Decomposing Trends in Air Pollution Disparities from U.S. Electricity

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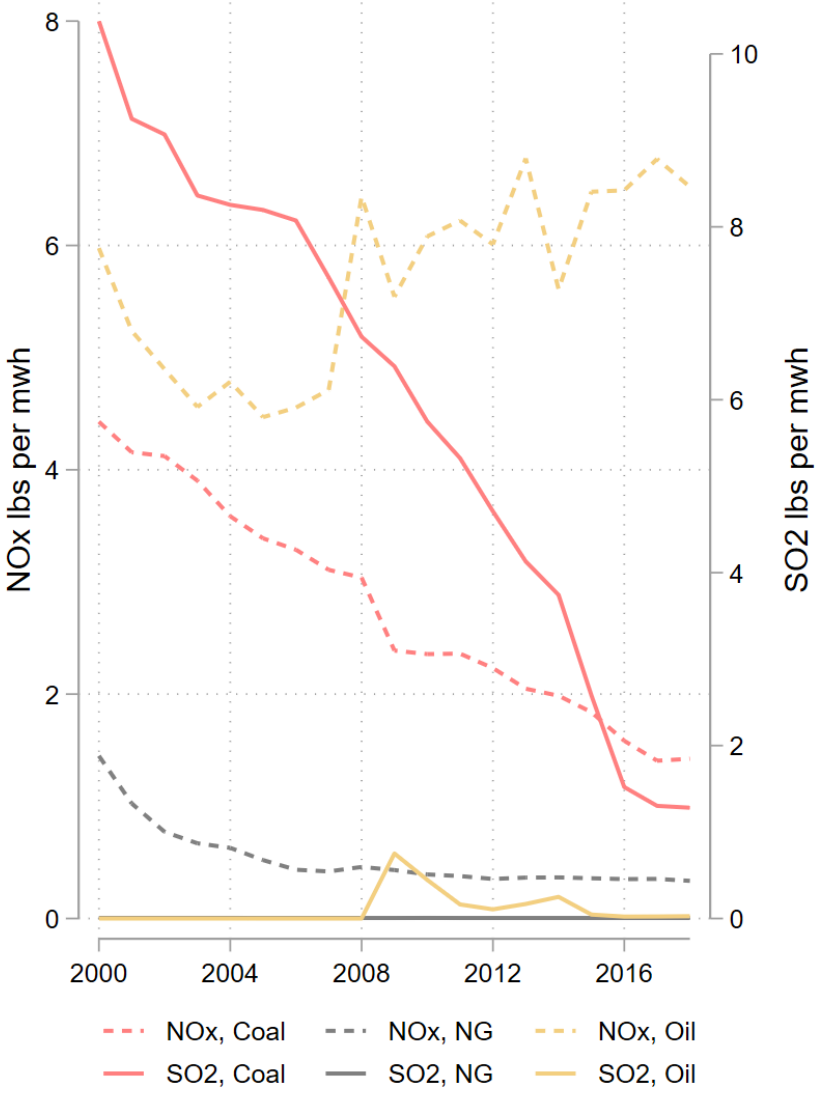
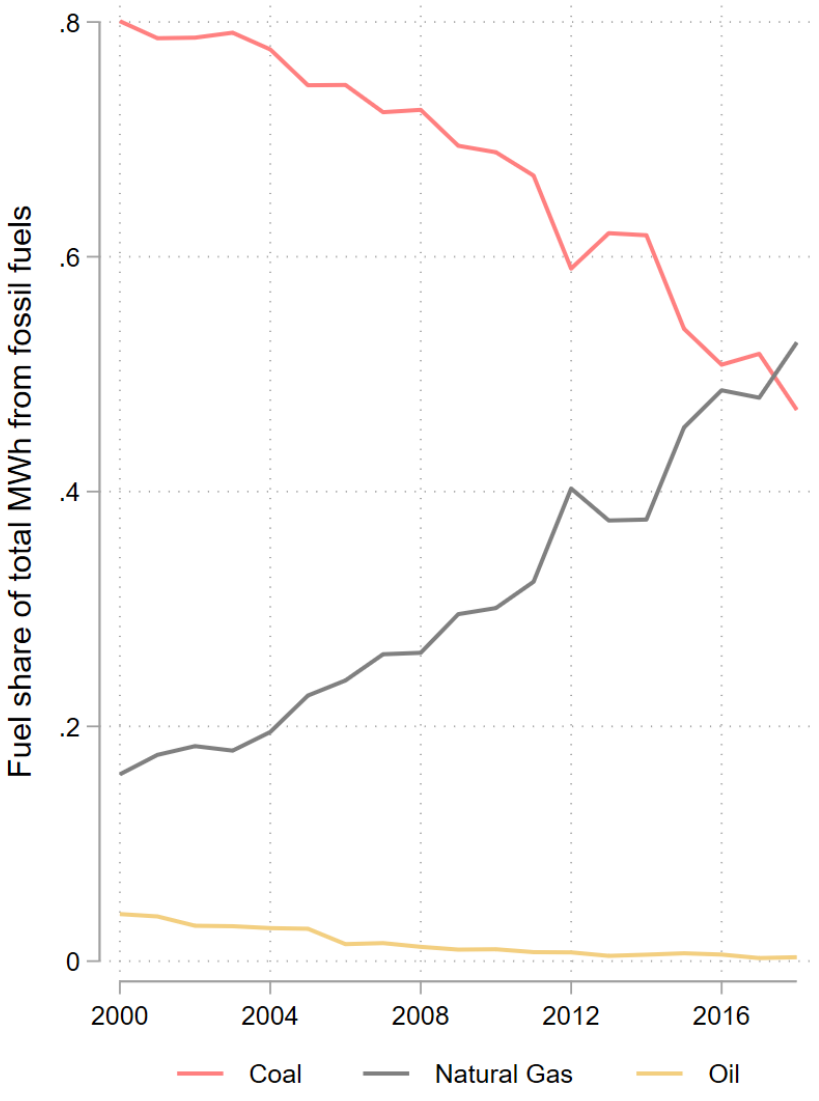
NBER EEPE

U.S. electricity: two key developments

Emission intensities



Fuel shares



Air pollution disparity implications

Uneven spatial distribution of:

- power plants and technologies
- demographics of downwind individuals

Emerging environmental justice concern:

Pollution disparity implications of local air pollution vs. climate policies?

Potential policy implications: If pollution disparities decrease due to spatially-differentiated changes in...

1. emissions intensities $\rightarrow$ local air pollution policies
2. coal-to-natural gas switching $\rightarrow$ climate policies

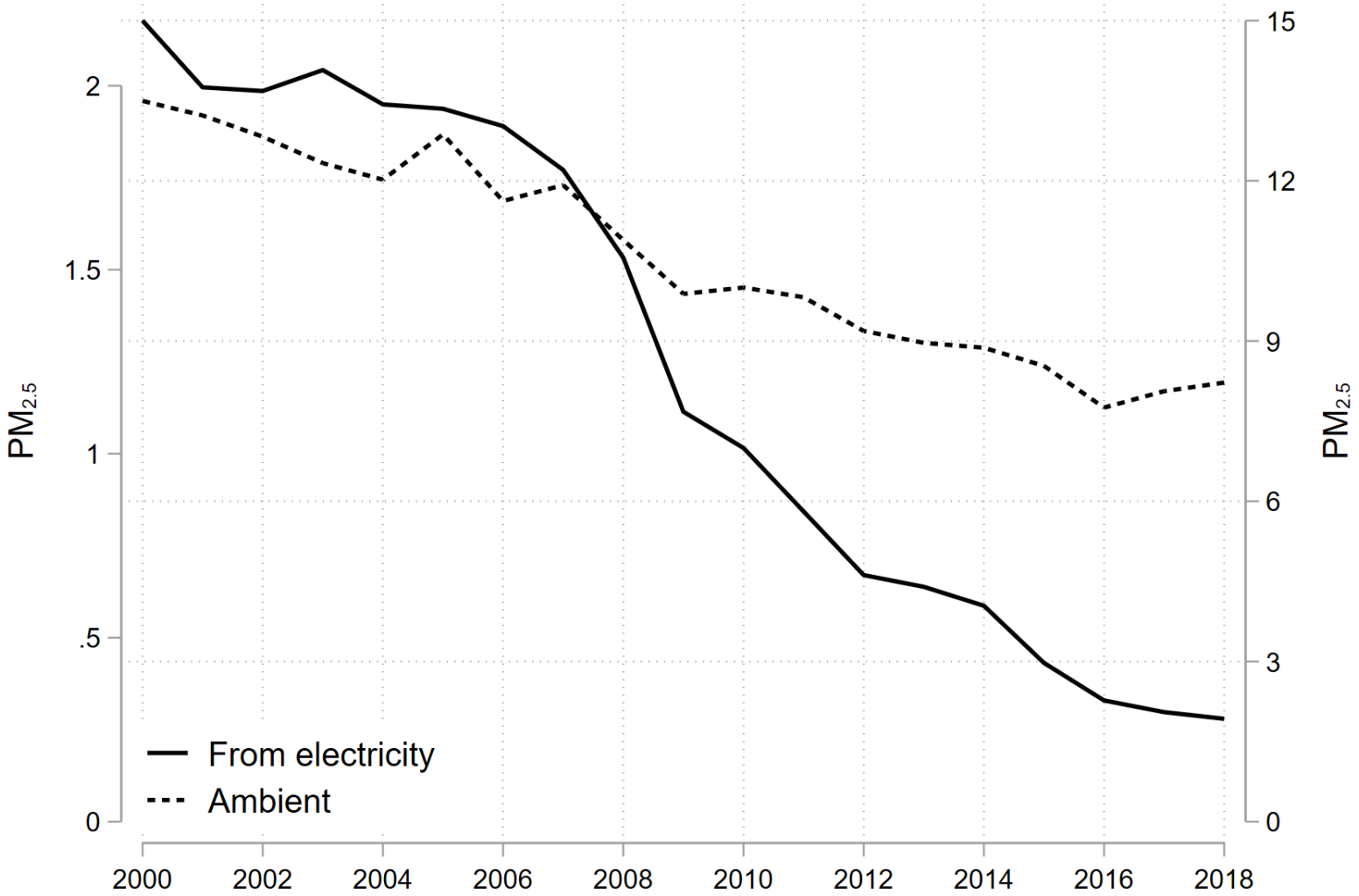
This paper

Questions:

1. What happened to U.S. $PM_{2.5}$ concentrations from electricity during 2000-2018?
   - Overall
   - By racial/ethnic groups
   - By income

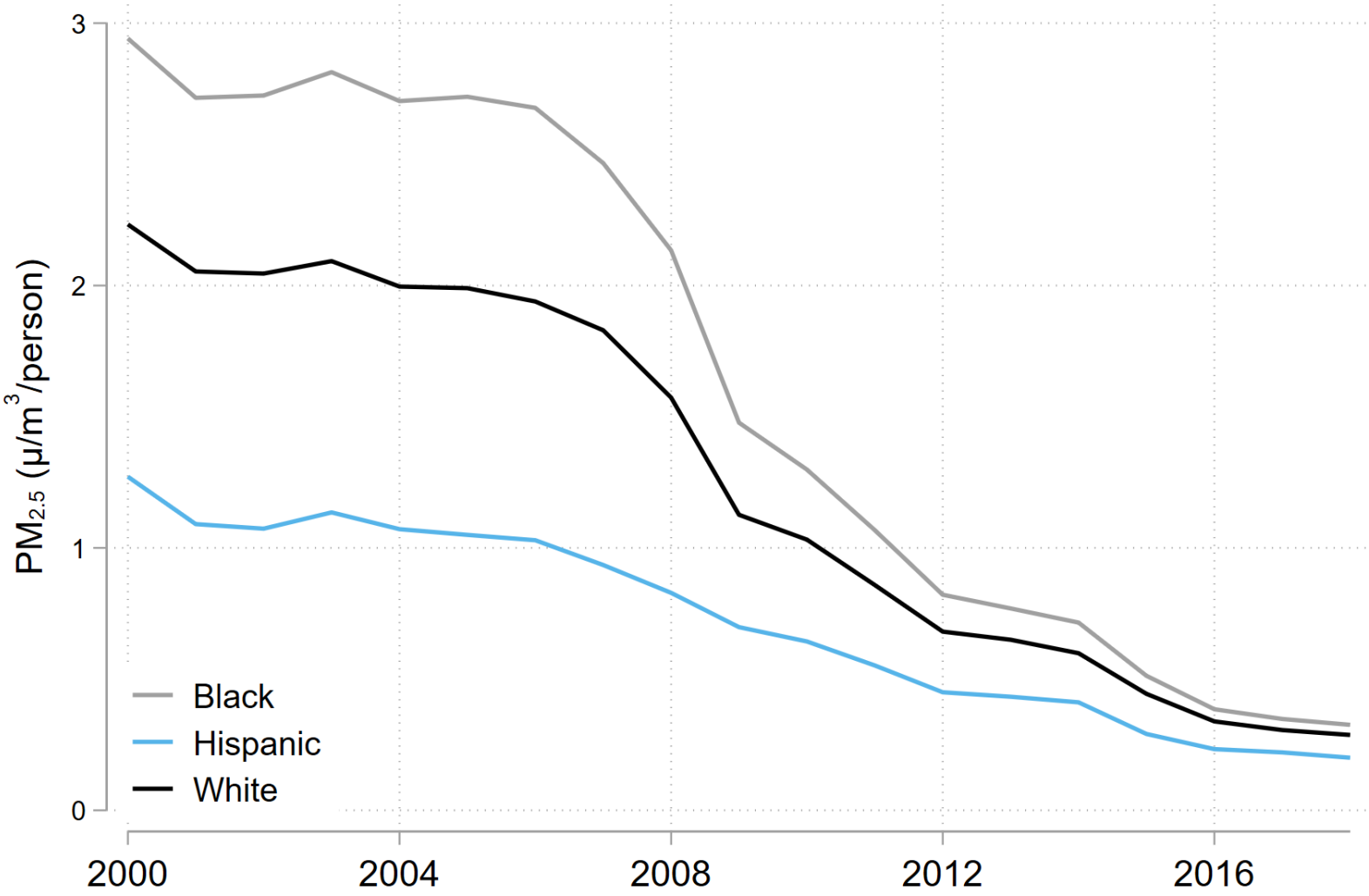
2. What drove trends in $PM_{2.5}$ concentration disparities? Contributions from changes in
   - total fossil fuel generation ("scale")
   - emissions intensities ("technique")
   - fossil market shares ("composition")
   - residential locations ("sorting")

Finding #1: Falling $PM_{2.5}$ concentrations



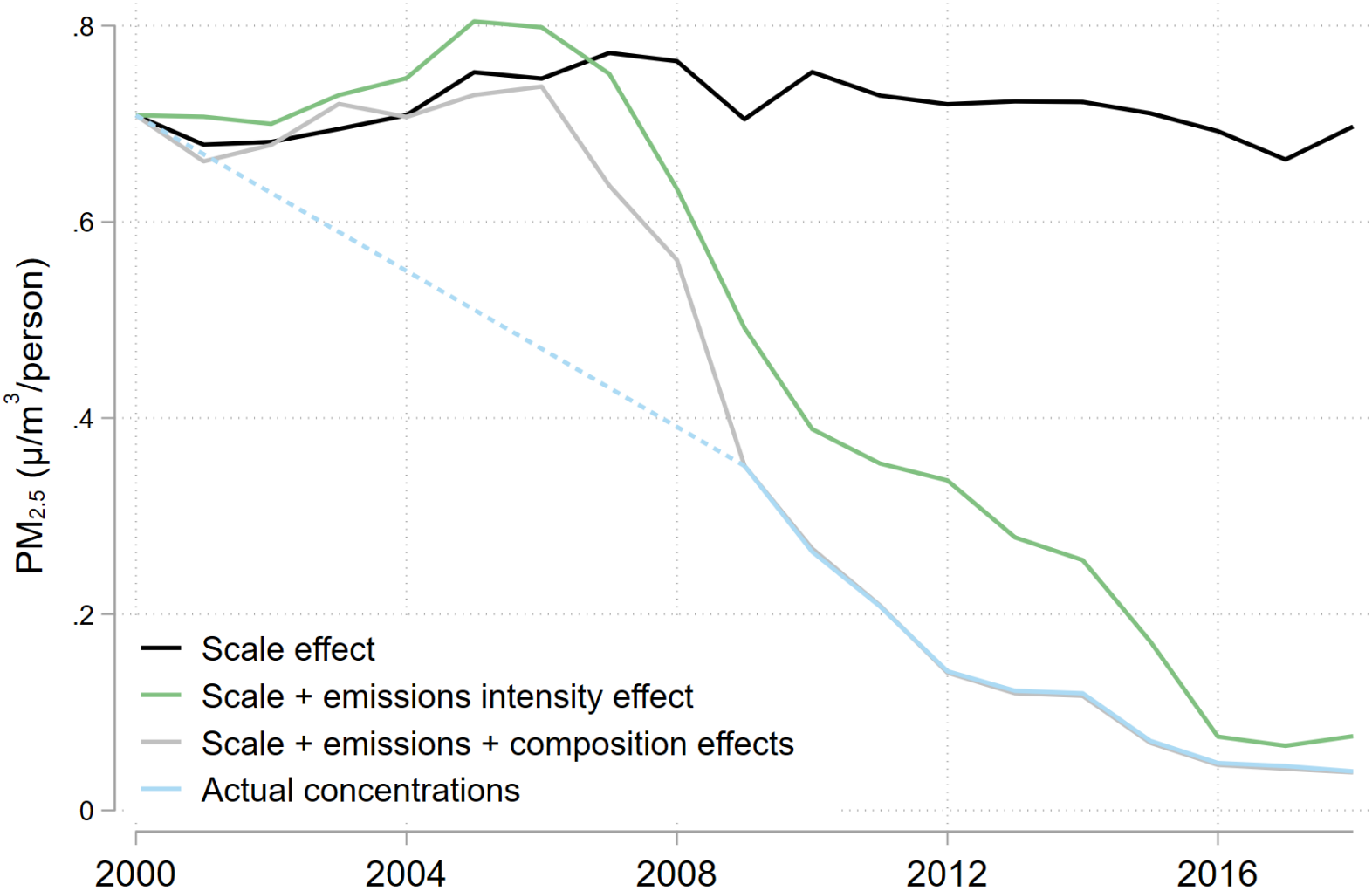
$PM_{2.5}$ concentrations from electricity have fallen by 87% overall, double the decline rate of ambient U.S. $PM_{2.5}$

Finding #2: Convergence in disparities



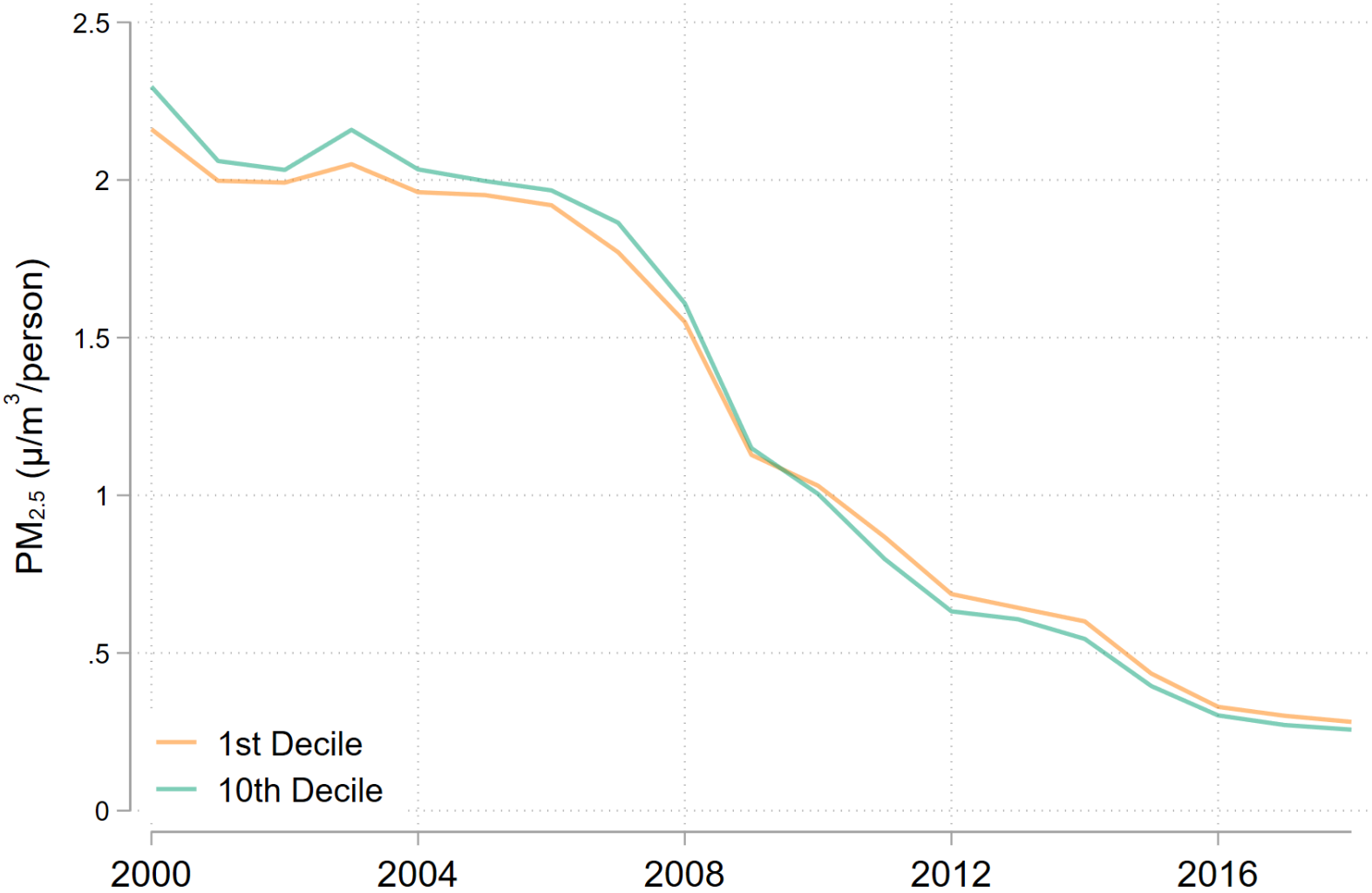
Convergence in $PM_{2.5}$ concentration gaps; 94% in Black-White gap; 92% in Hispanic-White gap .

Finding #3: Emissions intensity improvements play key role



Nearly all driven by spatially-varying emissions intensity improvements

Finding #4: Smaller disparities by income



Relatively small gap and trend by income differences

Contributions to the literature

Presence of pollution disparities

- Case studies (Bullard, 2000; Bowen, 2002; Ringquist, 2005; Mohai, Pellow and Roberts, 2009; Banzhaf, Ma and Timmins, 2019)
- Population studies (Colmer et al., 2020; Currie et al., 2021)

Role of policy in altering pollution disparities

- Local air pollution policy (Fowlie et al., 2012; Grainger and Ruangmas; Currie et al, 2021)
- Climate policy (Hernandez-Cortes and Meng, 2022; Weber, 2021)

Using a fine-resolution pollution transport model

- Addressing bias (Muller and Mendelsohn, 2007; Sullivan, 2017, Deschenes and Meng, 2018, Tessum et al., 2017)

Extending emissions decomposition approach

- Metcalf (2008), Levinson (2009), Shapiro and Walker (2018)

Data and Methods

Data

Electricity generating units

U.S. EPA Clean Air Markets Division:

- Continuous Emissions Monitoring Systems
- Electricity Generating Units (EGUs) over 25MW
- Hourly generation, fuel inputs, NO_x, and SO_2
- 2000-2018

EIA-860:

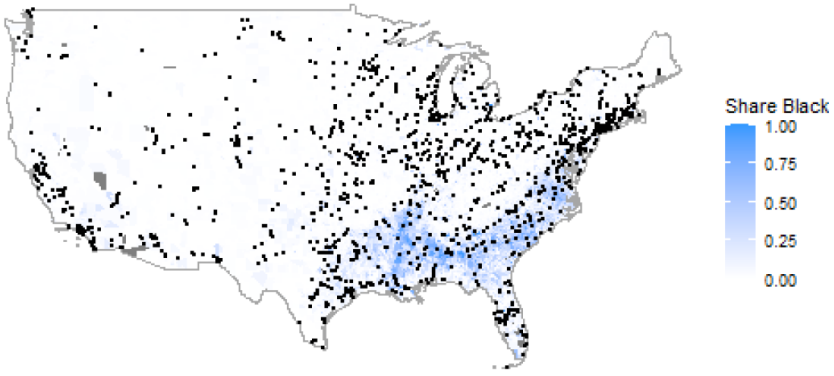
- Stack height, temperature, velocity, and diameter
- 2007, 2008, 2009, and 2011

Census tract demographics:

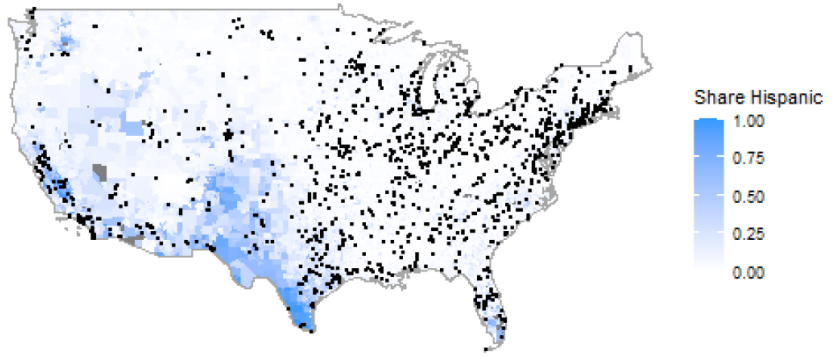
- 2000: Decennial Census
- 2009-2018: ACS

Demographic data (2018)

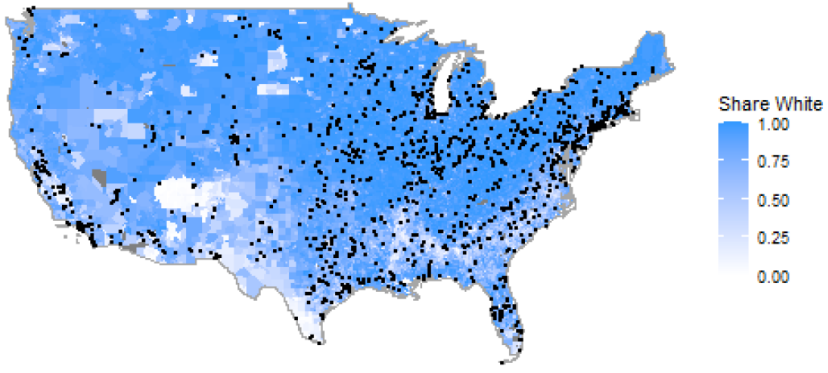
(a) Black share



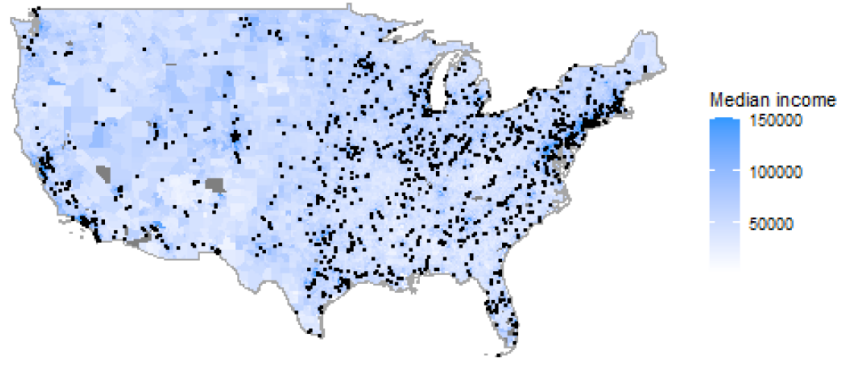
(b) Hispanic share



(c) White share



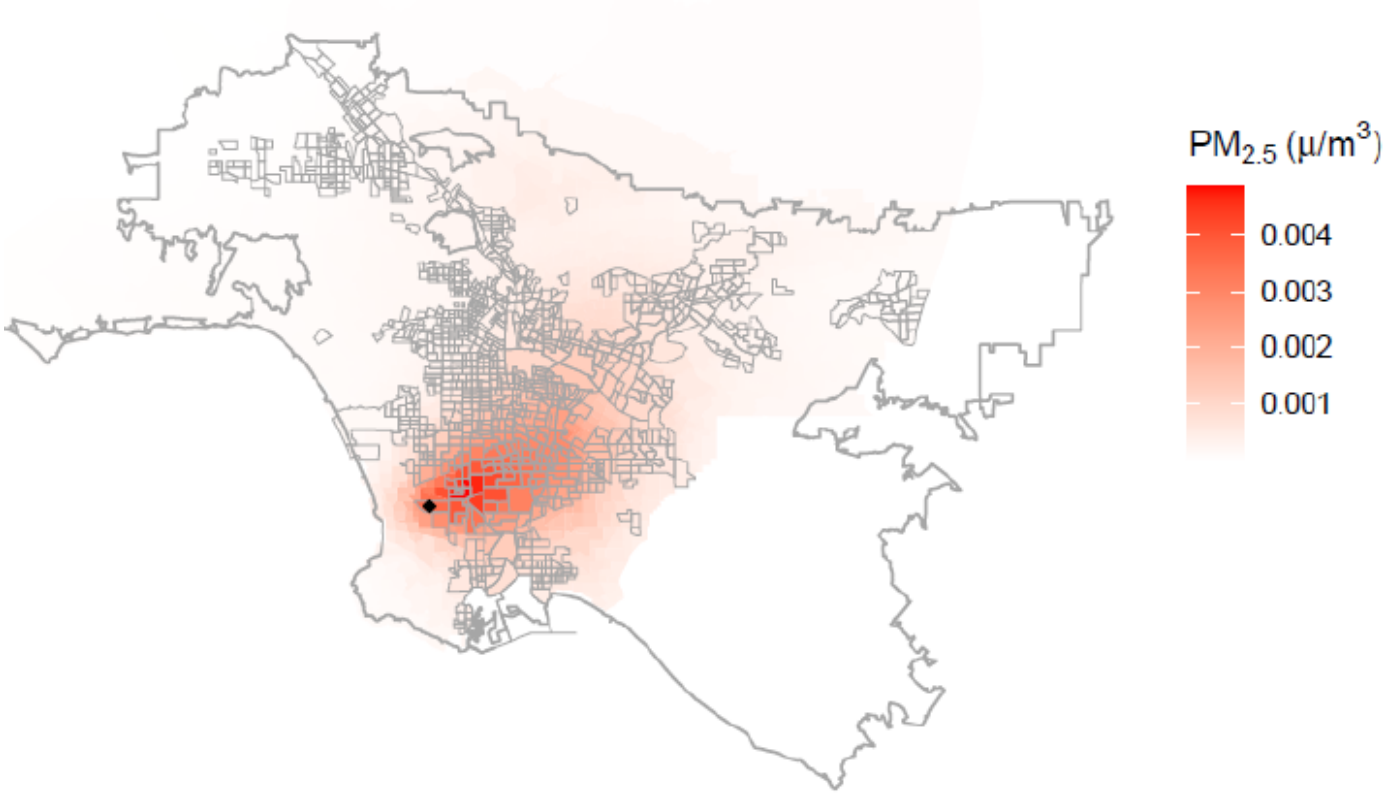
(d) Median income



Data

InMAP Source-receptor matrix (Tessum et al. 2017, Goodkind et al., 2019)

- Models total $PM_2.5$ (primary and secondary)



Method: from emissions to concentrations

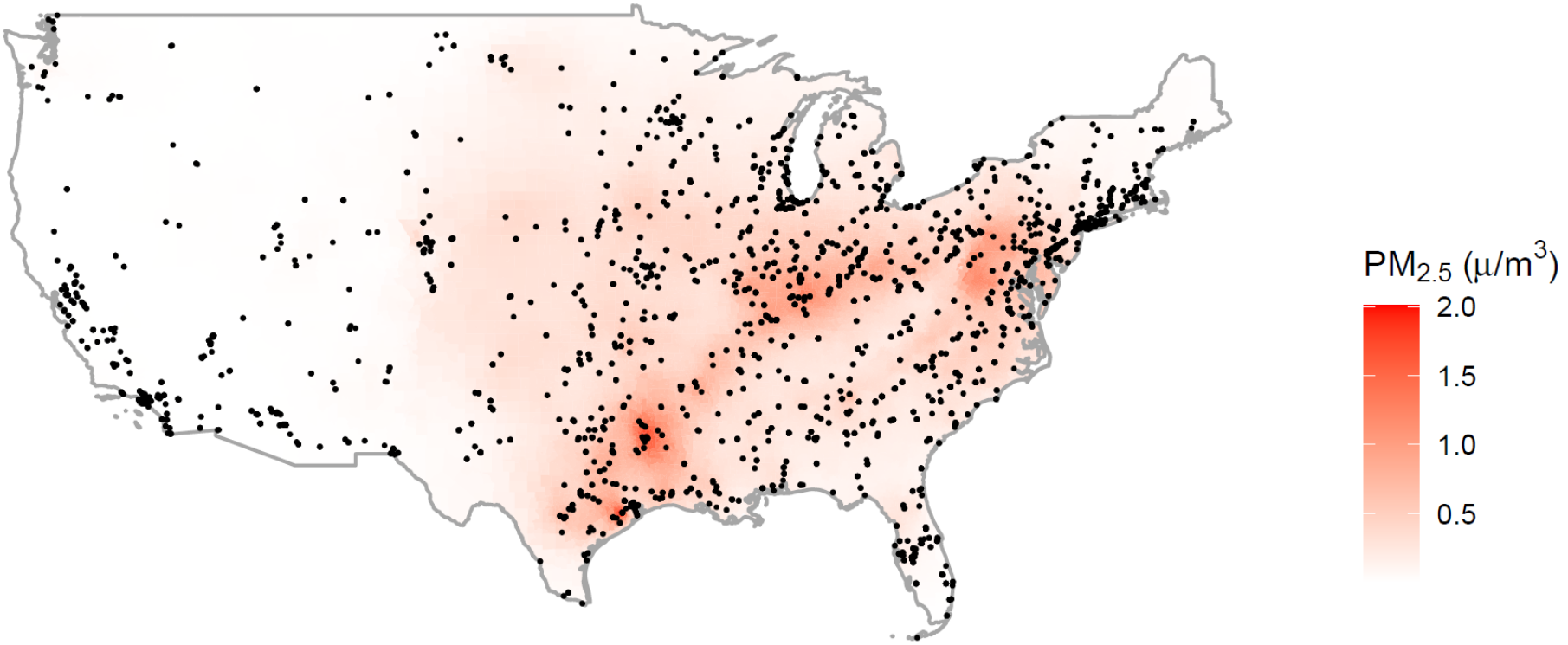
Pollution emissions from facility j in year t of pollutant p

$$E_{jt} = \underbrace{\phi_{jt}^{p}}_{\text{em. int.}} \underbrace{\delta_{jt}}_{\text{share}} \underbrace{Q_t}_{\text{total output}}$$

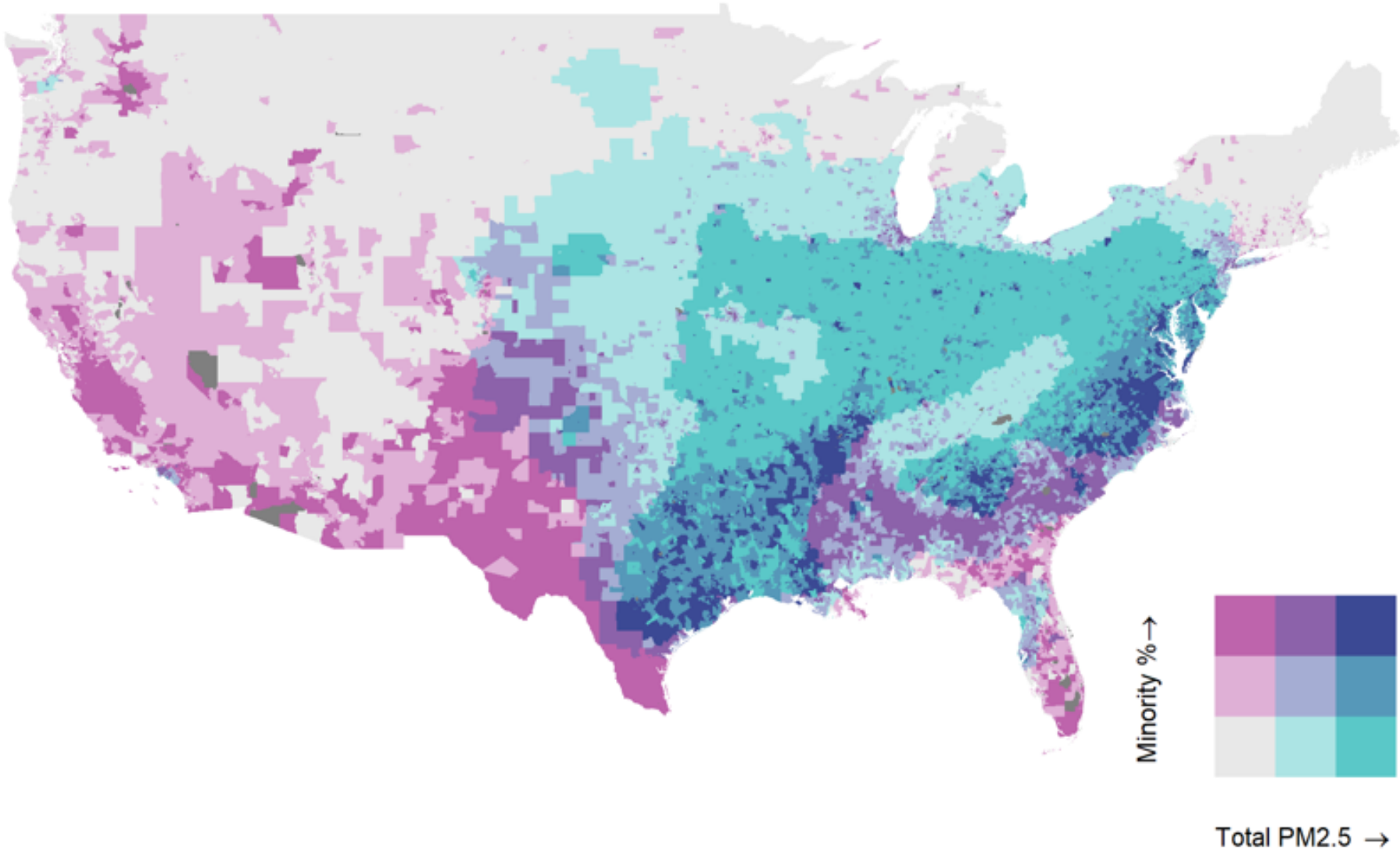
Pollution concentrations for census tract i in year t:

$$C_{it} = \sum_{p} \sum_{j} E_{jt}^{p} \underbrace{w_{ji}^{p}}_{SRM}$$

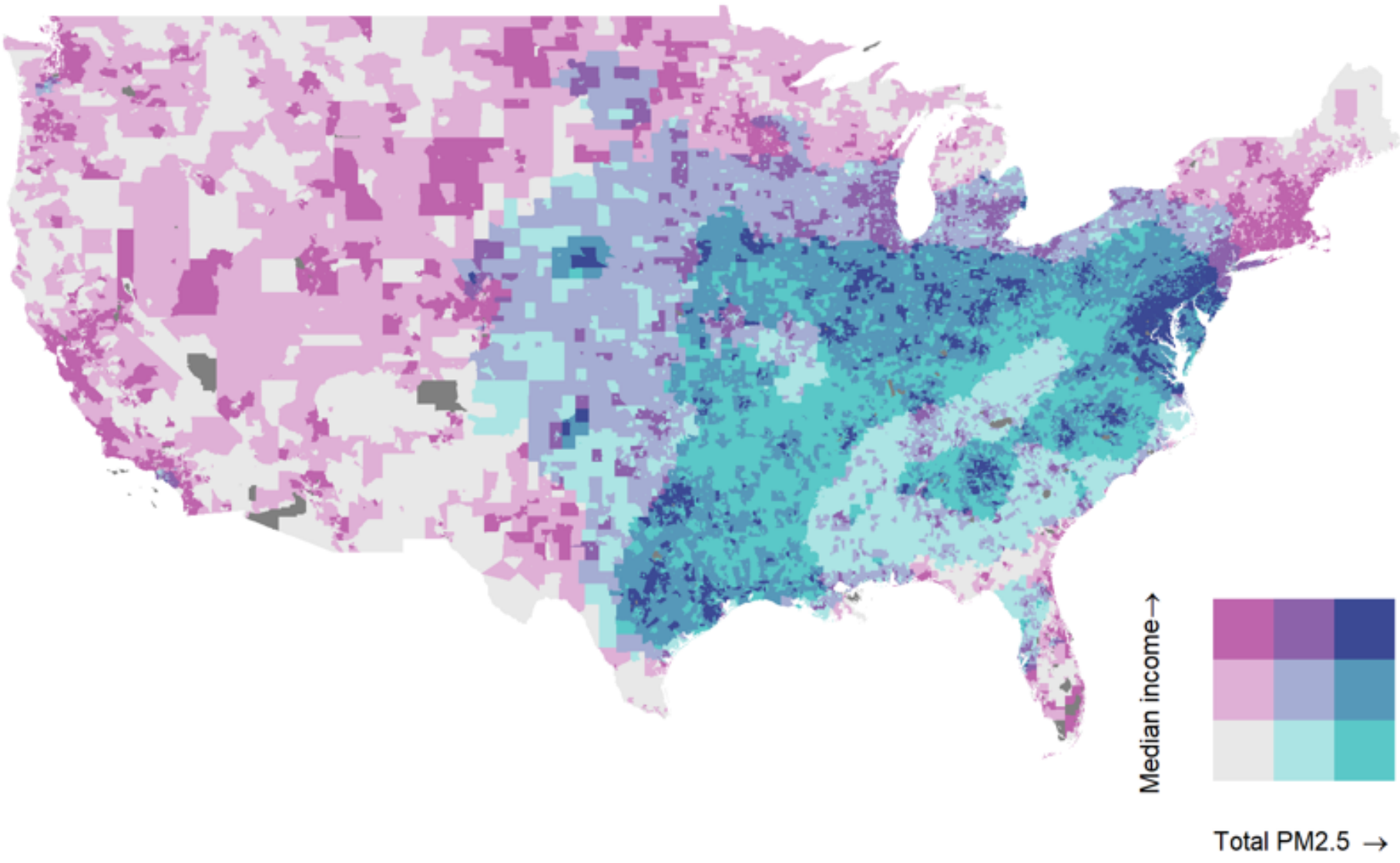
$PM_{2.5}$ concentrations from electricity (2018)



Current (2018) spatial pattern (% minority)



Current (2018) spatial pattern (median income)



Method: average pollution for individual by group

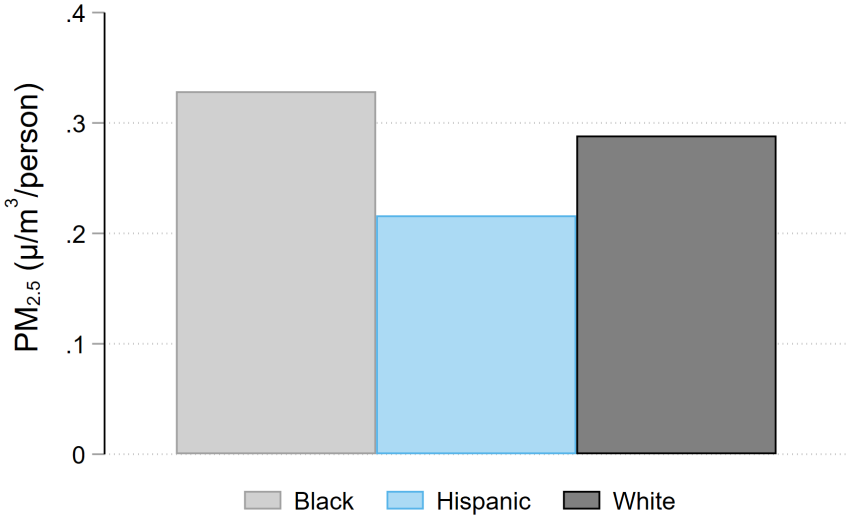
Pollution concentrations for demographic group g:

$$C_{gt} = \frac{\sum_i C_{it} S_{git} N_{it}}{\sum_i \underbrace{S_{git} N_{it}}_{\text{pop.}}}$$

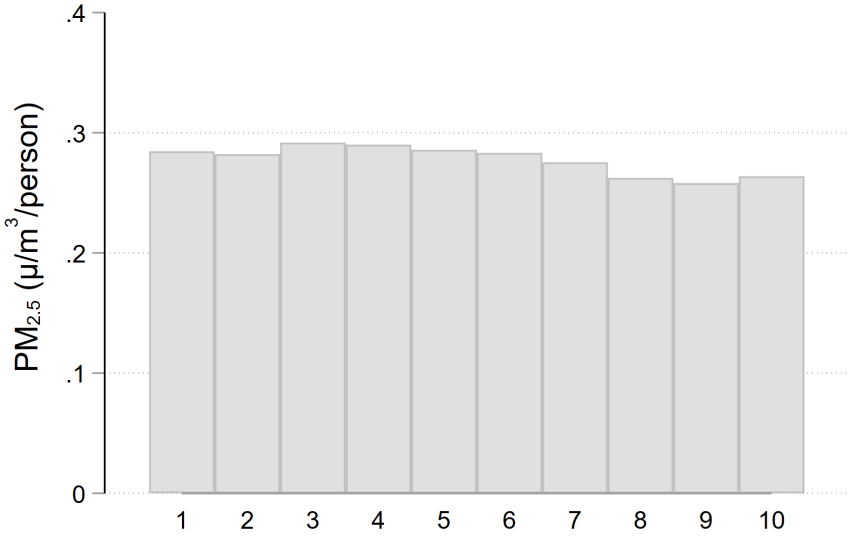
Pollution disparities: $C_{gt} - C_{g't}$

$PM_{2.5}$ concentrations by race/ethnicity and income (2018)

Race/ethnicity

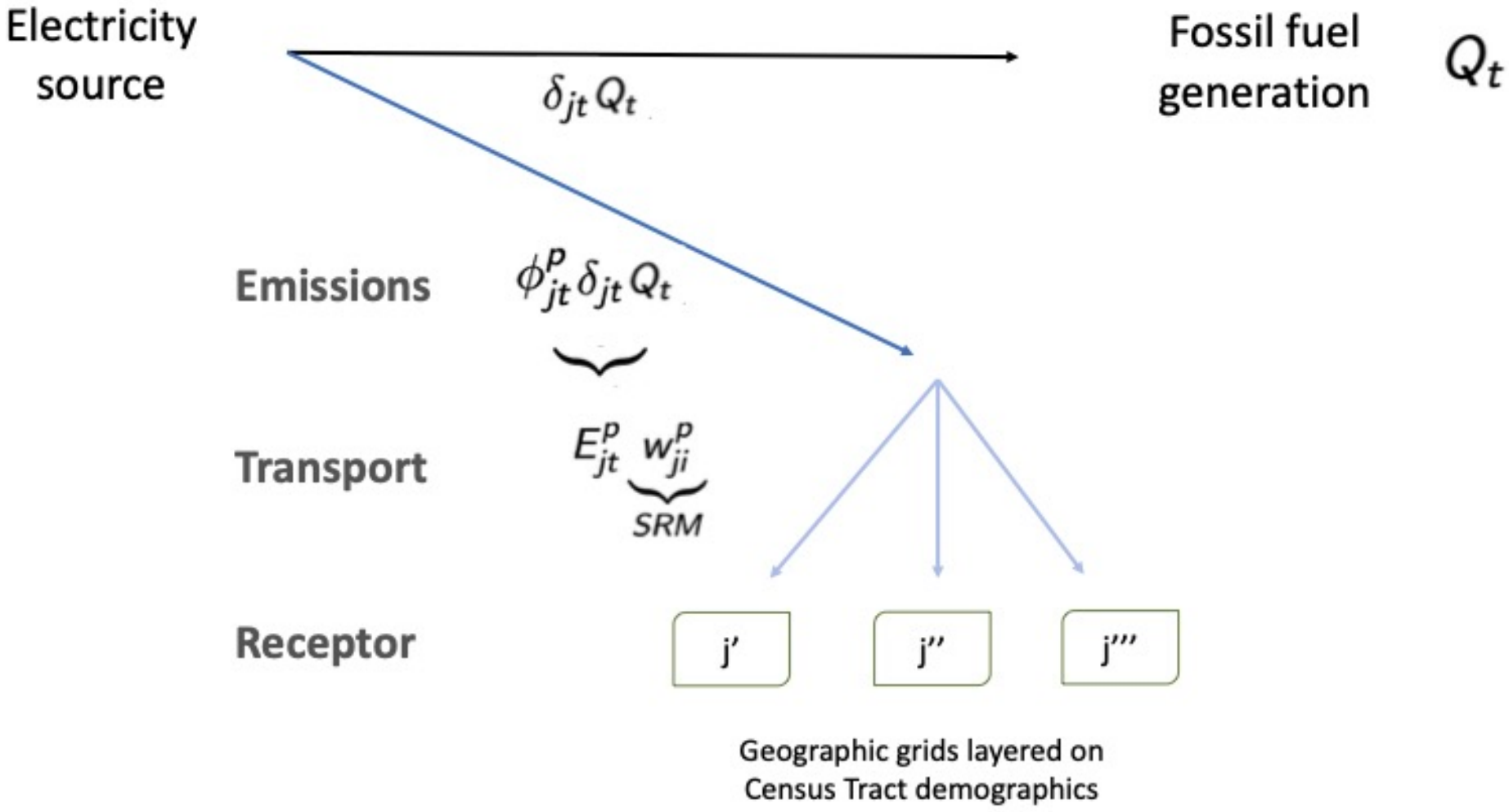


Income deciles



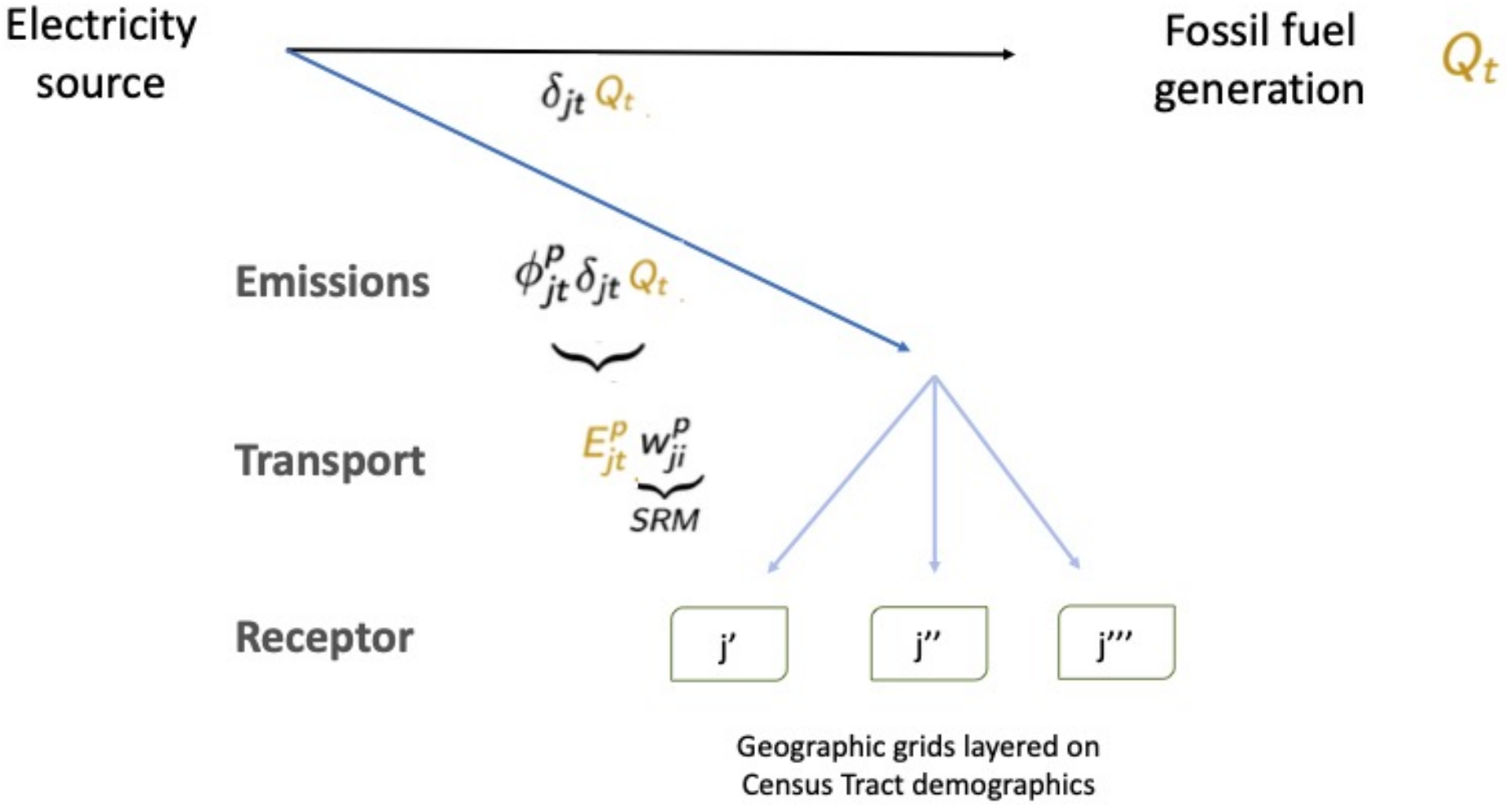
Average Black individual resides in a location with 64% more $PM_{2.5}$ concentration than average Hispanic

Actual exposure



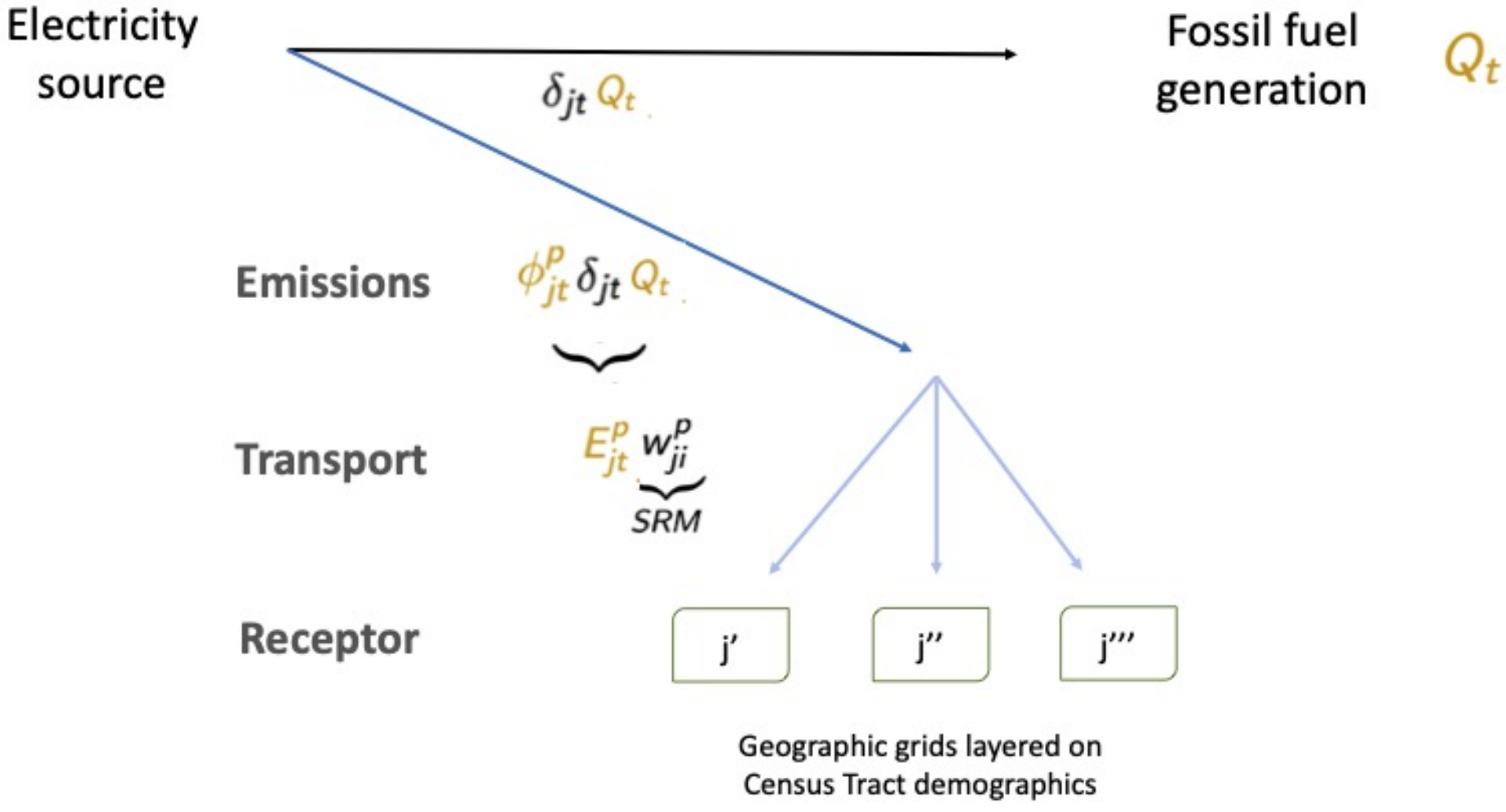
Scale effect

Allow only electricity production to vary over time



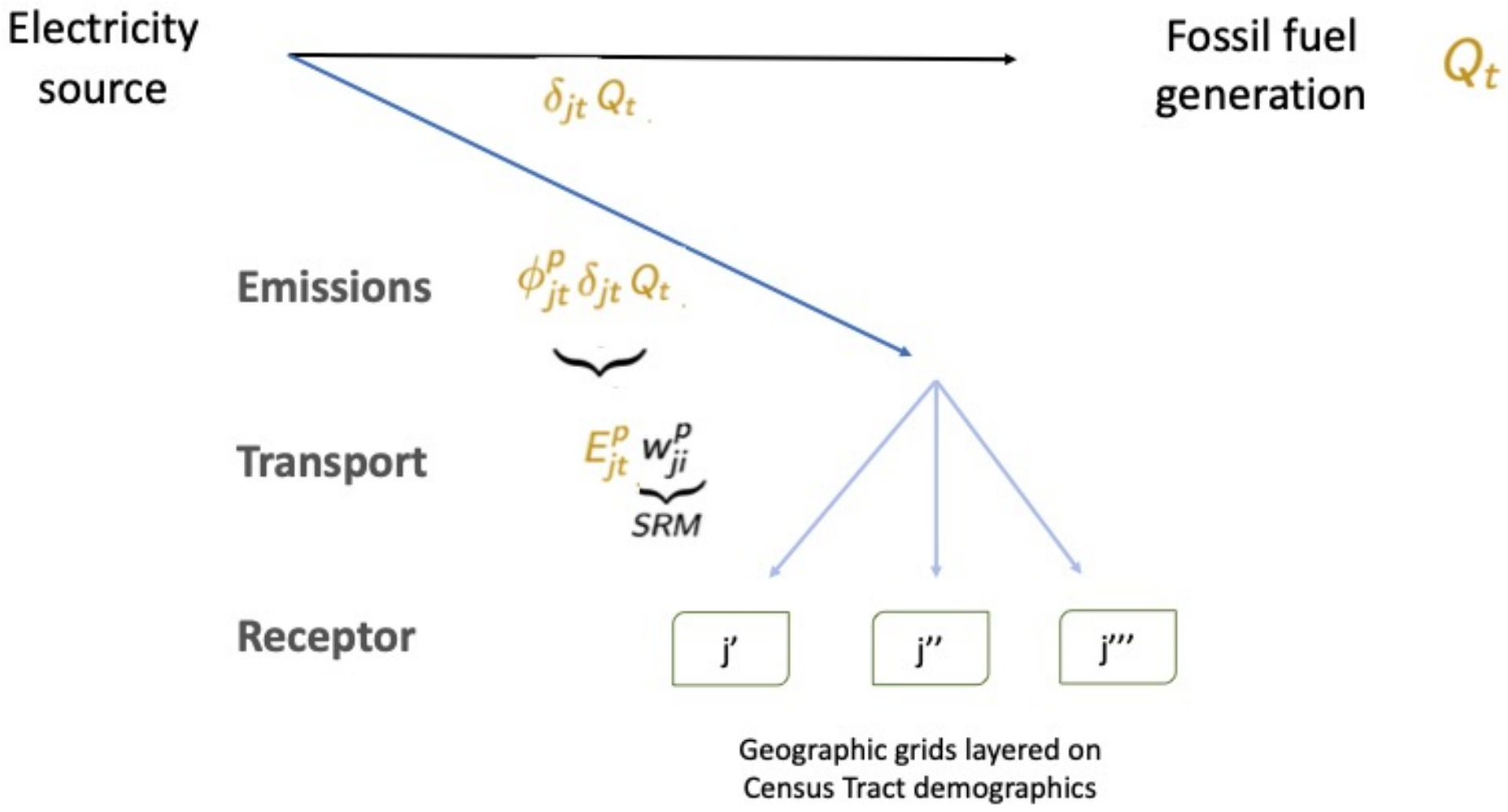
Scale + emissions intensity effects

Allow electricity production and emissions intensities to vary over time



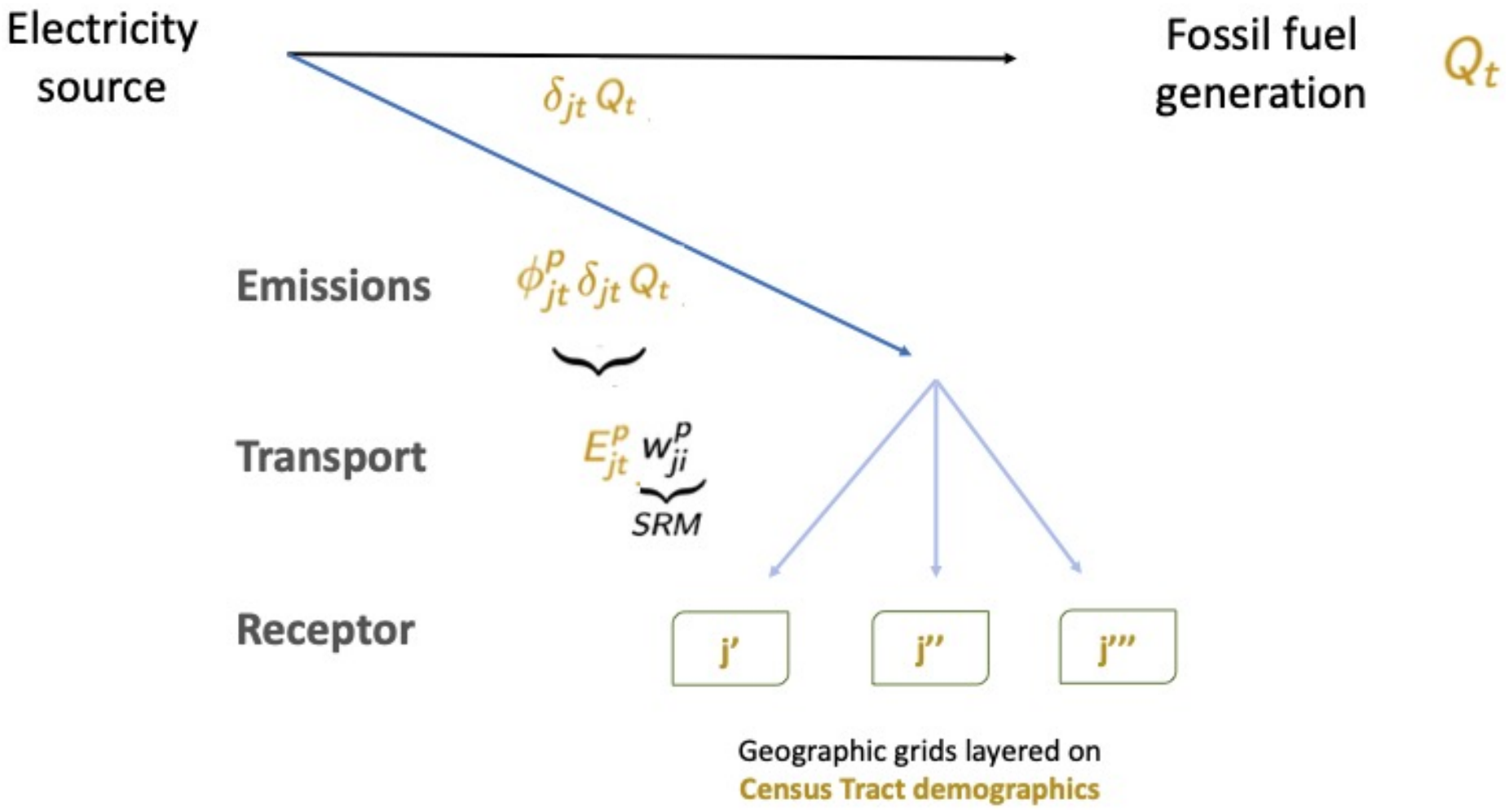
Scale + emissions intensity + composition effects

Allow electricity production, emissions intensities, and fossil market share to vary over time



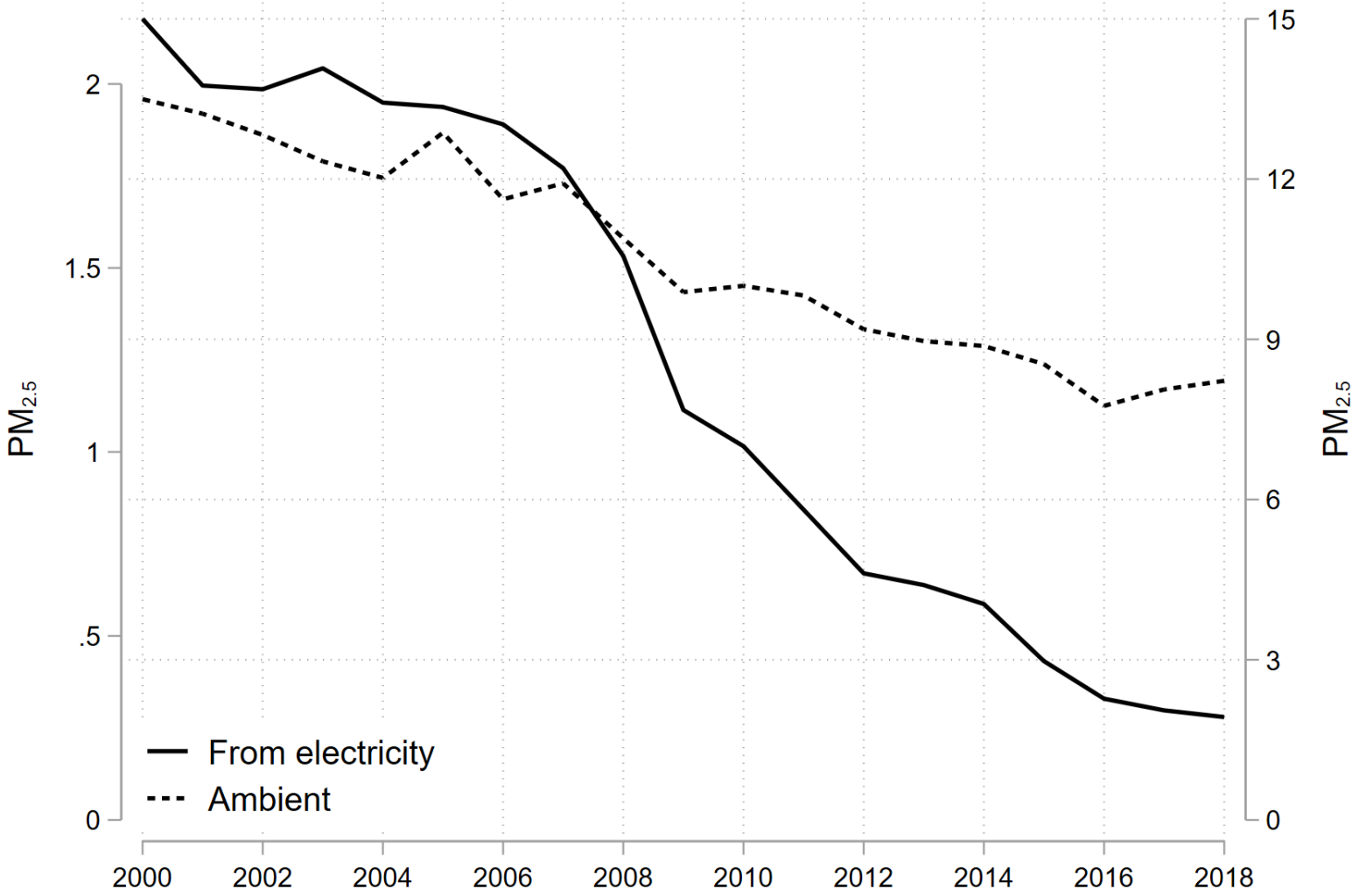
Total effect

Allow electricity production, emissions intensities, fossil market shares, and demographics to vary over time



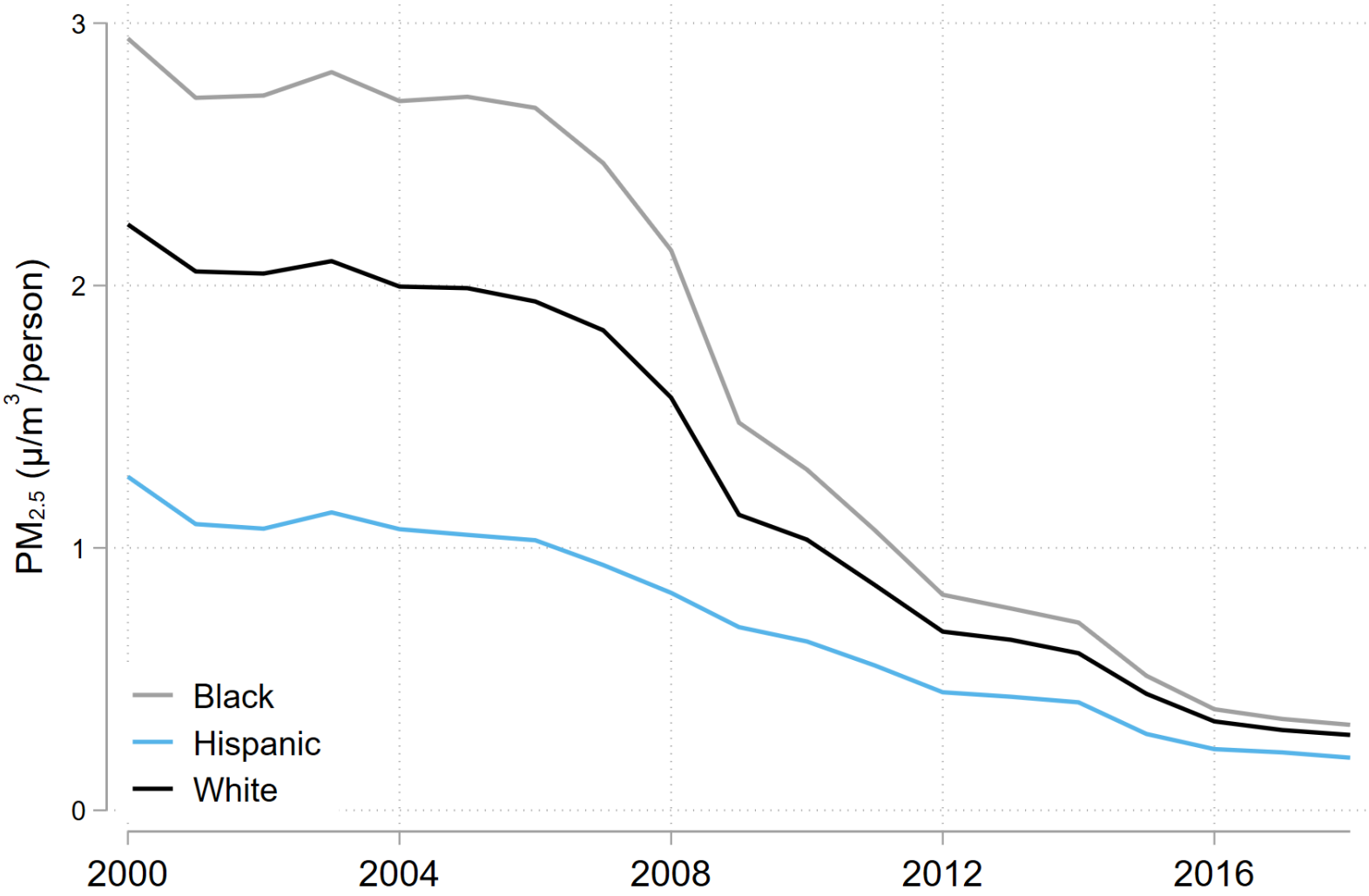
Results

$PM_{2.5}$ trend for avg. individual



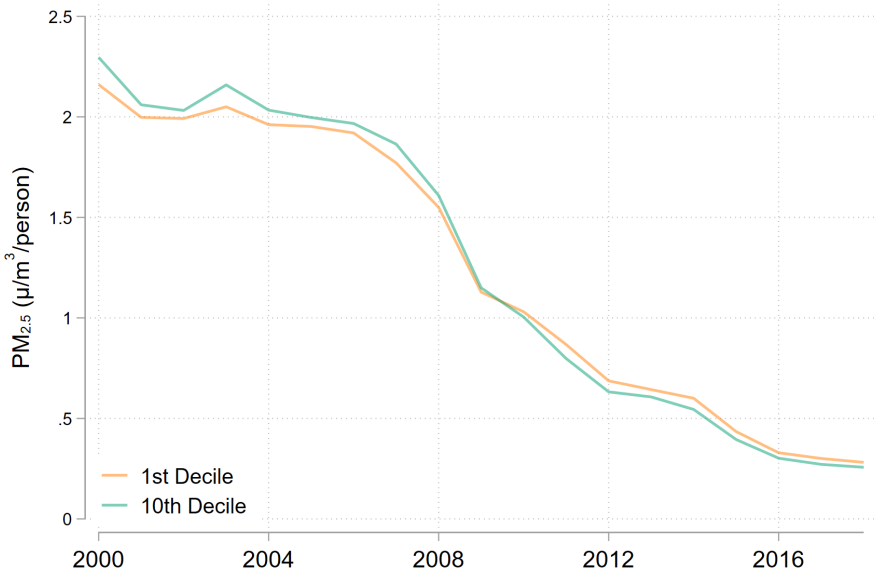
$PM_{2.5}$ concentrations from electricity have fallen by 87% overall, while national average has fallen by 39%

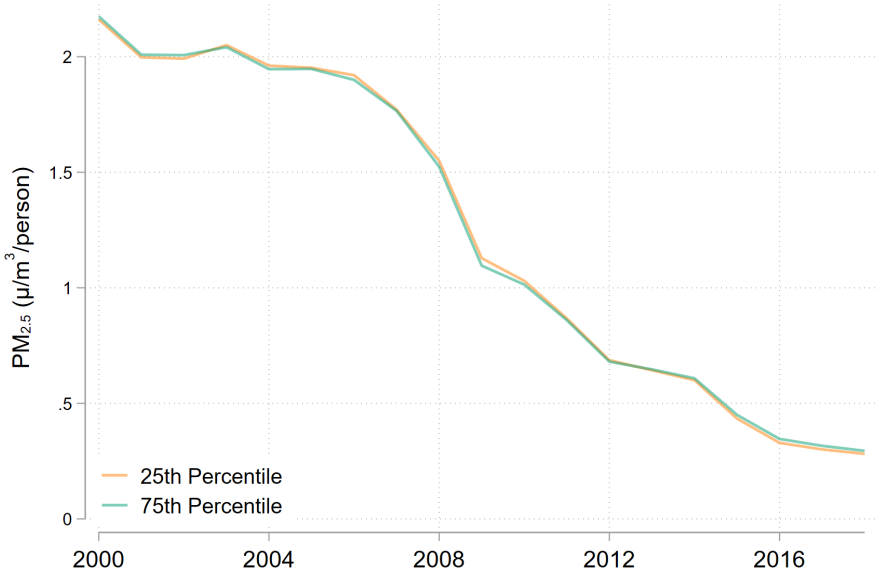
$PM_{2.5}$ trend by race/ethnicity



Convergence in $PM_{2.5}$ concentration gaps; 94% in Black-White gap; 92% in Hispanic-White gap

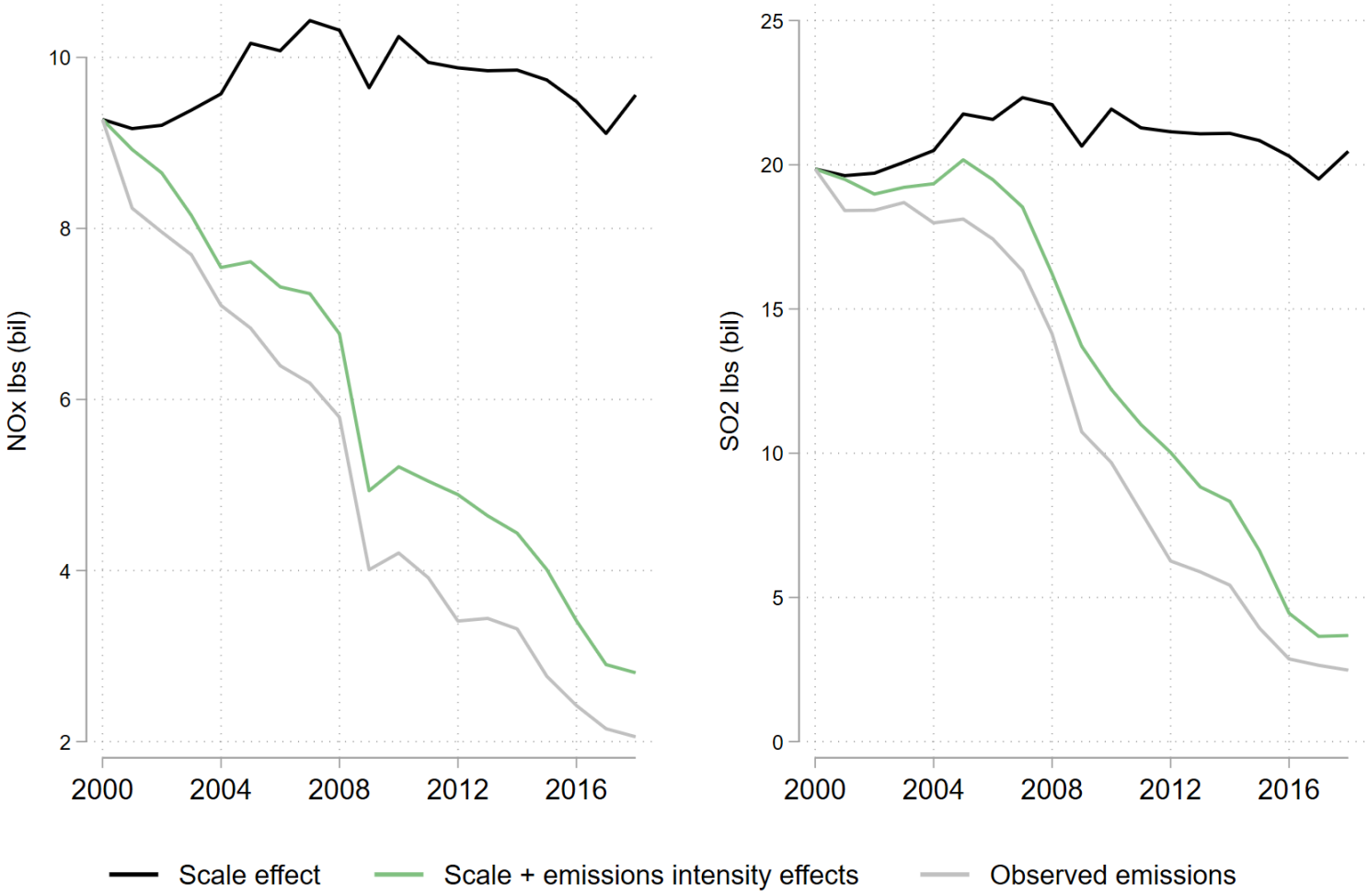
$PM_{2.5}$ trend by income





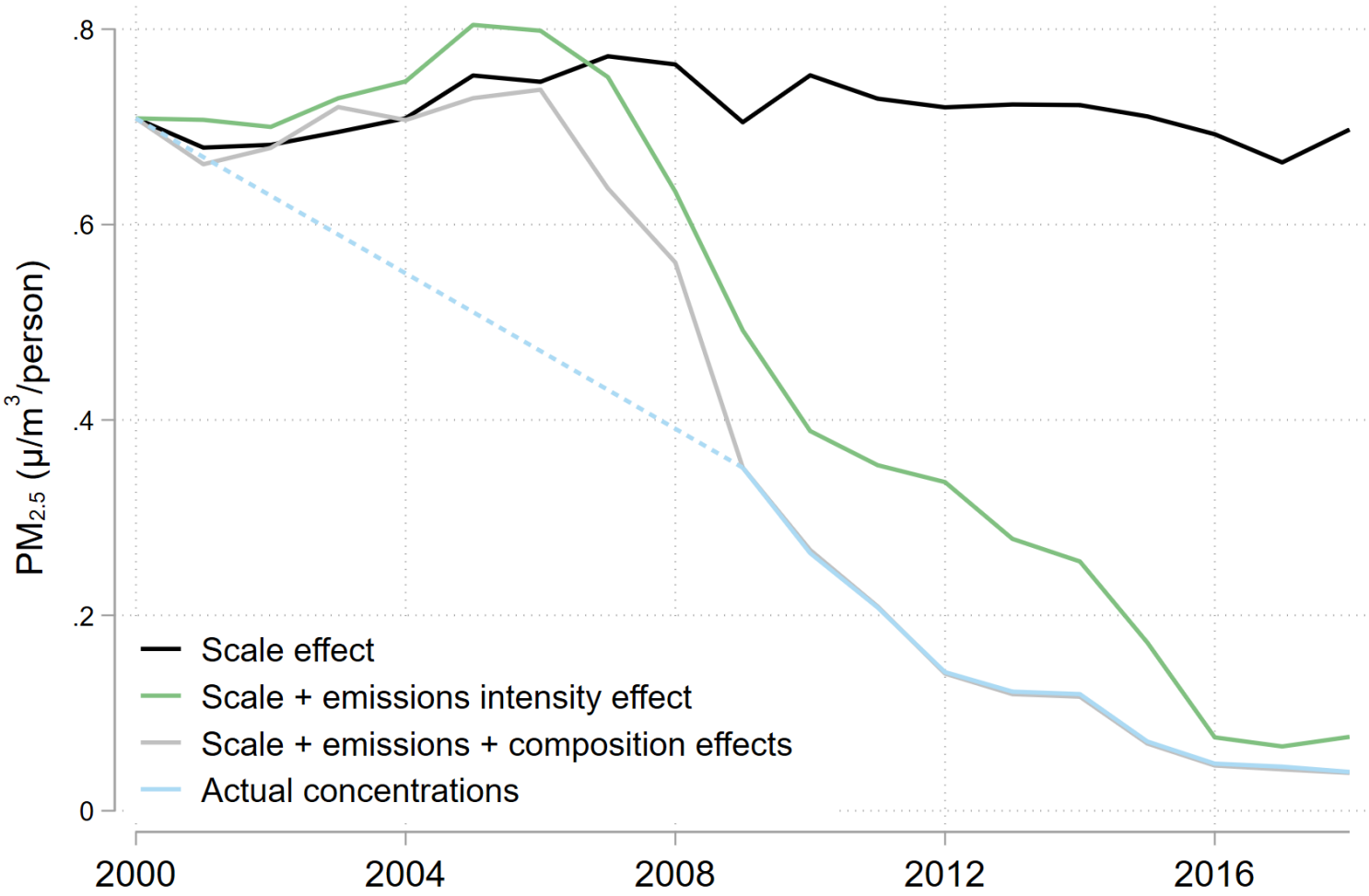
Relatively small gap in concentrations by income groups over the study period

Decomposition: emissions



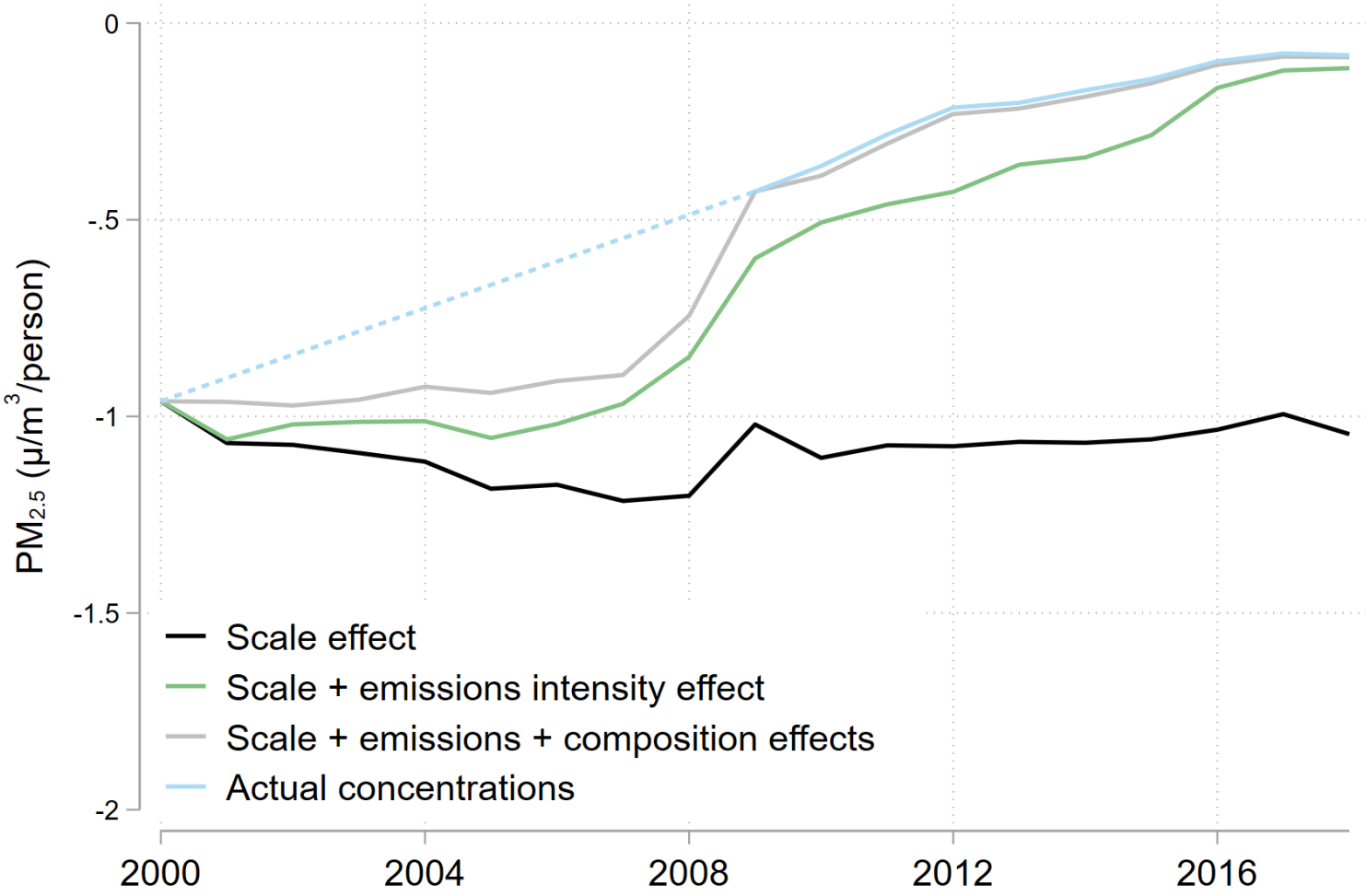
Emissions fell by 88% (NO_x) and 78% (SO_2).
NO_x: Scale effect: 4%. Emissions intensity: $\approx$ 86%. Compositional changes: $\approx$ 10%.

Decomposition: Black-White $PM_{2.5}$ disparity trend



Black-White disparity falling, driven mostly by emissions intensity improvements.

Decompostion: Hispanic-White $PM_{2.5}$ disparity trend



Hispanic-White disparity falling, driven mostly by emissions intensity improvements.

Why are disparities impacted by changes in emissions intensities?

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Determinants of impact:

1. **Location** of emission intensity improvements
2. **Rate** of emission intensity improvements

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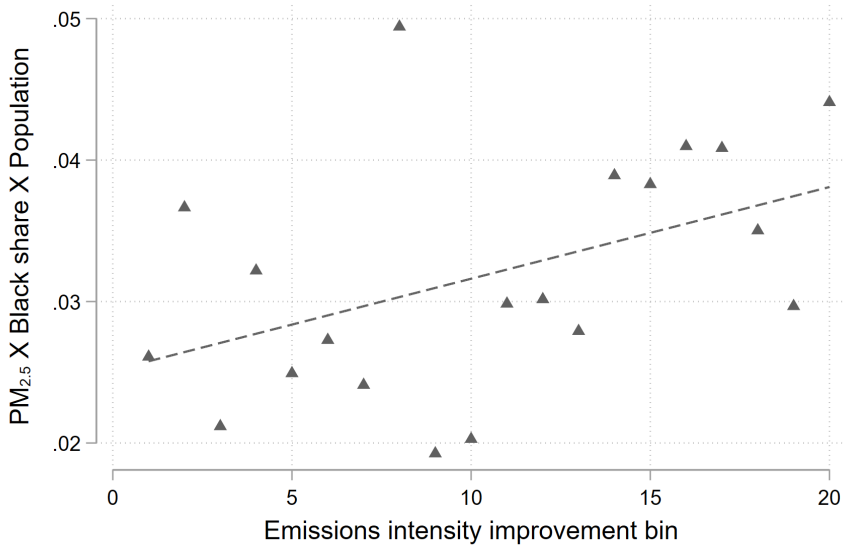
Determinants of impact:

1. **Location** of emission intensity improvements
2. **Rate** of emission intensity improvements

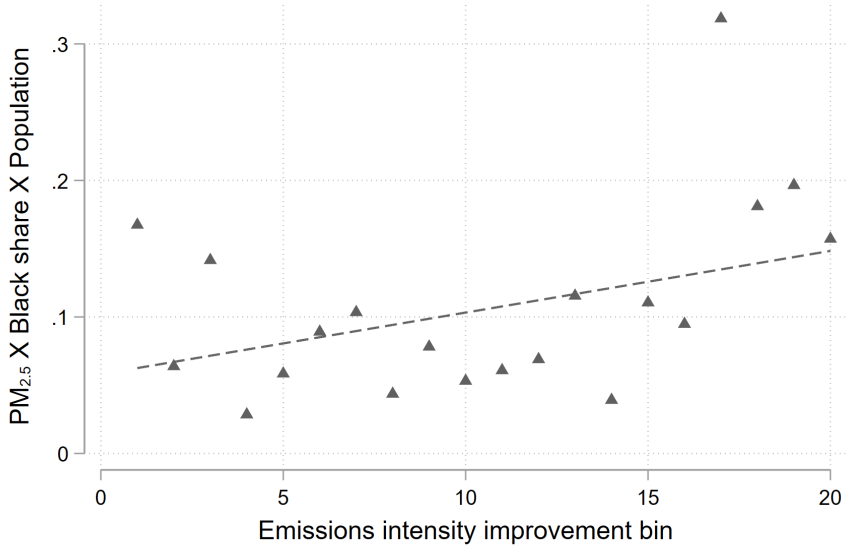
Relationship between **where** emissions intensity **improvements occur**, the **size** of improvement, and the **demographic groups** that are **downwind** from these improvements

Why are disparities impacted by changes in emissions intensities?

NO_x bin



SO_2 bin



Positive relationship between counties with coal EGUs that improve NO_x & SO_2 emissions intensity and $PM_{2.5}$ contribution to Black population

Summary

- This paper quantifies recent trends and determinants of U.S. **$PM_{2.5}$ concentrations** and their **disparities** from electricity
- Differences in the **residential locations** create distinct trends for each racial/ethnic group
- $PM_{2.5}$ concentrations across racial/ethnic groups have **converged** over the last two decades but **disparities still exist**
- Much of the convergence can be explained by **changing emissions intensities**
- **Compositional effects** including fuel-switching and **residential sorting** play smaller roles

Caveats and future work

- **Concentration** versus **exposure**: role of occupational exposure, access to health care, and other defensive investments
- Impact of increasing **renewable energy** penetration across space
- **No causal** interpretation for decomposition results
- Characterize **equity-efficiency tradeoffs** between air pollution disparity improvements and electricity prices across various climate and local air pollution policies.

Questions?