Enforcing Environmental Regulation: Evidence from India

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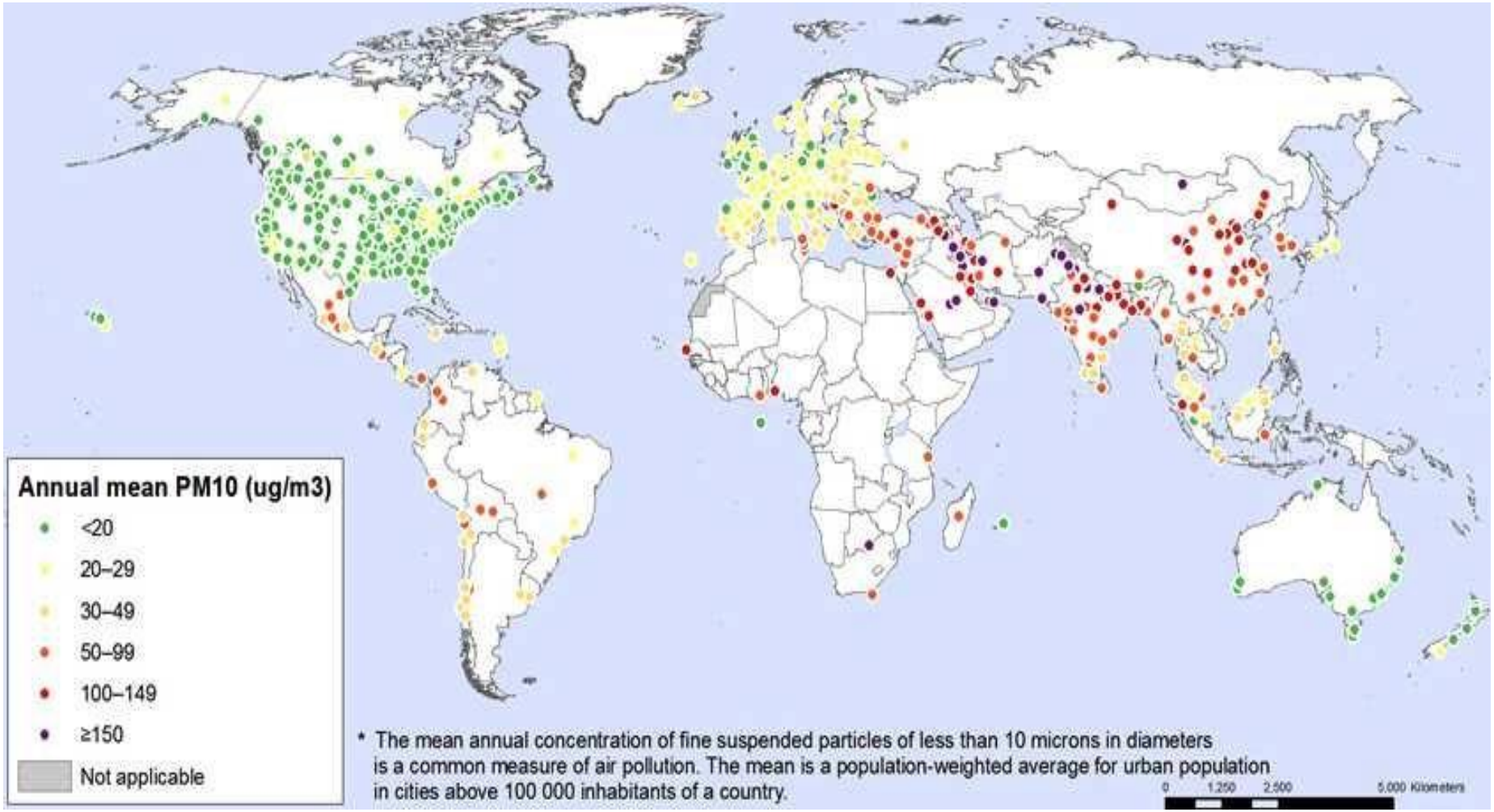
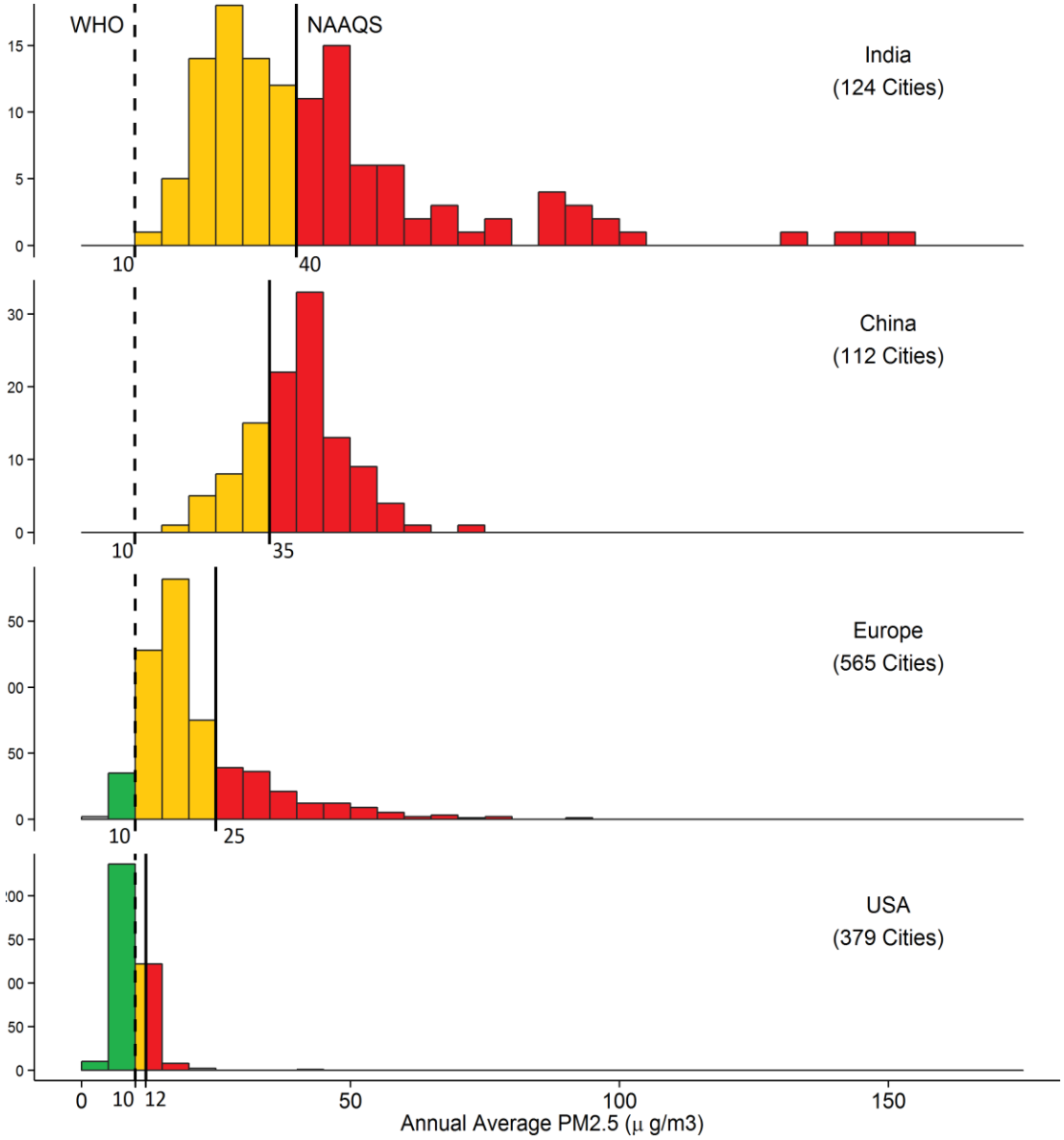
Based on Work with Michael Greenstone, Rohini Pande, and Nick Ryan

Reducing Particulate Matter (PM) is a key concern in many emerging economies



And, according to WHO, India has many of the most polluted cities on earth

Cities	Level of PM 2.5
Delhi	153
Patna	149
Gwalior	144
Rajpur	134
Karachi	117
Peshwar	111
Rawalpindi	107
Khoramdabad	102
Ahmedabad	100
Lucknow	96


WHO
NAAQS
India
(124 Cities)
China
(112 Cities)
Europe
(565 Cities)
USA
(379 Cities)
Annual Average PM2.5 (μ g/m3)

Payoff for reducing ambient pollution

- Large air pollutant concentrations have health consequences, including reduced lives
  - Chen et al, 2011 in china
  - Greenstone and Hanna, 2012 in India (lower air pollution have reduced infant mortality)

Why is India so polluted?

- It is not because of a lack of policies
  - Water Act of 1974 and Air Act of 1981
  - Creates CPCB and States counterparts. States can strenghten standards but not weaken them.
  - Standards are similar to those in the US
- But the policies are not always adequately enforced
  - Greenstone and Hanna (2012) show that stricter environmental regulations in India have led to some improvement in air pollution, but none for water

“ I must emphasise that standards are not enough. They must also be enforced which is often difficult. . . . It is also necessary to ensure that these regulatory standards do not bring back the License Permit Raj which we sought to get rid of in the wake of economic reforms of the nineties”

Former Indian Prime Minister Manmohan Singh, Delhi Sustainable Development Summit, 2011.

Two projects focusing on the enforcement of regulation

- 2008-2011 (Duflo, Greenstone, Pande, Ryan)
  - Evaluation of Environmental Audit system for 473 regulated facilities of highest pollution potential
  - Evaluation of Increased Inspection Frequency for 961 regulated facilities

Industrial Pollution in Gujarat, India

Context: Pollution in Gujarat

- 8% annual output growth since 1991-1992 and largest share of post-licensing reform investment of any Indian state
- State with most critically polluted industrial clusters (8), including 2 most polluted in the country: Vapi area among ten most polluted places on Earth in 2007 (groundwater mercury 96 times higher than WHO)
- 3 of India's 5 most polluted rivers and major cities in violation of National Ambient Air Quality Standards.

Context: Enforcement

- Gujarat Pollution Control Board regulates about 20,000 plants through command-and-control regulation
  - Main standards maximum pollution concentrations
- Powerful regulator
  - Penalties include bonds against future performance and closure enforced by disconnecting electricity or water

Context: Enforcement

- Board has two primary tools for monitoring compliance:
  - Regulatory inspections
  - Third-party audits

- Third-party audits introduced by High Court
  - Supplementary to inspections, in response to civil suit on severe urban water pollution
  - Limited to plants with the highest pollution potential

Duflo, Greenstone, Pande and Ryan, 2013

EVIDENCE ON A MARKET FOR ENVIRONMENTAL AUDITS

Context: What is an audit and what are its consequences?

What is an Audit?

- Auditors visit three times per year
- Collect pollution readings (concentrations) for set of 8 air and water pollutants and observe pollution treatment practices
- Submit annual report with pollution readings and suggested improvements in operations

Consequences of an audit

- Non-submission or non-compliance is punishable, in principle, by closure and disconnection of water and electricity
- False audits can lead to auditor decertification

Context: Environmental Audits

But, third-party auditing system creates conflict of interest, because firms hire their auditors.

→ The auditors' interest may not be perfectly aligned to report the truth.

Gujarat installed several safeguards including:

1. Audit teams must be comprised of four people with particular degrees and experience
2. Auditors cannot consult for the same plant
3. Rotation mandated every three years

Only (1.) was very rigorously implemented

Context: Qualitative description of auditor market

Audit quality dubious to all parties

- Regulator suspicious of audit quality and seldom used findings as the basis for action
- Regulated plants sued to end audits on the (ironic, but accurate) grounds that GPCB was not acting upon the audit reports
- Price of an Audit Appeared Lower than Cost of Conducting the Tests

Evaluation of Reform to the Audit Market

Treatment has four components:

1. Random assignment of auditors to firms
2. Financial independence. Fixed payment from central pool.
3. Monitoring of auditors.
4. Accuracy incentives for auditors (year 2 only).

Evaluation of Reform to the Audit Market

Sample:

- All 473 audit-eligible plants from GPCB regions around Gujarat's two most populous cities.
- All interested GPCB certified auditors were included. Auditors can and do work in both groups at once.

	Treatment	Control
Year 1	Audit reform (233 plants)	Status Quo (240 plants)
Year 2	Audit reform	Status Quo
During year 2	Measure audit quality	
End of year 2 + 6 months	Measure pollution at all plants	

Data: Three Sources

- Auditor reports of Pollution Readings
- Backcheck reports
  - Measure the same pollutants at the same plant within several weeks.
- Survey for final pollution outcomes.

Report Outcomes for Index of Important Pollutants

- Water pollutants most important broad measures of quality: measure oxygen demand required to stabilize samples, solid content, etc.
  Water = {BOD, COD, TDS, TSS, NH_3-N}.
  Use final outlet samples
- Air pollutants principal byproducts of combustion and all EPA criteria pollutants.
  Air = {SO_2, NO_x, SPM}. Use boiler stack samples
- *All* = *Water* ∪ *Air*
- Pollutant readings standardized by dividing by pollutant standard deviations *in backchecks*

Results

1. Reporting was corrupt under status quo.

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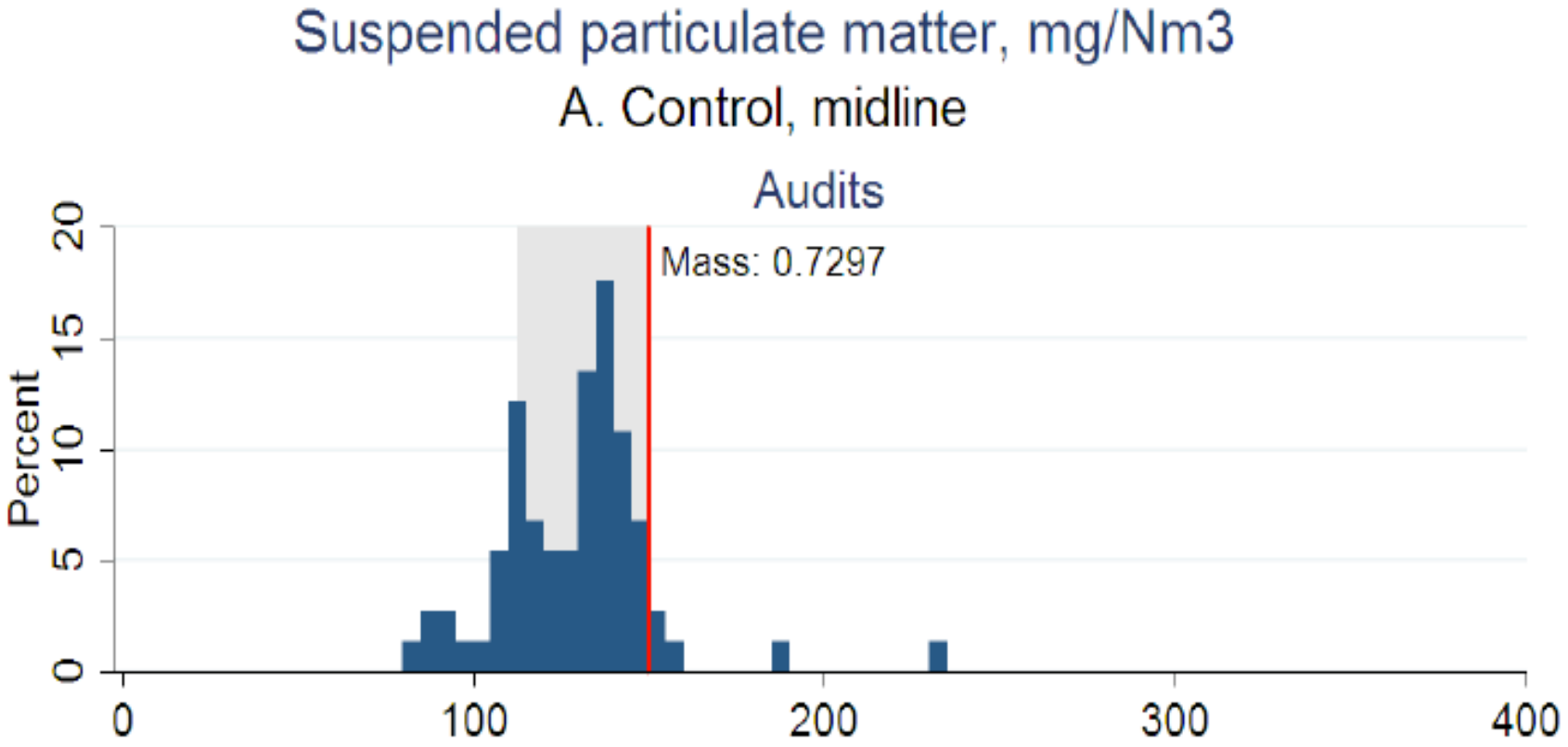
Figure : Control: Audit Readings for Suspended Particulate Matter (SPM)



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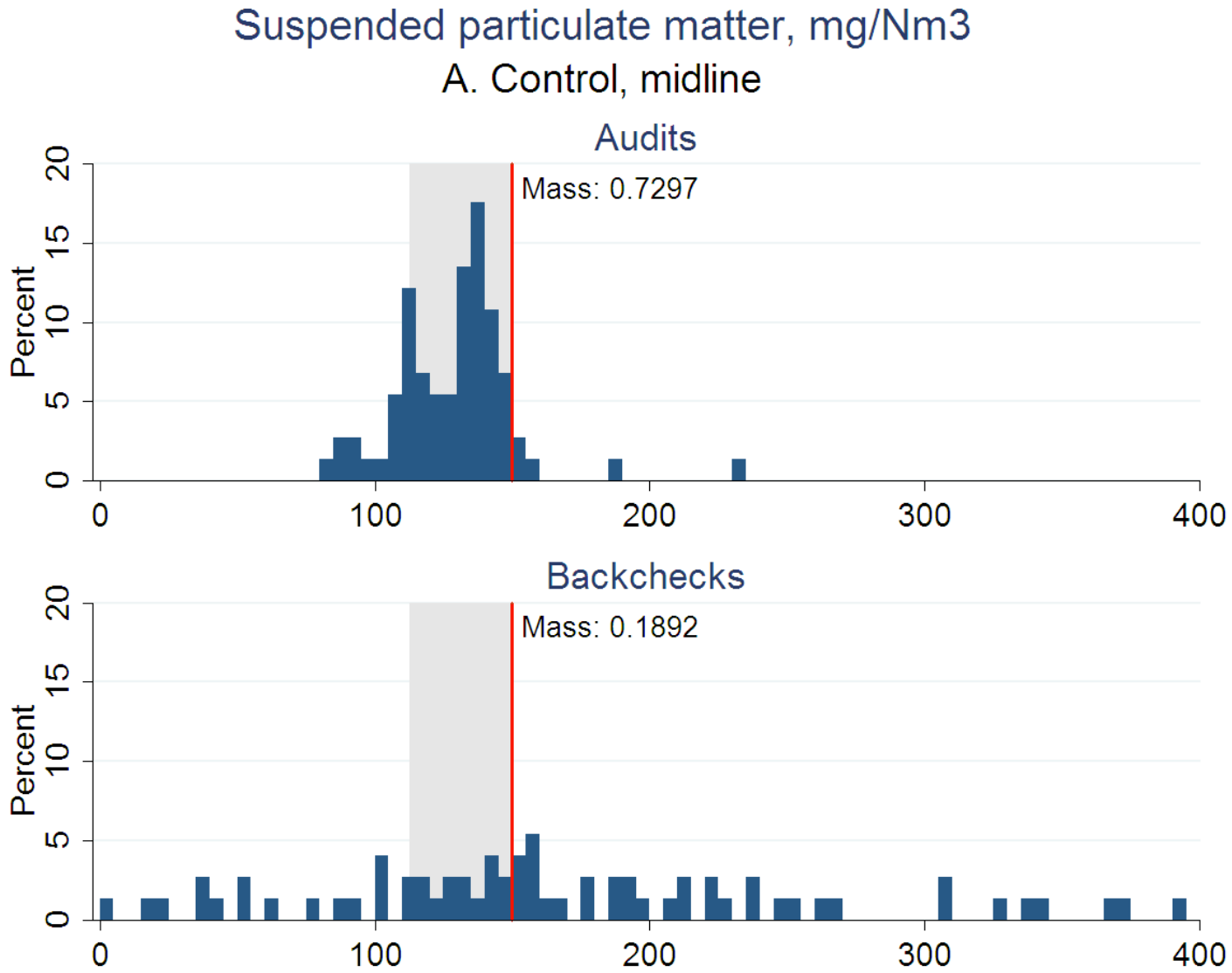

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2. Treatment caused the auditors to become more truthful (even when auditors operating in both markets simultaneously).

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Figure : Audit Readings for Suspended Particulate Matter (SPM)

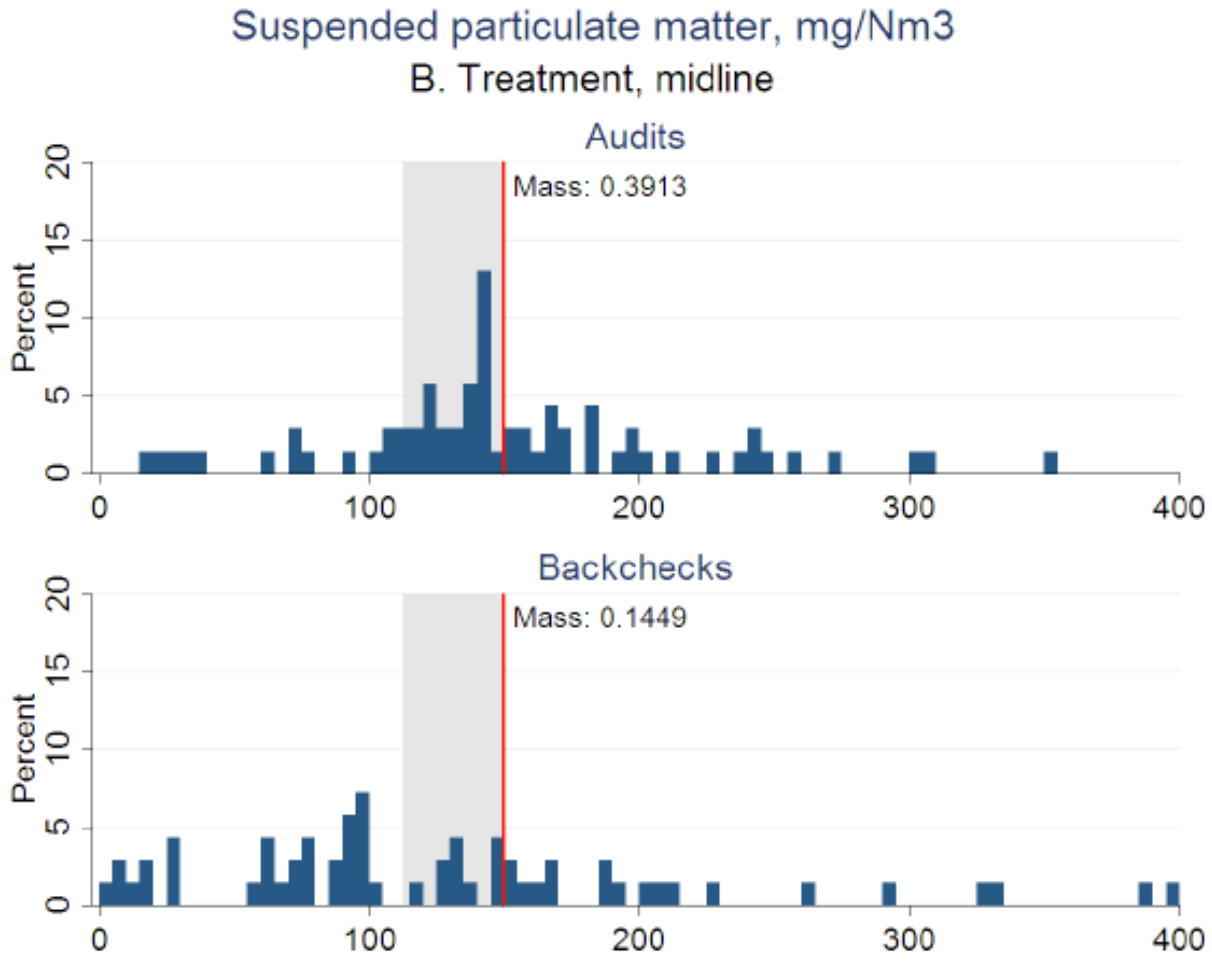
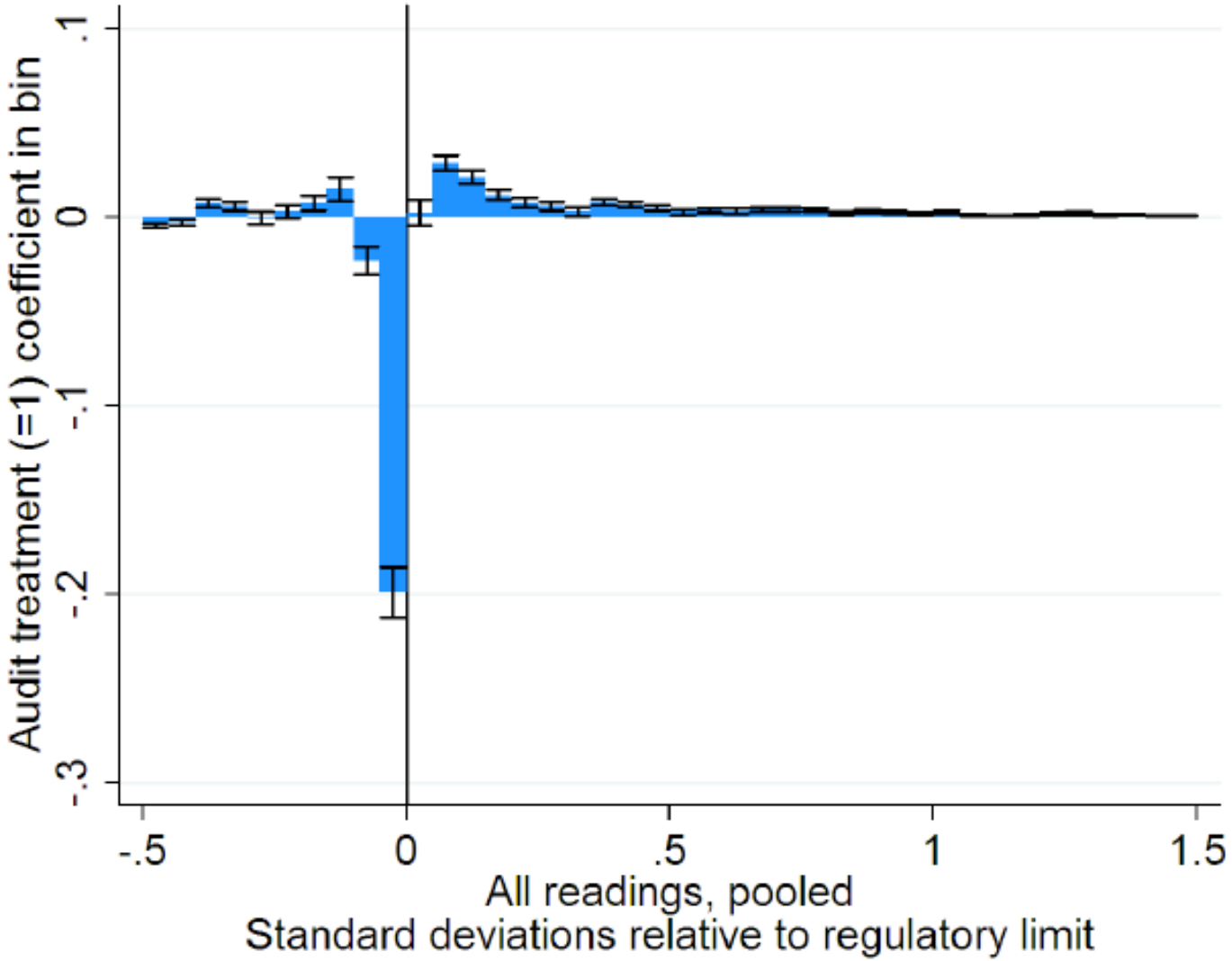


Figure : Audit Treatment Effect in Density Bins, All Pollutants



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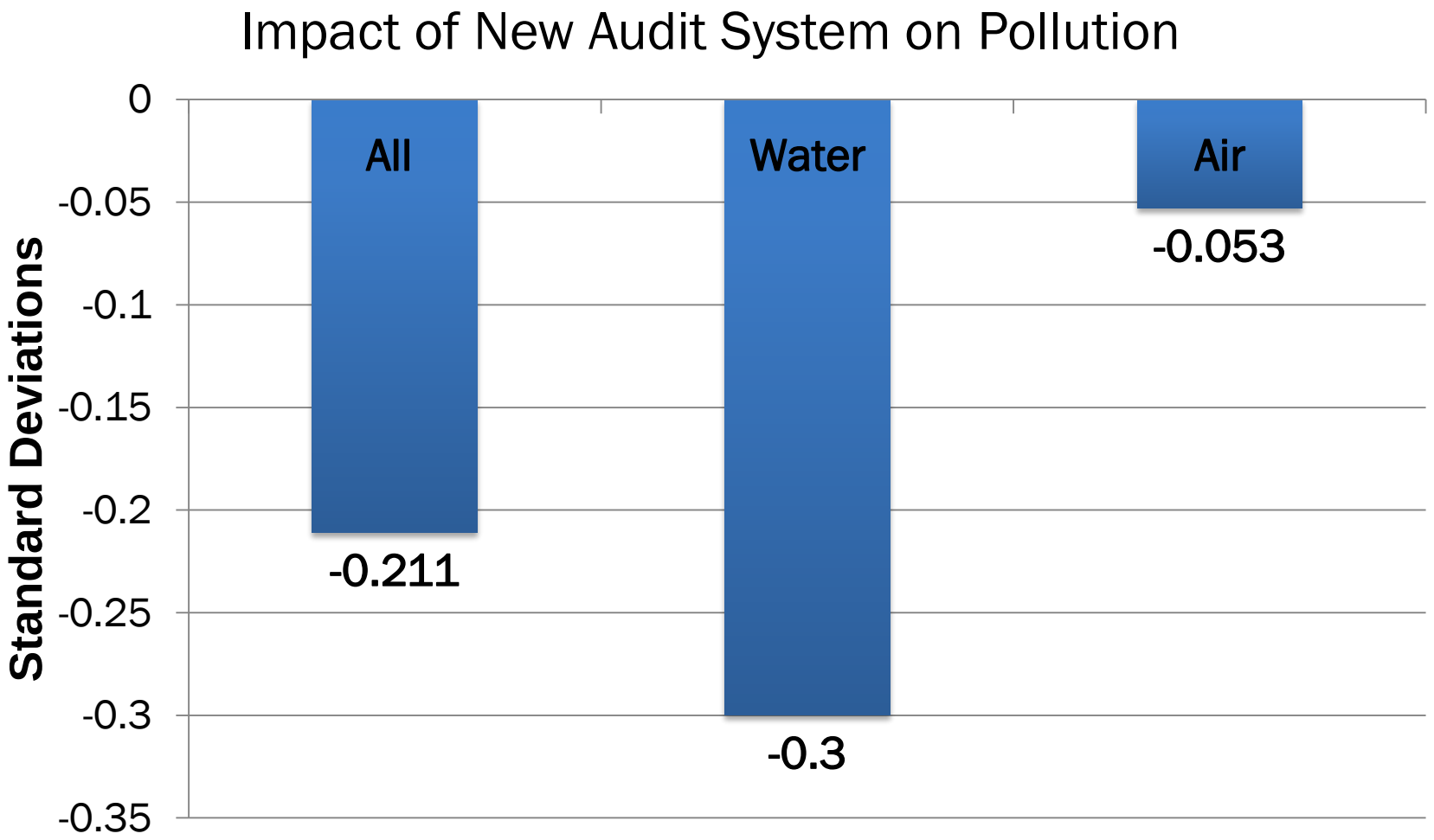
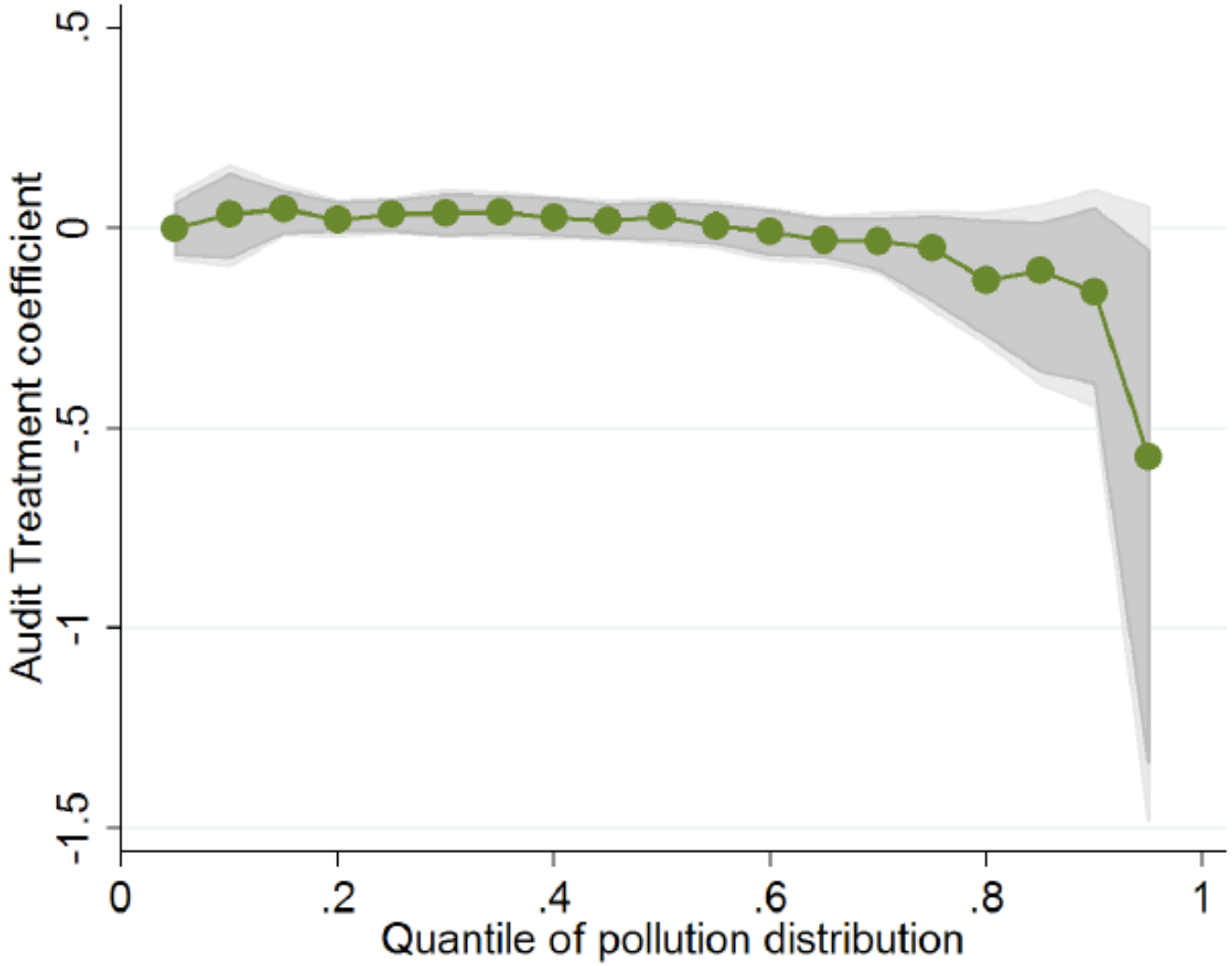


Figure : Quantile Regression Effects of Treatment on Endline Pollution



Reducing Conflict of Interest Has Huge Effect on the Quality of Audit Reporting

Gujarat Pollution Control Board accepted and enforced the tree main recommendations

1. Randomly assign auditors to plant
2. Regulator sets the fee for an audit.
3. Monitor auditors reporting through back-checks

Duflo, Greenstone, Pande and Ryan, 2014

MEASURING THE IMPACT OF MORE FREQUENT COMPLIANCE INSPECTIONS

Description of Inspections

Inspection gathers information

- Staff engineers and scientists visit plant, observe and sample water and air emissions
- Record findings in Inspection Report that goes in the plant's file
- Lab analyzes samples and records pollution readings
- Report received by regional officer who decides further action

Reasons for Inspection and Actions

Based on inspection reports, officers decide whether to act:

May cite plant for violation, request explanation, threaten plant with closure, mandate installation of equipment, or require posting of a bond

Regulation has two spines:

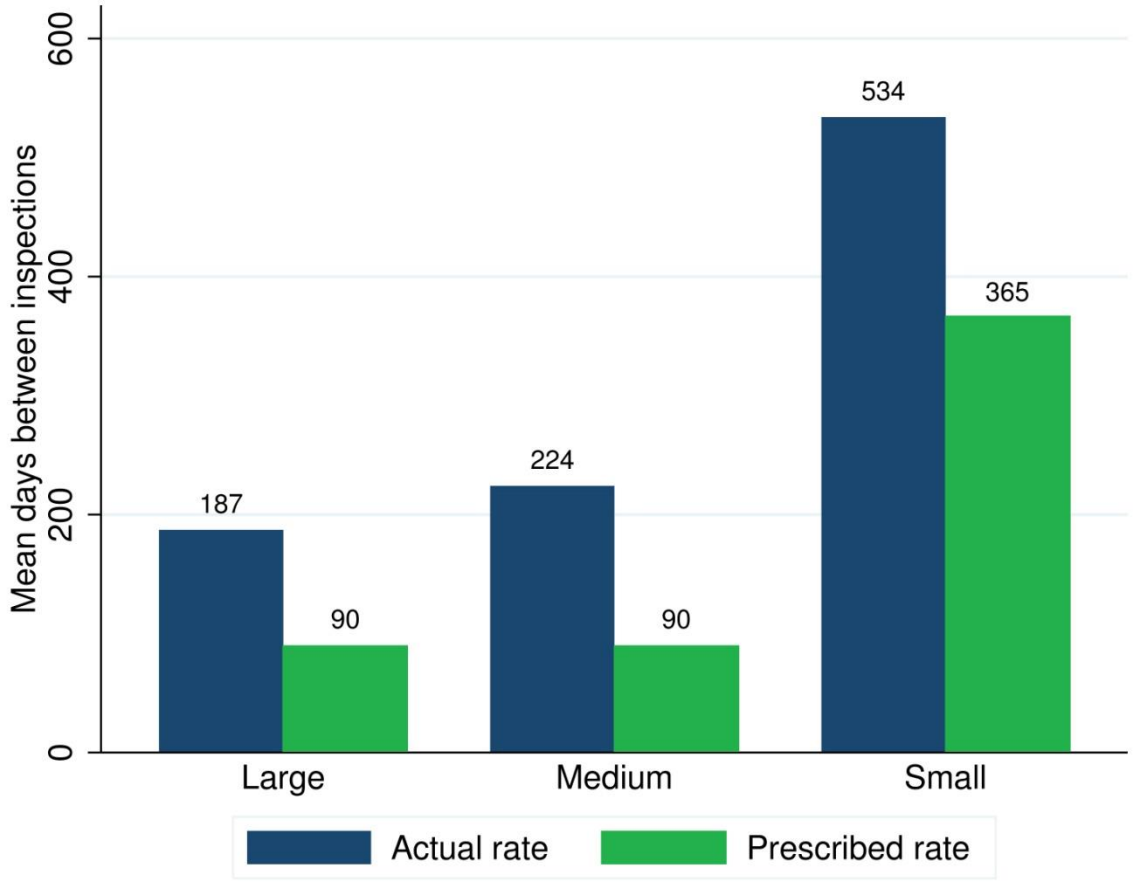
1. Forced closure: regulatory action through utility disconnections
2. Court route also possible but seldom used

Main reasons:

1. *Routine*. More or less randomly, based on time since last inspection but at discretion of Regional Officer (35%)
2. *Licensing*. To check terms of plant's application for license (30%)
3. *Follow-up*. To confirm prior results or orders (24%)

Plants Not Inspected at Prescribed Rate

Figure: Inspection Rates for Plants in the "Red Category"



Experimental Design to Increase Inspection Frequency

Random half of plants assigned to be inspected more often

- All treatment plants assigned in initial quarter, 2/3 chance of assignment to revisit in subsequent quarters (reset after 4)
- Ran from about 2009 Q3 - 2011 Q1 inclusive.

Data sources

1. Administrative data

- Plant characteristics of relevance to regulator (at baseline)
- Complete records of interactions between regulator and plants before, during and after experiment

2. Endline survey

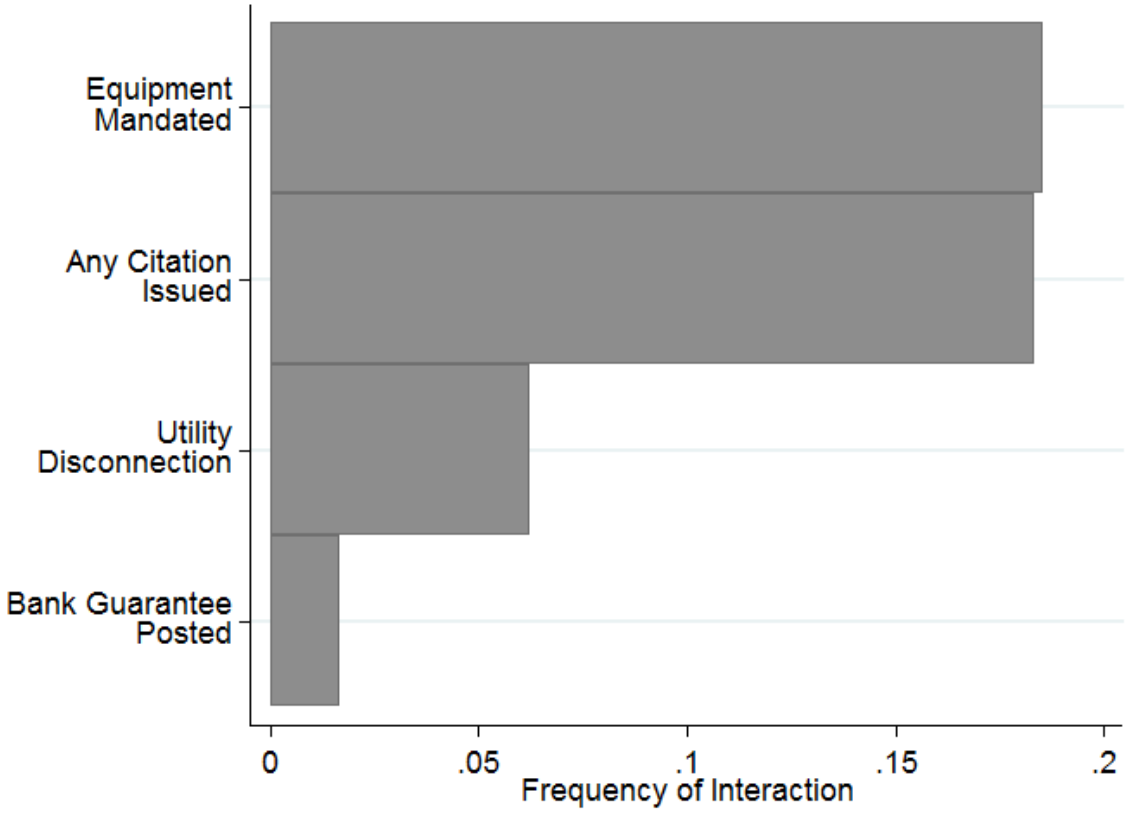
- April through July of 2011, soon after inspection treatment ends.
- Pollution sampling in the survey was conducted by independent agencies, mainly university engineering departments.
- Also survey on abatement investment and other aspects of plant.

Research questions

- Experimental estimates: Impact of the treatment on inspections, penalties, and compliance.
- Conditional probabilities: When and how do the regulator and the firm chose to act and comply?
- Dynamic structural estimate: estimate the costs of regulation to plant using dynamic interactions between the plants and the regulator

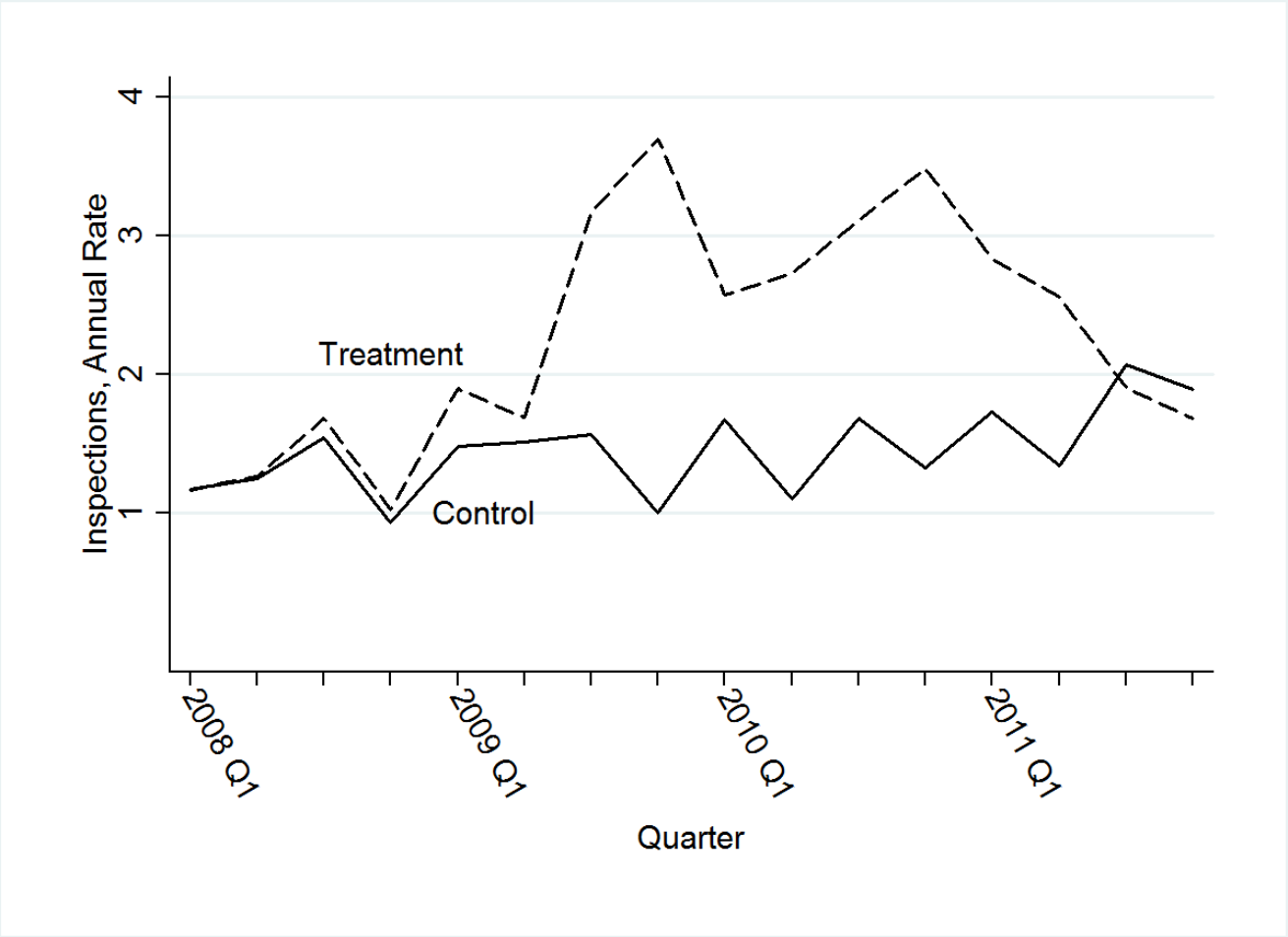
Regulation Looks Costly to Plants

Figure: Number of Interactions in the year before the start of the treatment (Control Plants Only)



Treatment Plants Inspected More During Experiment

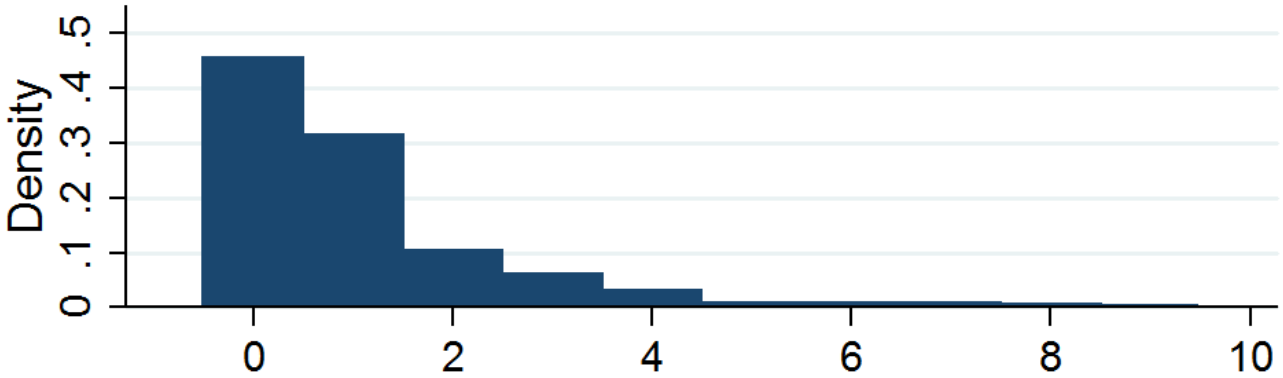
Figure: Inspections per Plant, Treatment and Control



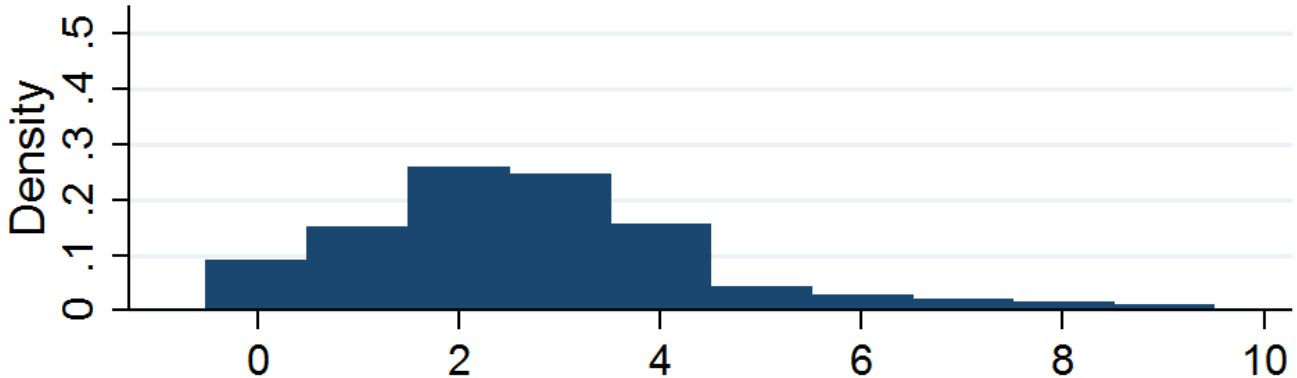
Inspection Mass Shifted Up from Low Levels

Figure: Annualized Inspections, by Treatment Status

(a) Control Plants



(b) Treatment Plants



Regulatory Interactions During Experiment

Figure: Number of Interactions (Control Plants only)

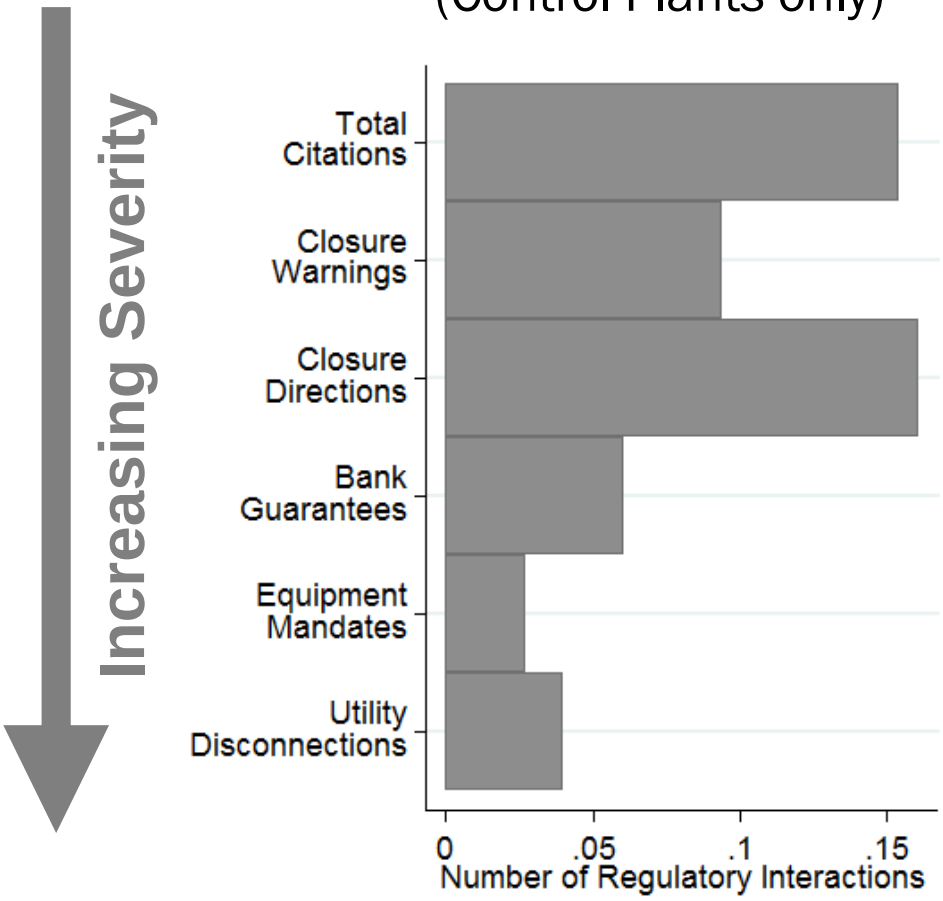
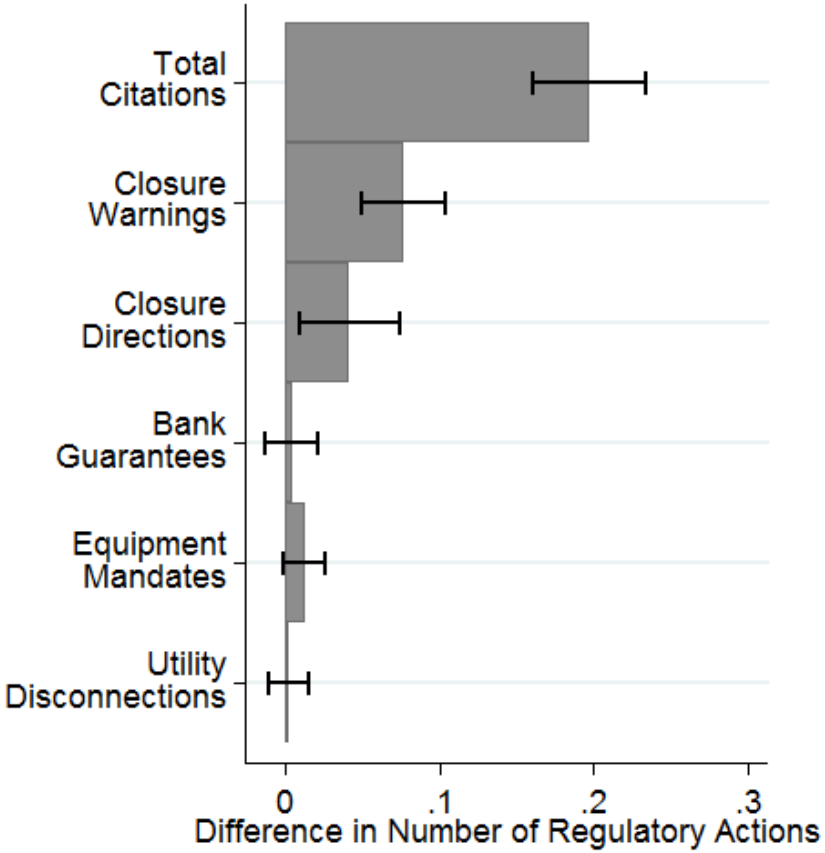
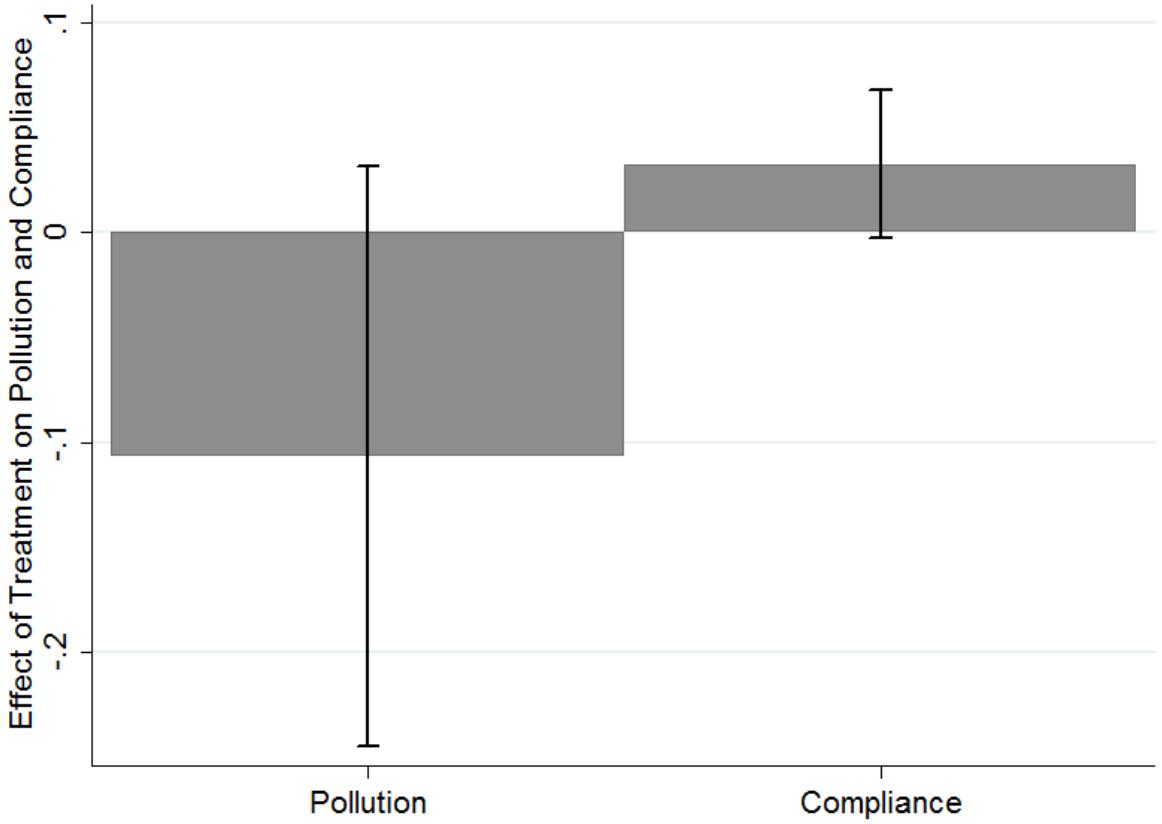


Figure: Difference Between Treatment and Control Groups



Firm Responses

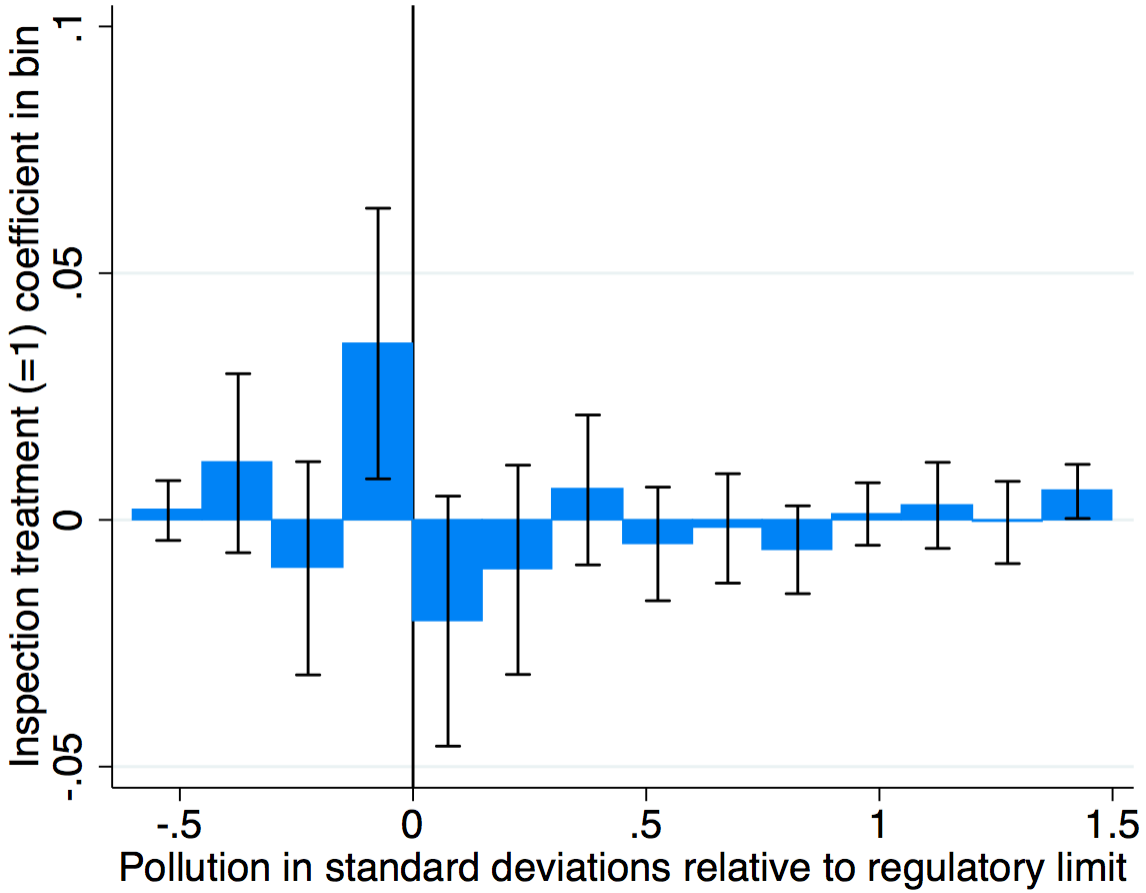
Figure: Effect of Inspection Treatment on Pollution and Compliance



Graph shows point estimates with 90% confidence interval

Pollution on Inspection Treatment

Figure: Inspection Treatment on Density Bins, All Pollutants



Treatment induces (somewhat) higher pollution abatement costs

	Capital Cost, Annual		Maintenance Cost, Annual	
	(1)	(2)	(3)	(4)
Medium size industry (=1)	11.10**	11.01**	0.418	0.482
	(4.525)	(4.514)	(0.672)	(0.668)
Coal or lignite as fuel (=1)	-0.0265	-0.0526	0.136	0.164
	(1.619)	(1.612)	(0.525)	(0.520)
Waste water generated > 100 kl/day (=1)	10.18***	10.17***	0.146	0.152
	(2.102)	(2.108)	(0.493)	(0.491)
Inspection treatment (=1)		-1.079		0.821*
		(1.102)		(0.480)
Constant	2.319***	2.893***	0.524	0.0850
	(0.503)	(0.832)	(0.404)	(0.259)
Mean	6.110	6.110	0.669	0.669
Observations	791	791	791	791

Cost in USD 1000s. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Summary of Results

1. Treatment carried out

- Treatment plants inspected 2 more times per year on a base of 1.4

2. More regulation

- Cited for violations of pollution standards and threatened with closure more often
- Treatment plants not subject to more *costly* penalties

3. Measurable, but weak, compliance response

- Treatment plants increase compliance by 0.0366 (se 0.0213, p-value 0.087) percentage points, driven by air pollution, on base of 61%
- Treatment plants reduce pollution, coefficient -0.110 (se 0.0838, p-value 0.19) standard deviations, on base of 0.682

WHY ? This is where the rich administrative data and structural model can help us.

Possible regulator's action

Action	Document	Description
Inspect	Inspection report	Analysis of air and water samples; report on plant characteristics.
Warn	Letter	Non-threatening letter ordering improvement in pollutant concentrations.
	Citation	Threatening letter demanding explanation for high pollution levels, missing permit to operate, or missing pollution abatement equipment.
	Closure Notice	Notice that the plant will be ordered to close in 15 days if the plant does not take action to improve pollution.
Punish	Closure Direction	Order to close immediately.
	Utility notice	Notice that water or electricity has been disconnected.
Accept	Revocation of Closure Direction	Permission to start operation.
	None	No further GPCB action.

Possible plant's action

Action	Document	Description
Ignore	None	Implied by consecutive GPCB actions.
	Letter	Official letter of protestation to GPCB. Challenges evidence or directives.
Comply	Equipment installed	Notice that pollution abatement equipment has been installed.
	Process installed	Notice that a process has been installed.
	Bond posted	Letter from bank to GPCB explaining that the firm has posted a guarantee against future misconduct.

Link documents into chain of regulatory action and firm reaction

- Observe 9,624 actions overall
- Group them into 7,423 chains, starting with an inspection by the regulator
- Non-singleton chains linked together based on explicit references (56%) and date ordering, imputation or inference (44%)
- Chain ends with regulator accepting the plant's compliance

Model

- Plants are characterized by a distribution of pollution levels
- They can chose to abate by running an equipment at cost c
- Regulator does not observe the running cost (which are different then the cost of installing capital)
- Running the equipment may affect the probability of inspection, and the cost of the inspection if it occurs

What does the experiment do?

- We assume the experiment does not affect what happens during and after an inspection (this is the nature of our situation)
- However it affects the *actual* probability of an inspection as a function of the state
- And also the *perceived* probability of inspection (something we see in the data)

Goal: estimate a model of firm and plant interaction

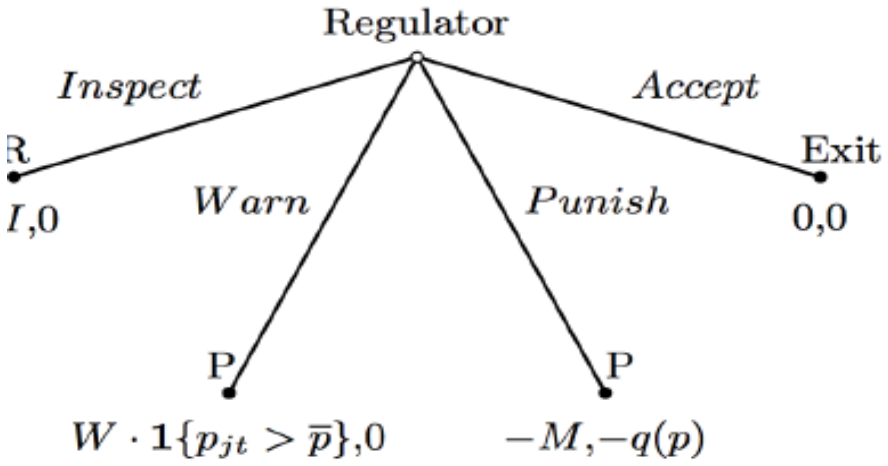
- Estimate the following model backwards:

1. How does the plant react to increased inspections?
2. What happens after a firm is inspected.
    1. Ultimate goal of the structural exercise here: what is the cost of a visit by the regulator?

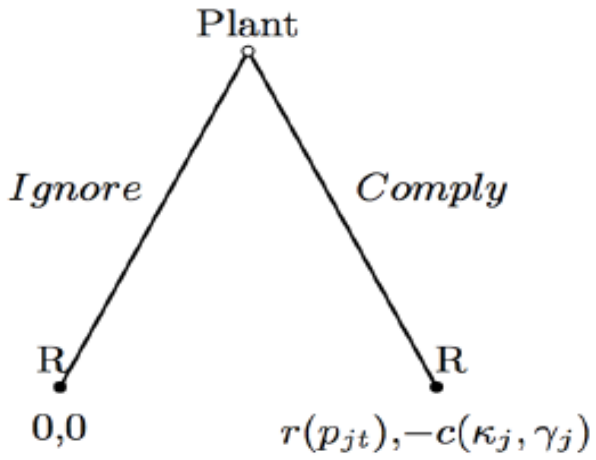
The dynamic game between the plant and the regulator

1. Regulator moves first and inspect, gets pollution reading p
2. Plant moves next
3. Players alternate actions as below

Figure 6 : Actions of the Players at Each Node



A. Actions of the Regulator



B. Actions of the Plant

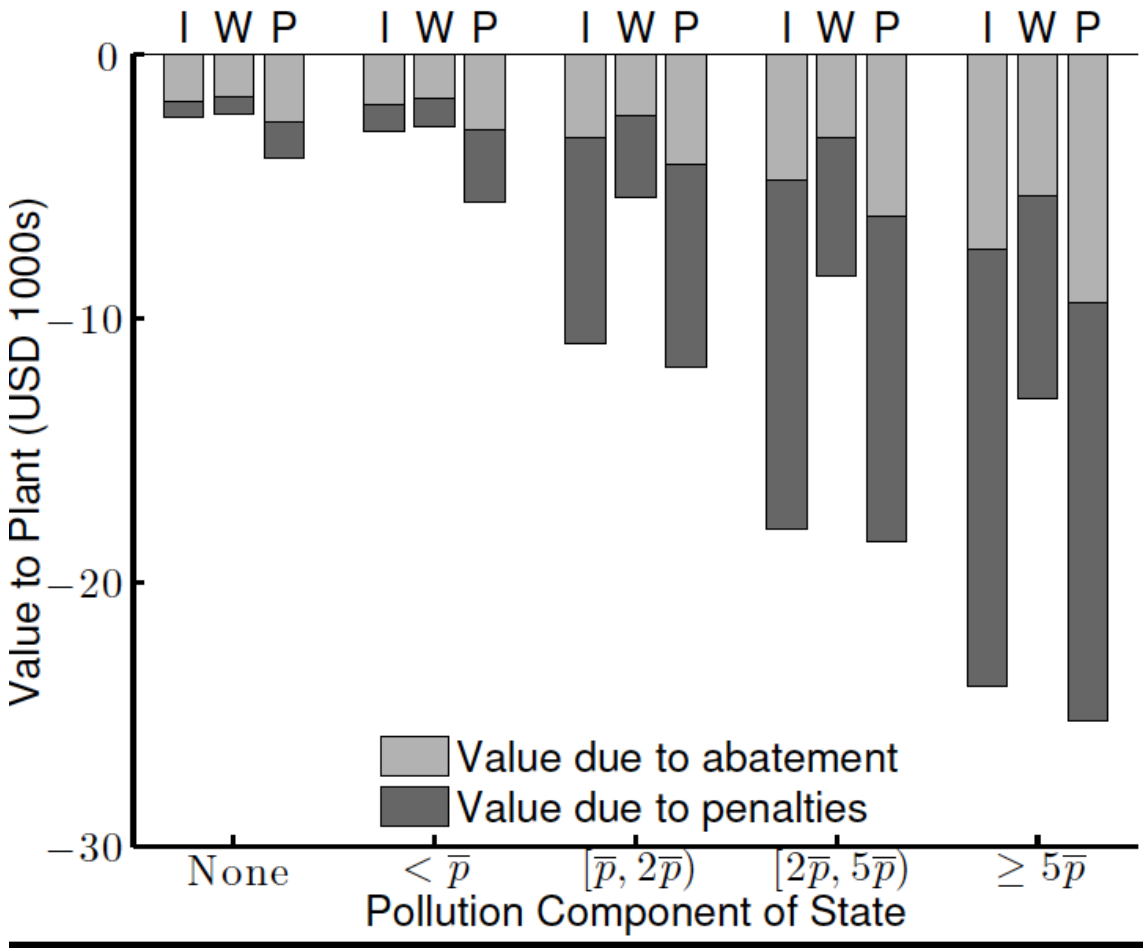
Table 4 : Structure of Chained Regulator-Plant Interactions

	Regulatory Action				Plant Action			
	Inspect	Warn	Punish	Accept	Ignore	Comply	N	% left
1	100.0	0.0	0.0	0.0			7423	100.0
2					99.6	0.4	7423	
3	1.0	9.5	2.2	87.3			7423	100.0
4					92.8	7.2	941	
5	23.3	4.8	5.3	66.6			941	12.7
6					91.1	8.9	314	
7	18.8	11.8	9.9	59.6			314	4.2
8					83.5	16.5	127	
9	21.3	5.5	18.1	55.1			127	1.7
10					82.5	17.5	57	
11	26.3	3.5	10.5	59.6			57	0.8
12					87.0	13.0	23	
13	26.1	4.3	8.7	60.9			23	0.3
14					77.8	22.2	9	
15+	16.7	8.3	0.0	75.0	100.0	0.0	9	0.1
Total	31.0	3.2	1.1	29.4	34.6	0.6	25217	

Estimation

- We are after the value of a visit for a firm
- Estimation proceeds in 6 steps:
  1. Technology: how expensive is it to abate?
  2. State: what is the state of the world
  3. State transition: how do we move from state to state
  4. Policy function: what do the regulators and the plant do in response to the state
  5. Value function: How much do the players value state
  6. Likelihood: putting it all together

Cost of regulator's action



Regulatory penalty significant but not frequent…

- Mean plant annual sale USD 2.9 Million
- Mean penalty 24.5 days closure
- With 20% profit margin this mean penalty cost is USD 38,800

- Expected value of penalty is lower because often there is no punishment…
- This is particularly true in the treatment group where many firms drop out of the conveyor belt because they are not targeted to be high polluters.

Lower value of the treatment inspection

Table 7 : Cost of Environmental Regulation to Plants Per Inspection (USD 1000s)

	Treatment (1)	Control (2)	Difference (3)
Total cost per inspection	1.34	2.65	-1.31***
	[0.18]	[0.44]	(0.02)
Regulatory penalty cost	0.62	0.96	-0.34***
	[0.12]	[0.24]	(0.01)
Number of penalties	0.030	0.050	-0.020***
	[0.00]	[0.01]	(0.00)
Abatement equipment cost	0.71	1.69	-0.97***
	[0.14]	[0.39]	(0.02)
Number of installations	0.066	0.097	-0.032***
	[0.01]	[0.02]	(0.00)
Observations	480	480	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Back to step 1

- We see that treatment plant run their equipment a bit more
- Extra cost in running equipment is roughly equal average to cost of a visit in T
- Basically, if plants find an easy way out of running into problems, they do it:
  - This may not address the real problem of pollution in Indian city which is at much higher thresholds.

Still to come….

- Counterfactuals. e.g. Suppose that, given a fixed budget, GPCB used all their resources randomly, and firms knew the policy change.
- Mildly polluting firms now know that they may be inspected, they have some incentive to abate if cheap
- Highly polluting firms may in fact be inspected LESS often which may result in increase in pollution at the top.

Conclusion

- The audit system can be reformed to work better. It does not mean a 3d party audit system was a good idea in the first place (we do not know that).
- The inspection system as it is works much better than frequently suggested.
  - Modi's idea to randomly assign inspections seem to be going the wrong direction… at least for his own states.
- Cost and benefits of environmental regulation:
  - A cost benefit of audit reform suggests it is worth it
  - However, it is worth pointing out that most of the cost of inspections to firms come from closure, NOT equipment. This is pure deadweight loss.
  - This would be an avenue for further reform.
- All of this will be come very pertinent if and when there is an effort to regulate climate change.