Allocation-Based Pricing, Household Water Demand and Consumer Welfare in California

Ken Baerenklau
Associate Professor
School of Public Policy
University of California – Riverside

Joint work with Ariel Dinar and Kurt Schwabe

How should water be priced?

- Three common goals of a water price structure:
  - Efficiency: send an appropriate marginal cost signal
  - Equity: ensure affordability for essential uses
  - Financial stability: maintain a balanced budget

Common rate structures

- Flat rate: a fixed charge per billing period
- Uniform rate: a constant price per unit consumed
- Increasing block rate: price per unit depends on amount consumed
- Allocation-based rate: blocks depend on household and environmental characteristics

Water pricing in California

- As of 2005: about half of all public utilities (400+) were using increasing block rates
- As of 2008: fewer than 14 utilities were using allocation-based rates
- From 2009-2011: 9 more utilities adopted allocation-based rates
  - Major driver: Governor's *20x2020 Water Conservation Plan*
- Why the apparent reluctance to adopt allocation-based rates?
  - Short-term cost
  - Long-term financial risk
  - Legal questions
  - ***Uncertain effect on demand***: is it worth the cost/risk?

Case study #1: EMWD

Eastern Municipal Water District (EMWD) switched from uniform rates to increasing block allocation-based rates in April 2009:

- *Indoor* water use: $w_1 = (HHS \times PPA) \times DF + IV$
- *Outdoor* water use: $w_2 = (ET \times CF \times IA + OV) \times DF$
- *Excessive* water use: $w_3 = \frac{1}{2}(w_1 + w_2)$
- *Wasteful* water use: in excess of w_3

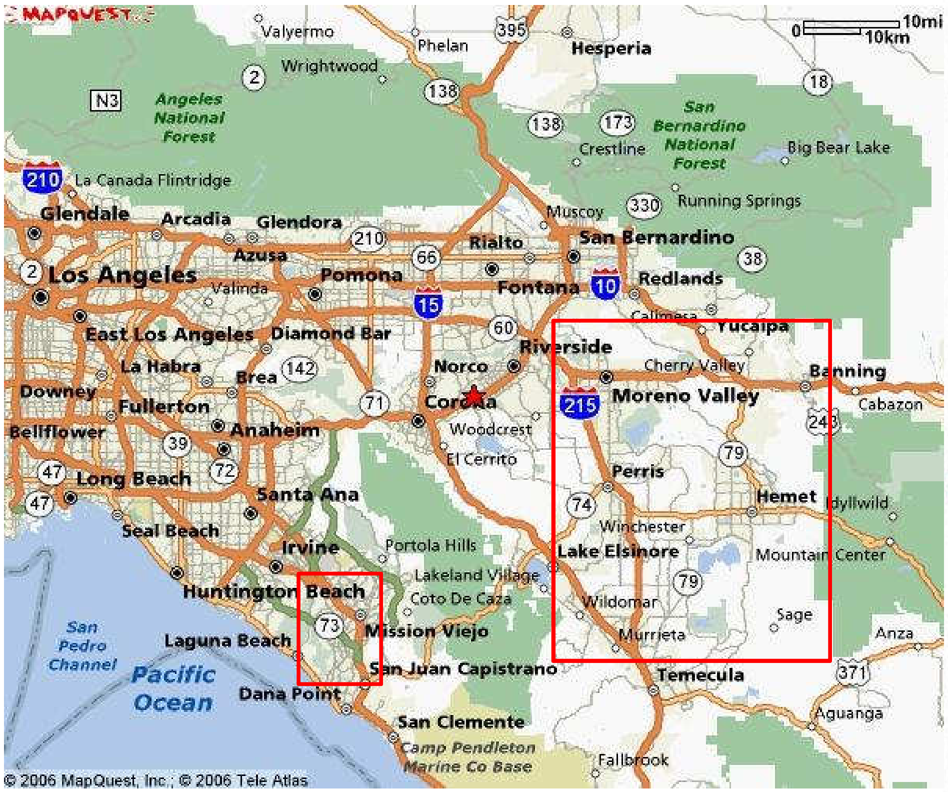
Goal was to promote conservation while maintaining fiscal balance

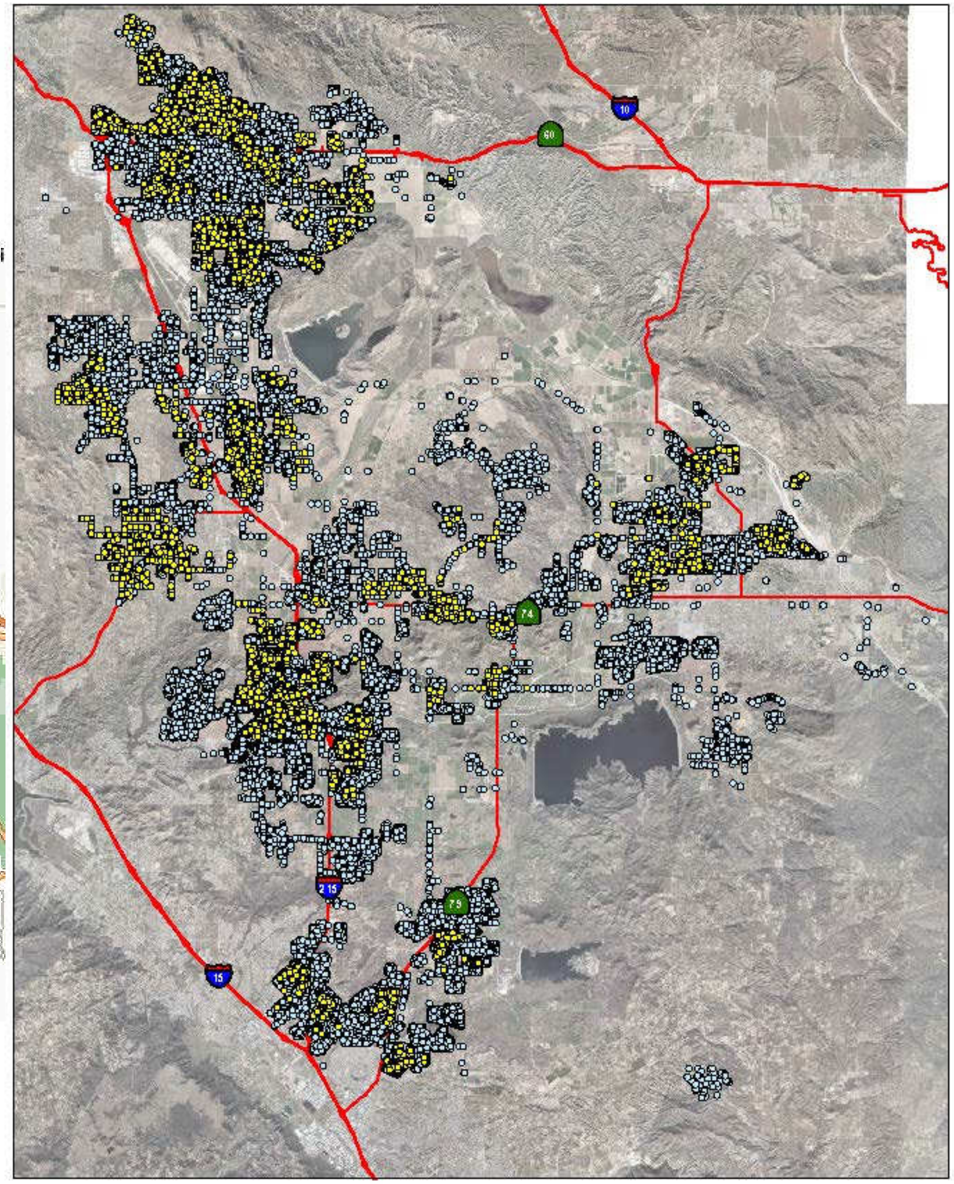
→ *How much conservation did they achieve?*

Data: sources and types

- 12,065 residential accounts (~10% of total) with good spatial coverage
- Continuous records from Jan. 2003 – Apr. 2014
- From EMWD:
  - Pricing, usage, household size, irrigated area, voluntary conservation requests, microclimate zone, latitude/longitude
- From other sources:
  - ET: EMWD/Hydropoint, CIMIS
  - Income, education: U.S. Bureaus of Census and Labor Statistics

Data: spatial distribution of sample households





- Sample accounts
- All water service connections

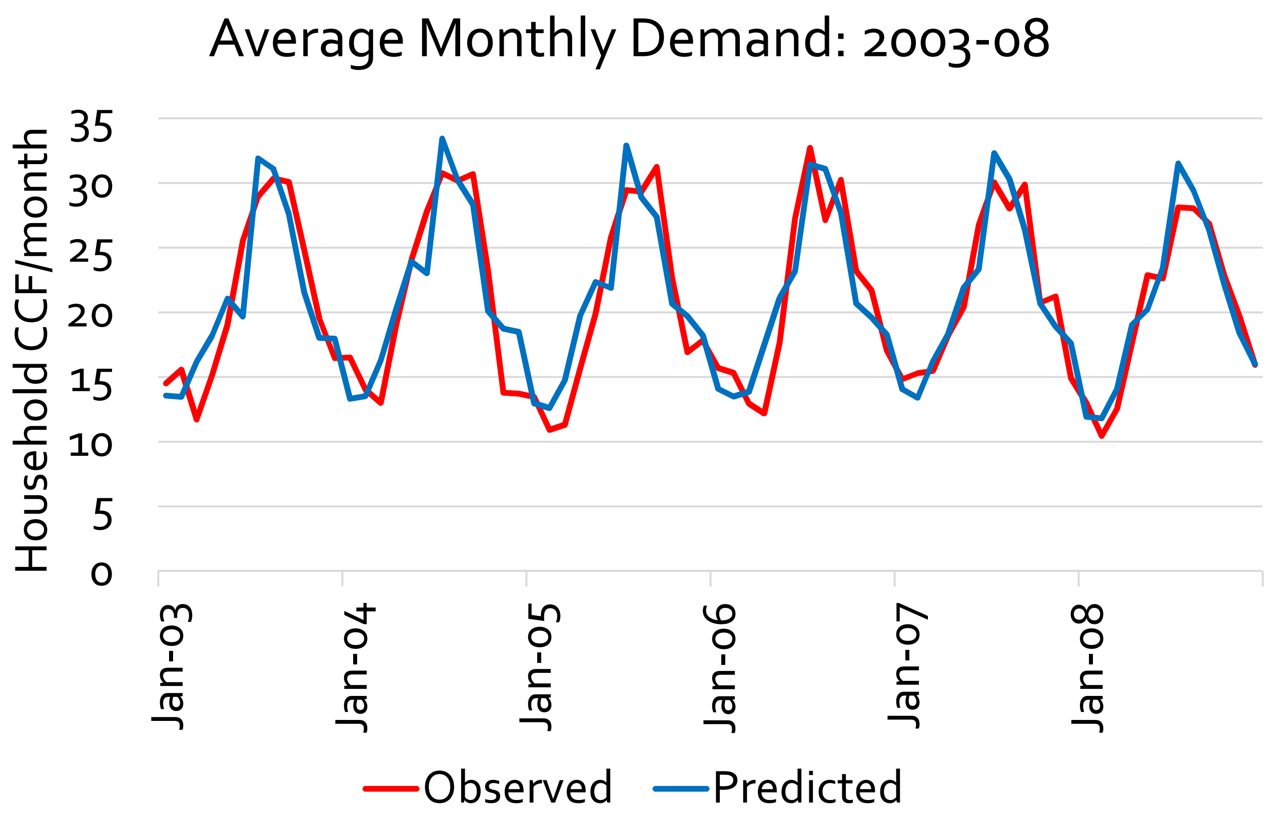
Data: summary statistics

Variable	2003	2004	2005	2006	2007	2008	2009		2010		2011	
Usage (CCF/month)	20.70	21.14	20.12	20.77	20.99	19.74	17.77		15.99		15.73	
ET (in/month)	4.67	4.87	4.59	4.73	4.87	4.81	4.70		4.55		4.85	
Nominal price ($/CCF)	1.43	1.46	1.53	1.62	1.69	1.85	1.93	1.27 2.33 4.17 7.63	2.10	1.43 2.61 4.68 8.56	2.05	1.44 2.64 4.73 8.65
Real price (2010$/CCF)	1.66	1.66	1.68	1.72	1.77	1.86	1.98	1.30 2.37 4.25 7.78	2.10	1.43 2.61 4.68 8.56	1.98	1.39 2.54 4.55 8.33
Income (2010$/month)	316.26	317.45	318.05	319.20	320.78	316.70	311.07		309.96		309.44	

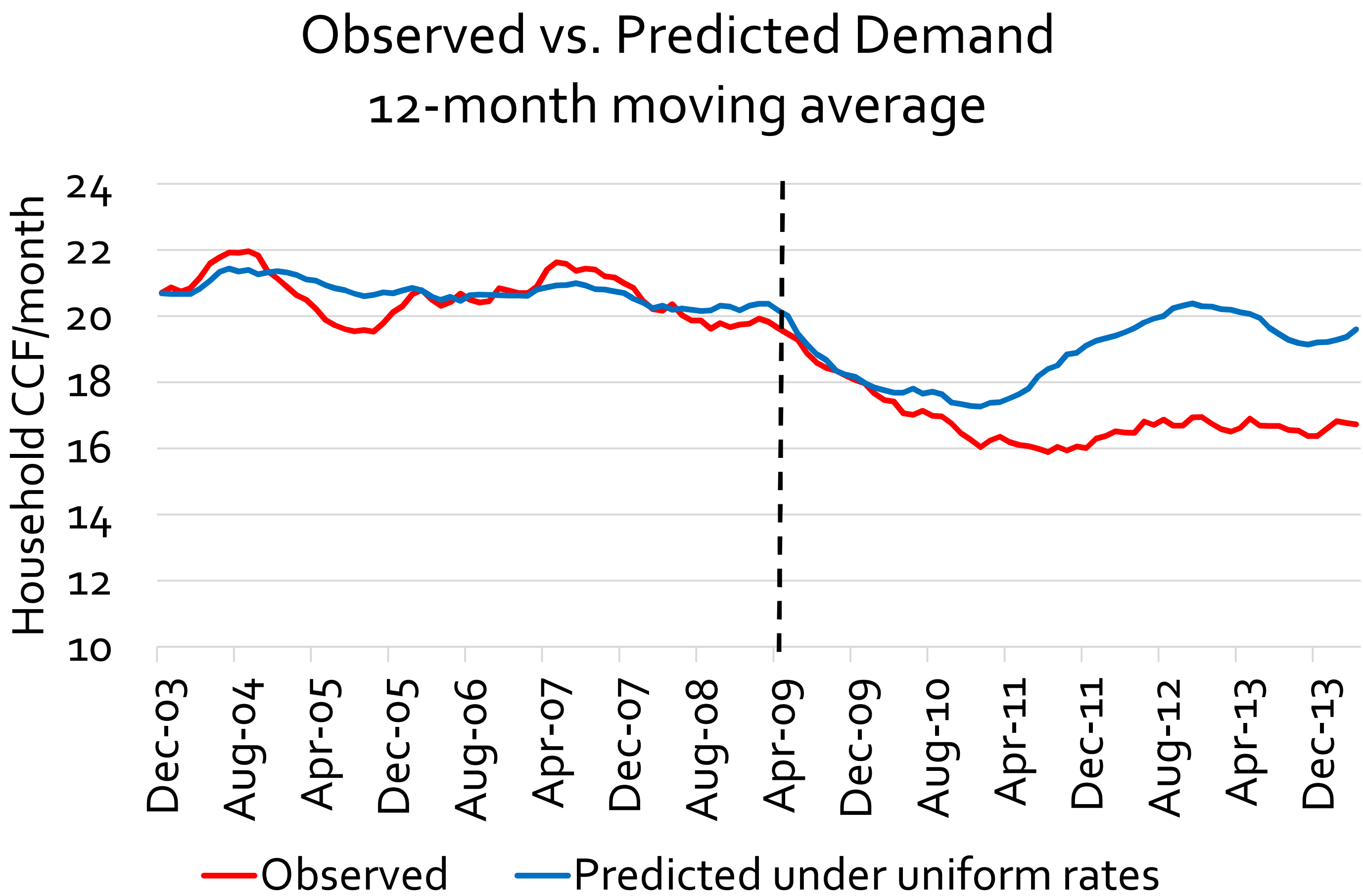
Estimation strategy

- Estimate a uniform rate demand model using data from January 2003 – December 2008
  - Estimated with household-level fixed effects
- Use the model to predict demand from April 2009 – April 2014 under equivalent uniform prices
- Difference between actual and predicted demand is the water budget-induced demand effect

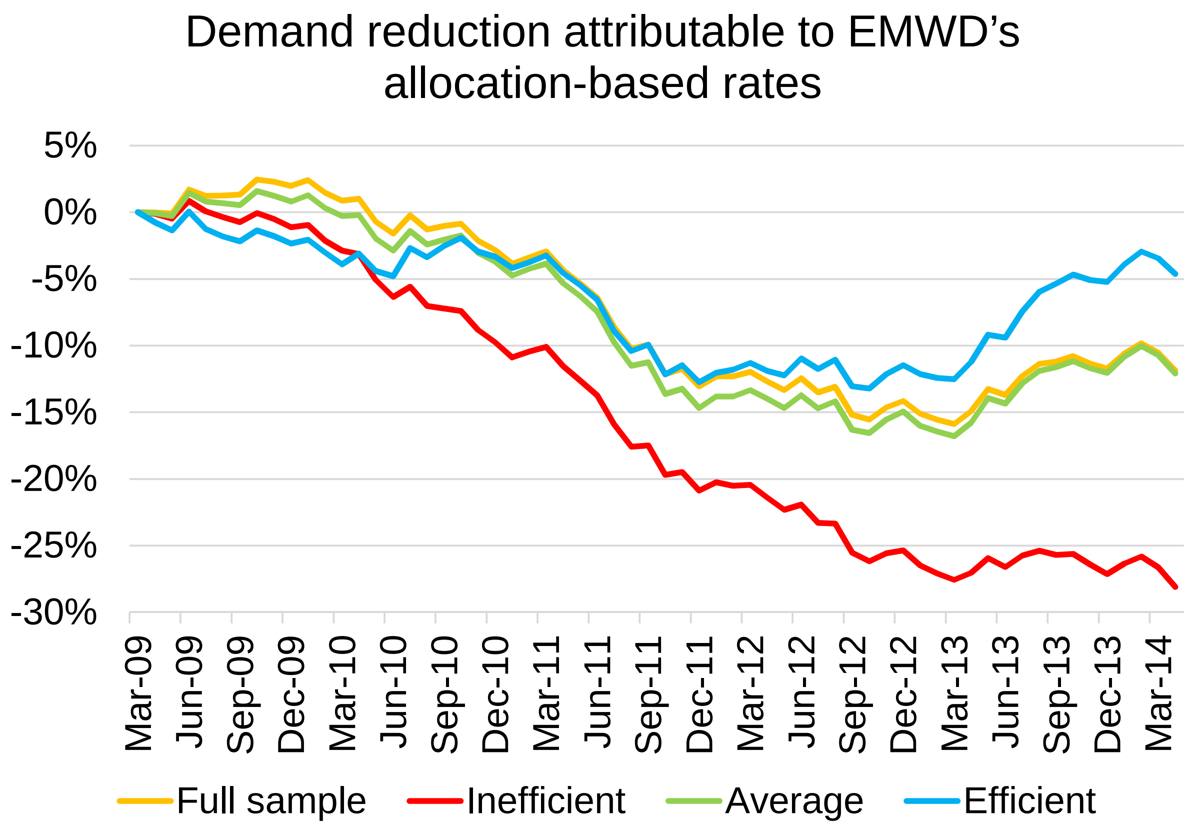
Estimation results



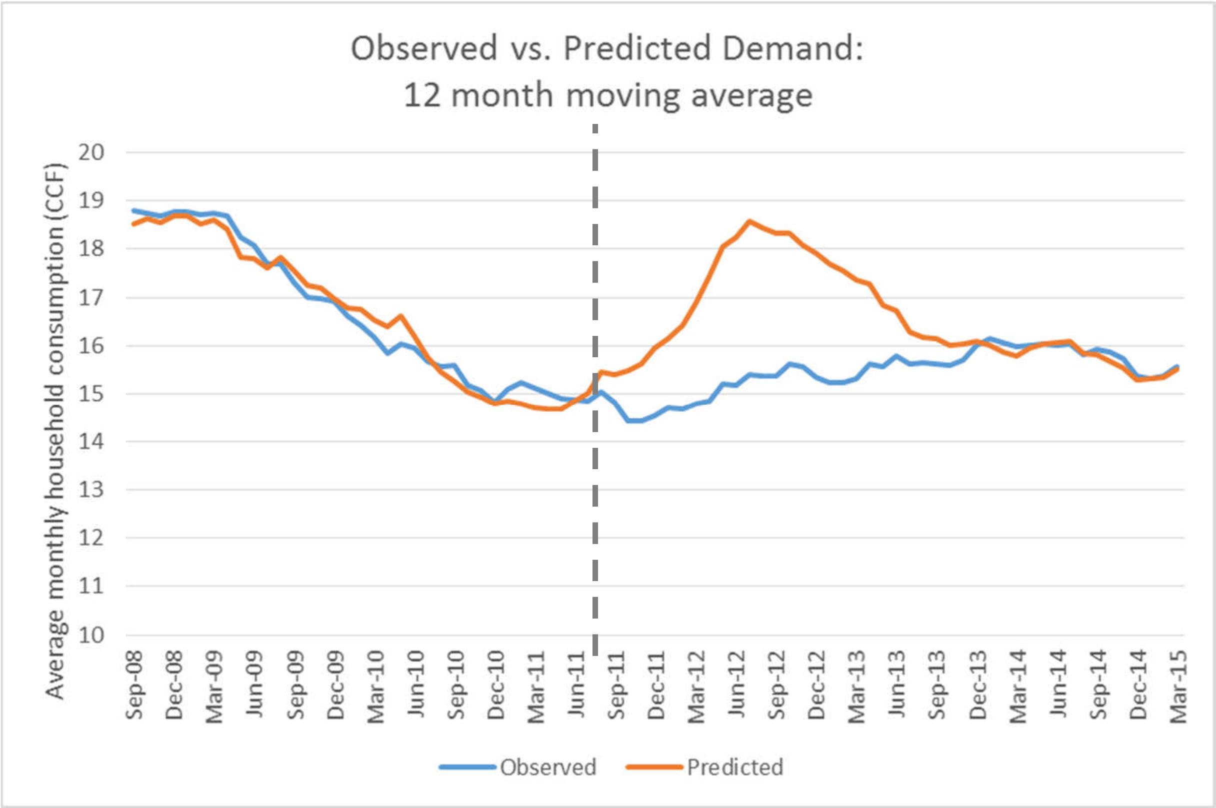
Estimated demand effect



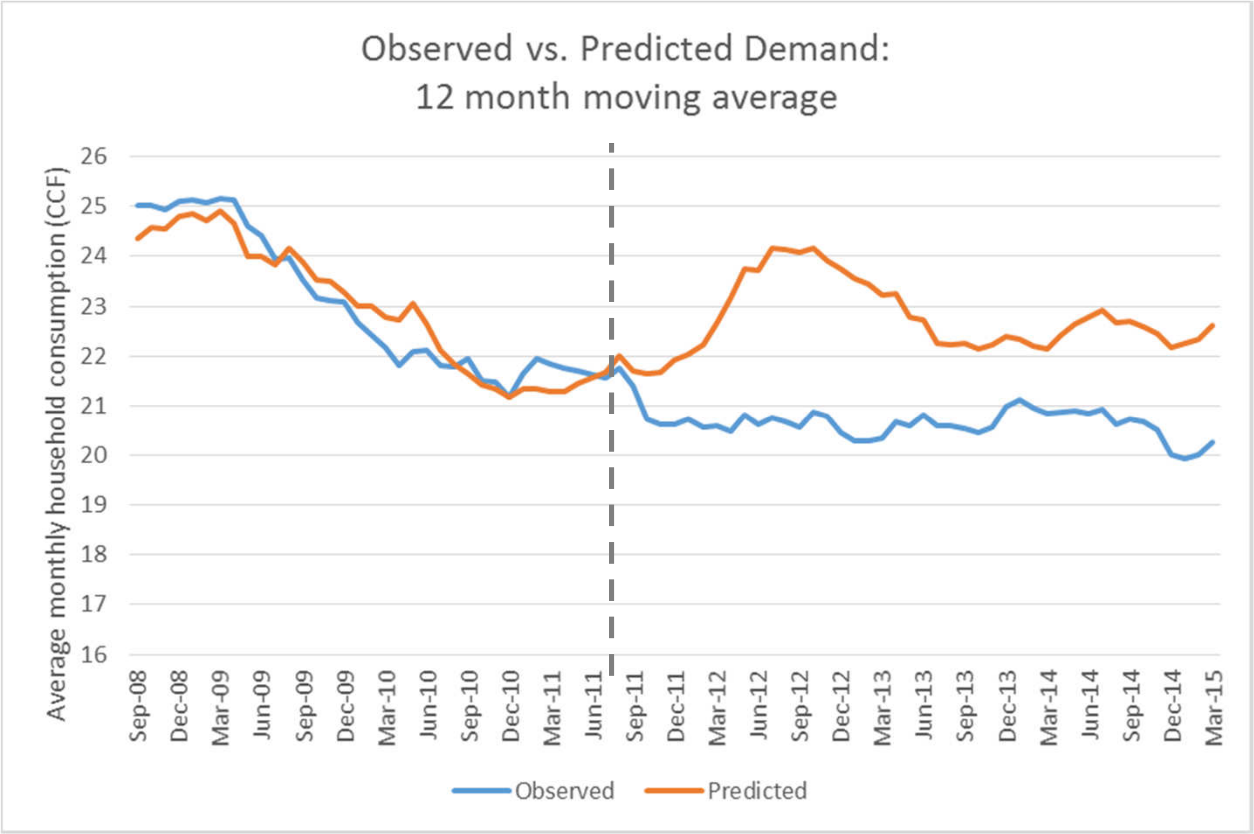
Larger, more persistent effects on inefficient users



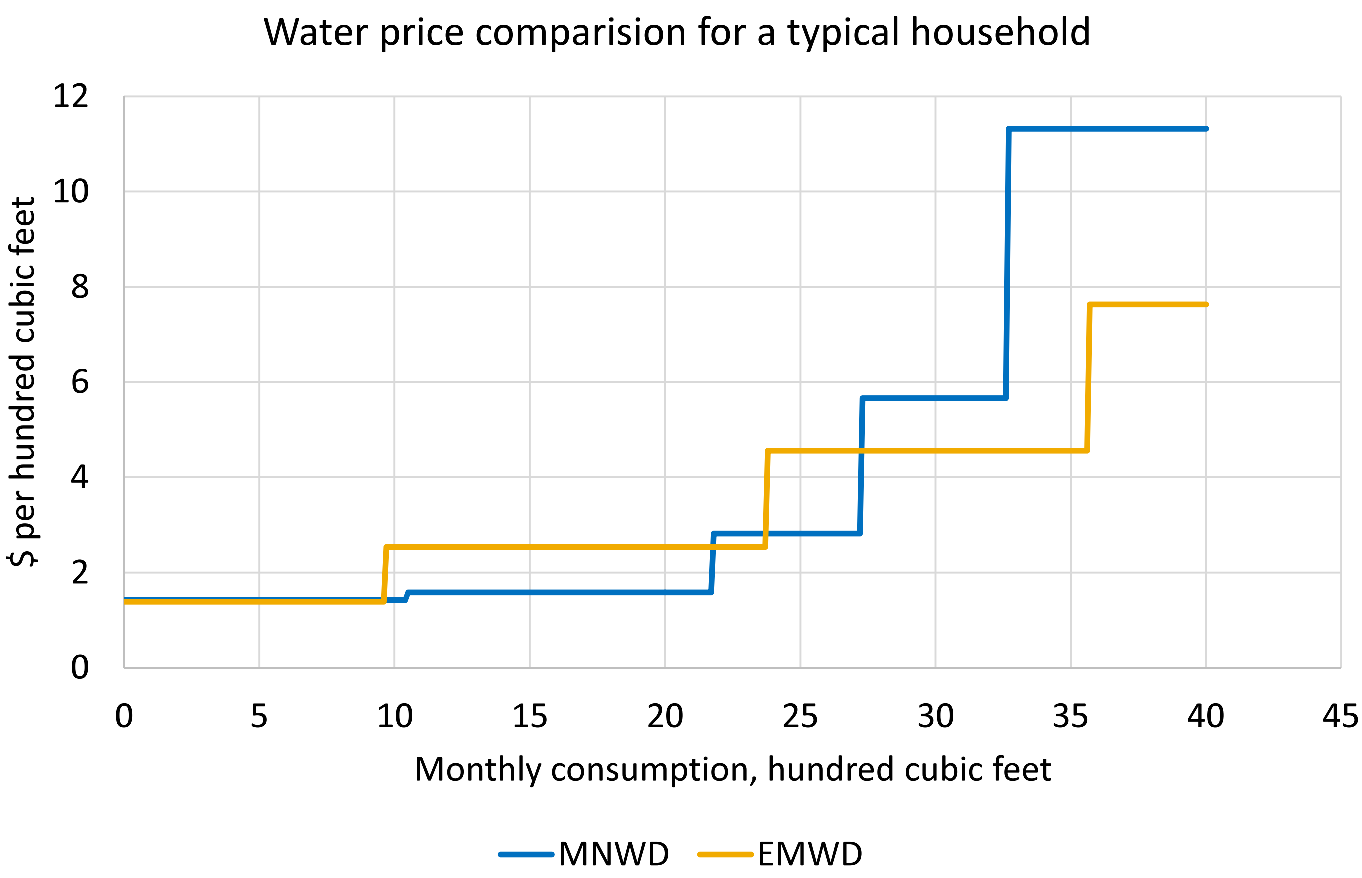
Case study #2: MNWD



Effect on inefficient households



Rate structure comparison



Summary: demand effects

- Demand reduction of up to 15% overall, and up to 30% by inefficient users, across two water districts.
  - Larger reductions when initial water use efficiency is lower and/or mid-tier prices are higher.
- Reductions by the most inefficient users are the largest and most resilient.
  - Consistent with a price-induced “ratcheting effect”: higher prices create new habits that become permanent.
- EMWD: Real average prices rose ~3% under water budgets, but would have had to rise ~30% under uniform pricing to achieve the same demand effect.
  - Significant conservation potential while also addressing equity concerns.
  - Suggests marginal price matters more than average price.

Estimating welfare effects

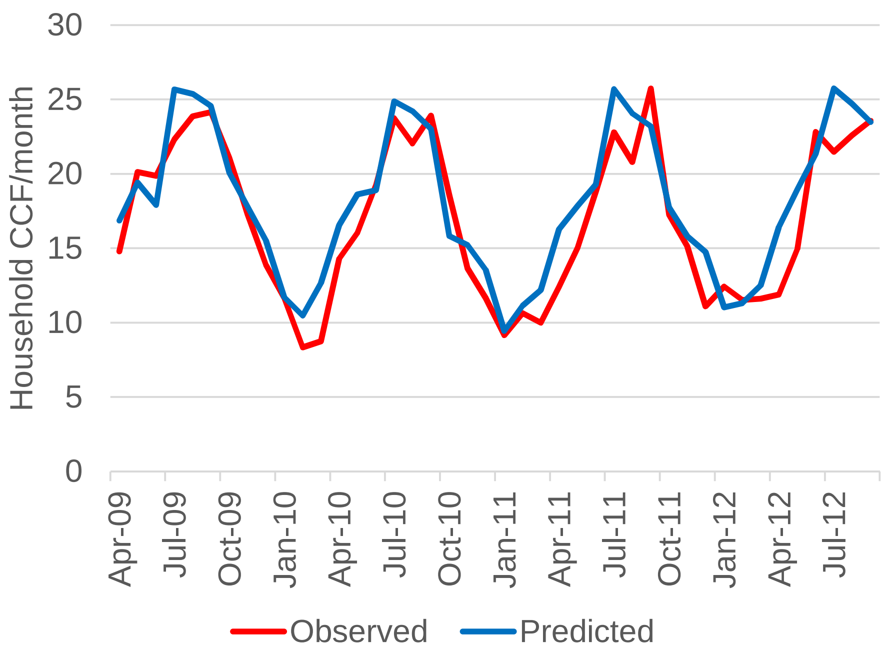
- Nonlinear pricing is challenging for empirical work
  - Price is endogenous
  - Solution for block pricing: model demand as a two step process
    - First, select the optimal consumption block
    - Next, select the optimal consumption level
  - This is the “discrete-continuous choice (DCC) model”

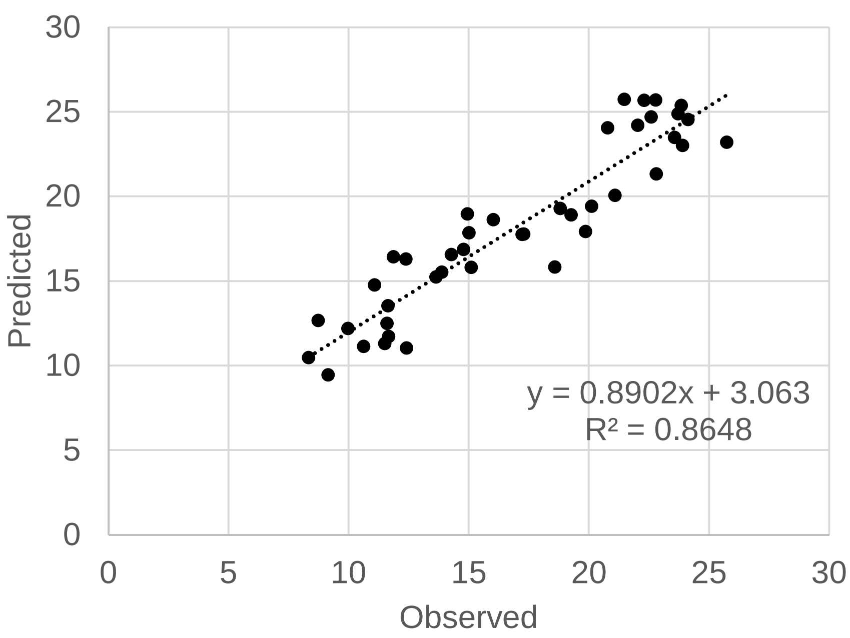
- Welfare estimation is even more challenging
  - Generally there is no analytical expression for demand under nonlinear prices
  - Implication: no analytical expressions for welfare effects
  - Solution: rely on numerical simulations

DCC model estimation results for EMWD

Variable	Description	Estimate
Constant	Constant	1.5550
Education	Fraction of census tract residents reporting "at least some college" or more education	0.5556
HHS	Household size (# of persons)	0.1347
IA	Irrigated area (1000 sq ft)	0.0295
Spring	Dummy for Apr-Jun	0.2335
Summer	Dummy for Jul-Sep	0.5185
Fall	Dummy for Oct-Dec	0.4670
Conserve	Dummy for conservation request	-0.1350
ET	ET (in/month)	0.1140
Time trend	Linear annual increments	-0.0727
Heterogeneity	Household-level preference heterogeneity	1.1106
p_{it}	Real price	-0.2201
d_{it}	Real money budget	0.0001
σ_ε	Standard deviation for ε	0.5676
σ_η	Standard deviation for η	0.2386

Overall good model fitness





Welfare effects under alternative policies

	Allocation-based rates	Price increase	Price increase with fixed cost decrease	Quantity restriction	Quantity restriction with fixed cost increase
Minimum EV ($/month)	-170.93	-150.97	-139.95	-7.26	-16.41
Mean EV ($/month)	1.98	-15.29	-7.40	-0.61	-7.26
Median EV ($/month)	5.70	-13.73	-5.82	-0.52	-7.16
Maximum EV ($/month)	168.28	-0.99	7.10	-0.04	-6.69
# of better-off households	8455	0	2298	0	0
% of better-off households	62%	0%	17%	0%	0%
Mean equivalent variation ($/month) by income terciles					
Top third	4.99 (1.4%)	-15.78 (-4.4%)	-7.90 (-2.2%)	-0.60 (-0.17%)	-7.24 (-2.0%)
Middle third	2.51 (0.8%)	-14.69 (-4.6%)	-6.78 (-2.1%)	-0.59 (-0.18%)	-7.23 (-2.3%)
Bottom third	-1.57 (-0.6%)	-15.42 (-5.5%)	-7.51 (-2.7%)	-0.65 (-0.23%)	-7.30 (-2.6%)

OLS regressions of EV on household characteristics

	Allocation-based rates	Price increase	Price increase with lump sum rebate	Quantity restriction	Quantity restriction with fixed cost increase
Constant	-26.4059	-14.3333	-6.3713	-0.8748	-7.5571
Income	0.1152	0.0384	0.0386	0.0028	0.0030
Consumption	-0.1566	-0.6683	-0.6741	-0.0342	-0.0361
(In)efficiency	-5.1170	0.3707	0.3408	0.0659	0.0910

Summary: welfare effects

- ABR is the only policy that improves overall welfare compared to baseline
- ABR is the only policy that is progressive in water use efficiency
- Each income group is better-off under ABR than it would be under a fiscally neutral uniform price or quantity instrument
- All policies are regressive in income
- Welfare under quantity restriction is slightly higher than under uniform price increase