# Defensive Investment in Municipal Water Hardness Reduction

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# Background

Water hardness

- High concentration of $Ca^{++}$ and $Mg^{++}$

Damages from water hardness

- $\downarrow$ efficacy of cleaning products/ detergents, $\downarrow$ service life of house appliances, scaling, distaste of water

Prevention

- Households: softening salts, additives, other products. Process: ion exchange
- Desalination plants: reverse osmosis

# Motivation

What?

- Measuring Willingness to Pay (WTP) of Households to reduce water hardness caused damages.

Why?

- Private softening $\rightarrow$ excess salt in the flow back water $\rightarrow$ effects on the aquatic environment $\rightarrow$ negative externality
- HHs' WTP help decide central water desalination+ softening cost and volume
- Public provisioning of private good

# Motivation

How?

- Using water softening purchase and total dissolved solids (TDS) data, estimate effects of TDS on softening purchase.

What we find?

- WTP ↑ as TDS ↑
- For $\geqslant$ 500 ppm in water hardness/ TDS $\rightarrow$ HHs WTP is \$7.5/ month.

# Question

## Research Question

How municipal water hardness affects households' (HH) willingness to pay (WTP) to reduce damages?

- Damages= Hardness caused damages (other than perceived/ true health risk)
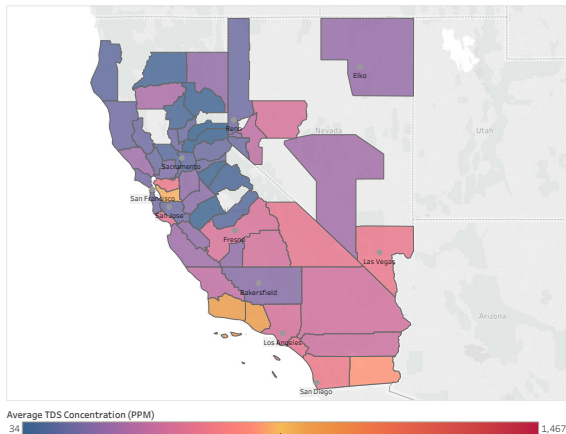
Figure 1: Average TDS Measures by County in Nevada and California 2006–2012
Source: Nevada Division of Environmental Protection – Drinking Water Watch
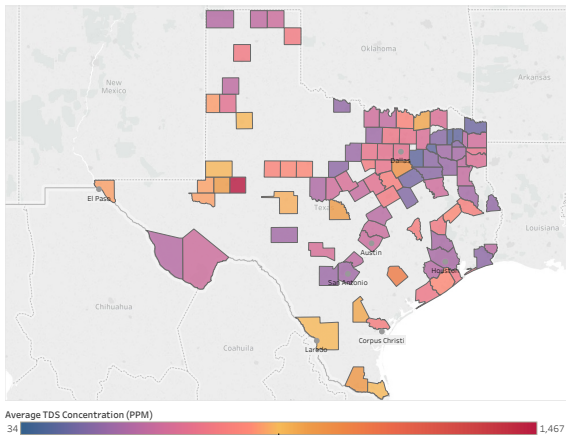California Water Boards – Drinking Water Watch

Figure 2: Average TDS Measures by County in Texas 2006–2012
Source: Nevada Division of Environmental Protection – Drinking Water Watch
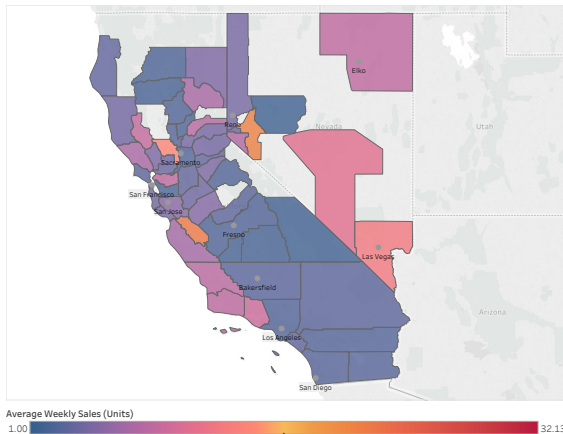California Water Boards – Drinking Water Watch

Figure 3: Average Weekly Unit Sales by County in California and Nevada 2006–2012
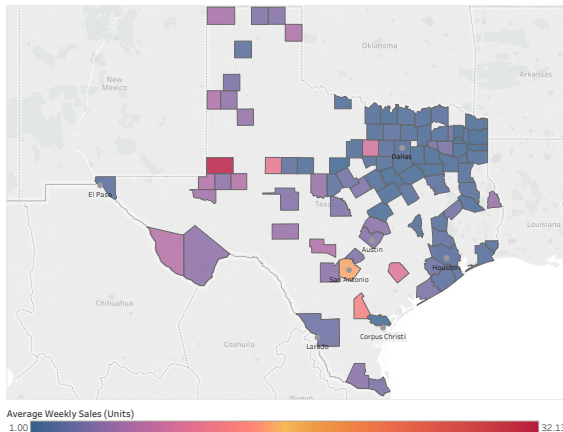Source: Nielsen Retail Scanner Database

Figure 4: Average Weekly Unit Sales by County in Texas 2006–2012
Source: Nielsen Retail Scanner Database

## Theory Model Summary

- Random utility model

$$u_{ijc} = \beta_i x_{jc} + \alpha_i p_{jc} + \lambda_c + \varepsilon_{ijc}, \tag{1}$$

here, $i =$ individual, $j =$ softener product, $c =$ county
$x_{jc} =$ Reduction in HH damages, $p_{jc} =$ Price of softening product, $\lambda_c =$ Time invariant fixed effects

- Market share of product $j$ in county $c$:

$$s_{jc} = \frac{\exp(\beta x_{jc} + \alpha p_{jc} + \lambda_c)}{\sum_{k=0}^{J} \exp(\beta x_{kc} + \alpha p_{kc} + \lambda_c)}$$

- Utility is zero if water softening product not bought, i.e. $x_{0c} = 0$ if $j = 0$

$$\ln s_{jc} - \ln s_{0c} = \beta x_{jc} + \alpha p_{jc} + \lambda_c$$

- Marginal WTP for one unit of TDS reduction: $-\beta/\alpha$

# Empirical Model and Identification

Estimated Model

$$\ln s_{ijct} - \ln s_{0ct} = \beta_1 x_{jct} + \alpha_1 \widehat{p}_{jct} + \beta_2 y_{ct} + \lambda_j + \delta_t + \varepsilon_{ijct} \qquad (2)$$

Here, $j$=products, $c$= counties, $t$=time

$s_{ijct}$= share of HH purchasing softeners, $s_{0ct}$= share of HH not purchasing softeners

$y_{ct}$=income

- Softener product sales to measure LHS
- TDS to measure $x_{jct}$ i.e., water hardness reduction

# Empirical Model and Identification

- Price and softener demand: reverse causality
- Instruments for softener price: Chemical Manufacturers' Income $Z_t$ and EPA's Non-Attainment Index $NA_{ct}$
  - Instrument story: Corr(Chemical Manufacturers' Income $Z_t$, $p_{jc}$) $> 0$
  - Corr(EPA Nonattainment index $NA_{ct}$, $p_{jc}$) $\neq 0$, non-attained area facilitates softener production

  - Not weak instrument: $corr(p_{jc}, Z_t) \neq 0$, $corr(p_{jc}, NA_{ct}) \neq 0$
  - Validity: $corr(\varepsilon_{ijc}, Z_t) = 0$, $corr(\varepsilon_{ijc}, NA_{ct}) = 0$
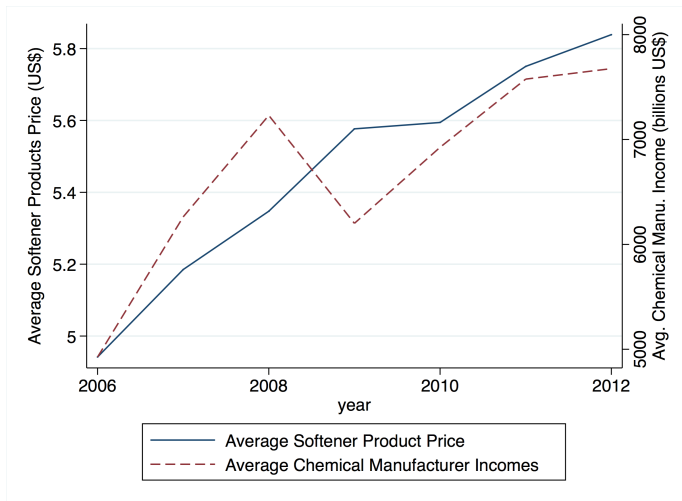
Figure 5: Average Price and Average Net US Chemical Manufacturers' Income , 2006-2012
Source: Nielsen Scanner Data and US Census Quarterly Financial report

# Data Source

- TDS: State Drinking Water Watch (DWW)
- Softener Sales: Nielsen
- County income: BLS
- Household statistics: Census Bureau
- Chemical Manufacturer Income: Census Bureau
- NAAQS index: EPA
- Weekly store-product level panel. 2006-2012
- 158 counties. 50 CA, 99 TX, 9 NV.

# Results

Table 1: IV Regression Results: Households' WTP to reduce Water Hardness 2006-2012

|  | (1) IV-FE | (2) IV-FE |
|---|---|---|
| Price of Softening Products (US$) | -0.0922** | -0.0912** |
|  | (0.0428) | (0.0445) |
| Damages Avoided (TDS) | 0.00135*** | 0.00137*** |
|  | (0.000256) | (0.000271) |
| County Wages (Thousand US$) | 0.000306 | 0.00676 |
|  | (0.00266) | (0.00532) |
| Constant | -12.38*** | -12.47*** |
|  | (0.180) | (0.226) |
| MWTP | 0.0147*** | 0.0150 |
|  | (0.0054772) | (0.0062808) |
| Month FE | No | Yes |
| Observations | 982,378 | 982,378 |
| No. Groups | 153 | 153 |
| No. Clusters | 153 | 153 |
| First-stage $F$ statistic | 111.99 | 90.74 |

Notes: Dependent variable: ln(HH share purchasing softeners)- ln(HH share not purchasing softeners). Standard Errors (in parentheses) are clustered by counties. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

# Robustness Checks

Table 2: Robustness Checks: Households' WTP to reduce Water Hardness 2006-2012, Winter Weather Instrumenting Price

|  | (1)<br>IV-Winter Weather | (2)<br>IV- Drought Index |
|---|---|---|
| Price of Softening Products (US$) | -0.0962** | -0.0848* |
|  | (0.0457) | (0.0449) |
| Damages Avoided (TDS) | 0.00139*** | 0.00137*** |
|  | (0.000269) | (0.000270) |
| County Wages (Thousand US$) | 0.00682 | 0.00692 |
|  | (0.00567) | (0.00559) |
| Drought Index | No | Yes |
| MWTP | 0.0144** | 0.0161** |
|  | (0.0058568) | (0.0074468) |
| Month FE | Yes | Yes |
| Observations | 955,734 | 982,378 |
| No. Groups | 153 | 153 |
| No. Clusters | 153 | 153 |

Notes: Dependent variable: ln(HH share purchasing softeners)- ln(HH share not purchasing softeners). Standard Errors (in parentheses) are clustered by counties. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
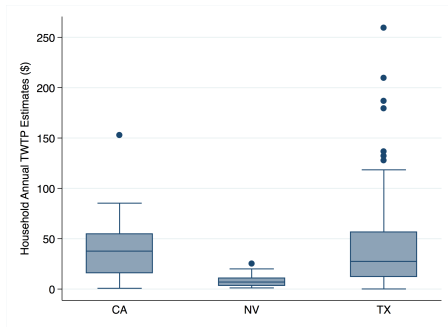
# Results Summary

- IV regression results: High TDS $\rightarrow$ $\uparrow$ softener sales, High Price $\rightarrow$ $\downarrow$ softener sales
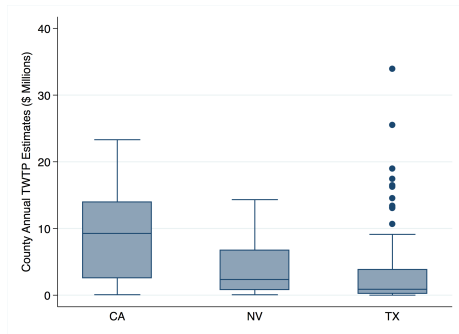
Using MWTP$= -\beta/\alpha$:

- Average HH's Monthly WTP \$7.5 when $TDS > 500$ ppm
- Average HH's Annual WTP \$12 when $TDS > 500$ ppm
- County level aggregate \$1.2 million WTP when $TDS > 500$ ppm

# WTP Estimates



(a) Household Annual Willingness to Pay Estimates, 2006-2012

(b) County-level Annual WTP Estimates, 2006-2012

Figure 6: Total Willingness to Pay Estimates

# Conclusion

- High TDS $\rightarrow$ high WTP
- HH WTP $\rightarrow$ water utilities decision on water desalination plants and costs
- Salt management: internalize the externality

Thank you.
Questions?
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