HARVARD ENVIRONMENTAL ECONOMICS PROGRAM

Research Workshop
for
Pre-Doctoral Fellows and Alumni

Thursday-Friday, September 19 – 20, 2019
Harvard Kennedy School
Cambridge, Massachusetts

Emissions Regulation and Electric Vehicle Introduction

Sarah Armitage & Frank Pinter
Harvard University

September 19, 2019

Motivation: Attribute-Based Technology Standards

- Regulatory revealed preference for technology-forcing standards.
- Regulator cannot easily identify technology adopters and marginal firm investment in product innovation.

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- **Research question:** What is impact of ZEV Program on a) trajectory of EV adoption and b) characteristics of EVs offered by automakers?

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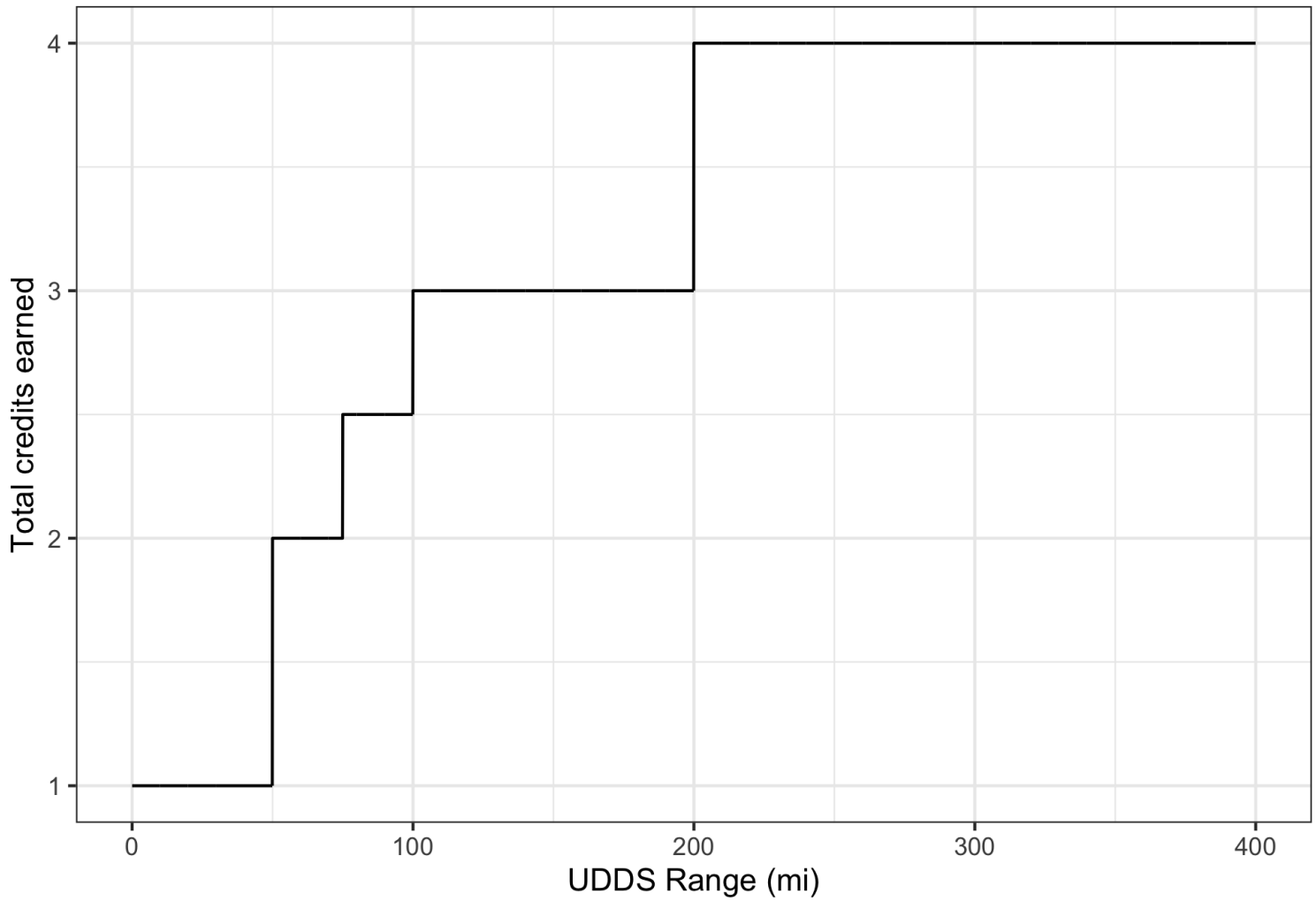
- **Related literature:** auto manufacturer response to emissions regulation (Knittel, 2011; Klier and Linn, 2012; Jacobsen, 2013; Reynaert, 2019); attribute-based regulation (Ito and Sallee, 2018)

ZEV Program, 2009–2017

Credits Earned by ZEVs as Function of Range:

▸ Credit Trading



Theoretical Predictions

Consumers choose vehicle type and range:

$$\max(\max_{r}\{\theta_i + \gamma_i G(r) - P(r) + \alpha + \beta r\}, \bar{v})$$

- θ_i: inherent preference for EVs
- $\gamma_i G(r)$: utility from vehicle range r
- $P(r)$: EV price
- $\alpha + \beta r$: EV subsidy
- $\bar{v}$: net utility from outside option (ICE vehicle)

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- Assume $\theta_i = 0$ with probability p and $\theta_i = \bar{\theta}$ with probability $(1 - p)$.
- By change of variables, overall share adopting EVs:

$$1 - (1 - p) \cdot F_{U|\theta=\bar{\theta}}(\bar{v} - \bar{\theta} - \alpha) - p \cdot F_{U|\theta=0}(\bar{v} - \alpha)$$

where $U = \gamma_i G(r^*(\gamma_i)) - P(r^*(\gamma_i)) + \beta r^*(\gamma_i)$.

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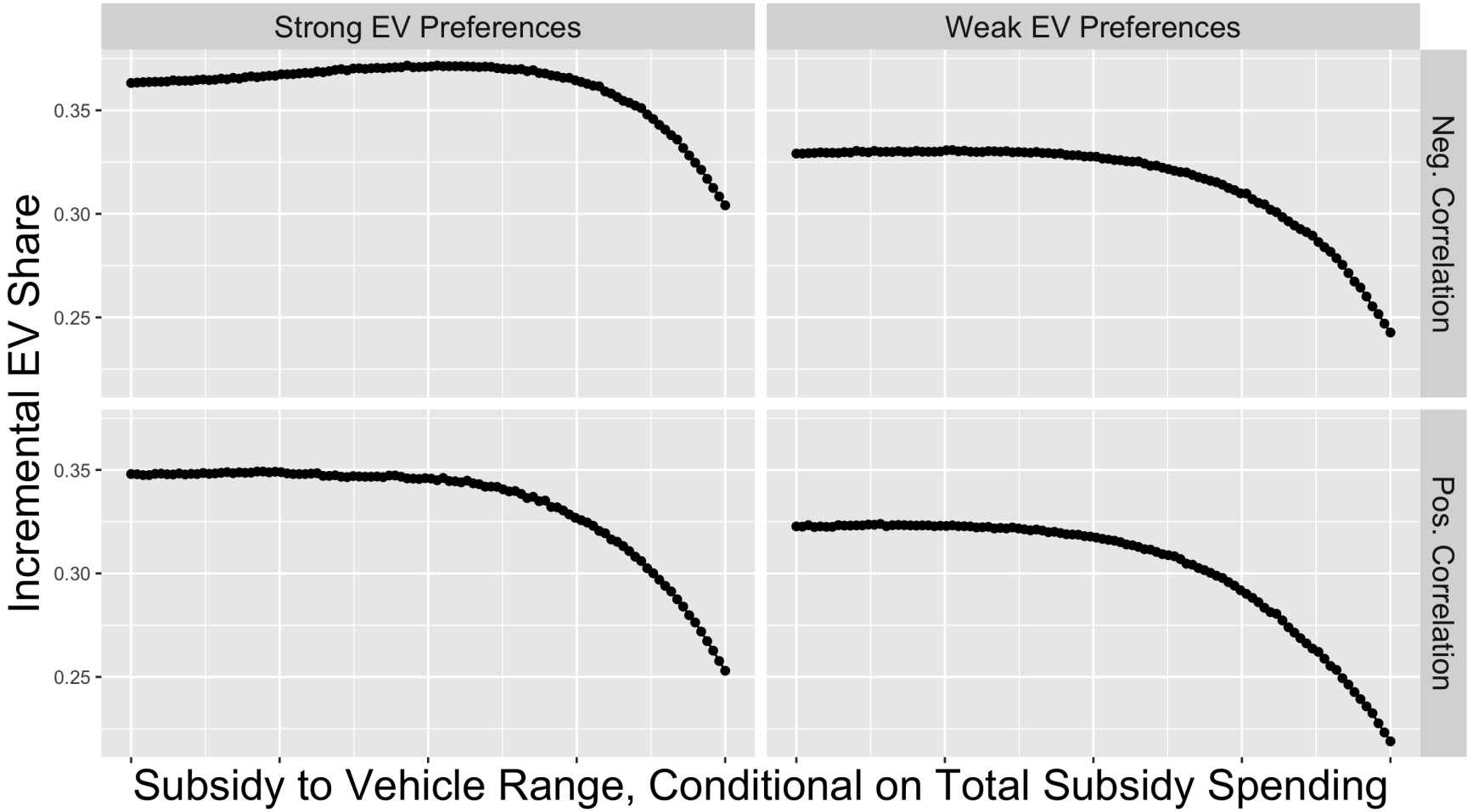
- How does subsidy on vehicle range (β) affect overall share of EVs?

Theoretical Predictions



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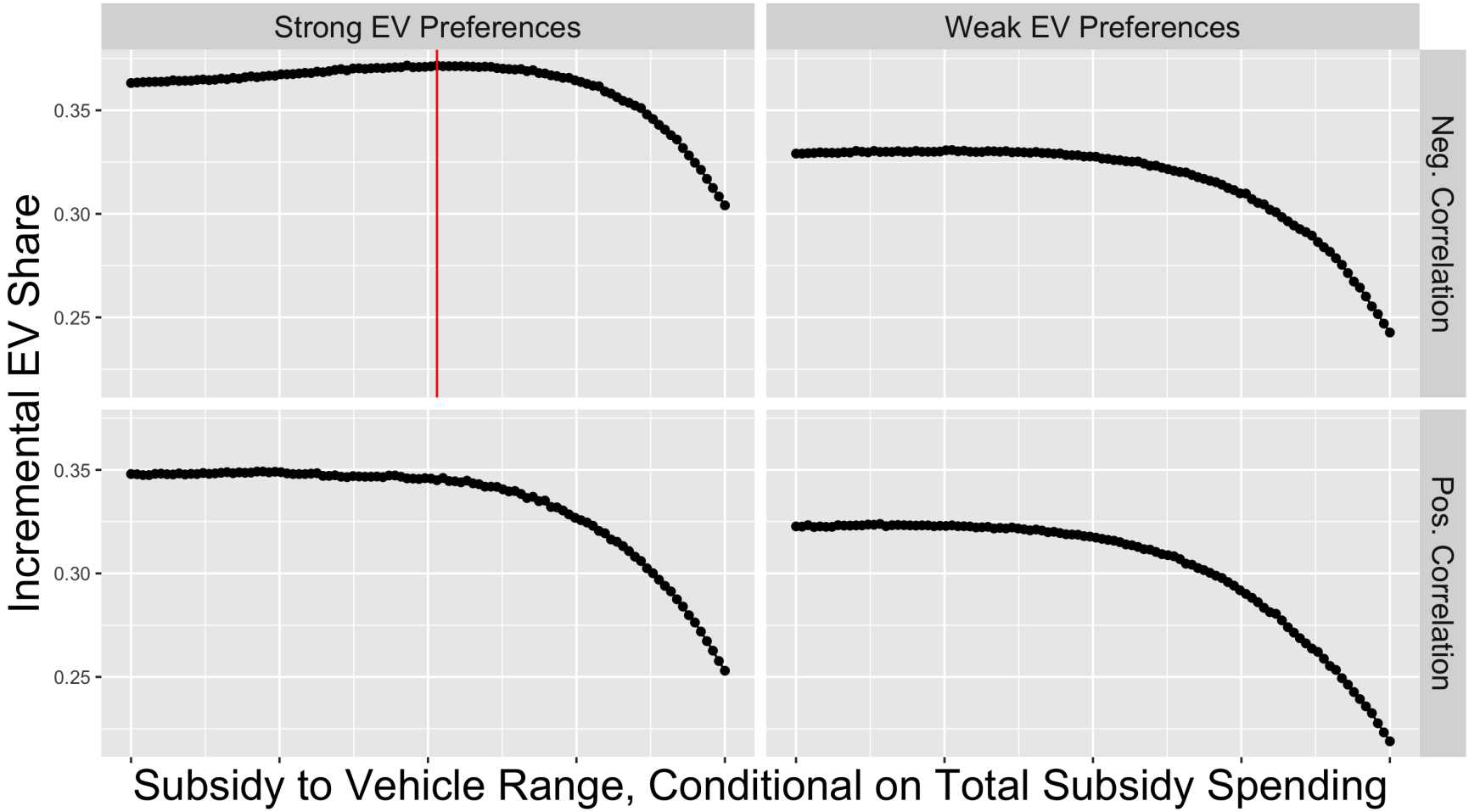
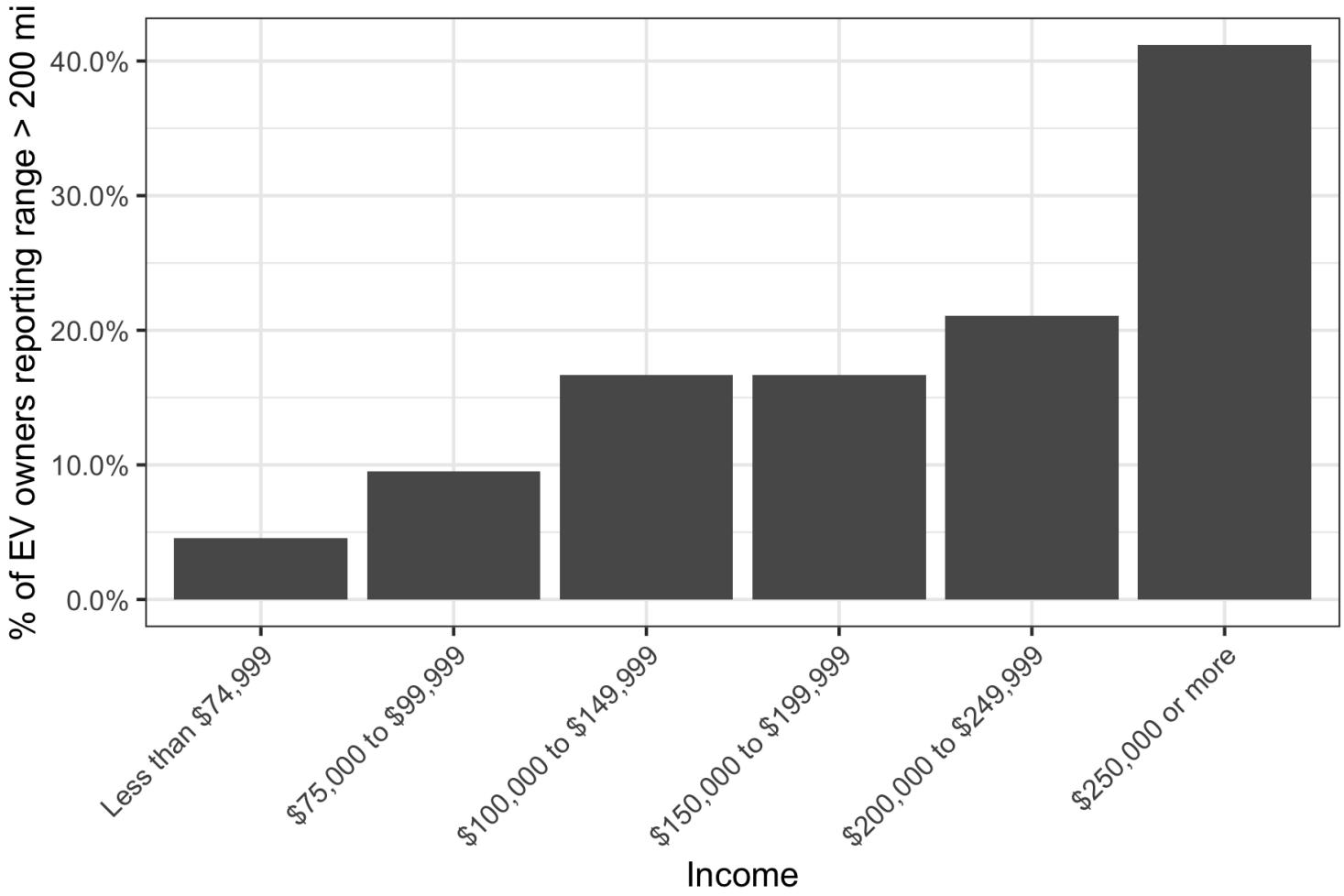


Historical EV Adoption

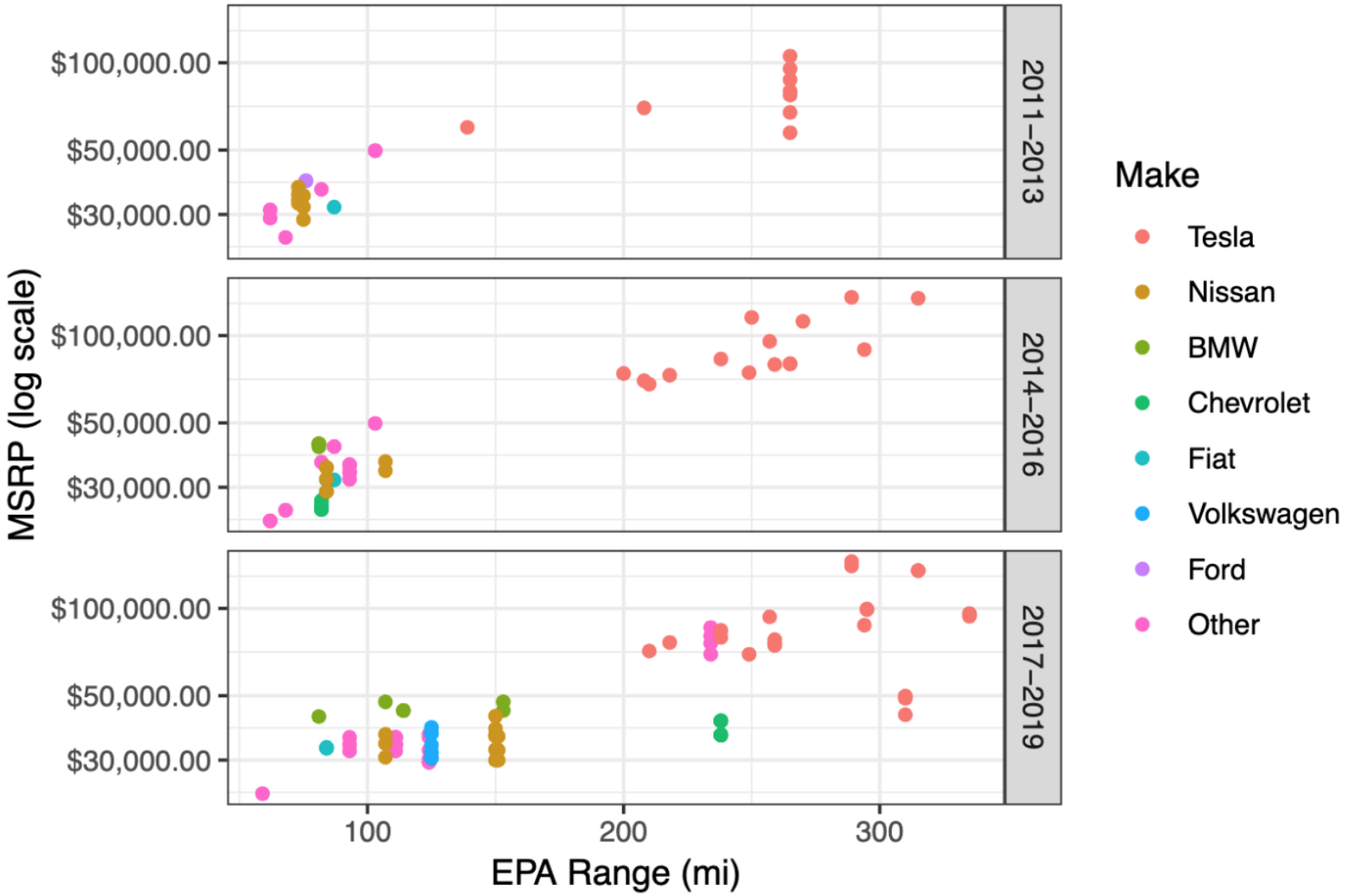
Proportion of EV owners with long-range vehicles



Source: California Vehicle Survey, 2017

Evolution of EV Range

Range and price for all available models, 2011–2019: New Models



Empirical Strategy & Next Steps

- First build BLP-style demand model of preferences over auto and EV-specific characteristics.
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  - Moment inequalities from ZEV compliance options ("compliance cars," range bins, reliance on tradeable credits).

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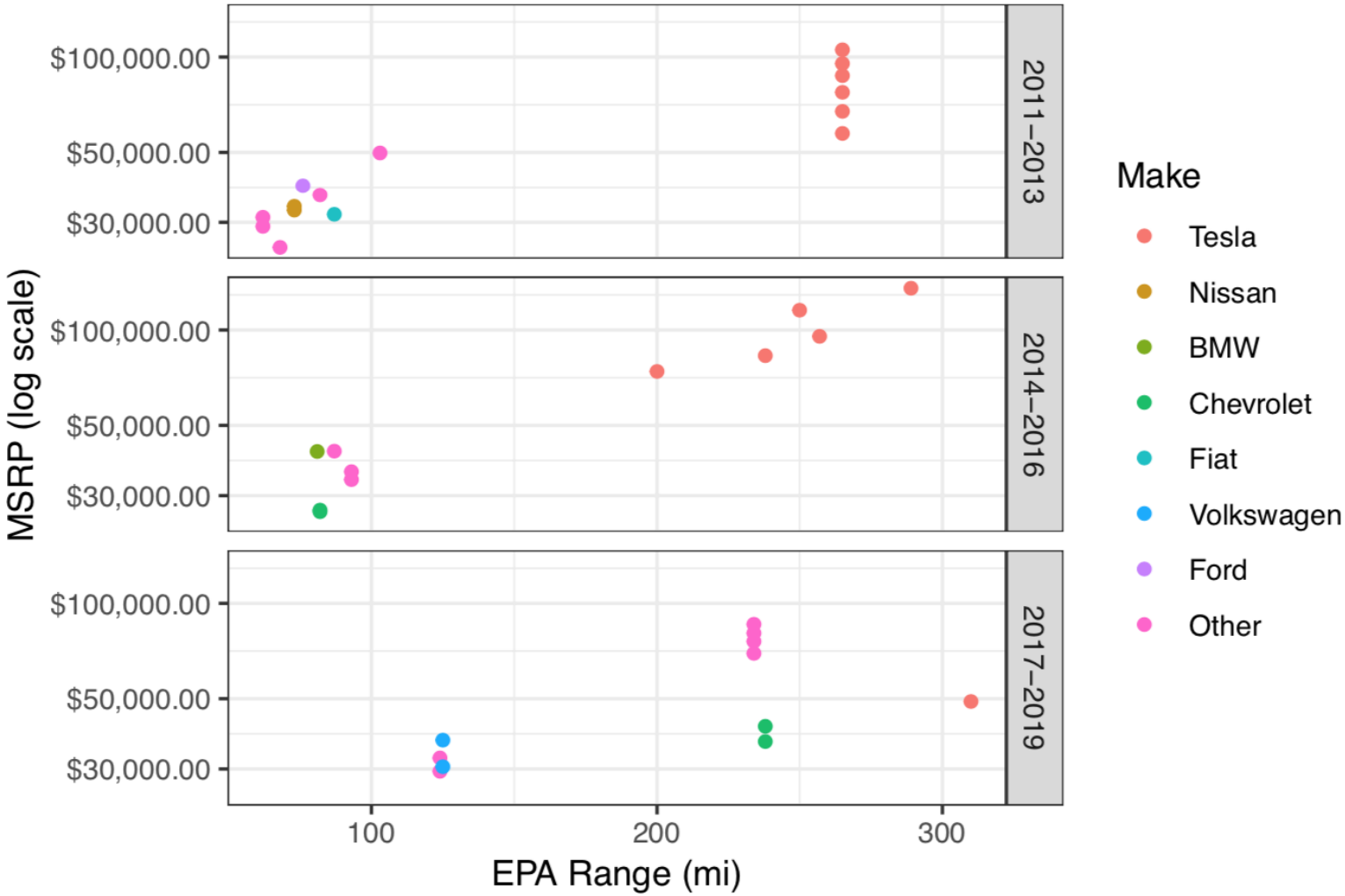
  - Moment inequalities from ZEV compliance options ("compliance cars," range bins, reliance on tradeable credits).
- Counterfactuals: non-attribute-based ZEV program, ZEV subsidy, emissions pricing.

▸ Battery Prices ▸ EV Sales

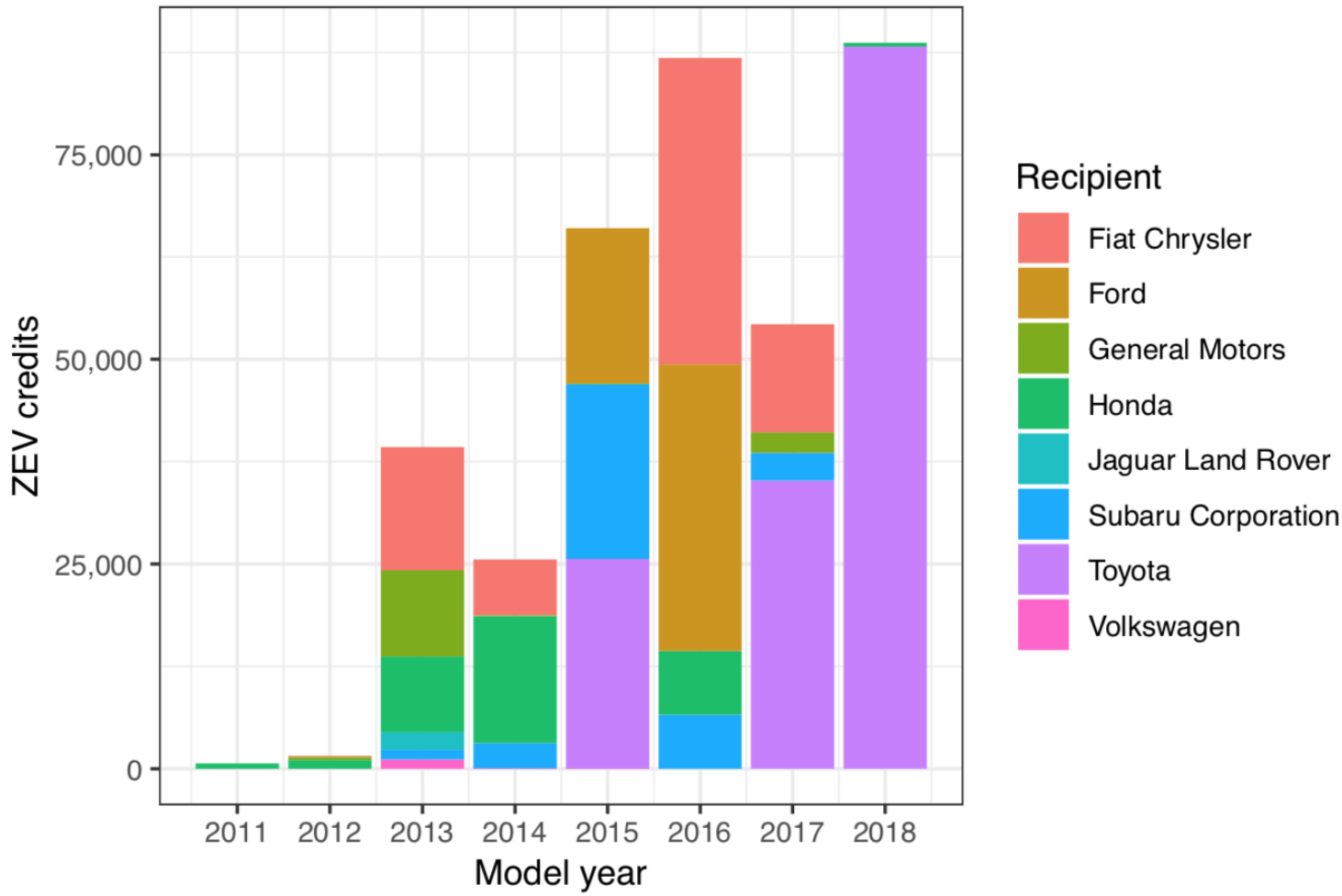
Evolution of EV Range

Range and price for all new models, 2011–2019: ▸ All Models



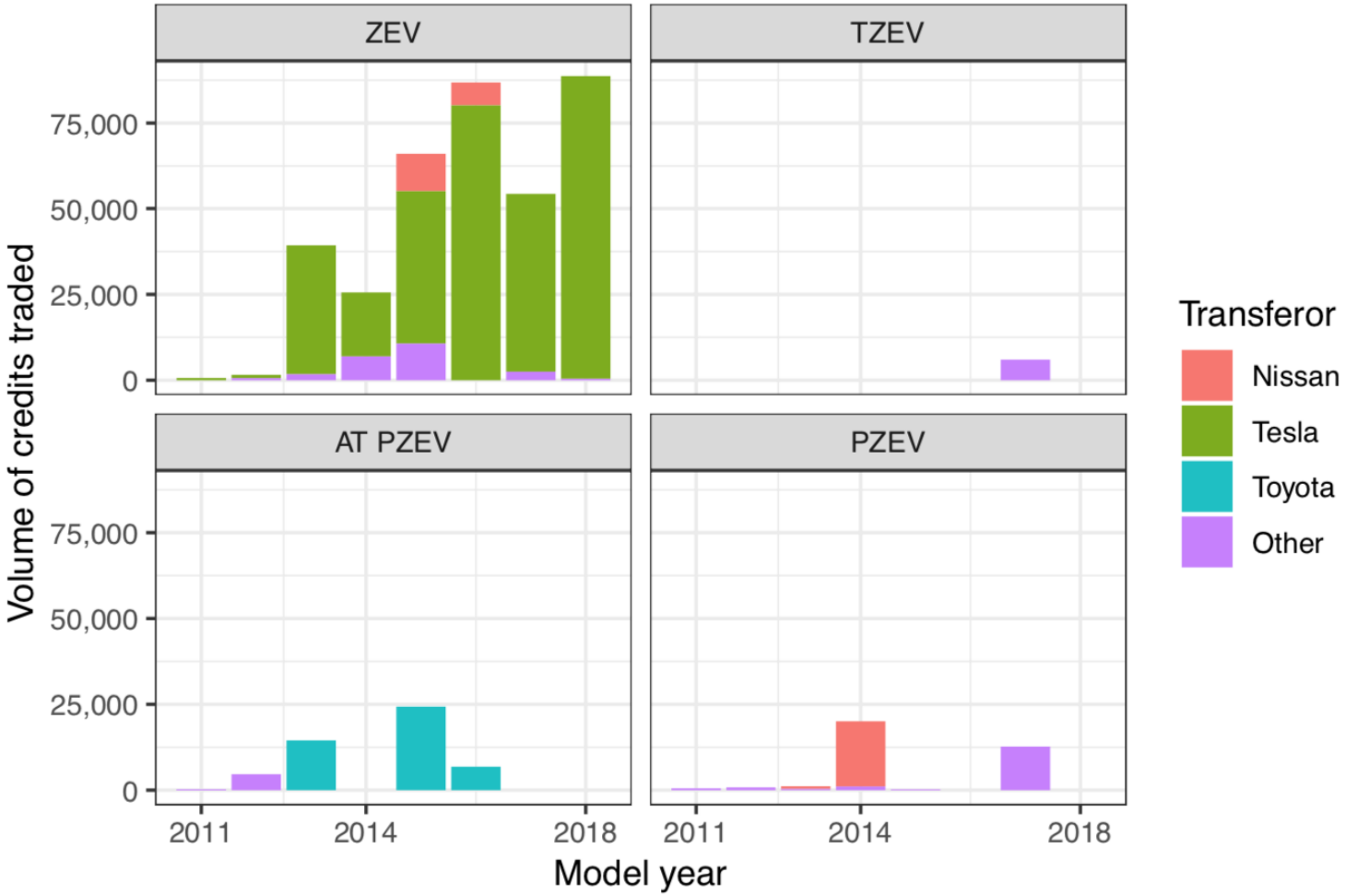
ZEV Credit Trading

Recipients of credit transfers:



ZEV Credit Trading

Volume of credit trading, 2009–2017: Back



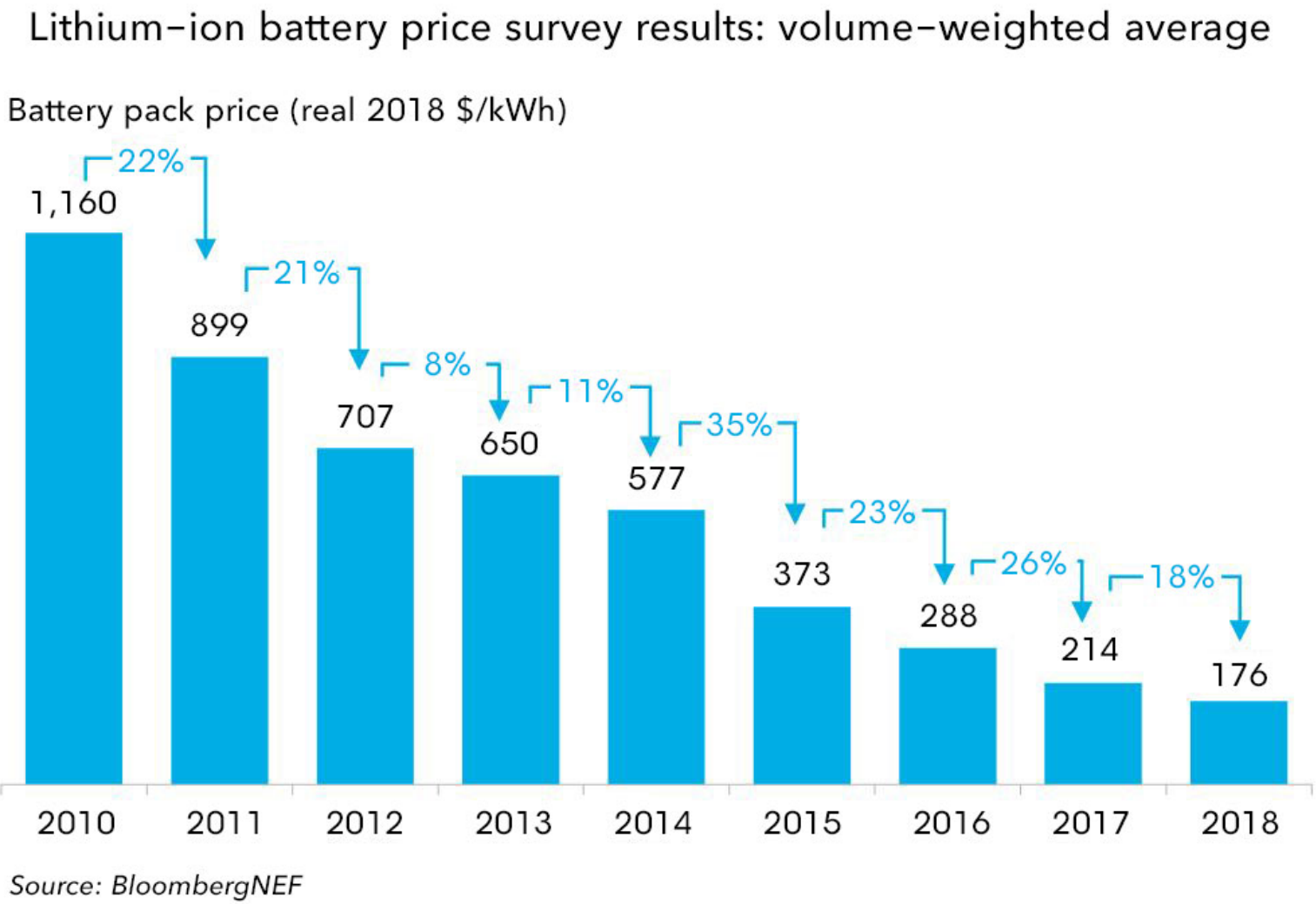
EV Sales

Battery electric vehicle sales by calendar year, 2011–2017:

Make	2011	2012	2013	2014	2015	2016	2017
Tesla		2,171	19,000	16,750	26,408	49,800	49,970
Nissan	9,674	9,819	22,610	30,200	17,269	14,006	11,230
BMW		965		6,092	11,004	7,625	6,276
Chevrolet			560	1,145	2,629	3,614	23,320
Fiat			260	1,503	3,477	3,737	3,336
Volkswagen				357	4,232	3,937	3,534
Ford		683	1,738	1,964	1,582	901	1,817
Other	386	1,012	3,526	5,405	4,443	3,111	4,988
Total	10,060	14,650	47,694	63,416	71,044	86,731	104,471

Back

Battery Prices



Water Pollution, Enforcement Activity, and Economic Outcomes in the United States

Sarah Armitage and Daniel Stuart

September 19, 2019

Background

- Investment costs in surface water quality, drinking water treatment, and air pollution abatement averaged ≈1% of GDP between 1970 and 2014 (Keiser and Shapiro, 2018).
- EPA regulations are combined with enforcement efforts. In 2017, 11,750 inspections, 1,900 civil cases, 115 criminal cases and $37 billion in projects to reduce pollution and fund environmentally beneficial projects.
- EPA claims that its civil enforcement results in 1.25 billion pounds of reduced air, water and toxic pollution per year.

Research Questions: CWA and NPDES Permits

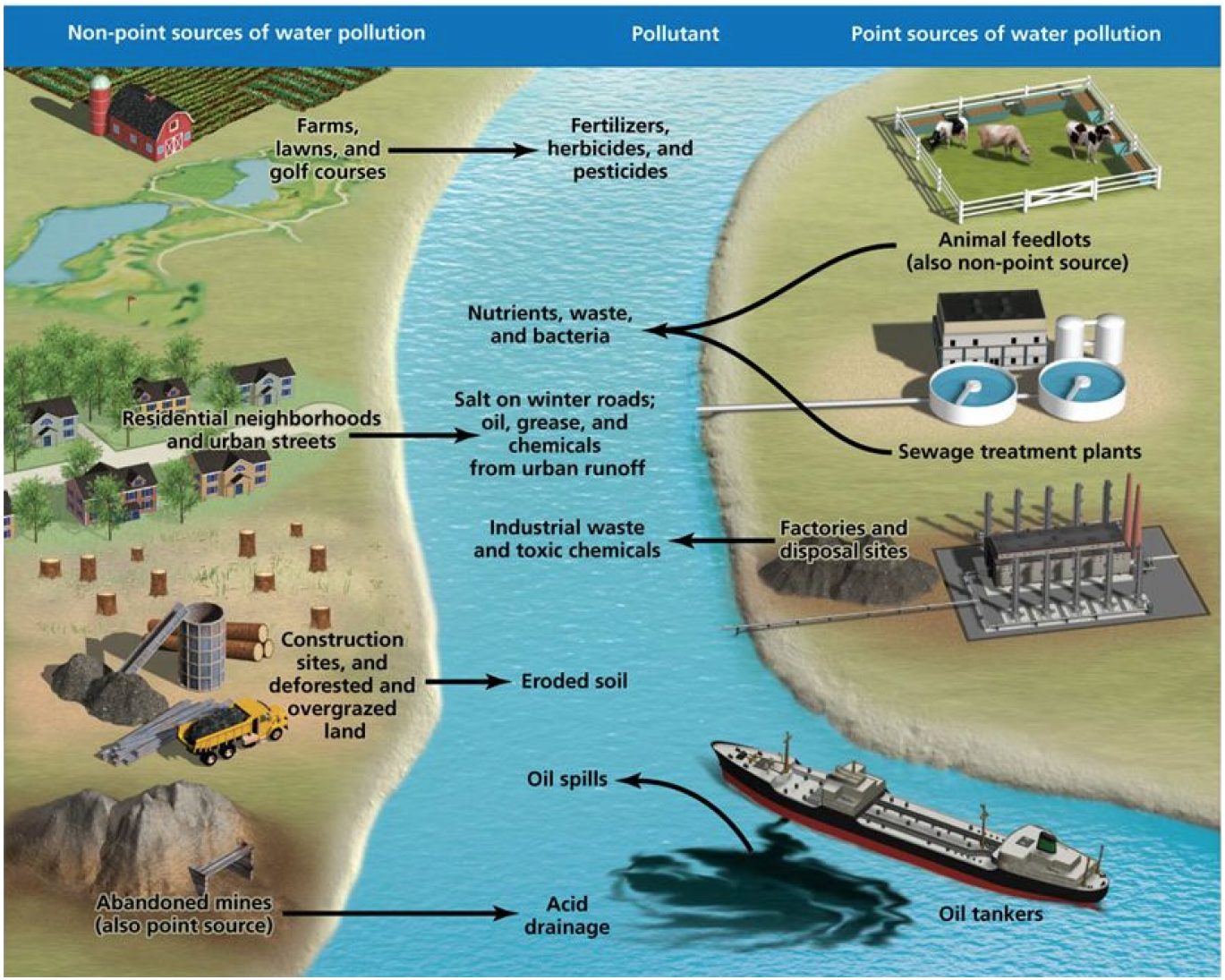
Today

1. What are the impacts of CWA point source regulations on emissions?
2. Do EPA enforcement actions reduce future emissions violations via specific or general deterrence?
3. How do state and federal agencies exercise discretion when enforcing regulations?
4. What are the impacts of environmental regulation and enforcement on real economic outcomes?

Previous Literature

- Sizable existing literature finds large impacts of inspections and fines on compliance and "over-compliance" for the CWA (Gray and Shimshack, 2012) and CAA (Shimshack, 2014; Hanna and Oliva, 2010)
- Recent work highlights efficiency gains of environmental regulators targeting persistent violators (Blundell, Gowrisankaran and Langer, 2018) and facilities with either higher environmental damages or lower costs of enforcement (Kang and Silveira, 2018).

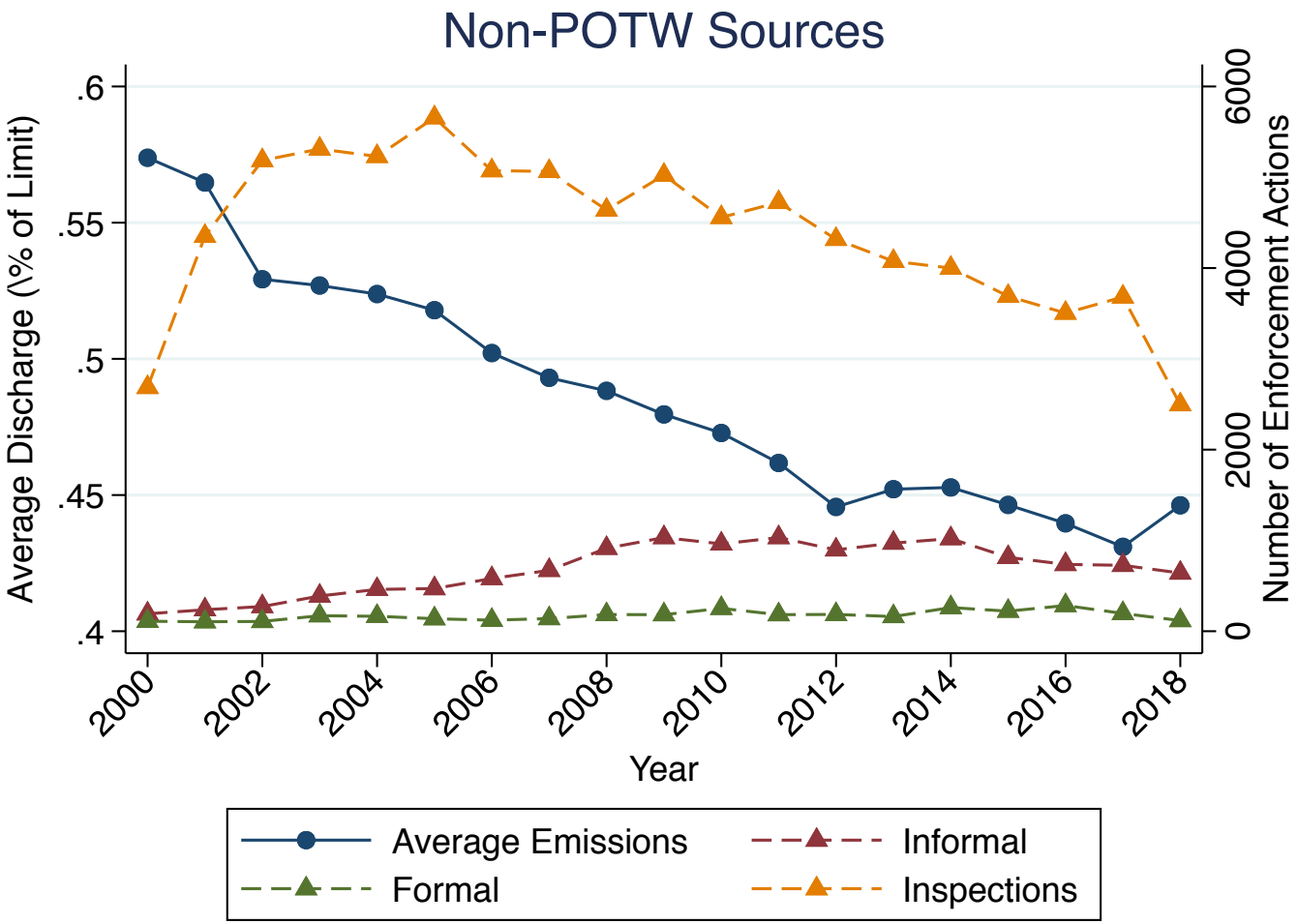
Sources of Water Pollution



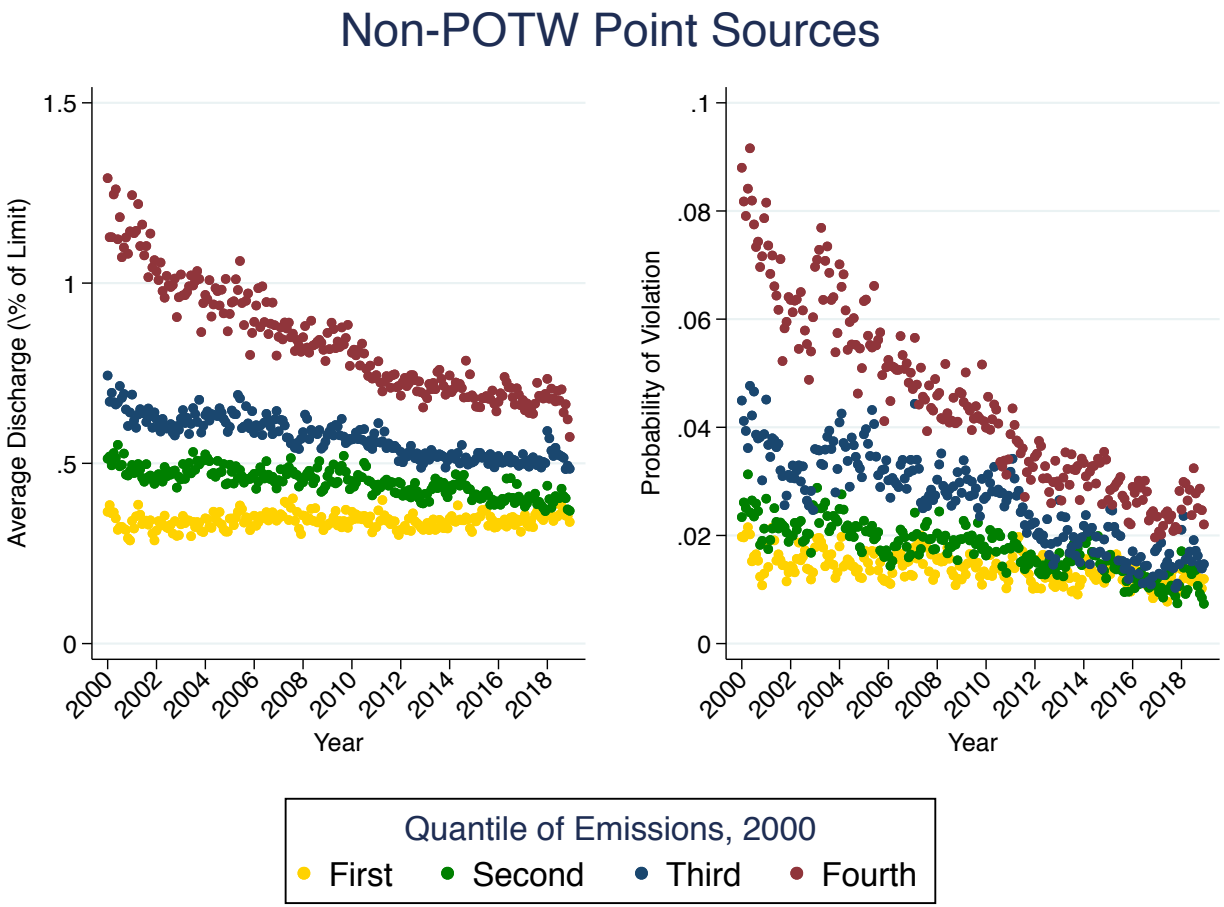
Data

- **Enforcement and Compliance History Online (ECHO)**. Covers all inspection, compliance, civil enforcement, and criminal enforcement actions in the history of the EPA across air, water, and toxic/solid waste statutes. For most statutes, includes both state and federal actions.
- **Environmental outcomes**: National Pollutant Discharge Elimination System (NPDES) and Discharge Monitoring Report (DMR). Self-reported monthly panel of all water discharges from point-source facilities in the United States. Includes statutory permit limits by chemical.

Trends in Average Discharges and Aggregate Enforcement Activity

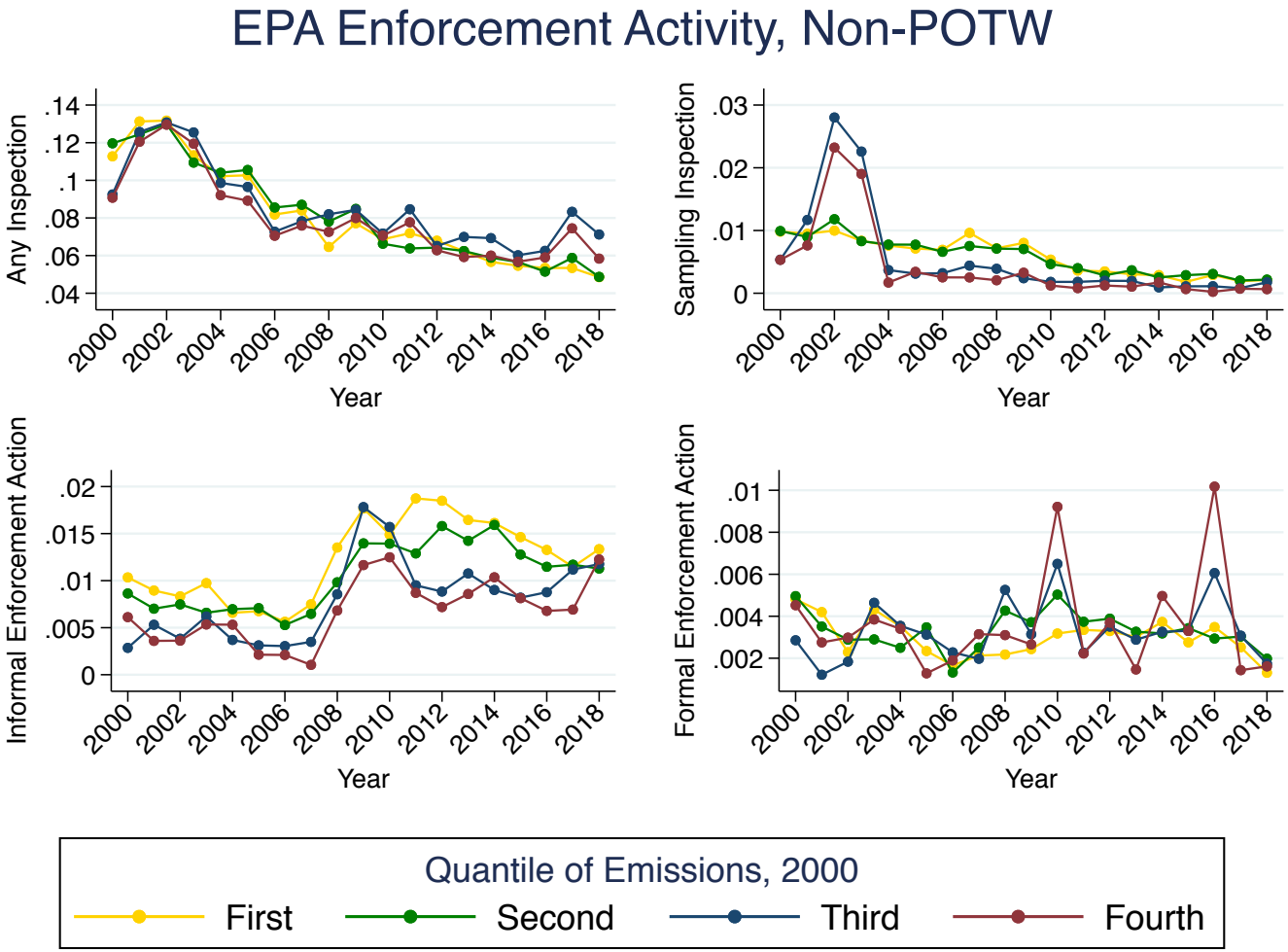


Declines in Water Pollution Concentrated Among Top Polluters

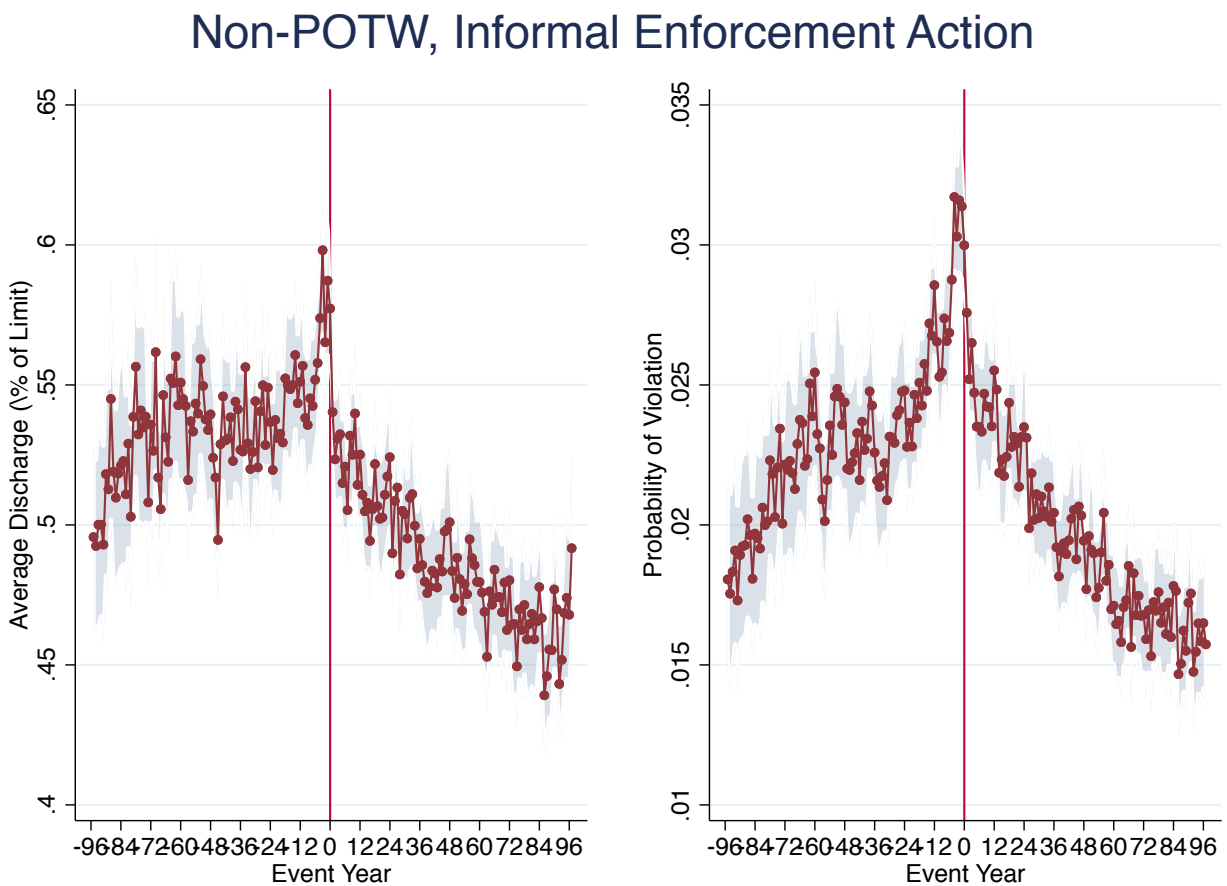


Note: Sample partially balanced by restricting to facilities with nonmissing emissions readings for 75% of calendar years. Results are similar but noisier for a balanced panel.

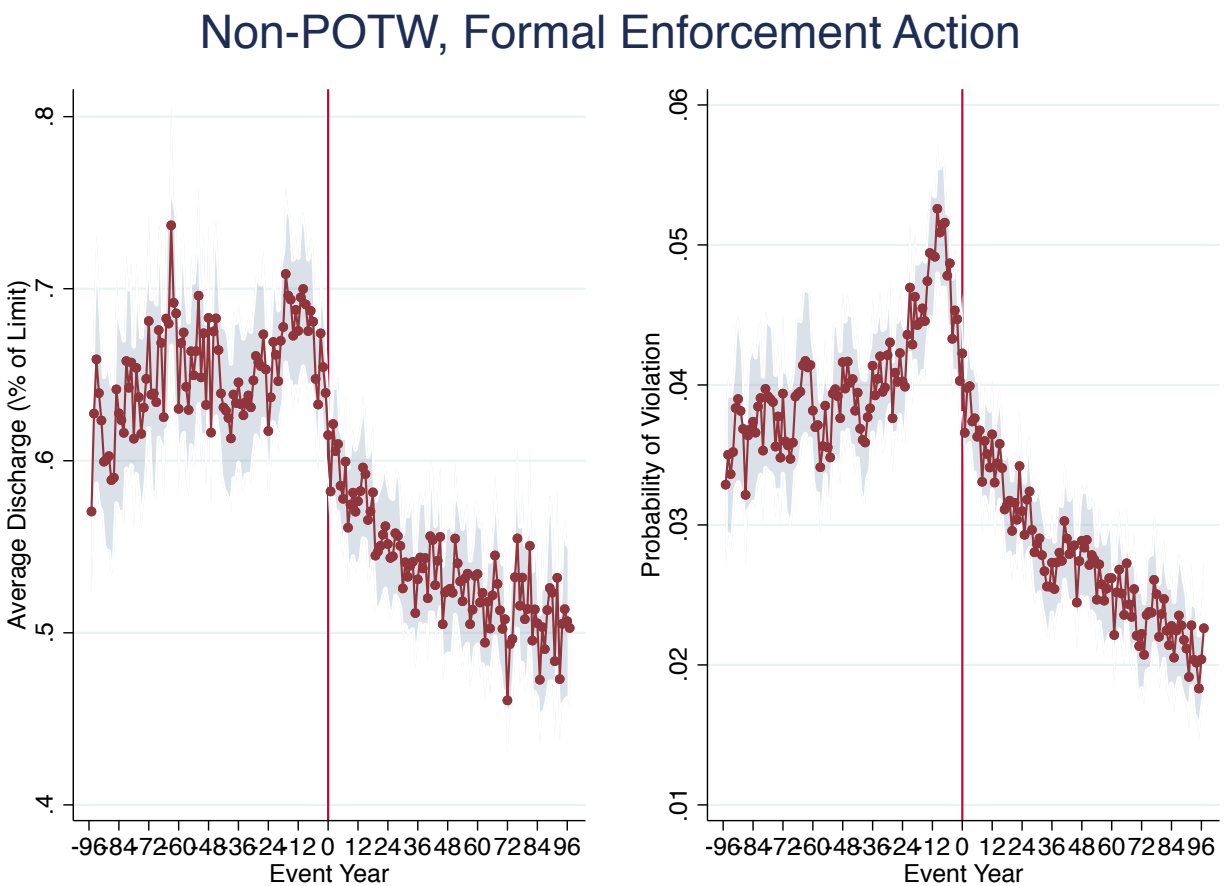
No Differential Trends in Enforcement Activity



Event Study: Informal Enforcement Actions



Event Study: Formal Enforcement Actions



With Fixed Effects

POTW

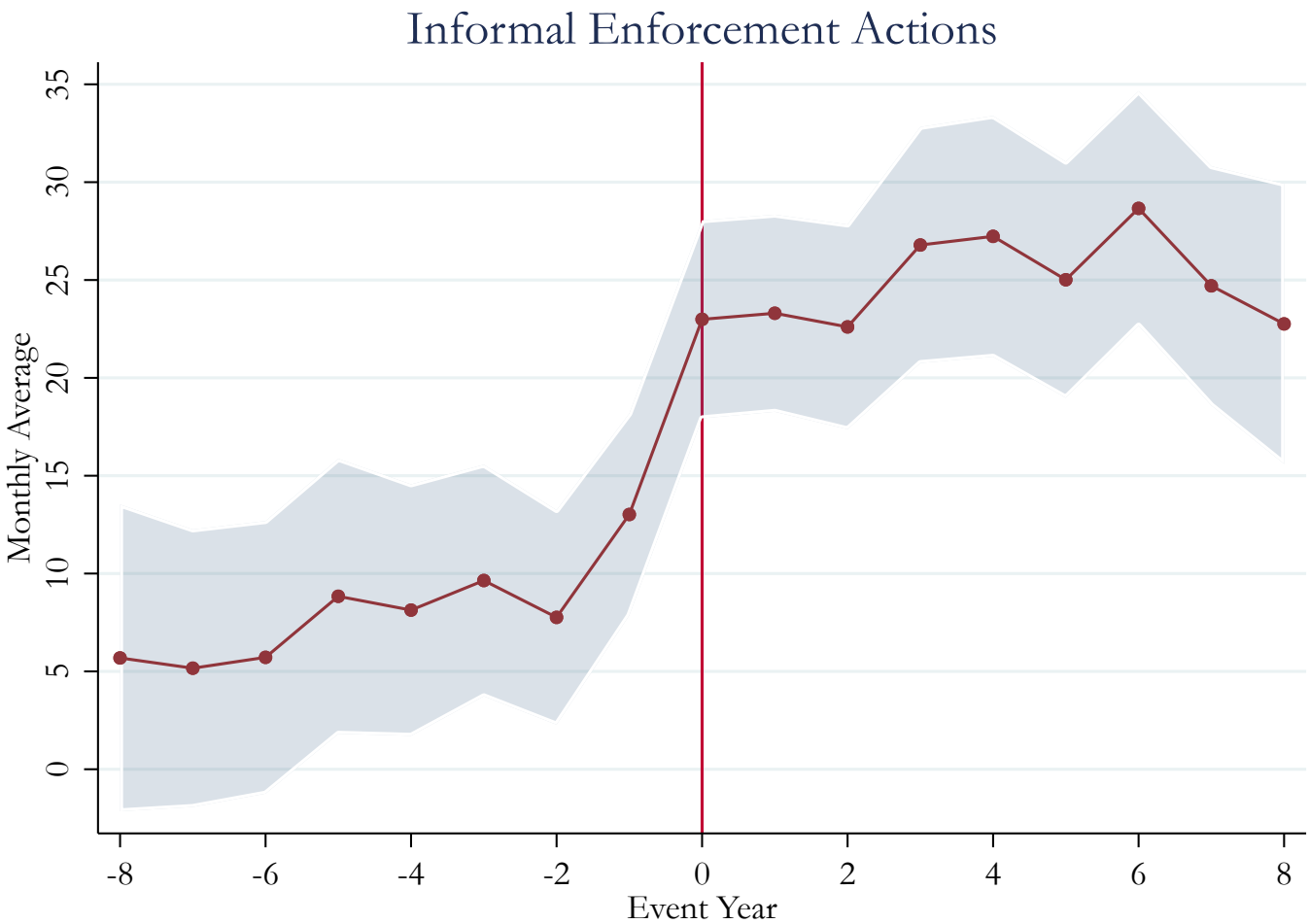
Discussion

- We find sizable specific deterrence impacts of CWA enforcement actions, in line with previous results in the literature
- Event study approach works well for identifying specific deterrence effects, but not clear if this approach can identify general deterrence impacts
- We need an instrument to identify general deterrence effects: something that impacts enforcement activity but does not have any direct effects on firm-level environmental or economic outcomes

Possible Instrument: Citizen Petitions

- States are often granted primary responsibility for enforcement; citizen groups may challenge state primacy if enforcement is inadequate.
- Identification strategy exploits change in enforcement stringency following citizen petitions.
- We do not observe any actual changes in primacy. Rather, we are studying the impact of the citizen petition itself.

First Stage: Impact of Citizen Petitions on Enforcement Activity



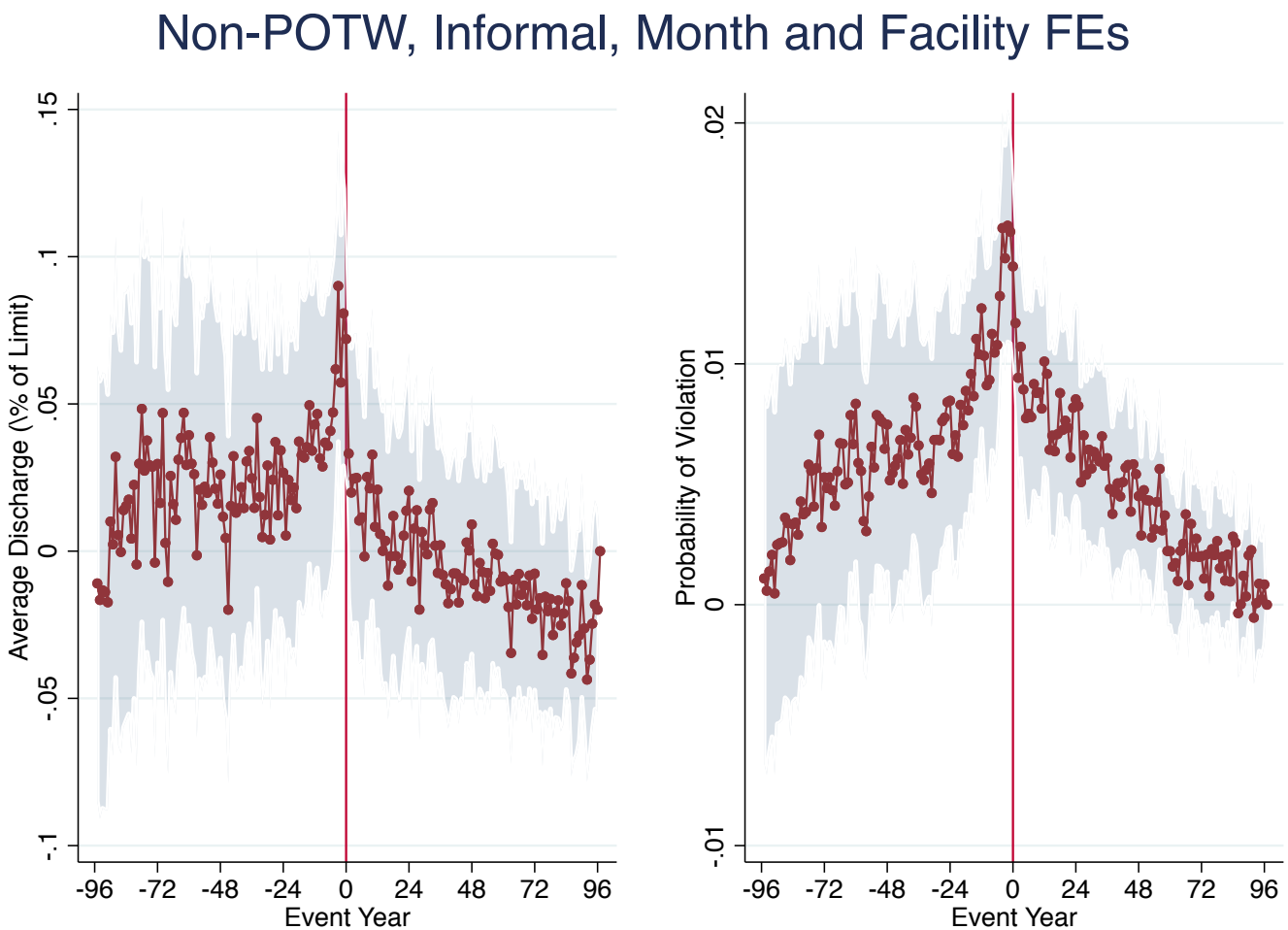
Inspections Formal Actions

Future Work

- Use citizen petitions as an instrument to identify general deterrence impacts of enforcement activity
- Study how the stringency of enforcement varies over time and across states; regulators have substantial ability to exercise discretion
- Study the dynamic causal effects of enforcement actions and regulatory stringency on manufacturing economic outcomes using Dun&Bradstreet and Longitudinal Business Database microdata

Appendix Slides

Impact of Informal Enforcement Actions: Non-POTW with FEs



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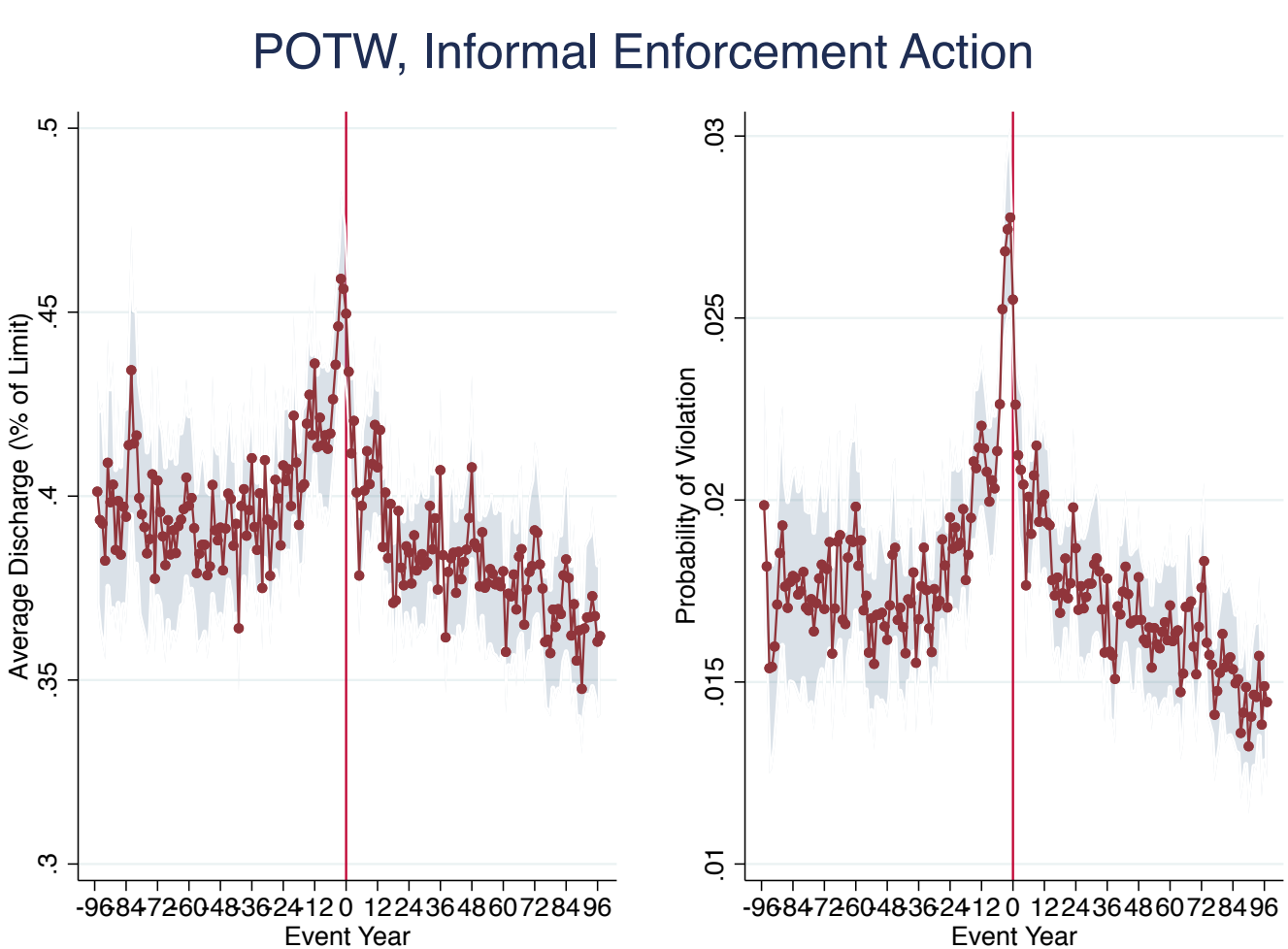
Impact of Informal Enforcement Actions: POTW



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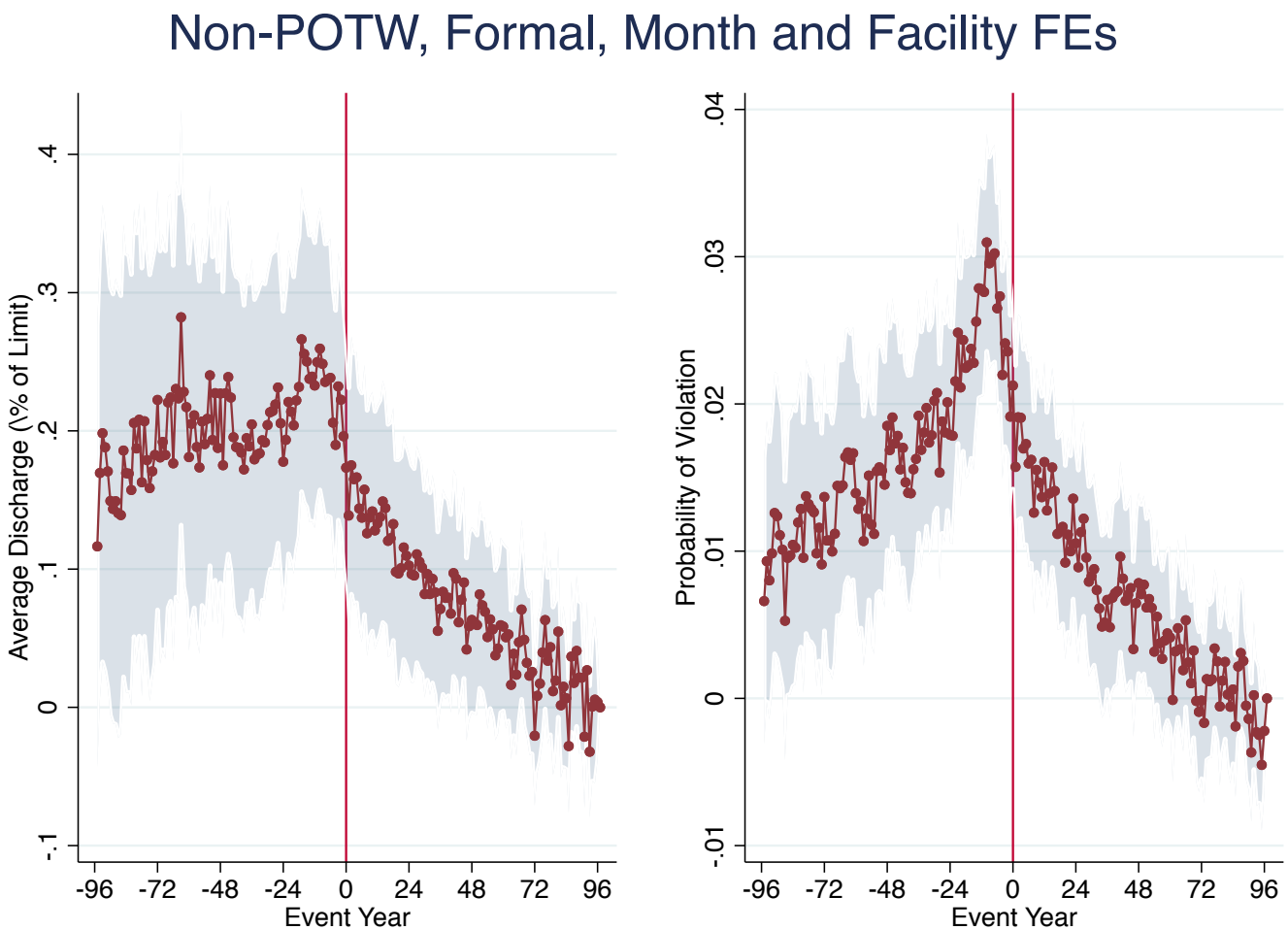
Impact of Formal Enforcement Actions: Non-POTW with FEs



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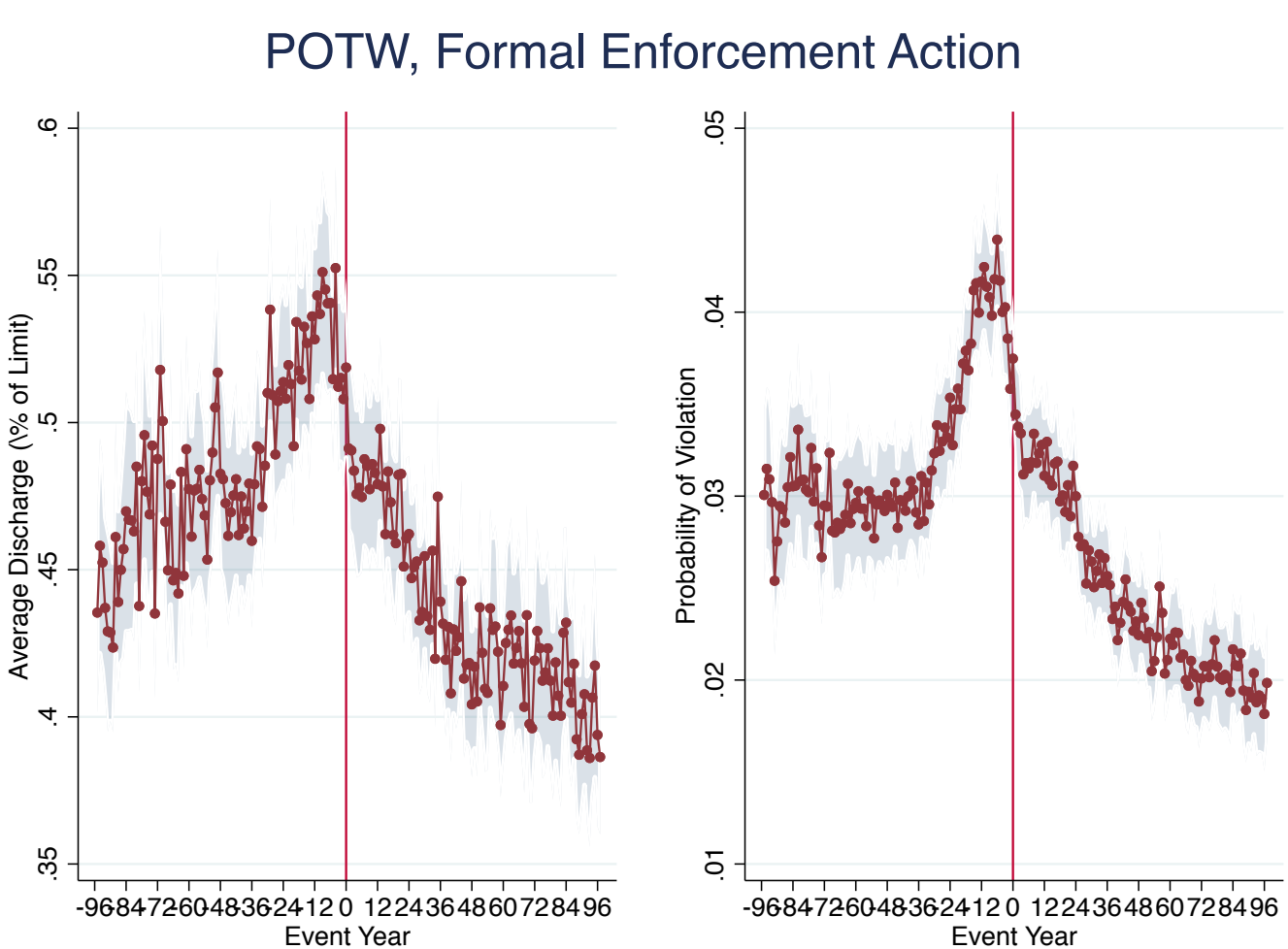
Impact of Formal Enforcement Actions: POTW



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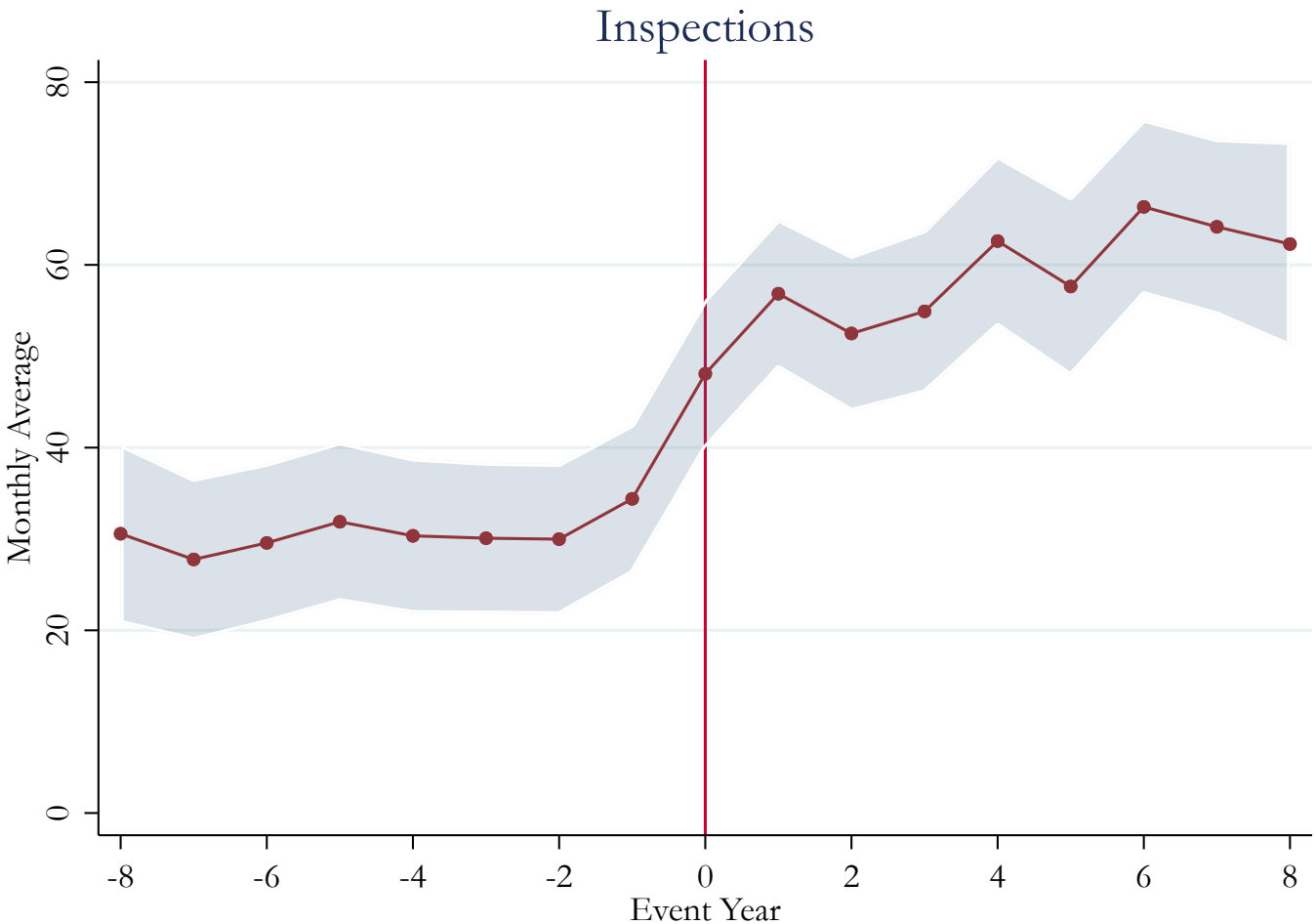

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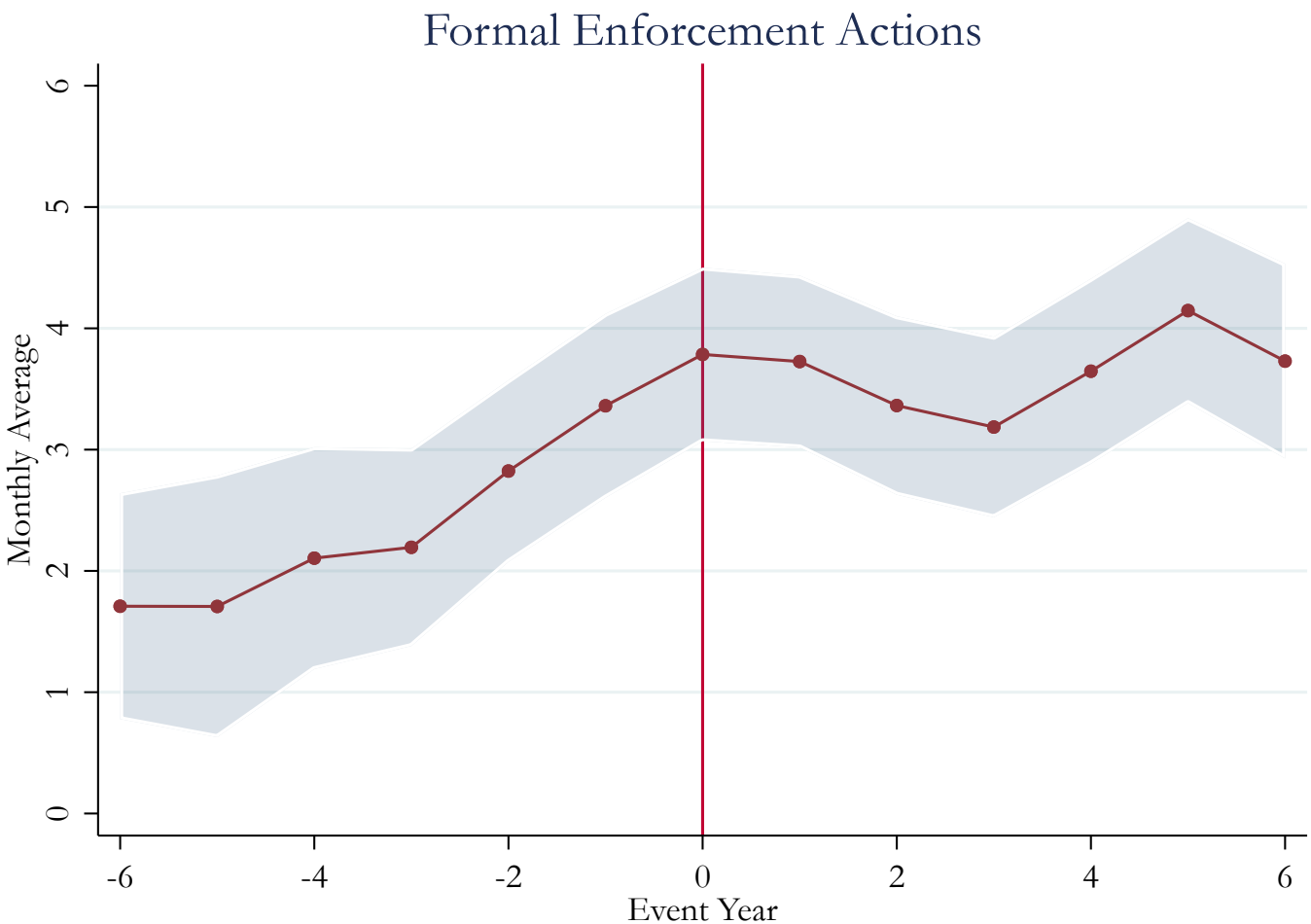

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Using Satellite Data to Fill the Gaps in the U.S. Air Pollution Monitoring Network

Daniel M. Sullivan[1] Alan Krupnick[2]

September 19, 2019

[1]JPMorgan Chase Institute

[2]Resources for the Future

Motivation: Clean Air Act and Pollution Monitors

- Clean Air Act $\rightarrow$ air quality limits $\rightarrow$ "Nonattainment"
- Air quality assessed with ground-based monitors.
- **Problem:** 37% of U.S. have no $PM_{2.5}$ monitor. (79% of counties.)

Questions:

1. Do the monitors miss any violating areas/people?
2. How much does misclassification cost society?

Data

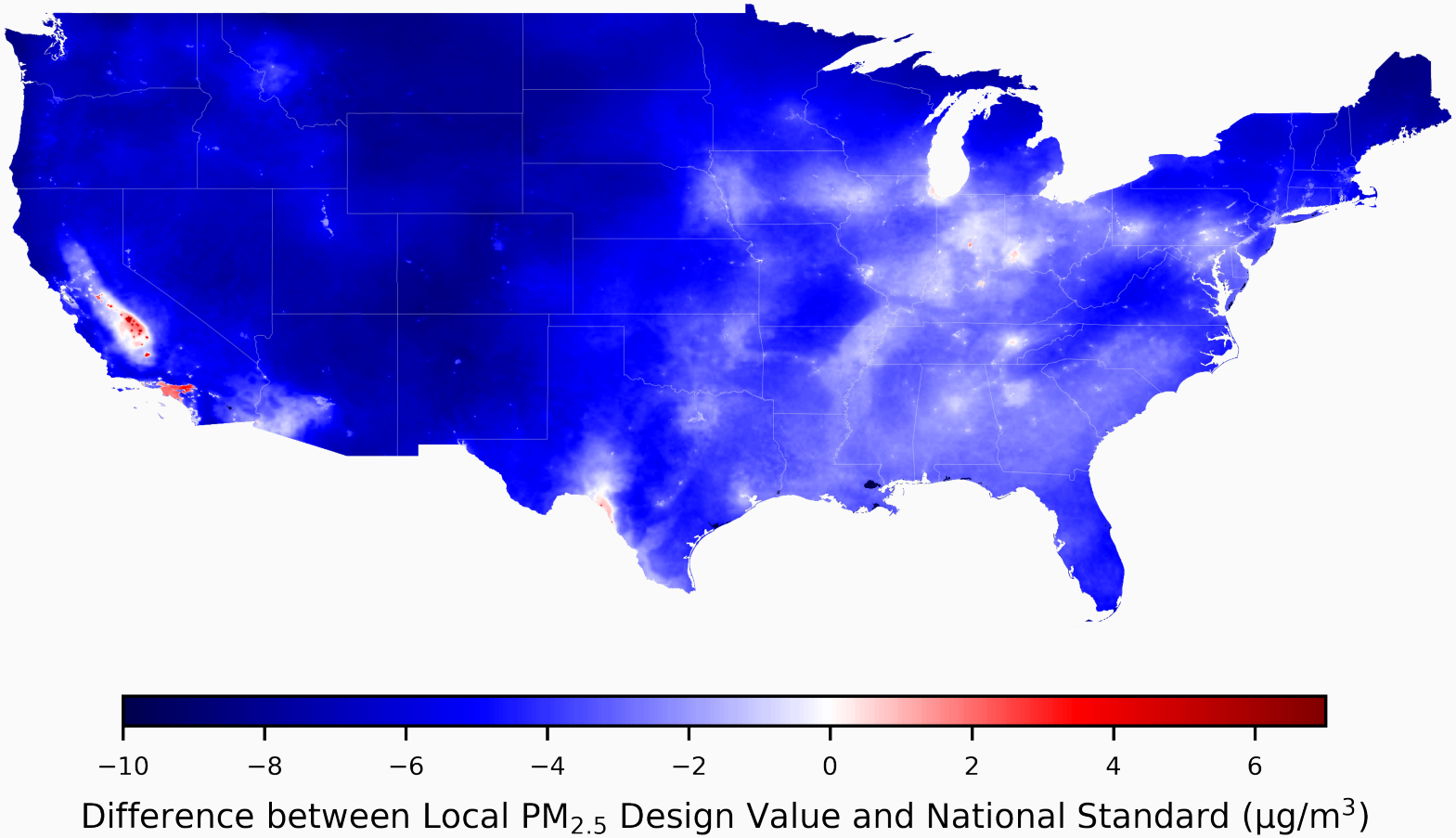
Montiors EPA, 1999–2017 (lat/long, days of operation, flag for NAAQS monitor, etc.)

Satellites Composite data from Dalhousie (van Donkelaar et al. 2019).

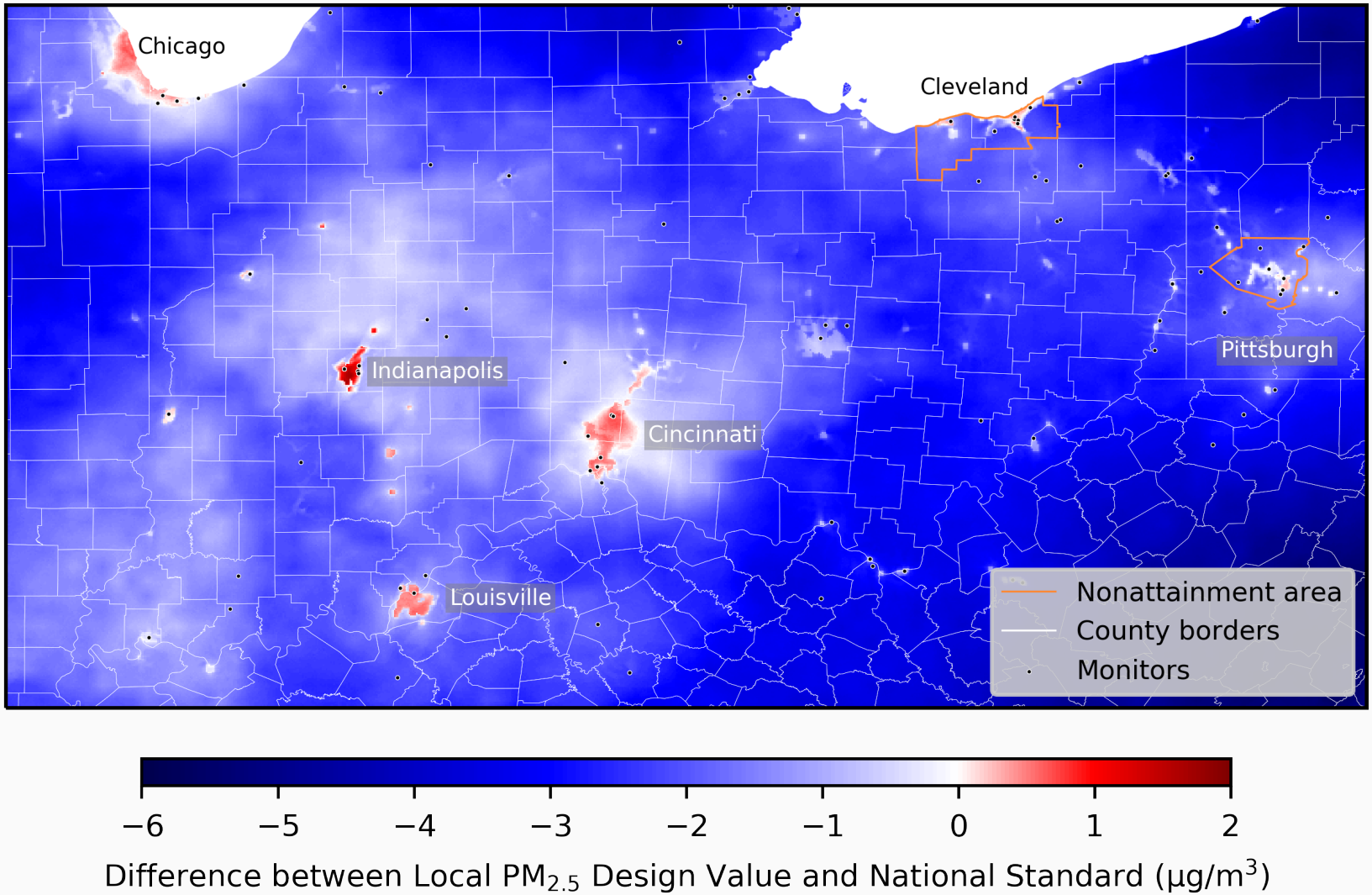
- MODIS, MISR, SeaWIFS
- GEOS-Chem
- Calibrated to North America
- Annual average $\mu g/m^3$ $PM_{2.5}$ for $0.01° \times 0.01°$ grid (~ 1 km^2).

Issue with satellites: Actually measure aerosol optical depth (AOD), must be calibrated.

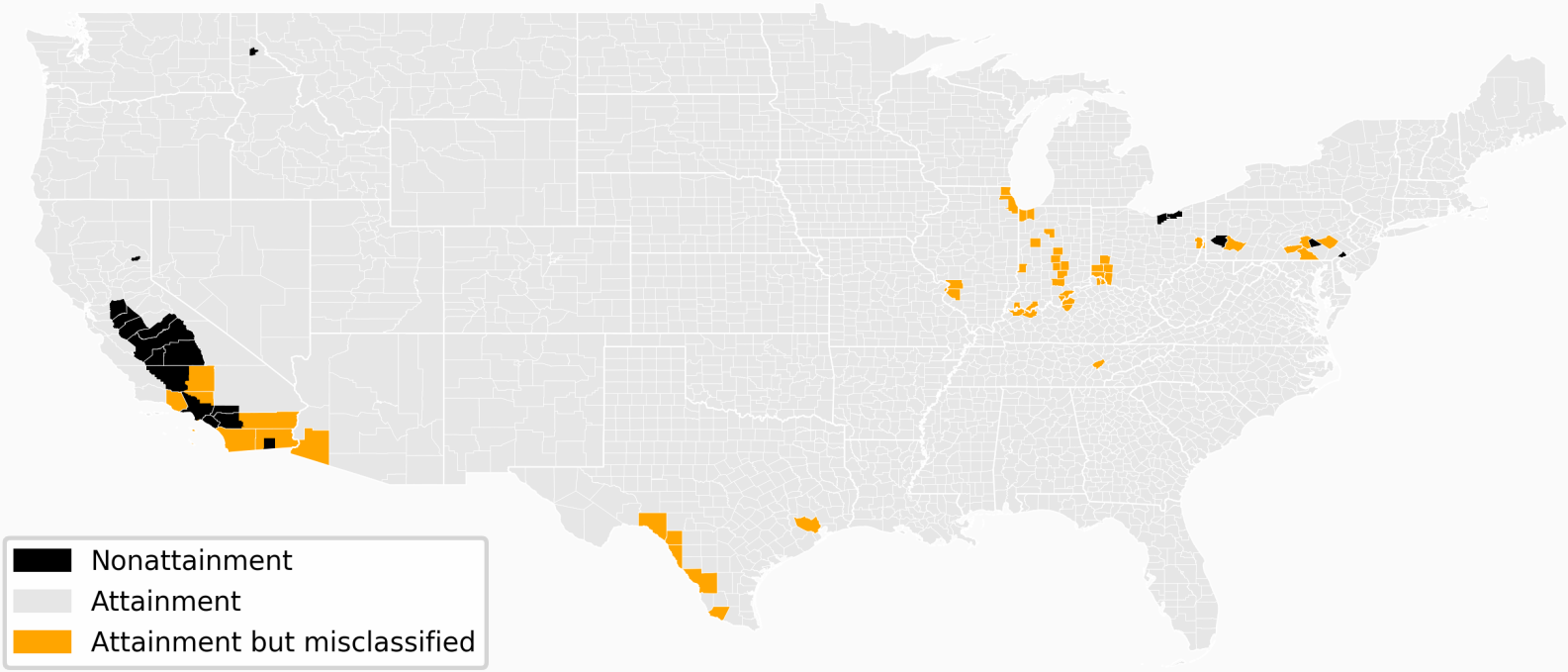
$PM_{2.5}$ Concentration and Attainment Status, 2011–2013



$PM_{2.5}$ Concentration and Attainment Status, 2011–2013



Counties misclassified under $PM_{2.5}$ 2012 annual standard



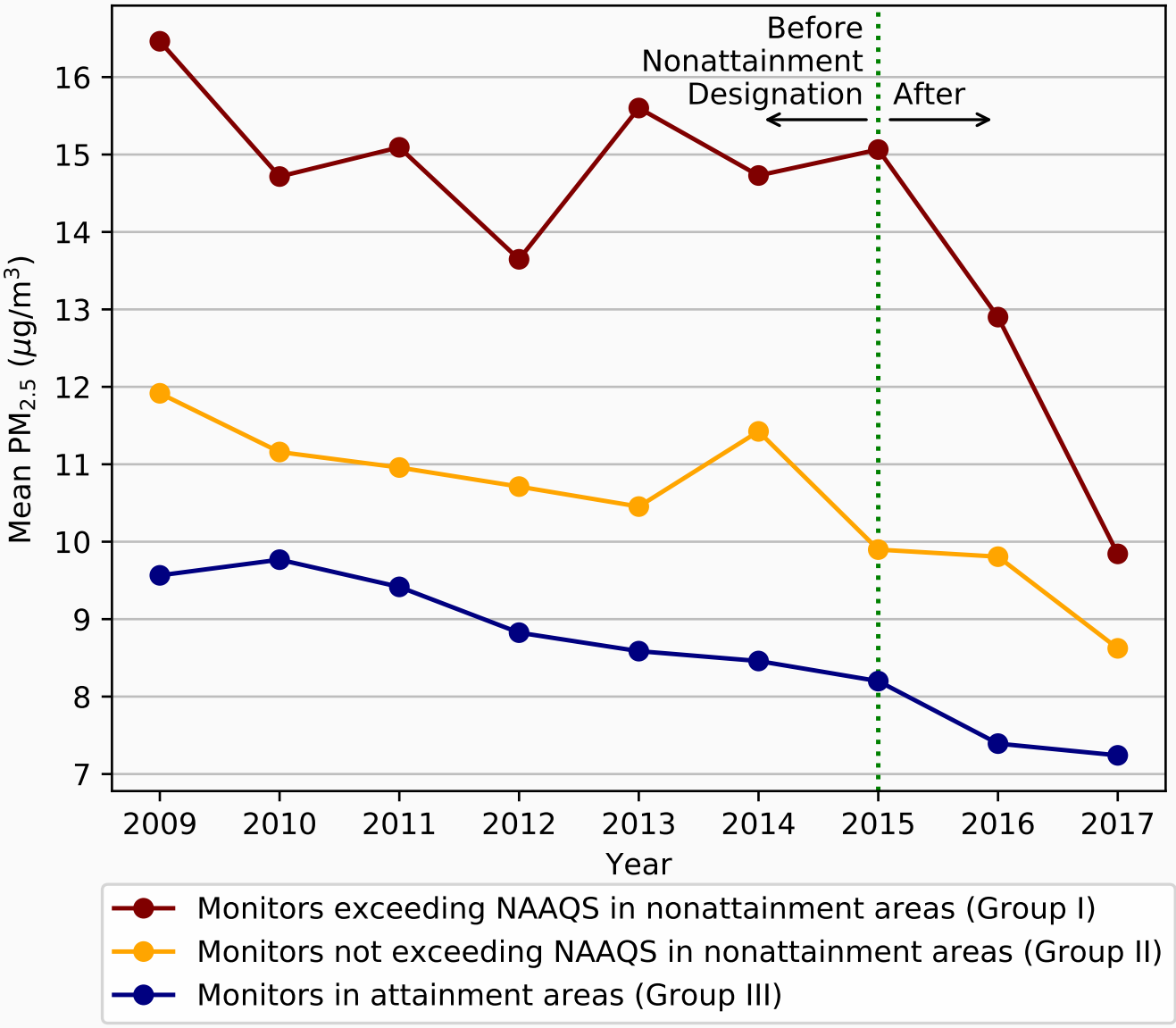
How much misclassification?

24.4 million people in misclassified counties

- Split between counties with and without monitors
- More likely to be rural, White, or Black
- Income and education groups hit equally

What is the cost?

Average monitor readings by attainment and NAAQS status



Excess Mortality Cost, 2016–2017

1. Estimated regulator effect (with spillovers): $51 billion
2. Scale exposure to meet NAAQS: $25.2 billion
3. Reduce violating areas to NAAQS (“peak shave”): $5 billion

Conclusion

- Satellite data can't be used directly for designations
- But they can inform monitor placement (sanity check)
  - This does *not* require change to CAA
- Benefits are potentially large.
- **Next:** Better enforcement areas?

Thanks!

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