Can Pollution Cause Poverty? The Effects of Pollution on Educational, Health and Economic Outcomes

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Although pollution is widespread, there is little evidence about how it might harm children's long run outcomes. Using the detailed, geocoded data that follows national representative cohorts of children born to the National Longitudinal Survey of Youth respondents over time, I compare siblings who were gestating before versus after a Toxic Release Inventory site opened or closed within one mile of their home. I find that children who were exposed prenatally to industrial pollution have lower scores on an outcomes index and fewer years of completed education. Those children whose families do not move between births have lower wages, are more likely to be in poverty as adults, have fewer years of completed education, and are less likely to graduate high school than their siblings.

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I. Introduction

Billions of pounds of toxic substances are released each year, yet little is known about whether exposure to these pollutants might harm children's long run educational and labor market outcomes. There are currently about 21,800 TRI sites operating across the United States and more than 221.5 million people had a TRI site operating in their zip code in 2016.[1] In addition, there are reasons to believe that the types of pollution emitted by TRI sites might be particularly detrimental to human health and development. For example, TRI sites release known neurotoxins, such as lead and mercury, into the air. While criteria air pollutants (for example, particulate matter) have been regulated for decades, little is known about the effects of most of the chemicals released by TRI facilities. Most of the chemicals emitted have never undergone any kind of toxicity testing (US Department of Health and Human Services 2010) and were essentially unregulated until 2011 when the U.S. introduced the Mercury and Air Toxic Standards (MATS). These regulations have been rolled back and are now being contested.[2]

Nevertheless, a growing literature suggests that airborne toxic pollutants from TRI sites can cause negative academic and behavioral outcomes for children in school (Persico and Venator 2019), cause cancer, harm birth outcomes (Currie, Davis, Greenstone and Walker 2015), and harm the brain and reproductive systems

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[1] I made this calculation based on linking zip code level census counts of the population to TRI data.

[2] The Supreme Court of the United States decided against the MATS rule in 2015 for lack of sufficient cost-benefit analysis and remanded the case to the U.S. Court of Appeals, which temporarily upheld the rule. In 2020, the EPA determined that it was not "appropriate and necessary" (A&N 2020 rule) to regulate hazardous air pollutants (HAPs, also known as airborne toxics) under the MATS rule and stopped some regulation of these airborne toxics. Litigation on the 2020 A&N rule is ongoing, which affects the legal basis of the MATS rule (Congressional Research Service 2020). On January 20, 2021, President Biden directed EPA to revisit the 2020 rule by August 2021, and the EPA has submitted a new proposed rule to regulate HAPs that is not yet in effect (EPA 2022).

(Centers for Disease Control and Prevention 2009).[3] However, contemporaneous measures of pollution might underestimate the total welfare effects of environmental toxicants if these toxicants negatively affect the developing brain, and consequently, long-run outcomes.

I use very detailed data from surveys of the children of the National Longitudinal Survey of Youth 1979 (NLSY79) and their parents that allows the matching of siblings and geographic information on families to examine how TRI pollution affects children's long run outcomes. By leveraging TRI plant openings and closings, I compare siblings within the same family in which one sibling was exposed to TRI pollution during gestation and the other was not exposed because the plant had not opened yet or because it closed before a later child was conceived. I consider two different approaches – comparing siblings who do not move away from close proximity to a TRI site and estimating an intent-to-treat (ITT) model that assigns initial TRI proximity and open/close dates to all siblings in the same family regardless of whether or not the family moved. By exploiting the short distance over which TRI toxicants can travel through air (i.e., one mile) and using within-family comparisons, I am able to isolate the effects of pollution from other difficult-to-observe and possibly endogenous factors, such as local sorting, avoidance behavior, and time-invariant characteristics of families that happen to be near a TRI site that could affect child outcomes.

The consequences of prenatal exposure to TRI pollution are stark. I find significant negative effects of prenatal exposure to TRI pollution, between -0.489 and -0.556 standard deviations, on a summary index of long-term outcomes. I also find that children who were gestating near an operating TRI site have 1.284 fewer years of education compared to their sibling, who was not exposed to the TRI pollution, in my preferred ITT specification. Children whose families do not move

[3] However, most of the evidence we have on the neurotoxic effects of these pollutants is from studies using animal models.

away from the TRI site between births have 30% lower wages and are 17.2 percentage points more likely to be on a public assistance program as an adult than their unexposed sibling. This represents a large increase of 43.6% in public assistance use above the mean. In addition, children who are prenatally exposed to TRI pollution are 12.4 percentage points less likely to graduate high school and are 9.4 percentage points more likely to have a cognitive disability as an adult than their sibling who was not prenatally exposed to pollution.

This paper provides some of the first evidence that prenatal exposure to hazardous air pollutants (HAPs) can cause negative long-run human capital outcomes on wages and educational attainment with important distributional consequences for fence-line communities of children who live within one mile of a TRI site. Most studies to date have focused on the negative effects of exposure to particulate pollution on birth outcomes[4] or contemporaneous test scores in primary or secondary school.[5] Although some research (Almond, Edlund, and Palme 2009; Bharadwaj et al. 2017; Black et al. 2019; Grönqvist, Nilsson and Robling 2020; Isen et al 2019; Persico, Figlio and Roth 2019; Sanders 2012) has focused on the negative effects of exposure to pollution during gestation or early life on later human capital outcomes, most of this work focuses on outcomes in primary or secondary school, rather than economic outcomes in adulthood.

Nevertheless, a few studies estimate the effect of pollution on wages. Isen and colleagues (2017) compare cohorts of children in nonattainment counties that had to reduce their air pollution after the Clean Air Act to those in attainment

[4] A growing literature has shown that children exposed in utero to pollution have higher infant mortality (Currie and Neidell, 2005), lower birth weight (Currie, Davis, Greenstone, and Walker, 2015), and a higher incidence of congenital anomalies (Currie, Greenstone, and Moretti, 2011). For example, a number of epidemiological studies have also found significant relationships between air pollution and preterm birth (Butler and Behrman, 2007).

[5] See, for example, Carneiro, Cole and Strobl (2021), Duque and Gilraine (2022), Ebenstein, Lavy, and Roth (2016), Gilraine and Zhang (2022), Heissel, Persico and Simon (2021), Marcotte (2017), Persico and Venator (2021), Pham and Roach (2023), and Sanders (2012).

counties. They find that cohorts exposed to more air pollution in early life is associated with a 0.7 percent decrease in the number of quarters worked and a one percent decrease in mean annual earnings. In a working paper, Voorheis (2017) also finds that pollution exposure in early life is associated with lower college attendance and wages. Grönqvist, Nilsson, and Robling (2019) show that children who were exposed to less lead through removing lead from gasoline in Sweden were more likely to graduate high school, were less likely to commit crimes, and had 4% higher wages in adulthood. Black et al (2019) uses regional variation in radioactive fallout to estimate effects on later life outcomes, finding that radiation exposure during gestation decreased educational attainment and later earnings by ~1% in Norwegian children.

My findings are much larger than previous estimates of the effect of air pollution on wages, which highlights four contributions of this paper. First, prenatal exposure to TRI pollution, which contains a mix of known neurotoxins like lead and mercury, might be much worse than exposure to other types of air pollution, such as emissions from traffic or lead alone. Despite TRI sites being a commonly encountered source of pollution, this is the first paper to examine the effects of HAPs and TRI sites on outcomes in adulthood. Second, I show that there are important distributional consequences for exposure to pollution wherein people living very close to TRI sites are much more strongly affected by the pollution, which could be missed by estimates that assume a county-level or regional treatment. Indeed, results using regional fixed effects are likely to be driven by people living very close to the sources of pollution, which has important implications for policy and where we locate these sites. Since disadvantaged families are more likely to live closer to TRI sites, exposure to pollution might push families without resources to compensate into poverty. Third, my analysis uses family fixed effects, which remove time invariant characteristics of families that might otherwise bias the findings, as well as an intent to treat strategy that addresses bias caused by residential sorting.

Fourth, given that TRI sites remain open for long periods of time, the potential length of exposure to TRI pollution for children in this sample is quite long (potentially 9.8 years). Thus, these results are potentially showing the effects of cumulative exposure as well as prenatal exposure. This analysis is also among the first to investigate how pollution might affect income in adulthood through educational, employment, crime, and health channels using very detailed data from surveys of the children of the National Longitudinal Survey of Youth 1979 (NLSY79) and their parents for families that live close to toxic sites. Finally, this paper contributes to a literature on how neighborhoods affect health, educational attainment and intergenerational mobility, showing that even within a zip code, proximity to sources of pollution can cause inequality. The results are robust to a variety of specifications and suggest that pollution is a major channel through which inequality is reproduced.

II. Background

In 2017, Toxic Release Inventory (TRI) sites alone (which represent only one type of industrial plant) released 3.97 billion pounds of (untreated) toxic chemicals in America into the air, land and water, out of 30.57 billion total pounds of toxic chemicals created in production-related wastes (EPA 2017). The Environmental Protection Agency (EPA) estimates that more than 59 million people (about 19 percent of the population) live within one mile of an operating TRI site (EPA 2014). While most toxic chemicals are managed so that they are not released into the environment, some release of these chemicals is the inevitable byproduct of manufacturing. Research on the effects of pollution on children most commonly focuses on the link between exposure and health outcomes, such as birth weight, mortality or the prevalence of respiratory diseases for children in highly polluted areas.[6]

According to the "fetal origins" hypothesis, prenatal health conditions can have large impacts on health and brain development that reverberate into adulthood (Currie and Almond 2011). Such effects are persistent and occur through "fetal programming" that occurs in the womb through brain development or epigenetic mechanisms, which are just beginning to be explored. There is some evidence that environmental toxicants might interact with genetic susceptibilities to alter developmental trajectories and produce cognitive disabilities, such as specific learning disabilities, speech and language impairments, intellectual disability, and autism (Miodovnik, 2011; Jurewicz et al, 2013). While cognitive disabilities may have a substantial underlying genetic component, there is also evidence that the development of cognitive disabilities is strongly influenced by the environment (Miller and McCardle, 2011). Recent research further points to the ways that genes are especially susceptible to environmental context, since genes are always stored, transcribed and translated within an environment that may influence these processes. Randomized control trials of early-life epigenetic changes in rats show that these changes also affect subsequent gene expression in the brain (Kundakovic. 2011; Roth, 2012; Green, 2015). There is also a growing body of evidence that during the prenatal, perinatal and early postnatal periods, as well as in early childhood, the developing human brain is highly vulnerable to toxic chemical exposures (Bearer, 1995; Rice and Barone Jr, 2000). During these sensitive periods, chemicals can cause permanent brain injury at low levels of exposure that would have little or no harmful effects in an adult (Bearer, 1995; Grandjean and Landrigan, 2014). Increasing evidence points towards non-genetic, environmental

[6] For an overview of how in utero and early life exposure to negative environmental factors, such as pollution, can impact later life outcomes, see Almond and Currie (2011).

exposures that are involved in causation of cognitive disabilities, in some cases by interacting with genetically inherited risk factors and epigenetic mechanisms.[7]

Unfortunately, there are no studies to date comparing the effects of different types of toxicants on cognitive outcomes, though there is a literature showing the different types of toxicants can harm cognitive development in children. Aizer and colleagues (2015) found that a 5 micrograms per deciliter increase in children's preschool lead levels reduces elementary school test scores by 43 percent of a standard deviation. Lead reduction policies explained roughly half of the decline in the Black-White test score gap in these cohorts. Because lead easily crosses the blood-brain barrier, exposure to lead can lead to brain damage in the prefrontal cerebral cortex, hippocampus and cerebellum (Finkelstein et al., 1998).[8]

There is also evidence that other environmental toxicants found in TRI sites (e.g. methylmercury, arsenic, polychlorinated biphenyls, dioxin, volatile organic compounds, etc.) are similarly damaging to the developing brain, though there is far less research on these chemicals than on lead.[9] For example, there are growing epidemiological literatures on how exposure to TRI pollutants, such as Polycyclic Aromatic Hydrocarbons (PAHs) (Lovasi et al., 2014; Margolis et al., 2016; Perera et al., 2009), Volatile Organic Compounds (VOCs) (Allen et al., 2015; Grandjean & Landrigan, 2006; Wu, Bhanegaonkar, & Flowers, 2006), and other heavy metals

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[7] For a more in-depth discussion of how different types of environmental toxicants affect cognitive development, please see the NBER working paper version of this paper (Persico et al., 2016).

[8] The EPA (2013) provides a comprehensive review of hundreds of studies investigating the effects of lead from epidemiology, toxicology, economics, public health, neuroscience, and other disciplines. Early-life exposure to lead causes lower IQ, decreased test scores, increased rates of high school dropout, lower adult earnings, attention deficit disorders, impulsiveness, hyperactivity, conduct disorders, and criminal behavior.

[9] For reviews of the recent literature on how toxicants like methylmercury, arsenic, polychlorinated biphenyls, dioxin, volatile organic compounds, and other toxicants found in Superfund sites affect child development and the brain, see Bellinger (2013), Bose et al (2012), Grandjean and Landrigan (2006 and 2014), and Behrman, Butler and Outcomes (2007). Most of these toxicants have been tested in rat studies to show that they are neurotoxic, but the evidence on how they affect developing human brains is relatively small.

(e.g., Bellinger, 2013; Ciesielski et al., 2012; Counter & Buchanan, 2004), might harm child development. However, epidemiological studies usually employ longitudinal methods that control for a range of variables and use the amount of a toxicant in a child's or mother's blood or hair as a predictor of the effects of early toxic exposures. Often a disaster in which a large number of people were exposed to a large amount of the toxicant is used to detect the effects of the toxicant in humans. In some cases, epidemiologists use a comparison group of unexposed children. However, because of the nature of the research, there can be no random assignment, and there is often no data on the same outcomes before the disaster. Thus, it is difficult to control for pre-trends and account for possible biases using these methods.

However, a growing literature links pollution exposure during gestation to negative birth outcomes[10] and cognitive outcomes. For example, Persico, Figlio and Roth (2016) explore the effects of in utero exposure to Superfund pollution on health and cognitive outcomes in school, finding that pollution exposure is associated with worse infant health, 0.11 of a standard deviation lower test scores, and a higher likelihood of behavioral incidents, cognitive disabilities and repeating a grade. Ferrie, Rolf, and Troesken (2012) find that early exposure to lead affects later army intelligence test scores. Almond, Edlund, and Palme (2009) and Black et al (2013) use quasi-experimental designs and Scandinavian data and find effects of exposure to radiation from nuclear fallout during gestation on later test scores. Sanders (2012) finds that a standard deviation decrease in mean pollution level at birth is associated with 1.9 percent of a standard deviation increase in high school test scores in Texas. Bharadwaj, Gibson, Graff Zivin, and Neilson (2014) compare

[10] A growing literature has shown that children exposed in utero to pollution have higher infant mortality (Currie and Neidell, 2005), lower birth weight (Currie, Davis, Greenstone, and Walker, 2015), and a higher incidence of congenital anomalies (Currie, Greenstone, and Moretti, 2011). For example, a number of epidemiological studies have also found significant relationships between air pollution and preterm birth (Butler and Behrman, 2007).

Chilean siblings' differential exposure to air pollution during gestation to show that exposure to carbon monoxide during the third trimester is associated with a 3 to 4 percent of a standard deviation decline in test scores in fourth grade.

Fewer papers, however, investigate the effects of pollution on later earnings. Black et al (2019) find effects on later earnings and educational attainment in Norwegian children exposed to radioactive fallout. Isen and colleagues (2017) compare cohorts of children in nonattainment counties that had to reduce their air pollution after the Clean Air Act to those in attainment counties. They find that cohorts exposed to more air pollution in early life is associated with a 0.7 percent decrease in the number of quarters worked and a one percent decrease in mean annual earnings. In a working paper, Voorheis (2017) also finds that pollution exposure in early life is associated with modestly lower college attendance and wages. Grönqvist, Nilsson, and Robling (2019) show that children who were exposed to less lead through removing lead from gasoline in Sweden were more likely to graduate high school, were less likely to commit crimes, and had higher wages in adulthood.

Nevertheless, it is unclear what mechanisms might underly the relationship between pollution and long-run human capital outcomes and whether certain types of pollution, like HAPs, might have bigger impacts on wages. In addition, this is the first paper to investigate the spatial, racial and socioeconomic distributional consequences of prenatal pollution exposure on long-run outcomes. Most studies to date are unable to account for time-invariant characteristics of families and neighborhoods that could affect child outcomes. Finally, this paper examines an understudied, yet commonly encountered type of pollution (TRI pollution) that creates a situation in which communities are potentially exposed for years. This paper lends insight into the ways neighborhoods affect long-run outcomes for children, as well as the true costs of pollution.

III. Empirical Strategies

I evaluate the effects of in-utero exposure to environmental toxicants on children by comparing siblings who lived within 1 mile of a TRI site that opened or closed so that at least one sibling was exposed during gestation, but the other was not. In my analyses, I concentrate on families residing within one mile of a TRI site because, as shown in Panel A of Figure 1, Particulate Matter2.5 (PM25) is much more concentrated with a mile of a TRI site. Heavy toxic compounds are likely to deposit in larger quantities more locally after being emitted. Panel B also shows that Particulate Matter 10 (PM10) increases following a TRI site opening.[11] Most TRI sites (72% in 2018) primarily emit air pollution and usually release a variety of pollutants such as PM2.5, PM10, lead, and ozone. While there are many more pollution monitors measuring PM2.5 in recent times, over most of the study period (the late 70s through 90s), PM10 was the most commonly monitored pollutant. Thus, I use in PM10 in Figure 1b. However, I use PM2.5 for Figure 1a since more data are available for this type of hazardous pollutant and the more recent results are likely to generalize to the past. Both PM10 and PM2.5 decrease over distance away from a TRI site, however.

I employ two different identification strategies that both use a family fixed effects design. My first comparison is an intent to treat (ITT) analysis where I account for potentially endogenous mobility by conditioning on the location of the first birth near a TRI site for all siblings in the same family born earlier or later, regardless of whether the family moved. In other words, I compare children conceived within one mile of an operating TRI site to their siblings that are conceived after the same site closed or before it opened, regardless of whether the

[11] A similar result was obtained by Persico and Venator (2021) for the distance traveled by PM2.5 and PM2.5 having increased after a TRI site opening. Furthermore, there is evidence from environmental modeling that airborne toxics, such as heavy metals, from TRI sites are concentrated at closer distances to a facility (Chakraborty, Maantay and Brender 2011; Dolinoy and Miranda 2004).

mother remained in the proximity of the site. These results include the entire population of siblings for which the first-born sibling was conceived within 1 mile of an operating TRI site.[12] Second, I compare siblings whose family does not move between births (though they might have moved before or afterwards) where at least one child was prenatally exposed to TRI pollution because the mother lived within 1 mile of an operating TRI site. The comparison group in the regressions is siblings living in the same neighborhood at birth who are conceived at a time when a TRI site is not operating because it had not yet opened or it closed.

Because pollution exposure is not randomly distributed, it is important to account for the time invariant characteristics of families and neighborhoods that could affect child outcomes in adulthood, which motivates my use of family fixed effects. Thus, my identifying assumption is that the only thing that changed between conceptions of siblings was that the local TRI site closed or opened (regardless of where later children were born). Because the timing of TRI site openings and closings is plausibly unrelated to the timing of conception, comparing siblings near a TRI site should yield an unbiased estimate of the effect of exposure to TRI pollution during gestation. Later in the paper I describe a variety of the tests and specification checks that I undertake in order to determine the degree to which my results are internally valid.

My basic family fixed effects estimation is given by:

(1) $$Y_{ijt} = \beta_1 ClosestSiteWithinMileisOpen_{ijt} + X_{ijt} + \theta_j + \gamma_t + \varepsilon_{ijt}$$

Where Y_{ijt} is some outcome of a child *i* born to family *j* at time *t*. I determine whether prenatal exposure to TRI pollution affects a variety of long-run outcomes, including the log of wages, family income, the likelihood of being on public

[12] I estimated the timing of conception by subtracting the weeks of gestation from the birth date. I also estimated the timing of exposure on the basis of the timing of the opening and closing of TRI sites.

assistance as an adult,[13] years of education, the likelihood of graduating high school, college attendance, as well as a summary index of adult outcomes. β_1 is the coefficient of interest on $ClosestSiteWithinMileisOpen_{ijt}$, which is a dummy variable for whether a child was conceived while a TRI site was operating within one mile of their mother's residence. θ_j is a family fixed effect that is specific to the mother, γ_t is a birth year fixed effect, and X_{it} is a vector of child-specific control variables (i.e., gender, birth order fixed effects, birth month fixed effects, birth spacing, adult marital status, age in the last survey wave in 2016, maternal marriage status at the time of birth, and total years of childhood poverty). The models that analyze economic outcomes (such as wages and income) use all available person-year observations for ages 20-45 and control for age of the economic outcome linearly, a quadratic in age and a cubic in age to avoid confounding life cycle and birth cohort effects. Because many individuals did not respond in some survey waves or were missing some adult outcomes, I weight my regressions by the inverse of the number of times an individual is observed in the adult survey data. ε_{ijt} is an error term. Standard errors are clustered at the TRI site level.[14]

Since children who live near TRI sites are more disadvantaged, as shown in Table 1, one might be concerned that other neighborhood factors might contribute to disparities in outcomes. My estimates also could be biased if there are unobserved factors affecting the outcomes of children within one mile of a TRI site that are correlated with a TRI site opening or closing. For example, when a TRI site opens, more motivated families might move away from a TRI site to escape the pollution. If there is substantial residential sorting around an opening or closing,

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[13] I define adulthood in this context as age 23 or older. I define public assistance receipt as the receipt of Supplemental Nutrition Assistance Program (SNAP, also known as food stamps), Temporary Assistance to Needy Families (TANF), Aid to Families with Dependent Children (AFDC), Women, Infants and Children (WIC), general cash assistance, or Supplemental Security Income (SSI). I do not include veteran's benefits, etc.

[14] The results are also robust to clustering at the zip code level.

another mechanism through which a TRI site opening might affect children is through peer effects. On the other hand, a factory opening might both increase pollution and also stimulate the local economy (Greenstone, Hornbeck and Moretti, 2010), meaning that the positive impacts of better economic conditions may cancel out any negative impacts that could arise from pollution exposure.

To address these concerns, in my preferred ITT specification I compare children in the same family in which I instrument the location of the first birth in the family near a TRI site (and the first TRI site status and location) for all other siblings born later, regardless of whether the family moved. This Intent to Treat (ITT) specification allows me to address residential sorting and avoidance behavior by proxying the location of the first birth and treatment status for all later-born siblings. Thus, one would expect these estimates to be smaller since some untreated siblings might count as treated and some treated siblings might count as untreated if families moved. In an additional specification, I compare children in the same family who do not move between at least 2 births (though they might have moved earlier or later). I also restrict the analysis to children who only live within a mile of one TRI site (or fewer) at a time to ensure that treatment intensity was consistent across all children in the sample. While in the ITT specification, first-born children are all likely to be exposed to TRI pollution during gestation, in the non-movers specification, there is more heterogeneity in which sibling is exposed prenatally.[15][16]

[15] While I also control for birth order fixed effects in all specifications, there could be concern with the confounding of birth order and treatment status that is alleviated in the non-movers specification.

[16] It is important to note that there are fewer families who have their first child near a TRI site than families who ever have two children near the same TRI site since in the non-movers specification, I am including later births (e.g., siblings 2 and 3 are born near a TRI site, but not sibling 1).

I show that my results are robust to a variety of tests and specification checks in Section V.C. of the paper.

These results could also be biased towards zero if environmental toxicants mothers were exposed to through living near TRI sites affect children who are conceived after the site closes. Some research suggests that once exposed, environmental toxicants remain in a person's body for a long time, contributing to chemical body burden (Thornton et al., 2002; CDC, 2009). If environmental toxicants from local TRI sites stay in a mother's body for a long time, they could affect siblings who are conceived even after a TRI site has closed. My results might also be biased towards zero if there exists measurement error in the recorded timing of openings and closings. I use the earliest time when the company first filed its tax records or first started reporting to the TRI as the opening date and the latest time when the company last filed or stopped reporting as the closing date, but if the site was not emitting pollution at those times, children might not have been meaningfully exposed.

IV. Data Description

In this study, I explore the long-term effects of being exposed to TRI pollution by using a rich, longitudinal survey connecting mothers and children. The National Longitudinal Survey of Youth 1979 Cohort (NLSY79) is a nationally representative sample of adolescents who were 14 to 22 years old when they were first surveyed in 1979. The survey follows 12,686 young men and women, with annual interviews through 1994 and biennial interviews after that. The survey collects rich data about labor market participation, education, health, training, family formation and mobility. The Bureau of Labor Statistics began a separate survey of all children born to NLSY79 female respondents in 1986, the NLSY79 Children and Young Adult Surveys (CNLSY). This survey (the CNLSY) can be matched to the mother's information from the NLSY79 and contains information on each child on health, education, labor market participation, engagement in risky behaviors, and disability through 2016.

The set of adult outcomes I focus on include (1) labor market and economic status outcomes (measured biannually and expressed in 2000 dollars) – wages, family income (20-45) and the incidence of poverty in adulthood (23-45), (2) educational outcomes – years of completed education, whether a person graduated high school, and whether a person attended college, and (3) health outcomes – the likelihood of having any disability[17] and the likelihood of having a cognitive disability.[18] Wages, defined by annual earnings/annual work hours, is my main labor market outcome. I compute wages for only those who have positive earnings in a given year, and valid data exists for 79 percent of the sample of children with siblings living within one mile of a TRI site.[19] The average wage (in 2000 dollars) at age 30 for the whole sample is $15.20.[20]

To reduce measurement error and address concerns about multiple inference, I construct a summary index of outcome measures (Kling, Liebman, and Katz 2007; Deming 2009). I normalize each outcome to have a mean of zero and standard deviation of one, adjust the signs of outcomes so that a more positive outcome is better (i.e., I flip the sign for being on public assistance or having disabilities), and take the simple average across those outcomes. I then standardize the summary index, which includes family income, likelihood of being on public assistance programs as an adult, years of education, graduating high school, graduating college, having a cognitive disability, and being employed in the last

[17] Having any disability is defined as reporting having a cognitive disability, epilepsy, a nervous disorder, a heart problem, cancer, or being handicapped.
[18] Having a cognitive disability is defined as having a learning disability, ADHD/hyperactive, intellectual disability or a speech impairment.
[19] I drop a few implausibly low wages that are lower than $2.75 per hour, as well as wages for those who report being in college in the year of the wage observation.
[20] As shown in Table 1, the average age of the most recently observed wage of the respondent in my sample is 29.

four years. While my primary analytic sample is small, I am identifying off of 239 families and 778 children in my preferred ITT specification.

I gathered data on the annual types of pollution released by TRI sites and the locations of TRI sites from the EPA. Because the toxic emissions measures in the TRI database have been widely criticized for containing substantial measurement errors,[21] I gathered data on the timing of TRI site opening and closings from the state tax filings. Companies that are operating are required to file taxes each year, and I was able to match TRI sites based on business names and address information. I use the time when the company first filed its tax records or started reporting to the TRI as the opening date and the time when the company last filed or stopped reporting as the closing date.[22] As shown in Figure A1, TRI sites are mostly located in the most densely populated areas of the United States.

Using geocoded census-tract and zip-code data from the NLSY79 and latitudinal and longitudinal coordinates for TRI sites, I calculate the closest distance between the population-weighted census tract or zip code centroid and the nearest TRI sites in the year a child was born. The sample in this study includes every child born within one mile of a TRI site. 693 TRI sites opened and 497 sites closed between 1970 and 1998, the latest birth year for which I could observe adult outcomes. I also match these data to additional census tract and zip-code level census data from the 1980, 1990, 2000 and 2010 censuses.

[21] The data on emissions is self-reported and based on criteria that have varied over time. The EPA does not require plants to measure their emissions precisely, or to report at all under certain circumstances. Facilities are required to report if they manufactured or processed more than 25,000 pounds of a listed chemical or "otherwise used" 10,000 pounds of a listed chemical. For persistent bio-accumulative toxins, the thresholds are lower. These thresholds have changed periodically over the life of the program. The EPA provides guidance about possible estimation methodologies, but plants estimate their emissions themselves. Estimating methodologies may vary between plants and over time (Currie, Davis, Greenstone and Walker, 2015).

[22] However, the first year of the TRI is 1987. If a company reported on the TRI in 1987, they could not be found in the tax records, and there was reason to believe it was operating before 1987, in a few cases I assigned its opening date as 1970. The results are also robust to the assignment of different opening dates.

Table 1 presents the characteristics of children of NLSY79 respondents overall in Column 1, within one mile of a TRI site in Column 2, within one mile of an open TRI site in Column 3, and my primary ITT sample who are within 1 mile of a TRI site in Column 4. As shown in Table 1, children living within one mile of TRI site are significantly more disadvantaged than children in the CNLSY79 overall. Their mothers and fathers had fewer years of education at birth, were less likely to be married, and were more likely to report being in poverty than the entire sample of CNLSY79 children. They are also more likely to be Black or Hispanic, and less likely to attend preschool. However, children who were gestating near an open TRI site are similar to all other children who ever live near a TRI site on observable characteristics. Children in the ITT sample (Column 4) are very similar to other children living near a TRI site. On average, children who are exposed to TRI pollution would be exposed for 9.766 years if they never move away from the TRI site. However, 34.2% of families move between births in the ITT sample.

V. Long-run Outcomes of TRI Exposure During Gestation

A. Main Results

Because the sample of children of the NLSY79 living near a TRI site is relatively small, I focus first on an index of long run outcomes and attempt to maximize the sample size of my data by including children living farther than 3 miles from a TRI site as a comparison group.[23] Each column of Table 2 presents results from a different specification and sample that compare siblings with and without TRI pollution exposure during gestation, controlling for all of the variables outlined in Section III.[24] Standard errors are clustered at the TRI site level.[25]

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[23] Unfortunately, about two thirds of the sample lives between 1 and 3 miles from a TRI site, meanings that even using a comparison group that is 3 or more miles away leaves me with only 3,246 children.

[24] The regressions are weighed by the inverse of the number of times an individual is observed in the adult survey data.

[25] Clustering at the family level produces very similar standard errors.

Column 1 shows the results of a balance test that compares the outcomes index of children who are within a mile of a TRI site to children who are 3 or more miles away, revealing that on average, the outcomes of these two groups are fairly similar (when not using any fixed effects or openings/closings to identify the effects of pollution). Column 2 adds the use of plant openings and closing and zip code fixed effects to show that when a plant is operating, effects begin to become more negative for children gestating within a mile of a plant, relative to those gestating 3 or more miles away, although these results are not statistically significant at conventional levels. Column 3 instead estimates the effects of gestating within one mile of an operating TRI site compared to 3 or more miles away for children using family fixed effects. The point estimate nearly doubles in magnitude as I add family fixed effects, but the results are not statistically significant. This implies that these fixed effects partial out time invariant characteristics of families that bias the results towards zero. However, a distance of 3 miles away is likely still close enough to affect the outcomes of children in the comparison group, particularly when wind can carry pollutants long distances. In addition, these specifications do not address potential residential sorting that could bias the estimates.

Thus, Column 4 presents the results of my ITT specification in which I account for endogenous mobility by instrumenting for birth location with the first time a family lived near a TRI site, regardless of whether the family moved using zip code fixed effects (but not family fixed effects). In other words, I compare childing conceived within one mile of an operating TRI site to their siblings that are conceived when the same site is not operating, regardless of whether the mother remained in proximity of the site for the sample of siblings residing within 1 mile of a plant that opens or closes. Once I account for residential sorting and only include siblings within 1 mile of a site, I find that children who are exposed to TRI pollution during gestion have -58.5% of a standard deviation worse outcomes on the outcomes index compared to others in the same zip code and cohort, who were not gestationally exposed to TRI pollution.

Column 5 presents my preferred ITT specification in which I use plant openings and closing to compare siblings that differ on their prenatal exposure to TRI pollution, while adjusting for endogenous mobility. I find that children who were exposed to TRI pollution during gestation have a -0.489 of a standard deviation decline in the long-run outcomes index relative to a sibling who was not prenatally exposed to TRI pollution. Column 6 adds TRI fixed effects to the model in Column 5, and the effects become more than twice as large when I also account for time invariant neighborhood and TRI characteristics. The estimates in Column 7 present the results from the specification that compares siblings for whom the family does not move between at least 2 births. Children in non-moving families who are exposed prenatally to TRI pollution have -0.556 of a standard deviation worse outcomes than their siblings. It is important to note that the result in Column 5 is slightly smaller on average than that in Column 7 since children might not have been prenatally exposed to TRI pollution if their family moved away between births, but they would be assigned as exposed if the site was still open.

Table 3 presents individual estimates for several long-run outcomes: the log of wages, log if individual income, log of family income, the likelihood of being on public assistance as an adult, years of education, the likelihood of high school completion, and likelihood of attending college. Panel A presents the results of my preferred ITT specification in which I account for endogenous mobility by instrumenting for birth location with the first time a family lived near a TRI site, regardless of whether the family moved. It is important to note that the models that analyze economic outcomes (such as wages and family income) use all available observations for ages 20-45 and control for a cubic in age to avoid confounding life cycle and birth cohort effects (in addition to all of the other controls outlined in Section III).

Being exposed to air pollution prenatally is associated with large negative effects on long-run outcomes. Children who are exposed to TRI sites during gestation also have 1.284 fewer years of education than their unexposed siblings. However, I do not find a statistically significant effect on high school completion, college attendance, wages, income, or public assistance receipt, though the pattern of results suggests negative effects.[26]

The estimates in Panel B of Table 3 present the results from the specification that compares non-moving siblings. In Panel B, I find that being prenatally exposed to TRI pollution have 30% lower wages and are 17.2 percentage points more likely to be on public assistance as an adult than their siblings, which represents a 43.6 percent increase above the mean. They also complete 1.263 fewer years of education and are 12.4 percentage points less likely to complete high school than their siblings who were not prenatally exposed to TRI pollution.[27] I find that children exposed to TRI pollution prenatally are also 7.58 percentage points more likely to have any disability and 9.42 percentage points more likely to have a cognitive disability than their siblings.[28] This represents a 144.9% increase in disability rates overall and a massive 342% increase in cognitive disabilities. The point estimates also imply that cognitive disabilities drive the results on disability. Although the pattern of results in Panels A and B of Table 3 are similar, I use the more conservative ITT specification of in most of the rest of the paper.

The negative effects on the outcomes index in both specifications is predominantly driven by decreased educational attainment, as shown in Panel B of

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[26] Panel A of Table A1 shows these results controlling only for family, birth month and birth year fixed effects. The results are very similar.

[27] Panel A of Table A2 show similar results for non-movers using zip code fixed effects instead of family fixed effects. However, the results are much smaller in magnitude and not statistically significant, again indicating that time invariant characteristics of families are important determinants of long-run outcomes. Thus, I control for family fixed effects in the rest of the paper.

[28] Because there could be differential slippage between these categories over time, I examine cognitive disabilities separately and together.

Table A1.[29] Table A3 presents some additional long run outcomes that could constitute other mechanisms through which TRI pollution affects long run outcomes. I find no statistically significant effects for being employed or on unemployment, low birth weight, or being convicted, on probation or in prison. Thus, I focus on the outcomes index and educational outcomes.

Because TRI pollution could have differential impacts on wages at different parts of the wage distribution, I also estimate a simultaneous quantile regression of the effects of gestational exposure to TRI pollution on wages, controlling for family fixed effects and all other controls, and instrumenting the location of the first birth for all other children in the same family to address endogenous sorting. Panel A of Figure 2 shows that the largest effects on wages are seen in the 70th through 90th percentile of the wage distribution, relative to the 10th through 60th percentiles. This implies that fewer children who are exposed prenatally to TRI pollution make wages in the higher end of the earnings distribution, relative to their siblings.

To investigate whether children in a zip code's outcomes were already on a downward trend before relative to after a TRI site opening, I estimate an event study of the outcomes index on time from a TRI site opening in a zip code. I estimate the following regression for children gestating within a mile of a TRI site that opens:

(2) $$Y_{izt} = \beta_0 + \sum_{j=-2}^{2} \beta_j \mathbb{1}[\tau_{it} = j]_{st} + X_i + \eta_z + \theta_t + \epsilon_{ist}$$

Y_{izt} is the long run outcomes index value for child *i* born in zip code *z* in year *t*. I include 5 years of leads and 9+ years of lags for the treatment, where τ_{it} denotes the year relative to the opening of a TRI site. For example, a value of τ_{it} =

[29] As shown in Panel B of Table A1, dropping the variables for educational attainment from the outcomes index produces an estimate that is much smaller and not statistically significant at conventional levels.

-1 represents children's outcomes index in adulthood if they gestated one year before the year in which the TRI site opens (the reference year). β is the effect of a site opening within one mile of gestating child's location on the long-run outcomes index. η_z is a zip code fixed effect, which captures unobserved time-invariant characteristics of zip codes, and θ_t is a birth year fixed effect. X_i is a vector of controls for gender, birth order fixed effects, birth month fixed effects and age. I estimate this event study for children who did not move between their birth and the birth of a sibling in order to isolate the effect of a TRI site opening on long run outcomes.

Figure 3 shows the results of the event study on the long-run outcomes index. Relative to children who gestated the year before a TRI site opened, children who gestated 1-2 years afterwards experienced about 50% of a standard deviation worse outcomes in adulthood.[30] These effects persist at least 9 years after a TRI site initially opens, indicating that TRI sites worsen outcomes at the neighborhood level years after an initial opening. In addition, the results in year 0 are primarily driven by TRI sites that open before children are born. This implies that during the next year (1), all children would have been exposed to the TRI pollution during gestation, which is why the effect on outcomes might increase in magnitude. I also formally test for pre-trends, and the estimates for time periods before an opening are jointly not significantly different from zero at conventional levels (F statistic=1.76).

The picture that emerges suggests that pollution exposure during gestation is associated with having a cognitive disability, dropping out of high school, and then being on public assistance. One reason the effects might be so large is that TRI sites are known to emit especially harmful classes of compounds, such as heavy

[30] Due to my relatively small sample size, I binned the years before and after an opening into 2 year bins. Thus, 1-2 represents 1 to 2 full years after a TRI opening, 3-4 represents 3 to 4 years after an opening, etc.

metals, volatile organic compounds and polycyclic aromatic hydrocarbons. There is currently little causal research in humans about what these might do to the developing human brain, largely because this topic is difficult to study. In addition, exposure lengths to these chemicals are likely to be longer than those in previous studies if families do not move away from these sites.

Next, I examine whether TRI site openings might have different effects from TRI site closings. The results are presented in Table 4, where Panel A presents the effects for a TRI site opening on long-run outcomes and Panel B presents the effects for a TRI site closing on outcomes. Both specifications use the sample of non-moving families and compare siblings. The results in Table 4 suggest that for the long-run outcomes index, family income, years of education, and college attendance, the effects of an opening are slightly larger than that of a closing. One might expect TRI site closings to produce larger effects than openings since in the case of closings, only one sibling is exposed to TRI pollution, while in the case of openings, both siblings are exposed to the pollution, but at different ages. However, the pattern of results for openings and closings are fairly similar, which suggests that prenatal exposure to TRI pollution is worse than exposure at other times. In addition, some TRI chemicals might linger in a mother's body, exposing later-born children even if the site is no longer operating.

B. Heterogeneity of Estimated Effects

Table 5 presents estimates of the effects of exposure to TRI pollution by gender and socioeconomic status. Panel A presents the results for boys, while Panel B presents the results for girls. Although most results are not statistically different from each other, the pattern of results suggests that exposure to TRI pollution might have somewhat worse effects for boys than for girls. The outcomes index is -51.5% of a standard deviation lower for boys, compared with 43.5% lower for girls, which is marginally significant at the $p<0.1$ level. Both girls and boys who were prenatally exposed to TRI pollution have fewer years of completed education (1.111 fewer years of education for girls, compared with 0.981 fewer years for boys), relative to their unexposed siblings. Boys who were prenatally exposed to pollution are 27 percentage points less likely to attend college, which is significantly different from the effect for girls at the $p<0.06$ level. This pattern of results is consistent with prior evidence that boys might be more harmed than girls by early pollution exposure (e.g., Persico, Figlio and Roth 2020).

Panel C of Table 4 presents the results for children whose mothers were not in poverty when they were born, and Panel D presents the results for low-income children whose mothers were in poverty when they were born.[31] While the results are not statistically different from each other across groups, the effects of prenatal exposure to TRI pollution are also somewhat larger in magnitude for low-income children than for higher income children. Low-income children who suffered prenatal pollution exposure have 1.125 fewer years of education and are 19.3 percentage points less likely to attend college than their unexposed siblings. In comparison, wealthier children have 0.991 fewer years of education, are 14.2 percentage points less likely to attend college than their siblings (though this is not statistically significant). The outcomes index is -0.453 for non-poor children and -0.516 for low-income children and these estimates are different from each other at the $p<0.1$ level. TRI pollution might be worse for lower income families because low-income children live in closer proximity to the TRI pollution than wealthier children and have less ability to practice avoidance behaviors. However, the pattern of findings also suggest that pollution could harm mobility and might push people at the margins of poverty into poverty.

Panels E and F present the results by race: Panel E shows the results for non-Hispanic White children and Panel F shows the results for Black and Hispanic

[31] Unfortunately, due to sample size constraints, I am unable to break the sample into smaller bins to estimate effects across the earnings distribution.

children.[32] Overall, the long-run outcomes index result suggests that the effects are similar across racial categories and most of the results are not statistically different from each other across racial groups, except for high school graduation, which is worse for Black and Hispanic children.

In Table 6, I present the results of an exploratory analysis in which I estimate the effects of pollution on children for TRI sites that report emitting pollution through stacks, compared with TRI sites that have fugitive emissions. Because pollution released through smokestacks is usually treated with scrubbers before being released, one might expect the results to be smaller in magnitude for stack releases than for fugitive releases, which are essentially untreated releases. All specifications maintain the family fixed effects model and only include non-movers. The results presented in Panels A and B of Table 6 show that the pattern for stack releases and fugitive releases is quite similar overall. However, the effects on the outcomes index are larger for fugitive releases, but the effect on years of education is larger for stack releases.[33]

Another important question for policy is what types of industries drive these effects. In Table A4, I estimate an exploratory analysis in which I regress the long run outcomes index on indicators for different types of TRI industries interacted with an indicator for the TRI site operating during gestation within one mile of the family (using my preferred ITT specification). I find that the results

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[32] Unfortunately, due to sample size constraints, the effects on Black and Hispanic children had to be estimated as one group.

[33] Because the EPA only includes data on stack vs fugitive releases for a subsample of TRI sites, the number of observations are smaller here than for the full sample. Sites with missing data on stack versus fugitive releases are treated as missing, though it is clear they released air pollution. The EPA defines fugitive emissions as unintended emissions from facilities or activities (e.g., construction) that "could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening" (see title 40 of the Code of Federal Regulations, sections 70.2 and 71.2). Thus, it might be the case that only the milder polluters volunteer this information. In addition, many sites release both stack and fugitive releases, making disambiguating the effects difficult.

from different industries are not statistically different from each other – all industry types are associated with negative effects on children's long run outcomes indexes.

C. Additional Threats to Internal Validity

My identification strategy relies on the theory that residences closer to TRI sites will have greater exposure to pollutants. However, the air quality monitoring data over this time period is somewhat sparse. Panel B of Figure 2 presents the results disaggregated by distance from the TRI site, in which we interact an indicator for the site operating with distance bins (for example, site is open x <1 mile, site is open x 1-2 miles, etc.), with the children who are farther than 8 miles from a TRI site as the control group. As expected, the strongest effects are on children who are closest to the TRI site, with children living less than 1 mile from the TRI site having 40% of a standard deviation worse outcomes than children living more than 8 miles away. However, the effects on long run outcomes appear to fade out rapidly over distance.

One alternative explanation for these findings is that family income, a mother's marital status, a mother's or father's education, prenatal care, or parental behavior may have changed between siblings so that children born when TRI sites were not operating experienced married parents or parents with higher education and more resources than siblings born during a TRI site operating. While I do not have data on all factors that might have changed within families, I test for this directly in Panel A of Table 7 by comparing years of maternal and paternal education and whether the mother was married, reported at birth, between siblings who were exposed to TRI pollution, relative to siblings who were conceived after a site closed or before it opened. I also compare total years of childhood poverty, the month prenatal care was first obtained, whether the mother smoked or drank during pregnancy, and where a child ever attended preschool between siblings who were exposed to the TRI pollution, compared with their unexposed siblings. The results, presented in Table 7, are small and not statistically significant.

One might also be concerned that the closing of a TRI site might make a neighborhood more attractive to live in – and this neighborhood improvement, not the TRI site closing per se, was the cause of the better long-run outcomes. For example, if a TRI site's closure causes more educated and affluent people to enter a neighborhood, later born children might do better in school than their earlier born siblings because the composition of children in neighborhoods changed, leading to positive peer effects. While I do not have data on the schools children born to NLSY recipients attended, I can compare neighborhood characteristics between births. Using data from the 1980, 1990 and 2000 Censuses, I compare median home values, median income, percent of dwellings that are rented, the percent Black and percent Hispanic[34] at the zip code or census tract level for children prenatally exposed to TRI pollution, relative to their siblings who were not exposed in the same neighborhood. The results, presented in Panel B of Table 7, show that siblings experienced roughly similar neighborhoods. However, children conceived when a TRI site was operating experienced neighborhoods that had $1,866 higher income and 1.6 percentage points fewer homes that were rented, suggesting that there could be some positive economic effects around TRI site openings. Nevertheless, on average there are few economically meaningful differences in neighborhood characteristics between the neighborhoods siblings experienced.[35] Similarly, Persico and Venator (2019) find that there is no differential sorting based on observable characteristics into or out of schools after the openings or closings of TRI sites.

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[34] I linearly interpolate these values for missing years of data.

[35] While Currie et al (2015) find that TRI sites lower housing values by 11%, they examine a much longer time period in 5 states. Since the average gap between siblings is roughly 3 years in my data, not finding much change in housing prices in that time might make sense in this context.

One might also be concerned that a few very polluted TRI sites are driving the results. Thus, Table 8 presents results that limit the types of TRI sites used in the analysis in two different ways. The results presented in Panel A are limited to those TRI sites that are emitting pollution below the 80th percentile nationally. In other words, I drop the top 20 percent of polluters from the sample entirely and estimate the results for only the bottom four fifths of the distribution of TRI sites. The results presented in Panel B are from a sample of TRI sites that do not have bad-sounding names, or names associated with pollution.[36] The results in both Panels A and B are very similar to those in Table 2, though the results in Panel A are only marginally significant for the outcomes index. This suggests that it is not negative selection into certain neighborhoods or especially bad TRI polluters that drive the results.

One might be concerned that even though I control for birth spacing, birth order and birth month and year, that the results might be driven by children who are very different in birth order. Thus, in Panel B of Table A2 I limit the sample to just children who are first or second born. The results are again very similar to those in Table 2, suggesting that birth order does not drive the results. To test this further, I estimate a specification in Table A5 that is limited to siblings gestating within one mile of a TRI site that was not operating. Birth order does not have statistically significant effects on the outcomes index or years of education. In addition, I also estimate the effects of prenatal exposure to TRI sites using a difference in difference strategy in which I compare siblings where one was exposed in utero to TRI pollution within one mile of a TRI site to the same contrast for families living eight

[36] Bad-sounding names were names that included the words “industry”, “concrete”, “metal”, “chemical”, “pharmaceutical”, “plastic”, “manufacturing” or “power plant.” I also flagged any names that sounded like something one would avoid living near, like oil refineries, landfills, recyclers or industrial names.

to ten miles away from a TRI site.[37] The results, presented in Table A6, are quite similar to the main results in Table 2, suggesting that time trends over this time period and birth order do not substantially affect the results.

VI. Conclusion

This is the first study to examine the long-run effects of living near industrial pollution on wages, income, adult poverty, years of education, high school completion, and the development of cognitive and other disabilities. Children prenatally exposed to TRI pollution have -0.489 percent of a standard deviation worse outcomes and 1.284 fewer years of education than their unexposed siblings. Children whose families do not move away from proximity to a TRI site also have 30% lower wages, a 17.2 percentage point increase in the likelihood of being on public assistance as an adult, 1.263 fewer years of education, and a 12.4 percentage point increase in dropping out of high school, relative to their siblings who were not exposed during gestation. They also have a 7.6 percentage point increase in disability rates overall, as well as a 9.4 percentage point increase in cognitive disabilities. Overall, the pattern of results suggest that early life exposure to industrial pollution contributes substantially to long-term cognitive, labor market and developmental outcomes, and that pollution has much higher costs than have previously been estimated. In addition, closing TRI sites substantially benefits children's long-run labor market and health outcomes.

While it is difficult to estimate the total costs of TRI pollution because of potential differences across samples, I attempt a rough back of the envelope calculation to estimate the cost of TRI pollution on the costs of providing public assistance for one year. The federal government spent $877.5 billion on benefits

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[37] This specification has the advantage of estimating birth order effects more cleanly, as well as accounting for time trends.

and services for people with low income in 2016 (Falk, Lynch and Tollestrup 2018), and there were about 39.7 million low-income people in poverty (Fontenot, Semega and Kollar 2018). This implies a total average benefits cost of $22,103.30 per person on food, housing, medical care, job training and the like. Given that 19 percent of the U.S. population live within one mile of a TRI site (EPA 2014) and there were 3,941,109 children born in 2016 (CDC 2016), this implies an additional cost of about $2.91 billion per birth cohort per year from TRI pollution.[38]

Because exposure to pollution might have distributional effects, pushing people on the margins into poverty and disability, the true costs of pollution might be quite high. In addition, the results suggest that prenatal exposure to TRI pollution, which contains known neurotoxins like lead and mercury, might be much worse than exposure to typical air pollution. Given that geography is an important determinant of human capital formation (Chetty, Hendren, Kline and Saez, 2014), it is important to understand the mechanisms behind the disparities in educational outcomes that could stem from location itself. This study shows that one important mechanism through which neighborhoods affect long run outcomes is through exposure to industrial pollution.

I find strong evidence of worse outcomes even though the comparison set of siblings are likely exposed to some pollution, particularly in the case where there is a TRI opening. In addition, I find large effects even though some parents might practice avoidance behaviors to reduce children's exposure to pollution. However, these findings might also reflect the effects of cumulative exposure to environmental toxicants, since some children may live near a TRI site for a long time before it closes or after it opens.

Nevertheless, my findings point toward the notion that regulating TRI pollution would benefit low-income communities substantially, since children born

[38] This calculation uses the estimate in column 4 of Table 3 (0.176) to estimate the additional fraction of people who would need public assistance.

to mothers living near sources of pollution are negatively affected in terms of their cognitive development and long-run outcomes. In addition, Black, Hispanic, and low-income children are nearly twice as likely to live within one mile of a TRI site as the average for all children in the sample. The fact that low-income, Black, and Hispanic children are more likely to be exposed to environmental toxicants has profound implications for environmental justice and residential segregation. If TRI sites negatively affect housing values (Currie, Davis, Greenstone, & Walker, 2015) and poor children are almost twice as likely to live nearby, exposure to industrial pollution might also partially explain the widening socioeconomic education gap (GAO 2019). Pollution exposure could also be partially responsible for low-income children having a higher incidence of cognitive disabilities than higher income children (Bloom et al, 2013).[39]

Unfortunately, my results do not speak to specific toxicants to which individuals were exposed, since exposure to different compounds and agents released by TRI sites are collinear – TRI pollution is a mixed treatment. Further research is also needed to address how the benefits of TRI regulation may vary across industries and types of pollution, as well as what schools and other programs can do to support children with early toxic exposures.

However, this study is among the first to provide insights into how environmental pollution and policies affect early development and long run human capital outcomes. This is the first paper to examine whether exposure to especially hazardous air pollution affects adult wages, poverty, education and disability. In addition, this work speaks to how residential and socioeconomic contexts contribute to children's unequal life chances. If proximity to some pollution has

[39] In families with an income of less than $35,000, the percentage of children with a learning disability (11 percent) is almost twice that of children in families with an income of $100,000 or more (6 percent) (CDC, 2013).

distributional consequences that push people into poverty, it might be far more costly to families and society than previously supposed.

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Tables

Table 1: Characteristics of Children Within One Mile of a TRI site

	(1) Characteristics of all Children in the NLSY	(2) Characteristics of Children Within 1 Mile of a TRI Site	(3) Characteristics of Children Within 1 Mile of an Open TRI Site	(4) Characteristics of Children Within 1 Mile of a TRI Site (ITT sample)
Maternal Education at Birth	12.87	12.17	12.19	12.25
Paternal Education at Birth	12.64	12.27	12.40	12.48
Mother was in Poverty in Birth Year	0.168	0.275	0.277	0.288
Years of Education in Adulthood	13.69	13.31	13.48	13.39
Percent Black	0.157	0.290	0.291	0.287
Percent Hispanic	0.080	0.167	0.161	0.171
Maternal Marriage Status	0.744	0.555	0.556	0.541
Attended Preschool	0.662	0.602	0.599	0.616
Age of Oldest Observed Wage	28.74	28.9	28.53	29.06
Years Exposed to TRI Pollution if Respondent Does not Move Away	1.564	5.067	10.60	9.766
Observations	11,521	2,602	1,014	1,130

Notes: This table depicts the mean characteristics of children in the sample. Column 1 shows the characteristics of all CNLSY79 individuals using sample weights. Column 2 shows characteristics of all children within one mile of a TRI site. Column 3 shows characteristics for all children within one mile of an operating TRI site. Column 4 shows characteristics of children in the ITT sample in which one sibling is within 1 mile of a TRI site at birth.

Table 2: Long-Run Outcomes Index for Children Conceived Within One Mile of a TRI Site

	(1) Outcomes Index (Within 1 mile vs 3+ miles away)	(2) Outcomes Index (Within 1 mile vs 3+ miles away)	(3) Outcomes Index (Within 1 mile vs 3+ miles away)	(4) Outcomes Index (Within 1 mile)	(5) Outcomes Index (Within 1 mile)	(6) Outcomes Index (Within 1 mile)	(7) Outcomes Index (Within 1 mile using non-moving families)
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	0.000457	-0.0143	-0.259	-0.585**	-0.489**	-1.012***	-0.556***
	(0.0366)	(0.122)	(0.295)	(0.236)	(0.193)	(0.272)	(0.161)
Observations	3246	3246	3246	988	988	988	1,399
Mean of outcome	0.0893	0.0893	0.0893	0.139	0.135	0.135	0.123
Using Plant Openings and Closings		X	X	X	X	X	X
Zip code Fixed Effects		X		X			
Family Fixed Effects			X		X	X	X
Adjusting for residential sorting (using the location of the first birth)				X	X	X	
TRI site Fixed Effects						X	

Notes: Columns 1-7 present the results for different long-run outcome variables. The estimates in Panel A are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. In Panel B, only children from families living consistently within one mile of a TRI site and not changing census tracts or zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table 3: Individual Long-Run Outcomes with Family Fixed Effects for Children Conceived Within One Mile of a TRI Site

	(1) Log Wages	(2) Log of Individual Income	(3) Log Family Income	(4) On Public Assistance	(5) Years of Education	(6) Completed High School	(7) Attended College	(8) Has a Disability	(9) Has a Cognitive Disability
	Panel A: Intent to Treat								
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.0956	-0.353	-0.181	0.0665	-1.284**	-0.0629	-0.167	0.0240	0.0280
	(0.184)	(0.300)	(0.222)	(0.100)	(0.540)	(0.0705)	(0.103)	(0.0412)	(0.0392)
Observations	649	715	721	903	795	871	860	1,073	1,073
Mean of outcome	2.458	9.695	10.216	0.370	13.38	0.845	0.633	0.0475	0.0196
	Panel B: Restricted to Non-Moving Families								
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.300**	-0.103	-0.155	0.172**	-1.263***	-0.124**	-0.0720	0.0758*	0.0942**
	(0.133)	(0.262)	(0.182)	(0.0765)	(0.438)	(0.0575)	(0.0655)	(0.0407)	(0.0472)
Observations	958	1045	1054	1,295	1,138	1,235	1,217	1,530	1,530
Mean of outcome	2.400	9.694	10.267	0.394	13.40	0.849	0.629	0.0523	0.0275

Notes: Columns 1-7 present the results for different long-run outcome variables. The estimates in Panel A are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. In Panel B, only children from families living consistently within one mile of a TRI site and not changing census tracts or zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table 4: The Effects of Openings versus Closings on Long-Run Outcomes with Family Fixed Effects for Children Conceived Within One Mile of a TRI Site

	(1) Outcomes Index	(2) Years of Education	(3) Completed High School	(4) Attended College
	Panel A: Restricted to Openings			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.653**	-1.321*	-0.100	-0.254**
	(0.272)	(0.789)	(0.0809)	(0.124)
Observations	913	736	800	791
Mean of outcome	0.155	13.45	0.856	0.649
	Panel B: Restricted to Closings			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.465**	-1.427***	-0.0949	-0.153
	(0.186)	(0.525)	(0.0666)	(0.101)
Observations	970	779	853	842
Mean of outcome	0.128	13.36	0.844	0.629

Notes: Columns 1-6 present the results for different long-run outcome variables. In Panel A, I restrict to TRI site openings and in Panel B I restrict to TRI site closings. The estimates are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table 5: Long-Run Outcomes by Gender, Race and Poverty Status at Birth

	(1) Outcomes Index	(2) Years of Education	(3) Completed High School	(4) Attended College
	Panel A: Boys			
Conceived when TRI Site is Open (Compared to Closed)	-0.515**	-0.981	-0.109	-0.270**
	(0.217)	(0.653)	(0.0773)	(0.125)
	Panel B: Girls			
Conceived when TRI Site is Open (Compared to Closed)	-0.435*	-1.111*	-0.00479	-0.0545
	(0.247)	(0.666)	(0.0884)	(0.124)
P val boys=girls	0.137	0.504	0.194	0.0625*
Mean of outcome	0.135	13.38	0.845	0.633
	Panel C: Non-Poor Children			
Conceived when TRI Site is Open (Compared to Closed)	-0.453**	-0.991*	-0.0270	-0.142
	(0.194)	(0.535)	(0.0649)	(0.0977)
	Panel D: Low-Income Children			
Conceived when TRI Site is Open (Compared to Closed)	-0.516**	-1.125*	-0.112	-0.193*
	(0.216)	(0.573)	(0.0731)	(0.109)
P val non-poor=low income	0.095*	0.181	0.514	0.457
Mean of outcome	0.135	13.38	0.845	0.633
	Panel E: Non-Hispanic White Children			
Conceived when TRI Site is Open (Compared to Closed)	-0.650**	-1.895**	0.0684	-0.0896
	(0.286)	(0.963)	(0.104)	(0.152)
	Panel F: Black and Hispanic Children			
Conceived when TRI Site is Open (Compared to Closed)	-0.434*	-0.869	-0.110	-0.183*
	(0.229)	(0.571)	(0.0679)	(0.109)
P val white=non-white	0.676	0.901	0.051*	0.247
Observations	988	795	871	860
Mean of outcome	0.135	13.38	0.845	0.633

Notes: Columns 1-6 present the results for different long-run outcome variables. In Panels A and B, I estimate the effects by gender, and Panels C and D show the effects by maternal poverty status in a child's birth year. Panels E and F estimate the effects by race. The estimates are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. Standard errors are clustered at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table 6: Long-Run Outcomes by Treatment Intensity

	(1) Outcomes Index	(2) Years of Education	(3) Completed High School	(4) Attended College
	Panel A: Stack Releases			
Conceived when TRI Site is Open	-0.386*	-1.374**	-0.0959	-0.171
(Compared to Conceived When TRI was Closed)	(0.214)	(0.629)	(0.0876)	(0.118)
	Panel B: Fugitive Releases			
Conceived when TRI Site is Open	-0.498**	-1.147**	-0.0625	-0.156
(Compared to Conceived When TRI was Closed)	(0.194)	(0.553)	(0.0716)	(0.106)
P val stack=fugitive	0.310	0.0472**	0.312	0.254
Observations	980	788	863	852
Mean of outcome	0.132	13.37	0.844	0.633

Notes: Columns 1-6 present the results for different long-run outcome variables. In Panel A, I restrict to TRI sites reporting stack releases and in Panel B I restrict to TRI sites with fugitive releases. The estimates are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table 7: Average Difference in Family and Zip Code Characteristics between Siblings Living Within 1 Mile of a TRI Site

	(1) Maternal Marriage Status	(2) Years of Maternal Education	(3) Years of Paternal Education	(4) Poverty Status in Birth Year	(5) Total Years of Childhood Poverty	(6) First Month Prenatal Care Was Obtained	(7) Mother Smoked During Pregnancy	(8) Mother Drank During Pregnancy	(9) Ever Attended Preschool
	Panel A: Average Difference in Family Characteristics between Siblings								
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	0.0674 (0.0642)	-0.0458 (0.205)	-0.691 (0.521)	0.0340 (0.0969)	0.0663 (0.434)	0.0741 (0.339)	-0.00298 (0.0643)	0.117 (0.0951)	0.138 (0.0945)
Observations	988	811	467	988	988	892	988	988	893
Mean of outcome	0.744	12.29	12.46	0.290	2.18	2.604	0.250	0.415	0.622
	Panel B: Average Difference in in Zip-code level Characteristics between Siblings								
	(10) Median Home Value	(11) Median Household Income	(12) Percent Black	(13) Percent Hispanic	(14) Percent of Homes Rented				
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-13782.2 (8384.6)	1866.5** (864.8)	0.00141 (0.0164)	0.00942 (0.0209)	-0.0156*** (0.00536)				
Observations	471	592	592	592	592				
Mean of outcome	111768.5	35066.7	0.247	0.115	0.405				

Notes: Columns 1-9 present the results for running my main specification where the outcomes are different family characteristics. The estimates are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. Columns 10-14 present the results of the non-moving specification where the outcomes are different zip code characteristics. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table 8: Long-Run Outcomes with Family Fixed Effects for Children Conceived Within One Mile of a TRI site, Limiting to TRI Sites with Pollution Below the 80th Percentile for TRI Sites Nationally or Without Bad-Sounding Names

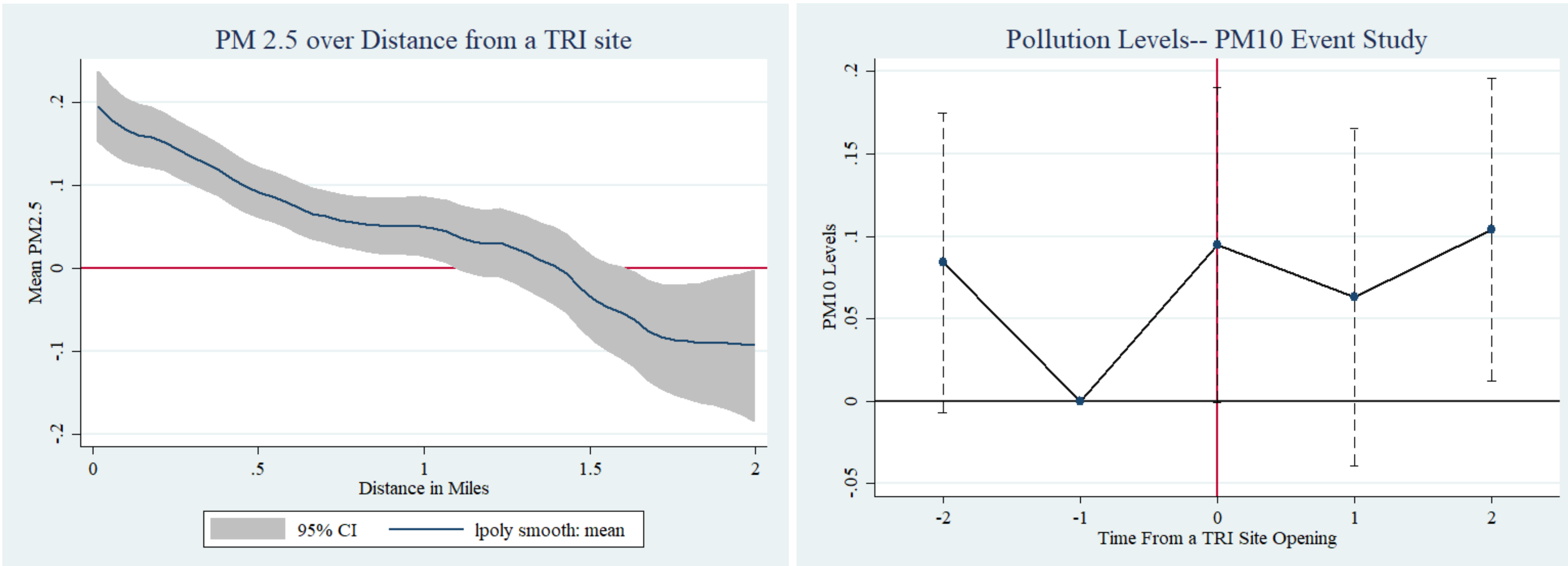
	(1)	(2)	(3)	(4)
	Outcomes Index	Years of Education	Completed High School	Attended College
	Panel A: Limiting to TRI Sites with Pollution Below the 80th Percentile for TRI Sites Nationally			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.393	-1.215*	-0.106	-0.134
	(0.281)	(0.621)	(0.0931)	(0.132)
Observations	804	651	709	702
Mean of outcome	0.112	13.35	0.842	0.625
	Panel B: Limiting to TRI Sites without Bad-Sounding Names			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.636***	-1.571**	-0.0837	-0.111
	(0.240)	(0.691)	(0.0897)	(0.127)
Observations	862	690	758	749
Mean of outcome	0.110	13.28	0.835	0.619

Notes: Columns 1-6 present the results for different long-run outcome variables. In Panel A, I restrict to TRI sites with pollution emissions that are below the 80th percentile nationally for TRI sites. In Panel B I restrict to TRI sites that do not have bad-sounding names. The estimates are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Figures

Figure 1: Particulate Matter 2.5 levels over Distance Away from a TRI site and Event Study of Particulate Matter after a TRI site Opening

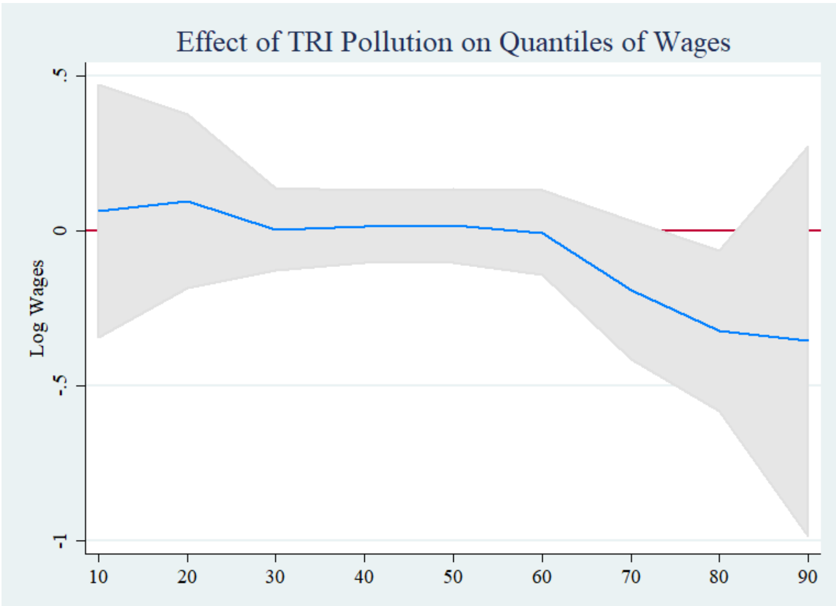
Panel A Panel B



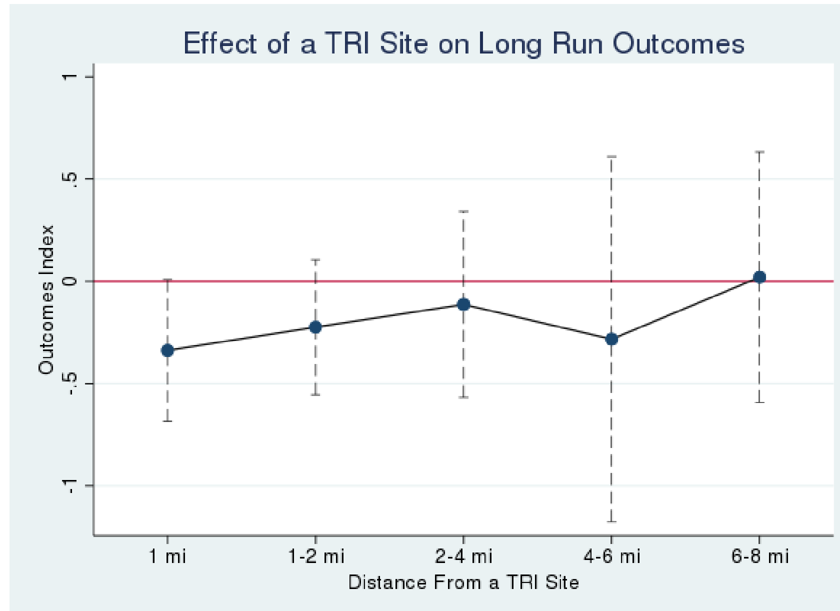
Notes: Panel A of Figure 1 depicts the level of Fine Particulate Matter (PM 2.5) over distance from the TRI site using data from 1990 to 2012. I show pollution levels by calculating the distance between PM 2.5 EPA monitors and the open TRI sites, regressing a kernel-weighted local polynomial smoothed plot of the average PM2.5 measured at a monitor on distance from a TRI site. Panel B of Figure 1 plots the coefficients from a regression of mean level of PM10 on leads and lags of a TRI site opening within a mile of the pollution monitor using pollution data from 1988 to 2012. T is the year the TRI site opens and all coefficients are normalized such that the coefficient in the year prior to opening (T-1) is zero. Dotted lines represent 0.95 confidence intervals for the coefficients. Standard errors are clustered at the pollution monitor level.

Figure 2: Effects of in Utero Exposure to TRI Pollution over Quantiles of Income and Outcomes with Family Fixed Effects for Gestational Exposure at Different Distances from a TRI site

Panel A

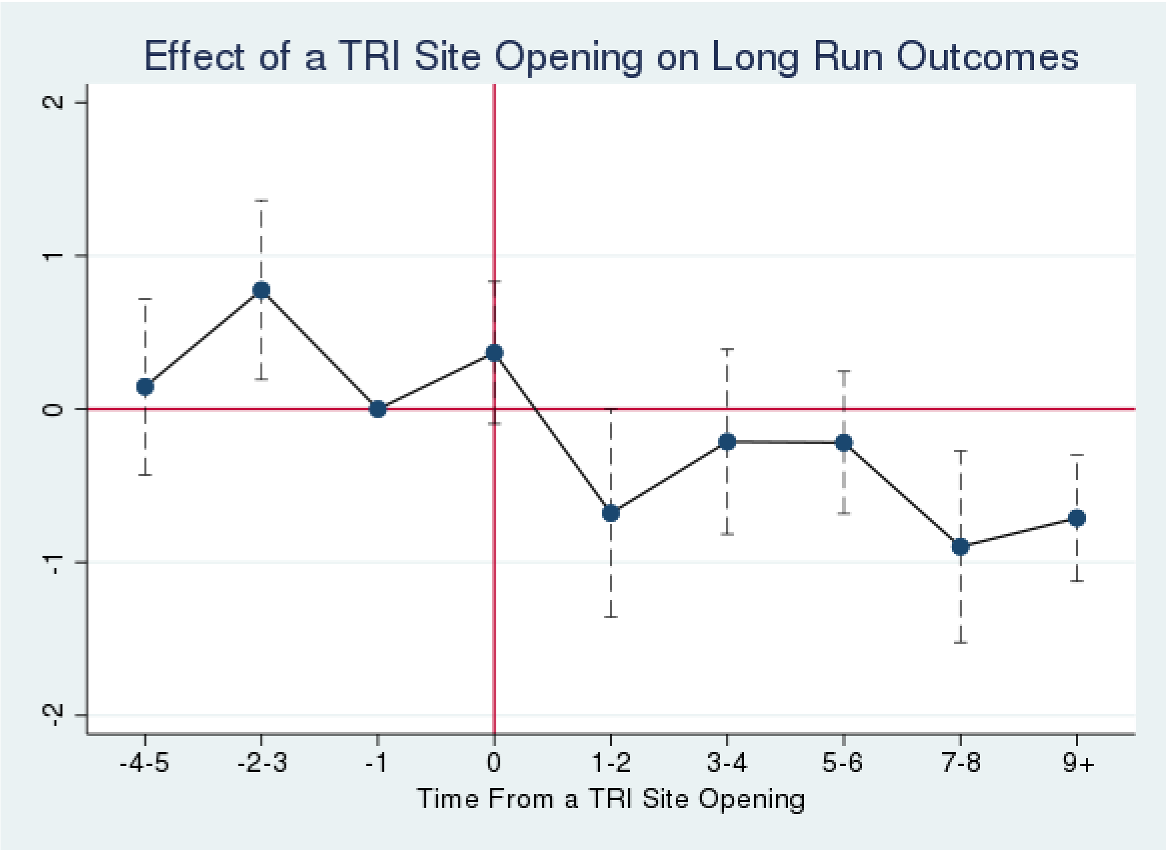


Panel B



Notes: Panel A of Figure 2 plots the effects of gestational exposure to TRI pollution on quantiles of the log of wages in adulthood. The line represents point estimates from a simultaneous quantile regression of the effects of gestational exposure to TRI pollution on wages, controlling for family fixed effects, birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. I also instrument the location of the first birth for all other children in the same family to address residential sorting. The shaded region represents 95% confidence intervals from bootstrapped standard errors. Panel B of Figure 2 plots the effects of in utero exposure to an operating TRI site at different distances away from the site. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, and gender. Standard errors are adjusted for clustering at the site level; the vertical lines represent 95 percent confidence intervals.

Figure 3: Event study of Outcomes with Zip Code Fixed Effects after a TRI site Opening



Notes: Figure 3 plots the coefficients from a regression of the outcomes index on leads and lags of a TRI site opening within a mile. 0 is the year the TRI site opens and all coefficients are normalized such that the coefficient in the year prior to opening (-1) is zero. In addition to zip code fixed effects, the regression controls for birth year, birth order and birth month fixed effects, gender, and age. Dotted lines represent 0.95 confidence intervals for the coefficients. Standard errors are clustered at the zip code level.

For Online Publication
Appendix

Table A1: Results with No Controls and Outcomes Index Results without Including Educational Outcomes

	(1) Outcomes Index	(2) Years of Education	(3) Completed High School	(4) Attended College
	Panel A: Results with No Controls			
Conceived when TRI Site is Open	-0.496**	-1.417***	-0.104	-0.211**
(Compared to Conceived When TRI was Closed)	(0.192)	(0.499)	(0.0729)	(0.102)
Observations	988	795	871	860
	Panel B: Outcomes Index Results without Including Educational Outcomes			
Conceived when TRI Site is Open	-0.0429	--	--	--
(Compared to Conceived When TRI was Closed)	(0.160)			
Observations	1129			
Mean of Outcome	0.135			

Notes: This table includes output from a single regression in which the effects of different types of TRI industries were estimated on the long run outcomes index. The location of the first birth is instrumented for other children in the same family. In addition to family fixed effects, regressions control for birth month and year.. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table A2: Long-Run Outcomes with Zip Code Fixed Effects or Family Fixed Effects Limited to First or Second Born Children (Limited to Children Conceived Within One Mile of a TRI site)

	(1) Outcomes Index	(2) Years of Education	(3) Completed High School	(4) Attended College
	Panel A: With Zip code Fixed Effects			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.0347	0.175	0.0304	0.112
	(0.165)	(0.570)	(0.0688)	(0.0911)
Observations	1399	1138	1235	1217
Mean of outcome	0.123	13.40	0.849	0.629
	Panel B: ITT Limiting to First and Second born Children			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	-0.623**	-1.737**	-0.112	-0.254*
	(0.269)	(0.869)	(0.0957)	(0.143)
Observations	828	668	717	710
Mean of outcome	0.184	13.54	0.865	0.662

Notes: Columns 1-6 present the results for different long-run outcome variables. In Panel A, only children from families living consistently within one mile of a TRI site and not changing census tracts or zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level. In addition to zip code fixed effects, regressions control for maternal marriage status at birth, total years of childhood poverty, birth month and year, birth order, birth spacing, age in the last survey wave, adult marital status, and gender. In Panel B, only first and second-born children are included in the analysis in which the location of the first birth is instrumented for other children in the same family. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table A3: Mechanisms and Other Long-Run Outcomes

	(1) Employed (in Either of the Last 2 Surveys)	(2) Ever on Unemployment	(3) Ever Convicted, on Probation or in Prison	(4) Low Birth Weight
	Panel A: Intent to Treat			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	0.0129	0.0143	0.00958	-0.0225
	(0.104)	(0.0222)	(0.0655)	(0.0701)
Observations	1,002	1,073	1,062	943
Mean of outcome	0.540	0.108	0.193	0.0827
	Panel B: Restricted to Non-Moving Families			
Conceived when TRI Site is Open (Compared to Conceived When TRI was Closed)	0.0115	0.0153	0.0230	0.00514
	(0.0887)	(0.0201)	(0.0697)	(0.0469)
Observations	1,435	1,530	1,514	1354
Mean of outcome	0.548	0.115	0.201	0.0827

Notes: Columns 1-5 present the results for different long-run outcome variables. The estimates are from the Intent to Treat specification in which the location of the first birth near a TRI site is instrumented for all other children in the same family. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table A4: The Effects of TRI Pollution by Industry Type

	Outcomes Index			
	(1)	(2)	(3)	(4)
	All other Industries	Metals	Mechanical	Plastic
Conceived when TRI	-0.334	-0.319	-0.970*	-0.176
Site is Open (Compared to Conceived When TRI was Closed)	(0.247)	(0.302)	(0.557)	(0.257)
		0.966	0.262	0.633
P val compared to all other industries	980	980	980	980
Observations	-0.334	-0.319	-0.970*	-0.176

Notes: This table includes output from a single regression in which the effects of different types of TRI industries were estimated on the long run outcomes index. The location of the first birth is instrumented for other children in the same family. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table A5: Limiting the Sample to Siblings Conceived When a Site Was Not Operating

	(1) Outcomes Index	(2) Years of Education
Second Born Siblings vs. First Born	-0.172	-0.391
	(0.115)	(0.263)
Third Born Sibling vs. First born	-0.0691	0.139
	(0.159)	(0.433)
Fourth+ Born Siblings vs. First Born	-0.389	0.193
	(0.296)	(0.712)
Observations	1062	879
Mean of Outcome	0.0261	13.14

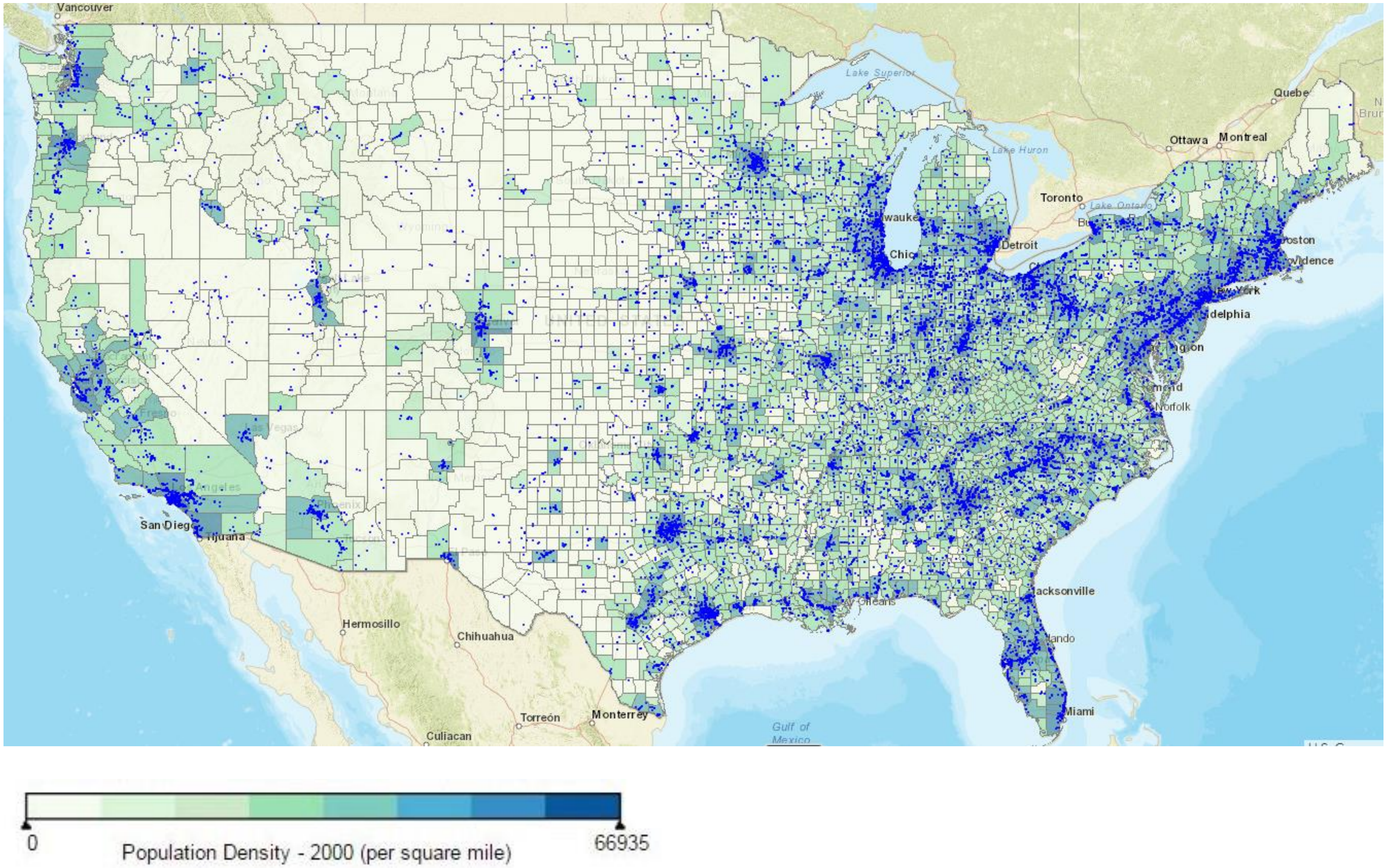
Notes: Columns 1-2 present results for the outcomes index and years of education. Only siblings residing within a mile of a TRI site that was not operating are included in the analysis. The omitted category is being first born. Standard errors are clustered at the TRI site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse of the number of times an individual is observed in the data. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Table A6: Difference in Difference Results with Family Fixed Effects for Children Conceived Within One Mile of a TRI site, Compared to Siblings in Families Living 8 to 10 Miles Away

	(1) Outcomes Index	(2) Years of Education	(3) Completed High School	(4) Attended College
(Conceived when TRI Site is Open Compared to Conceived When TRI was Closed within 0-1 mile) – (Conceived when TRI Site is Open Compared to Conceived When TRI was Closed in 8-10 miles)	-0.574*** (0.191)	-1.148*** (0.436)	-0.129** (0.0532)	-0.0492 (0.0649)
Observations	1246	1170	1276	1257
Mean of outcome	0.131	13.41	0.848	0.631

Notes: Columns 1-6 present the results for different long-run outcome variables. Only children from families living consistently within one mile of a TRI site and not changing census tracts or zip codes between births are included in the analysis, which compares siblings in families within 1 mile of an operating TRI site with siblings living 8-10 miles away. Standard errors are adjusted for clustering at the site level. In addition to family fixed effects, regressions control for birth month and year, birth order, birth spacing, age in the last survey wave, age squared, age cubed, maternal marriage status, total years of childhood poverty, adult marital status and gender. All regressions are weighted by the inverse probability of responding to the survey. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

Figure A1: TRI Sites over Population Density



Notes: Figure A1 shows the location of TRI sites (blue dots) nationally (according to the National Institute of Health's Toxmap website, 2019) overlaid on a population density map by county. Darker blue areas are more population dense. TRI sites are disproportionately located in the most population dense areas of the United States. Source: National Institute of Health, U.S. National Library of Medicine, TOXMAP. https://toxmap.nlm.nih.gov/toxmap/app/