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Short communication

Prenatal exposure to air pollution and intergenerational economic mobility: Evidence from U.S. county birth cohorts

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ABSTRACT

New estimates reveal intergenerational economic mobility varies substantially across U.S. counties. The potential role of local environmental health exposures in structuring mobility outcomes has been thus far unexamined, despite mounting evidence that early life exposure to environmental pollutants has lasting impacts for individual human capital development and labor market performance. This study aims to fill this gap by estimating the impact of exposure to air pollution in the birth year on the average intergenerational mobility outcomes of children from low-income families as measured in adulthood. We do so by linking measures of intergenerational economic mobility for U.S. county-cohorts born between 1980 and 1986 to the county average concentration of total suspended particulates (TSP) in the birth year. We then estimate multivariate linear regression models that adjust for birth-cohort fixed effects, county-fixed effects and time-varying county-level covariates to address potential confounding. We find higher levels of TSP in birth year is associated with less upward economic mobility for children from low-income families: a one standard deviation increase in TSP levels is associated with a 0.14 point reduction in average income percentile ranking as measured in adulthood. Notably, we find no association for children from high income families. Our findings indicate early life exposure to air pollution may reduce the prospects children from low-income families will achieve upward economic mobility and suggest variation in environmental quality may help explain observed variation in mobility outcomes.

1. Introduction

Intergenerational economic mobility varies substantially across U.S. counties (Chetty et al., 2014a, 2014b). Whether and to what extent a child born to parents in the poorest income quartile ascends the economic ladder in adulthood is strongly conditioned by where he or she grows up. Efforts to account for local variation in levels of economic mobility have examined a wide range of potential explanatory factors including government spending, early childhood investments, education quality, access to health care, demographic composition, and even crime levels (Chetty et al., 2014a, 2014b; Sharkey and Torrats_Espinosa., 2017). Identifying the factors that bolster access to the American Dream for all Americans is a public policy issue of bipartisan interest.

The role of environmental health exposures in explaining area-variation in economic mobility has not been explored. This is surprising given wide spatial and temporal variation in environmental quality, particularly air quality. Air pollution—specifically the concentration of particulate matter in the air—has been tied to a number of health and human capital outcomes thought to be critical for upward mobility, even when exposure occurs before birth. For example, analyzing variation in total suspended particulate (TSP) pollutant levels—a broad measure of inhalable particulate concentration historically measured by the Environmental Protection Agency (EPA)—Sanders (2012) finds a negative relationship between in utero exposure and high school test scores in a sample of Texas counties. Exploiting the substantial decline

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in TSP levels following the enactment of the 1970 Clean Air Act, Isen et al. (2017) demonstrate a causal link between pollution level in the birth year and lower earnings and reduced labor force participation at age 30. These causal studies are consistent with a large and growing number of correlational studies linking prenatal exposure to air particulate matter to negative health and development outcomes across a range of settings and time periods around the world (e.g, Clemens et al., 2017; for a review see Šrám et al., 2005).

Consistent with the fetal origins hypothesis (see Almond and Currie, 2011)—which posits the prenatal environment has lasting consequences for an individual's health and development—there are multiple biological pathways through which in utero exposure to particulate matter may negatively impact a child's prospects of moving up the economic ladder in adulthood. Inhaling particulate matter can negatively impact a pregnant woman's respiratory and cardiovascular function which may reduce oxygen flow to the fetus and stunt fetal growth and brain development (Dejmek et al., 1999). This mechanism is consistent with studies linking particulate levels in the birth year with a higher incidence of low-weight births (Dadvand et al., 2013; Chay and Greenstone, 2003; Bobak, 2000); being born underweight has been causally linked to poorer child and adult health, lower academic achievement and reduced earnings in the labor market (Currie, 2011; Figlio et al., 2014). Smaller particles may prove particularly damaging to the health of mother and fetus. When inhaled by the mother, small particles may enter the bloodstream through the lungs and impact the fetus directly, impeding development of respiratory and cardiovascular systems (see Environmental Protection Agency, 2009). Such a mechanism is in line with a growing body of evidence linking prenatal exposure to particulate matter and other air pollutants to childhood asthma (see Hehua et al., 2017, for a systematic review), a major driver of school absenteeism (see, e.g., Moonie et al., 2006; Moonie et al., 2008; Taras and Potts-Datema, 2005) and school achievement (Liberty et al., 2010).

Motivated by extant research demonstrating a link between particulate exposure in utero and reduced human capital and labor market achievement in adulthood, we hypothesize that higher levels of air pollution in the birth year would be associated with lower levels of intergenerational economic mobility for children from low-income families. We test this hypothesis using new county-cohort estimates of economic mobility outcomes for children born in the early 1980s. Our research strategy exploits within-county variation in the concentration of total suspended particulates (TSPs) for the years 1980–1986 to estimate the association between air pollution levels in the birth year and the economic mobility outcomes of county-birth cohorts as measured in adulthood.

We build on the existing literature in several important ways. First, this is the first study to examine the impact of air pollution—or any environmental exposure—on levels of intergenerational economic mobility. Understanding whether air pollution shapes mobility outcomes has implications for our understanding of the structural determinants of the "American Dream," as well as our assessment of the societal benefits of policies designed to reduce pollutant levels or mitigate potential exposure. Second, in examining the mobility outcomes of cohorts born in the early 1980s—well after the implementation of the Clean Air Act of 1970—we are able to track the long-term implications of relatively modest differences in air pollution exposure in the birth year. Third, in examining mobility levels at the level of county-birth cohorts we demonstrate how ecological exposures shape population health that in turn has implications for large-scale economic processes.

2. Methods

2.1. Data

Outcome. Estimates of intergenerational economic mobility were generated by Chetty et al. (2014a), as part of the Equality of Opportunity Project (hereafter "EOP"). Mobility outcomes for a given county-birth cohort are derived from linked parent-child federal income tax records for the nearly full U.S. population of children born between 1980 and 1986. EOP used these data to estimate economic mobility through a multistage process. First they ranked all children in a given birth-year cohort according to their income in adulthood as measured at age 26. They next ranked the parents of these children relative to each other based on family income when the children were young adolescents. From these data, EOP generated and published estimates of the expected mean income percentile rank in adulthood of children born to low-income (25th income percentile) and high income (75th income percentile) parents for each county-birth cohort for the years 1980–1986 inclusive.

Table 1
Descriptive statistics for analytic sample of county-years: United States, 1980–1986.

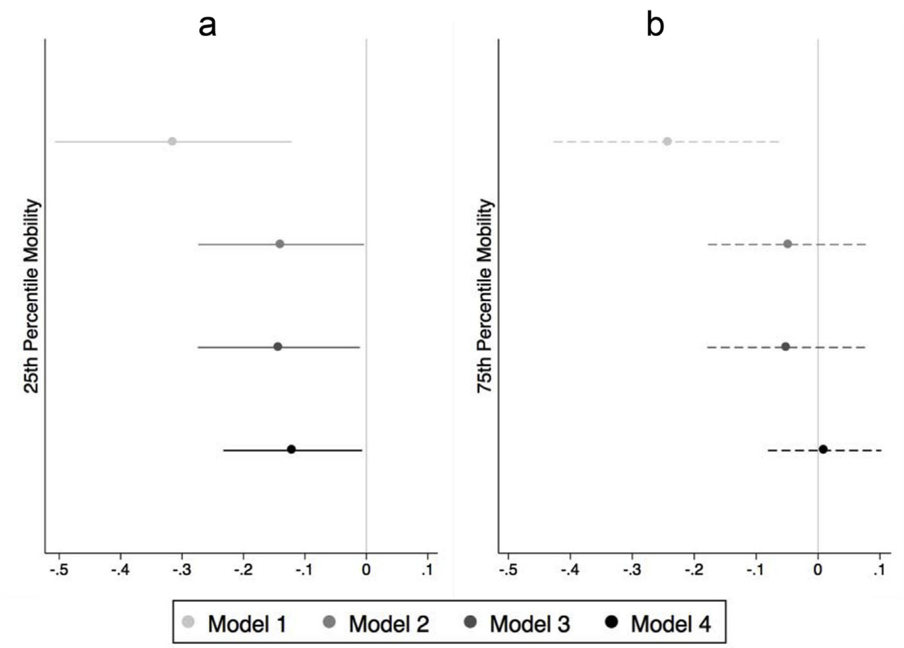
Variable	Mean	Median	Std. Dev.	Interquartile Range	Within-County SD
County-level income percentile rank in adulthood					
Children born at 25th percentile	45.07	44.91	4.74	41.89, 47.96	1.50
Children born at 75th percentile	58.12	58.12	3.44	55.89, 60.26	1.46
Total Suspended Particulates μg/m^3	55.5	53.05	16.88	44.88, 63.32	8.18

Notes: Income percentile rank is measured using parents' incomes between 1980 and 1986 and children's incomes at age 26 (between 2006 and 2012). Total Suspended Particulates (TSP) concentration is measured between 1980 and 1986. Our unit of analysis is county-years (n = 5076).

As detailed in Table 1, across the county-birth cohorts in our sample, children born to parents at the 25th percentile of income end up, on average, in the 45th income percentile at age 26. Yet this figure masks important underlying heterogeneity in mobility outcomes: across the county-cohorts in our sample, the mean expected income rank of a child born to parents at the 25th percentile of income ranges from the 5th percentile to 70th percentile in adulthood. For children born to high income parents—those at the 75th percentile of income—the mean expected income rank in adulthood across all county-years is the 58th percentile, with a range from the 4th percentile to the 73rd percentile across all county-cohorts. We also see within-county variation in mobility outcomes across the focal birth cohorts born between 1980 and 1986 with an average standard deviation of about 1.5 income percentiles.

Exposure. Air pollution data are taken from the U.S. Environmental Protection Agency's (EPA) Air Quality System (AQS), which provides annual summaries of various pollutants at sites throughout the U.S. From passage of the Clean Air Act of 1970 until the late 1980s, the EPA monitored total suspended particulates or TSP, a broad measure of the total concentration of inhalable particulates. In 1988 the EPA shifted from measuring total particulate matter to measuring concentration of particulates with a diameter less than 10 μm and replaced TSP with PM10 (and later added measures of concentration of even finer particles, e.g., PM2.5). Given smaller particulates are constitutive of TSP, there is reason to believe TSPs and particulates with smaller diameters "move together" (Currie and Neidell, 2005). As our focal birth cohorts were born before adoption of the PM10 standard—and consistent with the approach used by Sanders (2012) and Isen et al. (2017)–the analyses below employ TSP levels as captured from air quality monitors and published by the EPA.

Following previous literature (Sanders, 2012; Isen et al., 2017) we created a measure of the county-level TSP for each year from 1980 through 1986 by taking the average across all air monitors in the county, weighted by the number of readings per year. This measure was assigned to each of the county-birth year data points available in the



Notes: Point estimates represent association between TSP concentration (standardized) and mobility outcomes. All models adjust for county and year fixed effects. Model 2 adjusts for county characteristics. Model 3 adjusts for county and birth cohort characteristics. Model 4 adjusts for state time trends.

Fig. 1. Total Suspended Particulate (TSP) Concentration in Birth Year and County-Birth Cohort Mobility Outcomes for Children Born at 25th and 75th Income Percentiles: United States, 1980-1986
Notes: Point estimates represent association between TSP concentration (standardized) and mobility outcomes. All models adjust for county and year fixed effects. Model 2 adjusts for county characteristics. Model 3 adjusts for county and birth cohort characteristics. Model 4 adjusts for state time trends.

Table 2
Total suspended particulate (TSP) concentration in birth year and county-birth cohort mobility outcomes for children born at 25th and 75th income percentiles.

Variable	25th Percentile Mobility				75th Percentile Mobility			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
TSP (standardized)	−0.31 (-0.51, −0.12)	−0.14 (-0.27, −0.004)	−0.14 (-0.27, −0.01)	-.12 (-0.23, −0.01)	−0.24 (-0.43, −0.06)	−0.05 (-0.18, 0.08)	−0.05 (-0.18, 0.08)	0.01 (-0.08, 0.10)
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County characteristics [a]	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Birth cohort characteristics [b]	No	No	Yes	Yes	No	No	Yes	Yes
State time trends	No	No	No	Yes	No	No	No	Yes

Notes: Standard errors are clustered at the county level; 95 percent confidence interval in brackets; Counties weighted by average cohort size over focal years.
[a] Additionally adjusts for log transformed county population, government spending, personal income, and total employment, as well as interpolated values for median household income, unemployment rate, and poverty rate.
[b] Additionally adjusts for the percentage of births to non-Hispanic white mothers, the percentage of births to single mothers, and the percent of teenage births.

EOP data. Roughly 5% of monitors had 15 or fewer readings per year; data from these monitors were omitted from our analysis.

As detailed in Table 1, the mean level of TSP is 55.5 μg/m^3 across all county-years, and the mean within-county standard deviation is 8.2 μg/m^3. For context, the EPA "primary standard" for TSP levels—in place from the passage of Clean Air Act in 1970 until the adoption of the PM10 standard in 1988—was set an annual mean of 75 μg/m^3 (Environmental Protection Agency, 2009; Environmental Protection Agency, 1996), although concentrations below these threshold levels may still negatively impact health (Currie et al., 2009).

2.2. Analytic strategy

Our analytic sample consists of 5076 county-year observations for which we have data on both TSP levels and the level of economic mobility achieved by that county birth cohort. Our sample includes data from 1205 counties which account for nearly 70% of all U.S. births between 1980 and 1986.

We estimated multivariate linear regression models regressing measures of economic mobility on TSP levels for the county-year corresponding with the birth year of that cohort. The models adjusted for birth cohort (year fixed effects) to account for secular trends that may be correlated with economic mobility and TSP, as well as county-fixed effects to adjust for confounding time-invariant county-level factors. Consequently, the models leverage within-county variation in TSP across years. Our analytic strategy is designed to isolate the effect of TSP levels in the birth year (and only the birth year) on the mobility outcomes of those birth cohorts as measured in adulthood. Relevant confounders would thus have to vary within counties over time. To address this possibility, we include two sets of county-level time-varying covariates. The first set includes county economic characteristics including population, government spending, income per capita, and total employment as well as interpolated values for percent unemployed, median household income and percent in poverty. The second set of covariates adjusts for characteristics of the birth cohort including measures of the percent of births born to single mothers, non-Hispanic White mothers, and teenage mothers.

As a sensitivity analysis, we additionally estimated models including state-specific time trends. We also estimated models using upward mobility at the 75th percentile of the income distribution as the dependent variable in a falsification exercise. We did not expect within-county TSP variation to be associated with this measure given that the burden of pollution is more strongly borne by lower-income households (see Evans and Kantrowitz, 2002).

3. Results

Fig. 1a presents coefficients from models estimating the association between TSP concentration in the birth year on the economic mobility outcomes for children born to low-income (25th percentile) parents (see Table 2).

Among children born at the 25th percentile, model 1 finds TSP concentration in the birth year is negatively associated with economic mobility outcomes, net of county and year fixed effects. The point estimate indicates a one-standard deviation increase in TSPs is associated with a 0.31 percentage point decrease in the mean income percentile ranking of these children as measured in adulthood nearly three decades later. The point estimate attenuates after we include time-varying county-level covariates (model 2) but remains substantively unchanged after adjusting for county birth cohort characteristics (model 3). The point estimate in model 3 indicates that a one standard deviation increase in TSP concentration in the birth year is associated with a 0.14 point reduction (95% CI = −0.27, −0.01) in the mean income percentile rank these low-income children achieve in adulthood. The association is also robust to inclusion of state-specific time trends (see model 4, Table 2).

At the 25th income percentile, a 0.14 point reduction in income percentile rank is equivalent to about $140 a year less in household income. This effect size is consistent with the estimates of Isen et al. (2017) who, using individual-level earnings data from older birth cohorts, find a 10 $\mu g/m^3$ reduction in TSP in the birth year is associated with a $260 increase in annual income in adulthood, or about one-tenth of the return to an extra year of education (see Card, 1999).

Although we see some evidence of a negative association among children born at the 75th percentile (Fig. 1b), the point estimates become substantively and statistically insignificant after including time-varying characteristics. That the estimates are so sensitive to covariates in this case, while remaining robust for mobility in low-income families, illustrates the power of the covariates in accounting for key confounders, and raises confidence in making causal inferences.

4. Discussion

Exploiting within-county variation in TSP concentration, we find evidence that low-income children in birth cohorts exposed to higher levels of air pollution in their birth year achieved less upward economic mobility as measured in adulthood nearly three decades later. This finding echoes a growing body of work demonstrating that early life exposure to air pollution has a deleterious effect on later life health, educational attainment and labor market outcomes. It also underscores the importance of considering how spatial and temporal variation in environmental health exposures may help us account for observed variation in economic mobility levels.

Notably, TSP concentrations were not associated with mobility outcomes for children born to high income parents. This may be expected as air pollution levels—and coincident negative health effects—are typically higher in low-income and minority communities relative to high income and white communities in the same metropolitan area (Coker et al., 2016; Casey et al., 2018; Lopez, 2002; Morello-Frosch and Jesdale, 2006). In addition to residential segregation, differential effects may also be driven by the capacity for higher income parents to engage in behaviors that mitigate the level of air pollution experienced by their children (Cushing et al., 2015). It may also reflect increased susceptibility of low-income children to air pollution exposures, given other social vulnerabilities and higher cumulative environmental exposures. These factors may include worse baseline health status and psychosocial stressors as well as lower quality housing, indoor air pollutant exposures (including tobacco smoke), and greater residential proximity to hazardous facilities (see Evans and Kantrowitz, 2002).

Although our use of county-level data enables us to explicitly link environmental quality in the birth year to economic mobility levels, the data are not well suited to explore potential mechanisms or model variation within counties or across household types. And, as with other studies that rely on available measures of local air quality from the early 1980s, we cannot rule out the possibility that our estimates of the effect of particulate matter are also capturing the effect of other air pollutants—such as carbon monoxide, ozone, and nitrogen dioxide—that may rise and fall with TSP levels (see Sanders, 2012). Detailing the relative effect of exposure to different pollutants on human capital and economic outcomes—harnessing data on more recent birth cohorts—is currently an active area of research (Almond et al., 2017).

5. Conclusion

This study demonstrates that low-income children exposed to higher levels of air pollution early in life are less likely to achieve the American dream of upward economic mobility. This association should be integrated into cost benefit analyses and empirical assessments of public policies and regulations aimed at improving environmental health and reducing negative exposures, particularly for children. Future work should examine how the spatial and temporal patterning of other environmental exposures—from lead paint to superfund sites—and protective factors like high-quality schooling and access to health promoting built environments may help to account for subnational variation in levels of intergenerational economic mobility.

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