Enforcement and Deterrence with Certain Detection:

An Experiment in Water Conservation Policy

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EEA

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Historically Regulatory Enforcement Has Been Ineffective

- Environmental regulations look strong on paper
- But non-compliance appears rampant, globally (Alm & Shimshack, 2014)
- HP: Low apprehension probability is key factor leading to low compliance (Becker, 1968)
  - Monitoring costs are prohibitive (e.g., on-site inspections)
  - There are ample opportunities to hide violations (Duflo et al., 2013; Gibson, 2019; Reynaert & Sallee, 2021; Vollaard, 2017; Zou, 2021)
  - Backlash can erode political capital (Brollo et al., 2019)

A New Era of Automated Enforcement

Remote sensing and real-time monitoring are becoming cheap and ubiquitous, enabling **Automated Enforcement**:

- **Benefits:**
  - Decrease in monitoring costs (Fowlie et al., 2019)
  - Near perfect detection of violations (Duflo et al., 2018; Greenstone et al., 2020; Banerjee et al., 2008; Meeks et al., 2020)
  - Potential gains in deterrence (Li et al., 2020; Ali et al., 2018)

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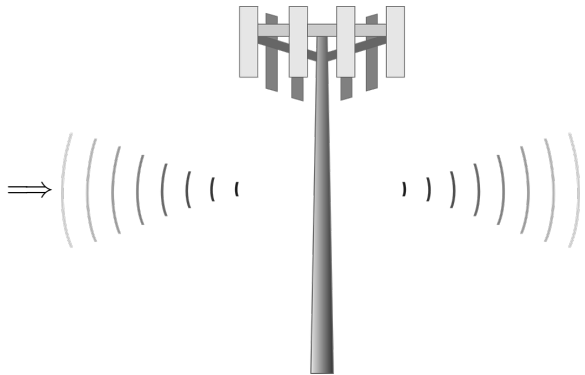
- **Costs:**
  - Political costs of higher fine burden
  - Existing policies (designed for low-tech enforcement) may no longer be appropriate

Water Conservation: Water Cops vs. Smart Meters

- Water is not priced at the margin and tiered pricing is controversial
- Many US cities restrict lawn watering to a few nights per week
- Outdoor watering restrictions currently enforced by 'water cops'

Water Conservation: Water Cops vs. Smart Meters

- Smart meter data in Fresno reveal that **68% of households violated**
- Yet, water cops (2.5 FTEs) issued fines for only **0.4%** of violations
- Automated enforcement via smart meters identifies **100%** violations



Research Questions

What are the effects of **automated enforcement** and **perfect detection**:

1. **Benefits:** Water use and compliance?
2. **Costs:** Fine incidence and political capital?
3. **Mechanisms:** Are effects heterogeneous by household characteristic and fine levels?
4. **Decomposition:** Do people respond to enforcement actions?

Contributions

This paper presents results from a unique experiment that:

- Introduced automated enforcement of outdoor water use restrictions (summer of 2018)
- Randomly assigned households to one of 12 groups varying enforcement method and fine levels
- Monitored water use and customer service interactions

Outline

Background: Outdoor Watering Regulations in Fresno

- By 2013, all 114,508 single-family households in Fresno had smart meters
- Outdoor watering allowed 3 nights a week, different for odd/even house numbers
- First violation yields warning; subsequent violations yield fines (one per month)
- Baseline fine schedule: 0, \$50, \$100. Average summer 2017 monthly bill: \$79.29
- Violations are notified with mailer, then fines added to next month's water bill
- Households can request audits and timer tutorials

The Experiment: Jul-Sep 2018

- Random assignment into 1 of 12 groups
- Stratified by Census block-group household median income and baseline (April 2017) water use above median
- Households could opt out of pilot, defaulted into harshest automated enforcement (ITT)

Enforcement Type:	Non-Auto	Auto	Auto	Auto
Threshold / Fine	N/A	300 gal/hr	500 gal/hr	700 gal/hr
Baseline: 0,$50,$100	40,311	4,479	4,479	4,479
50% of Baseline	4,479	4,479	4,479	4,479
25% of Baseline	4,479	4,479	4,479	4,479

Data

- Real-time household-level water use (Jan 2017 - Feb 2019)
- Household-level call logs from customer service (Jun 2018 - Feb 2019)
- Service request data (Jul 2018 - Sep 2018)
- Sample restrictions:
  - One year of baseline data with reasonable water use (e.g., no moves)
  - Address matched to single-family parcel in assessor file
- Analysis sample includes 88,904 single-family households

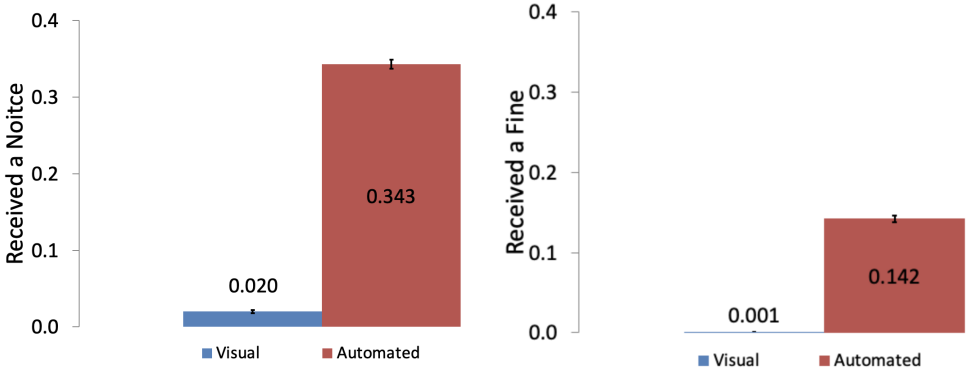
Call Categories

Topic of Conversation	Count	Percent of Category
Complaints/Disputes	**1,428**	
Misc. complaint regarding a notice but no formal dispute	394	27.6%
Request to review notice or meter reading	344	24.1%
General dispute or appeal of notice	205	14.4%
Dispute - Other	185	13.0%
Dispute - Filling, draining or using a pool, pond or home spa	184	12.9%
Request to review date and time of violation	116	8.1%
Misc.	**351**	
Service Request	**286**	
Sprinkler/timer inspection request	84	29.4%
Leak Survey request	64	22.4%
Notification of known infrastructure repair request	38	13.3%
Sprinkler timer has been set incorrectly	37	12.9%
Service Request - Other	37	12.9%
Request for help managing a sprinkler timer	26	9.1%
Opt out	**76**	
Request to opt out of the pilot	35	46.1%
Initially requested to opt out but decided to remain in program	17	22.4%
Opt out confirmation request	15	19.7%
Opt out confirmation - Other	9	11.8%

Outline

Result 1: Automation Increases Warnings by 1,615%, Fines by 14,100%

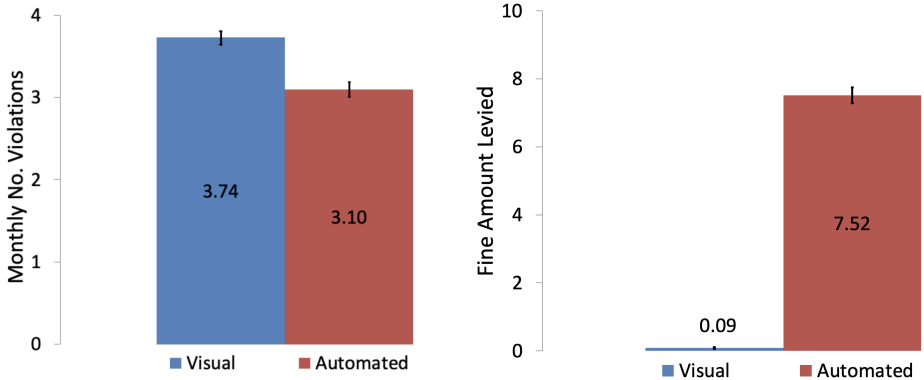
$$y_i = \beta \text{Automated}_i + \sum_{j \in \{25,50\}} \gamma_j \text{Visual} \times \text{Fines}_{ij} + \varepsilon_i$$



Sample Period: July-Sep 2018; SE clustered at HH level; Bars indicate 95% CI

Result 2: Automated Enforcement Decreases Violations by 17%, Increases Fines Paid per Month by $7.43

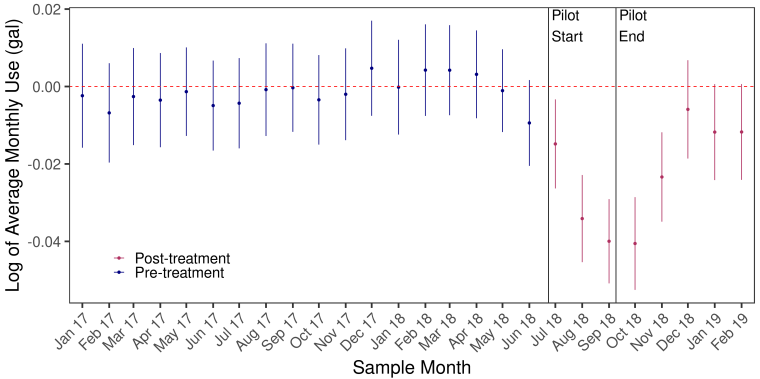
$$y_{it} = \beta \text{Automated}_i + \sum_{j \in \{25,50\}} \gamma_j \text{Visual} \times \text{Fines}_{ij} + \varepsilon_{it}$$



Sample Period: July-Sep 2018; SE clustered at HH level; Bars indicate 95% CI

Result 3: Automated Enforcement Decreases Water Use by 3%

$$y_{it} = \sum_{t \in [Jan2017, Feb2019]} \beta_t \text{Month}_t \times \text{Automated}_i + \sum_{j \in \{25,50\}} \gamma_j \text{Visual} \times \text{Fines}_{ij} + \gamma_t + \varepsilon_{it}$$

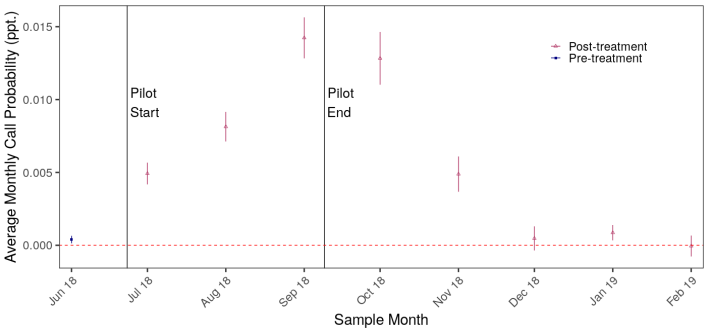


Water use decreases by 60 mil gal in summer in automated group, 174 mil gal if scaled citywide

Result 4: Automated Enforcement Increases Customer Calls by 554%

$$y_{it} = \sum_{t \in [Jun2018, Feb2019]} \beta_t \text{Month}_t \times \text{Automated}_i + \sum_{j \in \{25,50\}} \gamma_j \text{Visual} \times \text{Fines}_{ij} + \gamma_t + \varepsilon_{it}$$

- 1,747 calls in 3 months; 4 staff
- Additional complaints to Council Members
- 76% of result explained by complaints and disputes



Bars plot 95% CI with SEs clustered at the HH level.

Additional Results

- We see similar reductions in log water use across the income/baseline use distributions
- But high/high-income users complain more

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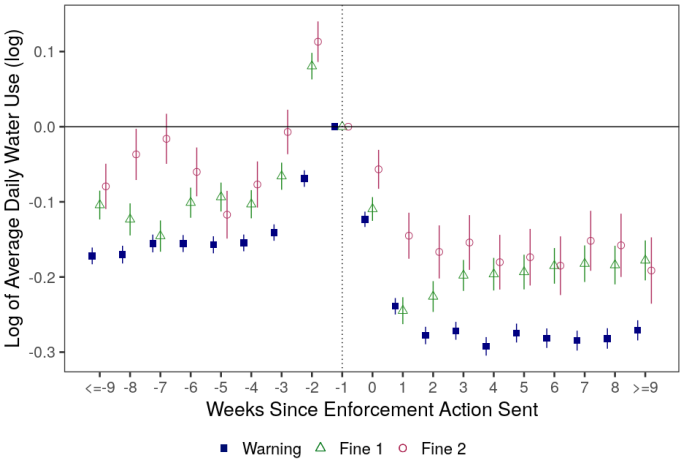
- We see similar reductions in log water use across the income/baseline use distributions
- But high/high-income users complain more
- More lenient thresholds lead to higher water use, fewer complaints
- Fine levels don't appear to matter much: might be leveraged?

Households' Water Use Responds to Enforcement, Including Warnings

$$y_{it} = \alpha + \sum_{j \in [-9,9] \setminus \{-1\}} \beta_j \times I_{it}(j \text{ weeks Post-Violation}) + \gamma_i + \gamma_t + \varepsilon_{it}$$



Plots of HH water use relative to enforcement, with HH & week FEs. Bars plot

95% CI, SEs clustered at HH level.

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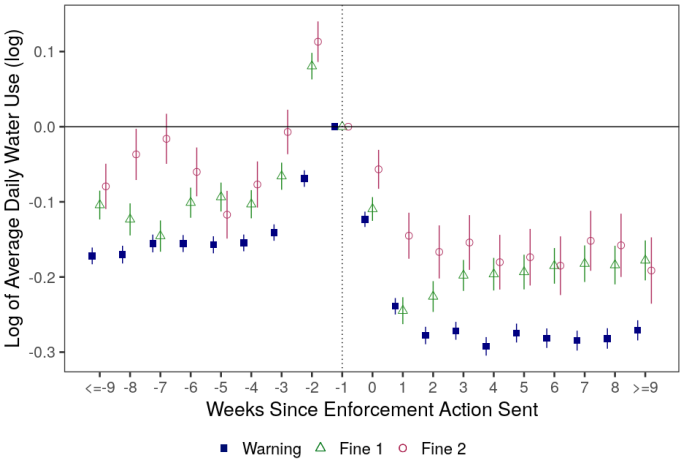

Plots of HH water use relative to enforcement, with HH & week FEs. Bars plot 95% CI, SEs clustered at HH level.

Enforcement effect can be explained by:

- Inattention
- Incorrect beliefs about own water use or enforcement probability
- Increasing fine schedule

Households Call Customer Service after Enforcement, Especially Fines

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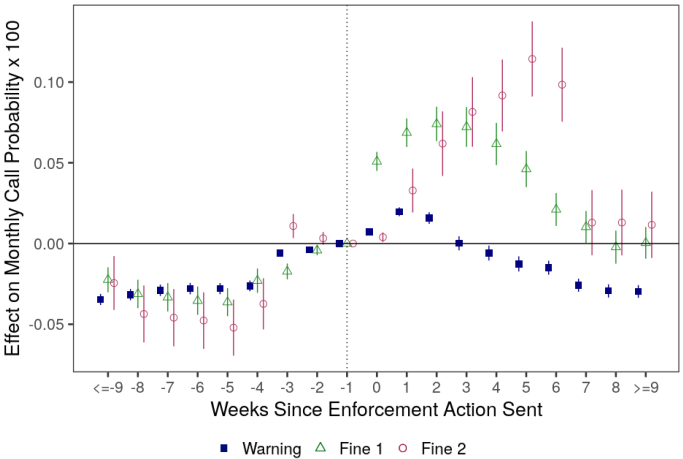
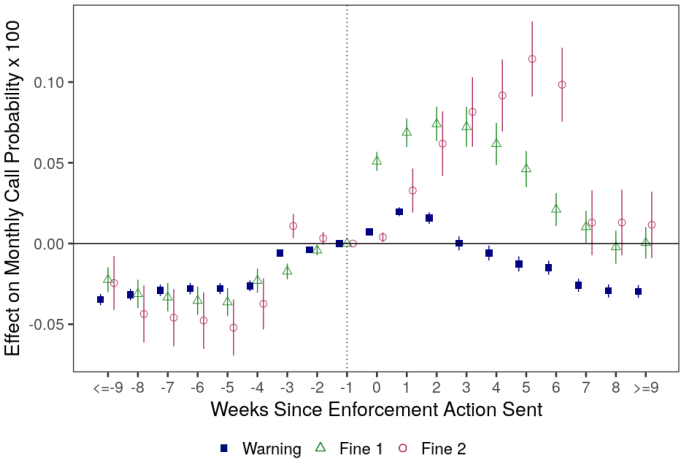


Plots of HH probability of calling relative to enforcement, with HH & week FEs.

Bars plot 95% CI, SEs clustered at HH level.

Households Call Customer Service after Enforcement, Especially Fines

$$y_{it} = \alpha + \sum_{j \in [-9,9] \setminus \{-1\}} \beta_j \times I_{it}(j \text{ weeks Post-Violation}) + \gamma_i + \gamma_t + \varepsilon_{it}$$



Enforcement effect can be explained by:

- HH in auto group more likely to call conditional on violating
- Lower burden of proof?
- Big brother?

Plots of HH probability of calling relative to enforcement, with HH & week FEs.

Bars plot 95% CI, SEs clustered at HH level.

Conclusion

- Automated enforcement caused:
  1. Increased detection of violations
  2. Improved compliance with watering restrictions
  3. Decreased water use
  4. Surge in customer complaints which ultimately halted scale-up

- Our results speak to the political economy of automated enforcement that leverages remote sensing

Thank You!

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Appendix: Peer Effects

Dependent Variable	Log of Daily Water Use (gal)				
	(1)	(2)	(3)	(4)	(5)
Automated Enforcement	-0.030***	-0.031***	-0.033***	-0.031***	-0.033***
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Share Automated		0.028	-0.008		
		(0.037)	(0.027)		
Share 300gal/hr Threshold				0.031	-0.022
				(0.053)	(0.038)
Share 500gal/hr Threshold				0.051	0.007
				(0.054)	(0.038)
Share 700gal/hr Threshold				-0.008	-0.016
				(0.053)	(0.038)
N	7,466,297	7,466,297	7,466,297	7,466,297	7,466,297
Additional Controls			X		X

Appendix: Substitution

Dependent Variable	Log of Average Water Use over a Month (gal/hr)		
	Overall	Permitted Hours	Banned Hours
	(1)	(2)	(3)
Automated Enforcement			
July	-0.015**	0.002	-0.028***
	(0.006)	(0.008)	(0.006)
August	-0.034***	0.006	-0.081***
	(0.006)	(0.008)	(0.006)
September	-0.040***	0.007	-0.083***
	(0.006)	(0.008)	(0.006)
Non-Automated			
50% Fine Level	-0.026**	-0.030*	-0.012
	(0.012)	(0.016)	(0.013)
25% Fine Level	0.007	0.014	0.003
	(0.012)	(0.016)	(0.013)
Control Mean	9.482	5.301	5.258
N	261,311	260,405	261,153
Average Number of Hours	667.8	178.4	489.4