Understanding Disparities in Punishment: Regulator Preferences and Expertise

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Regulatory Discretion

- Regulations often written flexibly
- This reflects
  - Circumstances surrounding violations vary across cases
  - Written regulation cannot specify all contingencies
- However regulators may pursue their own interests
- This paper quantifies
  1. Various sources of disparity in enforcement
  2. Consequences of policy reforms limiting regulator discretion

Water Quality Regulation Enforcement

- The Clean Water Act
  - Regulates discharges of pollutants into waters
  - Implementation and enforcement delegated to states
- Study the CWA enforcement in California
  1. Data on violations and enforcement actions for each violation
  2. Large state with heterogenous localities (e.g. rural/urban, rain)
- Focus on wastewater treatment facilities (73% of CWA violations)

What This Paper Does (1/2)

Documents disparities in punishment of water quality violations across wastewater treatment facilities

1. Dispersion in penalties for observationally identical violations
2. Higher penalty to facilities with a large size or located in a high-income or low-turnout county

What This Paper Does (2/2)

Explain sources of penalty disparity & evaluate regulatory discretion:

1. Specify a model of law enforcement (Mookherjee & Png, 1994)
   - Regulator determines *penalty schedule* for *each* facility
   - She considers (a) compliance costs, (b) external costs from violation, and (c) political/administrative cost of penalty
   - Weights on these factors may differ by the identity of facility
2. Establish the nonparametric identification of the model
3. Semiparametrically estimate the model and conduct counterfactual analyses

What This Paper Does (2/2)

Explain sources of penalty disparity & evaluate regulatory discretion:

1. Specify a model of law enforcement
2. Establish nonparametric identification of the model
   - Exogenous institutional changes help identify compliance costs
   - Regulator preferences (weights) from the regulator optimality
3. Semiparametrically estimate the model and conduct counterfactual analyses

Preview of the Findings

1. Regulators tailor penalties to local residents' preferences
   - Regulators consider violations more damaging and penalties less costly to impose in counties with high valuation of water quality
   - Residents' preference on water quality measured by vote share for a proposition to fund water quality projects
2. Penalty disparities mainly due to compliance cost heterogeneity
3. One-size-fits-all policy will increase both the level and the dispersion of violation

Preview of the Findings

1. Regulators tailor penalties to local residents' preferences
2. Penalty disparities mainly due to compliance cost heterogeneity
   - If the regulator has the same objective function for all facilities, the dispersion of penalties will fall by 5-15 percent
3. One-size-fits-all policy will increase both the level and the dispersion of violations across facilities
   - Same penalty schedule on average; overall less violations under the current regime (especially, large facilities/dense population)
   - Illustrate the value of regulators' discretion in employing their knowledge on compliance costs

Literature Review

- Empirical studies on regulatory mechanism and incentives
  - Reduced-form evidence on determinants of enforcement stringency (Cropper et al, 1992; Agarwal et al, 2014)
  - Field experiment on regulator expertise in targeting inspections (Duflo et al, 2016)
  - Benefits and costs of regulation not directly observed
  - By separately identifying/estimating compliance cost and regulator preferences, we evaluate regulatory mechanism
- Structural empirical literature on regulation under asymmetric information pioneered by Wolak (1994)
- Empirical crime literature (Fu and Wolpin, 2017)

Today's Talk

1. Institutional background
2. Descriptive statistics on penalty disparity
3. Model of optimal regulation enforcement
4. Identification and estimation of the model
5. Results

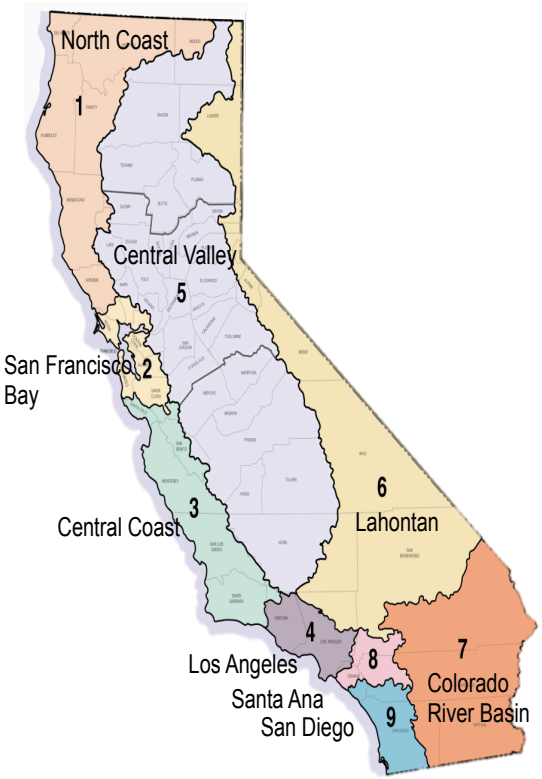
Water Discharges Regulation

- Clean Water Act requires surface water dischargers to
  - Obtain permits specifying effluent limits
  - Periodically self-report effluents
- Enforcement actions mostly based on the self-reports
  - Frequent inspections encourage truthful self-reporting
  - Intentional misreporting punishable by criminal sanctions
  - Self-reported data often used by literature on compliance (Magat and Viscusi, 1990; Earnhart, 2004; Shimshack and Ward, 2005; Gray and Shimshack, 2011)

Water Discharges Regulation in California

- State Water Resources Control Board oversees regulation
- Regional water boards perform most enforcement
  - 7 board members serving 4-year terms, appointed by the governor and confirmed by the State Senate
  - Board members are part-time (employee/owner of a business, public servant, academic, retiree)
  - Staffs (mostly with science background) conduct day-to-day tasks
  - Board members make key decisions

Regional Water Boards



- Divided by watersheds (not political boundaries)
- Water pollution problems are regional
- Local preferences differ:
  - Income, population density, political views
  - Industry composition and water use, water quality

Determination of Penalties

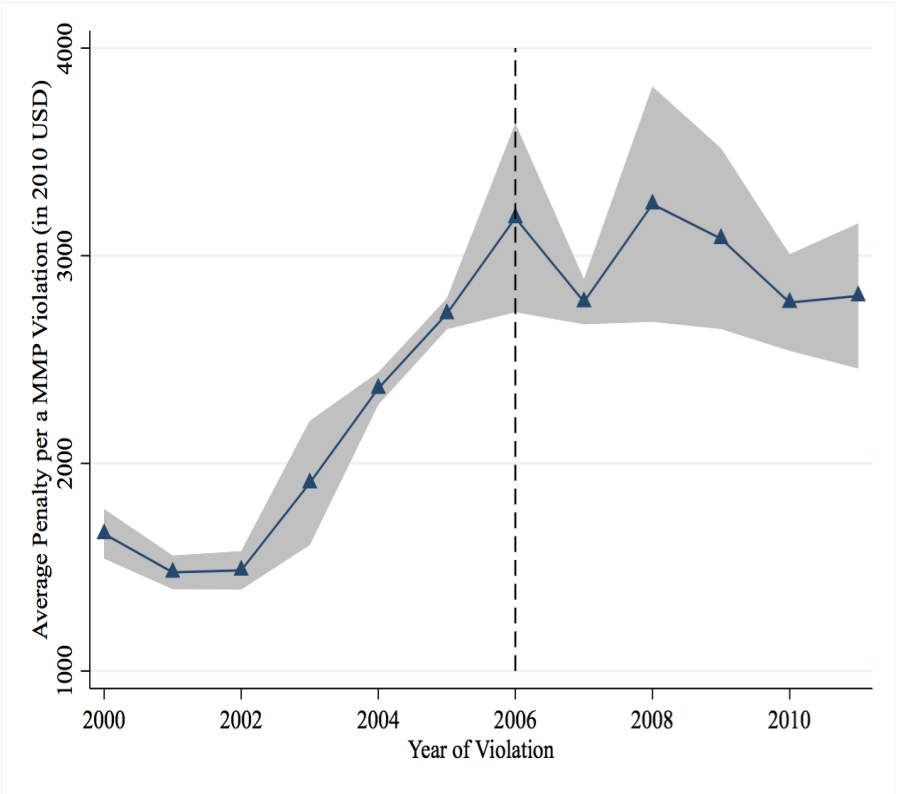
- When a violation is identified and confirmed
  1. Administrative civil liability (ACL) can be issued
  2. Violator may pay the liability or dispute the ACL
- Penalty amount in an ACL is based on
  - Factors requiring judgement: Harm to the beneficial water uses, toxicity and volume of the discharge, economic benefit from violation and violator's conduct, violator's financial ability, etc.
  - Mandatory minimum penalty (MMP) for serious/chronic violations
  - Exemptions (e.g. new facility, natural disaster, third party's act)

Exogenous Institutional Changes (1/3)

- Important changes in enforcement practices in 2006:
  - Data system for electronic submittal/review of self-reports
  - Established the Office of Enforcement to help regional boards
  - New administrative measure to expedite penalty process
- Not associated with a change in the abatement cost structure
  - Very little entry and exit
  - Steady flow of capital investment over time for maintenance

Institutional Changes: Penalty Increase (2/3)

Average Penalty per Violation

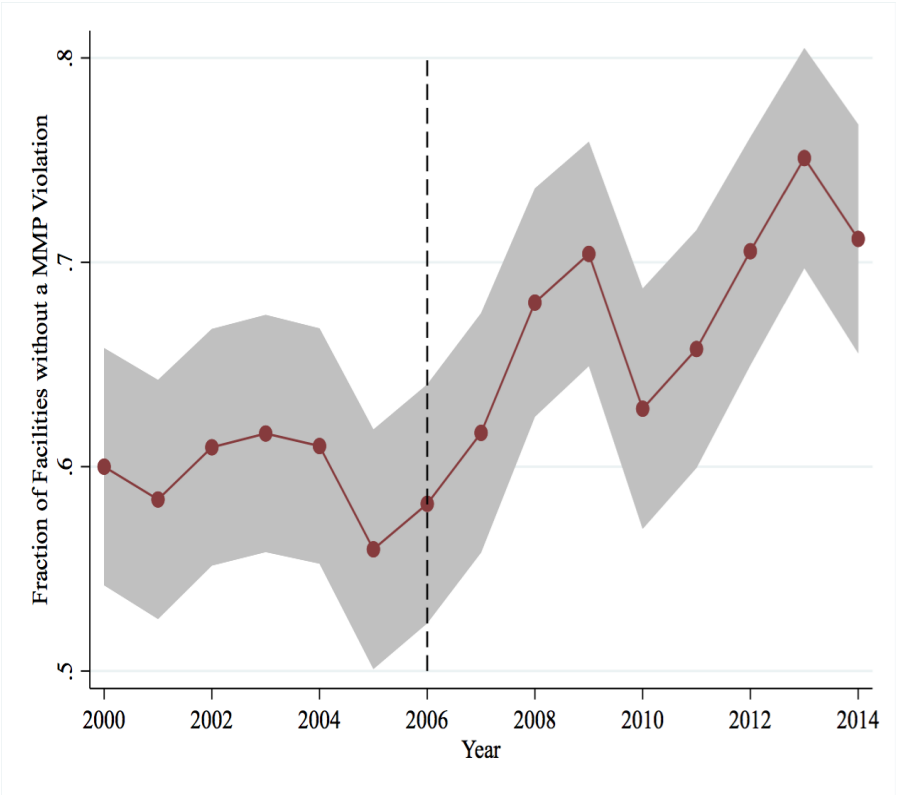


Based on the CWIQ database regarding all wastewater treatment facilities; 95% CI in shaded area

- Average penalty per *MMP violation* within 4 years of violation
- The 2006 institutional changes incorporated in penalizing the violations of 2002 and after

Institutional Changes: Compliance Increase (3/3)

Fraction of Facilities in Compliance



Based on the CWIQ database regarding all wastewater treatment facilities; 95% CI in shaded area

- Fraction of facilities without a MMP violation per year
- Compliance rate increase after 2006
- Facilities responded to penalty increase

Revisit the Agenda

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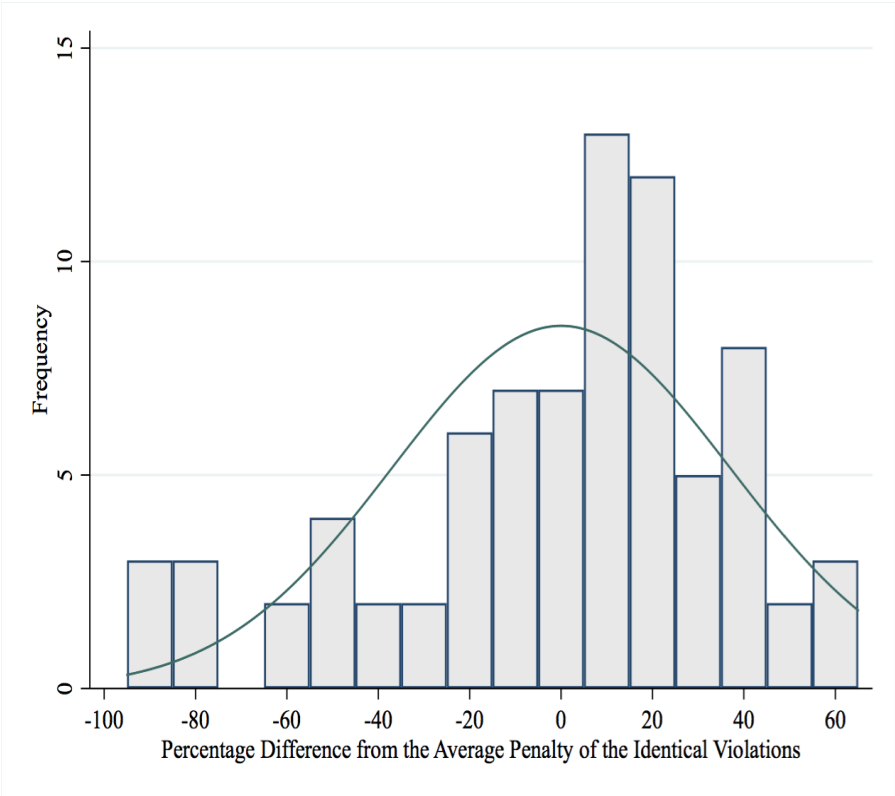
From the 2010 Water Quality Enforcement Policy:

Although a consistent penalty is expected for standard and routine violations, for more complex matters, *"the need to assess all of the applicable factors in liability determinations may yield different outcomes in cases that may have many similar facts."*

Penalty Disparities & Regulator Discretion

- Out of 32,378 MMP violations in 2000-2014,
  1. 40% exempt from penalty by law
  2. Among non-exempt violations, 30% led to no penalty within 4 years
  3. Conditional on penalty: Average $2,706 and max over $100,000
- Penalty dispersion may reflect variation in violation severity
- To quantify penalty disparities and regulator discretion,
  1. Strategy 1: Focus on identical violations only (pollutant and permitted/actual amount of discharge)
  2. Strategy 2: Regress penalty on both violation and facility attributes

Identical Violations are Penalized Differently



Based on 79 violation records, grouped into 21 unique cases of identical violations

- Histogram of the percentage difference from the average penalty for the identical violations
- Dispersion ranging from -86% to 53%
- 53% of violations had penalties higher/lower than 20%+ of the average

Facility Attributes Matter for Penalty

Dependent variable: Indicator for nonzero penalty			
Group I pollutant	0.0670	0.0653	0.0534**
	(0.0510)	(0.0507)	(0.0252)
Other MMP violations in same quarter		0.0886**	0.109***
		(0.0372)	(0.0376)
MMP violations in previous quarter		-0.0181	0.0299
		(0.0708)	(0.0498)
Major facility			0.143***
			(0.045)
Log (Average income)			0.759***
			(0.206)
% Turnout in gubernatorial election			-0.017***
			(0.006)
Other violation controls	Yes	Yes	Yes
Other facility controls	No	No	Yes
Adjusted R^2	0.169	0.171	0.414

Notes: 16,314 violations. Other violation controls: whether the violation is ranked as "priority"; the quarterly total precipitation amount; and year dummies. Other facility controls: the facility age; population density; the ratio of fresh water withdrawal for irrigation; the vote share for proposition 84; and the water board region dummies. Standard errors adjusted for two-way clustering at the county and facility levels.

Penalty Disparities & Regulator Discretion

- Observationally identical violations are penalized differently
- Regulations allow accounting for various circumstances
- *Why are facilities in a high-income county penalized more?*
  1. Compliance cost is higher
  2. Regulators care more about (political) costs from violations
  3. Cheaper to impose penalty (e.g. less capture/more admin support)
- Structural approach provides an answer to this question

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Model: Setup (1/3)

- Consider a regulator and a single regulated facility
- Facility of type $\theta \in (0, \overline{\theta})$ decides negligence level, $a \geq 0$
  - Determines the number of violations $k \sim Poisson(a)$
  - Benefits the facility by $\underbrace{\theta}_{\textit{facility type}} \times \underbrace{b(a)}_{\textit{baseline}}$
- Facility knows its type, but regulator only knows $\Theta \sim F(\cdot)$
- Regulator sets penalty schedule depending on k, $\bar{\epsilon}(k)$
  - Expected penalty at negligence a: $e(a) \equiv \sum_{k \in \mathbb{N}} \bar{\epsilon}(k) \frac{a^k e^{-a}}{k!}$

Model: Setup (2/3)

- Facility takes penalty schedule as given, and maximizes payoff:

$$\max_{a} \ \theta b(a) - e(a)$$

The FOC:

$$\theta b'(a) = e'(a) \tag{1}$$

Model: Setup (3/3)

- Regulator minimizes *total* cost associated with enforcement:

$$\min_{e(\cdot)} \int_0^{\overline{\theta}} \Big\{ \underbrace{-\theta b[a(\theta)]}_{\text{compliance cost}} + \underbrace{\gamma a(\theta)}_{\text{environmental cost}} + \underbrace{\psi e[a(\theta)]}_{\text{enforcement cost}} \Big\} \underbrace{f(\theta)}_{\text{type dist.}} d\theta$$

subject to

1. Incentive compatibility: $a(\cdot)$ maximizes facility payoff under $e(\cdot)$
2. Limited liability: $e(\cdot)$ is less than maximal penalty
3. Nonnegative penalty: $e(\cdot) \geq 0$

Model: Equilibrium

- Regulator's problem (revisited):

$$\min_{a(\cdot)} \int_0^{\overline{\theta}} \left\{ -\left((1-\psi)\theta + \frac{\psi[1-F(\theta)]}{f(\theta)} \right) b[a(\theta)] + \gamma a(\theta) \right\} f(\theta) d\theta$$

  - Point-wise optimization:

$$b'[a(\theta)] \left(\theta + \frac{\psi[1-F(\theta)]}{(1-\psi)f(\theta)} \right) = \frac{\gamma}{1-\psi} \tag{2}$$

  - Under standard conditions, optimal $a(\cdot)$ is continuous and *strictly increasing* for any θ with $a(\theta) > 0$

Model: Equilibrium

Proposition

Suppose (i) $b(\cdot)$ and $h(\cdot)$ are strictly increasing, (ii) $(1-\psi)\theta + \frac{\psi[1-F(\theta)]}{f(\theta)}$ is strictly increasing in θ, and (ii) the SOC for (1) and (2) are satisfied for all $\theta \in (0, \overline{\theta})$.

Then the optimal negligence schedule, $a^*(\cdot)$ is continuous and nondecreasing in θ. For θ such that $a^*(\theta) > 0$, $a^*(\cdot)$ is characterized by (2) and strictly increasing in θ.

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Identification

- Allow model primitives to vary with observed attributes (**x**)
  - Region dummies, facility's attributes (age, size), county characteristics (income, population density, etc) and weather
  - Exclusion restriction: The 2006 changes affected (γ, ψ) only
- Identification problem:

Model Primitives

For each **x**:

$F(\cdot)$: Distribution of types
$b(\cdot)$: Compliance cost
γ and ψ: Preferences
(pre & post 2006)

Observables

For each facility and period:

Number of violations
Penalty for each violation

Sketch of Identification Proof: Step 1

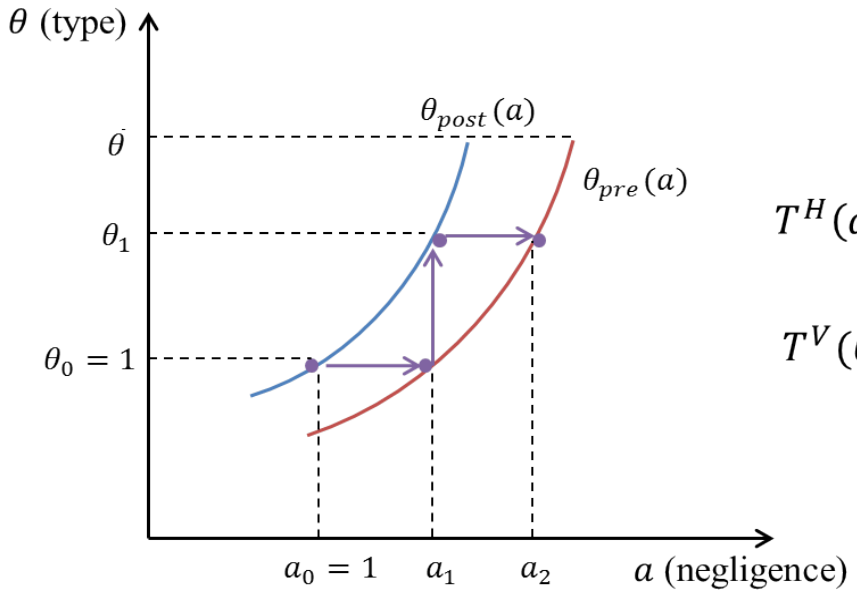
Conditioning on $\mathbf{x}$, identify the following equilibrium objects:

1. Enforcement schedules as a function of number of violations
   - Denoted by $e_{pre}(\cdot)$ and $e_{post}(\cdot)$
   - Directly observed from the data
2. Distributions of negligence level (a)
   - Denoted by $G_{pre}(\cdot)$ and $G_{post}(\cdot)$
   - Recall number of violations follows $Poisson(a(\theta))$
   - Use moment generating function, identify the distribution of a from the observed distribution of the number of violations (Aryal, Perrigne & Vuong, 2015)

Sketch of Identification Proof: Step 2

From Step 1, identify $\theta_{pre}(a_\ell)$, $\theta_{post}(a_\ell)$, $b'(a_\ell)$, and $F(\theta_\ell)$ for finite ℓ's:

- Rely on (i) a is strictly increasing, and (ii) $F(\cdot)$ and $b(\cdot)$ invariant
- Use facility's FOC (D'Hautfoeuille & Février, 2015)



$$T^H(a) = G_{pre}^{-1}[G_{post}(a)]$$

$$T^V(\theta, a) = \frac{e_{post}'(a)}{e_{pre}'(a)}\theta$$

Sketch of Identification Proof: Step 3

From Steps 1 & 2, identify ψ_{pre}, ψ_{post}, γ_{pre}, γ_{post}, $b'(\cdot)$, and $F(\cdot)$

- Regulator's FOC: $b'[a_j(\theta)]\left(\theta + \frac{\psi_j[1-F(\theta)]}{(1-\psi_j)f(\theta)}\right) = \frac{\gamma_j}{1-\psi_j}$
- Rewrite the FOC using the quantile function $Q(\alpha)$ of F (Luo, Perrigne & Vuong, *forthcoming*): $\frac{Q'(\alpha)}{Q(\alpha)} = \frac{\gamma_j - e_j'\left[G_j^{-1}(\alpha)\right](1-\psi_j)}{e_j'\left[G_j^{-1}(\alpha)\right]\psi_j(1-\alpha)}$

1. Using (θ_l, a_l)'s from Step 2, identify γ_j and ψ_j for $j = pre, post$
2. Identify $F(\cdot)$ and $b'(\cdot)$ from regulator and facility FOC's

Semiparametric Estimation

- Parametrically estimate
  1. Enforcement schedule: For $j = pre, post$,

$$\bar{\epsilon}_j(k|\mathbf{x}_{i,t}) = \begin{cases} \epsilon_{0,j}(\mathbf{x}_{i,t}) + \epsilon_{1,j}(\mathbf{x}_{i,t})k \text{ if } k > 0, \\ 0, \text{ otherwise} \end{cases}$$

  2. Distribution of violations: $Poisson(\nu_{i,t} \exp[\beta_j \mathbf{x}_{i,t}])$, where $\nu_{i,t} \sim \Gamma(\delta_j, \delta_j)$
- For any given $\mathbf{x}_{i,t}$, nonparametrically estimate ψ_j, γ_j, $b'(\cdot)$, and $F(\cdot)$

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Model Fit

- Estimated model primitives satisfy assumptions for strictly increasing $a(\cdot)$
- Fits the data well:

	Before		After	
	Data	Model	Data	Model
Number of violations				
0	0.79	0.80	0.86	0.83
1	0.07	0.06	0.04	0.06
2	0.04	0.03	0.02	0.03
3	0.03	0.02	0.02	0.02
4 and more	0.09	0.09	0.06	0.06
Average penalty (in $)	2,978	2,943	3,415	3,291

Estimates

$$\int_0^{\overline{\theta}} \Big\{ \underbrace{-\theta b[a(\theta)]}_{\text{compliance cost}} + \underbrace{\gamma a(\theta)}_{\text{environmental cost}} + \underbrace{\psi e[a(\theta)]}_{\text{enforcement cost}} \Big\} \underbrace{f(\theta)}_{\text{type dist.}} \, d\theta$$

	Mean	Standard Deviation	Interquantile Range
Marginal compliance cost	2,041	1,729	2,595
Environmental cost per violation (γ)			
Before the 2006 changes	2,390	2,631	1,426
After the 2006 changes	5,956	3,360	2,456
Enforcement cost per penalty (ψ)			
Before the 2006 changes	1.11	0.10	0.12
After the 2006 changes	1.08	0.09	0.10

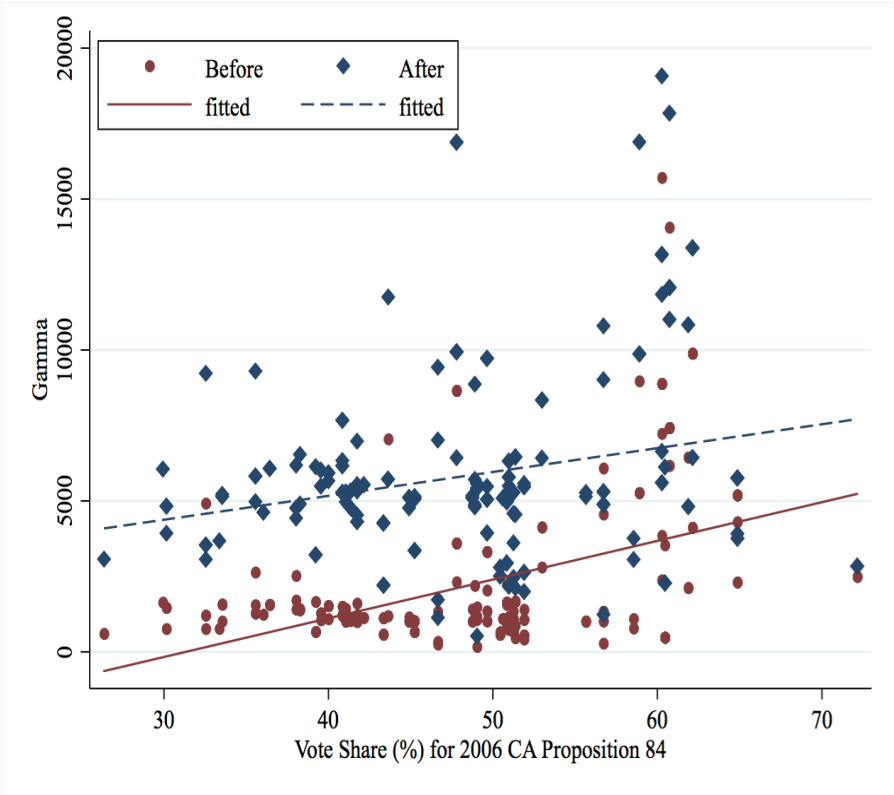
Notes: Statistics based on estimates for 264 facilities. The marginal compliance cost for each facility is based on the median cost type and evaluated at a negligence level equal to one ($Med(\Theta)b'(1)$).

Explaining Compliance Cost & Regulator Preferences

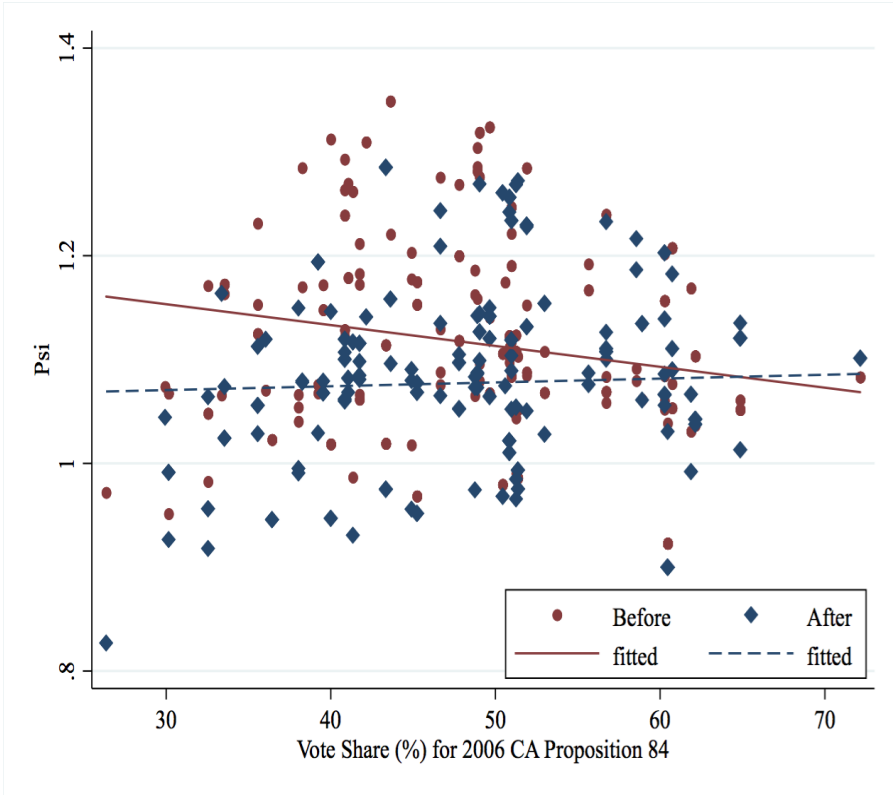
	Compliance Cost	γ		ψ	
		Before	After	Before	After
Major	2,046***	601**	1,043***	0.060***	0.098***
	(86.61)	(228)	(331)	(0.011)	(0.010)
Average income (log)	277	2,647**	8,101***	0.091**	0.045
	(367)	(1,072)	(1,667)	(0.044)	(0.037)
Pop. density (log)	677***	-1,069***	-1,556***	0.016*	0.013*
	(69.15)	(188)	(324)	(0.009)	(0.009)
Irrigation water use (%)	2,173***	-3,989***	-4,030***	0.147***	0.095***
	(280)	(709.4)	(1,071)	(0.027)	(0.019)
Turnout (%)	28.49***	-12.96	-95.09	-0.001	-0.0004
	(9.80)	(28.86)	(41.11)	(0.001)	(0.001)
Water proposition (%)	-81.65***	124.9***	62.18	-0.003***	0.0001
	(9.69)	(26.78)	(39.52)	(0.001)	(0.001)
Adjusted R^2	0.881	0.612	0.469	0.478	0.549

Notes: Unit of observation is a facility. All regressions based on 264 observations. Additional controls (included in all specifications) are: the age group of the facility; the total precipitation amount during the quarter in which the violation occurred; and and the water board region dummies.

Regulator's vs. Local Constituents' Preferences



(a) γ (Environmental cost)



(b) ψ (Enforcement cost)

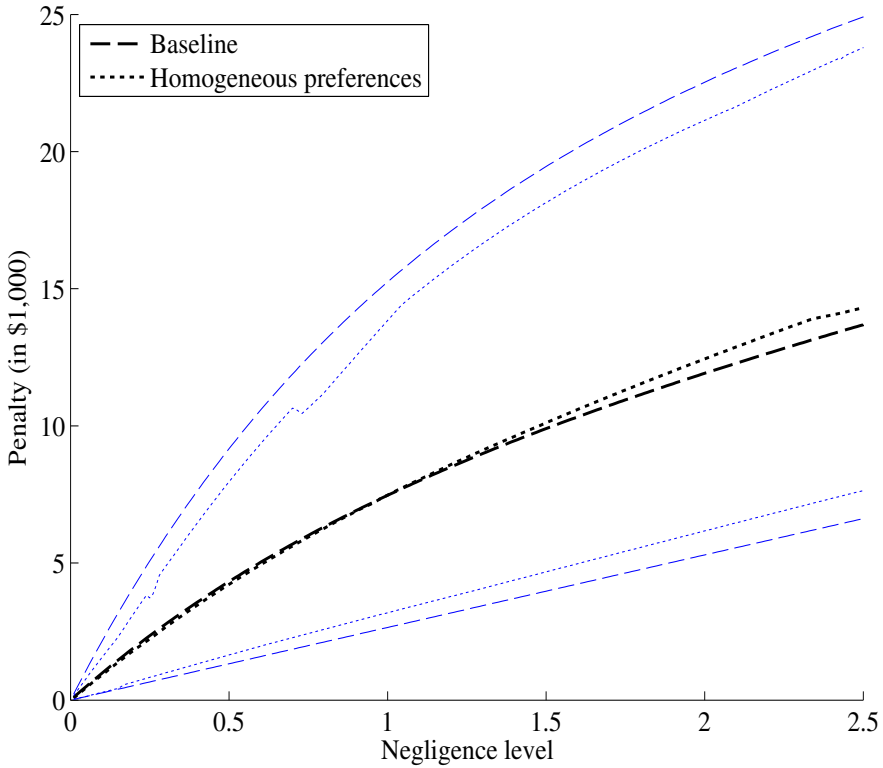
Why Penalty Disparities?

To decompose the source of disparities into two: (1) heterogeneity in regulator preferences and (2) compliance cost heterogeneity

- Consider a scenario where (γ, ψ) is identical across facilities
- Compare the dispersion of penalty schedules under the current and the alternative scenarios
- Note that penalty dispersion under the alternative scenario is due to compliance cost heterogeneity

Why Penalty Disparities? Compliance Cost Heterogeneity

Simulated Penalty Schedules

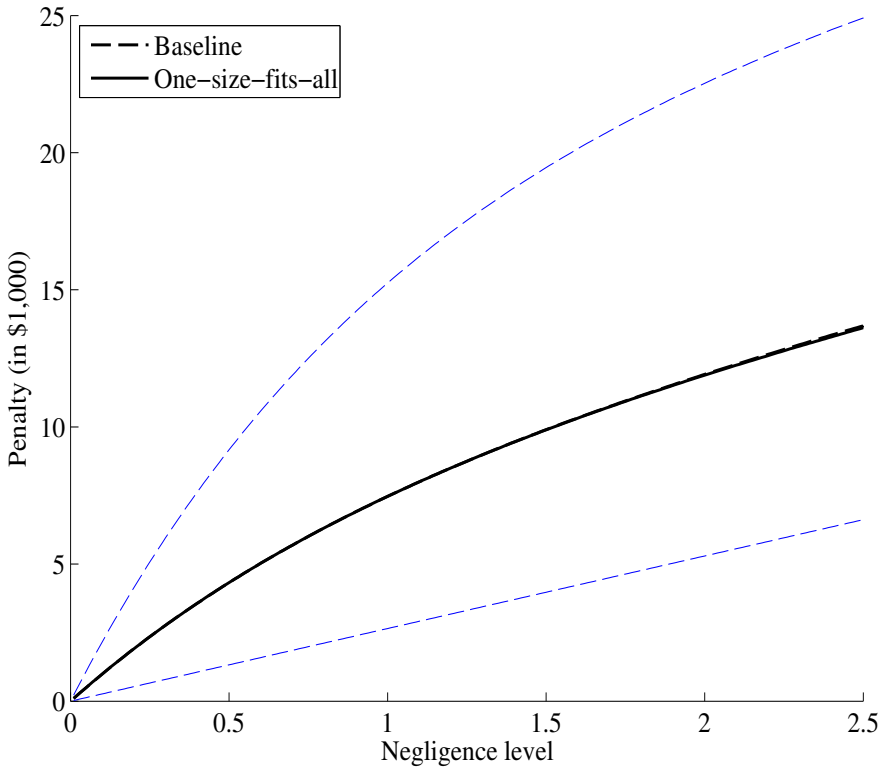


Point-wise average and 5th and 95th percentiles of the simulated penalty schedules across 264 facilities active in 2005 Q1, based on the estimated model parameters for the post-2006 period

- Dispersion of penalty schedules are similar under both scenarios
- For example, the standard deviation of $e(a = 1)$ is \$3,859 (baseline) vs. \$3,350 (alternative)

What about the One-size-fits-all Policy?

Simulated Penalty Schedules



Point-wise average and 5th and 95th percentiles of the simulated penalty schedules across 264 facilities active in 2005 Q1, based on the estimated model parameters for the post-2006 period

- Consider a policy for an average facility based on the average (γ, ψ)
- Coincidentally, this policy is very similar to the point-wise average penalty schedule under the current regime

What about the One-size-fits-all Policy?

Table: Simulated Violation Frequency Distribution

	Baseline scenario		Homogeneous regulator prefer.		One-size-fits-all penalty schedule	
	Before	After	Before	After	Before	After
	(1)	(2)	(3)	(4)	(5)	(6)
Mean	1.49	0.80	1.06	0.70	1.77	0.85
Standard deviation	1.35	0.72	0.95	0.69	1.60	0.77

1. Vs. the current regime: Increase in both mean and standard deviation of violation frequencies
2. Vs. the homogenous regulator preference case: Even larger increase in both accounts $\rightarrow$ Value of regulator expertise

Distributional Effects of Enforcement Discretion

Dependent variable: An increase in the negligence level due to a policy change?				
	Before 2006		After 2006	
	UPS−B	HRP−B	UPS−B	HRP−B
Major	0.659***	0.111***	0.606***	0.068
	(0.039)	(0.047)	(0.041)	(0.059)
Income	0.082	0.231	0.077	1.166***
	(0.127)	(0.214)	(0.129)	(0.252)
Population density	0.066***	-0.187***	0.055*	-0.183***
	(0.029)	(0.041)	(0.029)	(0.043)
Irrigation water use (%)	0.019	-0.809***	-0.024	-0.689***
	(0.080)	(0.133)	(0.082)	(0.156)
Turnout (%)	0.007*	-0.008	0.014***	-0.016**
	(0.004)	(0.005)	(0.005)	(0.006)
Water proposition (%)	0.001	0.022***	0.007*	0.002
	(0.005)	(0.004)	(0.005)	(0.006)
Adjusted R^2	0.765	0.591	0.742	0.437

Notes: Unit of observation is a facility. All regressions based on 264 observations. Additional controls (included in all specifications) are: the age group of the facility; the total precipitation amount during the quarter in which the violation occurred; and and the water board region dummies.

Conclusion

- Provide an empirical framework to evaluate regulatory discretion
  - Consider an adverse selection model of regulation enforcement
  - Identify and estimate discharger costs and regulator preferences
  - Apply to California water quality regulation
- Find support for regulatory discretion in reflecting local preferences and utilizing expertise