Evaluation of controllable and uncontrollable drivers on residential water demand: An application to the Las Vegas area

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OUTLINE

1. Factors affecting residential water demand

    i. Uncontrollable by utility: exogenous factors
    ii. Controllable by utility: factors that alter behavior of customers through conservation policies

2. Model formulation

3. Descriptions of variables

3. Data sources

4. Results and Projections

5. Conclusion

WATER DEMAND DRIVERS AFFECT CUSTOMER DECISIONS AND BEHAVIOR

Residential Water Demand

- Avg Temperature
- Avg Wind Speed
- Precipitation Days

- Seasonality
- Economic trends

- Household Income
- Household Size

Exogenous, uncontrollable by policy; but can affect policy results

- Marginal Price

Price Policies

- Turf Restriction Regulation

- Turf Area
- Treed Area
- Non Irrigated Area
- Swimming pools

Non-Price Policies

Controllable: These drivers influence water through policies

We explicitly model the effects of these drivers on customers' behavior

- Use observed data to predict monthly water use as a function of variables that represent controllable and uncontrollable drivers (next slides)

- Observations over time to account for seasonality and economic trends

- Observations at customer level to account for household differences

- Uncontrollable drivers: account for how exogenous effects influence how customers respond to controllable drivers (policies).

- A random effects model accounts for heterogeneity of households and time invariant variables

- Use estimated model to:
    - predict how customers will respond to multiple policy tools, as represented by systematic changes in controllable drivers
    - predict how responses to policies vary with systemic changes in uncontrollable drivers.

Random Effect Model

For a given household i, water demand in month t can be expressed as

$$y_{it} = \hat{p}_{it}\beta_p + \hat{d}_{it}\beta_d + x_i'\beta_x + c_t'\beta_c + m_t'\beta_m + \varepsilon_{it} \quad (1)$$

where $\varepsilon_{it} = \mu_i + e_{it}$,

and

$$p_{it} = b_i'\beta_{b_{it}} + x_i'\beta_x + c_t'\beta_c + m_t'\beta_m + \varepsilon_{it1} \quad (2)$$

$$d_{it} = b_i'\beta_{b_{it}} + x_i'\beta_x + c_t'\beta_c + m_t'\beta_m + \varepsilon_{it2} \quad (3)$$

Variables:

y_{it} – household monthly water use in 1000s of gallons

p_{it} - estimated marginal price associated with household i and month t

d_{it} - estimated difference variable associated with household i and month t

x_i - is a k by 1 vector of household characteristics including landscape characteristics

c_t - is a l by 1 vector of climate indicators

m_t - is a n by 1 vector of period indicator variables corresponding to time period t,

b_i is a k by 1 vector of water bill characteristics

μ_i - a household-specific random error

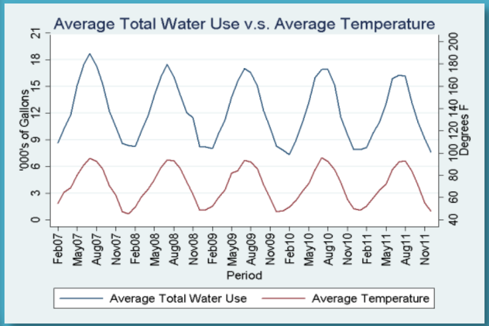
e_{it} - regression random error

β -terms are coefficients corresponding to their associated regressors

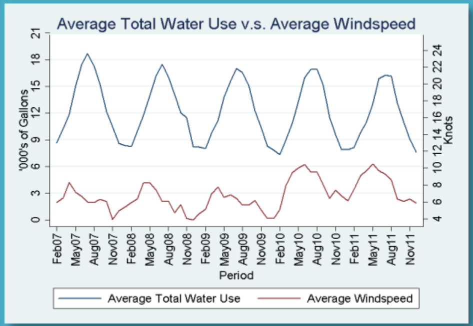
VARIABLES TO REPRESENT UNCONTROLLABLE (EXOGENOUS) DRIVERS

Climate Variables
account for weather parameters as perceived and acted on by consumers

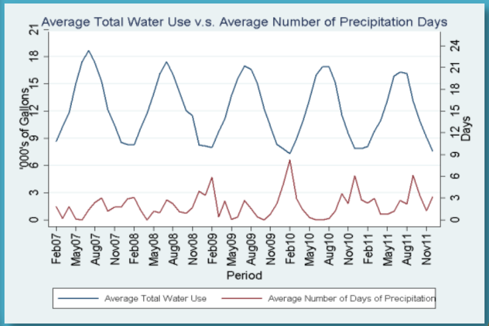
Average Daily Temperature (F)



Average Daily Wind Speed (Kn)



Number of Precipitation days



VARIABLES TO REPRESENT UNCONTROLLABLE (EXOGENOUS) DRIVERS

Household Variables:
account for unique features of households

59 Period Variables

account for seasonality and economic trends (dummy variables)

Income
(1,000 $ dollars)

Proxy:
Appraised House Value times 0.025 (Nieswiadomy and Molina, 1988)

Billing days in month
(# of days)
Varies across sample

Household Size

Proxy:
Number of bedrooms

VARIABLES TO REPRESENT CONTROLLABLE DRIVERS: PRICE POLICIES

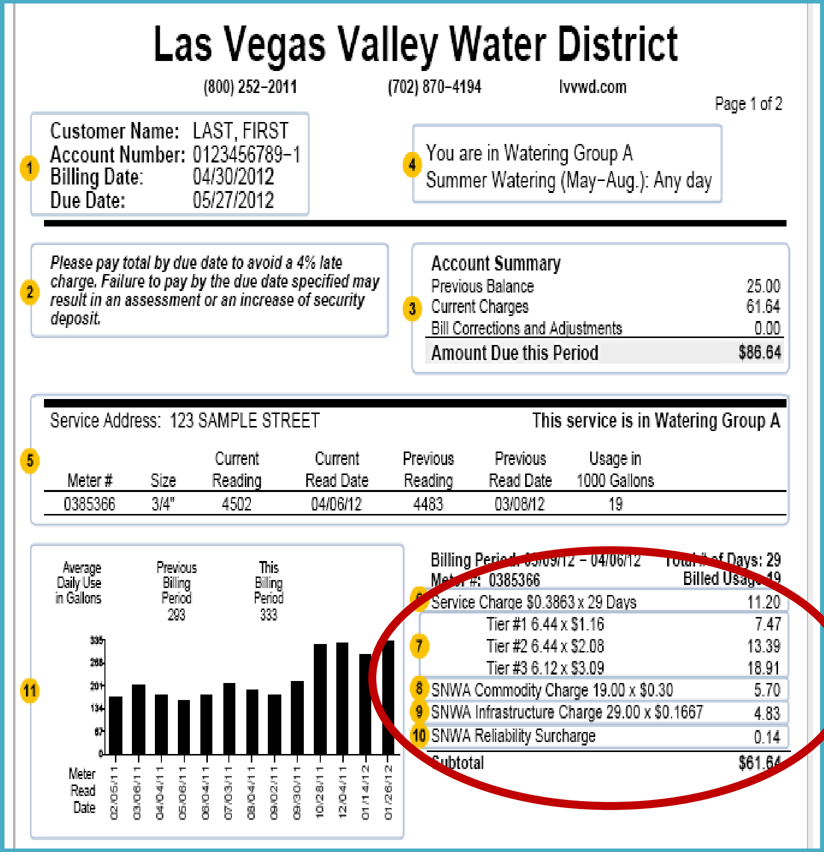
Price Variables
account for block-rate structure as well as household-specific features

Marginal price, $

Price per unit of water at the maximum block used for each billing period per household

Difference, $

The difference between actual bill and bill at the marginal price; must be used with marginal price



Las Vegas Valley Water District

(800) 252-2011 (702) 870-4194 lvvwd.com

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1 Customer Name: LAST, FIRST
Account Number: 0123456789-1
Billing Date: 04/30/2012
Due Date: 05/27/2012

4 You are in Watering Group A
Summer Watering (May–Aug.): Any day

2 *Please pay total by due date to avoid a 4% late charge. Failure to pay by the due date specified may result in an assessment or an increase of security deposit.*

3 Account Summary

Previous Balance	25.00
Current Charges	61.64
Bill Corrections and Adjustments	0.00
Amount Due this Period	$86.64

Service Address: 123 SAMPLE STREET — This service is in Watering Group A

5

Meter #	Size	Current Reading	Current Read Date	Previous Reading	Previous Read Date	Usage in 1000 Gallons
0385366	3/4"	4502	04/06/12	4483	03/08/12	19

11 Average Daily Use in Gallons — Previous Billing Period 293 — This Billing Period 333

Meter Read Date: 02/05/11, 03/06/11, 04/04/11, 05/06/11, 06/04/11, 07/03/11, 08/04/11, 09/02/11, 09/30/11, 10/28/11, 12/04/11, 01/14/12, 01/26/12

Billing Period: 03/09/12 – 04/06/12 Total # of Days: 29
Meter #: 0385366 Billed Usage: 19

6	Service Charge $0.3863 x 29 Days	11.20
7	Tier #1 6.44 x $1.16	7.47
	Tier #2 6.44 x $2.08	13.39
	Tier #3 6.12 x $3.09	18.91
8	SNWA Commodity Charge 19.00 x $0.30	5.70
9	SNWA Infrastructure Charge 29.00 x $0.1667	4.83
10	SNWA Reliability Surcharge	0.14
	Subtotal	$61.64

VARIABLES TO REPRESENT CONTROLLABLE DRIVERS: NON-PRICE POLICIES

Involuntary conservation policy:

Turf Restriction Regulation for new houses in 2003 (dummy variable)

Voluntary conservation policy:

Landscape variables represent expected effects from conservation policies that target landscaping. (Voluntary conservation program data is not used directly because of an endogeneity problem - this is future work)

Landscape Variables –
account for unique features of households (from Judy Brandt's GIS imaging, SNWA)

Turf sqft

Trees & shrubs sqft

Non-Irrigated area, sqft

Calculated as difference between yard size and sum of turf and treed areas

Swimming Pool,

(dummy variable)

SHAPING DATASET:

DATA WERE OBTAINED FROM FIVE NATIONAL AND REGIONAL AGENCIES .
THIS UNIQUE, DISAGGREGATED DATASET INCLUDES ABOUT 40% OF SINGLE-FAMILY HOUSEHOLDS OF LAS VEGAS WITH UNINTERRUPTED WATER HISTORY FROM 2007 TO 2011

- Southern Nevada Water Authority (SNWA)
- LV Valley Water District (LVVWD)
- National Climatic Data Center (NCDC)
- Bureau of Labor Statistics
- Clark County Assessor

→ Study dataset: 62.237 households with 3,671,983 monthly observations

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	**-0.0203**	0.00148***
Marginal price	**-0.1356**	0.01221***
Days	**0.0274**	0.00054***
Household size	**0.0869**	0.00188***
Income	**0.00004**	1 E-06***
Avg, Temperature	**0.0090**	0.00018***
Days of Precipitation	**-0.0082**	0.00018***
Avg, Wind speed	**0.0153**	0.00041***
Size of Turf	**0.00028**	6 E-06***
Size of Trees	**0.00012**	2 E-06***
Non-Irrigated Area	**0.00002**	6 E-06***
Turf Restriction Policy	**-0.0906**	0.00370***
Constant	**0.1240**	0.04702**

** Significance level of 5%
*** Significance level of 1%
R-sq overall = 0.4777

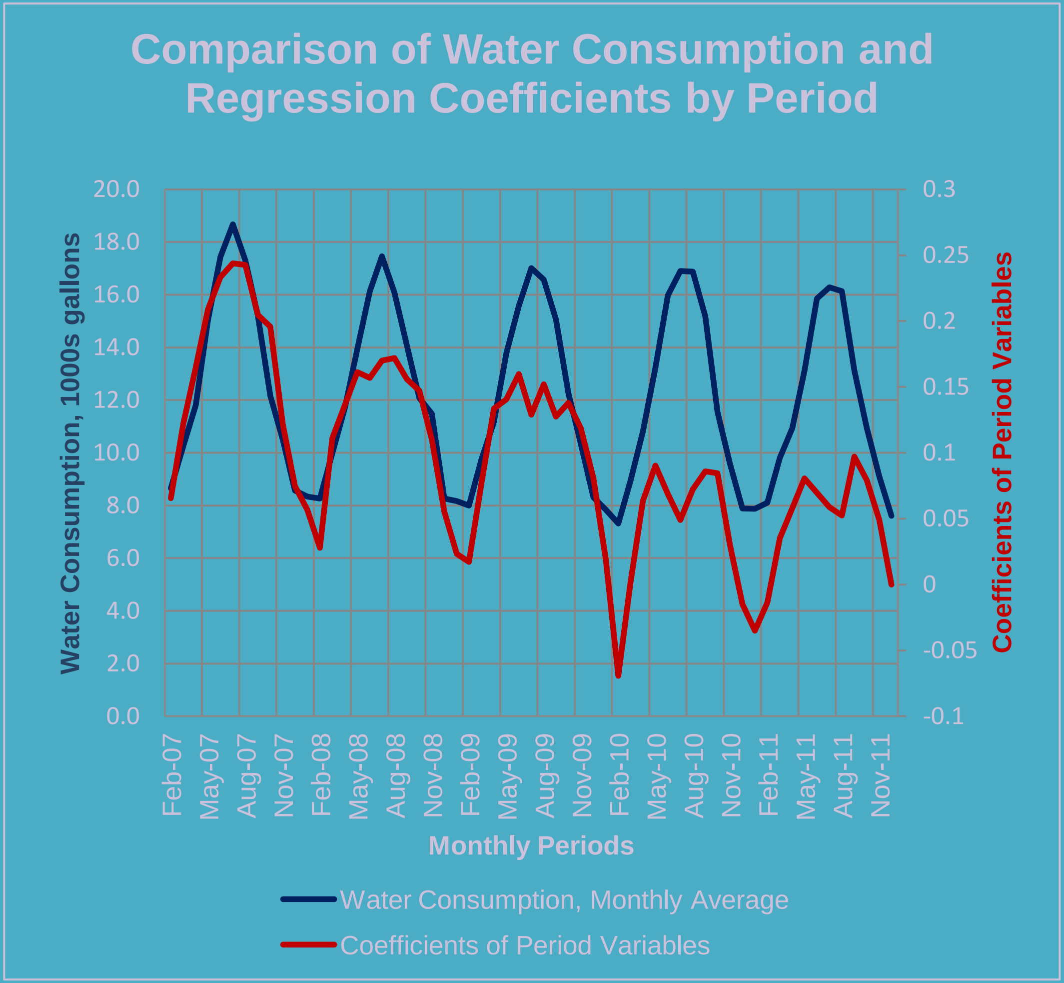
Therefore, for a policy that targets replacing turf with trees :

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

Time Trends: Period Dummy Variables

Estimated Coefficients:

- ✓ Are in accordance with seasonal changes (summer ups and winter downs)
- ✓ Clearly reflect a recession effect (decrease since 2008)



ELASTICITIES

Elasticity measures the change in consumer water demanded as a result of a change in an explanatory variable (price, income, temperature ...)

For example:

$$\text{Price elasticity} = \text{slope}^{*} \frac{\text{price}}{\text{quantity of water}}$$

Important:
Price elasticity is not constant – it increases with increasing price!

Why elasticity is important?

Because elasticity is:

- ✓ Unit free
- ✓ Easily interpreted
- ✓ Comparable across studies
- ✓ Effective for exploring different scenarios

RESULTS – ELASTICITY
(FOR SOME REGRESSORS OF INTEREST)

- ✓ Water demand is inelastic for all presented regressors, but is responsive to change
- ✓ Demand is most responsive to temperature among non-controllable variables
- ✓ Demand is 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	-0.315	-0.285
Family size	0.295	0.261
Size of Turf (skewed right)	0.057	0.006
Size of Trees	0.168	0.137
Income	0.145	0.134
Avg, Temperature	0.639	0.622
Days of Precipitation	-0.017	-0.016
Avg, Wind speed	0.104	0.098

* Increase of price by 10% leads to decrease in water demand by 3.15%

EXAMPLE OF POLICY SCENARIOS: WATER DEMAND PROJECTIONS USING ELASTICITIES

Using elasticities, it is possible to create alternative policy scenarios

Analysis of Elasticities of Manageable Variables: Price and Turf Size

			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, sqft	20% price increase	30% turf decrease	**Sum of water decrease, %**	30% price increase	20% turf decrease	**Sum of water decrease, %**
Min	1.1	0	-2.98 %	0 %	-2.98 %	-4.48 %	0 %	-4.48 %
10%	1.18	0	-3.20 %	0 %	-3.20 %	-4.80 %	0 %	-4.80 %
25%	1.91	0	-5.18 %	0 %	-5.18 %	-7.77 %	0 %	-7.77 %
50% (Median)	2.1	20	-5.70 %	-0.17 %	-5.86 %	-8.55 %	-0.11 %	-8.66 %
Mean	2.33	202	-6.32 %	-1.70 %	-8.02 %	-9.48 %	-1.13 %	-10.61 %
75%	2.99	249	-8.11 %	-2.09 %	-10.20 %	-12.17 %	-1.39 %	-13.56 %
90%	3.1	643	-8.41 %	-5.40 %	-13.81 %	-12.61 %	-3.60 %	-16.21 %
Max	4.52	8115	-12.26 %	-68.14 %	-80.40 %	-18.39 %	-45.43 %	-63.82 %
Coeficients	-0.1211	0.0003		Average, %	-16.21 %		Average, %	-16.24 %

We see that 1st and 2nd scenarios give on average the same percentage of decreased water use, but effects differ through the price and turf size groups (2nd scenario is more evenly distributed among groups)

CONCLUSIONS

1. Modeling approach relies on use of a fully disaggregated data set

2. The model estimates are robust and support current empirical as well as theoretical knowledge of water demand

3. Results used to create tools for water demand forecasting and targeting the most sensitive groups

THANK YOU!

QUESTIONS?