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Environmental contributors to the achievement gap☆

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ABSTRACT

Extensive research shows that blacks, those of low socioeconomic status, and other disadvantaged groups continue to exhibit poorer school performance compared with middle and upper-class whites in the United States' educational system. Environmental exposures may contribute to the observed achievement gap. In particular, childhood lead exposure has been linked to a number of adverse cognitive outcomes. In previous work, we demonstrated a relationship between early childhood lead exposure and end-of-grade (EOG) test scores on a limited dataset. In this analysis, data from the North Carolina Childhood Lead Poisoning Prevention Program surveillance registry were linked to educational outcomes available through the North Carolina Education Research Data Center for all 100 counties in NC. Our objectives were to confirm the earlier study results in a larger population-level database, determine whether there are differences in the impact of lead across the EOG distribution, and elucidate the impact of cumulative childhood social and environmental stress on educational outcomes. Multivariate and quantile regression techniques were employed. We find that early childhood lead exposure is associated with lower performance on reading EOG test scores in a clear dose-response pattern, with the effects increasingly more pronounced in moving from the high end to the low end of the test score distribution. Parental educational attainment and family poverty status also affect EOG test scores, in a similar dose-response fashion, with the effects again most pronounced at the low end of the EOG test score distribution. The effects of environmental and social stressors (especially as they stretch out the lower tail of the EOG distribution) demonstrate the particular vulnerabilities of socio-economically and environmentally disadvantaged children. Given the higher average lead exposure experienced by African American children in the United States, lead does in fact explain part of the achievement gap.

1. Introduction

Extensive research shows that blacks, those of low socio-economic status, and other disadvantaged groups continue to exhibit poorer school performance compared with middle and upper-class whites in the United States' educational system (Gamoran, 2001; Hallinan, 1988; Hedges and Nowell, 1999; Jencks and Phillips, 2000; Kao and Thompson, 2003; Walters, 2000). Blacks score lower on tests than whites, starting in childhood and continuing throughout their education. Although this gap has narrowed in the last three decades, on most standardized tests, median black scores are below 75 percent of whites (Jencks and Phillips, 2000).

Environmental exposures may contribute to the etiology of the achievement gap. Childhood lead exposure has been linked to a number of adverse cognitive outcomes, including reduced performance on standardized intelligence quotient (IQ) tests (Schnaas et al., 2006; Canfield et al., 2003; Tong et al., 1996; Bellinger et al., 1992; Dietrich et al., 1993; Lanphear et al., 2005; Schwartz, 1993), decreased performance on cognitive functioning tests (Lanphear et al., 2000), adverse neuropsychological outcomes (Ris et al., 2004), neurobehavioral deficits (Chiodo et al., 2004), poorer end-of-grade (EOG) test scores (Miranda et al., 2007), and classroom attention deficit and behavioral problems (Fergusson et al., 1988; Hatzakis et al., 1985; Needleman et al.,

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Abbreviations: EOG, end-of-grade; BLL, blood lead level; NCERDC, North Carolina Education Research Data Center; NCCLPPP, North Carolina Childhood Lead Poisoning Prevention Program.

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1979; Silva et al., 1988; Thomson et al., 1989; Yule et al., 1984; Braun et al., 2006).

Socioeconomic status (measured as occupation, income, education, wealth (Conley, 2001; Orr, 2003; Mayer, 1997; Brooks-Gunn and Duncan, 1997) or home ownership (Mayer, 1997; Green and White, 1997; Aaronson, 2000; Hill and Duncan, 1987)) is positively correlated with many measures of educational attainment, including children's reading levels (Department of Education, 2002), placement in high-achievement curricular tracks (Dougherty, 1996), not dropping out of high school (Alexander et al., 1997), college matriculation directly from high school (Baker and Velez, 1996), elite college attendance (Baker and Velez, 1996), and college graduation (Baker and Velez, 1996).

In previous work (Miranda et al., 2007), we linked lead surveillance data to EOG testing data for seven North Carolina counties. We showed that: (1) African American children in these seven counties are routinely exposed to more lead; and (2) blood lead levels in early childhood are negatively correlated with educational achievement in early elementary school, as measured by performance on EOG testing. This association holds at blood lead levels as low as 2 μg/dL (Miranda et al., 2007).

This paper extends our previous work, and the literature more generally, in three distinct ways. First, we extended the analysis to all 100 counties in NC, which made the constituent school systems and housing stock, as well as the local demographics, much more varied. In addition, this larger study area solved some of the small cell number problems noted in the 2007 paper (Miranda et al., 2007). Second, traditional multivariate regression analysis only examines what is happening at the means of distributions. In contrast, we employ quantile regression analysis to elucidate what is happening across the entire distribution (i.e., the technique shows how the coefficients on the explanatory variables change depending on location along the EOG test score distribution). Thus the technique can answer questions like, "Does lead exposure have a bigger or smaller effect on EOG scores at the bottom tail of the distribution compared to the top tail?" This is especially important when thinking about the tails of EOG scores, which are particularly relevant to educational policy/outcomes. Third, we examined the joint and cumulative effect of social and environmental stressors, again using quantile regression analysis. This analysis allows us to consider how combined effects of social and environmental stress might compound in certain subpopulations.

Insights from this paper provide early signals for identifying children who are particularly at risk for poor performance in school, as well as other longer term adverse developmental outcomes. Early identification of such children allows health care providers and child advocates to play a pivotal role in educating parents and connecting children at risk with relevant resources in a timely manner.

2. Methods

This research was conducted under the auspices of the Children's Environmental Health Initiative at Duke University according to a research protocol approved by the university's Institutional Review Board.

The North Carolina Education Research Data Center (NCERDC) maintains a database with records of all EOG test results for all public school systems in the state for tests from the 1995–1996 school year to present. After establishing a data sharing agreement, researchers can access identifying information such as name, birth date, and test scores, as well as data on parental education, race, ethnicity, participation in the free or reduced lunch program, English proficiency, testing condition modifications, and school district. These data can be linked longitudinally for all years each child has taken EOG tests in NC. The North Carolina EOG reading test is designed to measure students' mastery of the content outlined in the North Carolina English Language Arts Standard Course of Study (NC Department of Public Instruction, 2008). Because states typically develop their own curricula and associated EOG exams, the North Carolina testing data cannot be directly compared to testing outcomes for children residing in other states.

The North Carolina Childhood Lead Poisoning Prevention Program (NCCLPPP) maintains a state registry of blood lead surveillance data. Through a negotiated confidentiality agreement, the Children's Environmental Health Initiative has access to individual blood lead screening data from 1995 to present. The NCCLPPP blood lead surveillance data include child name, birth date, race, ethnicity, test date, blood lead level (BLL), and home address. A description of the laboratory protocols followed by the NC State Laboratory of Public Health can be found in Miranda et al. (2007). For children with duplicate screens, we retained entries with the highest blood lead level, which is consistent with Lanphear et al. (1998) and several studies by Miranda et al. (2002, 2007) and Kim et al. (2008).

To construct our integrated database, children who were screened for lead between the ages of 9–36 months from 1995 through 1999 in the 100 NC counties (318,068 records for 263,403 children) were linked to records in the EOG testing data in age-corresponding years (2001–2005). Our process linked 38.8% of screened children to at least one EOG record. Preliminary analysis was restricted to students who self-reported race as either white or black and who did not report limited English proficiency. We conducted all analyses on 4th-grade reading scores. The final linked dataset for 4th-grade reading results contained 57,678 observations.

We used two methods to analyze the relationship between social factors and blood lead levels and EOG test scores. We employed multivariate linear regression with EOG test scores as the response variable. The explanatory/predictor variables include child's race, child's sex, parental education, whether or not the child is enrolled in the free and reduced lunch program, whether the school is a charter school (in NC, this is typically an indicator of lower socioeconomic status of the enrolled children), and early childhood lead exposure, as well as dummy variables for each school system in the state. Early childhood lead exposure was modeled using dummy variables for each blood lead level. A blood lead level (BLL) of 1 μg/dL served as the referent group, resulting in nine dummy variables (BLL = 2 μg/dL, BLL = 3, ..., BLL = 9, BLL $\geq$ 10 μg/dL). Models that use a series of dummy variables for blood lead levels have been shown to fit better than models that use a linear function of lead exposure (Miranda et al., 2007). The child's age at screening for lead was controlled for using two dummy variables (screened between 18 and 27 months, and between 27 and 36 months), with the referent group of being screened between 9 and 18 months.

The linear regression assumes that the distributions of EOG test scores at different social or environmental "exposures" have the same shapes but different means. This may not be the case. For example, poverty or lead exposure may have a greater or lesser impact on those students who tend to be at one end or the other of the EOG test score distribution. Thus, we employed a second method of analysis, quantile regression (Koenker, 2005; Feudtner et al., 2006; Lal et al., 2003), which enabled us to examine distributional differences.

Quantile regressions predict conditional percentiles of an outcome variable from a set of explanatory variables (e.g. what is the 10th percentile of EOG test scores conditioned on early childhood lead exposure levels). It results in an equation for predicting conditional percentiles of interest rather than conditional means. Quantile regression has previously been used in the pediatric literature to assess the risk of chronic lung disease in