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INEQUALITY BEFORE BIRTH:
THE DEVELOPMENTAL CONSEQUENCES OF ENVIRONMENTAL TOXICANTS

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ABSTRACT

Millions of tons of hazardous wastes have been produced in the United States in the last 60 years which have been dispersed into the air, into water, and on and under the ground. Using new population-level data that follows cohorts of children born in the state of Florida between 1994 and 2002, this paper examines the short and long-term effects of prenatal exposure to environmental toxicants on children living within two miles of a Superfund site, toxic waste sites identified by the Environmental Protection Agency as being particularly severe. We compare siblings living within two miles from a Superfund site at birth where at least one sibling was conceived before or during cleanup of the site, and the other(s) was conceived after the site cleanup was completed using a family fixed effects model. Children conceived to mothers living within 2 miles of a Superfund site before it was cleaned are 7.4 percentage points more likely to repeat a grade, have 0.06 of a standard deviation lower test scores, and are 6.6 percentage points more likely to be suspended from school than their siblings who were conceived after the site was cleaned. Children conceived to mothers living within one mile of a Superfund site before it was cleaned are 10 percentage points more likely to be diagnosed with a cognitive disability than their later born siblings as well. These results tend to be larger and are more statistically significant than the estimated effects of proximity to a Superfund site on birth outcomes. This study suggests that the cleanup of severe toxic waste sites has significant positive effects on a variety of long-term cognitive and developmental outcomes for children.

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I. Introduction

There has been considerable recent research on the deleterious effects of environmental toxicants on children. The sources of such pollution are manifold: millions of tons of hazardous wastes have been produced in the United States since World War II and have been dispersed into the air, into water, and on and under the ground. Much of this waste has accumulated in hazardous waste sites, and these sites are widespread across the nation (Landrigan, Suk, and Amler, 1999). Indeed, one in four (or 80 million) Americans live within 3 miles of a federal Superfund[1] site (US EPA, 2012), a location with particularly high levels of environmental toxicants, and about 11 million Americans, including 3-4 million children, live within one mile of a Superfund site (Steinzor and Clune, 2006). Given that children born to less educated and minority women are more likely to be exposed to environmental toxicants in utero (Anderson, Anderton, and Oakes, 1994; Currie, 2011) because disadvantaged mothers are more likely to live near sources of pollution, exposure to environmental toxicants is a relatively unexplored mechanism through which poverty produces negative cognitive and health outcomes over the life span.

We connect population-level birth and schooling records in Florida and compare siblings who gestated before versus after Superfund cleanup to study the effects of exposure to environmental toxicants on cognitive outcomes. In addition to the effects of toxicant exposure on

[1] The Comprehensive Environmental Response, Compensation, and Liability Act (P.L. 96-510, 1980), which is now known as Superfund, is the largest and most expensive federal program to clean up toxic waste in the United States.

children's early health outcomes, which could in turn translate to poorer cognitive outcomes,[2] the prenatal environment can have lasting impacts on various biological systems in the developing fetus (Almond and Currie, 2011; Kuzawa, 2005) and exposure to environmental toxicants could affect fetal brain development via epigenetic or other mechanisms (Fox et al, 2012; Lanphear, 2015; Stein et al, 2003) above and beyond the mechanism operating through early health.

Several recent papers have addressed the relationship between exposure to environmental toxicants and later human capital outcomes. Almond, Edlund, and Palme (2009) and Black, Bütikofer, Devereux, and Salvanes (2013) make use of Scandinavian data and quasi-experimental designs to study the effects of nuclear accidents or testing during gestation. Sanders (2012) estimates the relationship between county-level measures air pollution during gestation (making assumptions about location and timing of birth) in Texas and later test scores. Bharadwaj, Gibson, Graff Zivin, and Neilson (2014) compare Chilean siblings' differential exposure to air pollution during gestation during a period of rapid economic development in Chile, making use of three air quality monitors in Santiago. Aizer, Currie, Simon, and Vivier (2015) exploit Rhode Island's rules regarding residential lead abatement to investigate the effects of lead exposure on children's test scores. All of these studies find evidence of deleterious effects of pollution, lead exposure, or nuclear fallout on children's human capital development. That said, we know very little to date about the effects of substantial industrial toxicants in a highly developed setting like the United States.

[2] A growing literature has shown that children exposed in utero to pollution exhibit 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). Since health at birth is a strong predictor of a wide range of long-term outcomes, including income, education, and disability (Aizer and Currie, 2014; Black, Devereux, and Salvanes, 2007; Figlio, Guryan, Karbownik, and Roth, 2014), and early exposure to pollution affects neonatal and early health (Almond and Currie, 2011; Carneiro and Heckman, 2003; Figlio et al., 2014), it stands to reason that there would be a health channel connecting in utero exposure to environmental toxicants and later human capital formation.

We apply a new research design that allows us to directly compare siblings who were in utero at different stages of Superfund site cleanup. Relying on a sibling comparison of children whose families do not move away from close proximity to Superfund sites allows us to address concerns about local sorting, avoidance behavior, and other difficult-to-observe and possibly endogenous time-invariant characteristics of families that could affect child outcomes. We explore a range of cognitive outcomes, including both high-stakes student test scores as well as the development of cognitive disabilities and other school-based cognitive and behavioral outcomes. In addition, this is the first study to investigate the developmental effects of living near Superfund sites during the prenatal period on both birth and long-term outcomes. Although Superfund sites often house numerous developmental toxicants and exist in large population centers, little is known about the hazards to pregnant women living near these sites or the long-term consequences for children who are born nearby. While the costs of the Superfund program are substantial, the benefits of cleanup are poorly understood; therefore, this study will hopefully lend insight into how environmental pollution and policies in the U.S. might affect early brain development. This work also speaks to how residential and socioeconomic contexts can contribute to inequality before children are born.

Using new population-level data that follows cohorts of children born in the state of Florida between 1994 and 2002[3], we examine the long run impacts of being conceived proximate to a Superfund site before it is cleaned on children's performance in school. We match all births in Florida from 1994 through 2002 to subsequent student records for those children remaining in the state and attending public school. We then compare siblings living within two miles from a Superfund site at birth where at least one sibling was conceived before or during cleanup of the

[3] We can observe siblings for residents of counties representing a substantial majority of Florida's population. Additional details about the sibling match capabilities of the data are described in Figlio et al (2014).

site, and the other(s) was conceived after the site cleanup was completed using a family fixed effects model. This research design allows us to estimate the effect of prenatal exposure to pollution (and Superfund cleanup) on (1) birth outcomes, such as birth weight and APGAR scores, (2) significant school-related behavioral problems, and (3) longer term cognitive outcomes, including elementary school test scores, likelihood of grade repetition and diagnosis with cognitive disabilities or autism. It also allows us to estimate some unrecognized long-term benefits of Superfund cleanup.

We find large and substantial evidence that exposure to Superfund sites in utero reduces later cognitive outcomes. Children conceived to mothers living within two miles of a Superfund site before it was cleaned are 7.4 percentage points more likely to repeat a grade and have 0.06 of a standard deviation lower test scores than their siblings who were conceived after the site was cleaned. Children conceived to mothers living within two miles of a Superfund site before it was cleaned are also 6.6 percentage points more likely to have a behavioral incident in school than their later born siblings. Children conceived to mothers living within one mile of a Superfund site before it was cleaned are 10 percentage points more likely to be diagnosed with a cognitive disability than their later born siblings as well. Using the same identification strategy, we find comparable effects to birth outcomes to those observed by Currie, Greenstone, and Moretti (2011). This pattern of results indicates that the effects of environmental toxicants on later cognitive outcomes far outstrip those implied by looking at birth outcomes alone. In other words, the effects of environmental toxicants on later human capital are likely much more serious than the already reasonably large estimates implied through the early health channel.

II. Background

The Comprehensive Environmental Response, Compensation, and Liability Act (P.L. 96-510), which is now known as Superfund, is the largest and most expensive federal program to clean up toxic waste in the United States. Since 1980, the Environmental Protection Agency (EPA) has identified more than 15,000 such sites, which are labeled Superfund sites after they are admitted to the National Priority List (NPL), and usually house multiple toxicants (Landrigan et al., 1999). Once the sites are cleaned by the EPA, they are deleted from the NPL.

There is growing evidence that environmental toxicants interact with genetic susceptibilities to alter developmental trajectories and produce poor academic performance and cognitive disabilities, such as learning disabilities (Cognitive disabilities), speech and language impairments, intellectual disability, and autism (Jurewicz et al, 2013; Miodovnik, 2011). Although cognitive disabilities may have a substantial underlying genetic component, there is evidence that the development of cognitive disabilities is strongly influenced by the environment. Some of the most compelling data provided by twin and family studies shows that the relatives of probands (e.g., children of parents) with cognitive disabilities are at higher risk for developing cognitive disabilities themselves (Miller and McCardle, 2011). However, overall genetic factors seem to account for no more than perhaps 30–40 percent of all cases of neurodevelopmental disorders (Grandjean and Landrigan, 2014; Hallmayer et al., 2011), which indicates that environmental influences are heavily involved in the development of cognitive disabilities. Nevertheless, one issue with these sorts of genetic susceptibility studies is that it can be particularly difficult to control for shared environmental factors that may cause cognitive disabilities (e.g., parental influence, shared exposures to the same chemicals, etc.). Thus, most estimates from such studies (e.g. 40 percent) represent a higher bound of estimation, indicating that environmental factors are mainly involved in causing cognitive disabilities.

Furthermore, a growing body of recent research 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. Early-life epigenetic changes are also known to affect subsequent gene expression in the brain (Green, 2015; Kundakovic. 2011; Roth, 2012). Thus, a growing body of evidence points towards non-genetic, environmental exposures that are involved in causation of cognitive disabilities, in some cases by interacting with genetically inherited risk factors and epigenetic mechanisms. Thus, many researchers are beginning to ask: what sorts of toxic exposures might produce low academic achievement and cognitive disabilities and how are children exposed?

One plausible answer is that children might be exposed to hazardous waste through living in locations near hazardous waste sites, like Superfund sites. A recent study by Currie (2011) utilizing a difference-in-differences analysis on data from five states shows that women living within 2000 meters of a Superfund or Toxic Release Inventory (TRI) site were more likely to be low income and African American or Hispanic than women living farther away in the same zip code (before the site was cleaned up compared to after). This finding indicates that children born to less educated and minority women are more likely to be exposed to pollution in utero (Currie, 2011). Furthermore, using a difference-in-differences analysis, Currie, Greenstone and Moretti (2011) find that mothers living within 2000 meters of a Superfund site before it is cleaned up are 20 to 25 percent more likely to give birth to babies with congenital anomalies than mothers living from 2000-5000 meters from the site (than after a site is cleaned). Congenital anomalies have been tied to autism (Hultman, Sparén, and Cnattingius, 2002; Larsson et al., 2005), mental retardation (C. A. Nelson, 2000) and other Cognitive disabilities such as dyslexia (Galaburda, LoTurco, Ramus, Fitch, and Rosen, 2006).

Moreover, several classes of compounds can readily cross the placenta to enter fetal circulation, including compounds with low molecular weight, those that are fat-soluble, and other specific compounds such as calcium and lead (Bearer, 1995). In one study of ten randomly chosen babies from among 2004's summer season of live births from mothers in Red Cross's volunteer, national cord blood collection program, researchers in two labs detected a total of 287 foreign chemicals in umbilical cord blood from the group (Grandjean and Landrigan, 2014; Houlihan, Kropp, Wiles, Gray, and Campbell, 2005). Of the 287 chemicals detected in umbilical cord blood, 180 have been reported to cause cancer in humans or animals, 217 are toxic to the brain and nervous system, and 208 cause birth defects or abnormal development in animal tests. The chemicals found in the umbilical cord blood include pesticides, consumer product ingredients such as Bisphenol A, and wastes from burning coal, gasoline, and garbage, including dozens of widely used brominated flame retardants and their toxic by-products (Houlihan et al., 2005). However, this study only includes a sample size of ten babies (albeit randomly selected). Thus, it may be the case that many of these ten babies could have been on the high end of the distribution of toxic exposures. A larger sample size would give a better approximation of the distribution of toxicants in umbilical cord blood. In addition, the study says nothing about the levels of these toxicants, or the total number of toxicants per baby. Nevertheless, it does indicate the need for more research in this area to see what sorts of chemicals might regularly cross the placental barrier, and whether children are negatively affected by these combinations of exposures before they are even born.

Furthermore, some toxicants may be transferred to the infant through human breastmilk after birth (Needham et al., 2010). Studies of breast milk have shown the presence of chlorinated organic contaminants such as polychlorinated biphenyls and dioxins (Moya, Bearer, and Etzel, 2004), which are known to cause brain damage (Grandjean and Landrigan, 2006). Breast milk contains fat in which these chemicals tend to accumulate (Moya, Bearer and Etzel, 2004). In addition, the blood–brain barrier (BBB) provides only partial protection against the entry of chemicals into the central nervous system (CNS) during the prenatal through early postnatal period (Zheng, Aschner, and Ghersi-Egea, 2003). A functionally "leaky" structure of the BBB and blood-cerebrospinal fluid barrier accommodates the high demand of blood-borne nutrients for brain growth (Zheng et al, 2003). This permeability can leave the developing brains of children highly vulnerable to toxicants.

Thus, there is increasing evidence that the developing human brain is highly vulnerable to toxic chemical exposures, particularly during the prenatal, perinatal and early postnatal periods, as well as in early childhood (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 (Grandjean and Landrigan, 2014; Bearer, 1995). In a recent study, 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.

There is also reason to believe that the effects of toxicants may differ for children relative to adults. First, of course, children are much smaller than adults, so the level of exposure that is toxic to them is lower than it would be for an adult. Second, unlike adults, children's organs are undergoing growth and maturation, processes that may be adversely affected by exposure to harmful chemicals (Bearer, 1995). Third, cells in children are undergoing differentiation and migration. Importantly, neurons originate in a structure near the center of the brain (the neural tube) and migrate out to a predestined location (C. Nelson, Shonkoff, and Phillis, 2000). Thus, for example, prenatal exposure to ethanol via the mother may result in interruption in neural migration severe enough to cause obvious malformations of the brain leading to mental retardation (Bearer, 1995; C. A. Nelson, 2000). Furthermore, some in-vitro studies suggest that neural stem cells are especially sensitive to neurotoxic substances such as methylmercury, which can reduce neuronal stem cell proliferation and alter the expression of cell cycle regulators and senescence-associated markers (Bose, Onishchenko, Edoff, Lang, and Ceccatelli, 2012). Moreover, some research suggests that organophosphate pesticides may inhibit cholinesterase function in the developing brain (Costa, 2006), which can affect the crucial regulatory role of acetylcholine as a modulator of gene expression and neuron differentiation before synapse formation (Augusti-Tocco, Biagioni, and Tata, 2006; Grandjean and Landrigan, 2014). Thus, there is some evidence that exposure to neurotoxins early in life may affect cellular growth, maturation, differentiation, and migration pathways, as well as gene expression and synapse formation, in the developing brain. However, much more research on how specific chemicals and combinations of chemicals cause different adverse outcomes in the human brain is needed, since much of this research is done in animals and in vitro cell cultures.

Although Superfund sites are often contaminated by numerous developmental neurotoxicants, we know little about the long-term consequences to children living nearby. Some evidence indicates that early exposure to pollution is associated with lowered test scores (Bharadwaj et al., 2014; Sanders, 2012) and that low income and minority children are more likely to live near Superfund sites (Currie, 2011). If this is the case, differential exposure to pollution due to residential segregation might partially account for some of the achievement gaps between minority and White children, and between wealthier and poor children. It might also partially explain why Black children are more likely to be diagnosed with Cognitive disabilities. Finally, little is known about the potential positive health effects of cleaning up Superfund sites.

III. Identification Strategy

We evaluate the effects of prenatal exposure to environmental toxicants on children by comparing siblings who were conceived at different times while living within two miles of a current or former Superfund site. Since residential sorting can lead to non-random exposure to pollution, we employ a family fixed effects model to make within family comparisons among siblings living in the same location who do not move between births.[4] We independently estimate the effects of being conceived before, during, or after Superfund cleanup by constructing dummy variables for each category[5]. The comparison group (omitted category) in the regressions is for children who are conceived after cleanup. This enables us to examine the relative effects of exposure to environmental toxicants on siblings conceived before cleanup and during cleanup, compared to siblings conceived after cleanup. We use the timing of conception rather than the birth date because previous research has indicated that birth outcomes (such as premature birth) are endogenously related to pollution exposure (Currie, Davis, Greenstone and Walker, 2015).

Our identifying assumption is that the only thing that changed between conceptions of siblings was that the local Superfund site was cleaned. Because the timing of Superfund cleanup is plausibly unrelated to the timing of conception, comparing siblings who do not move should yield an unbiased estimate of the effect of Superfund cleanup. There are numerous potential

[4] Note that we only observe zip code of residence at the time of birth, and not precise street address. As a consequence, we consider "non-movers" to be people who remained in the same zip code of residence across the births of their children.

[5] We estimated the timing of conception by subtracting the weeks of gestation from the birth date. We then constructed three dummy variables for being conceived before cleanup, being conceived during cleanup, or being conceived after cleanup based on the timeline of cleanup of the closest Superfund site to the child's home zip code.

threats to internal validity, and later in the paper we describe a variety of the tests and specification checks that we undertake in order to determine the degree to which our results are internally valid.

Figure 1 presents a schematic of the timetable of cleanup of the Florida Superfund sites that we study in this analysis.[6] Any Superfund site that either began or completed cleanup between early 1993 (when the oldest children in the data were conceived) and 2002 (when the youngest children in the data were born) provides variation that can be used in this analysis. Table 1 presents information on the number of families who have observed pairs of siblings with gestations that bookend changes in Superfund status. As can be seen, it is extremely rare to observe families where one sibling was conceived before a Superfund site began cleanup and another was conceived after the site was completely cleaned; this is largely due to the fact that (as is evident from Figure 1) the time it takes to complete cleanup is generally much longer than the time range in which families have children. As such, there are only 59 families living within one mile of a Superfund site whose pregnancies completely bookend a Superfund site cleanup, and 669 families within two miles and 1,353 families within five miles. On the other hand, many more families have one child gestating before cleanup and another gestating during cleanup, or one child gestating during cleanup and another child gestating after cleanup: All told, 1,026 families living within one mile of a Superfund site have sibling pairs who span Superfund site cleanup transitions; the comparable statistics are 4,485 families within two miles and 13,039 families within five miles. In all of our analyses, we use bias-reduced linearization and adjust our standard errors for clustering at the Superfund site level; results are modestly more statistically

[6] Our data-sharing agreement with the Florida Departments of Education and Health prohibits the identification of any geographic units, so we cannot reveal the identities of the Superfund sites in our analysis.

significant if we only adjust for clustering, so we report the most conservative standard errors in the results that follow.

Our basic family fixed effects estimation is given by:

(1) $$Y_{ijt} = \beta_1 Before_{ijt} + \beta_2 During_{ijt} + X_{ijt} + \theta_j + \varepsilon_{ijt}$$

where Y_{ijt} is some outcome of a child *i* born to family *j* at time *t*. In our analyses, we concentrate on families residing within two miles of a Superfund site, though we also present results for other distances. We determine whether Superfund site cleanup affects (1) birth outcomes, (i.e., APGAR scores at 1 and 5 minutes[7], and the likelihood of congenital anomalies, abnormal birth conditions and low birth weight[8]) (2) significant school-related behavioral problems, and (3) longer term cognitive outcomes, including elementary school test (Florida Comprehensive Assessment Test) scores, likelihood of grade repetition and diagnosis with a cognitive disability or autism. $Before_{ijt}$ is a dummy variable for whether a child was conceived before a Superfund site was cleaned. Similarly, $During_{ijt}$ is a dummy variable for whether a child was conceived during cleanup of the site. The omitted category is a dummy variable for being conceived after cleanup of a site was completed. θ_j is a family fixed effect that is specific to the mother, and X_{it} is a vector of child-specific control variables (i.e., gender, birth year, birth month and birth order). ε_{ijt} is an error term. Our results are invariant to whether or not we control for time-varying maternal characteristics like age and education.

Our estimates of β_1 and β_2 would be biased if there were unobserved determinants of cognitive ability associated with living within two miles of a Superfund site before or during cleanup. However, our family fixed effects model helps to account for many unobserved

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[7] APGAR scores are a standard measure of infant health on a ten-point scale, with higher scores indicating normal physiologic functioning at birth.

[8] These were estimated with binary dependent variables that express the likelihood of abnormal conditions, congenital anomalies, or low birth weight. APGAR scores are continuous.

determinants of both birth and schooling outcomes and exposure to pollution, such as the home environment, shared genetics, and shared parents. Nevertheless, the family fixed effects models cannot account for changing family or neighborhood characteristics that could affect child outcomes. We address these issues directly in section IV.A below.

These results could also be biased if environmental toxicants affect children who are conceived after cleanup. Some research suggests that once exposed, environmental toxicants remain in a person's body for a long time, contributing to chemical body burden (CDC, 2009; Thornton, McCally, and Houlihan, 2002). If environmental toxicants from local Superfund sites stay in a mother's body for a long time, they could affect siblings who are conceived even after a Superfund site has been cleaned. This possibility might downwardly bias the estimates of the benefits of Superfund cleanup since siblings conceived after cleanup might still be affected by the pollution. Our results might also be downwardly biased if there exists measurement error in the recorded timing of cleanup: We use the time when the EPA first finished construction on the site cleanup, but the site had not yet been deleted from the NPL, so some children whom we treat as exposed to the Superfund site might not have been meaningfully exposed. On the other hand, it is also possible that later born children could still have been exposed to some pollution from the site if the first cleanup attempt was not successful[9]. Families can also engage in avoidance behaviors in order to reduce exposure to pollution, by, for example, selectively moving outdoor activities to cleaner locations, which would also downwardly bias our estimates.

One additional potential threat to internal validity is that we can only make use of test score and other school related data for siblings if all siblings have test scores and other school data. If one sibling is present in the test score data but not the others, and the reasons for

[9] The EPA typically waits several years and regularly monitors and reviews sites that have been cleaned to ensure that there are no leaks and the contamination has been removed before deleting sites from the NPL.

differential inclusion in the data are correlated with exposure to pollution from Superfund sites, the absence of one sibling's test score could present a source of bias. However, this is somewhat mitigated by the fact that there is not a statistically significant or economically meaningful difference in the likelihood of siblings taking the FCAT, as we discuss below.

A related concern is that we only observe education records for individuals born in Florida who remained in Florida, and attended Florida public schools. Various tests reported in detail in Figlio et al. (2014) suggest that in practice the selection bias resulting from either of these sources is likely to be minimal. This reduced threat is reinforced by focusing only on siblings whose families do not move between births. If we included families that moved, one might worry that moving could be a response to Superfund cleanup or other factors that could correlate with better child outcomes, such as parents getting better jobs. This response could upwardly bias estimates of Superfund cleanup. By limiting our sample to families who stay in the same neighborhood between births, we can compare siblings in a context where the only thing that changed (on average) between conceptions of siblings was the local Superfund site being cleaned.

A final potential limitation of our study design – albeit not a threat to internal validity -- is that we do not know the mechanisms of exposure at each site. We do know that Superfund sites in Florida contaminated the air, water and soil at the site, and that people often live very close to such sites where there is uncontrolled contamination. In addition, the same environmental toxicants found in Superfund sites can contaminate the air, water, or soil of a place, depending on a large variety of factors. The EPA documented in each case that there was an uncontrolled level of human exposure when they assessed the site for admission to the NPL before it was cleaned. Finally, there is a growing literature that documents the ways in which people living near Superfund sites and other sources of contamination are exposed and affected[10]. More research on the subject is needed in order to understand the degree to which uncontrolled hazardous waste sites are a problem for children in the United States.

IV. Data Description

A. Description of the Datasets

The sample in this study includes every child born in the state of Florida between 1994 and 2002, and educated in Florida public schools from 1996 through 2012. Our data follows these cohorts of children by linking birth certificate data and school records. Overall, 81 percent of all births in Florida were matched to school records – virtually identical to the rate expected using American Community Survey data; see Figlio et al. (2014) for details on the validity of the match. For the purposes of this study, Florida's education and health agencies matched children along three dimensions: first and last names, exact date of birth, and Social Security Number, with a small degree of fuzziness permitted in the match. Common variables excluded from the match were used as checks of match quality. These checks confirm that the matches are very clean: in the overall population, the sex recorded on birth records disagreed with the sex recorded in school records in about one one-thousandth of 1 percent of cases, suggesting that these differences are due to typos in the birth or school records.

Because we do not have access to home addresses of the families in our data due to privacy constraints, the distance to the nearest Superfund site was calculated via the family's zip code of residence (from the birth certificate). Having this data reduces bias due to Superfund-related mobility because we know where the child was living when he or she was born, as well as where the child went to school. First, populated-weighted zip code centroids were calculated

[10] See, for example, the Harvard School of Public Health's Superfund Research Program publications: http://srphsph.harvard.edu/publications/

for each zip code in our data as latitude and longitude coordinates. We then found the bird's eye distance (in miles) between the latitude and longitude coordinates of each population-weighted zip code centroid and each Superfund site. Next, we calculated the shortest distance between each zip code of residence and each Superfund site.

About one quarter of all children born in Florida move out of state, leaving about 1.6 million children who remain in the state of Florida and attend public schools. We can identify siblings in 70 percent of Florida children. Of these children, about 40,519 children were born to families living within one mile of a Superfund site, and 163,453 children were born to families living within two miles of a Superfund site. As observed in Table 1, 4,485 families living within two miles of a Superfund site and not moving have children conceived in different Superfund cleanup regimes; the comparable figure is 1,026 families within one mile and 13,039 families within five miles.

We gathered data on the timing of Superfund cleanup and the locations of Superfund sites from the EPA. Superfund sites are located in most major cities in Florida, including often the most population-dense areas of these cities. As seen in Figure 2, which presents the cumulative density of the distance to a Superfund site, 9.7 percent of children in Florida live within two miles of a Superfund site and 33 percent of children live within five miles. More than half (57.3 percent) of children in Florida live within ten miles of a site. For families with multiple children observed in the Florida linked data, the figures are moderately higher – 12.4 percent of siblings in our data live within two miles of a Superfund site; this is because the sibling linkage takes place in a set of relatively urban counties, rather than because families who live closer to Superfund sites have higher degrees of fertility. Therefore, it is clear that a considerable number of children might be affected by the toxic waste associated with a Superfund site.

B. Comparisons of the Children living around Superfund Sites to the Overall Population

Table 2 shows the attributes of the population of non-moving children living within two miles of a Superfund site along a number of dimensions: maternal race and ethnicity, maternal education, age, and marital status at the time of the child's birth, maternal immigrant status, child birth outcome averages, and child schooling outcome averages. We also measure a indicator of permanent family income based on the frequency with which we observe a child receiving free or reduced-price lunch in school, and categorize families as always low income, sometimes low income, and never low income. We concentrate on the population of children for whom we observe siblings, as this is the set of children we analyze in our study.

As can be seen in the table, there is a considerable difference in family advantage between non-moving families living within two miles of a Superfund site and the full set of Florida families. Children born within two miles of a Superfund site are almost twice as likely to be always low income in their schooling history (47.4 percent) than average for Florida (24.3 percent). Their mothers are more likely to have low education and less likely to be married at the time of birth. In addition, mothers of children born within two miles of a Superfund site are more likely to be foreign-born and Hispanic than the average for Florida. Mothers living near Superfund sites are also twice as likely (45.8 percent) to be Black compared with the average for Florida (22.4 percent). Children born within two miles of a Superfund site have lower test scores on average and are more likely to repeat a grade by fifth grade or have a behavioral incident in school.

Families who consistently live within two miles of a Superfund site are, along numerous dimensions, even more disadvantaged than all families who live within two miles of a Superfund site at the time of any of their children's births. These families are more likely to be low income and have low education. In addition, they are significantly more likely to be Black than all children born near a Superfund site. However, families with siblings who move away from Superfund sites are quite similar along a number of dimensions to those who stay[11].

These descriptive statistics make clear that children who live proximate to toxic waste sites tend to be substantially more disadvantaged than the general population of children. These statistics highlight the value of conducting sibling comparisons, since proximity to a Superfund site is so tied to disadvantage. They also suggest that our results are likely to be particularly relevant for the population of relatively disadvantaged children – the types of families who are most likely to live near Superfund sites.

V. Main Results on Birth and Schooling Outcomes

A. Birth Outcomes

We now turn to the main regression results for the OLS family fixed effects regressions, which control for gender, birth year, birth month, and birth order. Table 3 shows the birth outcomes using different specifications in each panel, and different outcomes in each column. We consider a set of birth outcomes -- APGAR scores, measured on a ten-point scale, at one and five minutes; and the likelihood of abnormal conditions, congenital anomalies, or low birth weight. We limit our analysis to the families who do not move between births. Panel A compares siblings who consistently live within two miles of a Superfund site, and panel B compares those who consistently live within one mile of a Superfund site. We adjust all standard errors for clustering at the Superfund site level, and since the number of Superfund sites in our analysis is modest – 37 – we calculate standard errors using bias-reduced linearization. Here and elsewhere in the paper, we opt for the bias-reduced linearization approach because the reported standard

[11] See the third and fourth columns of Table 2. On some metrics, families who move away are more disadvantaged than those who stay (e.g. the mother being married at the time of birth, never having low income, etc.)

errors are particularly conservative; were we to report Superfund site-clustered standard errors, the standard errors would be somewhat smaller.

We find mixed evidence on birth outcomes: We find evidence that children living very close (within one mile) to a Superfund site are more likely to have low birthweight and to have lower APGAR scores before cleanup than after cleanup. Slightly farther away, however, the results regarding birth outcomes disappear or even change signs. While our results differ somewhat from Currie, Greenstone, and Moretti's (2011) findings using a difference-in-difference strategy surrounding Superfund cleanups – notably, we do not find much evidence of changes in congenital anomalies following cleanup, while they did – the fact that we find evidence that birth outcomes appear to improve following cleanup for children living very close but not for those slightly farther away is consistent with the general theme of Currie, Greenshone, and Moretti's findings on birth outcomes. The fact that the general thrust of our birth outcome findings using a sibling fixed effect design is roughly consistent with Currie, Greenstone, and Moretti's general finding using a difference-in-difference design makes us reasonably confident that there exist modest neonatal health benefits associated with Superfund cleanup for those living very nearby a Superfund site.

B. Cognitive Outcomes

The point of this paper, however, is to focus on longer-term cognitive outcomes, which we present in Table 4. As with the birth outcomes, we control for gender, birth year, birth month, and birth order in our family fixed effects models. We consider several outcomes – pooled standardized reading and math test scores, as well as the likelihood of repeating a grade, having a behavioral incident in school, having a cognitive disability or being a child with autism. As with the birth outcomes, we present results for those families consistently living within two miles of a Superfund site and for those families consistently living within one mile of a Superfund site.

As can be seen in Table 4, we find substantial evidence to suggest that Superfund site cleanup improves children's longer-term cognitive outcomes. Children conceived to mothers living within two miles of a Superfund site before it was cleaned are 7.4 percentage points more likely to repeat a grade by fifth grade than their siblings who were conceived after cleanup. Compared against the fact that, on average, 18.5 percent of children who were conceived after cleanup repeat a grade, a 7.4 percentage point increase in grade repetition represents a 40 percent increase in the likelihood that a child will repeat a grade. Children conceived before cleanup are also 6.6 percentage points more likely to have a behavioral incident at school than their later born siblings. On average, 14.3 percent of children conceived after a neighborhood was cleaned have a behavioral incident. Thus, this represents a 46 percent increase in the chance that a child will have a behavioral incident in school, compared to the average for children born in cleaned neighborhoods. In most cases, behavioral incidents result in suspension from school, so these children are also more likely to be suspended. In addition, children conceived to mothers living within two miles of a Superfund site before or during cleanup have 0.062 of a standard deviation lower test (FCAT) scores on average than their siblings who were conceived after the site was cleaned. Given that the Black-White test score gap is about half of a standard deviation (Clotfelter, Ladd, and Vigdor, 2009), this represents between a tenth and a fifth of the Black-White test score gap[12]. These results are statistically significant at the $p<0.01$ level[13].

The school-based results for being conceived during cleanup, relative to after cleanup, are similar, but smaller in magnitude. The results are stronger for siblings who were conceived

[12] Representing these results as a share of the Black-White test score gap is just for the sake of comparison. It is unclear whether cleaning all Superfund sites would lower the Black-White test score gap by this amount.
[13] These results are the same when also controlling for maternal age, marital status and education level.

before cleanup than for siblings conceived during cleanup. If Superfund cleanup is effective, one would expect the results for being conceived during cleanup to be downwardly biased, since children conceived on the tail end of cleanup would have very little pollution exposure. This suggests that Superfund cleanup is effective at limiting children's exposure to environmental toxicants.

The effects of exposure to environmental toxicants might be more pronounced when children are gestating very close to a Superfund site; indeed, Currie, Davis, Greenstone, and Walker (2015) find that toxic air emissions affect air quality only within one mile of a plant. Therefore, children living within one mile of a Superfund site might be more likely to be exposed to pollution from Superfund sites than children living farther away. Only a relatively small number of families consistently live within one mile of a Superfund site that provides variation, but nonetheless there is good reason to further tighten the radius surrounding the Superfund sites to gauge the effects of cleanup, even if doing so comes at the expense of statistical power.

Indeed, we find that, in general, the results are even stronger at for children conceived before cleanup who were born within one mile of a Superfund site. As shown in Panel B of Table 4, children conceived before or during cleanup within one mile of a Superfund site are 6.5 percentage points more likely to be diagnosed with a cognitive disability than their siblings who were conceived after the site was cleaned. Children conceived before cleanup were 10 percentage points more likely to be diagnosed with a cognitive disability than their siblings conceived after the site was cleaned. In addition, there is a small suggestive increase in the likelihood of being diagnosed with autism within one mile of a Superfund site for the siblings who were conceived before or during cleanup, relative to their siblings conceived after cleanup[14]. The estimates of the likelihood of repeating a grade, having lower test scores, or having a behavioral incident are also somewhat stronger than the estimates for the two mile radius. However, an important caveat is that the likelihood of having a behavioral incident and autism results are sensitive to the type of specification and distance used to estimate them.

We also investigated which kinds of disabilities were affected by being conceived within one mile of a local Superfund site in Table 5[15]. We observe evidence suggesting that being within one mile of a Superfund site before a site is cleaned increases the likelihood of specific learning disabilities, speech and language impairments, intellectual disability and autism. However, Superfund sites apparently did not affect the likelihood of most physical disabilities that we observed, with the exception of being visually impaired[16]. Children conceived before cleanup within one mile of a Superfund site were also 0.3 percentage points more likely to be visually impaired than siblings conceived after cleanup.

Figure 3 presents results disaggregated by distance from the Superfund site, in which we interact an indicator for conception before/during cleanup with distance bins (e.g. conceived before/during cleanup x <1 mile, conceived before/during cleanup x 1-2 miles, etc.). While we do not have large numbers of families in each of these distance bins, and perhaps as a result the results are not monotonic, the general pattern of results is clear: In general, the farther away from a Superfund site that a pregnant mother lives, the smaller the relative long-term cognitive

[14] This finding was highly sensitive to the type of specification used to estimate the results, likely because there are so few cases of autism in the general population (<0.5 percent).
[15] We concentrate on the one mile definition for specific disabilities because we had found that the one mile radius appears to be particularly important for predicting the likelihood of disabilities.
[16] It makes sense that proximity to pollution would not affect conditions such as the likelihood of emotional disabilities or traumatic brain injury, and this is exactly what we find. There are null results for physical disabilities one would not expect to be affected by pollution. It could be that the increased likelihood of (severe) visual impairment is related to the increased likelihood of congenital anomalies around Superfund sites since individuals are often born with such impairments.

outcomes are for siblings born to those mothers become smaller in magnitude and lose statistical significance. Interestingly, the likelihood of repeating a grade even reverses with distance away from the pollution.

As large as our estimated effects of Superfund exposure are, there is reason to believe that these results are underestimates of the effects of exposure to the environmental toxicants found in Superfund sites. A large body of research has shown that once a person is exposed to pollution, toxicants often stay in his or her body for long periods, contributing to chemical body burden (CDC, 2009; Thornton, McCally, and Houlihan, 2002). In addition, most participants in studies measuring the amounts of these chemicals in blood, tissue and urine test positive for multiple chemicals. Thus, if a mother is exposed to pollution during her first pregnancy, she may still have a strong chemical body burden during her next pregnancies. If this is the case, then the comparison sibling conceived after Superfund cleanup would still have been affected by the mother's previous exposure to environmental toxicants, and we would have only identified the effects of levels of toxic exposure, rather than the presence versus absence of toxic exposure. As such, the true effects of toxicant exposure is likely even larger than that which we report.

While the comparison of siblings in non-moving families is our preferred model specification, we have also estimated the effects of Superfund exposure using several alternative approaches. One approach, reported in Panel A of Appendix Table A1, pools both non-movers and those families who move between births. While we prefer to identify the effects of Superfund site exposure based on families who do not change location, given that active moving may be endogenous, we carry out these exercises so that we can vary the birth order of the more-versus-less-exposed siblings in ways that would be impossible with the non-movers analysis, where the less-exposed sibling is always younger.[17] In the set of moving families, one child was born within two miles of a Superfund site that had not yet begun cleanup or that was in the process of cleanup, and another child was born at least five miles away from any Superfund site. This specification therefore makes use of two different ways in which siblings could differ in their in-utero exposure[18]. Panel B of Table A1 also shows the results just for siblings whose families move into or out of neighborhoods with a nearby Superfund site. In this specification we compare children who were conceived within 2 miles of a site before or during cleanup to their sibling who was conceived more than 5 miles away from a Superfund site. These results again indicate that those exposed to environmental toxicants associated with Superfund sites have worse cognitive outcomes, along a number of dimensions, than do those less exposed to Superfund toxicants, either because they were born more than five miles away from a Superfund site or because the Superfund site was cleaned up.[19] Another alternative approach, reported in Appendix Table A2, involves a difference-in-difference strategy, in which we compare those conceived before or during cleanup versus after cleanup for families living within two miles of a Superfund site to the same contrast for families living eight to ten miles away from a Superfund site. Again, the pattern of results suggests that Superfund cleanup has positive effects on children's cognitive outcomes.

[17] We have also carried out birth order comparisons in cases in which both siblings were born before Superfund site cleanup and where both siblings were conceived after Superfund site cleanup. In both cases, we consistently find the typical birth order relationships seen in the literature. And, of course, the post-cleanup siblings are necessarily younger – and typically would have worse outcomes based on birth order– than did their older, toxicant-exposed siblings, but we find the opposite pattern of results. For these reasons and others, we are convinced that our findings are not driven by birth order differences in outcomes.

[18] Of course, it is possible that the child born far away from a Superfund site still gestated nearby a Superfund site. This is one reason that we prefer the models in which we compare non-movers and identify solely off of Superfund cleanup timing.

[19] We also estimated a model including both family fixed effects and Superfund site fixed effects, allowing us to identify off of movers across proximity to different Superfund sites. The results are comparable, but somewhat stronger when we include both sets of fixed effects.

In addition, some of the school-based results might be driven by the fact that the older sibling (who is more likely to have been conceived before Superfund cleanup) might have had more time in school to accumulate grade repetitions, FCAT scores and behavioral incidents than her younger siblings who were not exposed to the pollution. Thus, the first two columns of Appendix Table A3 show the likelihood of repeating a grade or having a behavioral incident in school by third grade for children who were conceived before or during cleanup (relative to their siblings conceived after cleanup), conditional on all siblings attending third grade. Column three also shows the difference in third grade FCAT scores for siblings conceived before cleanup or during cleanup, compared to siblings conceived after cleanup. The results in Appendix Table A3 are roughly similar in magnitude to those in our main specification, indicating that age is not driving the results. Column 4 also indicates that siblings conceived before or during cleanup are also not more or less likely to take the FCAT in third grade, conditional on being observed in third grade, than their siblings conceived after cleanup[20].

We have also conducted exercises in which we drop one Superfund site at a time to see whether any given site is driving our results; as seen in Appendix Figure A1, in which we present confidence intervals in which we drop each site in turn from the analysis, there is no evidence that our results are being substantially driven by any single Superfund site.

C. Heterogeneity of Estimated Effects

Having population-level data for a state as large and diverse as Florida allows us to investigate heterogeneity in the effects of pollution exposure in ways that have not been possible in other related work prior to this point. Table 6 presents results broken down by student gender,

[20] In less than one percent of cases, Florida permits severely disabled children to take the Florida Alternative Assessment (FAA) rather than the FCAT (Florida Alternate Assessment Technical Report, 2009-2010). Unfortunately, we do not have data from the FAA. Taking the FCAT at all signals that a child is socially and intellectually competent enough to sit for a normal standardized test and is evidence of mainstreaming.

race/ethnicity, and our proxy for family income. For the purposes of space parsimony, we concentrate on the two mile radius definition of Superfund exposure, though patterns are similar for the one mile radius definition as well. All specifications maintain the family fixed effects model, and look only at non-movers. The results for repeating a grade or having a behavioral incident at school are slightly stronger for boys than girls, while the test score results are similar for boys and girls. The results are also similar across different racial and ethnic groups.

However, the results differ by income groups, and tend to be stronger for children of low income families. Children who always received free and reduced price lunch during their years in public school have the strongest results, followed by children who are sometimes listed as low income. Children who have never received free and reduced price lunch have the weakest results. It may be the case that higher income families practice more avoidance behaviors to reduce children's exposure to pollution, creating less of a disparity between siblings; that said, while not statistically distinct from zero, we find the largest point estimates for cognitive disabilities for the most affluent families.

D. Additional Threats to Internal Validity

One alternative explanation for our findings is that family income or a mother's education may have increased between siblings so that children born after Superfund cleanup experienced mothers with higher education than siblings born before cleanup. While we do not have data on all factors that may have changed within families, we are able to compare years of maternal education, reported at birth, between siblings who were conceived before or during cleanup, relative to siblings who were conceived after cleanup. We also compare whether there was any difference in free and reduced price lunch status in school between siblings who were conceived before or during cleanup, compared to after[21]. The results, presented in the first two columns of Table 7, are small and not statistically significant at the p<0.1 level. On average, mothers living within two miles of a Superfund sites did not significantly increase their education between children, and our family income measure did not differ significantly between siblings[22].

However, the estimates in Columns 3 through 6 of Table 7 show that there were some small differences between siblings in preschool attendance, marital status and prenatal care. We will address these in turn. Another alternative explanation for why siblings in the same family may have differed is if one sibling attended preschool, but the other(s) did not. In order to investigate this possibility, we compare whether there was any difference in preschool attendance between siblings who were conceived before or during cleanup, compared to siblings conceived after cleanup. The results in column 3 of Table 7 show that siblings conceived before or during cleanup are, on average, 4 percentage points more likely to attend preschool than their siblings conceived after cleanup was completed[23]. These results further suggest that our estimates of the impact of pollution from Superfund sites are not driven by differential preschool attendance between siblings, since the children who were fully exposed to the pollution were more likely to attend preschool than their later-born siblings who were conceived after cleanup.

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[21] Free and reduced price lunch status is our only direct measure of family income.

[22] We have also investigated other specifications that test for potentially omitted variables related to the time between births and birth order. For instance, we have limited the analysis to those Superfund sites cleaned within five years; and we have restricted our analysis to families where we observe the first two children only. The results are fundamentally the same as those presented herein. These results are available on request.

[23] This estimate is consistent with Gerner and Lillard (2006), who find that second born children are approximately three percentage points less likely to attend preschool than first born children. Gerner and Lillard (2006) find that children born later in the birth order were even less likely to attend preschool, relative to first born siblings, because parents invest more in earlier born children, with smaller investments in later children. However, it is also possible that siblings conceived before or during cleanup were more likely to attend preschool because parents were compensating for their poor health or performance. If preschool attendance increased school performance for these children, this would downwardly bias our results.

In addition, one might worry that mothers were less likely to be married for older siblings, which might hurt their school performance. The results in Column 4 of Table 7 show that children conceived before or during cleanup were 1.3 percentage points less likely to have mothers who were married at the time of their birth[24]. Because most of the sample includes mothers who eventually marry the father, the father is usually present for the birth, and the marital status differs in only 1 percent of cases, this is unlikely to affect the results strongly. Indeed, when we control for maternal marriage status, the main results are identical[25]. We also control for whether the fathers of the siblings are the same or different, and controlling for fathers does not affect the results[26].

We also investigated whether differential access to prenatal care may have differentially affected sibling outcomes. While it is largely unknown how prenatal care affects school outcomes, low access to prenatal care could negatively affect birth outcomes. The results presented in Columns 5 and 6 of Table 7 indicate that mothers had later initiation of prenatal care and fewer prenatal care visits for children conceived before or during cleanup, relative to their siblings conceived after cleanup. Columns 5 and 6 present results where the dependent variables

[24] Although only 54 percent of mothers of were married at the time of birth in the sample, 76.6 percent of the children had the same father listed on the birth certificate for all births in the same family (with the same mother). Of the 23.4 percent of children (6,126) who had different fathers listed on the birth certificate, the mother was married to (different) fathers at the time of birth in 25 percent of cases. This leaves 17.7 percent of the sample (4,614 children) where the mother was unmarried for at least one of the births and the fathers were different (or not listed on the birth certificate). Of these 4,614 children where the mother was unmarried at the time of birth and the fathers differed, the father was present at the time of birth in 2,740 of these cases. This leaves about 7 percent of the sample in which the mother was unmarried and the father was not present at the time of birth.

[25] We also estimated a model in which we control for the gap between births, as well as the interaction between being conceived before or during cleanup and the gap between births, to see if there having a large gap between births might account for the results through an interaction effect. When we control for the gap between births and an interaction between the gap and being conceived before/during cleanup, the results get stronger. Controlling for the birth order interactions produces results in which children conceived before or during cleanup (within 2 miles) have -0.077 of a standard deviation lower test scores, and are 4.4 percentage points more likely to repeat a grade, 7.4 percentage points more likely to have a behavioral incident, and 3.4 percentage points more likely to have a cognitive disability than their siblings conceived after. These results are all statistically significant at the $p<0.05$ level.

[26] We also have estimated an additional specification where we only compare children who have the same mother and father who are conceived before or during cleanup, compared to after. Our results are slightly stronger when both parents are the same.

are separate dimensions of the Adequacy of Prenatal Care Utilization (Kotelchuck) Index, which is on a scale score from 1 to 4, where lower scores indicate better prenatal care. When we control for these dimensions of prenatal care in our main results, the test score results become slightly stronger and all other results remain the same.

One might also be concerned that the cleanup of a Superfund site might make a neighborhood more attractive to live in rather than affecting development. For example, if a Superfund site's cleanup 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 students in the schools changed, leading to positive peer effects. The schools themselves might also improve over this period if Superfund cleanup attracts wealthier residents who value school quality and invest in local schools. Thus, the improved schooling outcomes for later born children could be the result of peer effects or school quality improving over time.

In order to investigate this possibility, we utilize date from the Florida School Indicators Report (FSIR) from the same time period to identify whether school quality or composition changed over time between siblings. The FSIR has data on the percent free and reduced price lunch[27], average teacher years of experience[28], average class size[29] and school stability by school[30]. We also use the Florida matched birth and schooling data to estimate the average

[27] Data on the percent free/reduced price lunch (FRL) by school are available in the FSIR from 1997-2008.
[28] Data on the average teacher years of experience per school are available in the FSIR from 1997-2008.
[29] Class size data are available in the FSIR from 1997-2002.
[30] School stability data are available in the FSIR from 2001-2008. We appended all years of FSIR data together and merged this with our matched birth and school records data from Florida by school and year for each child. We then took an average of each school quality variable over the years and schools each child actually attended so that there was one average for each variable for each child reflecting the average percent FRL, class size, etc. that child experienced over her time in school.

maternal education by school, the percent of children with single mothers, and the percent of Black students by school from 1992 through 2012[31].

The first four columns of Table 8 show family fixed effects regression results in which we investigate whether the peers in the schools the siblings attended differ on average by average maternal education, percentage of children on free and reduced priced lunch, percentage of children who are Black, and percentage of children with single mothers. In other words, we estimate family fixed effects regressions where we determine whether being conceived before or during cleanup is associated with differences in school quality between siblings. We find that there are no differences in the composition of schools in the three indicators we investigated between siblings conceived before/during cleanup compared to siblings conceived after cleanup. In other words, a child being conceived before or during cleanup did not predict attending a school that had children with lower average maternal education, on free and reduced price lunch, with more single mothers, or who were Black, compared to her siblings conceived after cleanup.

Unfortunately, many of the school quality indicators in the FSIR data could have been affected by the local Superfund sites. For instance, if Superfund cleanup affects test scores and behavior, measures such as school grades, test scores and disability rates are potentially endogenous measures for determining whether the schooling environments change between siblings. Thus, we examined three school quality indicators from the FSIR that are less likely to have been affected by local Superfund sites: average teacher years of experience, average class size, and school stability. We find that there was no statistically significant change in the average years of experience teachers had or the average class size between earlier and later born siblings.

[31] Similarly, using the population level matched birth and school records data, we created an average of the maternal education, the percent of single mothers, and the percent Black at each school in Florida from 1992-2012. We then took an average of each of these variables over the schools in the years each child actually experienced them. In the end there was one average for each variable for each child reflecting the average percent Black and maternal education in the schools each child experienced over her time in school.

However children conceived before or during cleanup experience schools that have 0.6 percent less school stability than their siblings who were conceived after cleanup. Although statistically significant, the point estimate of the change in school stability is sufficiently small that it is quite unlikely to account for our results[32].

In addition, we also investigate whether the neighborhood compositions might have changed over this time period for children living within 2 miles of a Superfund site. Using data from the 1990 and 2000 Censuses, we compare median home values, median income, percent of dwellings that are rented, the percent Black and percent Hispanic[33] at the zip code level for children conceived before cleanup or children conceived during cleanup, relative to their siblings conceived after cleanup in the same neighborhood. We find that on the whole, there are no statistically significant or economically meaningful differences in neighborhood characteristics between the neighborhoods siblings experienced[34]. As an alternative, we use information from the Internal Revenue Service's Statistics of Income tax statistics data, to observe whether family income in the zip codes in which children live changed meaningfully following Superfund cleanup; while there are slight increases in average family income, again the differences are far from statistical significance.[35] We also investigated whether the local Superfund site was located in the same zip code in which the children lived. The local Superfund site was in the same zip code 59.6 percent of the time. Controlling for whether or not the Superfund site was in the same neighborhood does not affect the main results.

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[32] We also investigated whether siblings attended the same schools at different times and find that siblings attended the same schools in the same year at least once in 90.46 percent of cases, which furthers the idea that the schools siblings attended were not likely to be substantially different.

[33] We linearly interpolate these values for missing years of data.

[34] There is one minor exception to this: siblings conceived before cleanup lived in neighborhoods where the percent of people renting was one percent higher than the same neighborhood after cleanup. This might reflect the fact that more people bought homes in neighborhoods after cleanup.

[35] The IRS Statistics of Income tax statistics data are reported for 1998, 2001, 2002, and annually from 2004 forward. We conduct our analysis of zip code income in the year the child turned six in order to maximize the number of observations available for this exercise.

VI. Cumulative Exposure

Given that earlier born children in our study still live in the same location when their siblings are born, the sibling comparison necessarily combines both in utero exposure and at least some degree of postnatal exposure. This section takes an exploratory step toward understanding whether the results are principally driven by in utero exposure, or by a combination of in utero and postnatal exposure. The potentially long duration of exposure could explain why children exhibit negative cognitive outcomes even in the absence of negative birth outcomes. In order to investigate this possibility, we compare the effects of cleanup for children who were living within two miles of a Superfund site whose cleanup was completed by their first birthday[36], and children who lived near a site whose cleanup was completed after the first birthday. In each case, children are compared to their siblings who were conceived after cleanup was completed. If cleanup was completed by a child's first birthday, this implies that most of the exposure to environmental toxicants a child might have had was in utero. If cleanup of a site was completed after a child's first birthday, this implies that the child may have been exposed both in utero and for a longer period after birth. Thus we estimate:

(2) $$Y_{ijt} = \beta_1 CleanByFirstYr_{ijt} + \beta_2 CleanAfterFirstYr_{ijt} + X_{ijt} + \theta_j + \varepsilon_{ijt}$$

Y_{ijt} is some outcome of a child *i* born to family j at time *t*. $CleanByFirstYr_{ijt}$ is a dummy variable for whether cleanup of a Superfund site was completed by a child's first birthday. $CleanAfterFirstYr_{ijt}$ is a dummy variable for cleanup being completed after a child's first birthday. The omitted category is a dummy variable for being conceived after cleanup of a site was completed. θ_j is a family fixed effect that is specific to the mother, and X_{it} is a vector of child-specific control variables (i.e.., gender, birth year, birth month and birth order).

[36] For this group, cleanup of a nearby Superfund site was completed between conception and age 1.

This regression is likely to underestimate the effects of in utero exposure since some children who live near a site that is cleaned during their gestation will only be partially exposed in utero. In addition, sites near the end of cleanup are likely to be mostly clean. In other words, children conceived on the tail end of cleanup would have very little pollution exposure. Thus, this is a strong test for whether in utero exposure matters, and a weak test for whether cumulative exposure drives these results.

Table 9 shows the results for children living within two miles of a Superfund site whose cleanup was completed by, or after, their first birthday, compared to their siblings who were conceived after cleanup. The results for children living near Superfund sites that were cleaned by their first birthday are quite similar to the results for children where the sites were cleaned after the first birthday (who had more exposure). While there is a 3 percentage point increase in the probability of having a behavioral incident at school for children living near sites that were cleaned after their first birthday, relative to children living near sites that were cleaned in the first year of life, this is the only outcome that appears affected. In some cases the results are stronger for children with in utero and early infancy exposure, so the results are somewhat ambiguous. Thus, there does not seem to be strong support for the idea that postnatal exposure leads to worse outcomes in this analytical design. Future research should further explore in greater detail whether cumulative exposure matters for children living near toxic waste.

VII. Conclusion

This is the first large-scale study of the effects of living near Superfund sites on the development of cognitive disabilities and other school-based cognitive, developmental and behavioral outcomes to our knowledge. Notably, we investigate the developmental effects of exposure to environmental toxicants during the prenatal period on both birth outcomes and long-term cognitive and behavioral outcomes over time. Population-level data suggests that Superfund cleanup has apparently significant positive effects on a variety of long-term cognitive and developmental outcomes for children. Children exposed to pollution from Superfund sites showed lower test scores, increases in externalizing behaviors (as measured by behavioral incidents at school), higher likelihood of repeating a grade, and an increased likelihood of having a cognitive disability compared to their siblings conceived after cleanup. The results support the notion that early life exposure to pollution contributes substantially to long-term cognitive and developmental outcomes, and that pollution has much higher costs than have previously been estimated. In addition, Superfund cleanup substantially benefits children's cognitive development.

This pattern persists despite the fact that there exist strong birth order effects (see, e.g., Black, Devereux, and Salvanes, 2005; Booth and Kee, 2009; Conley and Glauber, 2006; Price, 2008), and the likelihood that pollution accumulates in the bodies of mothers over time downward-biases the magnitude of sibling contrasts in this application. In addition, this pattern persists despite the avoidance behaviors parents might perform in order to reduce their and children's exposure to pollution. This finding is in keeping with the literature that has shown that early life exposure to pollution is associated with lower birth weight and test scores.

There are several limitations of this study. First, our sample of siblings who do not move away from a Superfund site is quite disadvantaged along a number of measures (e.g., race and socioeconomic status) compared to the average for children in Florida, which means that our findings might not pertain to an advantaged population less likely to live near environmental toxicants. This finding is in line with Currie (2011), who finds that mothers living near Superfund sites are more likely to be less educated and non-White. However, the fact that our results were similar for children of different racial and ethnic backgrounds suggests that children from all backgrounds are harmed by proximity to Superfund sites before and during cleanup, and, of course, .since disadvantaged families are those most likely to be exposed to environmental toxicants, this population is most affected by Superfund cleanup. In addition, our findings may be showing the effects of cumulative exposure to environmental toxicants, since earlier born children may live near a Superfund site for a long time before it is cleaned.

Nevertheless, our findings point toward the notion that inequality exists before birth, since children born to mothers living near sources of pollution will have their cognitive development affected negatively. The fact that poor and minority children are more likely to be exposed to environmental toxicants has profound implications for environmental justice and residential segregation. If Black children are more likely to live near Superfund sites, and these sites affect their cognitive development, pollution exposure could partially explain the Black-White test score gap – our estimates suggest that pollution accounts for between a tenth and a fifth of the Black-White test score gap. Furthermore, if Superfund sites negatively affect housing values (Currie et al., 2015) and poor children are more likely to live nearby, environmental toxicant exposure might also partially explain the widening socioeconomic test score gap (Reardon, 2011). Pollution exposure could also be partially responsible for low-income children having a higher incidence of cognitive disabilities than higher income children (Bloom, Jones, and Freeman, 2013)[37].

While funding the cost of cleaning up Superfund sites has long been contentious, this study adds an important piece of information about the benefits of Superfund cleanup. According our back-of-the-envelope calculation, the Superfund program would pay for itself in 38 years in

[37] 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).

terms of reduced special education costs for specific learning disabilities alone[38]. In addition, this study reveals the importance of cleaning up Superfund sites quickly, since children's outcomes suffer even during cleanup. Further research is needed to determine whether specific site remediation is cost effective in improving both cognitive and health outcomes. Of course, our research does not speak to the question of whether Superfund site cleanup could be made still more efficient, or if there are alternatives to Superfund cleanup that could remove people from harm's way. But given that children exposed to pollution from Superfund sites are more likely to have externalizing behaviors, cognitive disabilities and lower test scores, as well as health problems, the Superfund program may be quite cost effective.

However, our results do not speak to specific toxicants to which individuals were exposed, since we do not have measures for exposure to different compounds and agents. Thus, further research is needed about which environmental toxicants present in Superfund sites are most likely to contribute to negative cognitive and behavioral outcomes for children. Further research is also needed to address how the benefits of Superfund cleanup may vary across sites, as well as what schools and other programs can do to support children with early toxic exposures.

This study provides some insights into how environmental pollution and policies affect early brain development. In addition, this work also speaks to how residential and socioeconomic contexts contribute to children's unequal life chances even before conception.

[38] We use a $3 million cost per year over 9 years ($27,000,000) to clean up the average site with 4 million children living near 1,269 sites nationwide. Chambers, Shkolnik, and Perez (2003) estimate that the SLD spending ratio is 1.6 relative to the average "regular education" student. 0.6 (the increment) x $8572 (NCES) x 8 (the average number of years a kid with SLD receives SLD services over the course of his schooling) = $40,000 in reduced lifetime special education costs per child with a learning disability. For every child born within one mile of the site, cleanup reduces every child born's SLD education costs (forgetting about any other disabilities, or any labor market/human capital implications) by about $4,000 (given a 10 percent reduction in Cognitive disabilities). $4000 x 175 kids per site on average = $700,000 saved per birth cohort. $27,000,000 cleanup cost / $700,000 savings per birth cohort = 38 years to pay off Superfund cleanup for the average site just in terms of conservative special education savings.

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X. Tables and Figures

TABLE 1: NUMBER OF FAMILIES WITH AT LEAST ONE CHILD CONCEIVED BEFORE, DURING AND AFTER CLEANUP

	Living within 1 mile	Living within 2 miles	Living within 5 miles
Number of families with at least one child conceived before and one conceived after cleanup	59	669	1,353
Number of families with at least one child conceived before and one conceived during cleanup	252	993	3,768
Number of families with at least one child conceived during and one conceived after cleanup	715	2,823	7,918
Totals	1,026	4,485	13,039

Notes: The first column shows the number of non-moving families with at least 2 children living within one mile of a Superfund site in each category born between 1994-2002. Similarly, columns 2 and 3 show number of non-moving families with at least two children living within two and five miles of a Superfund site in each category, respectively. The number of children in each family varies, but there are always at least two.

TABLE 2: CHARACTERISTICS OF CHILDREN LIVING NEAR FLORIDA SUPERFUND SITES

Panel A: Characteristics	**(1) All children born in Florida, 1994-2002**	**(2) All children born within 2 miles of a Superfund Site**	**(3) Moving siblings born within 2 miles of a Superfund Site**	**(4) Non-moving siblings born within 2 miles of a Superfund Site**
Number of children	1,682,489	163,453	20,837	26,120
Child is female	0.488	0.489	0.494	0.497
Mother is (Non-Hispanic) White	0.713	0.413	0.437	0.396
Mother is Black	0.224	0.335	0.403	0.458
Mother is Hispanic	0.24	0.382	0.397	0.342
Mother married at time of birth	0.643	0.560	0.503	0.539
Mother aged <=19	0.122	0.141	0.172	0.151
Mother aged >=37	0.075	0.067	0.029	0.047
Mother is HS dropout	0.205	0.244	0.284	0.26
Mother is college grad	0.21	0.152	0.099	0.136
Mother is foreign-born	0.264	0.392	0.362	0.329
Always low income	0.243	0.347	0.474	0.474
Never low income	0.465	0.340	0.15	0.19
Panel B: Outcome measures for the child				
Behavioral incidents in school	0.226	0.244	0.274	0.263
Average test score	0.06	-0.074	-0.136	-0.125
Ever repeats a grade	0.22	0.249	0.273	0.28
Abnormal conditions at birth	0.058	0.045	0.036	0.041
Congenital anomalies at birth	0.007	0.006	0.006	0.006
One minute APGAR	8.403	8.551	8.61	8.66
Birth weight in grams	3307	3282	3292	3299

Notes: The first column presents fractions of the total population of children with birth records with residential zip code data matched to school records born in Florida from 1994-2002. The second column presents fractions of children living within two miles of a Superfund site. The third column presents fractions of children with at least one sibling who do not move between births living within two miles of a Superfund site. Low income is measured by a child's eligibility for free or reduced price lunches when school-aged, and is aggregated over all observations of a child's schooling career.

TABLE 3: BIRTH OUTCOMES WITH FAMILY FIXED EFFECTS FOR CHILDREN BORN WITHIN ONE OR TWO MILES OF A SUPERFUND SITE – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)	(5)
Panel A: Those Born Within Two Miles of a Superfund Site	**Apgar at 1 min**	**Apgar at 5 min**	**Likelihood of Abnormal Conditions**	**Likelihood of Congenital Anomalies**	**Likelihood of Low Birth Weight**
Conceived Before Cleanup versus After	0.041 (0.050)	0.010 (0.020)	-0.003 (0.013)	-0.003 (0.003)	-0.018* (0.010)
Conceived During Cleanup versus After	0.001 (0.033)	0.031* (0.017)	0.007 (0.006)	0.003 (0.002)	-0.000 (0.006)
Conceived Before/During cleanup versus After	0.003 (0.029)	0.030* (0.016)	0.006 (0.006)	0.003 (0.002)	-0.001 (0.006)
Observations	26,120	26,120	26,120	26,120	26,120
Panel B: Those Born Within One Mile of a Superfund Site					
Conceived Before Cleanup versus After	-0.088 (0.075)	-0.089*** (0.034)	-0.013 (0.049)	0.000 (0.005)	0.033* (0.020)
Conceived During Cleanup versus After	-0.015 (0.061)	0.001 (0.020)	-0.007 (0.018)	0.005 (0.004)	0.020* (0.011)
Observations	6,184	6,183	6,195	6,195	6,195
Average of the dependent variable	8.26	8.95	0.058	0.007	0.074

Notes: Columns 1-5 present the results for different birth outcome variables. Only children from families living consistently within two miles (one mile) of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

TABLE 4: SCHOOL OUTCOMES WITH FAMILY FIXED EFFECTS FOR CHILDREN BORN WITHIN ONE OR TWO MILES OF A SUPERFUND SITE – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)	(5)
Panel A: Those Born Within Two Miles of a Superfund Site	**Likelihood of Repeating a grade**	**Average FCAT Score**	**Likelihood of Behavioral Incident**	**Likelihood of Cognitive Disability**	**Likelihood of Autism**
Conceived Before cleanup versus After	0.074*** (0.021)	-0.059 (0.037)	0.066*** (0.025)	0.024 (0.017)	-0.002 (0.003)
Conceived During cleanup versus After	0.050*** (0.012)	-0.062*** (0.015)	0.031*** (0.013)	0.013 (0.014)	-0.003 (0.002)
Conceived Before/During cleanup versus After	0.051*** (0.012)	-0.062*** (0.014)	0.033** (0.014)	0.013 (0.014)	-0.003 (0.002)
Observations	25,754	24,425	26,015	26,120	26,120
Panel B: Those Born Within One Mile of a Superfund Site					
Conceived Before cleanup versus After	0.125** (0.055)	-0.122* (0.063)	0.074 (0.045)	0.100*** (0.023)	0.012 (0.011)
Conceived During cleanup versus After	0.078*** (0.023)	-0.052 (0.042)	0.030 (0.026)	0.068*** (0.021)	0.006* (0.003)
Conceived Before/During cleanup versus After	0.074*** (0.022)	-0.045 (0.043)	0.026 (0.025)	0.065*** (0.023)	0.006* (0.003)
Observations	6,080	5,728	6,164	6,195	6,195
Average of the dependent variable	0.22	0.049	0.226	0.179	0.005

Notes: Columns 1-5 present the results for different schooling/cognitive outcome variables. Only children from families living consistently within two miles (one mile) of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

TABLE 5: INDIVIDUAL COGNITIVE AND PHYSICAL DISABILITY OUTCOMES WITH FAMILY FIXED EFFECTS FOR CHILDREN CONCEIVED WITHIN ONE MILE OF A SUPERFUND SITE – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)	(5)
Panel A: Individual Cognitive Disability Outcomes	**Likelihood of Specific Learning Disabilities**	**Likelihood of Speech and Language Impairments**	**Likelihood of Intellectual Disability**	**Likelihood of Autism**	**Likelihood of All Cognitive Disabilities**
Conceived Before Cleanup versus After	0.033 (0.022)	0.061** (0.030)	0.017* (0.010)	0.012 (0.011)	0.100*** (0.023)
Conceived During Cleanup versus After	0.018** (0.008)	0.052*** (0.016)	0.006 (0.005)	0.006* (0.003)	0.068*** (0.021)
Conceived Before/During Cleanup versus After	0.017** (0.008)	0.051*** (0.017)	0.005 (0.005)	0.006* (0.003)	0.065*** (0.020)
Average of the dependent variable	0.061	0.099	0.009	0.005	0.156
Panel B: Physical Disability Outcomes	**Likelihood of Physical Disabilities**	**Likelihood of being Deaf or Hard of Hearing**	**Likelihood of being Visually Impaired**	**Likelihood of Health Disabilities**	**Likelihood of Emotional / Behavioral Disabilities**
Conceived Before Cleanup versus After	0.004 (0.019)	-0.005 (0.004)	0.003*** (0.001)	0.007 (0.018)	0.009 (0.013)
Conceived During Cleanup versus After	-0.001 (0.012)	-0.002 (0.002)	-0.000 (0.000)	0.001 (0.012)	0.004 (0.006)
Conceived Before/During Cleanup versus After	-0.002 (0.012)	-0.002 (0.002)	-0.000 (0.001)	0.001 (0.012)	0.003 (0.006)
Observations	6,195	6,195	6,195	6,195	6,195
Average of the dependent variable	0.016	0.001	0.001	0.014	0.009

Notes: Each column represents a different disability category. Only children from families living consistently within one mile of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

TABLE 6: HETEROGENEITY ANALYSIS WITH FAMILY FIXED EFFECTS FOR CHILDREN LIVING WITHIN 2TWO MILES OF A SUPERFUND SITE WHO WERE BORN BEFORE OR DURING CLEANUP (COMPARED TO CONCEIVED AFTER CLEANUP) – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)
	Repeats any grade	**Average FCAT Score**	**Likelihood of Behavioral Incident**	**Likelihood of Cognitive Disability**
Boys				
[N=7,174]	0.057*** (0.013)	-0.056** (0.024)	0.037*** (0.014)	0.010 (0.013)
Girls				
[N=6,973]	0.035*** (0.012)	-0.064*** (0.018)	0.028* (0.016)	0.022 (0.017)
White				
[N=13,826]	0.040* (0.022)	-0.053** (0.026)	0.009 (0.012)	0.032 (0.020)
Black				
[N=11,965]	0.028* (0.015)	-0.055** (0.023)	0.015 (0.025)	-0.004 (0.013)
Hispanic				
[N=8,943]	0.024 (0.026)	-0.074** (0.035)	0.017 (0.014)	0.003 (0.017)
Always low income				
[N=12,391]	0.047*** (0.013)	-0.064*** (0.022)	0.023 (0.019)	0.001 (0.015)
Sometimes low income				
[N=21,160]	0.043*** (0.009)	-0.064*** (0.014)	0.025 (0.016)	0.009 (0.013)
Never low income				
[N=4,960]	0.010 (0.014)	-0.017 (0.037)	0.003 (0.024)	0.037 (0.028)

Notes: Each column represents a different disability category. Only children from families living consistently within two miles of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.
*

TABLE 7: AVERAGE DIFFERENCES IN FAMILY CHARACTERISTICS BETWEEN SIBLINGS LIVING WITHIN TWO MILES OF A SUPERFUND SITE (COMPARED TO CONCEIVED AFTER CLEANUP) – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)	(5)	(6)
	Years of Maternal Education	**Free and Reduced Price Lunch Status**	**Preschool Attendance**	**Maternal Marriage Status**	**Adequacy of Initiation of Prenatal Care (Kotelchuck Index)**	**Adequacy of Received Services (Kotelchuck Index)**
Conceived Before or During Cleanup	-0.038 (0.043)	-0.005 (0.003)	0.040** (0.018)	-0.013** (0.006)	0.049* (0.028)	0.072*** (0.026)
Observations	26,064	26,120	26,120	26,120	25,880	26,120
R-squared	0.035	0.007	0.013	0.044	0.014	0.005

Notes: Each column represents a different family attribute. Only children from families living consistently within two miles of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

TABLE 8: AVERAGE DIFFERENCES IN SCHOOL QUALITY BETWEEN SIBLINGS LIVING WITHIN TWO MILES OF A SUPERFUND SITE (COMPARED TO CONCEIVED AFTER CLEANUP) – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average Maternal Education by School (1992-2012)	**Percent Free / Reduced Price Lunch by School (1997-2008)**	**Percent Black by School (1992-2012)**	**Percent of Married Mothers by School (1992-2012)**	**Average Teacher Years of Experience (1997-2008)**	**Average Class Size (1997-2002)**	**School Stability (2001-2008)**
Conceived before or during Cleanup	0.002 (0.017)	-0.006 (0.378)	0.002 (0.002)	0.000 (0.002)	-0.001 (0.082)	-0.065 (0.365)	-0.003 (0.571)
Observations	26,120	24,940	26,120	26,120	24,393	7,327	24,915
Average of the dependent variable	12.43	0.525	0.259	0.611	11.89	23.82	65.17

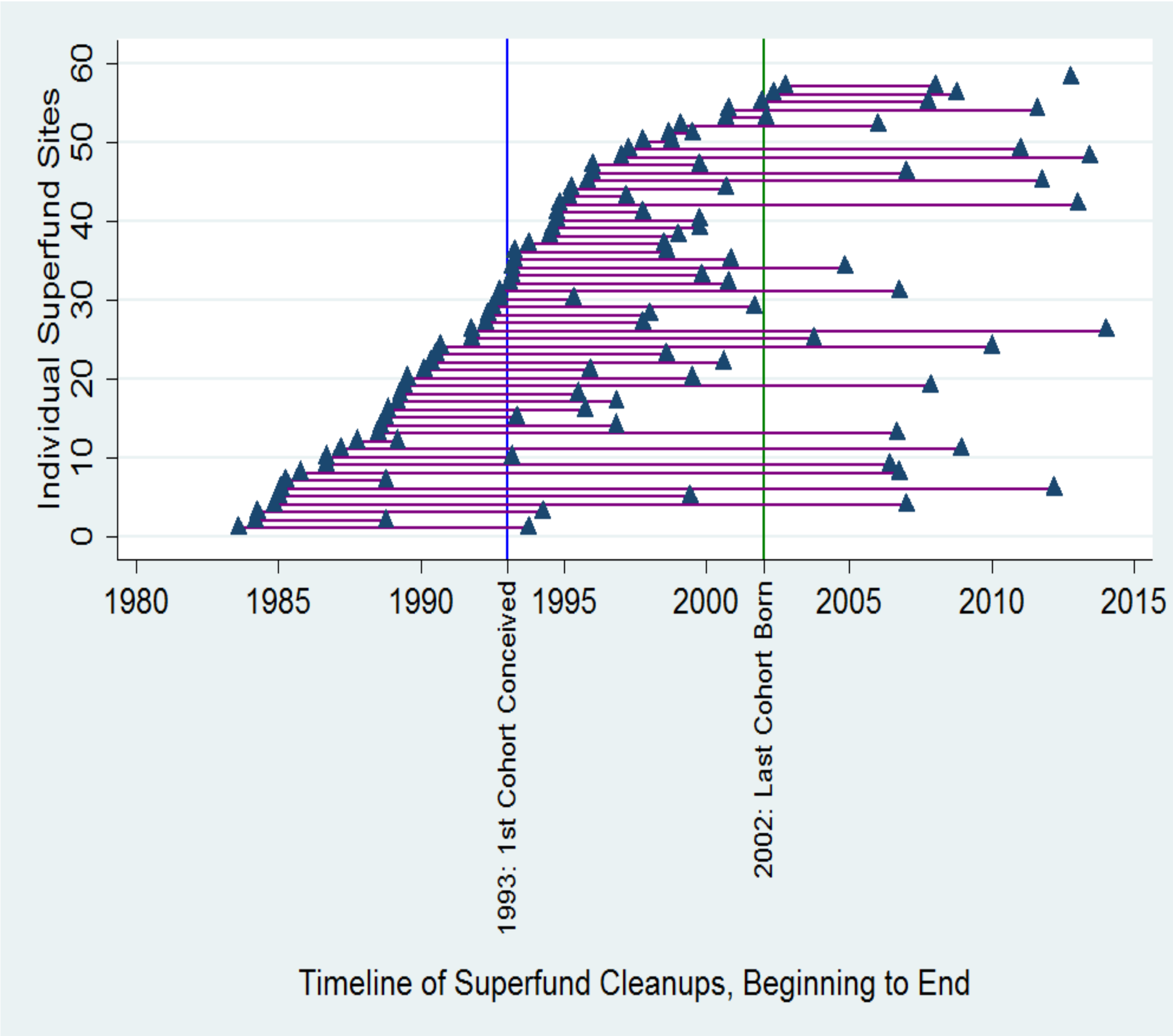
Notes: Each column represents a different school quality measure. Maternal education, race, and percent married mothers are calculated using birth records; the other measures come from the Florida School Indicators Report. Only children from families living consistently within two miles of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

TABLE 9: EXPLORING CUMULATIVE EFFECTS: SCHOOL OUTCOMES WITH FAMILY FIXED EFFECTS FOR SIBLINGS BORN WITHIN TWO MILES OF A SUPERFUND SITE (COMPARED TO CONCEIVED AFTER CLEANUP) – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)	(5)
	Likelihood of Repeating a grade	**Average FCAT Score**	**Likelihood of Behavioral Incident**	**Likelihood of Cognitive Disability**	**Likelihood of Autism**
Site Clean by Age 1 vs Conceived After Cleanup	0.035** (0.014)	-0.068*** (0.022)	0.021 (0.015)	0.018 (0.012)	-0.002 (0.003)
Site Clean After Age 1 vs Conceived After Cleanup	0.041* (0.024)	-0.060*** (0.022)	0.055** (0.023)	0.011 (0.019)	-0.001 (0.003)
Site Clean After Age 1 – By Age 1	0.006 (0.014)	0.005 (0.022)	0.034*** (0.012)	-0.007 (0.013)	0.001 (0.002)
Observations	21,684	20,473	21,904	21,993	21,993
R-squared	0.066	0.027	0.148	0.038	0.005

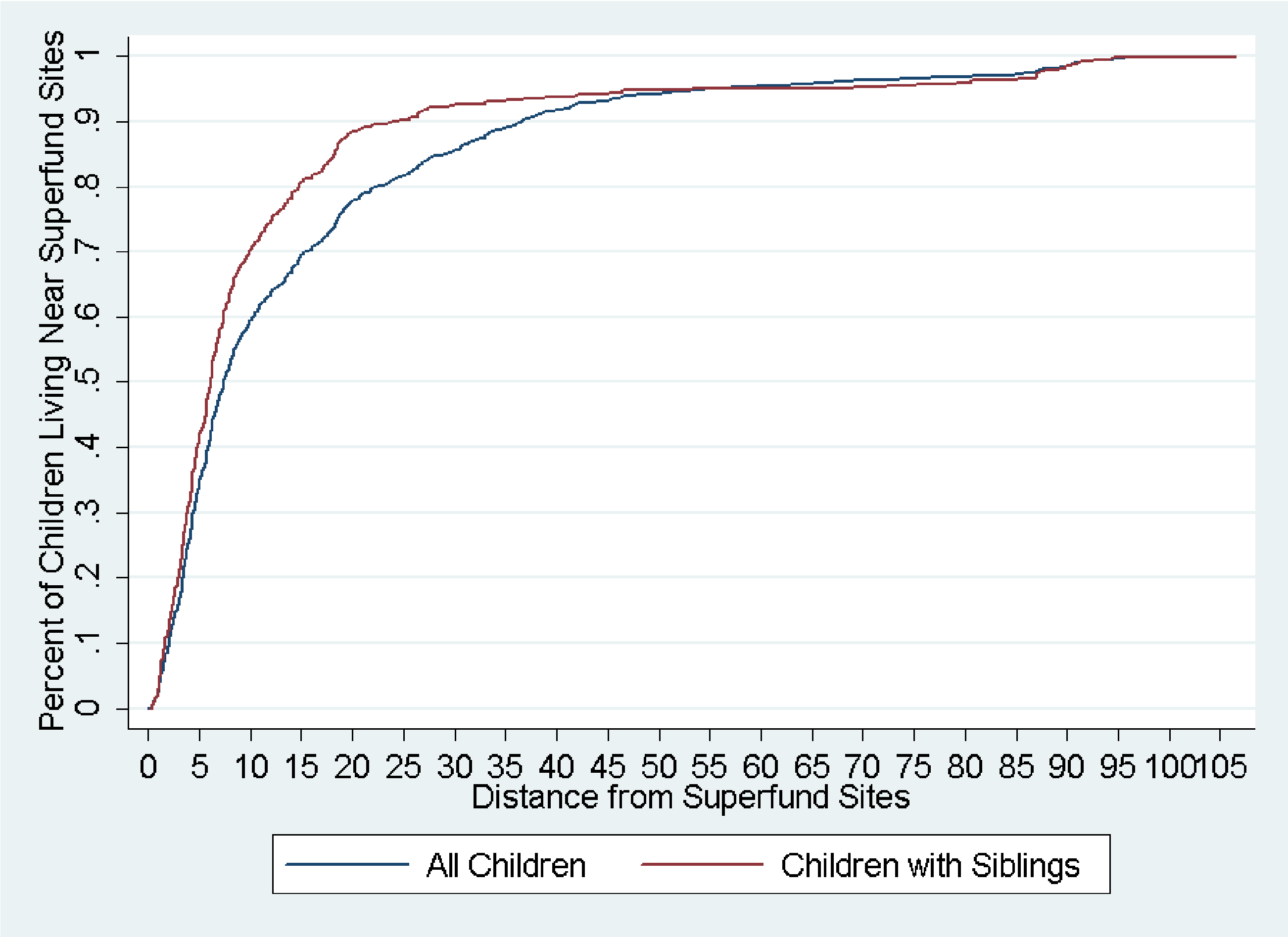
Notes: Each column represents a different cognitive/schooling outcome. Only children from families living consistently within two miles of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

FIGURE 1: TIMELINE OF SUPERFUND SITE CLEANUPS IN FLORIDA



Notes: The y-axis in Figure 1 represents individual Superfund sites, and the x-axis represents the timeline of individual Superfund site cleanups. The first blue triangle represents the beginning of cleanup for a particular site, the red line indicates the duration of cleanup, and the last blue triangle indicates the end of cleanup.

FIGURE 2: CUMULATIVE DISTRIBUTION FUNCTION OF CHILDREN LIVING NEAR A SUPERFUND SITE IN FLORIDA



Notes: The blue line represents all children born in Florida and the red line represents all children in the sibling sample in Florida. The sibling sample is more urban than the full Florida population, hence the higher frequency of proximity to a Superfund site. The figure only includes children with birth records with residential zip code data matched to school records in Florida born between 1994-2002.

FIGURE 3: SCHOOL OUTCOMES WITH FAMILY FIXED EFFECTS AT DIFFERENT DISTANCES FROM A SUPERFUND SITE: COMBINED ESTIMATES (COMPARED TO CONCEIVED AFTER CLEANUP) – NON-MOVING FAMILIES

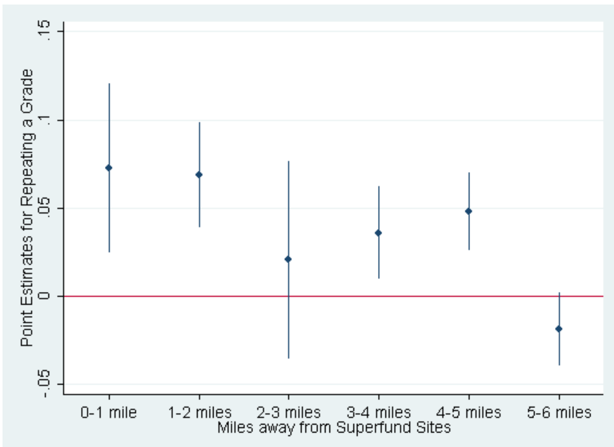


Figure 3.1: Grade Repetition

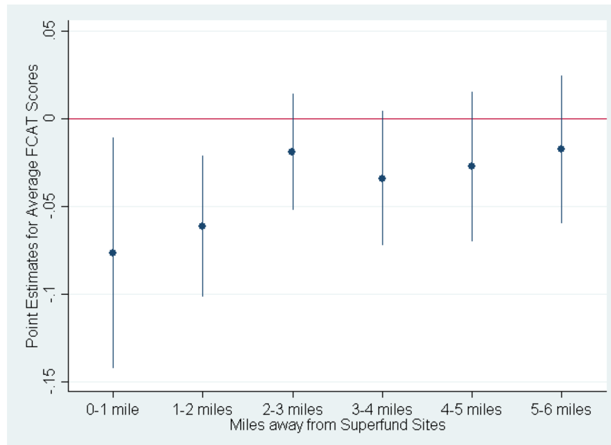


Figure 3.2: Pooled test scores

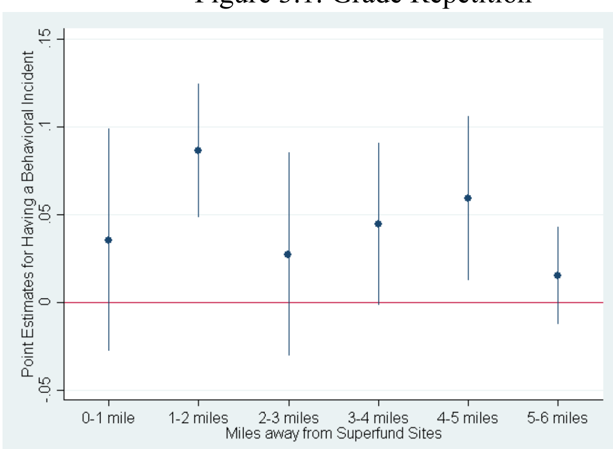


Figure 3.3: Behavioral Incident

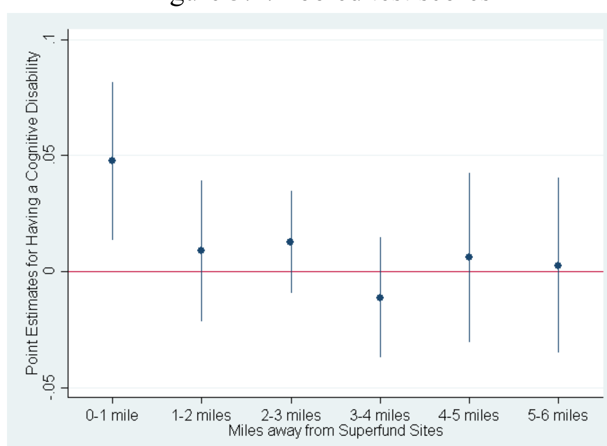


Figure 3.4: Cognitive Disability

Notes: Each panel represents a different cognitive/schooling outcome. We compare those conceived before/during Superfund cleanup to those conceived afterward. Only children from families living consistently within two miles of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level; the vertical lines represent 95 percent confidence intervals. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender.

APPENDIX TABLE A1: COMBINED ESTIMATES AND ESTIMATES FOR MOVING FAMILIES OF SCHOOL OUTCOMES WITH FAMILY FIXED EFFECTS FOR NON-MOVING AND MOVING CHILDREN BORN WITHIN TWO MILES OF A SUPERFUND SITE (COMPARED TO SIBLINGS CONCEIVED AFTER CLEANUP OR SIBLINGS BORN FIVE-PLUS MILES FROM A SUPERFUND SITE)

	(1)	(2)	(3)	(4)	(5)
Panel A: Combined Estimates of School Outcomes for Non-Moving and Moving Children	**Likelihood of Repeating a grade**	**Average FCAT Score**	**Likelihood of Behavioral Incident**	**Likelihood of Cognitive Disability**	**Likelihood of Autism**
Conceived Before Cleanup	0.055***	-0.046	-0.001	0.058***	0.010
vs After/ >5 Miles Away	(0.016)	(0.029)	(0.006)	(0.018)	(0.009)
Conceived During Cleanup	0.023**	-0.026**	-0.008*	0.022**	0.001
vs After/ >5 Miles Away	(0.009)	(0.010)	(0.005)	(0.008)	(0.005)
Conceived Before/During	0.029***	-0.030***	-0.007*	0.028***	0.002
Cleanup vs After/ >5 Miles Away	(0.009)	(0.011)	(0.004)	(0.010)	(0.005)
Panel B: Estimates for Moving Families Only					
Conceived Before Cleanup	0.045**	-0.047*	0.020	0.003	-0.001
vs Conceived >5 miles away	(0.017)	(0.024)	(0.015)	(0.010)	(0.002)
Conceived During Cleanup	0.001	0.009	0.003	-0.008	-0.003
vs Conceived >5 miles away	(0.007)	(0.011)	(0.007)	(0.006)	(0.002)
Observations	229,385	216,231	232,467	233,421	233,421
R-squared	0.057	0.023	0.158	0.029	0.003

Notes: Each column represents a different cognitive/schooling outcome. Panel A pools families consistently living within two miles of a Superfund site with families where one sibling was born within two miles of a Superfund site and the other was born five or more miles away from a Superfund site; Panel B focuses only on the moving families. 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, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

APPENDIX TABLE A2: DIFFERENCE IN DIFFERENCES RESULTS WITH FAMILY FIXED EFFECTS FOR CHILDREN BORN WITHIN TWO MILES OF A SUPERFUND SITE BEFORE OR DURING CLEANUP (COMPARED TO AFTER CLEANUP, AND COMPARED TO SIBLINGS IN FAMILIES LIVING EIGHT TO TEN MILES AWAY)

	(1)	(2)	(3)	(4)	(5)
	Likelihood of Repeating a grade	**Average FCAT Score**	**Likelihood of Behavioral Incident**	**Likelihood of Cognitive Disability**	**Likelihood of Autism**
(Conceived Before cleanup vs. After within 0-2 mi) – (Conceived Before cleanup vs. After in 8-10 mi)	0.114*** (0.024)	-0.081 (0.052)	0.171*** (0.021)	0.037 (0.040)	0.010 (0.008)
(Conceived During cleanup vs. After within 0-2 mi) – (Conceived During cleanup vs. After in 8-10 mi)	0.059*** (0.014)	-0.076*** (0.023)	0.105*** (0.015)	0.012 (0.024)	-0.002 (0.006)
Observations	39,476	37,400	40,015	40,172	40,172
Average of the dependent variable	0.22	0.049	0.226	0.156	0.005

Notes: Each column represents a different cognitive/schooling outcome. In each case, we compare the before/during versus after contrast for those living within two miles of a Superfund site to that for those living eight to ten miles away from a Superfund site. 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, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.

APPENDIX TABLE A3: SCHOOL OUTCOMES WITH FAMILY FIXED EFFECTS FOR CHILDREN CONCEIVED WITHIN TWO MILES OF A SUPERFUND SITE, CONDITIONAL ON ALL SIBLINGS ATTENDING THIRD GRADE – NON-MOVING FAMILIES

	(1)	(2)	(3)	(4)
	Likelihood of Repeating a Grade by 3rd Grade	**Likelihood of Behavioral Incident by 3rd Grade**	**3rd Grade FCAT Score**	**Likelihood of Taking the FCAT in 3rd Grade**
Conceived Before cleanup vs After	0.066***	0.060**	-0.068	0.002
	(0.019)	(0.025)	(0.043)	(0.008)
Conceived During cleanup vs After	0.037***	0.030**	-0.057***	-0.004
	(0.012)	(0.014)	(0.019)	(0.007)
Conceived Before/During cleanup vs After	0.039***	0.032**	-0.058***	-0.004
	(0.013)	(0.014)	(0.018)	(0.007)
Observations	23,723	23,400	22,776	23,723
R-squared	0.065	0.172	0.027	0.016

Notes: Columns 1-4 present the results for different schooling/cognitive outcome variables. Only children from families living consistently within two miles (one mile) of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender. Coefficients labeled as ***, **, and * are statistically significant at the 1, 5, and 10 percent levels, respectively.
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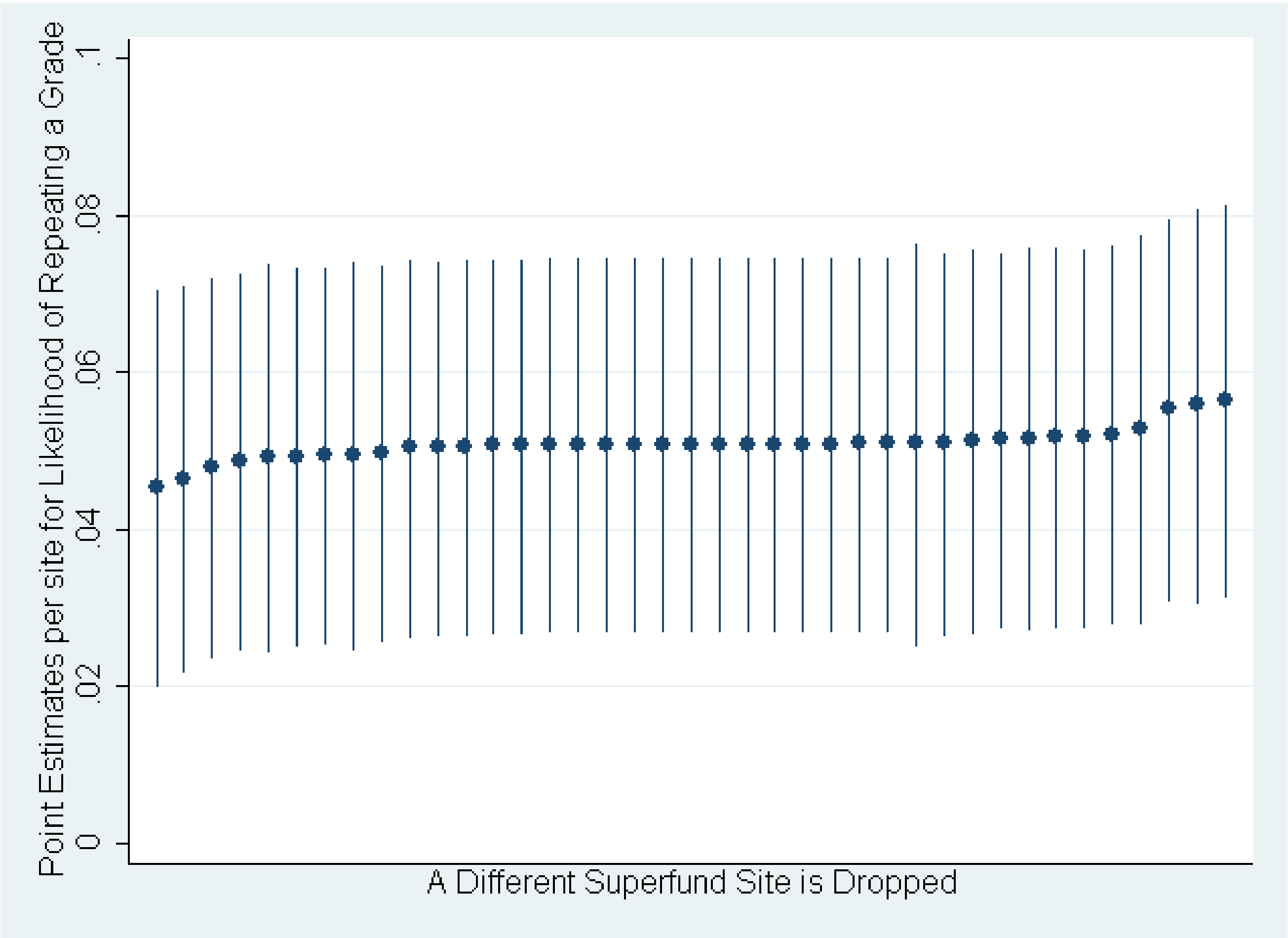
FIGURE A1: FAMILY FIXED EFFECTS POINT ESTIMATES WITH CONFIDENCE INTERVALS FOR THE LIKELIHOOD OF REPEATING A GRADE IF A CHILD WAS CONCEIVED BEFORE OR DURING CLEANUP, DROPPING A DIFFERENT SUPERFUND SITE EACH TIME



Notes: Each line represents a different 95 percent confidence interval for the likelihood of repeating a grade for those conceived before/during versus after Superfund cleanup, in which a different Superfund site is dropped in turn. For ease of presentation, we order the confidence intervals from smallest to largest point estimates. Only children from families living consistently within two miles (one mile) of a Superfund site and not changing zip codes between births are included in the analysis. Standard errors are adjusted for clustering at the site level and make use of bias-reduced linearization. In addition to family fixed effects, regressions control for birth month and year, birth order, and gender.