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Methods in Air Pollution Accountability Research: The Case of Mobile Source and Electricity Generating Unit Policies

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Stories of Policy Success: Real Examples of Inspiring Science-based Air Quality Actions

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Air Pollution Accountability Studies

- Accountability chain has provided important framework
- Assess effectiveness of interventions and guide plans for future actions
- Broad in nature, address questions on different policies (or actions), in different settings, at different spatial and temporal scales
- E.g., assess changes in emissions, air quality, and/or health:
  - Following a well-specified, immediate, local regulation
  - Resulting from a national air quality standard
- No clear study design classification

HEI Working Group (2003); Boogaard et al. (2017)

Indirect vs. Direct Accountability Studies

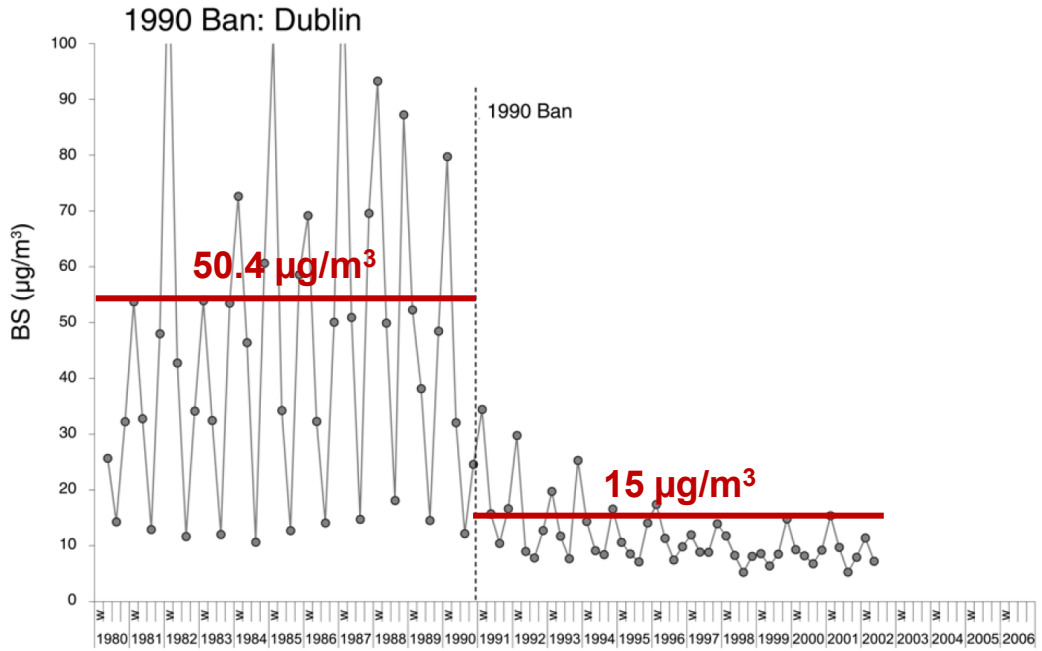
- Introduced by Zigler and Dominici (2014)
- **Indirect: "What is the relationship between exposure to pollution and health outcomes?"**
- **Direct: "What is the relationship between a specific regulatory intervention and health?"**
- Note epidemiological perspective; evaluating accountability chain systematically from one link to next more "direct" than from action straight to outcome
- Methods within both buckets important within the accountability study toolkit
- Key challenge is disentangling policy-related impacts from other factors that influence air pollution and/or health

Zigler and Dominici (2014); Zigler et al. (2016); Boogard et al. (2017)

Estimating the Impacts of Abrupt Localized Action

Ireland Coal Bans → Δ Ambient Air Quality

- Irish government banned the marketing, sale, and distribution of coal in Dublin on September 1, 1990; further bans in other cities in 1995 and 1998
- Found immediate impacts on pollution; e.g., 70% difference (reduction) in BS levels, mostly due to reduced winter-time levels



Dockery et al. (2013)

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- Clancy et al. (2002) and Dockery et al. (2013) investigated the health impacts of the coal ban

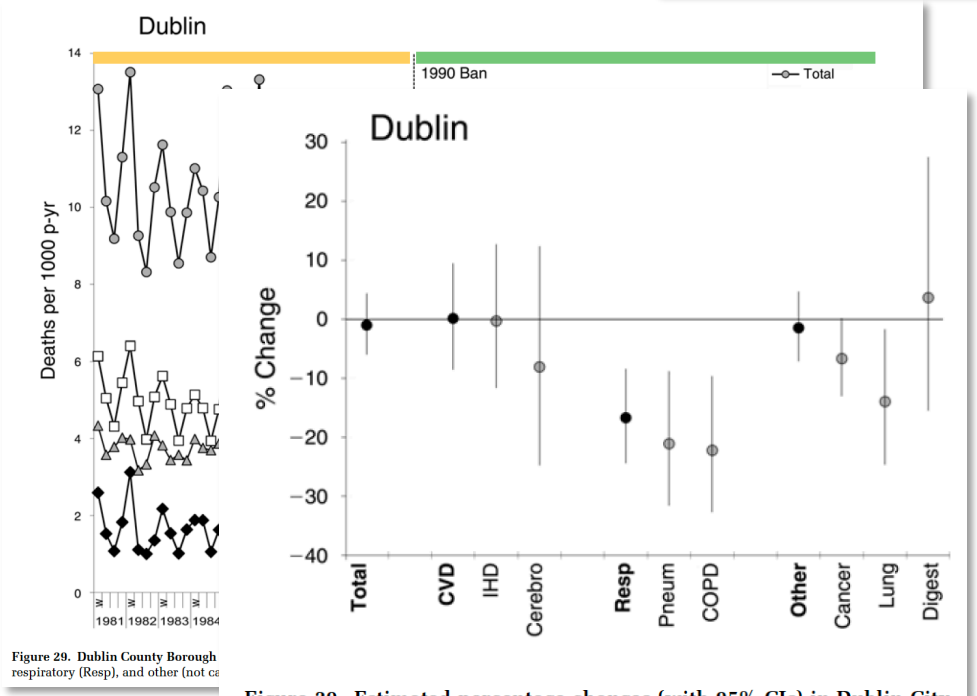


Figure 29. Dublin County Borough respiratory (Resp), and other (not ca

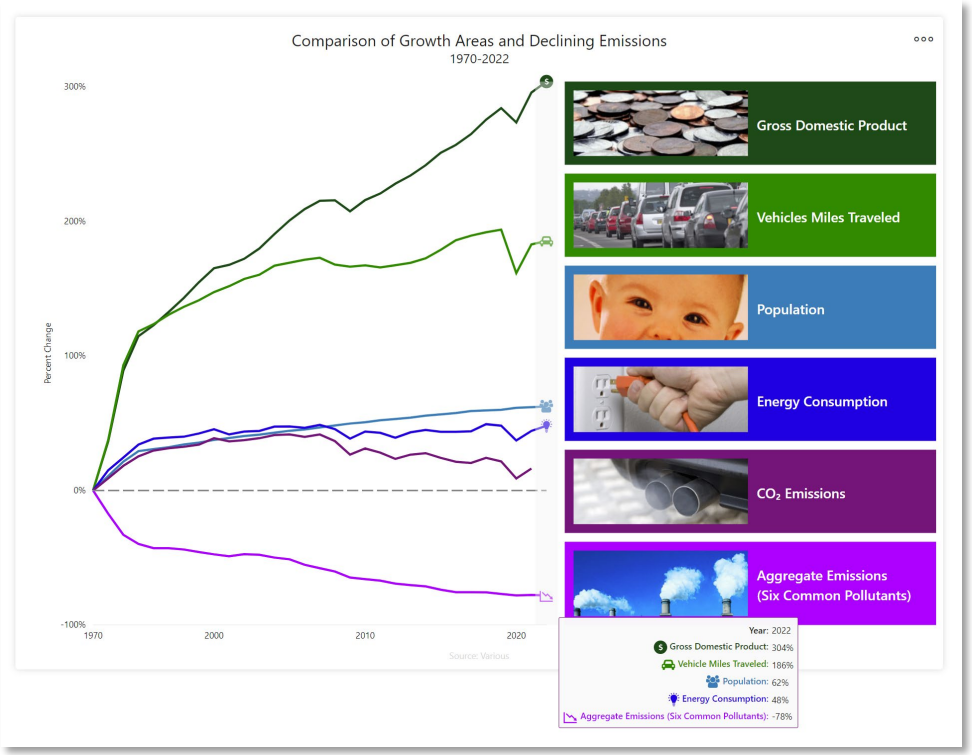
Figure 30. Estimated percentage changes (with 95% CIs) in Dublin City mortality rates by cause after the 1990 coal ban compared with pre-ban rates, adjusted for smoothed mortality rates by cause in Coastal counties, influenza weeks, and temperature (1981–2004). Causes include total, car-

Dockery et al. (2013)

Estimating the Impacts of Multiyear Regulation

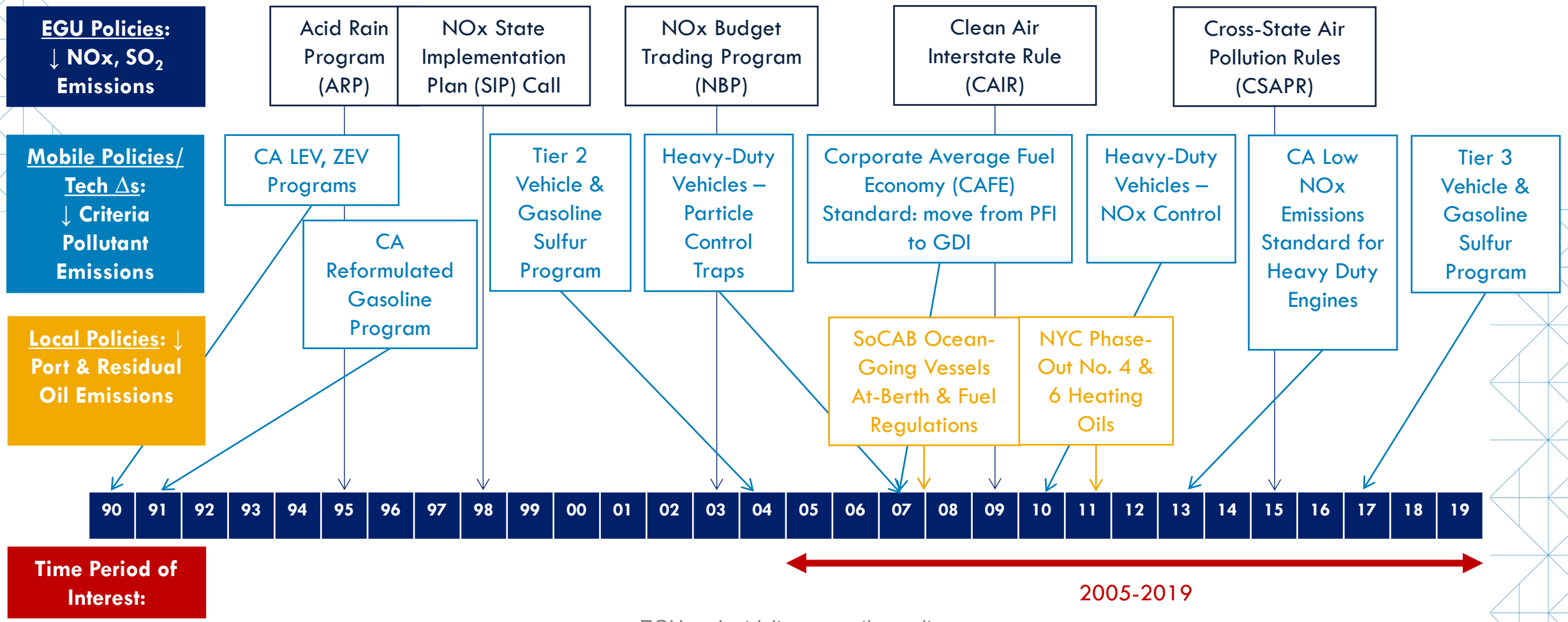
US AQ Policies → Δ Emissions → Δ Ambient Air Quality

- Few studies on impacts of actions implemented over longer time periods and larger spatial scales
- E.g., national policy measures resulting from US Clean Air Act
- Since 1970, 78% reduction in emissions and considerable improvements in air quality



https://gispub.epa.gov/air/trendsreport/2023/#growth

Start of Key US Air Quality Policies Over Time



EGU = electricity generating unit

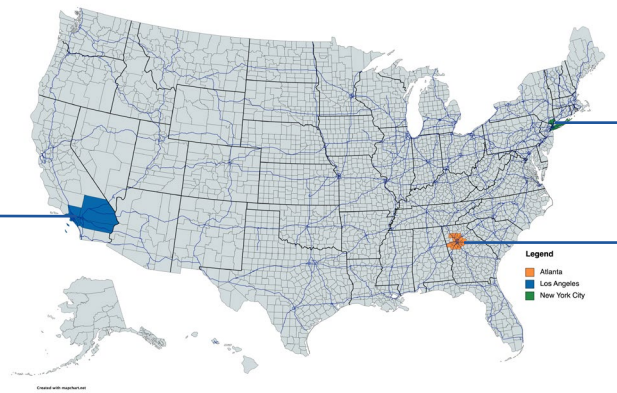
Consider Counterfactuals Along Accountability Chain

US AQ Policies → Δ Emissions → Δ Ambient Air Quality → Δ Health Outcomes

→Estimate what emissions, pollutant concentrations, and health outcomes (ED visits, hospitalizations) would have been in the absence of selected policies targeting EGUs, mobile sources, port activities

→Three US cities, 2005-2019

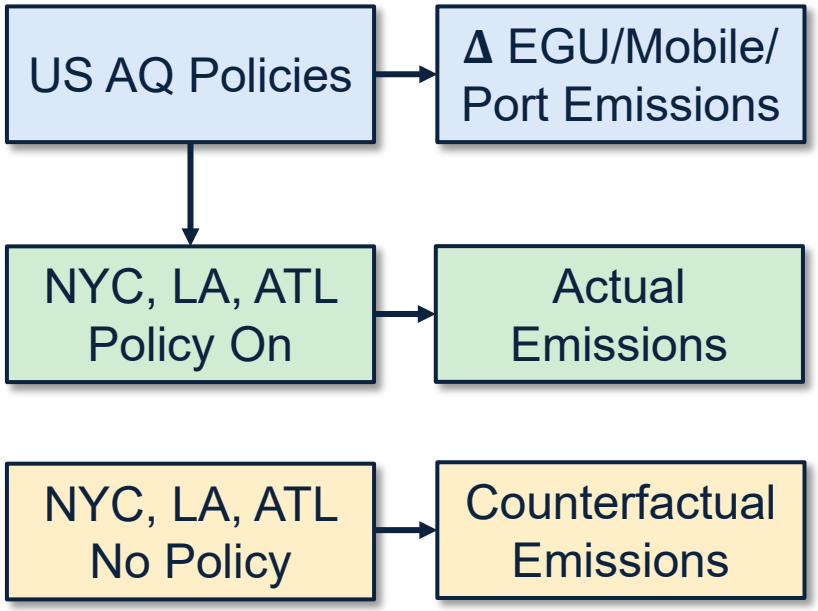
Los Angeles
- Mobile sources
- Port activities



New York City
- Coal-fired power plants
- Mobile sources
- Large building space heating

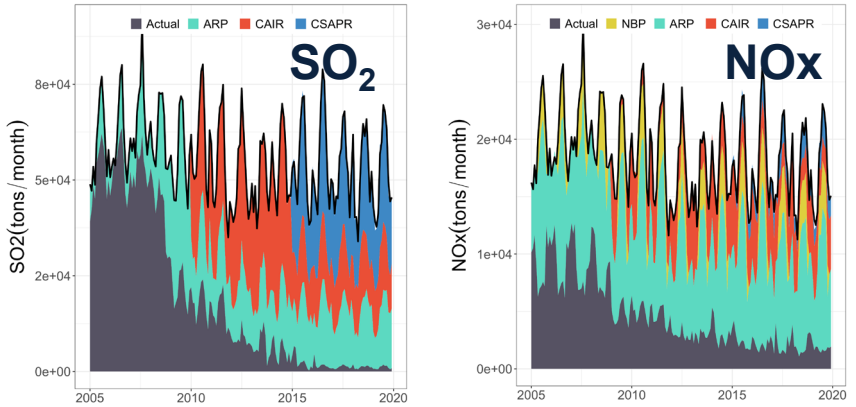
Atlanta
- Coal-fired power plants
- Mobile sources
- Biogenics

1. Calculate Impact of Policies on Emissions

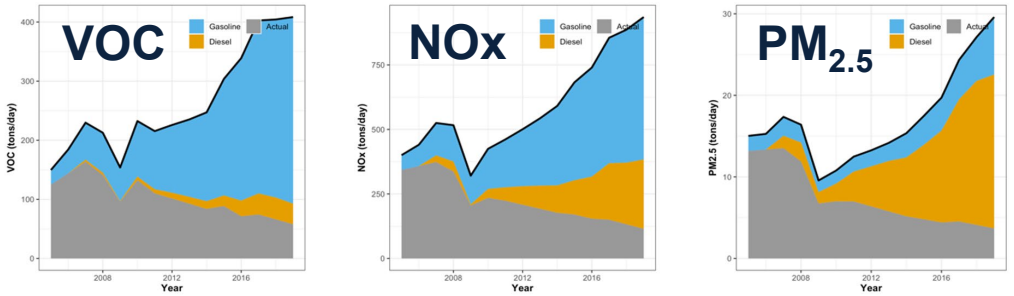


- Actual: measurements, national emissions inventory, mobile source emissions models (MOVES3, EMFAC)
- Counterfactual: Henneman et al. (2019), MOVES3, EMFAC

Actual and Counterfactual EGU Emissions, Georgia

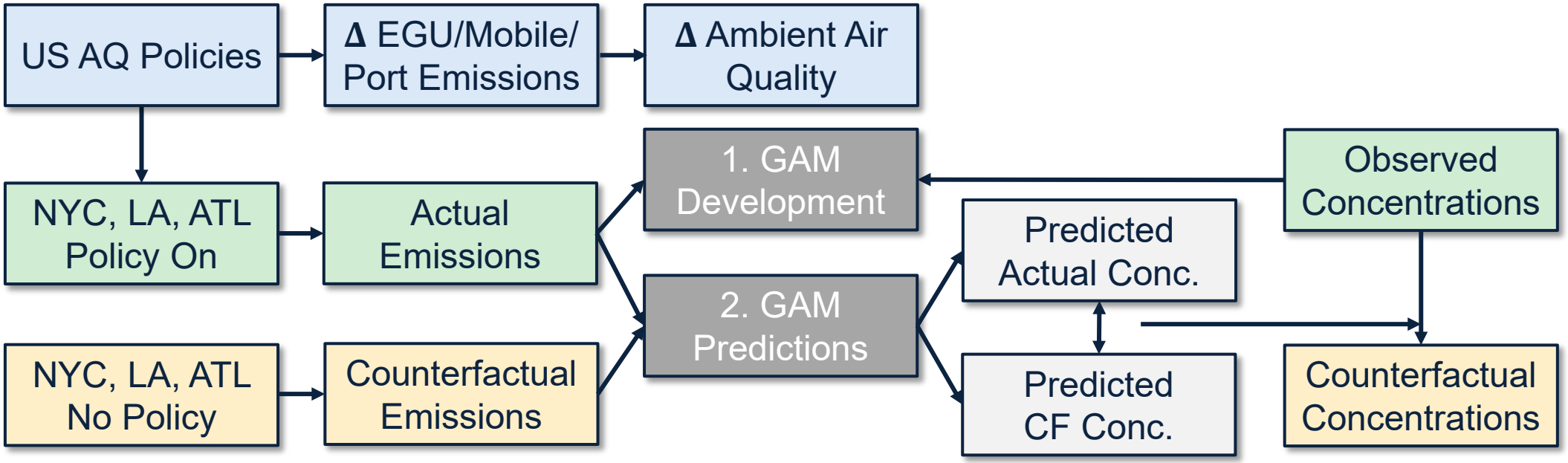


Actual and Counterfactual Mobile Emissions, Georgia



Mei et al. (2023); Gao et al. (2025)

2. Quantify Policy-Related Impacts on Air Quality



- Daily observed concentrations from 6 CSN sites in the 3 cities
- $PM_{2.5}$, CO, NO_2, SO_2, O_3, major $PM_{2.5}$ species and sources

Δ = Emissions Impact

Gao et al. (2025a, 2025b)

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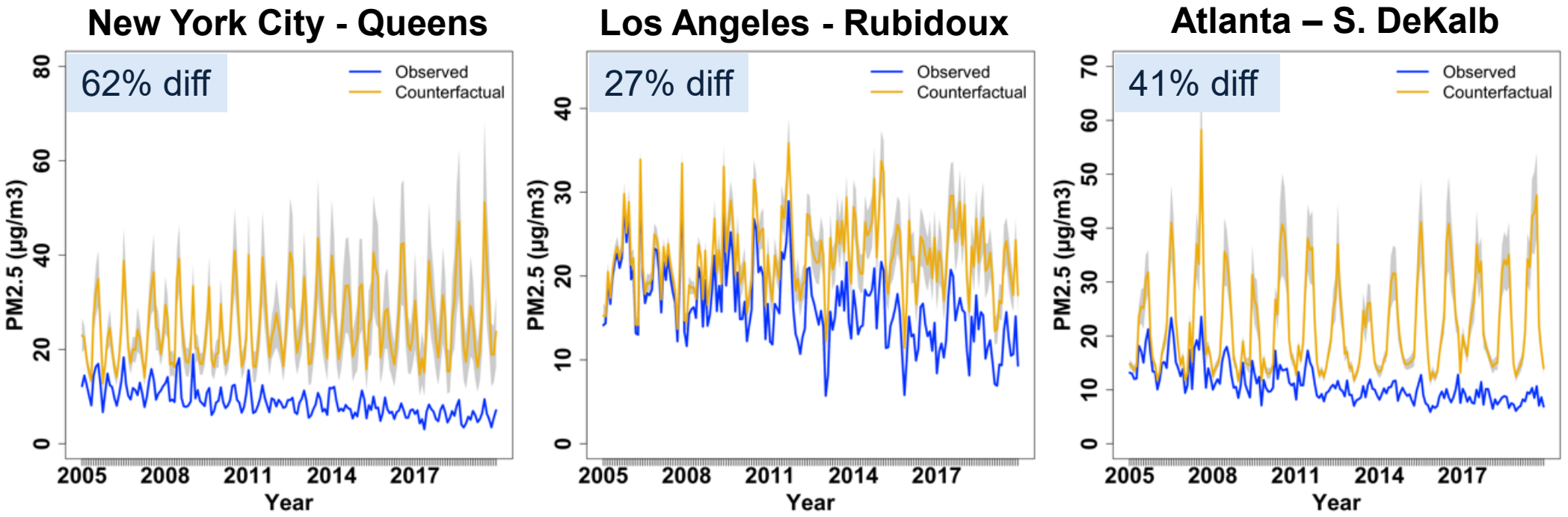
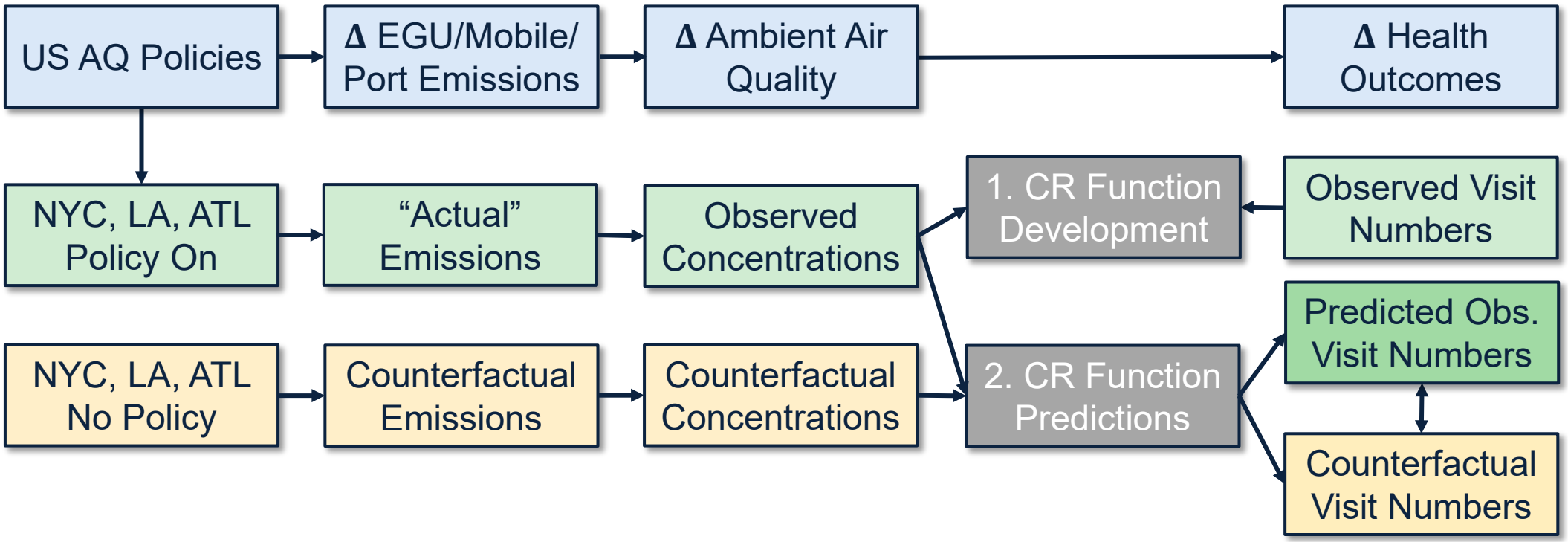


Observed
Counterfactual
Uncertainty in CF

→ Example results for $PM_{2.5}$
→ Also quantified for other criteria pollutants, major $PM_{2.5}$ components and sources

Gao et al. (2025a, 2025b)

3. Estimate Policy-Related Health Benefits



- Daily observed number of ED visits & hospitalizations from state agencies
- CR functions from multi-pollutant Poisson timeseries models at each city-site

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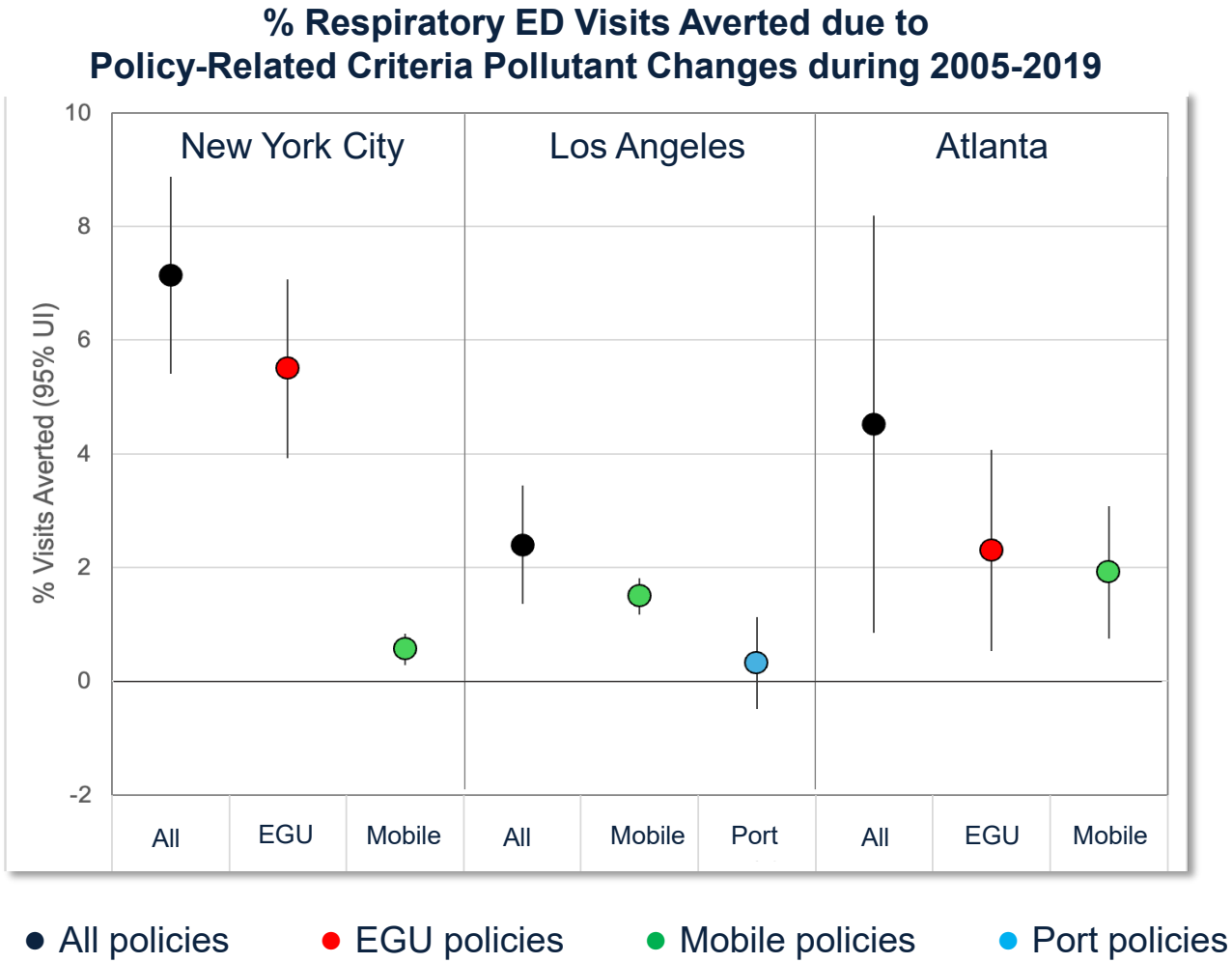

- 2.4 to 7.1% respiratory ED visits averted due to policy-related criteria pollutant changes
- → 185,000 respiratory ED visits averted during 2005-2019
- In NYC, EGU > mobile
- In LA, mobile > port
- In ATL, EGU ≅ mobile
- Consistent with earlier Atlanta findings (Russell et al., 2018; Abrams et al., 2019)

Strengths

- **Counterfactual design → direct assessment of multiple policies implemented over multiyear timeframe affecting emissions and concentrations of multiple pollutants**
- Quantified uncertainties and propagated them through the health benefits analyses
- Long study period (15 years)
- Health benefits used local CR functions for the study period from multi-pollutant models
- Three cities with different pollution source mixtures
- ED visits and hospitalizations

Limitations

- **Approach is complex, with uncertainties introduced throughout**
- **Assumptions made throughout not possible to validate**
- Challenges estimating counterfactual emissions from different sources
- Nuance in interpretation of benefits as visits averted (e.g., avoided completely vs. delayed)
- Generalizability – study populations resided within 10 miles of CSN sites
- Statistical power

Reflections

- Evaluating benefits of regulatory and other AQ actions challenging!
- Requires clarity on question of interest, and appropriate study design and data to address the question
- Advanced by interdisciplinary inputs and collaboration
- Current study suggests US air quality policies successful in reducing emissions, concentrations of multiple pollutants, and averting cardiorespiratory ED visits
- Health benefits likely much greater than estimated here (other cardiorespiratory health endpoints; other short- and long-term health outcomes)
- Next steps…

Acknowledgements

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  - David Rich (Co-PI, U Rochester)
  - Armistead Russell (Georgia Tech)
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  - Haisu Zhang (Emory)
  - Rebecca Zhang (Emory)
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https://scholarblogs.emory.edu/envision/

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Thank You!

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