Environmental and Development Economics
Module 5 - Environmental Policy Design in LMICs

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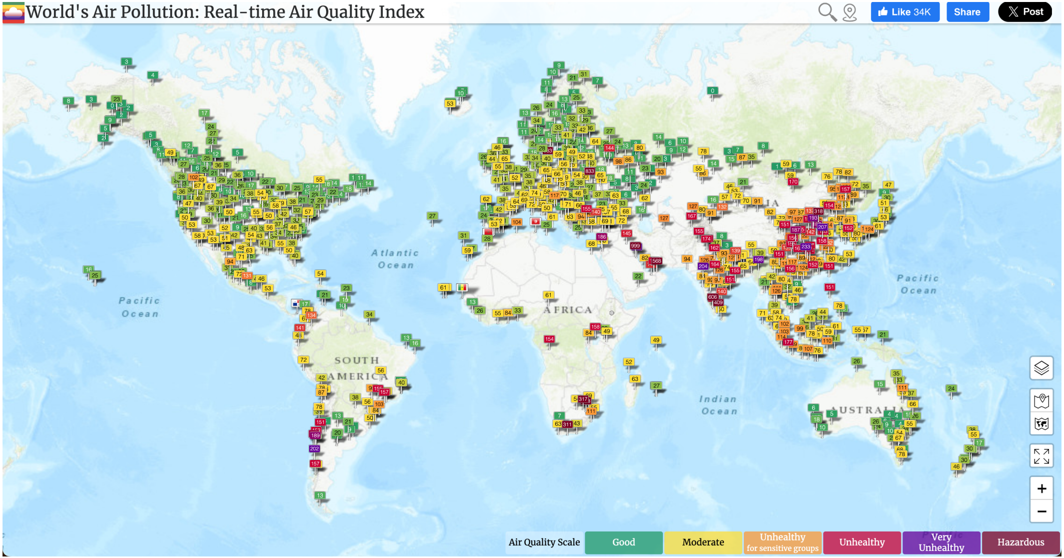
Lecture 8 (continued)

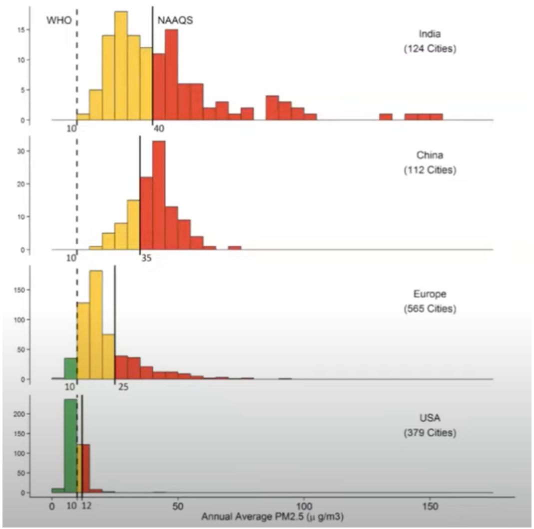
Environmental Policy Design in LMICs: Monitoring and Enforcement

Housekeeping

Rich countries have resolved many environmental problems



Within-country: Richer countries effectively use environmental regulation



Role of the state in improving environmental quality

- With perfectly functioning markets, agent sets:

$$MWTP_e = \frac{\partial c_e}{\partial \Delta e}$$

- This yields **first-best outcome**

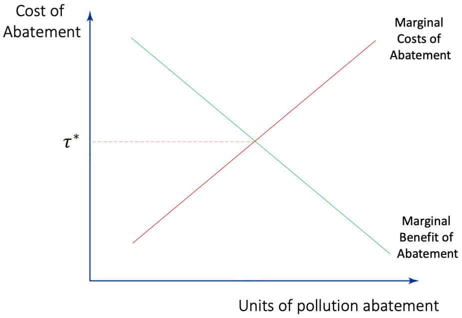
- For policy design, social planner sets optimal e
  - **Assumption 1:** Assume they know true $MWTP_e$ (last week)
  - **Assumption 2:** Costless technology to raise revenue

- **Assumption 2** fails in LMICs $\longleftrightarrow$ $\frac{\partial c_e}{\partial \Delta e}$ too high!

- LMICs on left of equilibrium
- Optimal to abate until MAC=MB
- Should be easy since MAC low

puzzle: $\frac{\partial c_e}{\partial \Delta e}$ **is high!**

- why?



Today

- **Guiding question:** How do we design optimal environmental policy in LMICs?

- Today's focus: challenges for designing low MAC policies
  - Perverse incentives (Duflo et al., 2013)
  - Spillovers and unintended consequences (Englander 2023)

- Next time: other barriers to efficient policy design
  - Trust
  - Knowledge

Background: Poor countries DO have environmental policies

Background: India

- Command-and-control regulation is the norm
- "Command" is easy, "control" is costly
- State Pollution Control Board (SPCB) enforces regulatons
    - State capacity is weak
    - Enforcement is very costly $\rightarrow$ less monitoring
- **Role of third-party auditors**

Duflo et al. (2013): Truth-Telling by Third-party Auditors

- **RQuestion:** How much do firms skirt environmental policy in developing countries?
  - Can realigning incentives of auditors $\uparrow$ compliance with environmental norms?
- **Setting:** Pollution audit system in Gujarat, India
- **Data:** 473 firms; audits, backchecks, and pollution monitoring
- **Research Design:** RCT
  - Treatment: random auditor assignment with fixed payment
- **Results:** 1) widespread corruption in status quo, 2) more truth-telling in treatment, 3) firms $\downarrow$ pollution

Context: Gujarat, India

- One of India's fastest growing states
  - Home to the two post polluted industrial clusters
- Pollution standards set nationally, enforcement is state-level
  - GPCB responsible for enforcing Air Act
- GPCB uses regulates 20,000 plants
- Main regulatory instrument: plant-level inspections + third-party audits

Environmental Audits in Gujarat

- Polluting firms submit yearly environmental audit
- Audit conducted by audit firm hired and paid by the plant
- Auditors visit plant three times/year to measure pollution
  - Submit audit report to GPCB
- (On paper) checks and balances on auditors
  - Max 15 plants per year
  - Can audit a plant at most 3 years in a row
  - Auditors with inaccurate reports can be decertified

Environmental Audits in Gujarat

- (On paper) checks and balances on plants
  - Failure to submit report punishable by closure/disconnection
  - Noncompliance audit report punishable by closure/disconnection

- Despite safeguards, system functions poorly
  - GPCB believes inaccurate reporting renders audits useless for enforcement

- Evidence of auditor shopping: Plants pay $\approx$ INR 24,000 (\$300)
  - Significantly less than true costs of conducting audit

Experimental Design: N=473 plants

	Comparison Group: Status Quo Audit System	Treatment Group: New Audit System
Auditor Section	Plants selected and paid their own auditors.	Auditors were randomly assigned to the plants that they would monitor.
Auditor Fees	Plants paid auditors directly and negotiated the price of the audit.	Auditors were paid a fixed fee of 45,000 rupees per audit from a common pool.
Monitoring	Auditors' reports were not verified for accuracy.	Twenty percent of auditor pollution readings were randomly selected to be **double checked, or "backchecked,"** by the technical staff of independent engineering colleges. Auditors were aware that they might be backchecked, but were not told when.
Accuracy Incentives	None.	In year two, auditors were also given incentive payments for accurate reports.

Lecture 9

Environmental Policy Design in LMICs

Housekeeping

- First draft due on Thursday
  - Peer review due one week later (2 pages)
- Proposal presentation (Oct 15th and 17th)
  - Consider drafting it as you write your first draft
  - Rubric added in github
- Replication (3 pages, due Oct 21st)
- Minor syllabus updates
  - State capacity in-class presentation
- Migration lecture readings will be posted this week

Model: Set Up

- **Three Players**: plant, auditor, and regulator.
- Plants face the decision to:
  - **Abate pollution**: Incurs a cost, but avoids penalties.
  - **Falsify reports**: Pay auditor to underreport pollution and avoid abatement.
- Auditors considers:
  - Payment from plant
  - Risk of disbarment by regulator if found cheating.
- Regulator: reduce pollution by enforcing penalties and disbarring false auditors

Plant's Decision and Cost Function

- The plant's goal is to minimize total costs:

$$S - 1\{Abate\} \cdot c - w - 1\{\text{Fine Imposed}\} \cdot f$$

- Where:
  - S = Value of production
  - c = Cost of abating pollution
  - w = Payment to auditors for the report
  - f = Fine imposed if non-compliance is detected
- **Abatement**: Reduces emissions from p_h to p_l, at cost $c \sim G(\cdot)$
- **Non-compliance**: Plant chooses $w(\hat{p}|p)$ to minimize costs
  - where $\hat{p}$ is auditor report, and p is true pollution

Auditor's Payoff and Reporting Incentives

- Auditor's payoff function is:

$$w - a + E[V(\hat{p}|p)]$$

- Where:
  - w is payment for performing audit
  - a $=$ Cost of performing the audit
  - $E[V(\hat{p}|p)]$ = continuation value of future business
  - Assume leniency increases EV: $V_{lh} = V(p_l|p_h) > V_{hh} = V_0$

- Auditors may have incentive to falsify reports to maintain business
  - Higher V_{lh}, more attractive for auditors to underreport
  - $E[V(\hat{p}|p)]$ incorporates likelihood of disbarrment

Regulator Problem

- Reviews reports $\hat{p}$ and may impose f on plant or disbar auditor
- Let $q =$ probability regulator observes true p (backchecks)
- Decide whether to impose f
- Continuation value of disbarred auditor is zero
- Regulator only goal: minimize pollution

Equilibrium: Proposition 1

Unique subgame-perfect equilibrium with regulation:

- **Plants Abate**: If $c \leq \min\{f, qV_{lh} - \Delta V\}$.
- **Underreporting**: If $qV_{lh} - \Delta V < \min\{c, f\}$.
- **Defy Regulation**: If $f < \min\{c, qV_{lh} - \Delta V\}$.

Intuition

- **Abatement**: when cheaper than paying fines or paying auditors to cheat
- **Underreport**: when paying auditors to cheat cheaper than abatement and fines
- **Defiance** when both abatement and bribing more expensive than risking fines

Equilibrium: Proposition 2 - Backchecks

Status Quo (control group)

- $q \to 0$ in status quo
- Negative cost of false reports: $qV_{lh} - \Delta V$
- Result: Widespread underreporting and no incentive for abatement

With Backchecks and Incentive Pay (Proposition 2)

- Backchecks: $\uparrow$ q s.t. $qV_{lh} - \Delta V > f$ induces fraction $G(f)$ of plants to abate
- Incentive pay: Makes underreporting more costly than fine if $q(V_{lh} + B) - \Delta V > f$

Intuition:

- Backchecks increase q, raising expected cost of false reporting
- When $qV_{lh} - \Delta V > f$, some plants prefer abatement over risking detection.

Random Assignment of Auditors

- **Flat fee:** Payment unconditional on report outcomes: $w(\hat{p}|p) = w(p)$
  - Plant cannot bribe auditor, nor can they refuse to pay
- Auditors only consider reputation $\rightarrow$ increase in q for plants to abate is smaller
- Reduces continuation value of notoreity, ΔV

Proposition 3: Rise in q s.t. $qV_{lh} \geq \Delta V$ induces share $G(f)$ to abate

$$\text{If } qV_{lh} \geq \Delta V \implies \text{Plants will abate if } c \leq f$$

- **Intuition**: If treatments are strong enough s.t. $q(V_{lh} + B) > \Delta V$, then $G(f)$ plants will abate and rest will report higher p and risk fine.

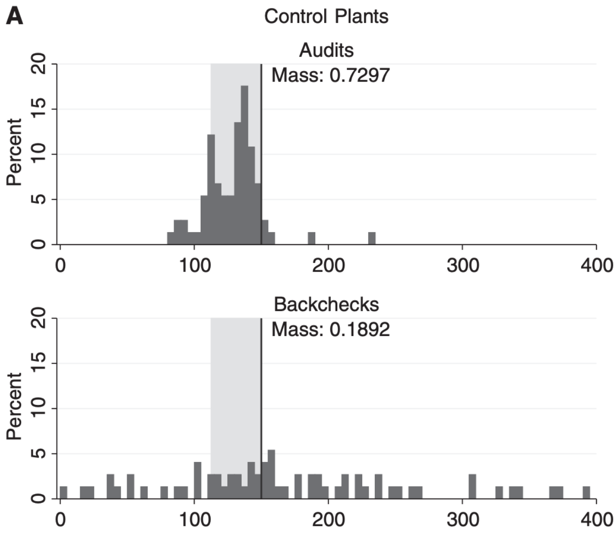
Model Summary

- **Higher** q through backchecks increases risk of detection for false reporting
- **Random assignment** and **centralized payment** $\downarrow$ auditors-plant dependency
- **Incentive Pay** boosts auditors' continuation value for truthful reporting
- Treatment makes false reporting costlier for auditors and plants
- Plants either abate pollution or risk fines, depending on abatement costs
- The equilibrium shifts towards increased compliance and truthful reporting

Data

- **Audit Reports (2009 & 2010)**: water and air pollution
  - Collected from auditors in both treatment and control groups
- **Backchecks**: independent *unannounced* verification of pollution levels
  - Conducted randomly on 20% of treatment plants in 2009 and 2010
  - Midline backchecks in 2010 for both treatment and control groups.
- **Endline Survey (2011)**:
  - Measured actual pollution outcomes after the audit intervention
- **Administrative Data from GPCB**:
  - Regulatory actions, violations, and enforcement measures
  - Fines, closures, and disconnections imposed on plants

Results: Status Quo Pollution



In Regression Form

$$1\{Compliant\}_{ij} = \beta_1 1\{AuditReport\} + \alpha_r + \epsilon_{ij}$$

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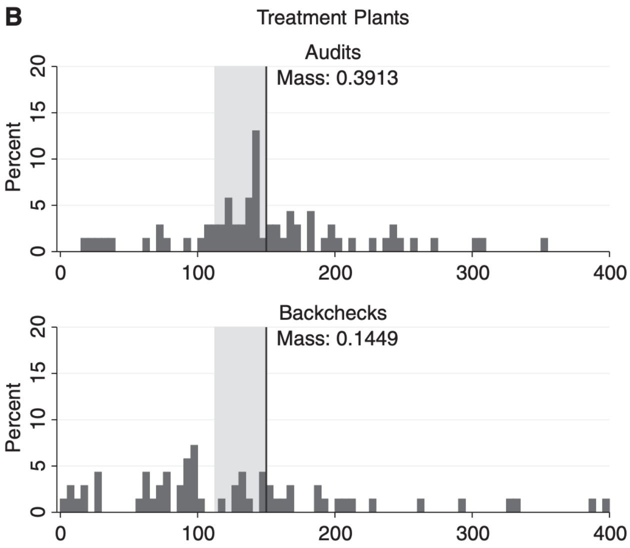
	(1) All pollutants	(2) Water pollutants	(3) Air pollutants
Panel A: Dependent variable: Narrow compliance (dummy for pollutant between 75% and 100% of regulatory standard)			
Audit report (= 1)	0.270***	0.297***	0.230***
	(0.025)	(0.034)	(0.033)
Control mean in backchecks	0.097	0.110	0.077

Treatment Effects: Truth Telling About Plant Compliance



In Regression Form

$$1\{Compliant\}_{ij} = \beta_1 1\{AuditReport\} \times T_j + \beta_2 1\{AuditReport\} + \beta_3 T_j + \alpha_r + \epsilon_{ij}$$

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$$1\{Compliant\}_{ij} = \beta_1 1\{AuditReport\} \times T_j + \beta_2 1\{AuditReport\} + \beta_3 T_j + \alpha_r + \epsilon_{ij}$$

COMPLIANCE IN AUDITS RELATIVE TO BACKCHECKS BY TREATMENT STATUS

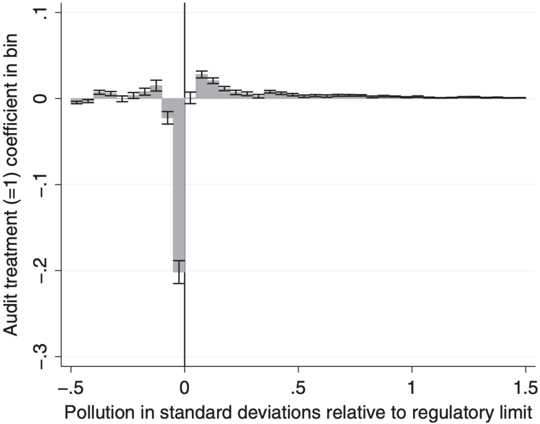
	(1) All pollutants	(2) Water pollutants	(3) Air pollutants
Panel A: Dependent variable: Narrow compliance (dummy for pollutant between 75% and 100% of regulatory standard)			
Audit report × Treatment group	−0.185***	−0.212***	−0.143***
	(0.034)	(0.044)	(0.046)
Audit report (= 1)	0.270***	0.297***	0.230***
	(0.025)	(0.034)	(0.033)
Treatment group (= 1)	−0.0034	−0.013	0.011
	(0.0176)	(0.025)	(0.024)
Control mean in backchecks	0.097	0.110	0.077

- Treatment increases truth-telling: 19pp less cheating in treatment

Which firms are getting told on?

- Convert pollution readings to deviation from regulatory standard
- Readings grouped into 40 different 0.05σ width bins
- 40 regressions: regress dummy for each bin on treatment indicator
  - Negative coefficient: treatment auditors less likely to report values in that bin
- Result: treatment reduces the mass just beneath the standard
  - **More likely** to report values above standard

Density of audit report pollution distribution



- Readings by treatment auditors 20% less likely to be in bin just below standard compared to control readings

Do plants reduce emissions?

- From model: treatment induces $G(f)$ plants abate by Δ incentives
- Regress plant pollution on treatment + region FE in endline (cross section)

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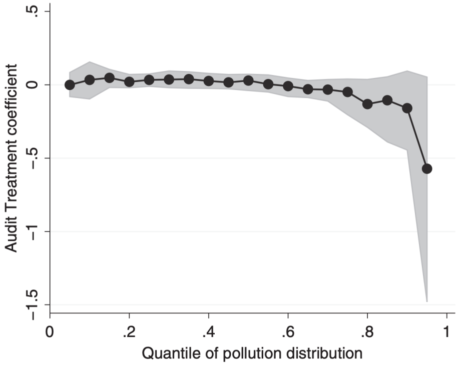
ENDLINE POLLUTANT CONCENTRATIONS ON TREATMENT STATUS

	(1) All pollutants	(2) Water pollutants	(3) Air pollutants
Panel A: Dependent variable: Level of pollutant in endline survey, all pollutants (standard deviations relative to backcheck mean)			
Audit treatment assigned (= 1)	−0.211**	−0.300*	−0.053
	(0.099)	(0.159)	(0.057)
Control mean	0.076	0.114	0.022
Observations	1439	860	579

- Treatment plants ↓ pollution by 0.21σ

Which plants are reducing pollution?

- Quantile regression: $Q_{y_{ij}|X_j}(\tau) = \beta T_j + \alpha_r + \epsilon_{ij}$



- Clean-up driven by dirty plants (>80th pctile)
- Driven by monotonic increase in severity of GPCB fines w/ non-compliance

Policy

- Eliminating conflict of interest led to policy change
- Scaled up to state level since 2015

GUJARAT'S POLLUTION CONTROL AUTHORITY ADOPTS ENVIRONMENTAL AUDIT REFORMS AFTER IMPACT STUDY SHOWS THEY REDUCE POLLUTION

Gujarat's Pollution Control authority approved the reforms after collaborating with leading academics on a pilot experiment that showed more accurate audit reports and lower pollution emissions

January 29, 2015, New Delhi – Environmental authorities in the Indian state of Gujarat reformed their environmental auditing system this month based on findings from a large-scale study conducted in partnership with economists at Harvard, MIT, the University of Chicago, and Yale. The new guidelines issued by the Gujarat Pollution Control Board (GPCB) require environmental auditors to be randomly assigned to industrial plants and have their work double-checked for accuracy. These changes were part of those tested in the pilot study, and led auditors to report more accurately and industrial plants to cut pollution.

LEARN MORE

Read more about the study here.

Related News Coverage: NY Times, Wall Street Journal, MIT News

Thoughts?

Other challenges for designing low MAC policies?

Barriers to Optimal Policy Design

- Recall, goal of social planner is to internalize externalities
- Objective is to set $MWTP_e = \frac{\partial c_e}{\partial \Delta e}$ using **regulation**
- We saw that low state capacity creates a wedge by keeping $\frac{\partial c_e}{\partial \Delta e}$ high
  - This is true even if market failures absent
- **Top down:** $\uparrow$ state capacity **directly** has large benefits (more next week)
- **Bottom up:** what if we instead change citizens' trust in the state?

Jack et al. (2013): Money not to Burn

- **Research Question:** Can PES contracts curb crop burning?
- **Setting:** North India; weak institutions for contract efficacy
- **Data:** 171 villages in North India
- **Design:** RCT with two treatments: 1) standard PES 2) partial payment upfront
- **Results:** Upfront PES has 10pp higher compliance than standard PES
  - Takeaway: trust is an important barrier for efficient environmental policy design

Textbook externality problem

Burning in Punjab...

...affects air quality in Delhi

Background

- Crop burning major source of pollution in Punjab
- Burning rice stalks post-harvest $\rightarrow$ 40% of winter pollution in Delhi
  - Severe health risks
- Ban on burning since 2015, with fines for violations, but weak enforcement
  - Fine: Rs. 2,500 to Rs. 15,000 based on landholding
- Subsidies for residue management equipment exist
  - insufficient to cover farmers' costs (still cheaper to burn)

PES Contracts

- PES contracts pay farmers for environmentally friendly practices
- Goal: increase the private costs of burning to incentivize "good" behavior
- Advantage: targets outcome not inputs
  - i.e. agnostic about technology, as long as abatement cost $<$ payment
- Challenge: trust and liquidity constrain standard PES contracts in LMICs
  - Treatment: pay 25% or 50% upfront

RCT Design

Control	$N = 486$ (51 villages)
Standard PES	₹800/acre $N = 310$ (30 villages)
	₹1600/acre $N = 272$ (28 villages)
PES with Upfront Payment	₹800/acre with 25% upfront $N = 285$ (31 villages)
	₹800/acre with 50% upfront $N = 315$ (31 villages)

Data

- Baseline survey: 1,668 farmers (N=171 villages) from two districts in Punjab
- Data: Demographics, income, trust in institutions, and CRM equipent
  - Farm plot shapefiles for linking with satellite imagery
- Monitoring: field visits, random spot checks, satellite imagery

Estimation

$$y_{ij} = \alpha + \beta StandardPES_j + \gamma UpfrontPES_j + \psi X_j + \epsilon_{ij}$$

- y_{ij} = outcome for farmer i in village j
- X_{ij} are strata fixed effects
- Subtreatments are pooled
- β: effect of standard PES relative to control
- γ: effect of upfront PES relative to control

Results: Contract Compliance

Table 1: Contract Compliance, Not Burning, and CRM Use

	Complied with Contract	Unburned: Max Accuracy	Unburned: Balanced Accuracy	CRM techniques: Baler	CRM techniques: Seeder
	(1)	(2)	(3)	(4)	(5)
Standard PES	0.085	0.020	0.008	-0.010	-0.020
	(0.015)	(0.030)	(0.042)	(0.037)	(0.023)
Upfront PES	0.183	0.077	0.115	0.096	0.013
	(0.020)	(0.032)	(0.042)	(0.039)	(0.026)
p-val: Standard PES = Upfront PES	0.000	0.071	0.008	0.014	0.157
Control mean	0.000	0.091	0.202	0.199	0.102
Standard PES mean	0.084	0.098	0.198	0.171	0.087
Upfront PES mean	0.185	0.161	0.313	0.295	0.112
N	1668	1664	1664	1387	1387

- Standard PES: 8.5% complied with contract
- Upfront PES: 18% complied with control — trust and liquidity important!

Other Results

- Relative to control, upfront PES $\uparrow$ non-burning by 7pp (85%)

- Most farmers still burned...
  - Cost of alternatives to burning still higher than PES payment

- Standard PES insignificant in column 2 (inframarginal)
  - farmers who complied would not have burned anyway

Mechanisms: Why do upfront PES increase compliance?

- Hypothesis: 1) distrust in conditional payment, 2) limited cash to rent CRM

Panel A: Liquidity Constraints and Distrust

Outcome variable:	Complied with Contract		Unburned (Maximum Accuracy)	
Type of constraint:	Distrust (1)	Liquidity (2)	Distrust (3)	Liquidity (4)
Upfront PES	0.114	0.088	0.054	0.051
	(0.030)	(0.029)	(0.029)	(0.029)
Highly constrained	0.030	0.010	0.003	0.014
	(0.024)	(0.022)	(0.025)	(0.030)
Upfront PES × Highly constrained	-0.032	0.018	-0.025	-0.022
	(0.036)	(0.038)	(0.039)	(0.042)
Standard PES mean	0.083	0.084	0.104	0.105
Upfront PES mean	0.185	0.185	0.143	0.142
N	1172	1182	1168	1178

- Upfront PES no better for farmers w/ liquidity constraints or distrust

Mechanisms: Why do upfront PES increase compliance?

Panel B: Trust in Payment and Importance of Cash Shortage

Outcome variable:	Trusted Payment (1)	Cash Shortage Not Important (2)
Upfront PES	0.068	0.038
	(0.028)	(0.043)
Standard PES mean	0.854	0.441
N	580	584

- Upfront farmers 7pp more likely to trust that payment will be made
- CRM cash shortages not important for either upfront or standard farmers

Discussion

- Limited short-term capital and distrust in institutions can limit effectiveness of standard PES contracts
- May generalize to conditional CCTs more broadly
- Thoughts?

Other barriers to efficient policy design

Unintended Consequences: Spillovers

Englander (2023): Information & Spillovers in Conservation Policy

- **Research Question:** What are the direct and spillover effects of targeted conservation policy?
- **Setting:** Temporary closures in Peru's anchoveta fishery
- **Data:** location, time, and # of fish caught per boat
- **Research Design:** "Potential' ' closure algorithm
- **Results:** direct effect: lower catch in closed areas
  - indirect effect: big positive spatial spillovers
  - net effect: policy backfires and $\uparrow$ catch!

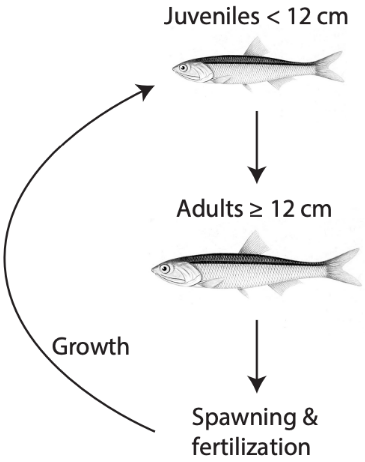
Targeted policies are common forms of incomplete regulation

- Reduce externality by targeting highest MD places
  - Road congestion pricing
- Incomplete regulation $\rightarrow$ spillovers (impacts on non-targeted units)
- Direction and magnitude of spillovers varies

Peru's Anchoveta Fishery

- World's largest (tons caught)
- 8% of global marine catch
- $2 billion export revenue per year
- 730 active vessels per season

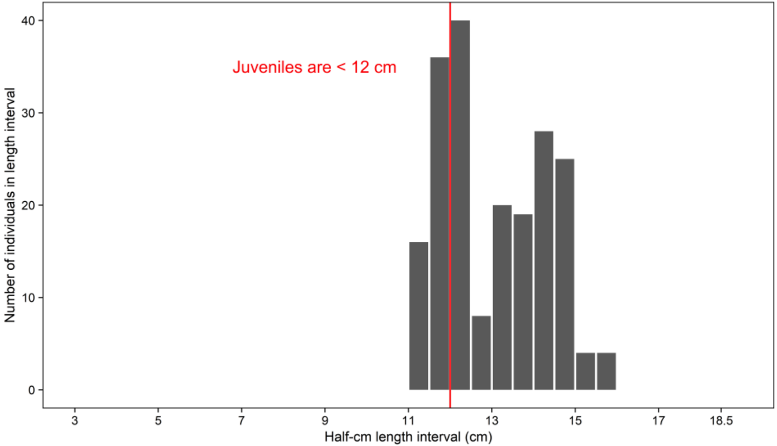
Catching juveniles is higher marginal damage than adults



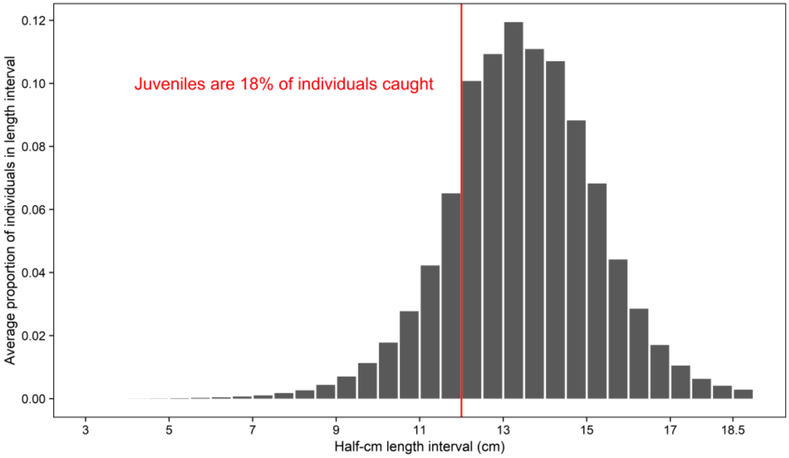
Spatial Closures

- Regulator temporarily closes area of ocean when % of juveniles $> 10\%$
- Regulator exercises discretion; sometimes no closure
- Vessels report catch with electronic logbooks
  - Time, tons, and % juvenile from each set
  - **Challenge:** fishermen underreport % juvenile
  - **Solution:** third-party inspection data
- **Closure rule:** observe % juvenile
  - Draw rectangle around overfished sets
  - Close area inside box
  - Announce on website, email, whatsapp

Reported Size Distribution (example set)



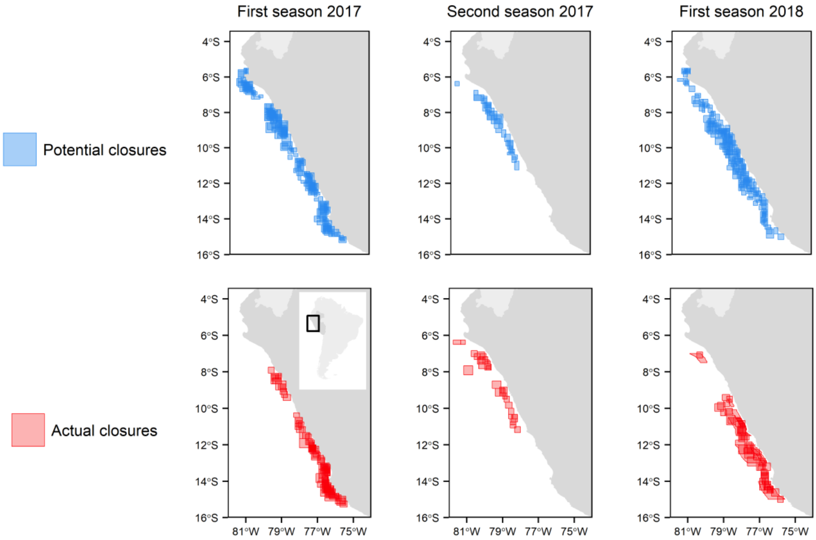
Corrected Size Distribution (example set)



Counterfactual Closures

- Mimic the closure rule (potential closures)
- Intersect potential closures (N=973) w/ actual declared closures (N=410)
- **Control for length distribution from which % juveniles drawn**
    - Comparable distribution of fish sizes
- Similar potential closures, regulator believes different

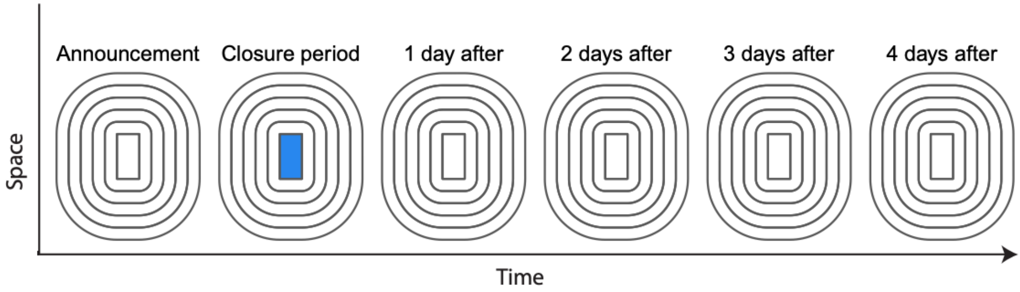
Treatment and Control Groups



Identifying variation

- Comes from controlling for length distribution
- Compare potential closures that by chance had higher % juvenile draws (and were thus closed by regulator) to potential closures that by chance had lower % juvenile draws (and were thus not closed by regulator)
- Key to identification: fishers report % juvenile catch from 200 anchoveta out of several million in a set

Empirical Strategy: Treatment Window for Spillovers

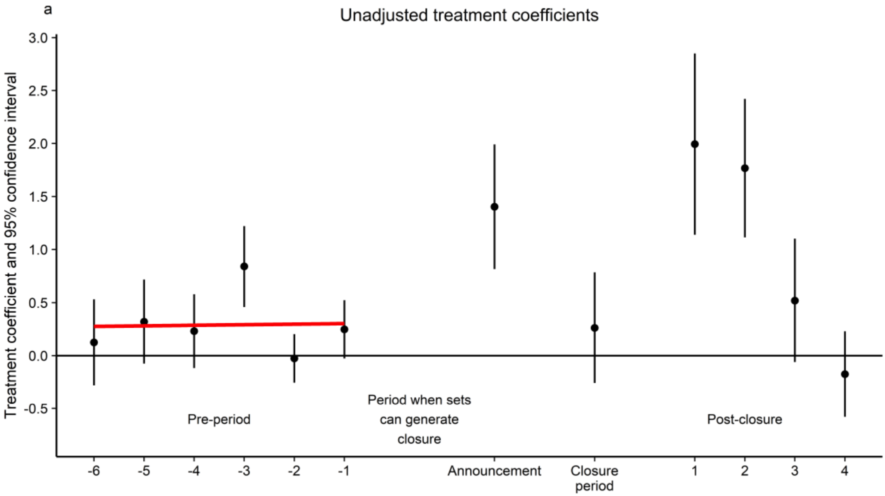


Empirical Strategy

$$JuvenileCatch_{ist} = \alpha_{st} + \beta_{st} TreatFraction_{ist} + \sum_{l} \eta_l Prop_{il} + \Gamma X_i + \sigma_{wg} + \delta_d + \epsilon_{ist}$$

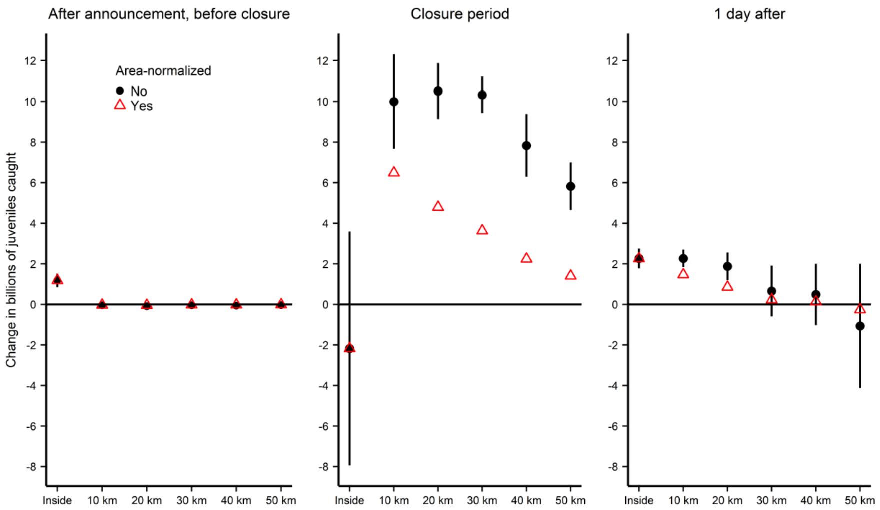
- i = potential closure
- s = spatial unit
- l = half-cm length interval
- w = two weeks
- g = grid cell
- d = day

Event Study



a
Unadjusted treatment coefficients
Treatment coefficient and 95% confidence interval
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Pre-period
Period when sets can generate closure
Post-closure
-6
-5
-4
-3
-2
-1
Announcement
Closure period
1
2
3
4

Main Results



Mechanism: Information Signal

- Game theoretic model
- Vessel chooses where to fish to max. expected profits
- Policy increases catch if:
  - Closures are $+$'ve signal relative to congestion costs
  - % juvenile sufficiently high near closures

- **Predictions:**
  - Ex-post value of information competed away in equilibrium
  - Expected profit would be higher near closures if not for signal
  - Vessels receiving bigger info shocks have larger treatment effects

Results: Value of positive signal is competed away

$$Tons_{vjk} = \beta_1 Near_{vjk} + \beta_2 DistToShore_{vjk} + \delta_{vj} + \gamma_d + \alpha_{jg} + \epsilon_{vjk}$$

where v=vessel, j=season, k=set, d=day, g=gridcell

	Dependent variable: asinh(tons caught)			
	Actual closures		Potential closures	
	(1)	(2)	(3)	(4)
$\mathbb{1}\{Near\}$	0.310	-0.022	0.177	0.082
	(0.080)	(0.033)	(0.073)	(0.026)
Distance to shore (km)	0.011	0.004	0.011	0.004
	(0.002)	(0.001)	(0.002)	(0.001)
Constant	3.306		3.289	
	(0.082)		(0.101)	
Fixed effects		X		X

Thoughts?

- Targeted policy backfires due to positive spillovers
- Policy implicitly signals info about non-targeted units