Evidence Based Environmental Policy: From Clean Air Today to Longer Lives Tomorrow

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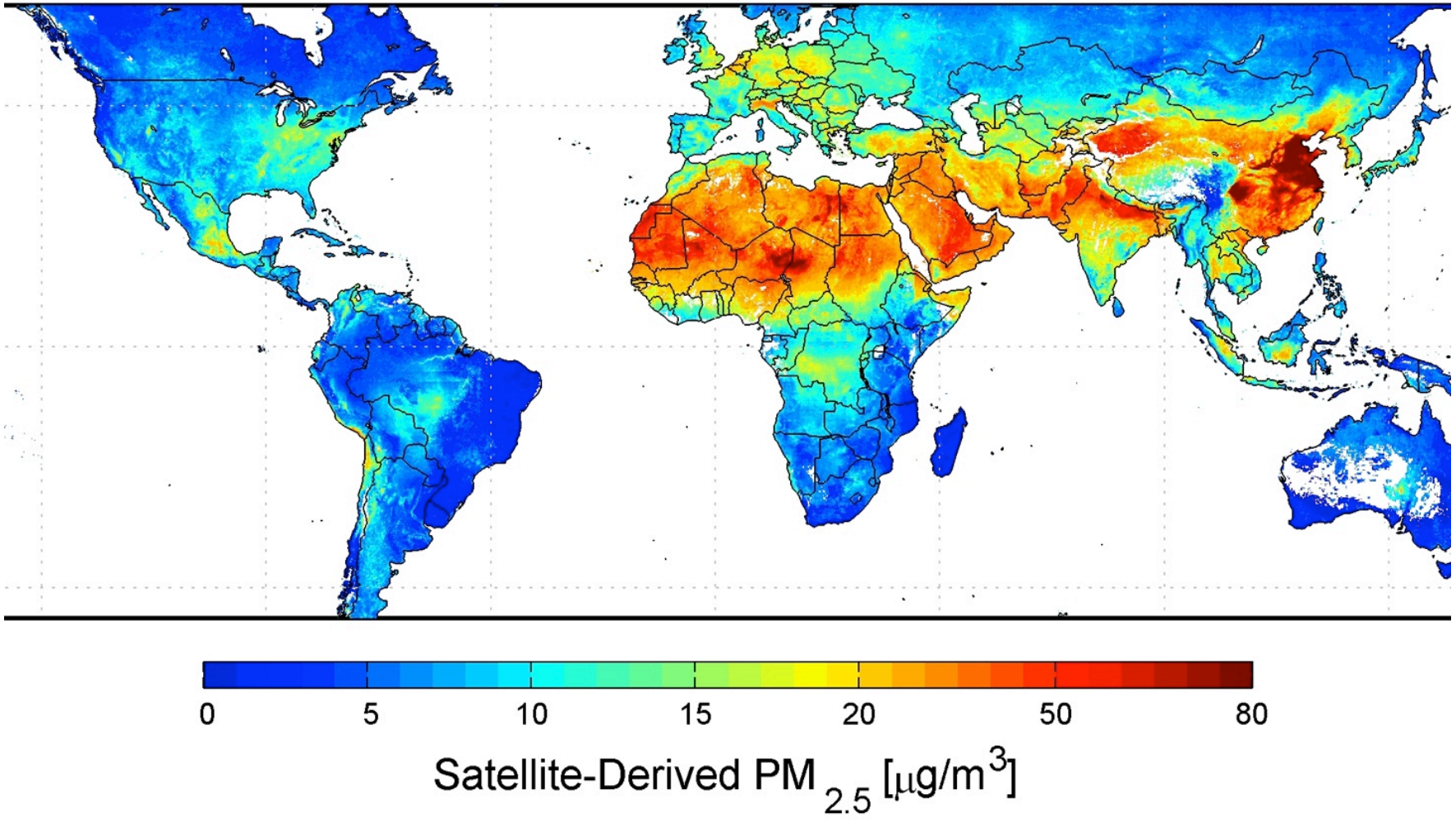
Evidence based environment policy

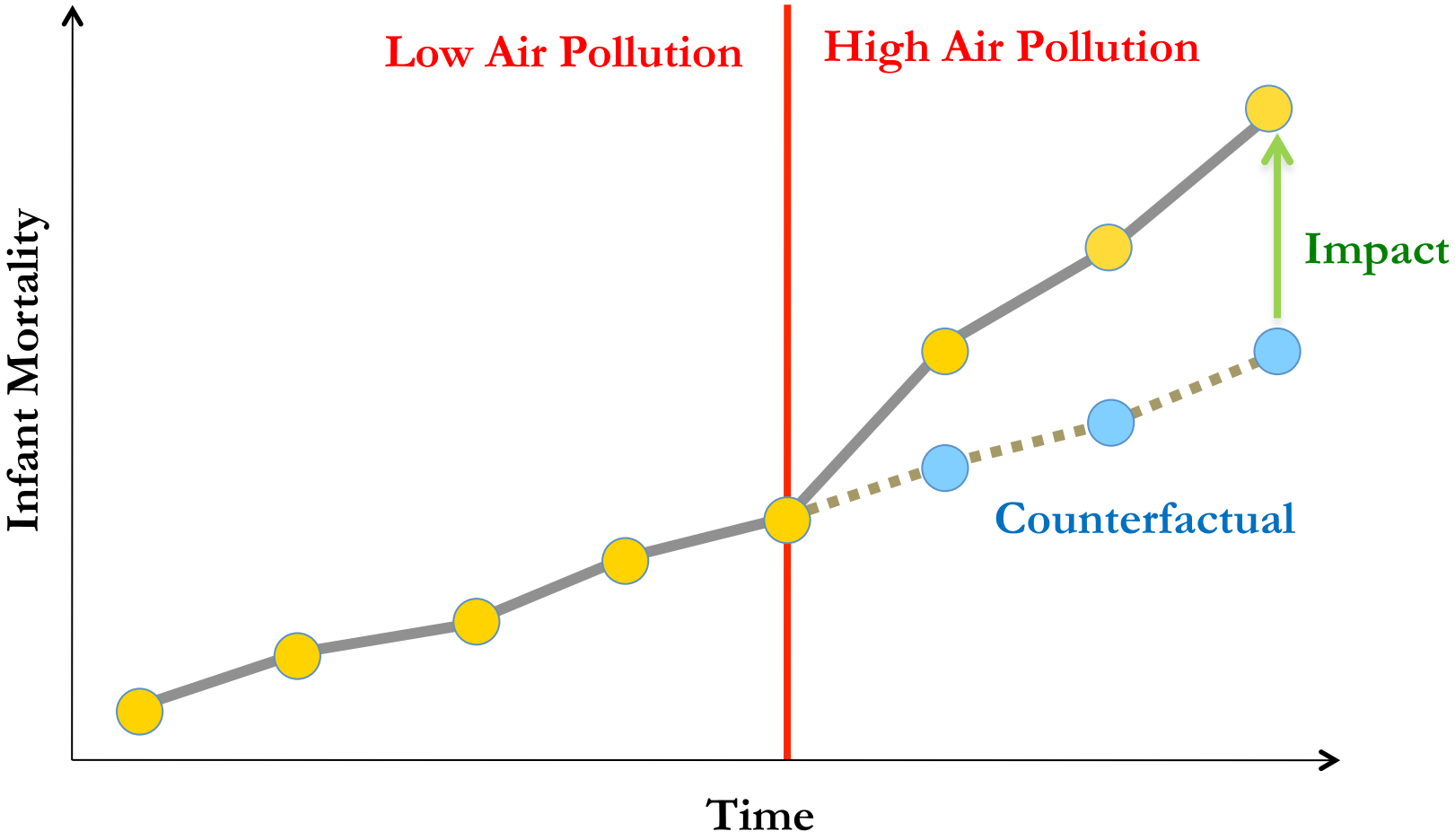
- Measuring environmental change: local (e.g pollution) and global (climate change)
- Identifying the impacts of environmental variables on socio-economic variables
- Measuring impacts of environmental policy

Outcomes do not look good for India



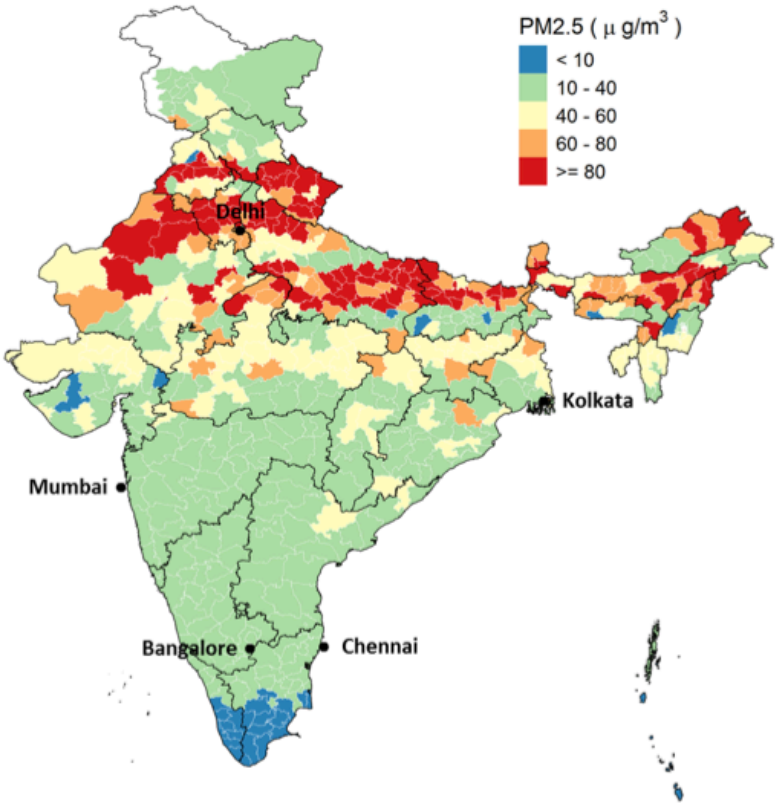
Source: Yale EPI (2012)

Impact of Pollution on Health Outcomes



Experimental and Quasi-Experimental Methods

- Quantifying the impacts of environmental factors requires accurate causal inference
- Difficult because pollution co-varies with many temporally varying factors: urbanization, density, transport, industry
- Impossible to experiment with pollution exposures!
- New approaches seek to identify 'natural experiments' creating quasi-random assignment of pollution levels



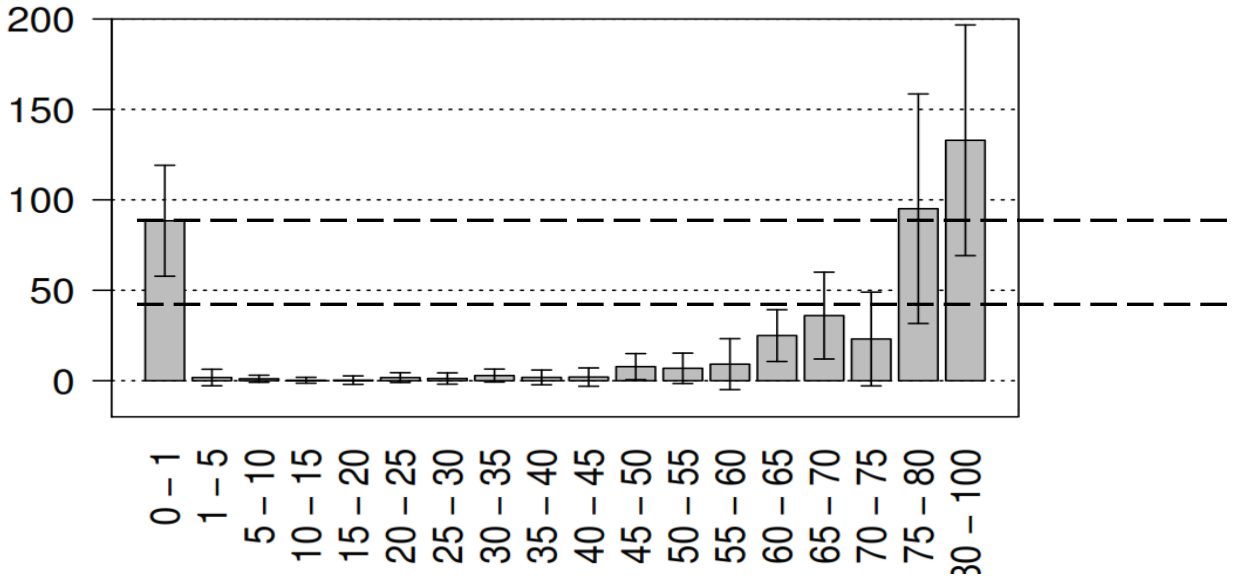
Short-run impacts of fine particulates on mortality

$$m_{it}^{a} = \alpha_i + \gamma_{mon} + \gamma_{yr} + \alpha_i \times q + N_{it}^{a} + P_{it} + X_{it} + \varepsilon_{it}$$

District fixed effects, Month-Year Fixed effects, District-Quarter FE

Population in district-age bin, PM 2.5 concentration measure

Temperature, Rainfall

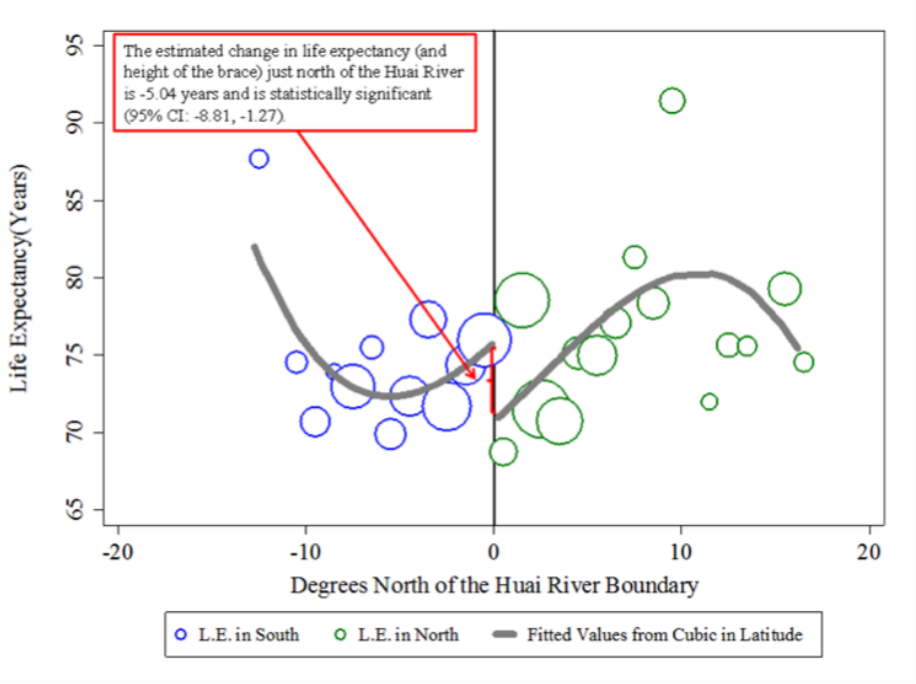


Chay and Greenstone (2003)

Tanaka (2012)

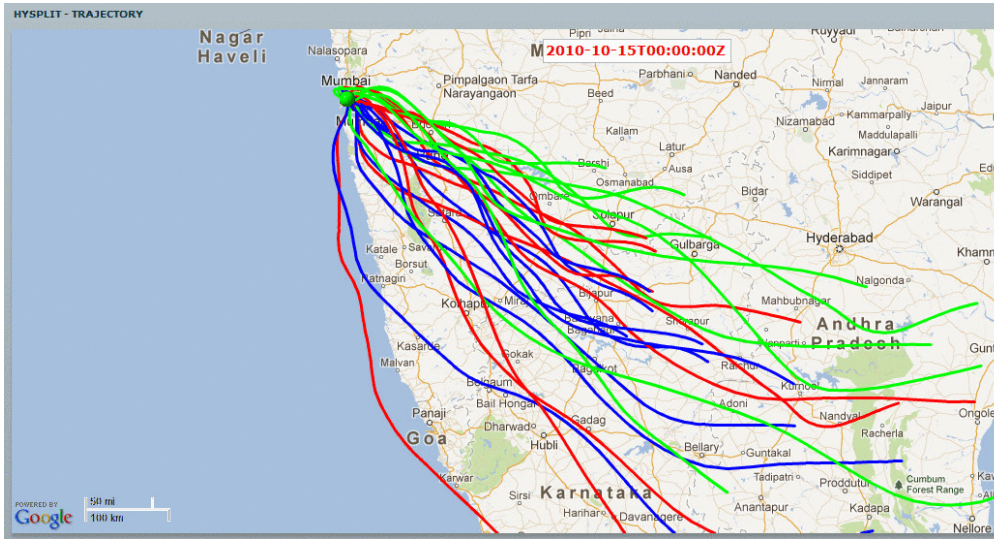
Policy induced quasi-random variation

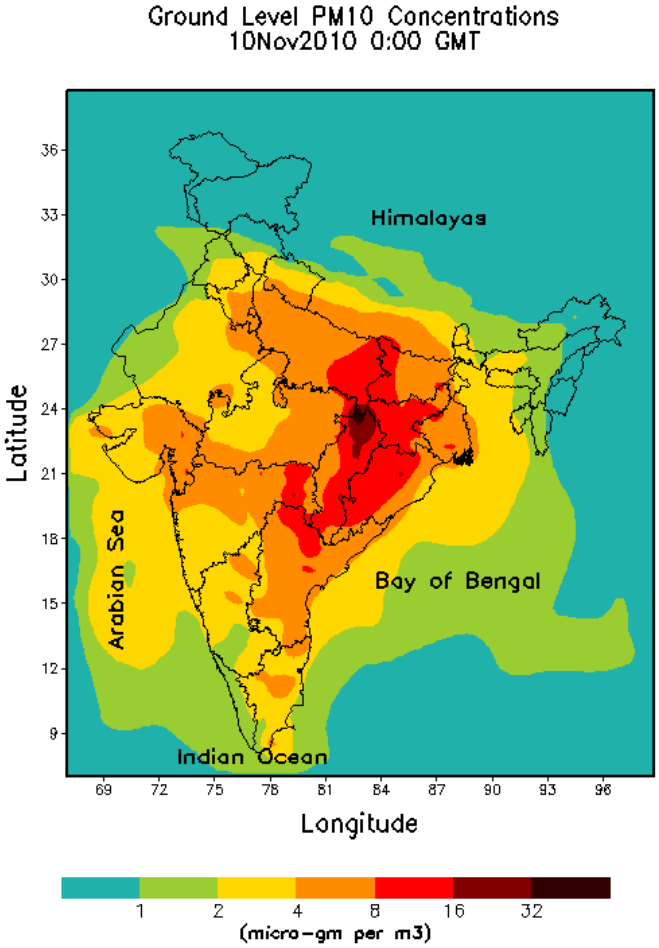
Y. Chen, A. Ebenstein, M. Greenstone, H. Li, "Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy", *Proceedings of the National Academy of Sciences*, 110, 12936-12941 (2013)



Natural quasi-random variation

Sudarshan, Dey and Guttikunda. 2014. "The long run effects of fine particulates on infant mortality in India.(Working Paper)





Source: Guttikunda and Jawahar (2014), UrbanEmissions.Info

Industrial pollution control in India

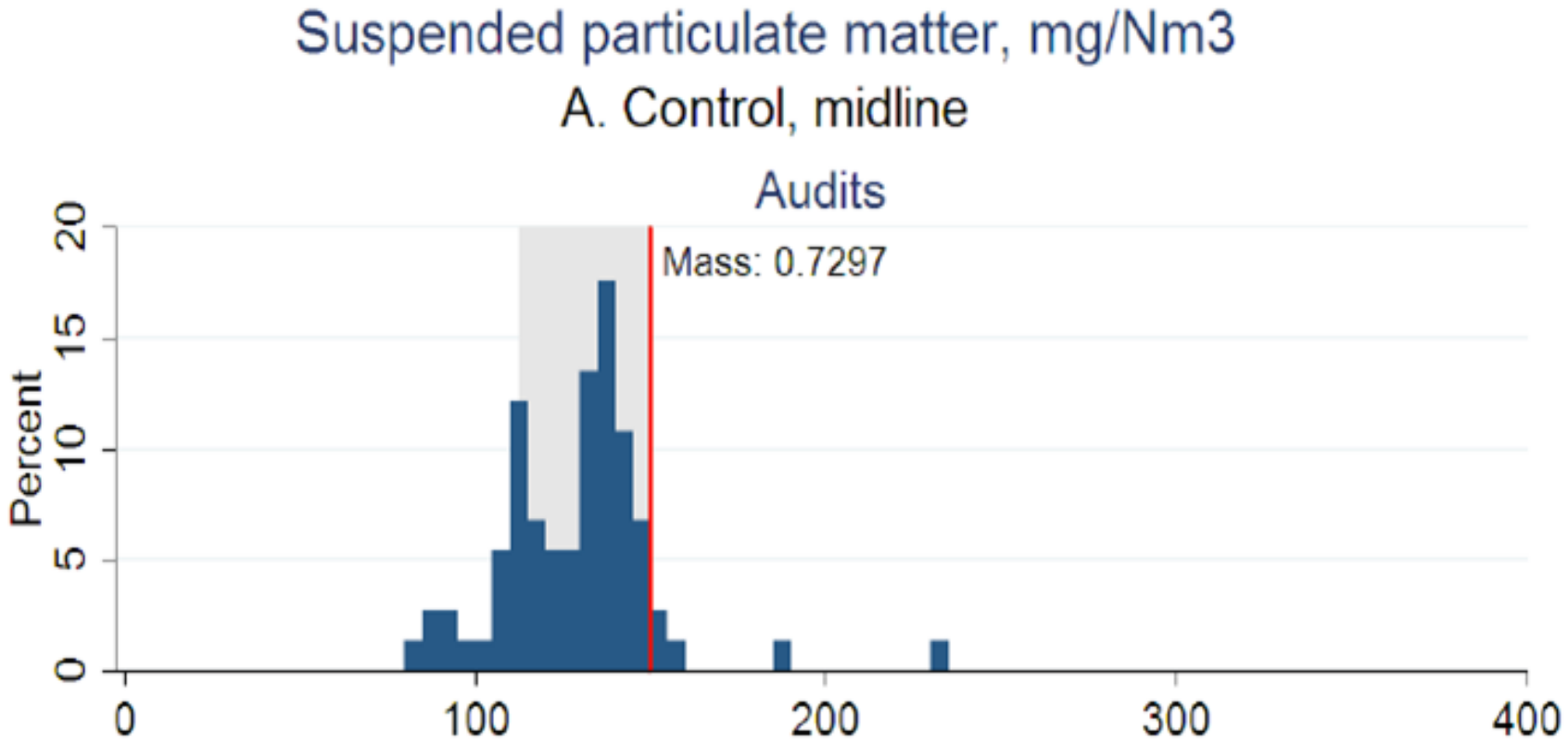
- Environmental regulation based on command and control
  - Equipment mandates (Plants must install specific pollution control equipment)
  - Performance standards (Plants must emit below a fixed concentration limit)
- Air Act of 1981 patterned after the U.S. Clean Air Act
- Command and control is politically easy to sell because it is easy to explain and sounds tough on pollution
- Do these regulations work? Why or why not?

What's wrong with command and control?

- High compliance costs on industry.
- Equipment mandates incentivize installation but not operation.
- High monitoring and regulatory costs
  - India has a fraction of the staff strength and budget of the United States
- Research also shows (Duflo et al 2013) that India's legal penalty provisions are too stringent and inflexible to be credibly enforced

1. Reporting was corrupt under status quo

Control: Audit Readings for Suspended Particulate Matter (SPM)



Source: Duflo et al. 2013. Truth-telling by Third-Party Auditors and the Response of Polluting Firms: Experimental Evidence from India. Quarterly Journal of Economics

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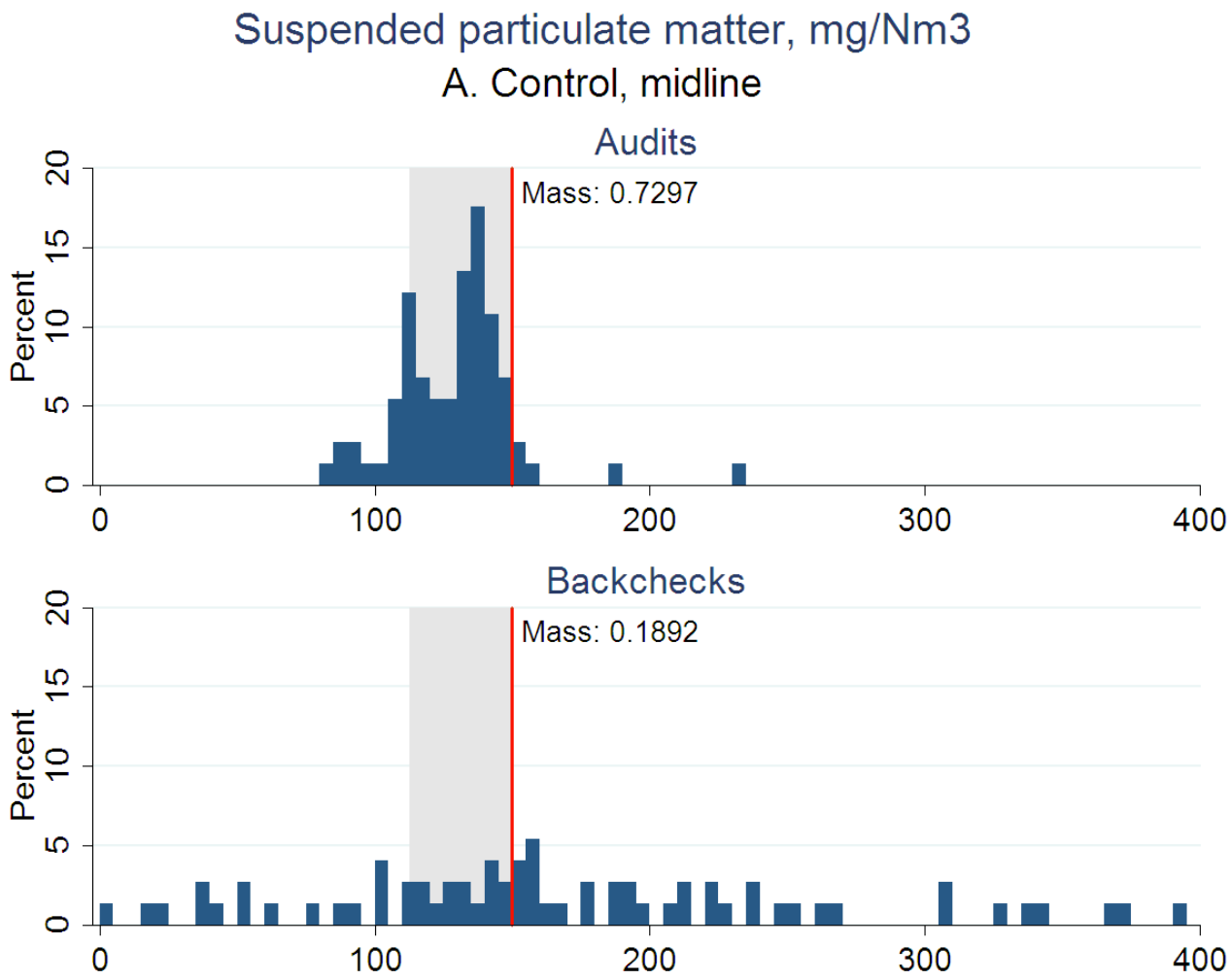

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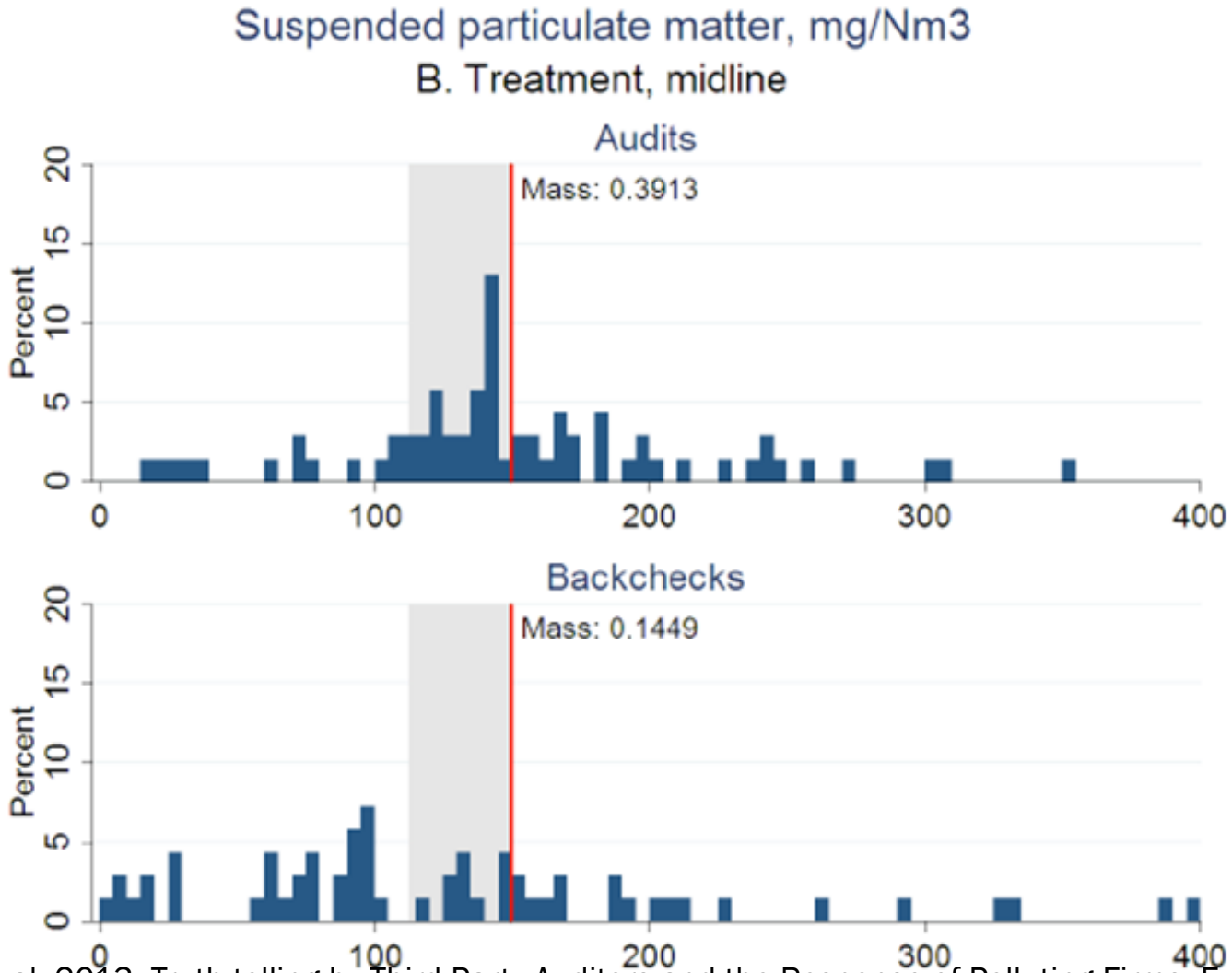
2. Treatment caused auditors to become more truthful



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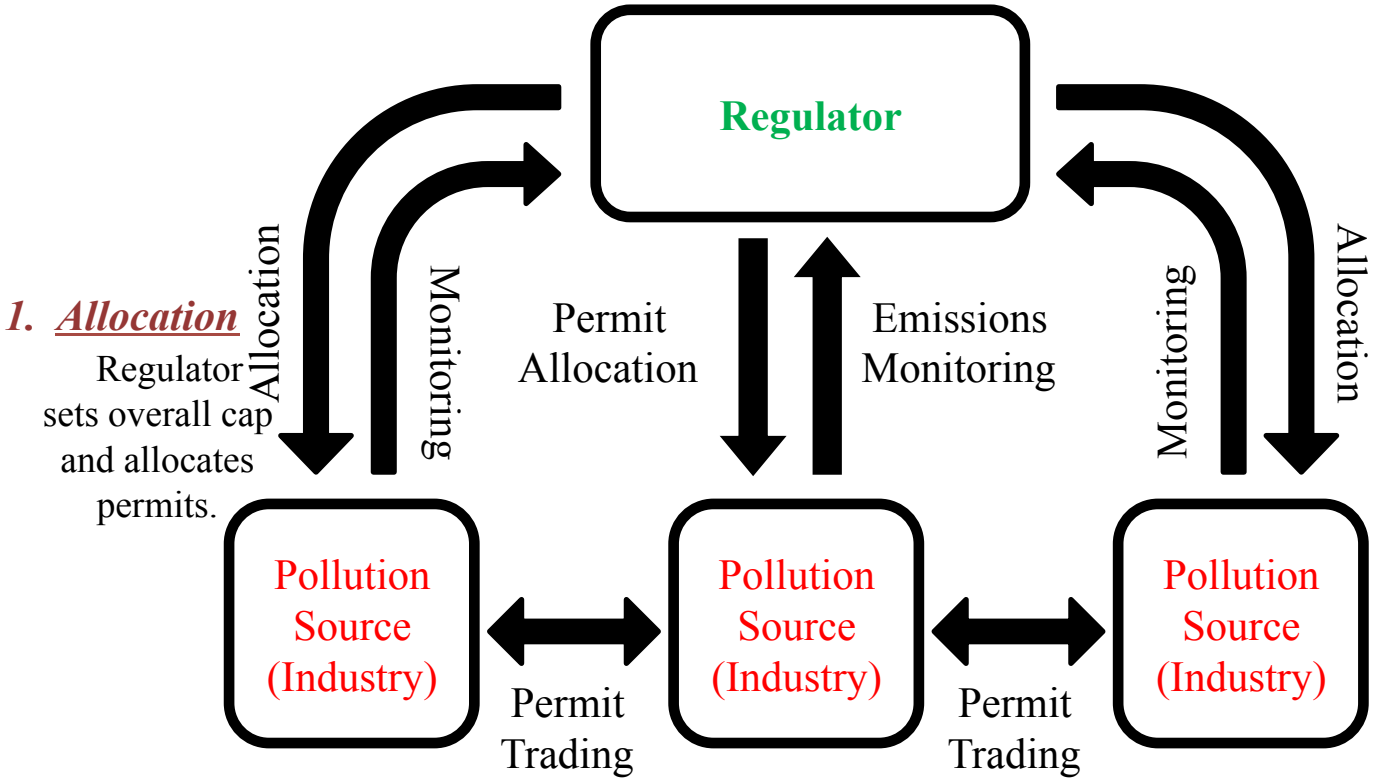
Key Findings

- Misaligned incentives can corrupt monitoring protocols and thus weaken regulatory effectiveness
- Smarter, incentive compatible design of monitoring can significantly improve matters
- GPCB is changing its audit policy in response to this evidence.
- But Gujarat is only state with 3rd Party Audit Programs. Additionally, it is difficult for the regulators to penalize plants because it is hard to identify the violators and the penalties are unwieldy.
- **This points the way to more ambitious solutions**

Unique partnership with Government of India

- **Suggested, designed, and testing new regulatory models for particulates air pollution**
  - Continuous Emissions Monitoring Systems (CEMS) for better pollution monitoring
  - Emissions trading or Cap-and-Trade scheme to lower compliance costs and reduce pollution
- **3 Pilot states covering 1,000 plants**
  - Total population of over 200 million in just these three states and about half of Indian manufacturing output
  - Particulate matter a severe public health problem

What is Emissions Trading?



1. *Allocation*

Regulator sets overall cap and allocates permits.

2. *Trading*

Industry buys more permits or sells excess and adjusts emissions to be below permit holdings.

3. *Monitoring*

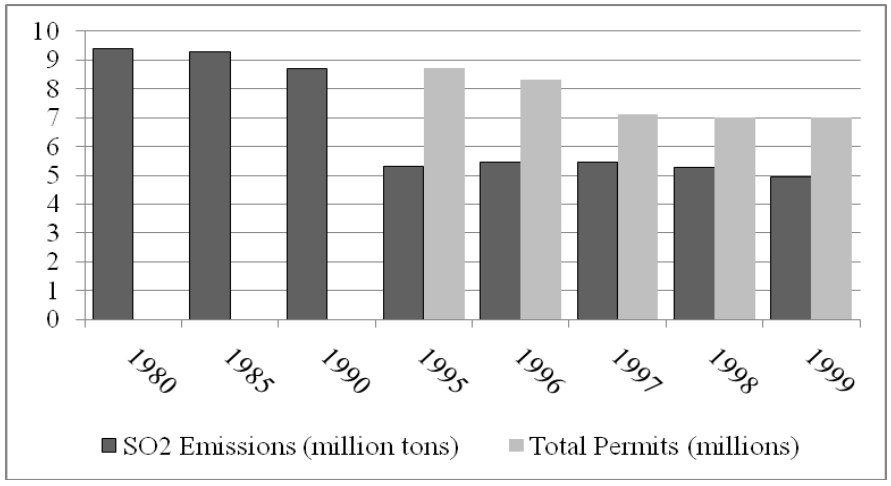
Regulator monitors total emissions of targeted pollutant.

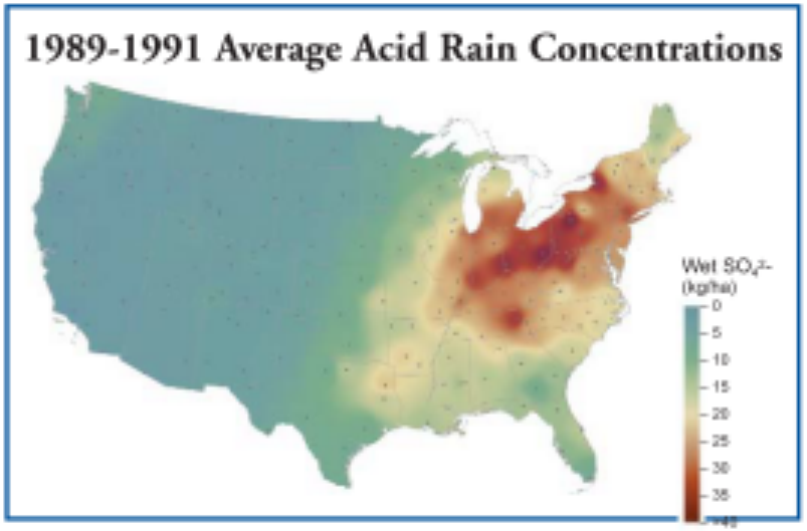
4. *Compliance*

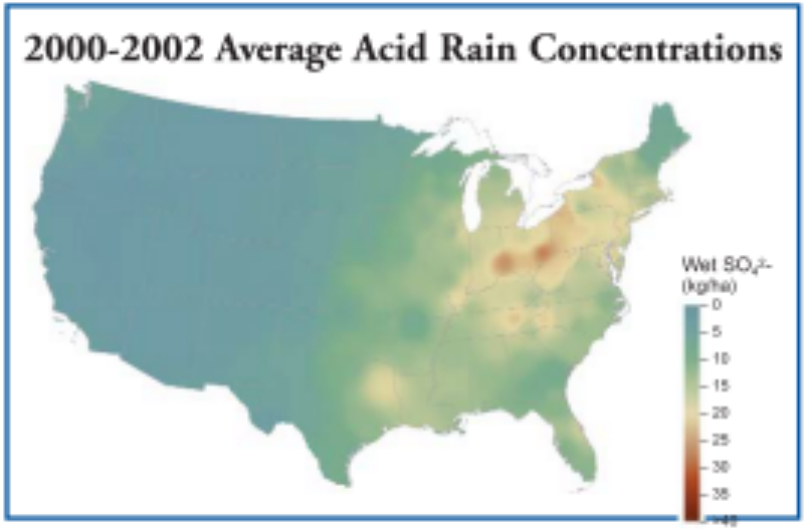
Regulator checks that all sources have enough permits for emissions.

U.S. Acid Rain Program

- In 1995, total emissions **fell** from **8 to 5 million tons**
- Switch to **low-sulfur coal** and using scrubbers to remove SO2 from stack gases
- Estimated **savings** to firms was **$225-$374 million**
- Scrubber efficiency increased from ~75% to ~95%







What is the counterfactual here?

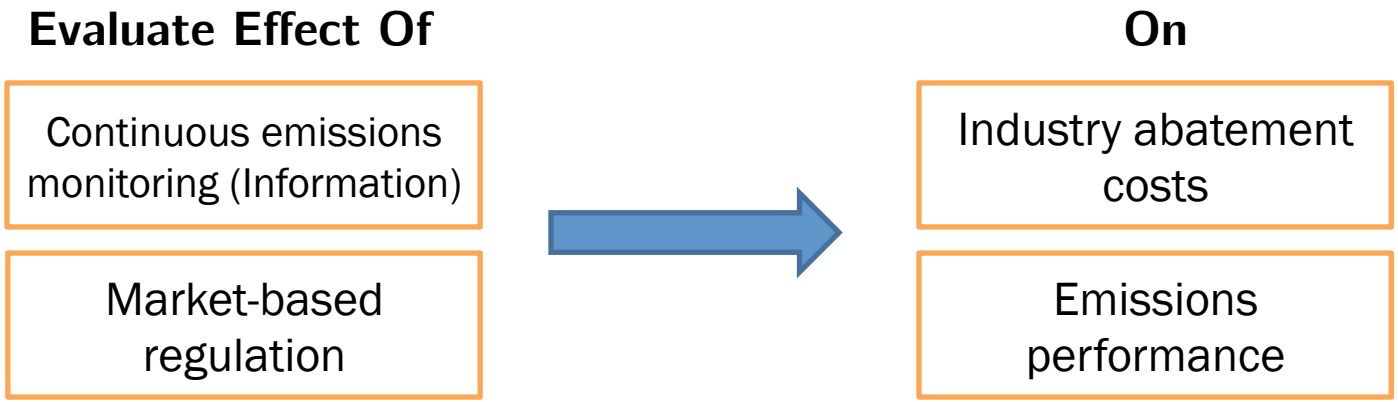
- Emissions before vs. emissions after?
- Costs before vs. costs after?
- Plants under ETS vs. those not trading?

Gains to trade where abatement costs differ

- **Industries have widely varying costs for abatement measures.**
  - Some plants are not burning or storing their fuel properly
  - While others are installing costly abatement equipment
- **Trade allows cost reduction**.
  - Not well-measured by US research: no comparison group

Emissions Trading Scheme Evaluation

- Piloting of CEMS as part of particulate matter emissions monitoring
- Piloting of innovative market based regulation: trading of particulate matter emissions (using data from CEMS)
- **Concurrent evaluation using rigorous research methodology**



Design and Evaluation: Treatments

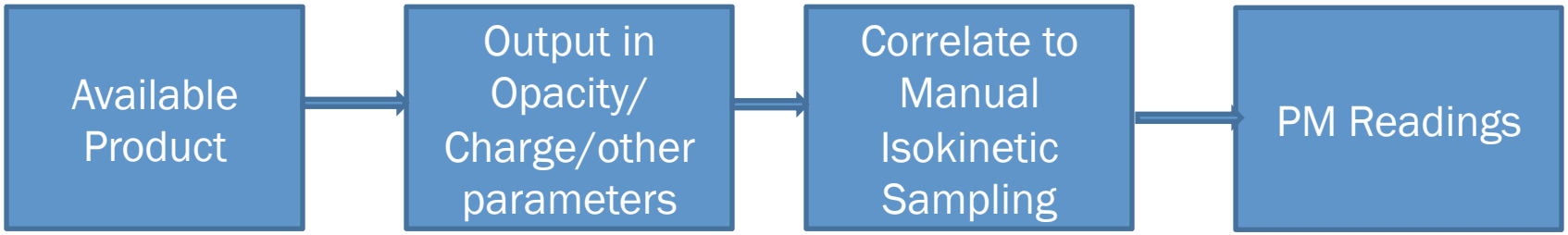
	Firms Phased into Different Groups (Random Assignment)				Research Question
Period 1	CEMS		No CEMS		*Measure the effect of continuous emissions monitoring*
Period 2	CEMS		CEMS		
Period 3	Trading	No Trading	Trading	No Trading	*Measure the effect of market-based regulation; All Plants Move to Load-Based Standard*

CEMS gives regulator better information

- Current system uses manual spot checks only
  - No data between checks
  - No total load / mass so regulations are based on concentration standards (not total air pollution)
- With CEMS can measure total mass / load of particulates
- But there's a problem – CEMS for particulates are expensive and measurements contain noise
- Fixing this has been a key project breakthrough

How do we measure PM?

- PM Measurement based on Indirect Measurement



- PM Measurements are dependent on parameters such as Stack Diameter, Particle Size, Moisture Content etc.

- Objective: Generate Mass Flow Data: Load of PM emissions in Kg/time instead of concentration (mg/Nm3) alone

Developed New Continuous Monitoring Protocol

- Frugal innovation: How can CEMS be made accurate and cheap?
- Key insight – CEMS is about the *interaction* of technology with regulation
- Costs of a monitoring protocol are a joint product of
  - Regulatory design (what do we want to achieve?)
  - Statistical inference (how do we use information?)
  - Technology (what are the tools of measurement?)

So what did we do different?

Command and control

- Regulator monitors a quantity measured at one point in time
- Regulator places a limit on concentration
- Technology challenge: Accurately measure the concentration of particulates right now

The India ETS

- Regulator is interested in a long run average measure
- Regulator places a limit on total load emitted
- Technology challenge: Accurately measure the total mass emitted over a period of time

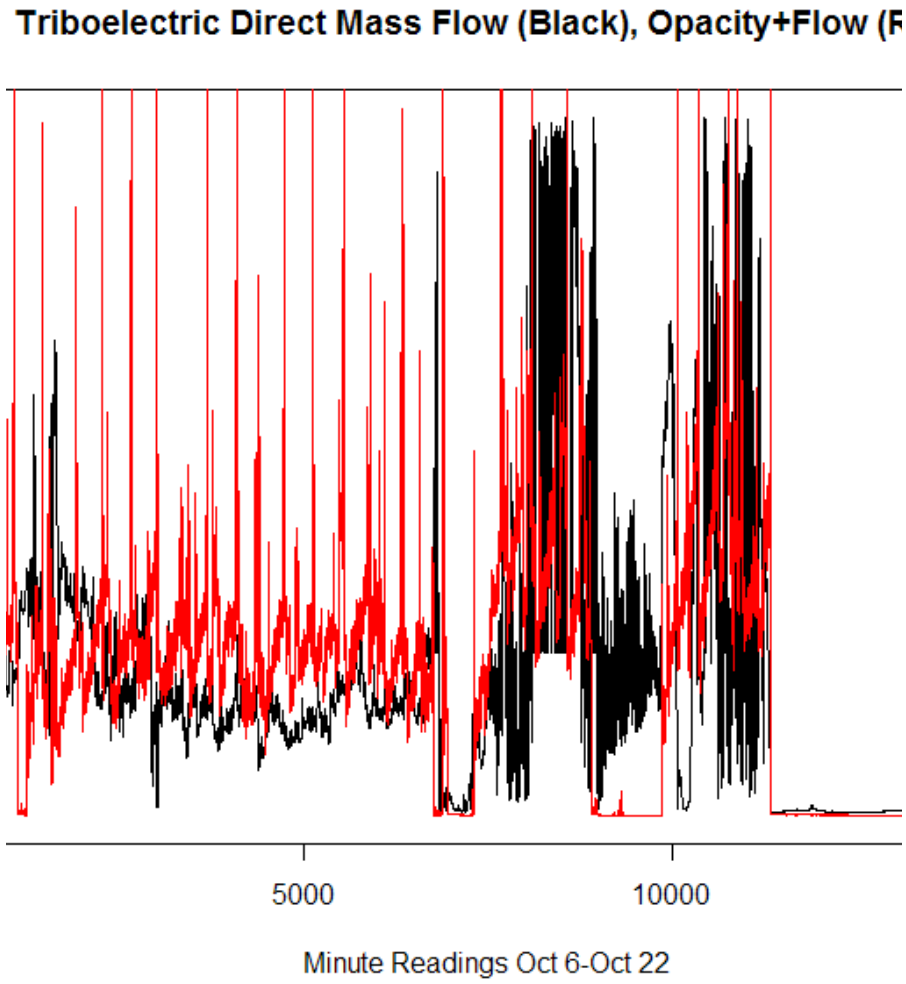
Uncertainty and Measurement

- Both light based and tribo-electric CEMS devices are (noisy) linear measurement $Y=aX+b+e$
- A linear calibration function therefore provides $\hat{Y} = \hat{a}X + \hat{b} + \varepsilon$
- Quantity of interest in an emission trading scheme = total mass emitted over time:

$$\bar{y} = \left(\frac{\sum_t y_t}{T}\right) = \frac{\sum_t (a+bx_t+e_t)}{T} = a + b\sum_t \frac{x_t}{T} + \sum_t \frac{e_T}{T}$$

- Thus in theory, a noisy unbiased signal may nevertheless be a precise measure of an aggregate statistic and therefore can underpin a load based regulatory regime
- A key lesson is that technology suitability is a function of regulatory form

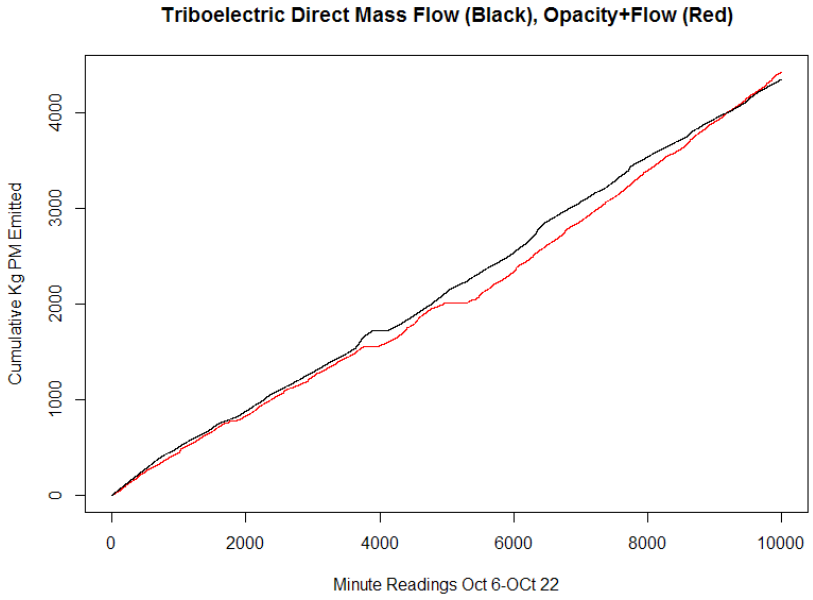
Two noisy signals rarely agree



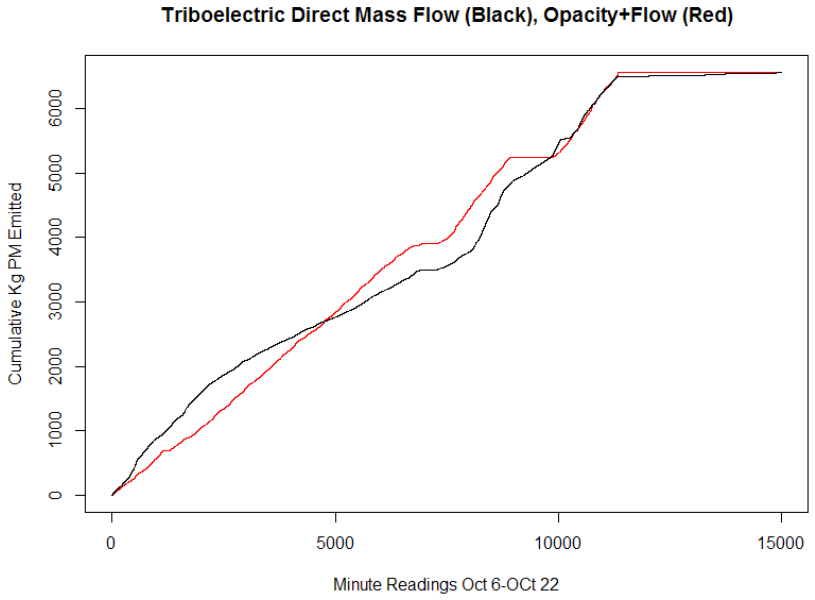
- Instantaneous readings can differ by up to 30% (sum of individual errors)
- Basic trend similar across both (note plant shutdown at end)

But the noise may not matter if you ask a different questions

Two Weeks in September

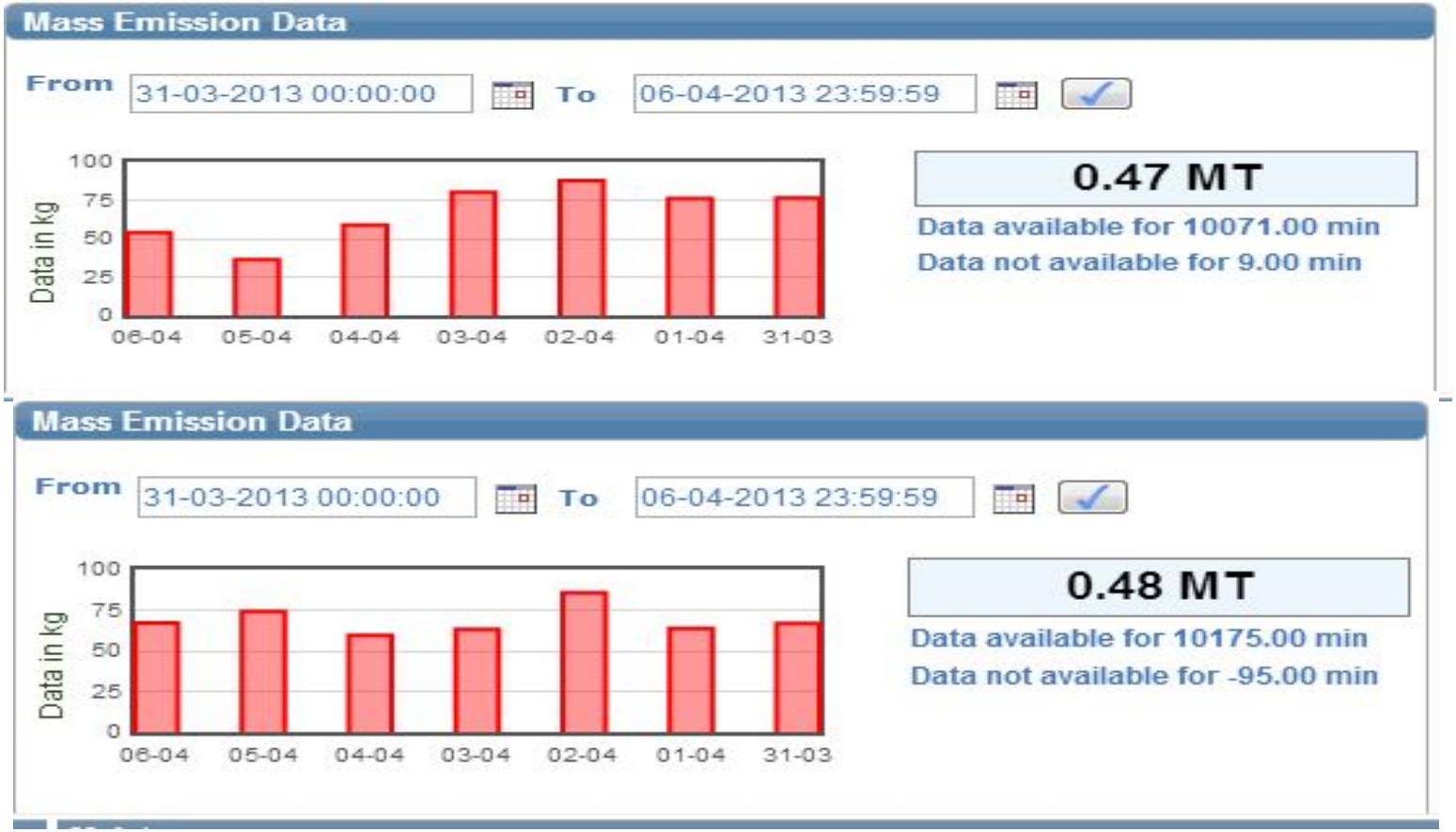


Two Weeks in October

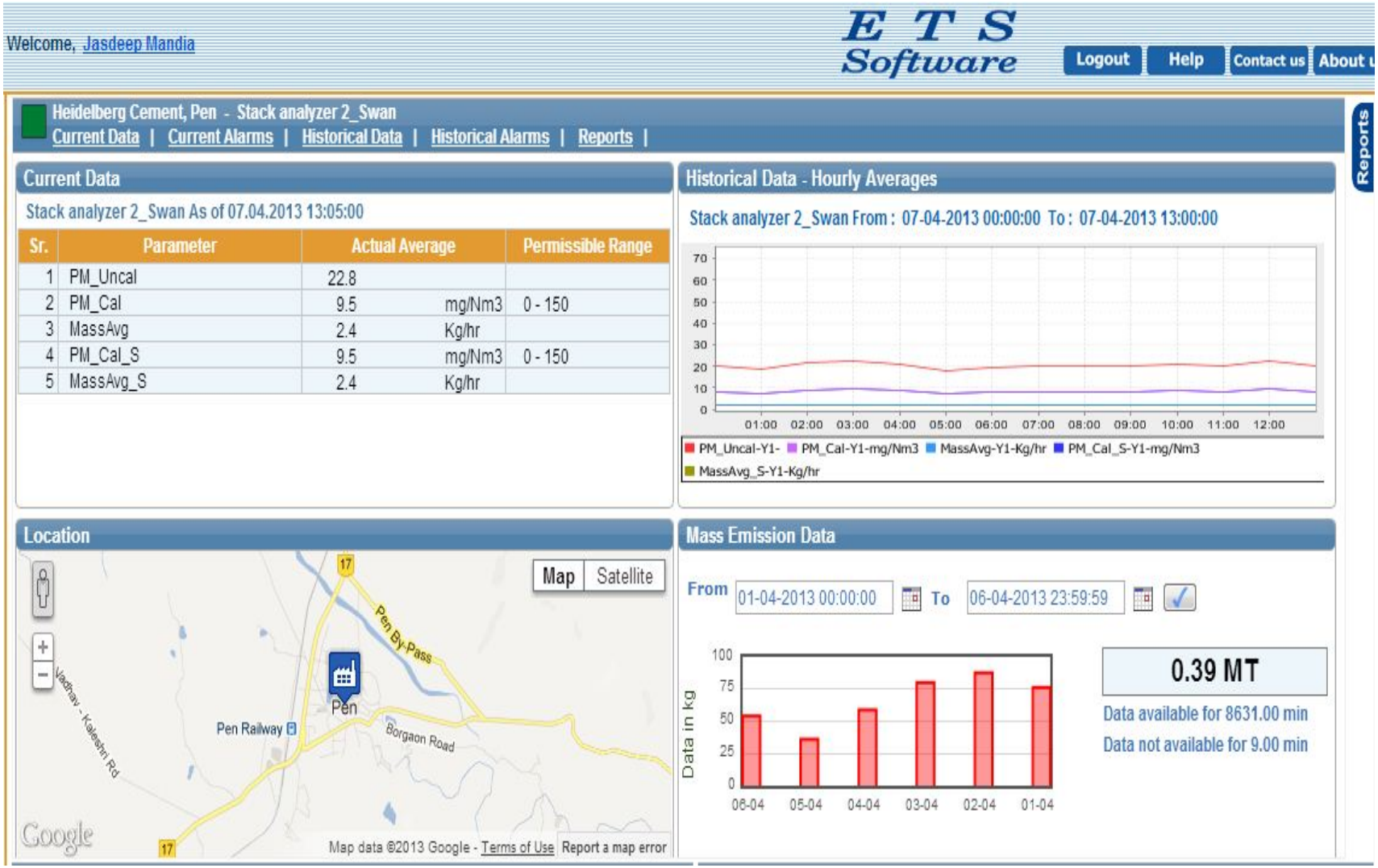


Data Acquisition and Handling System

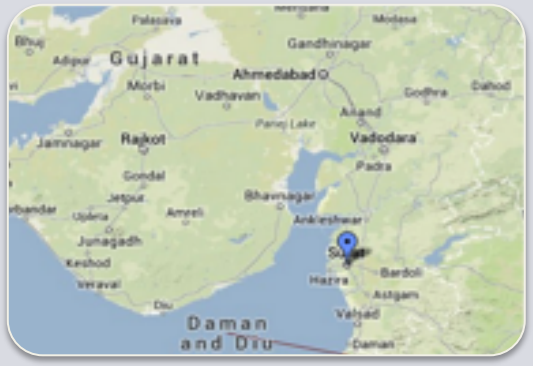
- **Real-time mass flow readings from devices installed at Maharashtra industry**

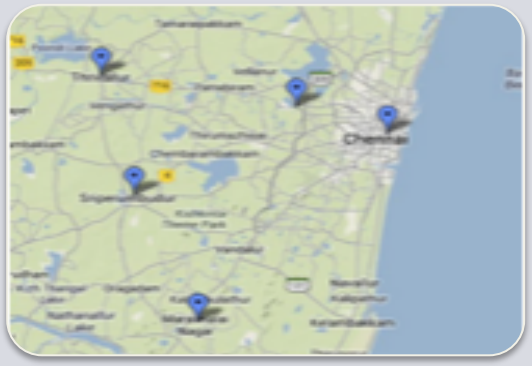


Implementation: Monitoring Framework



Next Steps: CEMS Installation and Rollout





Gujarat

Pilot Area(s): Surat

Maharashtra

Pilot Area(s): Dombivali, Aurangabad +Jalna, Chandrapur

Tamil Nadu

Pilot Area(s): Chennai, Ambattur, Maraimalai, Sriperumpudur, Tiruvallur

The Path Forward

Design: Mar 2011 – Jun 2014

CEMS Evaluation: Jun 2014 – Jun 2015

Trading Evaluation : Jul 2015 – Jun 2016

Implementation: Market Design

Aspect of Design	Recommendation	Rationale
Scope of trade	State-level markets across clusters	Align scope of trade with particulate dispersion
Permit duration	Annual compliance period to start	Sufficient time for industry to learn about and reduce emissions
Means of trade	Monthly two-sided auctions, with bilateral trade also allowed	Provide clear information on permit price to all
Price limits	Price ceiling to limit maximum permit price	Reduce uncertainty over compliance cost to industry
Penalty structure	Fines for emissions above permit holdings at ceiling price	Compel industry to purchase permits and comply

Thank you

Plants with different abatement costs can trade in ETS