# Economic and social impacts of air pollution: A causal inference approach

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## Background

### Particulate Matter ($PM_{2.5}$)

Although it is well documented that exposure to fine particulate matter ($PM_{2.5}$) increases the risk of several adverse health outcomes, less is known regarding its effects on educational attainment, long-term earnings, and particularly economic mobility (Khalili et al., Thompson and Heyd, Brokamp et al.). A significant motivation for the development of low-cost air pollution monitors is the opportunity to improve the collection and accessibility of high spatial resolution air quality data, which could then be used by planners and policy makers both to mitigate inequities and protect marginalized communities.

### Intergenerational Economic Mobility

Economic success of children relative to their parents varies across the continental U.S. and is highly correlated with segregation and concentrated poverty, income inequality, school quality, family structure, and social capital (Chetty et al. 2014). Absolute upward mobility (AUM) is defined as the income rank percentile a child born to parents at the 25$^{th}$ income rank percentile will reach 30 years later (Chetty et al. 2018). For example, a statistic of 46 means that a child born to parents at the 25$^{th}$ percentile from 1979-1983 will on average reach the 46$^{th}$ income percentile as an adult. While prior studies have shown confounding-adjusted correlations between poor air quality and reduced economic mobility, to our knowledge, our study is the first comprehensive effort aimed at providing evidence of a causal effect of childhood exposure to $PM_{2.5}$ on future absolute mobility (Swetschinski et al.).

## Objectives

1. Assess evidence of causation (build off correlation work)
2. Map geographic variability

## Methods

We have fine-tuned and applied three distinct causal inference frameworks to show evidence of causal mechanisms between air pollution and future economic outcomes of low-income children. We obtained data from the Opportunity Atlas dataset which linked childhood family income and future child earnings to create child-guardian pairs for 20.5 million people born between 1978 and 1983 (96.2%). Our analyses are at the finest spatial resolution for which there exist both $PM_{2.5}$ data and long-term economic data – the census tract (approximately 4,000 people per unit).

We applied and compared three different methods for causal inference (entropy balancing, inverse probability of treatment weighting (IPTW), and generalized propensity score (GPS) matching for continuous treatments) to estimate overall and county-specific causal effects of childhood exposure to $PM_{2.5}$ and AUM controlling for an extensive set of census tract level confounders, such as race, income, temperature, precipitation, and education (Hainmueller, Robins et al., Wu et al.).

## Application/Results

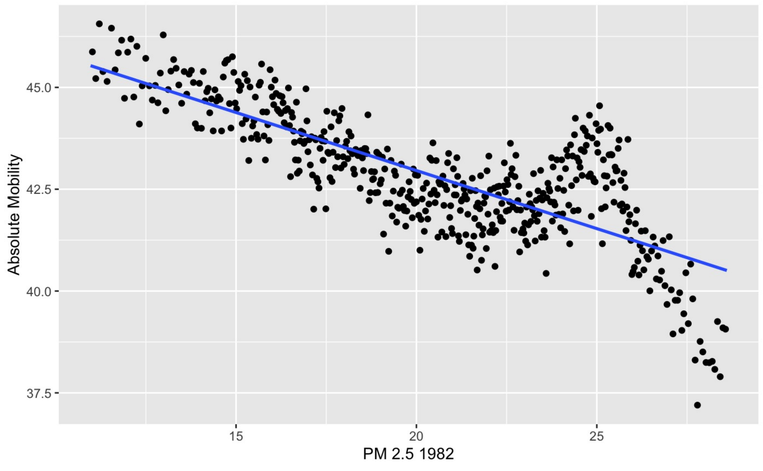


Fig 1. Absolute mobility vs PM 2.5 across 63,165 U.S. census tracts binned to 500 observations.

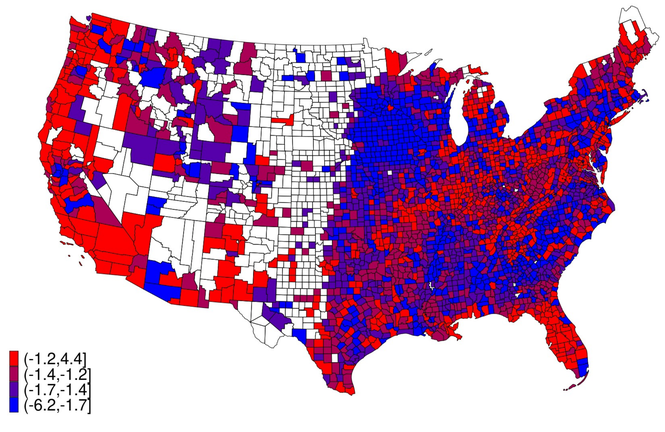


Fig 2. Quartile maps of the estimated county-specific causal effects (in percentage) obtained from IPTW. The values represent the percent change in AUM due to a 1 μg/m3 increase in childhood PM2.5. County boundaries in white were excluded from the analysis due to missing values. Final results exclude 13% of census tracts.

Our results showed evidence of a causal relationship between air pollution and economic outcomes among low-income communities with spatial variation. We found that a 1 μg/m3 increase of $PM_{2.5}$ exposure in childhood leads to a statistically significant reduction of AUM by 1.146% (95% confidence interval (CI): 0.834, 1.458) later in life. We also found strong evidence that these causal effects vary spatially across counties, exhibiting a stronger negative relationship in the Upper Midwest and the Southeast.

## Discussion

The results of this study support the collection of high spatial and temporal resolution air quality monitoring as tools to inform policies to reduce economic disparities in the US. Further analyses may identify specific causal mechanisms by which these environmental, health, and economic disparities arise.

Our study with $PM_{2.5}$ shows how causal inference may be used to

1. Identify specific mechanisms for engineering solutions to target
2. Assess how well implemented solutions/policy work

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## Contact

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