Modeling Multiple Factors of Residential Water Demand to Assess Price and Non-Price Instruments under Climate Change: An Application to Las Vegas, Nevada

Kimberly Rollins, Professor,
Department of Economics, University of Nevada, Reno

Coauthors :
Elena Tchigriaeva, PhD Student, Dept. of Economics, University of Nevada, Reno
Corey Lott, PhD Student, Dept. of Economics, University of California, Santa Barbara

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Objectives

- Predictive model for demand management analysis and planning
- Predict how water utility customers will respond to multiple policy tools
- Predict how responses to policy changes vary with exogenous effects.

Exogenous variables and policy variables together affect water customer behavior

Residential Water Demand

Exogenous

- Avg Temperature
- Avg Wind Speed
- Precipitation Days

- Seasonality
- Economic trends

- Household Income
- Household Size

Policy Instruments

Price Policies

- Block Price
- Tier Thresholds

Non-Price Policies

Mandatory programs:
- Turf restrictions

Voluntary incentive-based programs:
- Xeriscaping

Policy Variables

Price policy variable

- Marginal price ($)
- Difference (by Nordin 1976) ($)

Non-Price policy variables

Involuntary conservation policy:

- Turf Restriction Regulation

Voluntary conservation policy:

- Turf area (sq.ft.)
- Trees/shrubs area (sq.ft)
- Non-irrigated area (sq.ft)
- Pool (dummy)

Non-Price Policies and Variables

Involuntary conservation policy:

Turf Restriction Regulation for new houses in 2003

Voluntary conservation policy:

Landscape variables represent effects from conservation policies that target landscaping.

Landscape Variables – account for unique property features (GIS imaging, SNWA)

- **Turf (sqft)**
- **Trees & shrubs**
- **Non-Irrigated area, Sqft**
- **Swimming Pool Indicator**

Exogenous Variables

Climate Variables - perceived and acted on by consumers

- Average temperature
- Average wind speed
- # of precipitation days

Household Variables - unique features of households

- Household size (# of bedrooms)
- Income (appraised house value times 0.025) ($)
- # of days in a bill

59 period dummy variables (month/year)

- seasonality
- economic trends

DISAGGREGATED DATA

- Five national and regional sources
- 59,752 households with 3,525,368 observations
- 40% of single-family households of Las Vegas urban area
- Households with uninterrupted history of monthly water use from February 2007 to December 2011

Random Effects Model
with 2SLS technique

- Individual heterogeneity
- Time Fixed Effects

ln(water quantity) = f (

- Avg Temperature
- Avg Wind Speed
- Precipitation Days
- Income
- # bedrooms
- Turf Restriction
- Turf Area
- Trees Area
- Non Irrigated Area
- Swim pool
- Periods
- Marginal Price
- Difference

)

Endogeneity – billing data is used as IV

Results

Estimated coefficients are significant with expected signs:

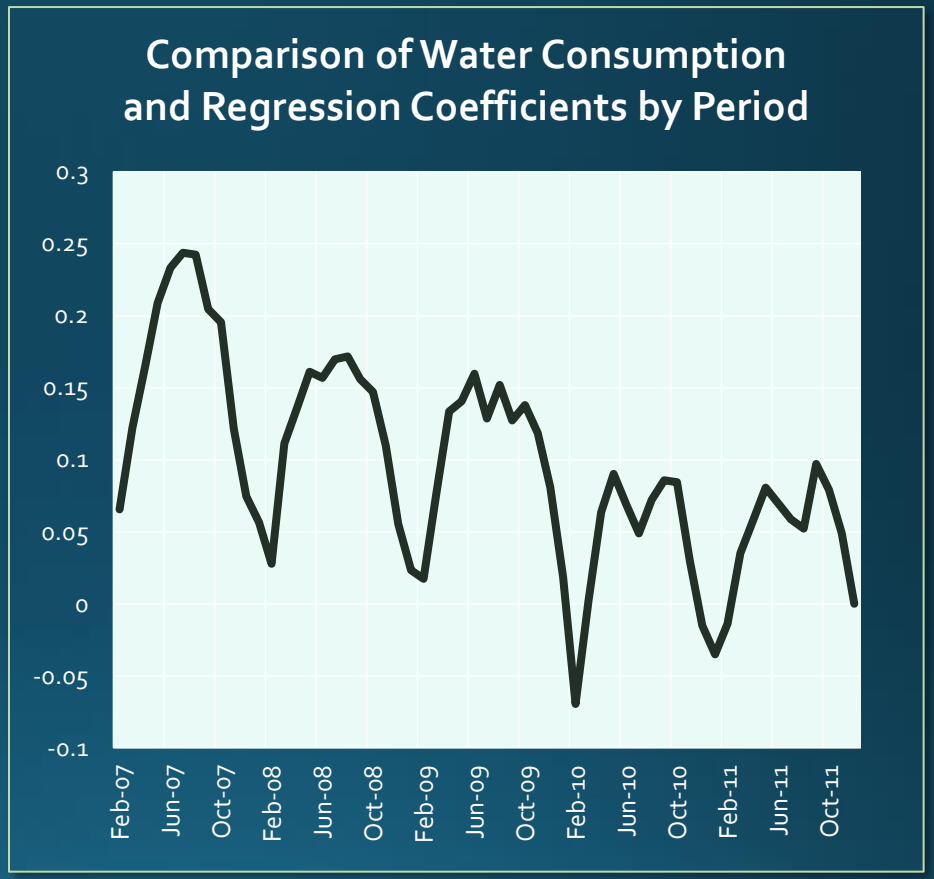
R sq = 0.47

Exogenous variables

- Avg Temperature (+)
- Avg Wind Speed (+)
- Precipitation Days (-)
- Household Income (+)
- Household Size (+)

Controllable variables

- Marginal Price (-)
- Difference (-)
- Turf Restriction Regulation (-)
- Turf Area (+)
- Trees Area (+)
- Non Irrigated Area (-)
- Swim pool (+)



Period variables - reflect seasonality and recession effects

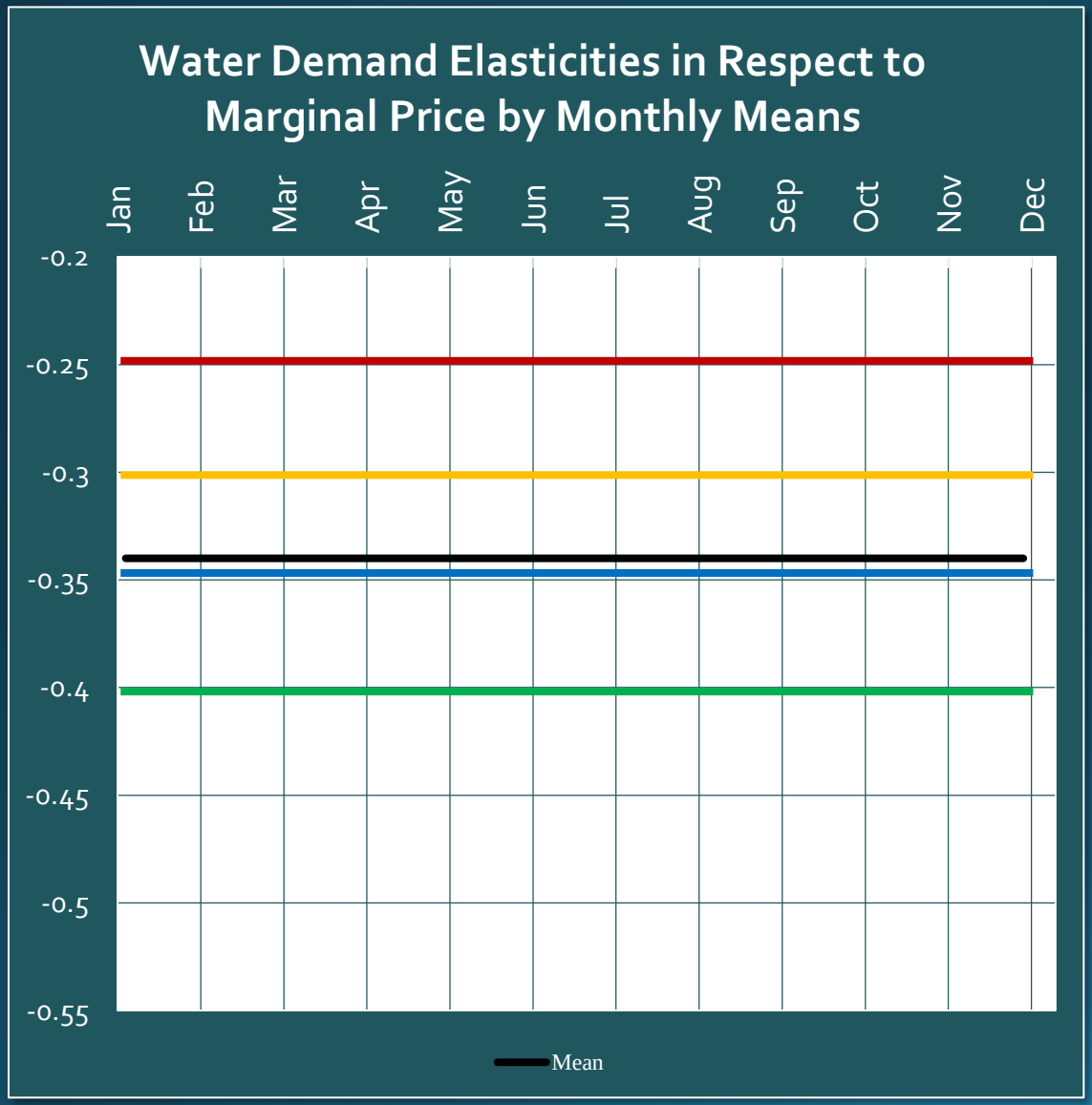
Results – Elasticities

- ✓ Water demand inelastic for all regressors, but is responsive to change
- ✓ Demand most responsive to temperature among exogenous variables
- ✓ Demand most responsive to price among controllable variables
- ✓ Price elasticity is similar to findings in other U.S. studies, confirming similar consumer behavior toward water use

Variables	Elasticity for mean of factor	Elasticity for median of factor
Marginal price	-0.343	-0.312
Family size	0.310	0.276
Size of Turf (skewed right)	0.058	0.005
Size of Trees	0.169	0.138
Income	0.129	0.119
Avg, Temperature	0.610	0.596
Days of Precipitation	-0.016	-0.016
Avg, Wind speed	0.095	0.089

* Increase of price by 10% leads to decrease in water demand by 3.43%

Elasticity by Season, Landscape Type

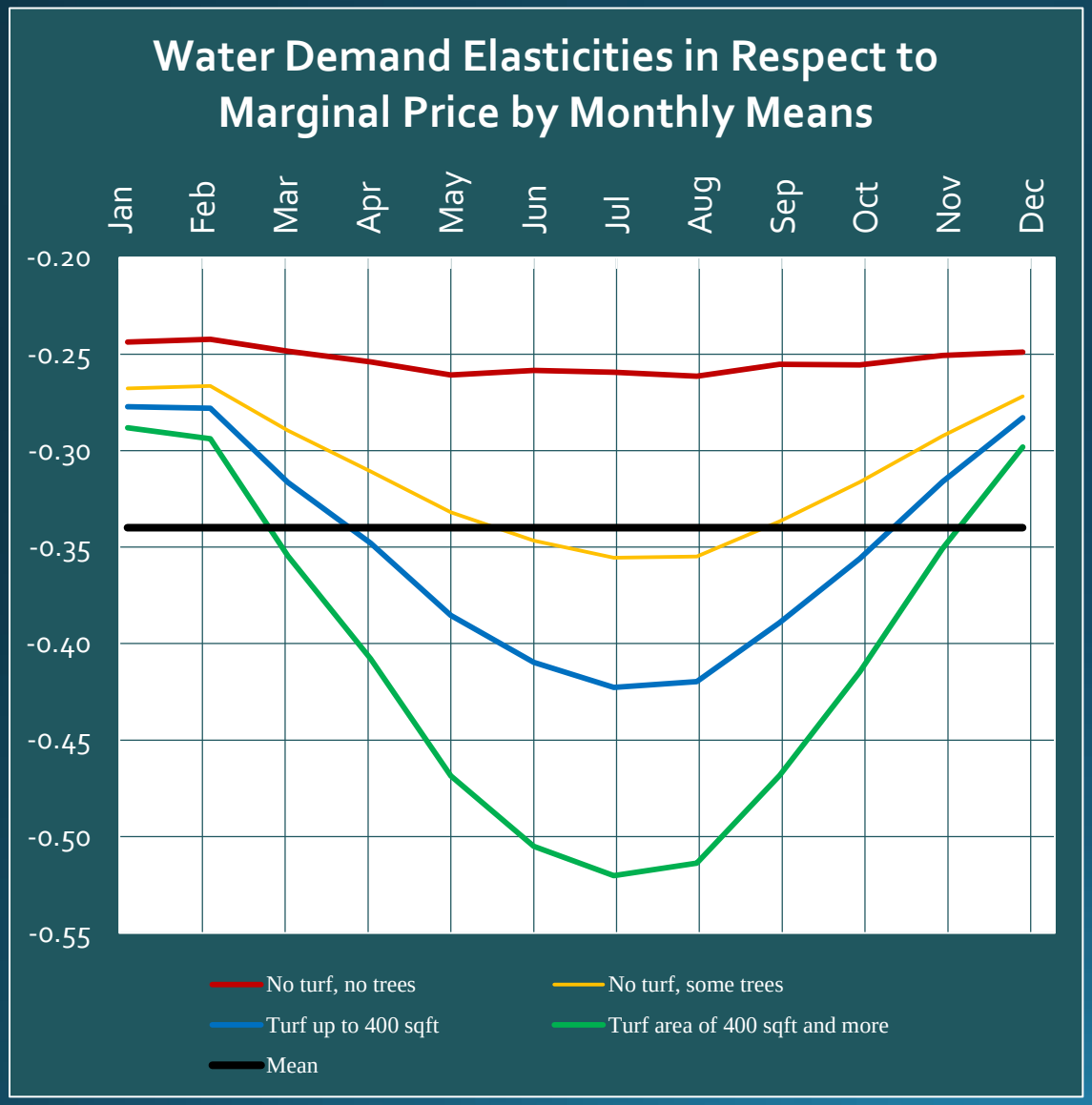


Mean Elasticity [-0.34]

vs.

- **No plants [-0.25]**
- **Trees only [-0.31]**
- **< 400 sq ft of turf (not eligible for xeriscape program) [-0.35]**
- **> 400 sq ft of turf (eligible for xeriscape program) [-0.41]**

Elasticity by Season, Landscape Type

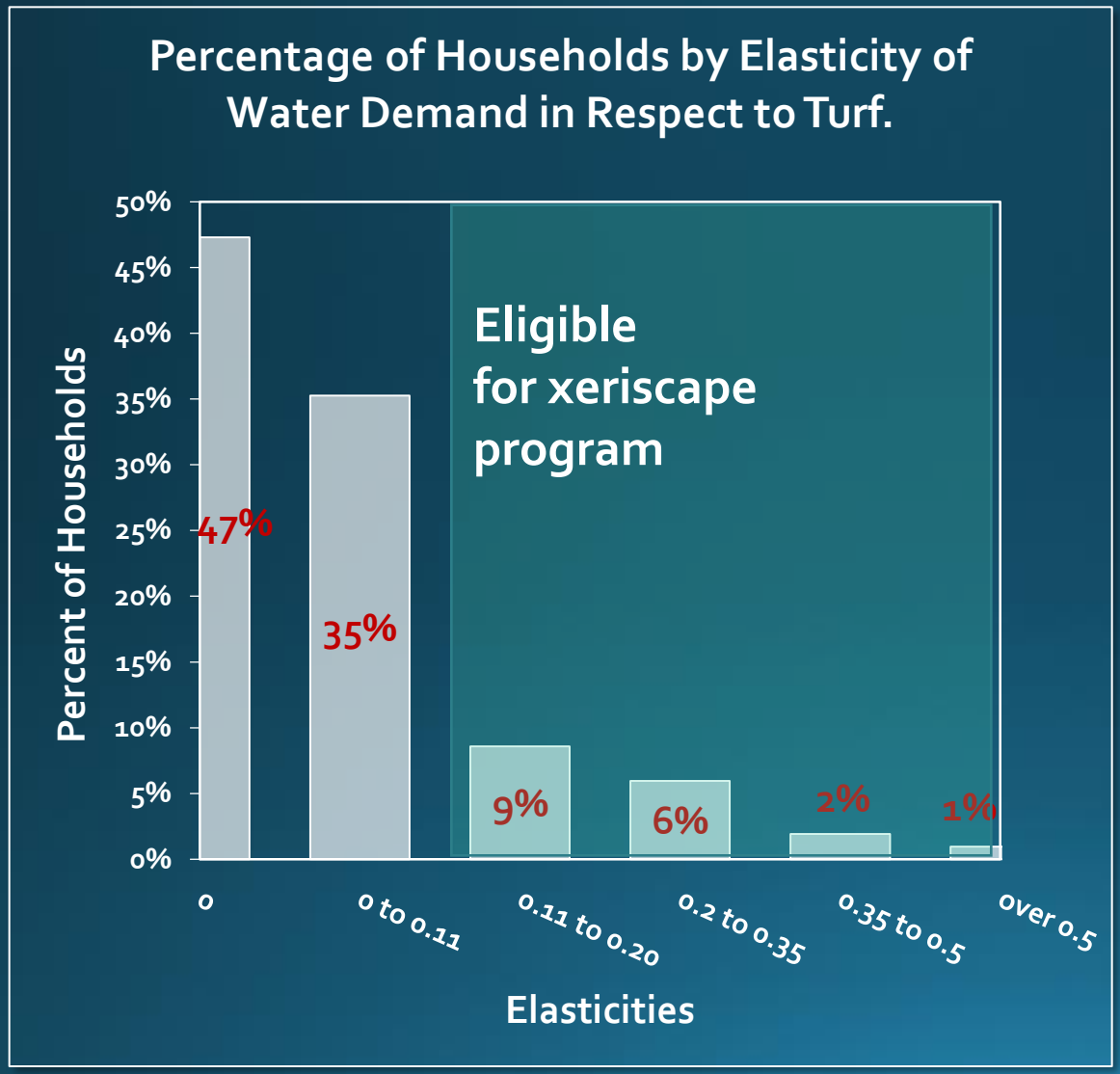


Mean Elasticity [-0.34]

vs.

- **No plants [-0.25]**
- **Trees only [-0.31]**
- **Not eligible for xeriscape program [-0.35]**
- **Eligible for xeriscape program [-0.41]**

Non Price Policy Analysis: Voluntary Turf Removal (Xeriscape) Conservation Program



- 18% eligible
- Of these 50% do not exceed elasticity of .20
- Demonstrates limited capacity of the program

Policy scenarios: Water Demand Projections

Alternative portfolios reduce water demand by 15%

			1st Portfolio (20% of Price Increase and 30% of Turf Decrease)			2nd portfolio (30% Price increase and 20% of Turf Decrease)		
Percentiles of explanatory variables	Price, $	Turf, sf	20% price increase	30% turf decrease	Sum of water decrease, %	30% price increase	20% turf decrease	Sum of water decrease, %
Min	1.1	0	3.3%	0.0%	3.3%	4.9%	0.0%	4.9%
10%	1.18	0	3.5%	0.0%	3.5%	5.3%	0.0%	5.3%
25%	1.91	0	5.7%	0.0%	5.7%	8.5%	0.0%	8.5%
50% (Median)	2.1	20	6.2%	0.2%	6.4%	9.3%	0.1%	9.5%
Mean	2.31	202	6.9%	1.7%	8.6%	10.3%	1.2%	11.4%
75%	2.99	249	8.9%	2.1%	11.0%	13.3%	1.4%	14.7%
90%	3.1	643	9.2%	5.5%	14.7%	13.8%	3.7%	17.5%
Max	4.52	8115	13.4%	69.6%	83.0%	20.1%	46.4%	66.5%
Regression coefficients	-0.1484	0.00029		Average, %	17.02 %		Average, %	17.29%

2 scenarios result in similar % decrease in water use, but effects differ through the price and turf size groups

Conclusions

Dissagregated data allow for results to be used for water demand forecasting and targeting

Next Steps:

- Economic conditions on household water use
- Landscape policies individual effects relative to overall water demand management over time
- Alternative combinations of multiple policies to achieve goals – effects on groups

THANK YOU!

QUESTIONS?

Results

As expected:

- ✓ **Difference: opposite in sign to income, thus negative (Nordin 1976)**
- ✓ **Marginal price: negative (law of demand)**
- ✓ **Water Demand Increases (+) with Bill Days, Household Size, Income, Temperature, Wind Speed, Turf, Trees, and Pool presence**
- ✓ **Water Demand Decreases (-) with Precipitation, Non-Irrigated area, and Turf restriction regulation implementation**

Variables	Coefficient	Std. Error
Difference	-0.0215	0.00150***
Marginal price	-0.1484	0.01234***
Days	0.0272	0.00053***
Household size	0.0919	0.00197***
Income	0.00004	1.04E-06***
Avg, Temperature	0.0086	0.00018***
Days of Precipitation	-0.0081	0.00018***
Avg, Wind speed	0.0140	0.00042***
Size of Turf	0.00029	6.68E-06***
Size of Trees	0.00013	2.55E-06***
Non-Irrigated Area	-0.00002	6.37E-06***
Pool	0.0595	0.00187***
Turf Restriction Policy	-0.0896	0.00374***
Constant	0.1652	0.04673*
R-sq overall = 0.4684		
*** Significance level of 1%, ** 5%, and * 10%		

Therefore, for a policy that targets replacing turf with trees :

- ➢ **An estimated 55% water savings over entire sample of residential customers**

*** A price increase of $1 leads to a 14.8% decrease in water demand**

*** Significance level of 10%**
***** Significance level of 1%**
R-sq overall = 0.4684