Water
Demand, Regulation, and Health

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Renwick, Green. “Do residential water demand side management policies measure up? An analysis of eight California water agencies” Journal of Environmental Economics and Management, (2000),Olmstead, Hanemann, Stavins, “Water demand under alternative price structures”, Journal of Environmental Economics and Management (2007)

Galiani, Gertler, Schargrodsky “Water for Life: The Impact of the Privatization of Water Services on Child Mortality” JPE, (2005), Zivin, Neidell, Schlenker “Water quality violations and avoidance behavior: Evidence from bottled water consumption” AER (2011)

Introduction

- Demand side management (DSM)as water resource management
- Economists: price policies
- Others: residential demand is price inelastic, why
  1. No close substitutes for water in most of its uses
  2. Money spent on water is generally small share
  3. Water is frequently demanded jointly with some other complementary good
- Economists:
  1. Demand become elastic as price rises
  2. Price inelastic $\neq$ no price responsive

Introduction

- "non-price" DSM policy instruments
  - public education campaigns
  - rationing
  - water use restrictions
  - subsidies for adoption of more water-efficient technologies
- Failure to account for non-price policies + both policies implemented ⇒ overestimate of price responsiveness of water demand
- An econometric model incorporates
  - alternative non-price DSM policies
  - endogenous block pricing schedules
  - harmonic model to separately capture the effects of seasonality and climatic variability on demand

DSM Policies in Urban California

- Study experience with residential DSM programs in Ca in 1989-1996
- Drought between 1985 and 1992
- Eight urban water agency (24% of Ca)
  - San Francisco Water District (SFWD)
  - Marin Municipal Water District (MMWD)
  - Contra Costa Water Agency (CCWA)
  - East Bay Municipal Utility District (EBMUD)
  - City of San Bernardino (SBERN)
  - City of Santa Barbara (SBARB)
  - Los Angeles Department of Water and Power (LADWP)
  - City of San Diego (SDIEGO)

Data

- Average Single Family Residential Monthly Water Use

Year	SFWD	CCWA	SBARB	LADWP	MMWD	SBERN	SDIEGO	EBMUD
	HCF[a]							
1989	6.53	15.28	14.65	19.11	10.48	24.97	14.50	10.68
1990	6.49	15.04	7.31	18.30	10.28	24.35	13.59	10.92
1991	5.53	10.10	7.29	14.48	7.58	22.18	10.83	9.41
1992	5.91	11.90	8.96	15.23	8.62	21.8	11.73	10.03
1993	6.31	12.67	9.78	15.51	9.23	22.14	11.73	10.78
1994	6.68	12.86	10.48	16.28	9.73	22.56	12.00	11.12
1995	6.61	12.82	10.51	16.07	9.90	22.90	11.88	11.13
1996	6.79	13.34	11.12	17.51	10.48	24.67	13.07	11.51
1989–1996 Avg	6.36	13.00	10.01	16.56	9.54	23.20	12.42	10.70

- One hundred cubic feet (HCF)
- Huge variation in usage and trend in reduction

Average Marginal Prices ($ per HCF) and Type of Pricing

- Both uniform (UR) and increasing block (IB) rate schedules
- Rates vary in both level and increasing trends

Year	SFWD	CCWA	SBARB	LADWP	MMWD	SBERN	SDIEGO	EBMUD
1989	0.59[UR]	1.01[UR]	1.30[UR, IB]	1.02[UR]	1.66[UR, IB]	0.49[UR]	1.04[IB]	0.72[UR]
1990	0.63[UR]	1.00[UR]	2.80[IB]	1.21[UR]	2.21[IB]	0.60[UR]	1.08[IB]	0.96[UR]
1991	0.81[UR]	1.00[UR]	3.62[IB]	1.13[UR]	2.97[IB]	0.69[UR]	1.06[IB]	0.98[UR]
1992	0.92[UR]	1.68[UR]	3.70[IB]	1.43[UR]	3.78[IB]	0.72[UR]	1.22[IB]	1.08[UR]
1993	0.96[UR]	1.68[UR]	3.70[IB]	1.61[UR, IB]	2.74[IB]	0.72[UR]	1.32[IB]	1.15[UR, IB]
1994	1.10[UR]	1.68[UR]	3.70[IB]	1.78[IB]	2.13[IB]	0.72[UR]	1.40[IB]	1.21[IB]
1995	1.17[UR]	1.75[UR]	3.63[IB]	1.84[UR]	2.30[IB]	0.72[UR]	1.43[IB]	1.31[IB]
1996	1.22[UR]	1.76[UR]	3.50[IB]	1.75[UR]	2.13[IB]	0.72[UR]	1.50[IB]	1.41[UR]
1989–1996 Avg	0.93	1.45	3.24	1.47	2.49	0.67	1.26	1.11
Predominant pricing schedule[b]	UR	UR	IB	UR	IB	UR	IB	UR

Key Non-price DSM Policy Instruments

- RETRO: policies for free Retrofit kits usually include a low-flow showerhead, tank displacement devices, and dye tablets for leak detection
- RATION: generally allocate a fixed quantity of water to households, impose penalties for exceeding allotment, such as severe marginal price penalties
- RESTRICT: prohibitions on washing down sidewalks and driveways or bans on landscape irrigation during peak evapotranspiration hours
- For example, Santa Barbara banned all forms of irrigation 1990-1991, hired "water police" to enforce policy
- COMPLY: all households to file an affidavit attesting that specific water-efficient devices were installed in the household, if did not file the affidavit faced higher marginal prices

Key Non-price DSM Policy Instruments by Agency

- DSM policies:
    - public information campaigns (INFO)
    - subsidies:ultra-low-flow toilet rebate programs (REBATE)
    - distribution of free retrofit kits (RETRO)
    - Rationing or allocation programs (RATION)
    - Water use restrictions (RESTRICT)
    - compliance affidavit (COMPLY)

	Type of DSM policy implemented[a, b]					
Agency	INFO	REBATE	RETRO	RATION	RESTRICT	COMPLY
SFWD	x	x		x		x
CCWD	x	x	x	x		
SBARB	x	x	x		x	
LADWP	x	x	x		x	
MMWD	x	x	x			
SBERN			x			
SDIEGO	x	x	x			
EBMUD	x	x	x			

Model

- Three basic components:
    - price equations (two equations)
    - climate equations (two equations)
    - water demand equation
- Old fashion demand system:
    - price equations capture endogenous pricing b/c func. of quantity
    - climate equations capture variations in climate

Model Specification- Price Equations

- Price Equations

$$
\begin{aligned}
ln(MP_{it}) &= \sum \alpha^{mp} ln(Z_{it}^{mp}) + e_{it}^{mp} \\
ln(D_{it}) &= \sum \alpha^{dw} ln(Z_{it}^{dw}) + e_{it}^{mp}
\end{aligned}
$$

- MP_{it} Marginal price ($ HCF)
- D difference between what a consumer would have paid if all units were purchased at the marginal price and the amount paid under the block pricing schedule

$$
D = P_m Q_m - m(P_1 Q_1 + (\sum_{i=2}^{m} P_i (Q_i - Q_{i-1})))
$$

- m : consuming block, P_i marginal price in block$_i$, Q_i threshold quantity block$_i$, Q_m total quantity

Model Specification-Climate Equations

- Climate Equations

$$
\begin{aligned}
ln(DTEMP_{it}) &= \gamma_0^{yp} + \sum_{j=1}^{6}\left\{\gamma_{1,j}^{tp} sin(\frac{2\pi jt}{12}) + \gamma_{2,j}^{tp} cos(\frac{2\pi jt}{12})\right\} + e_{it}^{tp} \\
ln(DPREC_{it}) &= \gamma_0^{pr} + \sum_{j=1}^{6}\left\{\gamma_{1,j}^{pr} sin(\frac{2\pi jt}{12}) + \gamma_{2,j}^{pr} cos(\frac{2\pi jt}{12})\right\} + e_{it}^{pr}
\end{aligned}
$$

- $DPREC_{it}$: Deviation of cum monthly rainfall from historic mean
- $DTEMP_{it}$: Deviation of avg max daily air temp from historic mean

Model Specification-Water Demand Equation

- Water Demand Equation

$$
\begin{aligned}
ln(W_{it}) \quad = \quad & \beta_0 + \beta_1 ln(\hat{MP}_{it}) + \beta_2 \hat{D}_{it} + \beta_3 ln(IN_{it}) + \beta_4 INFO_{it} \\
& + \beta_5 RETRO_{it} + \beta_6 REBATE_{it} + \beta_7 RATION_{it} \\
& + \beta_8 RESTRIT_{it} + \beta_9 COMPLY_{it} + \beta_{10} LIRR_{it} \\
& + \beta_{11} HIRR3_{it} + \beta_{12} ln(TE\hat{M}P_{it}) \\
& + \beta_{13} ln(P\hat{R}EC_{it}) + \beta_{14} LOT_{it} + \beta_{15,j} sin(\frac{2\pi jt}{12}) \\
& + \beta_{16,k} sin(\frac{2\pi kt}{12}) + e_{it} \\
& j = 1, \cdots, 5; k = 1, \cdots, 6; t = 1, \cdots, 96
\end{aligned}
$$

- W: Water use (HCF)
- $LIRR_i = 1$ for agency i, if expect low irrigation outdoor use
- $HIRR_i = 1$ for agency i, if expect high irrigation outdoor use
- LOT: Average household lot size

Specification

- where:

$$\begin{aligned} e_{it} &= \rho e_{i,t-12} + u_{it} \\ ln(Z_{it}^{mp}) &= (ln(P1_{i,t-1}), ln(P2_{i,t-1}), ln(P3_{i,t-1}), ln(IN_{it}), \\ &\quad ln(HH_{it}), ln(LOT_{it})) \\ ln(Z_{it}^{dw}) &= (ln(P1_{i,t-1}), ln(P2_{i,t-1}), ln(P3_{i,t-1}), ln(IN_{it}), \\ &\quad ln(HH_{it}), ln(LOT_{it}), BLOCK_{it}, ln(D_{i,t-1})) \\ ln(T\hat{EM}P_{it}) &= \hat{e}_{it}^{tp} = ln(DTEMP_{it}) - ln(DT\hat{E}MP_{it}) \\ ln(P\hat{R}EC_{it}) &= \hat{e}_{it}^{pr} = ln(DPREC_{it}) - ln(DP\hat{R}EC_{it}) \end{aligned}$$

Estimation

- Instrumental variables, $ln(Z)$:lagged marginal price for each block of the rate schedule + selected socioeconomic variables
- Fitted marginal price and difference variables are used in second stage
- Climate variables in deviation to mitigate multicollinearity
- Include sine and cosine terms to remove seasonal patterns
- Under increasing block pricing schedules, D acts as an implicit income subsidy $\Rightarrow$ positive effect
- Alternative non-price DSM policies expected to negative effect
- $T\hat{EMP}_{it}, P\hat{REC}_{it}$ capture influence of changes in historical climatic patterns

Data

- Agency-level mean monthly single family water use and cost data for 1989 to 1996 from agencies
- Socioeconomic from census
- Precipitation and temperature from Western Regional Climate Center in Reno, Nevada

Results

- Robust estimates:

Variable	Est coefficient	Variable	Est coefficient
Intercept	2.61	$\ln INC$	0.25
	0.16***		0.10**
$\ln \hat{MP}$	−0.16	$\ln LOT$	0.27
	0.03***		0.03***
$\ln \hat{D}$	0.01	*HIRR*	0.53
	0.02		0.05***
INFO	−0.08***	*LIRR*	−0.30
	0.02		0.04***
REBATE	−0.004	$\ln T\hat{EM}P$	0.45
	0.02		0.11***
RETRO	−0.09	$\ln PR\hat{E}C$	−0.01
	0.02***		0.01
RATION	−0.21	*SIN1*	−0.28
	0.03***		0.02***
RESTRICT	−0.34	*COS1*	0.10
	0.04***		0.02***
COMPLY	0.003	*RHO*	0.58
	0.03		0.03***
		R^2 (Adj)	0.91

Results

- a 10% increase in income will increase average household monthly water demand by 2.5%
- Difference variable is insignificant, due to aggregated nature of water use
- a 10% increase in lot size, a 2.7% increase in water demand on average
- Air temperature variable is positive
- Marginal price of water is negative, own-price elasticity of demand equals -0.16
- a 10% increase in price will reduce demand 1.6%

Results

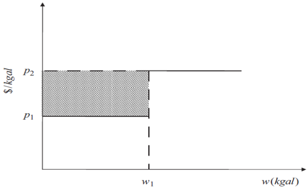
- Alternative DSM policy measurable effect on aggregate water demand
- Negative and significant: public information campaigns (INFO) 8%, retrofit subsidies (RETRO) 9%, water rationing (RATION) 19%, water use restrictions (RESTRICT)29%
- REBATE and COMPLY not significant

Introduction

- What is the problem of the paper?
  - Aggregate data
  - Identification (dummy for DSM policies correlated with dummy of agency)
  - Endogeneity in prices, schedule
- Olmstead, Hanemann, Stavins, "Water demand under alternative price structures", Journal of Environmental Economics and Management (2007)
- In 2000, one-third of US urban residential water customers faced increasing block prices (IBP)
  - household-level water demand data
  - structural water demand
  - elasticity for non-linear model
  - elasticity function of choice of price structure

Block pricing and efficiency

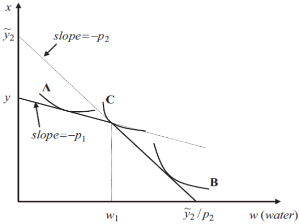
- Fixed water service fee
- Increasing block structures: staircase ascending from left to right



- Water prices below long-run marginal cost (LRMC)
- LRMC greater than short-run average cost, because LRMC reflects cost of new supply acquisition
- High consuming prices close to LRMC

Consumer responses to water prices and price structure

- Utility maximization under a two-tier increasing block price structure (w water, x all other goods)



- Similar to labor supply effects of progressive income taxation
- Why studies find higher elasticity due to IBP?
  - mathematical measure captures something different under uniform and IBP structures (probability in what segment)
  - elasticity function of price structure (behavioral reactions)

Demand models

- Demand $ln(w) = Z\delta_\alpha ln(p) + \gamma ln(y) + \eta + \epsilon$
- y income
- Z: daily weather observations, city fixed effects, household characteristics
- η heterogeneous water consumption preferences among households
- ϵ random error unobservable to all
- Under Uniform Pricing:

$$ln(L) = \sum ln\left(\frac{1}{\sqrt{2\pi}}\frac{exp(-(s)^2/2)}{\sigma_\nu}\right)$$

- $\nu = \eta + \epsilon$, $s = (ln(w) - ln(w^*(Z, p, y; \delta, \alpha, \gamma)))/\sigma_\nu$

Demand models

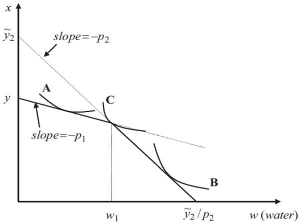
- K blocks, price p_k, separated by $K-1$ "kinks" at w_k
- Conditional in kth price block: demand as before at p_k, income $\tilde{y}_k = y + d_k$ (virtual income)

$$d_k = \begin{cases} 0 & if\ k = 1 \\ \sum_{j=1}^{k-1} (p_{j+1} - p_j) w_k & if\ k > 1 \end{cases}$$

- For $k > 1$, a wedge between the marginal and average price
- Implicit subsidy from infra-marginal rates by adding to income difference d_k
- What a household would pay if all units were charged at the marginal price and what paid.
- This income supplement cross-hatched in Fig. 1
- Next, unconditional demand, which price block to choose

Demand models

- If conditional demand block 2 (curve B)



- HH may choose kink point if kink (w_k) higher utility than all w in block k and also higher than all w utility in block $k+1$
- Unconditional demand adjust by errors
- w observed consumption
- $w_k^*(Z, p_k, \tilde{y}_k; \delta, \alpha, \gamma)$ optimal consumption on block k (denote by w_k^*)
- w_k is consumption at kink point k

Demand models

$$ln(w) = \begin{cases} ln(w_1^*) + \eta + \epsilon & if\ -\infty < \eta < ln(w_1) - ln(w_1^*) \\ ln(w_1) + \epsilon & if\ ln(w_1) - ln(w_1^*) < \eta < ln(w_1) - ln(w_2^*) \\ ln(w_2^*) + \eta + \epsilon & if\ ln(w_1) - ln(w_2^*) < \eta < ln(w_2) - ln(w_2^*) \\ \dots & \\ ln(w_{k-1}) + \epsilon & if\ ln(w_{k-1}) - ln(w_{k-1}^*) < \eta < ln(w_{k-1}) - ln(w_k^* \\ ln(w_k^*) + \eta + \epsilon & if\ ln(w_{k-1}) - ln(w_k^*) < \eta < \infty \end{cases}$$

- Error correlated with price, virtual income, so OLS is bias
- One solution is to use IV with simultaneous equations
- Two issues: it estimate block k assuming other in that block
- Second arbitrary assignment to blocks for neighbors.
- Solution Maximum Likelihood

Maximum Likelihood

- First term for consumption in K, second for k-1

$$ln(L) = \sum ln \left[\begin{array}{c} \sum_{k=1}^{K} \left(\frac{1}{\sqrt{2\pi}} \frac{exp(-(s_k)^2/2)}{\sigma_\nu} \right) (\Phi(r_k) - \Phi(n_k)) \\ + \sum_{k=1}^{K-1} \left(\frac{1}{\sqrt{2\pi}} \frac{exp(-(u_k)^2/2)}{\sigma_\epsilon} \right) (\Phi(m_k) - \Phi(t_k)) \end{array} \right]$$

- $\nu = \eta + \epsilon$, $t_k = (ln(w) - ln(w_k^*))/\sigma_\eta$
- $\rho = corr(\nu, \eta)$, $r_k = (t_k - \rho s_k)/\sqrt{1-\rho^2}$
- $s_k = (ln(w_i) - ln(w_k^*))/\sigma_\nu$, $m_k = (ln(w_k) - ln(w_{k+1}^*))/\sigma_\eta$
- $u_k = (ln(w_i) - ln(w_k))/\sigma_\epsilon$, $n_k = (m_{k-1} - \rho s_k)/\sqrt{1-\rho^2}$

Data

- 1082 hh, 11 urban areas,16 utilities
- 26 price structures; 8 two-tier IBP structures, 10 four-tier IBP structures, 8 uniform structures
- 2 weeks in arid weather, 2 weeks in wet weather
- lot size, square footage of homes, number of bathrooms, family size
- other variables:maximum daily temperature, moisture, dummy for arid, dummy for city

Results

	DCC full sample	Split sample models		DCC full sample block pricing test
		DCC IBP households only	Random effects UP households only	
Variable	(1)	(2)	(3)	(4)
ln price	−0.3407*	−0.6411*	−0.3258	−0.2330*
	(0.0298)	(0.0424)	(0.5644)	(0.0677)
block *p**ln price				−0.1106#
				(0.0626)
ln income	0.1306*	0.1959*	0.0432	0.1308*
	(0.0118)	(0.0163)	(0.0499)	(0.0118)
seas	0.3072*	0.3370*	0.2656*	0.3075*
	(0.0247)	(0.0330)	(0.0331)	(0.0247)
weath	0.0079*	0.0094*	0.0054*	0.0076*
	(0.0013)	(0.0017)	(0.0016)	(0.0013)
max *t*	0.0196*	0.0238*	0.0193*	0.0200*
	(0.0018)	(0.0024)	(0.0025)	(0.0018)
famsz	0.1960*	0.1959*	0.2095*	0.1957*
	(0.0056)	(0.0080)	(0.0225)	(0.0056)
bthrm	0.0585*	0.0553*	0.0498	0.0590*
	(0.0093)	(0.0127)	(0.0393)	(0.0093)
sqft	0.1257*	0.2001*	−0.0066	0.1253*
	(0.0140)	(0.0191)	(0.0600)	(0.0140)
lotsz	0.0065*	0.0097*	−0.0010	0.0064*
	(0.0009)	(0.0011)	(0.0046)	(0.0009)
age	0.0869*	0.1814*	−0.0870	0.0888*
	(0.0219)	(0.0304)	(0.0940)	(0.0219)
age2	−0.0137*	−0.0252*	0.0109	−0.0141*
	(0.0036)	(0.0050)	(0.0160)	(0.0036)
evap	0.2278*	0.2416*	−0.8139	0.2281*
	(0.0300)	(0.0334)	(0.6129)	(0.0300)
lasv	0.2590*	0.3391*		0.2570*

Results-Elasticity

- Standard error by bootstrap (param/nonparamet)

Discrete continuous choice model	Elasticity estimates			
	Parametric		Nonparametric	
	Price	Income	Price	Income
Full sample	−0.3309*	0.1261*	−0.3319*	0.1273*
	(0.0062)	(0.0031)	(0.0366)	(0.0133)
Increasing-block households only	−0.5893*	0.1786*	−0.6090*	0.1865*
	(0.0437)	(0.0138)	(0.0568)	(0.0159)
Random effects model				
Uniform price households only	−0.3258	0.0432		
	(0.5644)	(0.0499)		

- Elasticity of IBP higher than UP, despite the same average prices, and same share of expenditure (balanced data)
- Another explanation endogenous prices
- Unobserved characteristic of HH drives a utility's choice of price structure$\Rightarrow$ characteristic correlated with price elasticity
- Solution: two stage estimation, first use IV find price hat and use this in demand estimation

Results-Elasticity

- Sample to small to support selection
- Second-best approach: allow price elasticity vary with price structure (informal test)
- Fourth column
- Interaction term suggests demand among IBP households is more elastic than among UP households
- Other estimates remain unchanged
- Do not rule out possibility of a behavioral reaction to prices structure

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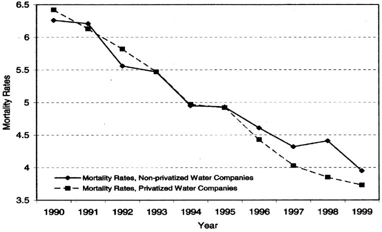
Introduction

- 2000 Millennium Summit UN: reducing child mortality by two-thirds and cutting in half HH not access to safe water
- Government by privatization to gain efficiency and more access
- Privatization bad service: not account health externalities
- Privatization hurt poor: price increases, enforcement of service payments, investment only in lucrative high income areas
- Question: impact of the privatization of water services on child mortality in Argentina?
- Young children because of vulnerability
- Two diseases
  - waterborne diseases: drinking contaminated water
  - water-washed diseases: lack of sanitation
    - diarrhea 15% of all child deaths worldwide
    - Argentina, diarrhea, septicemia, gastrointestinal infections are 3 of the top 10 causes of death for children under 5

Introduction

- Identification: local governments vs privatized afterwards
- 1990s, 30% of municipalities (60 % population) privatized
- Concern: privatization not orthogonal to unobservable factors that also affect mortality
- Privatization associated with a reduction in child mortality
- After privatization (1995) decline faster



Economics of Water Systems

- Water systems:
  - supply of clean water
  - treatment and removal of sewage
- Natural monopoly involving large fixed costs and significant economies of scale
- Alternative is self-provision through pumped wells, rainwater catchments, cesspools, septic tanks
- Self-provision low quality and high cost
- Life of water systems' physical plant is very long $\Rightarrow$ impedes dynamic competition.
- Externalities: water-related diseases are contagious
- Inelastic for necessary use

Economics of Water Systems

- Natural monopoly+externalities,+inelasticity of demand ⇒ justify public intervention
- Privatization: regulation to deliver water services
- Incentive for cost reductions + productivity enhancements
- Fear of deterioration of quality or exclusion from access is genuine only when supply conditions are noncontractible
- Water industry:low information asymmetries
  - Regulator monitor water quality, pressure, repair delays, shortages
  - Enforce network expansions,
- Political use of SOE resources
  - Non-benevolent governments: excess employment, corruption, subsidies .

Privatization of Water Services in Argentina

- 1870-1980: federal company Obras Sanitarias de la Nacio'n (OSN)
- 1980: OSN in federal district + local governments
- Before privatization 1990: 2/3 public companies + 1/3 not-for-profit cooperatives
- 1990s: half of public water companies privatized

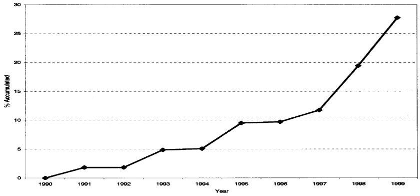
Ownership	Number of Municipalities	Percentage
Always public	196	39.7
Always private not-for-profit cooperative	143	28.9
Transferred from public to private for-profit	137	27.7
Always private for-profit	1	.2
No service or missing information	17	3.4
Total	494	100.0

Historical Context

- 1990s: Argentina structural reform + privatization
- 1980 huge deficit+hyperinflation, SOE losses contribute to deficit
- Argentina implemented most ambitious privatization
- 154 privatization contracts in 1990s
- Water companies 3.5% of privatization
- Privatization revenue: U.S.$24 billion (10% of public revenues)
- SOE to the private sector (mostly large foreign)

Why Did Local Governments Privatize Water Services

- Decision to privatize is local government
- Federal government focused on privatizing larges
- Initially no pressure on locals to privatize
- Water privatization after elections in 1995
- Accumulated % municipalities privatized



- Alternatively: privatization in response to an economic shock
- Threats: correlation both privatization and mortality with this unobserved

Why Did Local Governments Privatize Water Services

- Discrete-time hazard model of transiting from public to private

	Mean (Standard Deviation) (1)	Model 1 (2)	Model 2 (3)
Time-varying covariates:			
Federal government operates services (=1)	.018	15.975***	16.035***
	(.134)	(2.719)	(2.727)
Local government by Radical party (=1)	.139	−3.198***	−3.204***
	(.346)	(1.067)	(1.067)
Local government by Peronist party (=1)	.719	−.042	−.054
	(.449)	(.401)	(.402)
Δ log GDP per capita$_{t-1}$	.047	4.294	4.259
	(.135)	(3.567)	(3.561)
Δ unemployment rate$_{t-1}$	.006	−6.692	−6.805
	(.029)	(5.696)	(5.711)
Δ income inequality$_{t-1}$	.005	.483	.139
	(.014)	(7.483)	(7.503)
Δ child mortality rate$_{t-1}$	−.266		.034
	(2.994)		(.043)
Fixed pretreatment characteristics as of 1991:			
GDP per capita	60.601	−.022***	−.022***
	(30.388)	(.007)	(.008)
Unemployment rate	.045	12.871**	12.790**
	(.023)	(5.384)	(5.383)
Income inequality	.452	−3.591	−3.469
	(.021)	(5.820)	(5.805)
Child mortality rate	6.208		−.009
	(3.683)		(.036)
Population is 5,000–25,000 (=1)	.419	.227	.225
	(.493)	(.471)	(.480)
Population is 25,000–50,000 (=1)	.202	.106	.110
	(.402)	(.535)	(.540)
Population is 50,000–100,000 (=1)	.114	−.261	−.256
	(.318)	(.605)	(.610)
Population is 100,000–250,000 (=1)	.079	.663	.668
	(.269)	(.612)	(.615)
Population is more than 250,000 (=1)	.066	1.159*	1.151*
	(.249)	(.631)	(.640)
Proportion of families with UBN	.246	−13.660**	−13.328**
	(.151)	(6.067)	(6.226)
Proportion of families living in over-crowded housing	.097	13.560*	13.444*
	(.059)	(7.150)	(7.200)
Proportion of families living in poor housing	.060	6.980**	6.987**
	(.049)	(3.472)	(3.451)
Proportion of families living below subsistence	.036	5.221	4.917
	(.022)	(7.418)	(7.449)
Proportion of houses with no toilet	.095	10.143**	9.798**
	(.117)	(4.429)	(4.563)
No sewerage connection (=1)	.280	−.182	−.171
	(.449)	(.323)	(.328)
Proportion of household heads with more than high school education	.025	−27.242**	−27.182**
	(.012)	(10.971)	(11.003)
Mean household head's age between 45 and 52 (=1)	.653	.279	.288
	(.476)	(.343)	(.343)
Mean household head's age above 52 (=1)	.144	.506	.513
	(.351)	(.456)	(.456)
Duration dependence[a]		yes	yes
Observations		2,281	2,281

Why Did Local Governments Privatize Water Services

- Political variables: whether decision by federal or local
- Political affiliation with central government early priv.
- Poorer regions are more likely to privatize
- Lagged shocks used because
  1. privatization itself affect these timevarying variables
  2. length of time required privatization
- Likelihood of privatization increased over time
- Larger municipalities more likely to privatize
- None of the economic shocks are statistically significant.
- $\Rightarrow$ decision to privatize is uncorrelated with economic shocks, it might be correlated mortality
- Column 3 include mortality rate + lagged changes to mortality: not correlated with privatization decision.

Effect of Privatization on Child Mortality

- Our objective is to identify the average effect of privatization on child mortality rates in the municipalities in which the water supply system has been privatized
- Vital statistics registries, Argentine Ministry of Health
- Dependent variable: ratio of number of deaths of children less than 5 years old to total number of children less than 5 alive at the beginning of the year

Identification and Estimation Methods

- Nonexperimental methods
- May privatization correlated with mortality
- Poorer with higher mortality: privatization
- Then confounded variable: wealth
- Many of unobservable may confounded: fixed over time
- $\Rightarrow$ panel data + difference-in-differences
- DiD: change in outcomes in the treatment group before and after intervention to change in outcomes in control group
- By comparing changes, we control for observed and unobserved time-invariant municipality characteristics that might be correlated with the privatization decision as well as with mortality

Identification and Estimation Methods

- DiD: two-way fixed-effect linear regression model:

$$y_{it} = \alpha dI_{it} + \beta x_{it} + \lambda_t + \mu_i + \varepsilon_{it}$$

- y_{it} mortality rate in municipality i in year t
- dI_{it} indicator $= 1$ if i water services private
- x_{it} control variables, μ_i fixed effect to municipality i
- λ_t time effect common
- ε_{it} municipality time-varying error (ass. indep. of μ_i, λ_t)
- ε_{it} may correlated across time & space (biases in estimation of standard errors)
- Solution 1: arbitrary covariance structure within municipalities over time by clustered at municipality level
- Solution 2: standard errors clustered at province-year level

Identification and Estimation Methods

- α: DiD estimate of average effect of privatization of water services on mortality
- Identification: change in mortality in control areas is an unbiased estimate of the counterfactual
- How test identification validity: same trend before and diff. trend after
- Figure already confirmed this
- Formal test: al and only I pretreatment data+ separate year dummies for (eventual) treatments and controls
- Results: cannot statistically reject preintervention year dummies are the same for both (control vs treatment)

Identification and Estimation Methods

- $\Rightarrow$ mortality rates in treatment and control groups had identical time trends (and levels) in “pretreatment”
- $\Rightarrow$ validates difference-in-differences identification strategy

Results

- Column 1: whole sample + no covariates except for municipality fixed effects and year dummies
- Privatization of water services: 0.33 reduction in mortality rate (5.3%)
- Model 2, 3: GDP per capita, unemployment, income inequality, public spending per capita
- Estimated impact of privatization unchanged, (significance drops)
- Standard errors are clustered by province-year.
- Model 3 : dummy for political party controlled local
- No difference

Results

	Full Sample			Using Observations on Common Support			Kernel Matching on Common Support[a]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Private water services (=1)	−.334	−.320	−.283	−.540	−.541	−.525	− .604
	(.169)**	(.170)*	(.170)*	(.177)***	(.178)***	(.178)***	(.168)***
	[.157]**	[.163]**	[.162]*	[.191]***	[.198]***	[.195]***	
	{.195}*	{.203}	{.194}	{.261}**	{.274}**	{.266}**	
%Δ in mortality rate	−5.3	−5.1	−4.5	−8.6	−8.6	−8.4	−9.7
Other covariates:							
Real GDP per capita		.007	.009		.005	.006	
		(.005)	(.006)		(.006)	(.006)	
		[.006]	[.006]		[.007]	[.007]	
		{.007}	{.007}		{.007}	{.008}	
Unemployment rate		−.555	−.636		−.778	−.836	
		(1.757)	(1.758)		(1.797)	(1.802)	
		[2.161]	[2.166]		[2.249]	[2.263]	
		{2.862}	{2.846}		{2.635}	{2.635}	
Income inequality		5.171	5.085		2.932	3.052	
		(2.868)*	(2.880)*		(2.907)	(2.926)	
		[3.468]	[3.445]		[3.314]	[3.289]	
		{3.696}	{3.691}		{3.833}	{3.838}	
Public spending per capita		−.028	−.035		−.068	−.070	
		(.038)	(.038)		(.039)*	(.039)*	
		[.055]	[.055]		[.059]	[.059]	
		{.054}	{.055}		{.049}	{.050}	
Local government by Radical party (=1)			.482			.166	
			(.267)*			(.284)	
			[.281]*			[.301]	
			{.288}*			{.365}	
Local government by Peronist party (=1)			−.202			−.168	
			(.191)			(.193)	
			[.202]			[.230]	
			{.254}			{.309}	
R^2	.1227	.1256	.1272	.1390	.1415	.1420	
Observations	4,732	4,597	4,597	3,970	3,870	3,870	3,970

Heterogeneous Response

- If Heterogeneous two additional sources of bias:
  1. some privatization, but no comparable with no privatization
  2. Different distributions of observable variables affect mortality (x)
- Solution: matching eliminate two sources of bias
- Pairing privatized (treatments) with nonprivatized (controls) with similar observed attributes
- To eliminate second bias reweighting control group
- Heckman et al. (1998) generalized DiD matching estimator
- Rosenbaum, Rubin (1983) propensity score
- $P(x) = Pr(D = 1|x)$, matching assumes ,conditional on $P(x)$, counterfactual outcome distribution of the treated the same as observed outcome distribution of controls
- Matching on a scalar

Heterogeneous Response

- Propensity scores from a logit model of probability privatization
- Predict propensity a municipality will privatize
- Identify control and treatment on a common support
- Exclude all controls with propensity scores less(more) than propensity score of treatments municipality
- Second set of estimates as DiD on common support
- Kernel density weighting procedure generalized DiD matching estimator (Heckman et al. 1997)

Results

- Estimates on mortality increases when restrict on the common support
- Privatization 8.6% fall in child mortality rate
- Generalized DiD matching estimator 9.7 % reduction in child mortality rate.

Results by Cause of Death

- Robustness may other unobserved changes
- Say enhancements in health care system
- Not captured by public spending or political variables
- Privatization on mortality by cause of death
- Deaths from infectious and parasitic diseases
- All deaths in first 28 days of life: perinatal deaths
- If observed reduction in child mortality by improved access to and quality of water
- $\Rightarrow$ significant negative effects on deaths in perinatal deaths and infectious and parasitic diseases
- $+$ negligible effects on deaths from other causes such as accidents, cardiovascular diseases, or cancer.

Results by Cause of Death

	1990 Mean Mortality Rate	Estimated Impact Coefficients	%Δ in Mortality Rate
Infectious and parasitic diseases	.565	−.103	−18.2
		(.048)**	
		[.055]*	
		{.068}	
Perinatal deaths	2.316	−.266	−11.5
		(.105)**	
		[.107]**	
		{.123}**	
All other causes in aggregate	2.565	−.082	−3.2
		(.114)	
		[.101]	
		{.109}	
All other causes disaggregated:			
Accidents	.399	−.004	...
		(.057)	
Congenital anomalies	.711	−.022	...
		(.056)	
Skin and soft-tissue diseases	.000	.000	...
		(.001)	
Blood and hematologic diseases	.024	−.002	...
		(.008)	
Nervous system disorders	.163	.025	...
		(.026)	
Cardiovascular diseases	.236	.006	...
		(.030)	
Gastrointestinal tract disorders	.051	−.001	...
		(.010)	
Genital and urinary diseases	.020	−.006	...
		(.007)	
Osteoarticular and connective tissue diseases	.003	−.001	...
		(.001)	
Respiratory diseases	.511	−.038	...
		(.051)	
Immunodeficiencies, endocrine	.376	−.035	...

Results by Cause of Death

- DiD+ common support + all socioeconomic + political controls
- Child mortality rates for each cause of death
- Significant effect on mortality from infectious and parasitic diseases and perinatal deaths
- No statistically significant effect on mortality from any other cause
- Estimated effects a reduction of 18.2% & 11.5%

Impact by Socioeconomic Status

- H_0 privatization higher impact on poor municipalities
- Middle and high income already access to good network

	1990 Mean Mortality Rate	Estimated Impact Coefficients	%Δ in Mortality Rate
Nonpoor municipalities	5.07	.114 (.233) [.165] {.159}	...
Poor municipalities	6.97	−1.004 (.279)*** [.297]*** {.278}***	−14.4
Extremely poor municipalities	9.11	−2.415 (.544)*** [1.051]** {.605}***	−26.5

- Cutoff are 50%, 25% income percentile
- 26.5% reduction in poor area

Evidence

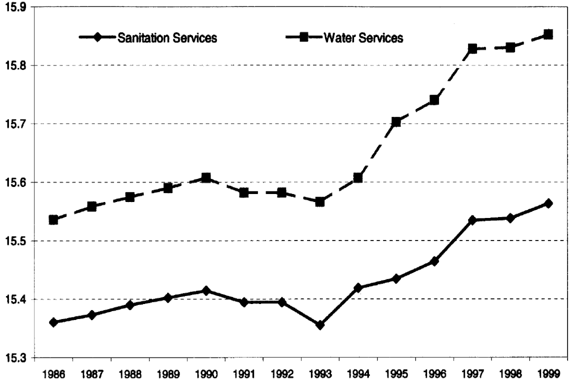
- Rather than assets being sold, water services were transferred to private sector through concessions
- In OSN, royalty was set at zero and firms competed for concession by offering lowest tariff
- Others in Cordoba and Corrientes, royalty 0.4% and 0.1%
- In May 1993, Aguas Argentinas, a private consortium led by the French company Lyonnaise des Eaux, won a 35-year concession
- Terms of concession
  - 100% of HH connected to water service
  - 95% to sewerage by 35-year
  - Service quality and waste treatment standards.
- All fees by regulator

Evidence

- Enforcement of payment was toughened after privatization.
- Allowed to cut service to customers with three unpaid bills
- OSN privatization, employees reduced from 7,365 to 3,800
- Reduction in employment+ increase in coverage and production⇒ large increases in productivity.
- First year negative returns, then highly profitable company
- In 1985 OSN investment was 67.8 % of what was needed to maintain current supply, and only 19.5 % in 1990
- 10 years before privatization, OSN invested U.S.$25 million annually
- 1993 to 2000, investment jumped to $200 million per year

Access to Water Services

- Logarithm of population connected to OSN network



- 1991 census and 1997 Encuesta de Desarrollo Social (EDS)
- DiD estimate of impact of privatization on proportion access

Access to Water Services

- Significant larger increase in proportion of HH connected

	All Municipalities	Excluding Buenos Aires
	Municipalities That Were Not Privatized before 1997	
Proportion of households connected in 1991 (p_{91}^{public})	.866	.866
Proportion of households connected in 1997 (p_{97}^{public})	.898	.898
Difference 1997 − 1991 ($p_{97}^{\text{public}} - p_{91}^{\text{public}}$)	.032	.032
	Municipalities That Were Privatized before 1997	
Proportion of households connected in 1991 (p_{91}^{private})	.730	.640
Proportion of households connected in 1997 (p_{97}^{private})	.780	.714
Difference 1997 − 1991 ($p_{97}^{\text{private}} - p_{91}^{\text{private}}$)	.050	.074
Difference-in-differences ($p_{97}^{\text{private}} - p_{91}^{\text{private}}$) − ($p_{97}^{\text{public}} - p_{91}^{\text{public}}$)	.018	.042
Z-test for difference-in-differences estimate[a]	2.83***	5.78***

- Connections increased the most among poor

Access to Water Services

- World Bank (2002a) household survey
- Share of HH connected to water and sewerage

		Income Quintile				
	All	Poorest	II	III	IV	Wealthiest
	Share of Households Connected to Water					
1992	.74	.61	.71	.75	.77	.83
2002	.88	.82	.85	.88	.92	.91
Change 1992–2002	+.14	+.21	+.14	+.13	+.15	+.09
	Share of Households Connected to Sewerage					
1992	.54	.35	.47	.51	.56	.74
2002	.64	.51	.57	.60	.68	.79
Change 1992–2002	+.10	+.16	+.10	+.09	+.12	+.05

Introduction

- Zivin, Neidell, Schlenker “Water quality violations and avoidance behavior: Evidence from bottled water consumption” AER (2011)
- Public information about health hazards an important part of programs designed to manage environmental and health risks. examples:
  - US Environmental Protection Agency (EPA) Toxics Release Inventory
  - US Food and Drug Administration fish advisories
  - California’s “smog alerts” program
- Information allows public to engage in behavioral responses to minimize exposure
- Question: study this behavior and whether such information is a substitute or complement to environmental standards

Introduction

- EPA, under the auspices of the Safe Drinking Water Act (SDWA), places strict limits on roughly 90 chemicals or contaminants in community drinking water systems, supplying water to nearly 270 million people in the United States
- One in ten Americans is served by a drinking water system that exceeds these limits on at least one dimension
- Violations must be disclosed to consumers under the SDWA Amendments of 1996
- Paper: examines avoidance behavior in response to these disclosures regarding drinking water violations.
- Matching geocoded violations data for Northern California and Nevada from 2001 to 2005 with sales data from a major supermarket chain

Results

- Estimate the change in bottled water purchases as a result of tap water violations
- Significant increase in bottled water sales
  - 22 % from violations due to microorganisms
  - 17 % from violations due to elements and chemicals
- Costs of avoidance behavior at $60 million in 2005

Data

- 150,000 community water districts (CWDs) monitor contaminants levels
- If exceed maximum contaminant level (MCL) Public Notification Rule
- Within 24 hours if microorganisms and nitrates
- Within 30 days for other health threats
- Notifications include
  - description of violation and potential health effects
  - population at risk
  - actions consumers can take
  - when the violation occurred
  - when a resolution is expected

Data

- Three broadly defined groups
  - "Microorganisms" immediate health threats (coliform bacteria, removed by boiling tap water)
  - "Nitrates": immediate threat of "blue-baby syndrome" to infants
  - "Elements/chemicals" natural occurring elements such as arsenic, manufacturing chemicals (health effect long exposure)

	Violations	Duration (Days)
Panel A. United States		
Microorganism	37,645	44.7
Nitrates	3,798	153.9
Elements/Chemicals	13,261	131.5
Panel B. Northern CA and NV		
Microorganism	239	36.9
Nitrates	25	65.7
Elements/Chemicals	21	223.2

Data Bottled Water Consumption

- Weekly sales (WednesdayTuesday)
- Sales in dollars as well as quantity
- Different bottle size
- Aggregate sales in dollars
- Store-level sales linked to water violations

	High	Low
Average bottled water sales ($)	3,500	4,227
Median house price ($)	220,362	284,499
Median household income ($)	49,120	55,820
Microorganism violations	9.12	2.31
Nitrates violations	2.06	0.08
Elements/chemicals violations	1.46	0.10
Observations	277	255

- High: above median violation

Methods

- If a violation occurs, the quality-adjusted price of tap water increases, thus increasing the demand for bottled water.

$$y_{swt} = \beta_1 + \beta_2 v_{swt}(p_{wz}/p_z) + \beta_3 w_{swt} + \alpha_{sw} + \delta_t + \varepsilon_{swt}$$

- y: log(weekly sales of bottled water) at store s, district w (both located in zip code z) in week t
- v_{swt} fraction of time a store water district combination was in violation for each of the three types of violations in week t
- p_{wz}/p_z fraction of population in z, served by w
- β_2 percentage change in sales at each store from a violation
- Controls weekly mean max & min temp & precipitation
- α_{sw} capture time-invariant factors
- Multi-cluster approach allows for arbitrary serial correlation in sales within stores and for correlation between multiple zip codes

Results

- 22% increase due to microorganism

	Log(sales)	Log(sales)	Log(price)
Microorganism	0.219**	−1.031	−0.011
	(0.076)	(0.666)	(0.007)
Nitrates	0.257	−14.652	−0.052
	(0.587)	(12.403)	(0.095)
Elements/chemicals	0.174**	0.533	−0.011
	(0.060)	(1.050)	(0.020)
Store-district FE	Yes	No	Yes
Observations	41,534	41,534	41,534

- If omit store-water district fixed effects all coefficients insignificant⇒ controlling for endogeneity of violations is essential.
- Third column explores potential impact of violations on price
- No significant relationship price and violation
- Heterogeneous responses to violations
  1. vulnerable individuals respond greater sensitivity

Heterogeneity of Estimated Responses to Water Violation

- Violations interacted with median household income, % under age 5, % over age 65

	Lowest quartile	Top quartile	p-value of difference
Panel A. Household income			
Microorganism	0.249**	0.181**	0.225
	(0.079)	(0.060)	
Nitrates	−0.689	0.775*	0.458
	(1.842)	(0.363)	
Elements/chemicals	0.271**	1.689**	0.001
	(0.047)	(0.464)	
Panel B. Percent over 65			
Microorganism	0.139**	0.314**	0.026
	(0.044)	(0.067)	
Nitrates	3.482	−2.318	0.261
	(2.333)	(2.910)	
Elements/chemicals	0.460**	0.281**	0.009
	(0.100)	(0.036)	

- Greater response to microorganisms in communities with a larger elderly population

Total Cost Estimate

- Bottled water sales as a measure of avoidance behavior
- Total expenditures on bottled water sales

$$Total\ costs = \sum_c \sum_t \hat{\beta}_2 \times S_{ct} \times \{v_{cwt} \times (p_{wc}/p_c)\}$$

- S_{ct} sales, week t, county c
- In 2005,
  - people spent \$11.34 million in response to microorganism violations
  - \$1.77 million in response to nitrate violations
  - \$47.15 million in response to element/chemical violations