The Value of Supply Reliability in Urban Water Systems

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Motivation

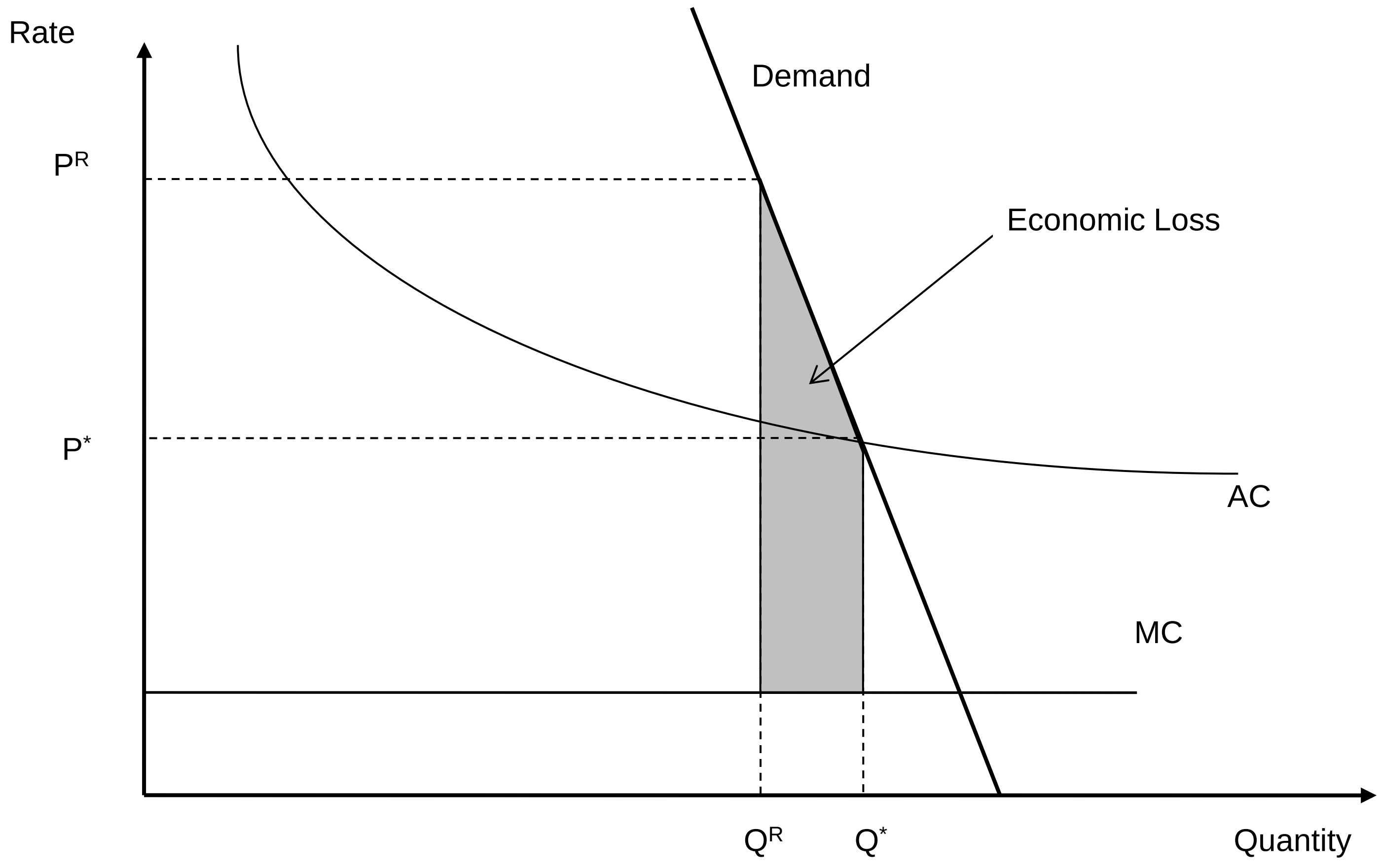
- Reliable and unreliable supply sources are sometimes treated as equivalent (e.g. public oversight agency)
  - They're clearly not, let's quantify the difference
- Difference in value is larger than one might imagine because water prices reflect marginal costs and fixed costs
- Empirical water demand literature lags electricity demand
- Implications for benefit-costs analyses related to:
  - Investment in infrastructure projects (e.g. Delta tunnel)
  - Impacts of environmental flow requirements

Loss framework: WTP for reliability

WTP is determined by:

- How utility covers costs
  - —Average cost versus marginal cost pricing
- Price elasticity of demand for water
  - —Spatial heterogeneity is significant
- Source of unreliability
  - —Marginal costs of service delivery varies by source

Simple graphic of losses



Data summary

- Observe 36 water retailers annually between 1996-2009 (unbalanced panel)
- BAWSCA Annual Survey: Rate and consumption data
- Direct survey of retailers in the MWDSC
- Census: Household income
- Western Regional Climate Center: Temperature and precipitation
- GIS: Overlaid Census and weather data over water district borders

Monthly HH consumption & price

Retailer	Obs.	CCF /month	(S.D. of CCF /month)	Price /CCF	(S.D. of Price /CCF)
Alameda CWD	13	12.78	(0.66)	1.83	(0.38)
Anaheim	11	19.21	(1.11)	1.26	(0.22)
Brisbane	9	5.66	(0.44)	2.98	(0.86)
Burbank	14	25.15	(2.29)	1.45	(0.30)
Burlingame	13	11.70	(0.60)	1.35	(0.60)
CWS - Bear Gulch	13	26.11	(1.82)	2.24	(0.40)
San Bruno	13	11.36	(0.84)	3.14	(0.92)
San Jose	14	9.23	(0.60)	1.56	(0.23)
Santa Ana	12	18.03	(1.99)	1.76	(0.55)
Santa Clara	14	13.90	(0.82)	1.60	(0.48)
Santa Monica	10	16.86	(1.01)	2.24	(0.55)
Skyline WD	12	11.95	(0.66)	8.16	(3.44)
Sunnyvale	14	13.11	(0.71)	1.90	(0.60)
Westborough WD	14	7.68	(0.86)	2.03	(0.44)
Unweighted Average	*12.24*	*14.82*	*1.04*	*2.39*	*0.66*

Regression specification

$$\ln(q_{it}) = \beta_1 \ln(p_{it}) + \beta_2 W_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

where,

- q_{it} is the average single family residential consumption in retail service area *i* in year *t*
- p_{it} is the marginal price paid by the average consumer
- W_{it} measures average daily temp. & annual precipitation
- μ_i is a retail service area fixed effect
- τ_t is a year fixed effect

Regression results

	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	IV	OLS	IV
ln(Price)	0.173***	-0.100***	-0.135***	-0.591***	-0.725***
	(0.043)	(0.033)	(0.031)	(0.194)	(0.166)
ln(Price)·ln(Income)				0.110***	0.131***
				(0.041)	(0.035)
Observations	453	453	453	453	453
Within R^2	0.32[a]	0.51	0.50	0.52	0.52
Weather controls	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Retailer fixed effects	No	Yes	Yes	Yes	Yes

[a] Unadjusted R^2. Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Implied price elasticities

SF Bay Area Agency	ϵ	Southern CA Agency	ϵ
East Palo Alto Co. Waterworks	-0.216	Compton	-0.269
Hayward Water Dept.	-0.205	San Fernando	-0.246
SFPUC	-0.199	Long Beach	-0.238
Cal Water - So. San Francisco	-0.193	Eastern MWD	-0.237
Daly City Public Works Dept.	-0.184	Los Angeles	-0.234
San Bruno Water Dept.	-0.183	Central Basin MWD	-0.234
Brisbane Public Works Dept.	-0.182	Santa Ana	-0.229
Mid Peninsula W.D.	-0.146	Torrance	-0.199
Milpitas Water Dept.	-0.145	West Basin MWD	-0.199
Menlo Park M.W.D.	-0.140	Three Valleys MWD	-0.194
San Jose Municipal Water Sys.	-0.138	MWD of Orange County	-0.176
Coastside County W.D.	-0.133	Calleguas MWD	-0.175
Palo Alto Water Dept.	-0.131	Foothill MWD	-0.163
Estero M.I.D.	-0.130	Beverly Hills	-0.161
Purissima Hills W.D.	-0.097	Las Virgenes MWD	-0.131
Cal Water - Bear Gulch	-0.097	San Marino	-0.097
Hillsborough Water Dept.	-0.097		

Calculating the value of reliability

- We assume constant elasticity of demand:

$$P_i = A_i \, Q_i^{\frac{1}{\varepsilon_i}}$$

- Let P_i^* and Q_i^* denote retail price and consumption.
- Define $Q_i(x) = (1 - r_i)Q_i^*$.

We may write,

$$W_i(x) = \int_{Q_i(x)}^{Q_i^*} P_i(Q)dQ_i = \int_{Q_i(x)}^{Q_i^*} A_i Q_i^{\frac{1}{\varepsilon_i}} dQ_i$$

Integrating we obtain,

$$W_i(x) = \frac{\varepsilon_i}{1+\varepsilon_i} P_i^* \, Q_i^* [1\text{-}(1-r_i)^{\frac{\varepsilon_i}{1+\varepsilon_i}}]$$

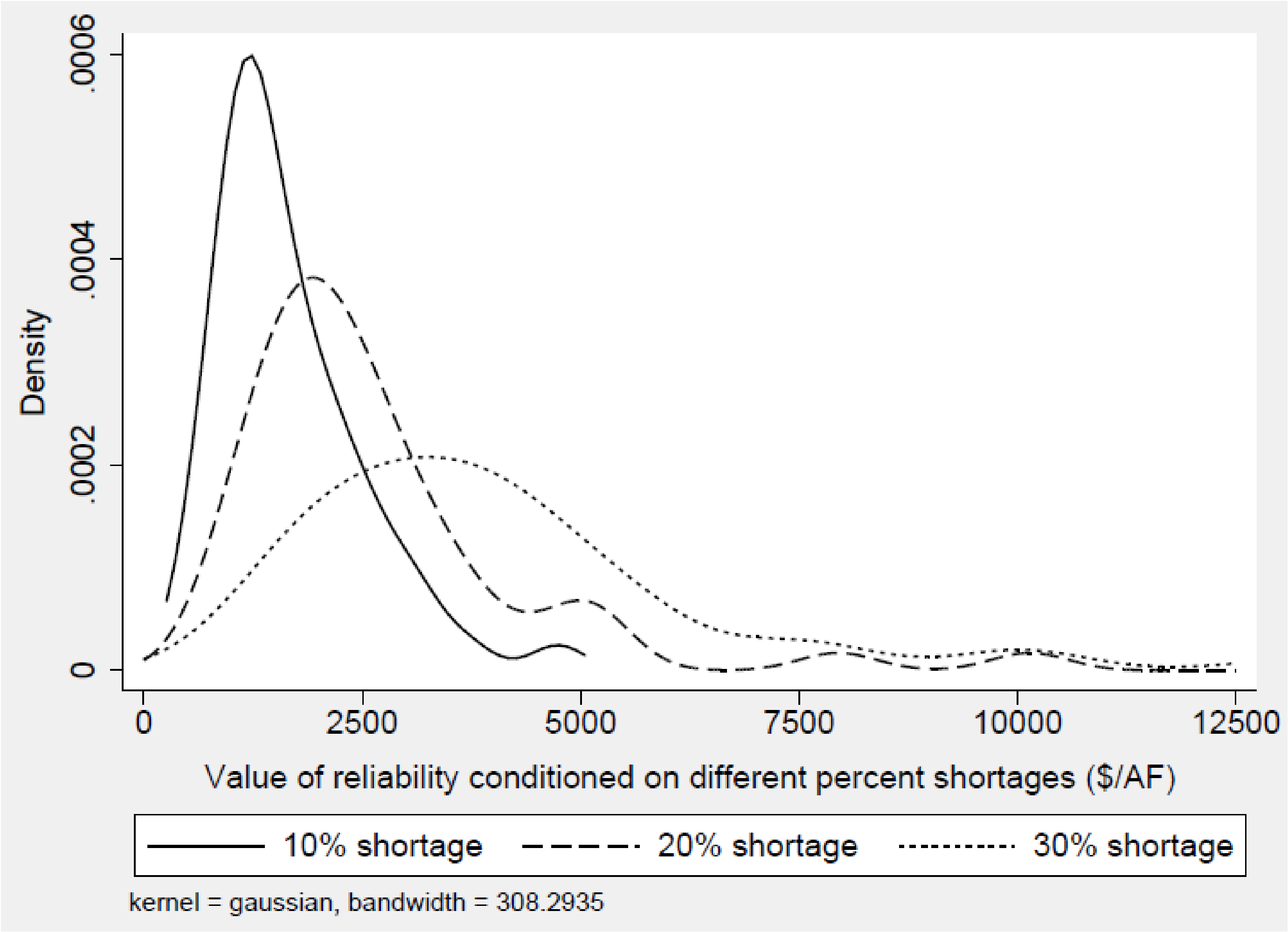
Welfare losses in the SFR sector

Panel A: SF Bay Area Agencies			
Average Price : $1,485/AF; Total SFR Demand (AF): 177,269; Avg. Elasticity: -0.153			
Percent shortage	10%	20%	30%
Total ($ millions)	$29	$95	$271
[95% Bootstrapped C.I.]	[$25 - $36]	[$67 - $157]	[$146 - $610]
Average ($/AF)	$1,616	$2,692	$5,091
[95% Bootstrapped C.I.]	[$1,387 - $2,029]	[$1,897 - $4430]	[$2,742 - $11,478]

Due to average cost pricing, losses are quite large even for a 10% shortage.

Panel B: Southern CA Agencies			
Avg. Price: $1,157/AF; Total SFR Demand (AF): 1,977,698; Avg. Elasticity: -0.204			
Percent shortage	10%	20%	30%
Total ($ millions)	$277	$778	$1,740
[95% Bootstrapped C.I.]	[$248 - $396]	[$614 - $1,729]	[$1,172 - $6,724]
Average ($/AF)	$1,400	$1,968	$2,928
[95% Bootstrapped C.I.]	[$1,256 - $2,000]	[$1,553 - $4,372]	[$1,975 - $11,334]

Heterogeneity: Losses by % shortage



Concluding remarks

- Panel methods increment upon past work of Renwick & Greene (2000)
- Our approach to measuring reliability addresses the financial structure of water agencies
- Heterogeneity in elasticities plays an important role in determining the value of reliability
- Application to benefit-cost analyses:
  - Framework is easily extended to other sectors (e.g. multifamily, commercial & industrial, ag)
  - Calculation of a reliability premium requires the probability dist. for shortage scenarios
  - Valuation of long-term supply management requires forecasts of demand

Future work

- Collect end-user billing data to examine:
  - Robustness of estimated price elasticities
  - Demand hardening w/ conservation & other sources of heterogeneity in elasticities
- More information on the marginal costs of service delivery
- Sensitivity of reliability premiums under alternative climate change scenarios
- Consider gains in the loss framework