across all households

Inc. Block Rate based on Water Budgets
 In addition to FC, households face an increasing block rate structure for all units consumed. Block widths are **specific** to each household, based on average daily indoor consumption (ADIC) and an irrigation allowance (IA). Households receive a varying percentage of their ADIC and IA in each block depending on drought conditions.

* Block widths in diagrams not to scale
 ** Rate structure type reflects the rate structure utilized during summer months

Source: City of Aurora: Water Management Plan (2002-2004) and ratesall.txt provided by the City of Aurora Utilities Department.



Highlighted Areas of the Study

- Impact of Water Smart Readers on Demand
 - Provide Households with real time water-use information
 - Cost \$30 (after \$25 rebate)
- Impact of Restrictions on Demand and the Effectiveness of Price
 - Impact of restrictions depends on “type” of household
 - Restrictions change how we respond to price

The Water Smart Reader



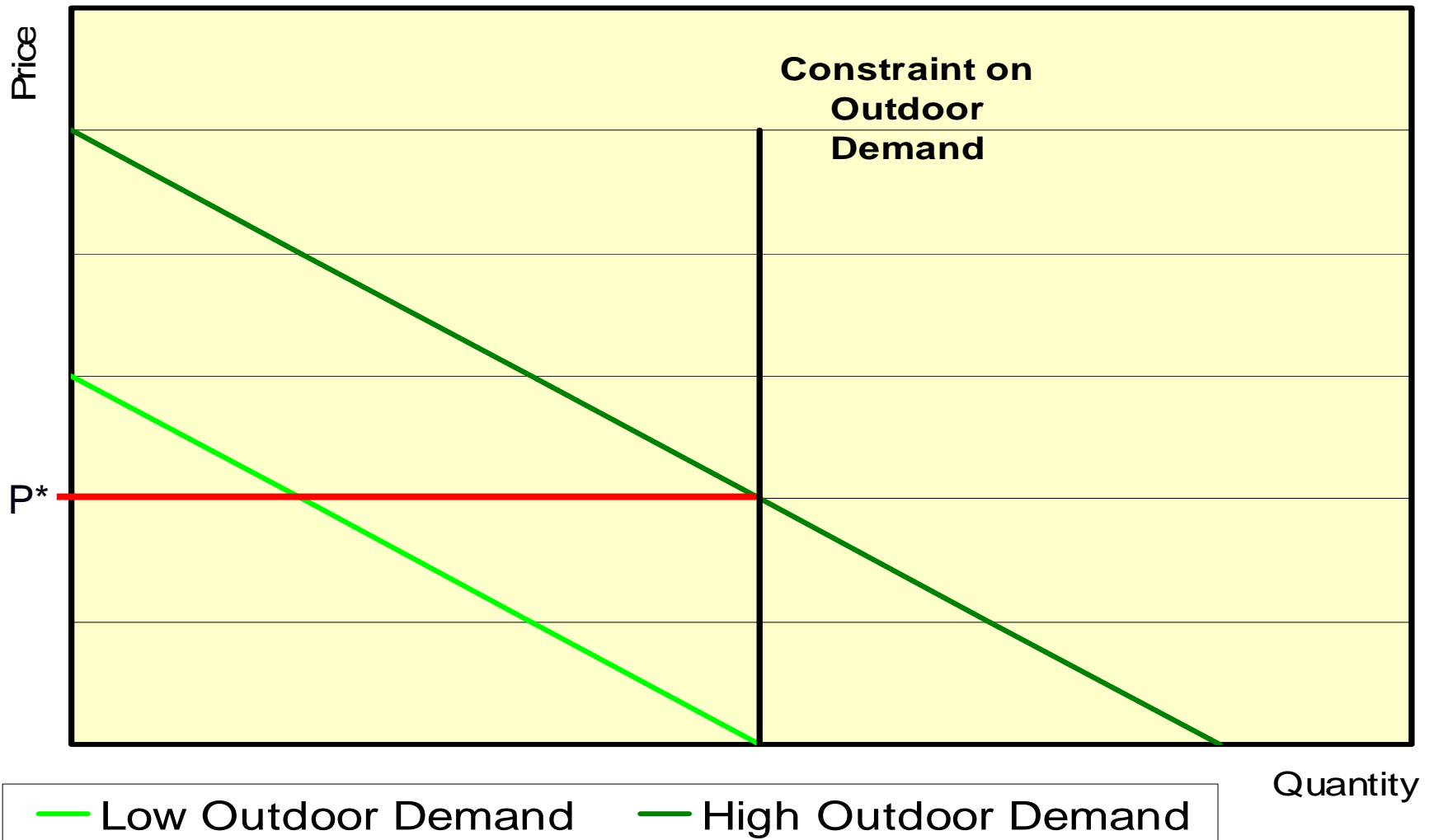
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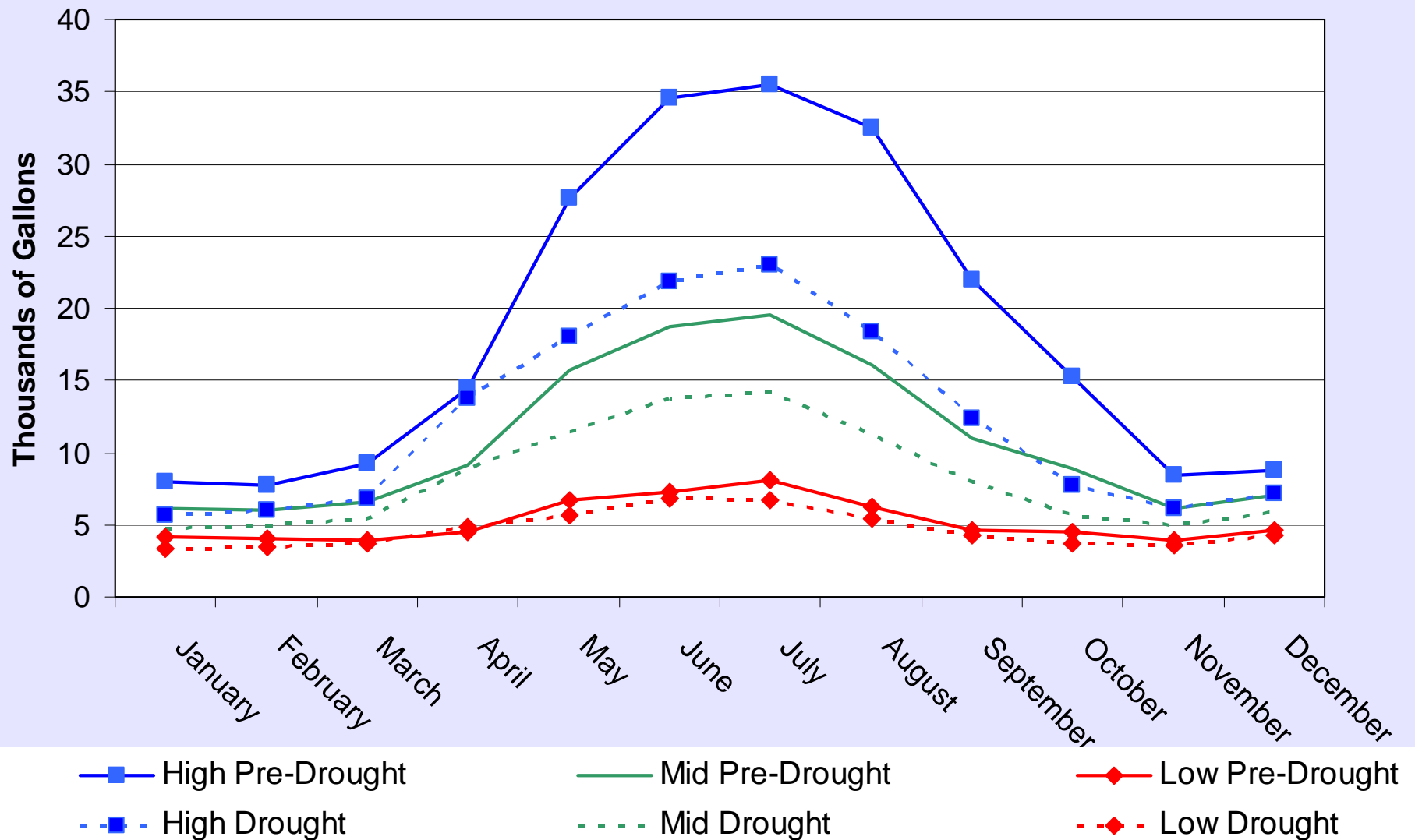
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Effect of Outdoor-use Restrictions on Demand: High v. Low Water Users



Average Consumption per Billing Period by User Type Before and During Drought



Previous Water Demand Literature

- Literature Focuses Primarily on Price
 - Which price do households respond to?
 - What do households know about price? Water-use?
- Few Studies Consider both Price and Non-price Policies Together (Renwick and Green 2000; Michelsen 1999)
- Few Studies Focus on Drought (Moncur 1987; Pint 1999; Renwick and Green 2000)

Residential Water Demand Model

$$\ln(w_{i,t}) = \left(\begin{aligned} &\beta_0 + \beta_1 \ln(\text{aveprice}_{i,t-1}) + \beta_2 (\ln(\text{aveprice}_{i,t-1}) * \text{restrict}_t) + \\ &\beta_3 \text{restrict}_t + \beta_4 \text{blockrate} + \beta_5 \ln(\text{blprddays}_{i,t}) + \beta_6 \text{outdoorreb}_{i,t} + \\ &\beta_7 \text{indoorreb}_{i,t} + \beta_8 \text{wsr}_{i,t} + \beta_9 \text{Irrigation}_t + \beta_{10} \text{Holiday}_t + \\ &\beta_{11} \text{avemax}_t + \beta_{12} \text{totprecip}_t + \phi_1 \ln(\text{hhinc}_i) + \phi_2 \text{medage}_i + \phi_3 \text{pph}_i + \\ &\phi_4 \text{houseowned}_i + \phi_5 \text{newhome}_i + \phi_6 \text{oldhome}_i + \phi_7 \text{numbedrooms}_i + \varepsilon_{it} \end{aligned} \right)$$

$$\varepsilon_{it} = \eta_i + \mu_{it}$$

$$\text{Price Elasticity} = \beta_1 + \beta_2 * \text{restrict}$$

$$\% \Delta \text{ Due to Restrictions} = \beta_2 * \ln(\text{aveprice}_{i,t-1}) + \beta_3$$

1. Why use lagged average price?
2. What about the simultaneous choice of price and quantity?
3. Aren't you missing a few things? Lot size, swimming pools...

Overview of Results

Dependent Variable: ln(consum)

All Households

Factors Under Utility Control

ln(cpilagap)	-0.595 (156.57)***
ln(cpilagap)*restrict	0.226 (34.54)***
restrict	-0.308 (57.9)***
blockrate	-0.050 (31.22)***
ln(blprddays)	0.611 (114.8)***
outdoorrebate	0.006 (0.69)
indoorrebate	-0.099 (15.54)***
wsr	0.161 (9.38)***

Factors Not Under Utility Control

irrigation	0.29645 (133.19)***
holiday	0.07216 (39.66)***
avemaxt	0.02379 (341.39)***
totprecip	-0.03604 (67.07)***
constant	-1.18024 (63.31)***

Number of Observations	679,134
Number of Households	10,143
Overall R-squared	.40

Absolute value of z statistics in parentheses;

* significant at 10%; ** significant at 5%; *** significant at 1%

Results- Interaction of Price and Restrictions by Type of User

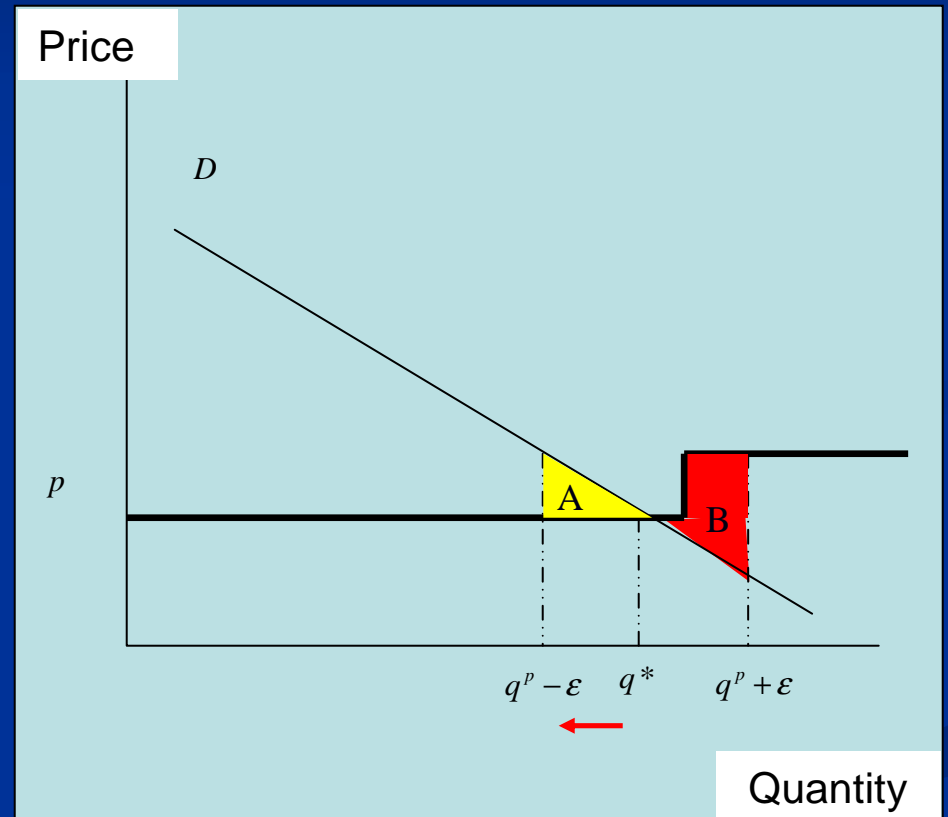
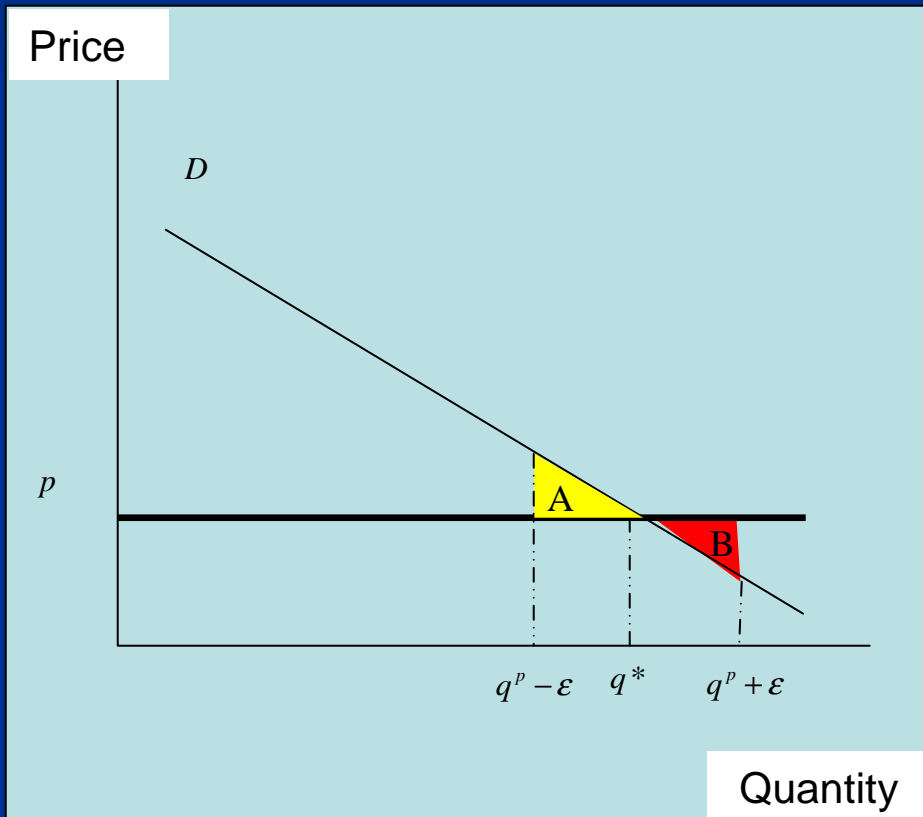
	β_1 Price Elasticity	$\beta_1 + \beta_2$ Price Elasticity During Restrictions	$\beta_2 * \ln(\text{aveprice}_{i,t-1}) + \beta_3$ % Change in Demand Due to Restrictions Only*
All	-0.60	-0.37	-13.44%
Low Users	-0.34	-0.46	-5.92%
Middle Users	-0.57	-0.39	-13.15%
High Users	-0.75	-0.24	-17.41%

- “High” Users More Responsive to Price than “Low” Users
- Price Changes Made When Restrictions are in Place Primarily Target “Low” users
 - Why does P.E. for Low Water Users Increase when Restrictions are in Place?
- “High” Users Respond Most to Restrictions

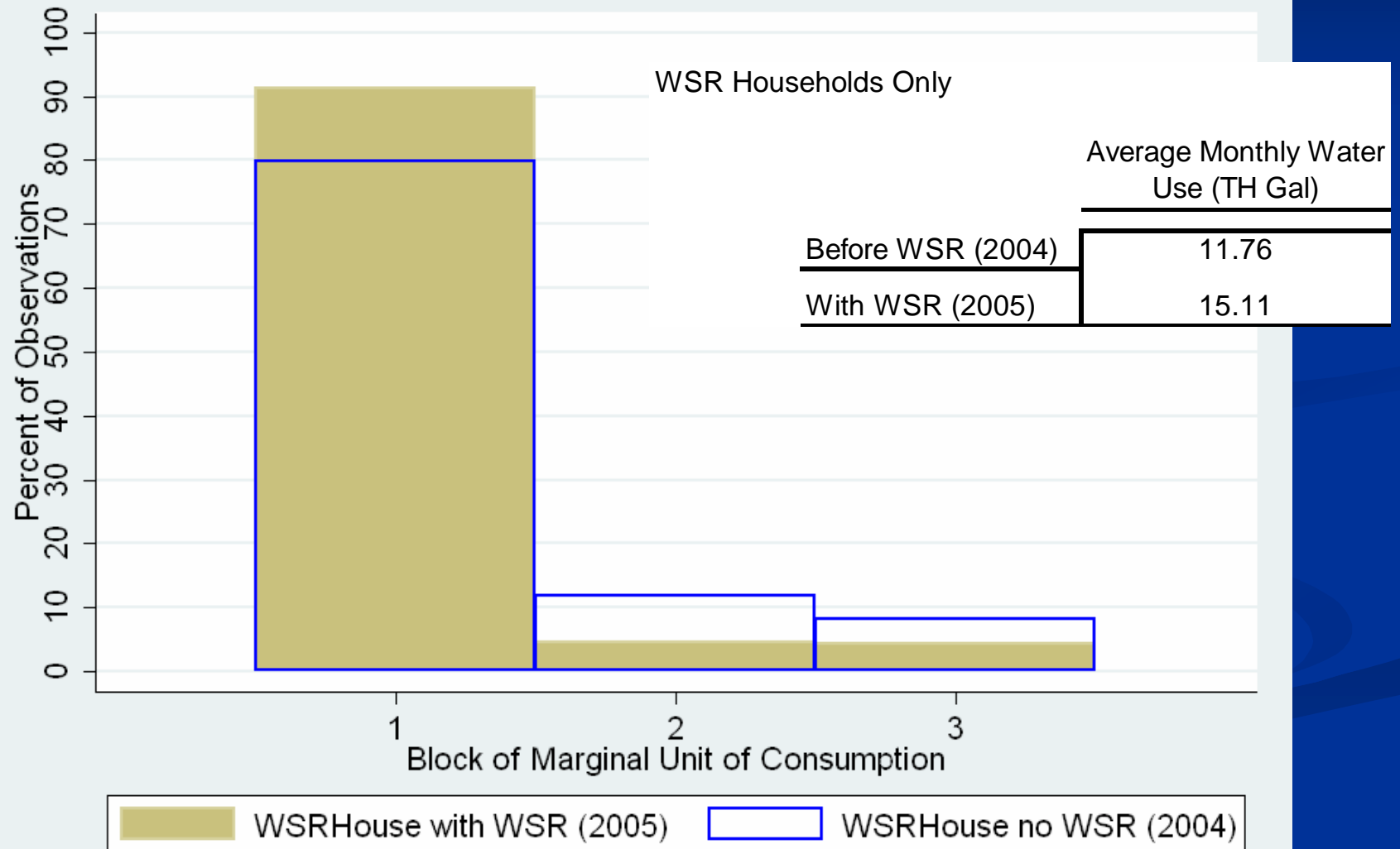
Results- WSR

- Does Owning a WSR Really Increase Water-use?
 - Instrumenting for WSR using "second" advertisements
- Why Would Owning a WSR Impact Water-use?
 - Better understanding of the cost of particular activities
 - "Quantity Uncertainty"

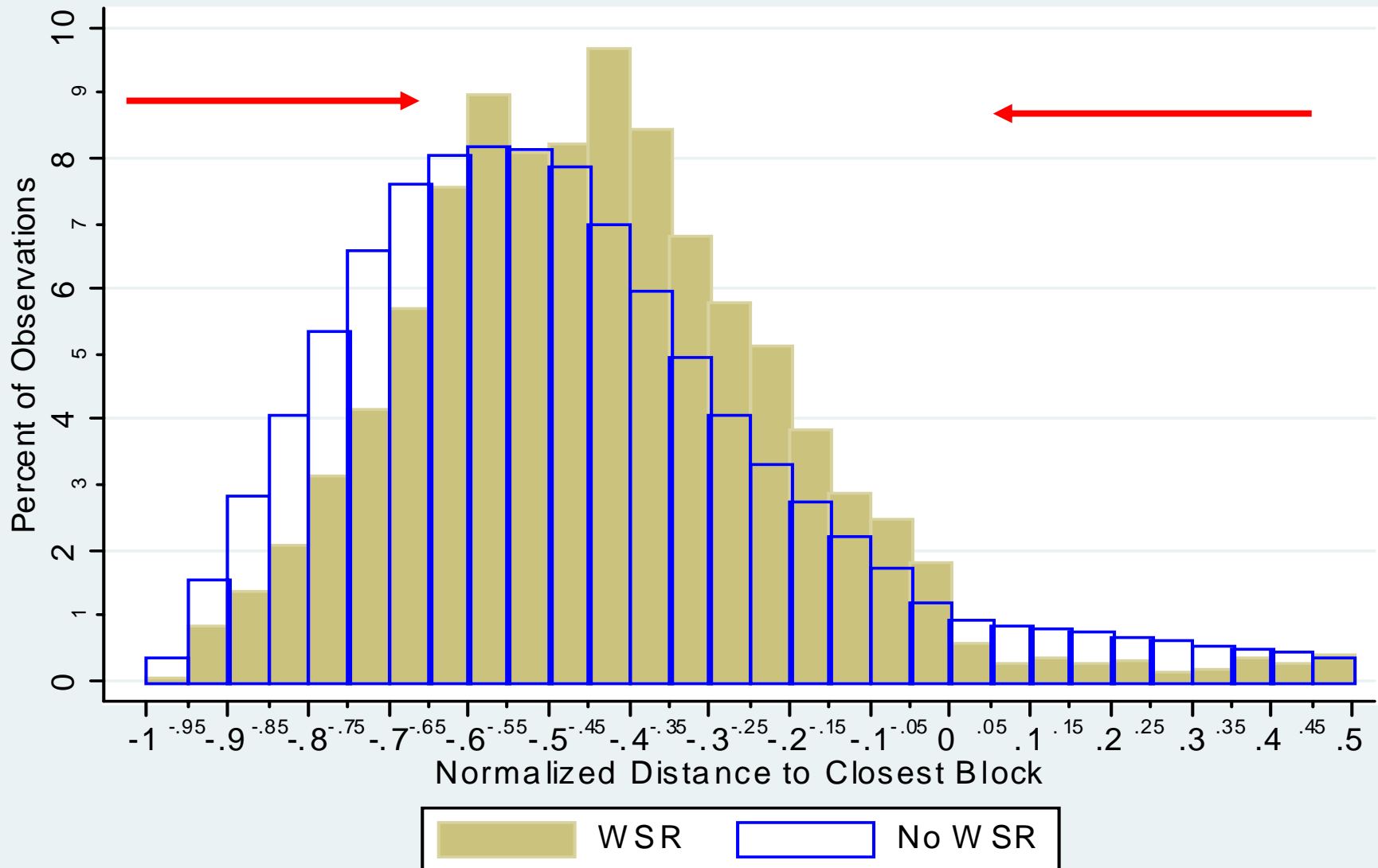
Quantity Uncertainty



Marginal Unit of Consumption with and w/out WSR, during Water Budget Periods



Normalized Distance to Closest Block With and W/out WSR during Water Budget Periods (All Households)



Questions? Comments? Suggestions?

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