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Additive Impact of Preterm Birth and Neighborhood Characteristics on Early Child Academic Achievement

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An abstract of
A thesis submitted to the Faculty of the
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Abstract

Additive Impact of Preterm Birth and Neighborhood Characteristics on Early Child Academic Achievement

By Amirah N. Patterson

Objective: This study aimed to assess independent and possibly supra-additive impact of being born preterm and living in impoverished, predominately black, and deprived neighborhoods on academic achievement.

Methods: The effect of failing state-administered standardized tests for first grade Georgia public school students were calculated using the Georgia Linked Birth Record and Educational Data Set for the Atlanta MSA (n=138,289). Exposures included preterm birth status and neighborhood exposures (poverty, racial composition, and deprivation). Using binomial-identity (risk difference) modeling, models were obtained that assessed the interaction of preterm birth and neighborhood exposures.

Results: Binomial-identity modeling showed statistically significant additive interactions of preterm birth status and each of the three neighborhood exposures in relation to failing statewide standardized tests (p-value = <.0001). This corresponds to an additional effect of 2.9-4.3% of failing when compared to the expected effect of preterm birth and highest quintiles of neighborhood exposures.

Conclusions: These results imply that those born both preterm and into neighborhoods classified with high concentrations of poverty, predominantly non-Hispanic black racial composition, and/or high deprivation are at increased risk of low academic achievement in early education. This provides further research about the impact that both preterm births and neighborhood environment has on a child's academic achievement. Results provide a targeted population for interventions aimed at limiting the risk of low academic achievement. Since children born both preterm and in certain neighborhoods have higher risks of failing standardized tests, interventions aimed at improving academic achievement should be aimed at these children and their families. This would enable children most at-risk a chance to mediate the possible effects of neighborhood and birth status in succeeding academically, positively impacting their future life course.

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Chapter 1: Background/Literature Review

Introduction

The life course theory proposes that events happening in people's lives accumulate so that the past influences the future (1). Educational attainment relates to the life course theory because it is affected by many factors (i.e. neighborhood, school quality) and impacts life in additional ways such as wealth and health (2). Impacts from adverse birth outcomes and neighborhood composition also impact academic achievement. Many studies have researched preterm births' risk factors, including maternal age, education, and neighborhood (3-8). Preterm births exhibit racial disparities (3-5, 7-10), and also have been shown to impact academic and social lives (5, 11, 12). Separately, researchers have studied neighborhood composition and its influences, including education, health, income, and social support (9, 13-16). However, few studies have researched the relationship into the impact of both preterm births and neighborhood makeup on academic achievement in a racially and socially diverse population. The present study aims to fill this gap in knowledge, and proposes to determine if there an independent and/or supra-additive effect of being born preterm and important neighborhood characteristics on early academic achievement. Results provide important implications as to discovering new populations for interventions and policies aimed at improving educational outcomes, which is an important factor in the life course perspective.

Exposures

Preterm birth

In the U.S, nearly 13% of births are considered preterm, which is defined as births occurring less than 37 gestational weeks (4-6). The preterm birth rate has increased 33% in the U.S. since the 1980s, when the rate was approximately 9%. Compared to other developed countries where preterm birth rates range from 5-9%, the U.S. has a high rate of preterm births (4). Preterm births are associated with negative health outcomes, and contribute to nearly one-third of infant mortality (17). This has led to federal recognition, such as initiatives like the Healthy People 2020 objectives, where one goal aims to "reduce the rate of fetal and infant death (18)."

Many risk factors place mothers at increased risk for delivering preterm. Risks include plural births and congenital malformations, which is a reason many studies exclude multiple births (twins, triplets, etc.) and births with congenital anomalies. Maternal age is another risk factor for delivering preterm. For example, women younger than 20 years and over 35 years of age at the time of a child's birth are more likely to deliver moderately- to late-preterm (5). Additional determinants include race, previous preterm birth, low educational status, and being unmarried at the time of birth (3-6). Some researchers argue that where one live is a persistent risk factor for preterm birth. Racial segregation, isolation, socioeconomic disadvantage, and deprivation are amongst neighborhood indicators that are considered when analyzing influences of preterm birth (3, 8, 10).

Racial/ethnic disparities are clearly evident and well-studied in those who deliver preterm (3-5, 7-9). Black, non-Hispanic women are 1.5 times more likely to have a preterm birth (5) and three times more likely to have a very preterm birth (prior to 32 weeks)

compared to white, non-Hispanic women (8). Furthermore, when race and maternal age are combined, black women experience the highest risks of preterm birth a decade sooner than white women. This is often referred to as the "Weathering Hypothesis" (10). Black women are at a higher risk for preterm birth, even when controlling for educational attainment (5). A multitude of reasons may contribute to this racial disparity seen in black women. These include social factors such as the impact of segregation and isolation, access to health care, stress, lack of social support, as well as biological factors including infection or inflammation and gene expression (3, 5, 7, 19, 20). Additionally, preterm births are the leading cause of death among black infants (3).

Infants who survive preterm births are often faced with a range of long-term health and social issues. Since the neurological and respiratory systems are among the last to develop in-utero, these systems often face complications. In school-age years, children born very preterm and with very low birth weights have lower academic achievement, as seen in math, reading, and IQ scores as well as organizational skills (5, 11). Preterm infants are more likely to have disabilities involving the brain. Some include cerebral palsy, autism spectrum, mental retardation, disorders of psychological development, behavior, and emotion, along with medical disabilities that affect work capacity in adulthood (5, 12). Adults born preterm also experience social difficulties. Lower gestational age is associated with reduced educational attainment (likelihood of completing high school, earning a bachelor's degree and postgraduate degree), having a high income, and increased likelihood of having a low income and receiving social security benefits (12). Historically, research was aimed at understanding the implications of very preterm births because the effect increases as gestational age at birth decreases (12). However, there has been a recent trend of

studying all preterm births because effects are still pronounced throughout all levels preterm birth categories when compared to term births. Furthermore, moderate and late preterm births comprise much larger proportions of preterm births than very preterm births, providing a more holistic view of the impact of preterm births (5, 6, 12).

Neighborhood Characteristics

Studying social determinants of health on the individual, familial, and community level have become increasingly popular as racial, socioeconomic, and gender disparities have become a concern nationwide. It is not a surprise that many health disorders affect racial or ethnic minorities disproportionately (16, 21). When stratifying disparities not only by race but also by neighborhoods, place plays a key role as to where the incidence and prevalence of health disparities occur. Those living in high-poverty and deprived neighborhoods plagued by crime, low overall educational attainment, and/or reduced access to social support are often the focus of health disparities (9, 13-15).

The place or neighborhood one lives, plays, and/or works can impact a person's life in multiple dimensions including health, education, opportunity, environmental exposures, and psychosocial factors (16). All are susceptible to impacts from neighborhood, but children and adolescents may face additional risks of impacts as implied from the life course theory. This theory, or approach, states that surroundings and events cumulatively influence one's life. Experiences play a role developmentally, and individual's lives are shaped form historical contexts (1). Stemming from this theory, impacts from neighborhood characteristics in a child's life will remain with a child throughout adolescence and adulthood. Specifically, neighborhood environment has been associated with children's and

adolescents' risk behaviors, educational outcomes, and integration within social institutions (14, 22). Children exposed to affluent, educated people in a neighborhood have a positive effect on school readiness and achievement, although some racial differences may exist (14, 15, 23). Additionally, neighborhood characteristics are associated with increased teenage births and dropping out of school (23).

Describing neighborhood depends on the scale and indicators. A neighborhood may be measured using a census tract, city or county boundaries, or metropolitan statistical areas, to name a few. Many measures of neighborhood exist, and many of these are derived from census information. Lantz et al rank the following indicators of neighborhood socioeconomic status (SES) as "powerful in assessing and motivating…population health" - poverty rate, unemployment rate, average household income, affordability of single-family homes, and bankruptcy and foreclosure rates (24). Other measures commonly used include percent of single-parent households, percent of children receiving free or reduced lunch, measures associated with educational achievement, measures of segregation and/or isolation, scales of concentrated disadvantage and affluence, and indexes of deprivation (10, 13, 14, 16, 17, 22, 24-26).

Outcome

Academic Achievement

The outcome of interest in this study is academic achievement, particularly early achievement seen in elementary-aged children. Excelling academically is associated with positive outcomes of wealth including job opportunities, financial stability, income, and neighborhood of residence (2). Academic achievement is an important indicator "of the

well-being of youth and a primary predictor and determinant of health outcomes (27)." Lower educational success is associated onset of chronic disease, disability, and declining functional status (2).

Excelling academically in younger years is of particular importance because it sets the stage for the future, once again demonstrating the life course theory (28). The first years of school are often associated with learning about children's strengths and weaknesses in their personal abilities and socializing with others. Early academic achievement can be measured in various ways, such as cognitive tests, math, reading, and literacy scores and assessments of social, behavioral, and developmental skills. Duncan et al showed that school readiness, seen in testing in math, reading, and attention skills among children entering school, were strong predictors of later achievement (29). Additionally, high academic achievement in elementary school has been associated with lower high school dropout rates (28). This connects back to the life course theory because educational achievement is not caused by an independent act, but as cumulative behaviors, ideas, and beliefs throughout school.

The achievement gap that extends between races, geographic locations, SES, and parental educational attainment is well studied and acknowledged (2, 13, 14). According to 2010 American Community Survey estimates, 29.5% of whites had a bachelor's degree or higher whereas only 17.9% of blacks had a bachelor's degree or higher (30). Numerous policy interventions, such as the No Child Left Behind Act, and organizations like Teach for America and the Harlem Children's Zone developed to equalize the educational gap so that all children have equal opportunities to excel academically, despite disparities in

achievement seen in racial, familial, and neighborhood demographics (2). Eliminating this educational disparity at a young age can impact the future life course.

Variation in early academic achievement may be affected by early life risk factors. Attending childcare and/or preschool and familial factors within a home, like educational attainment and presence of cognitive development activities in a household, are predictors of children's cognitive, language, social-emotional, and behavioral outcomes (31). Intervention programs, such as those consisting of preschool and/or kindergarten for low-income children, have been shown to buffer effects of poverty in terms of school readiness and language (31) in addition to positive long-term impacts leading to increased years of schooling, lower dropout rates, and lower rates of juvenile arrest (32). Additionally, school and teacher quality (33), student-teacher relationships (34), and small class sizes (29) have been shown to impact achievement.

Previous Research and Current Study

As seen above, research has separately described the impact of preterm birth on academic achievement and the impact of neighborhood composition on academic achievement. Few studies have aimed to describe the possible interaction or mediation of preterm birth and neighborhood characteristics on early academic achievement in a racially diverse, urban sample in the U.S., which is the focus of the present study. Previous research on similar topics is addressed below.

Ekeus et al studied the relationship between gestational age and cognitive ability, along with the impact of socioeconomic indicators in childhood among 18-19 year old men in Sweden. Socioeconomic variables were measured at the time of cognitive testing and

consisted of maternal age, marital status of the mother, SES of the father, and an index consisting of educational level and occupation. Cognitive performance was tested using a military assessment that tested logical, spatial, verbal, and technical capabilities. Results showed a gradual, increasing relationship between gestational age and test scores. The effect was reduced by 26% when adjusted for socioeconomic factors, which could suggest mediation or confounding. When SES was dichotomized, those from high-SES backgrounds had higher test scores than those from low-SES backgrounds in all gestational age categories, showing the differences in test scores among neighborhood indicators (35). Limits of external validity of this study include that the cohort was all men and was conducted in a socialist country where there is little socioeconomic variability as well as racial/ethnic diversity, which differs greatly from the U.S. Additionally, this study was conducted toward the end of adolescence, which limits generalizability to child populations.

A study conducted in Western Australia also investigated the relationship of gestational age to school achievement, and impacts from neighborhood SES and maternal factors. Researchers analyzed reading and writing assessments. Socioeconomic and educational indicators were measured using an index from census information at birth, but did not include individual or family SES. In multivariate analyses, researchers found that children born preterm had lower reading and writing scores despite SES and being firstborn was associated with higher scores (36). This study suggests that SES does not have large effects on academic achievement, however it was limited in measures of neighborhood indicators.

Andreias et al studied neighborhood effects on academic achievement comparing extremely low birth weight children to normal birth weight children. They used a multilevel

approach and considered individual (birth weight, sex, ADHD symptoms), familial (education, race, marital status, parental protection, neighborhood perception), and neighborhood (poverty rate, high school dropout rate) predictors among a small group in Ohio. Neighborhood poverty was significantly associated with lower academic achievement (37). Since this study utilized birth weight, and only the very extremes, it is not completely generalizable to all preterm births.

As shown, a minimal number of studies exist that investigate the potential moderating effects of neighborhood indicators on the relationship between gestational age and academic achievement among a racially diverse, urban city. Previous studies did not focus on gestational age, were not comparable to a diverse racial/ethnic population, and/or did not include measures of segregation. This gap in knowledge is the focus of the present study. This study aims to answer the following questions:

1. Is there an independent and/or supra-additive impact of being born preterm and neighborhood characteristics on academic achievement?
2. If so, what neighborhood characteristics are of importance in this relationship?
3. Does being born preterm in a middle or high-income neighborhood buffer the effects of being born preterm as seen in early academic achievement?

This study has important public health implications. Results from this study can be used to pinpoint target populations for new interventions and policies surrounding academic achievement. Currently, many services are aimed to mediate the effects of either neighborhood/SES factors, like women, children, and infant (WIC) services, or early school intervention programs. If results prove that there is a supra-additive impact, then interventions can be devised that focus on those born preterm and neighborhood composition

to increase early academic achievement. This could help lessen the educational disparity that exists in this country, and improve the life course of individuals with the highest risks of academic failure. If there is no significant relationship, then this study provides important findings leading to researching other possible factors important in student achievement and its association with neighborhood demographics and adverse birth outcomes.

Chapter II: Manuscript

Title/Author/Abstract

Additive Impact of Preterm Birth and Neighborhood Characteristics on Early Child Academic Achievement

Amirah N. Patterson

Abstract

Objective: This study aimed to assess independent and possibly supra-additive impact of being born preterm and living in impoverished, predominately black, and deprived neighborhoods on academic achievement.

Methods: The effect of failing state-administered standardized tests for first grade Georgia public school students were calculated using the Georgia Linked Birth Record and Educational Data Set for the Atlanta MSA (n=138,289). Exposures included preterm birth status and neighborhood exposures (poverty, racial composition, and deprivation). Using binomial-identity (risk difference) modeling, models were obtained that assessed the interaction of preterm birth and neighborhood exposures.

Results: Binomial-identity modeling showed statistically significant additive interactions of preterm birth status and each of the three neighborhood exposures in relation to failing statewide standardized tests (p-value = <.0001). This corresponds to an additional effect of 2.9-4.3% of failing when compared to the expected effect of preterm birth and highest quintiles of neighborhood exposures.

Conclusions: These results imply that those born both preterm and into neighborhoods classified with high concentrations of poverty, predominantly non-Hispanic black racial composition, and/or high deprivation are at increased risk of low academic achievement in early education. This provides further research about the impact that both preterm births and neighborhood environment has on a child's academic achievement. Results provide a targeted population for interventions aimed at limiting the risk of low academic achievement. Since children born both preterm and in certain neighborhoods have higher risks of failing standardized tests, interventions aimed at improving academic achievement should be aimed at these children and their families. This would enable children most at-risk a chance to mediate the possible effects of neighborhood and birth status in succeeding academically, positively impacting their future life course.

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Methods

Study Design

This is a retrospective cohort study of children born from 1998-2003 to mothers residing in the 20-county Atlanta Metropolitan Statistical Area (MSA). The Atlanta MSA counties were determined according to the Census in 1999 (38).

Data Set

The Georgia Linked Birth Record and Educational Data Set was previously created by matching Electronic Birth Records for births in Georgia from 1998-2003 to first grade Criterion-Referenced Competency Test (CRCT) results from 2004-2010. Matching and linking were completed using unique child identifiers including name, date of birth, sex, and mothers name and date of birth. Only births with matching birth data and student records were included.

Inclusion/Exclusion Criteria

A subset of the Georgia Linked Birth Record and Educational Data Set was also previously created. This data set excluded births that had congenital anomalies, chromosomal birth defects, or were missing last menstrual period estimates of gestational age. For this project, analysis of the Georgia Linked Birth Record and Educational Data Set was limited to births in the Atlanta MSA. Births were excluded if they were plural or unknown, occurred before 20 weeks or after 43 weeks, or if they were less than 500g. Additionally, births that were missing all CRCT results were excluded. A birth was included if they were missing zero, one, or two CRCT results, but was excluded if missing all three CRCT results.

Study Population

There were 628,115 total recorded resident births in Georgia from 1998-2002. Of those, 331,710 (53%) had linked birth data and student testing data and were therefore included in the Georgia Linked Birth Record Educational Data Set. Of those in the Georgia Linked Birth Record Educational Data Set, 138,212 (42 %) were born in the Atlanta MSA. The Atlanta MSA was chosen as the focus of this study to see the impacts on a large, primarily urban area. Results may differ for those living in rural areas and therefore were not included in this analysis. Additionally, important neighborhood characteristics may differ for those living outside the Atlanta MSA.

Data Measures

Exposure Variables

This study considers four exposure variables – pregnancy outcome and three variables related to neighborhood composition.

Pregnancy outcome was defined as term or preterm. A preterm birth is considered a birth less than 37 completed weeks of gestation. A term birth is a birth on or after 37 completed weeks of gestation.

Neighborhood composition exposures include poverty, racial composition, and deprivation index. These variables were chosen based off of prior research and the makeup of the Atlanta community (8, 10, 30)**.** All variables were collected at the census tract level and interpolated between Census collection times and thus represent year-specific values for

each tract. Census sources include the 1990 and 2000 decennial censuses and the 2005-2009 American Community Survey.

Poverty represents the percent of a neighborhood living under the federal poverty level. The range of data was from zero to one, where zero represents 0% of individuals living under the poverty level in a census tract and 100% represents all individuals living under the poverty level in a census tract. Poverty level was then divided into quintiles, so that the 1st quintile represents the 20% of individuals living in the lowest poverty census tracts, and the 5th quintile representing individuals living in the highest poverty census tracts.

Racial composition represents the percent of a census tract population that is non-Hispanic black. This was chosen because the Atlanta MSA has a large population of people who consider themselves African American/black and preterm births disproportionately affect African Americans. The range of data was from zero to one, which represents the proportion of individuals in a census tract that is racially black. The data was divided into quintiles, as described above.

Deprivation index is a composite measure of positive and negative indicators associated with health outcomes from census data. This includes the percent of households that are below the poverty level, earn less than $30,000 a year, female-headed, overcrowded, and receive welfare and the percent of adults with a high school education, unemployed, and working in management (26). Deprivation indexes are standardized to a N(0,1) distribution and then divided into quintiles, as described above.

Outcome Variables

The outcome variable of interest is student achievement. In Georgia, one measure of academic achievement is the CRCT. The CRCT is a summative, end-of-year standardized

test that is constructed to measure how well students acquire skills and concepts taught throughout the year as determined by the Georgia Performance Standards (GPS) and, previously, the Quality Core Curriculum (QCC) standards. All students in grades one through eight are tested in English/language arts, reading, and mathematics, annually. Starting in third grade, students also test in social studies and science. Scores are scaled and grouped into three categories – does not meet the standard, meets the standard, and exceeds the standard (39). For this study, CRCT scores are dichotomized into passing (meets or exceeds the standard) and failing (does not meet the standard). Scores in math, reading, and English/language arts were analyzed.

Covariates

Additional covariates, obtained from either the birth or educational record, were considered for analysis. These were child's sex, child's race/ethnicity (educational record), mother's race/ethnicity (birth record), mother's age (categorized into ≤17, 18-19, 20-24, 25-29, 30-34, 35-39, and ≥40 groups), mother's marital status at the time of birth (dichotomized into married and unmarried), mother's educational status (defined as the last year of formal education completed and categorized into four groups: less than 12^{th} grade, High school diploma/GED, some college, and college graduate), missing father's information (categorized as 'yes' if any information about the father was missing from the birth certificate and 'no' otherwise), alcohol use during pregnancy (binary 'yes' or 'no), tobacco use during pregnancy (binary 'yes' or 'no'), and prior adverse outcome ('yes' if a mother had a previous preterm, small for gestational age, or less than 2500g infant and 'no' otherwise).

Analysis

To explore the interaction of preterm birth and neighborhood environment, a simple stratified analysis without covariates was conducted to determine if modeling should be completed using additive or multiplicative interaction analysis measuring risk differences and ratios, respectively. Final modeling, conducted using binomial-identity modeling, included four models for each outcome – preterm alone, neighborhood exposure alone, preterm and neighborhood exposure together, and preterm, neighborhood exposure and the interaction of those terms. Covariates were included as confounders based off *a priori* criteria.

All data analysis was conducted using SAS version 9.3 (40). The parent project received IRB approval from Emory University, and this project used only de-identified data from the parent project. The significance level for p-values was 0.05.

Results

The study population consisted of 138,212 live births born in the 20 county Atlanta Metropolitan Statistical Area (MSA) from 1998-2002. Only singleton births were eligible, which excluded 3890 plural and unknown births (2.81%). All births were reported to occur inside the range of gestational age, and therefore no births were excluded because they occurred before 20 weeks or after 43 weeks. Nine births (<0.01%) were excluded because of birth weights less than 500g. Additionally, 24 births (0.02%) were excluded because they were missing data on all three outcome variables (CRCT scores for math, reading, and English/language arts). After exclusions, 134,289 eligible births remained.

Details about the sample are seen in Table 1. The population was split almost evenly among males and females and about 10% of children were born preterm. The majority of

children were identified as non-Hispanic white (46%) and non-Hispanic black (33%), which is similar to mother's race/ethnicity. At the time of the child's birth, about a quarter of mothers were 20-24 years, 25-29 years, or 30-34 years old. One-third of mothers were unmarried at the time of their child's birth. Twenty-one percent of mothers had less than a high school diploma/GED, 30% had a high school diploma/GED, 21% some college, and 26% were college graduates at the time of birth. Birth certificates were missing some information about the father for 13% of subjects. During pregnancy, 7% of mothers used tobacco and <1% used alcohol. Less than 1% of mothers had previous births with adverse outcomes. For the CRCT outcomes, 12% failed math, 9% failed reading, and 15% failed English/language arts.

Additive interaction (risk-difference modification) was evaluated by testing the significance of excess additional risk of failing standardized tests among child born preterm and with each neighborhood environmental characteristic (Appendix D). For each combination of neighborhood exposures and test types, four models were obtained. Model 1 includes preterm birth, Model 2 includes the neighborhood exposure, Model 3 includes preterm birth and the neighborhood exposure, and Model 4 includes preterm birth, the neighborhood exposure, and the cross-product of preterm birth and the neighborhood exposure indicator variables. The cross-product term (Model 4) was statistically significant in each of the combinations, with a p-value <0.0001. All models controlled for child's sex and race, mother's age, marital status, and educational attainment, missing information about the father on the birth certificate, and history of a prior adverse birth outcome.

Table 1 shows the magnitude of differences in association of failing a standardized test stratified on neighborhood exposures and birth outcome for the adjusted, interaction

model (see Appendix D, Model 4). Figure 1 graphically shows the same concept as Table 1. The risk difference of failing a CRCT is displayed on the y-axis (with term infants born in the lowest-quintile neighborhood as the common referent group) and neighborhood exposure quintiles are displayed on the x-axis. As seen in Table 1 and Figure 1.A, there is a dose response relationship between increasing quintiles of poverty among term births and increased risk for failing math. The risk of failing math is higher among preterm as compared to term-born children in the 1st poverty quintile, but for preterm-born children the slope of the dose-response increase in risk for failing math seen with increasing poverty is much steeper than with term-born children. The main effect of poverty is to increase risk of failure by 3% (Table 1), which is seen when subtracting the 5th poverty quintile from the 1st poverty quintile among term-born children. The main effect of being born preterm is to increase risk of failing math by 0.2%. This can be seen by comparing the risk difference of preterm versus term risk difference among those in the 1st quintile. Therefore, one would expect that the combined effect of being born preterm *and* living in the highest poverty neighborhoods would be the sum of both, an increased risk of failing math of 3.2%. However, the observed increased risk of failing math for a child doubly-affected by these exposures is actually and increased risk of 7.3%, which is significantly greater than the expected additive effect. This shows that there is synergism, or a supra-additive effect of neighborhood and preterm birth outcome. Similar trends are seen in the remaining figures. Risk of failure in excess of the expected additive effects of preterm birth and neighborhood environment ranged from 2.9-4.3%. Results for racial composition (Table 1, Figures 1.C, 1.D) are slightly different, in that the risk of failing either math or English/language arts is lower in the 5th quintile compared to the 4th quintile among children born term. Among those

born preterm, the risk of failing both math and English/language arts remains nearly steady in the 4th and 5th quintiles.

Discussion

The life course theory helps to explain the importance of early educational achievement because it has the power to affect numerous domains in people's current and future lives. Previous literature has shown that being born preterm is associated with difficulties in cognitive development and, thus, academic achievement. Separately, research has shown that neighborhood characteristics impact academic achievement. However, few studies investigated the interaction of between preterm birth and neighborhood composition. This study aimed to fill that gap in knowledge and, therefore, aimed to determine if there was an additional impact of being born preterm and in poor, racially similar, and/or highly-deprived neighborhoods on cognitive development.

Preliminary stratified analysis compared the risk of failing a CRCT if born preterm versus term amongst neighborhood exposures for each of the three CRCT results (Appendix C). To assess whether the effect modification of preterm birth status should be on the additive or multiplicative scale, comparisons of whether the interactions were greater than the expected additive risk difference or multiplicative risk ratio were calculated (Appendix C). For every combination of exposures and outcomes, the interaction was only present on the additive, or risk difference, scale. Therefore, the decision was made to progress with modeling using binomial-identity modeling, which provides results on the additive scale. Rothman argues that additive interaction more accurately describes the biological processes, which provides further reason to justify modeling on the additive scale (41).

Certain covariates were not included in the final models. Mother's race and mother's ethnicity were coded separately in the birth records. Coding was different for child's race and ethnicity, which was obtained from the educational record. Because of this, and collinearity problems with child's race, mother's race was not used in analyses. Alcohol and tobacco use were dropped to improve model convergence problems. Additionally, results for the risk of failing reading were excluded from analysis because of Hessian convergence issues with multiple variables. For ease of making comparisons between models, the same covariates were included in all models.

The Atlanta MSA population was a prime sample for this study for a number of reasons. The data contained a large population, and therefore, leads to a greater statistical power. Additionally, results (Table 1, Appendices A and B) show that the Atlanta MSA is diverse racially, in terms of educational attainment, and in terms of individual characteristics seen in neighborhood distribution. Limited research studies had similar aims but were conducted in countries with relatively low racial and neighborhood diversity (35-37), and therefore their results are not necessarily generalizable to many urban areas in the US. Furthermore, the dataset contained a wide array of information with relatively few missing values.

Results showed a statistically significant additive interaction of preterm birth and each of the neighborhood characteristics for both math and English/language arts. This suggests that there is indeed an excess additive risk of lower academic achievement among those born preterm and into neighborhoods with high poverty, percentage of black individuals, and/or deprivation. Results also showed that there is not a large difference in risk of failing among those born into neighborhoods in the 1st quartile of poverty, racial

composition, and deprivation. This suggests that neighborhood mediates the negative effects being born preterm among those born into neighborhoods with low poverty, percentage of black individuals, and/or deprivation.

These results have important public health and policy implications. Because of the excess risk of poorer early academic achievement, children are at additional risk for lower educational achievement as they progress throughout elementary, middle, high school, and beyond. As demonstrated by the life course theory, this translates into a population who has shown to be disadvantaged in terms of SES, social support, and is at risk for numerous health problems (2, 27, 28). This provides further research into the impact that a preterm birth has on a child's academic achievement, and the impacts of neighborhood environment.

Results provide information about possible target populations for interventions that aim at limiting the additional risks of low academic achievement. Results showed that kids living in environments plagued by poverty, high percentage of black residents, and deprivation were at an increased risk of failing both math and English/language arts. Therefore, interventions can target those in neighborhoods characterized by neighborhoods with these features, such as those in the 4^{th} and 5^{th} quintiles. Additionally, interventions may target children born preterm, since their risks of failing were higher than children born term. The findings of this study, however, suggest that since children born both preterm and in impoverished, predominately black, and deprived neighborhoods have the highest risks of failing standardized tests, interventions aimed at improving academic achievement should be aimed at these children. This would enable children most at-risk a chance to mediate the possible effects of neighborhood and birth status in succeeding academically. Furthermore, such interventions could help reduce educational disparities and improve future trajectories.

Limitations for this study exist. Accurately measuring gestational age has been a well-known issue (42). Gestational age is measured from the date of the last menstrual period, however the exact date of conception is often unknown. This could lead to misclassification errors in categorizing a birth as term or preterm, however these misclassification errors are likely to cancel out. Additionally, the linkage rate of the dataset was 53%. Among the children lost to follow-up were those who were born in Georgia but later emigrated to another state (~12.5-15%) and those who are not captured because they attend private school or are homeschooled (~10-14%) and, therefore not in the public school CRCT database. Linkage rates were fairly similar among key strata, including term or preterm status, so differences in those lost to follow-up compared to those included in the dataset is not much of a concern. Furthermore, this study lacks information of parental IQ, which some posit is important in considering the heritability of cognitive ability. However, the extent to how much cognitive function is inherited is debatable. SES has been shown to modify the effect of genes such that the environment limits the impact of genes in poor children but not in children with high SES (43). Lastly, academic achievement was measured using standardized tests taken at one point in time. This does not take into account students' testing abilities and academic achievement witnessed in other forms of assessments.

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Tables

Table 1. Distribution of exposures, outcomes, and covariates.

	Overall			Overall	
	n	%		n	%
	134289	100.00		134289	100.00
Sex			Poverty		
Male	67852	50.53	Q1	26944	20.06
Female	66437	49.47	Q2	26784	19.95
Child's race			Q3	26859	20.00
White	62250	46.36	Q4	26887	20.02
Black	45040	33.54	Q5	26815	19.97
Hispanic	17806	13.26	Percent Black		
Other	9193	6.85	Q1	26670	19.86
Preterm			Q2	26659	19.85
Yes	13205	9.83	Q3	26565	19.78
No	121084	90.17	Q4	26708	19.89
Failed Math			Q5	26603	19.81
Yes	16705	12.44	Missing	1084	0.81
No	117439	87.45	Deprivation Index		
Missing	145	0.11	Q1	26878	20.02
Failed Reading			Q2	26845	19.99
Yes	12255	9.13	Q3	26932	20.06
No	121905	90.78	Q4	26812	19.97
Missing	129	0.10	Q5	26821	19.97
Failed English/Language Arts			Missing	1	0.00
Yes	20663	15.39			
No	113456	84.49			
Missing	170	0.13			

(Table 1 continued)

	Overall	
	n	%
	134289	100.00
Mother's age		
≤ 17	5446	4.06
18-19	10148	7.56
20-24	32755	24.39
25-29	36779	27.39
30-34	31740	23.64
35-39	14851	11.06
≥ 40	2570	1.91
Mother's race		
White	66763	49.72
Black	45404	33.81
Hispanic	16577	12.34
Other	5545	4.13
Mother's marital status		
Unmarried	45086	33.57
Married	89156	66.39
Missing	47	0.03

	Overall	
	n	%
	134289	100.00
Mother's education		
Less than 12th grade	28178	20.98
HS Diploma/GED	40508	30.16
Some College	27633	20.58
College Graduate	35147	26.17
Missing	2823	2.10
Missing father's information		
Yes	17927	13.35
No	116362	86.65
Tobacco use		
Yes	9299	6.92
No	124364	92.61
Missing	626	0.47
Alcohol use		
Yes	955	0.71
No	132699	98.82
Missing	635	0.47
Prior adverse birth outcome		
Yes	937	0.70
No	133352	99.30

Table 2. Binomial risk difference model demonstrating additive interaction of preterm birth and neighborhood environment on risk of CRCT test failure in first grade. [a]

	Math			English/Language Arts		
		Term RD	*Preterm* RD		*Term* RD	*Preterm* RD
Poverty						
	Q1 [b, c]	0.000	0.002	Q1	0.000	0.006
	Q2	0.005	0.017	Q2	0.003	0.019
	Q3	0.009	0.048	Q3	0.006	0.042
	Q4	0.018	0.051	Q4	0.014	0.043
	Q5	0.030	0.073	Q5	0.018	0.053
Percent Black						
	Q1	0.000	0.004	Q1	0.000	0.007
	Q2	0.003	0.015	Q2	0.001	0.008
	Q3	0.005	0.033	Q3	0.004	0.031
	Q4	0.017	0.056	Q4	0.013	0.047
	Q5	0.010	0.057	Q5	0.003	0.049
Deprivation						
	Q1	0.000	0.002	Q1	0.000	0.005
	Q2	0.007	0.022	Q2	0.005	0.018
	Q3	0.009	0.044	Q3	0.008	0.048
	Q4	0.019	0.056	Q4	0.025	0.054
	Q5	0.030	0.073	Q5	0.025	0.066

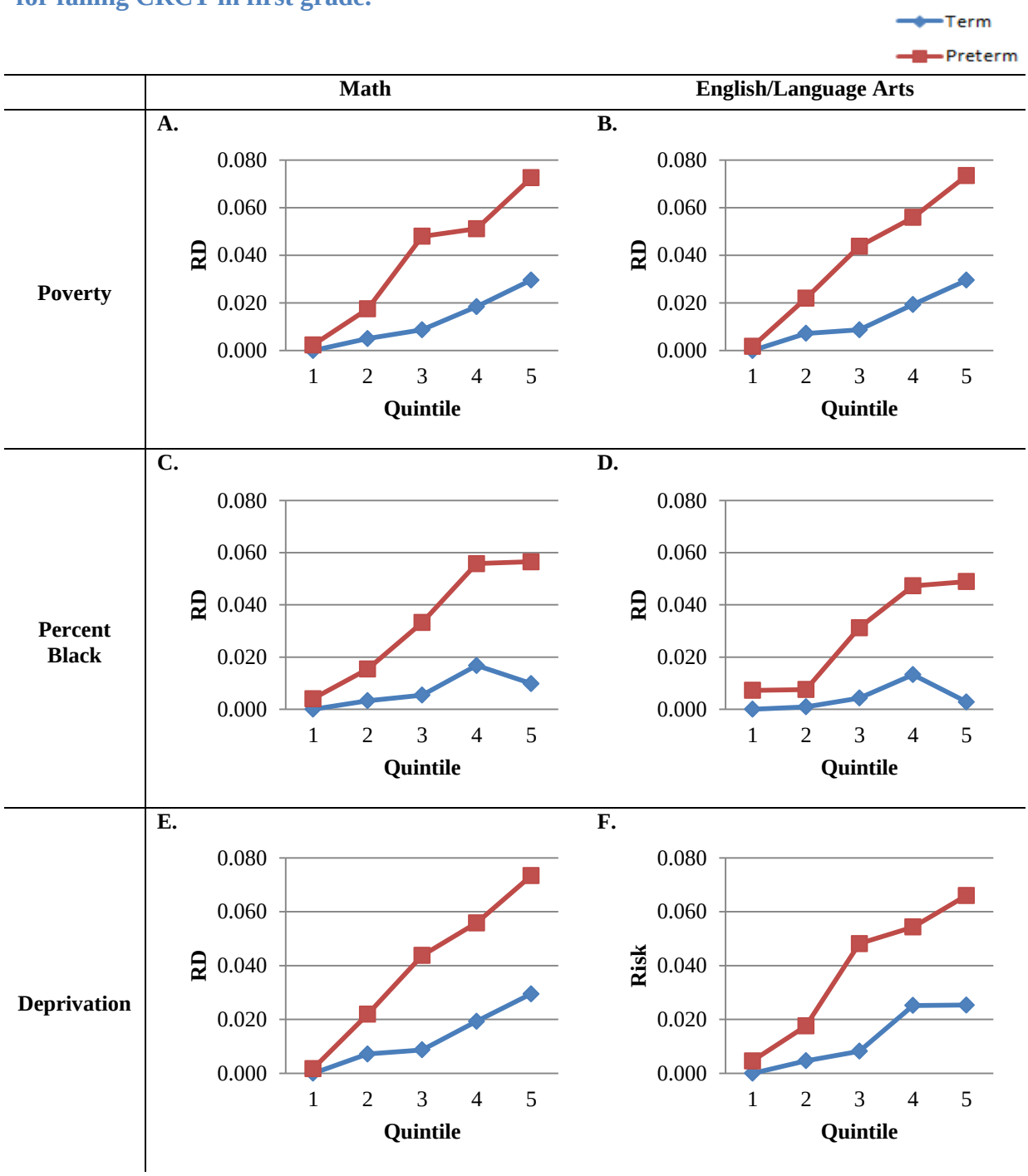
[a]: Adjusted for sex, child's race, mother's age, marital status, education, missing father's information on the birth certificate, and prior adverse birth outcomes

[b]: Q denotes quintile

[c]: Q1 is the common referent group for all RDs.

Figures

Figure 1. Additive interaction of preterm birth and neighborhood environment on risk for failing CRCT in first grade. [a]



[a]: Adjusted for sex, child's race, mother's age, marital status, education, missing father's information on the birth certificate, and prior adverse birth outcomes

Chapter III: Summary, Public Health Implications, Future Directions

This study aimed to determine if there an independent and/or supra-additive effect of being born preterm and important neighborhood characteristics on early academic achievement. Results showed a statistically significant additive interaction of preterm birth status and neighborhood exposures in relation to failing statewide standardized tests. These results suggest that those born both preterm and into neighborhoods classified with high concentrations of poverty, are predominately black, and/or high deprivation are at increased risk of low academic achievement in early education.

These results have important public health and policy implications. Because of the excess risk of poorer early academic achievement, children are at additional risk for lower educational achievement as they progress throughout elementary, middle, high school, and beyond. As demonstrated by the life course theory, this translates into a population who has shown to be disadvantaged in terms of SES, social support, and is at risk for numerous health problems (2, 27, 28). This provides further research into the impact that a preterm birth has on a child's academic achievement, and the impacts of neighborhood environment.

Results provide information about possible target populations for interventions that aim at limiting the additional risks of low academic achievement. Results showed that kids living in environments plagued by poverty, high percentage of black residents, and deprivation were at an increased risk of failing both math and English/language arts. Therefore, interventions can target those in neighborhoods characterized by neighborhoods with these features, such as those in the 4^{th} and 5^{th} quintiles. Additionally, interventions may target children born preterm, since their risks of failing were higher than children born term. The findings of this study, however, suggest that since children born both preterm and in

impoverished, predominately black, and deprived neighborhoods have the highest risks of failing standardized tests, interventions aimed at improving academic achievement should be aimed at these children. This would enable children most at-risk a chance to mediate the possible effects of neighborhood and birth status in succeeding academically. Furthermore, such interventions could help reduce educational disparities and improve future trajectories.

Results provide further opportunities for additional research. Research should continue to analyze children's educational achievement within this cohort as they progress through school to better understand impacts of birth outcomes and environment on academic achievement throughout the life course. Additionally, results could be stratified by race. This study analyzed neighborhood demographic data at the time of birth, so future studies could analyze demographic data at the student's current address. Because this study did not include information about the school that a child attended, studies could address the impact of a school, such as demographics within a school along with teacher and school quality.

Appendices

A. Tables of exposures by covariates.

A.1. Distribution of preterm births by covariates.

	Overall		Preterm		p-value
	n	%	n	%	
	134289	100.00	13205	9.83	
Sex					
Male	67852	50.53	6955	10.25	<.0001
Female	66437	49.47	6250	9.41	
Child's race					
White	62250	46.36	5388	8.66	<.0001
Black	45040	33.54	5630	12.50	
Hispanic	17806	13.26	1411	7.92	
Other	9193	6.85	776	8.44	
Mother's age					
≤ 17	5446	4.06	682	12.52	<.0001
18-19	10148	7.56	1110	10.94	
20-24	32755	24.39	3239	9.89	
25-29	36779	27.39	3305	8.99	
30-34	31740	23.64	2958	9.32	
35-39	14851	11.06	1598	10.76	
≥ 40	2570	1.91	313	12.18	
Mother's race					
White	66763	49.72	5797	8.68	<.0001
Black	45404	33.81	5660	12.47	
Hispanic	16577	12.34	1303	7.86	
Other	5545	4.13	445	8.03	
Mother's marital status					
Unmarried	45086	33.57	5382	11.94	<.0001
Married	89156	66.39	7818	8.77	
Missing	47	0.03	5	10.64	
Mother's education					
Less than 12th grade	28178	20.98	3078	10.92	<.0001
HS Diploma/GED	40508	30.16	4236	10.46	
Some College	27633	20.58	2797	10.12	
College Graduate	35147	26.17	2864	8.15	
Missing	2823	2.10	230	8.15	
Missing father's information					
Yes	17927	13.35	2306	12.86	<.0001
No	116362	86.65	10899	9.37	
Missing	626	0.47	66	10.54	

(Table A.1 continued)

	Overall		Preterm		p-value
	n	%	n	%	
	134289	100.00	13205	9.83	
Alcohol use					
Yes	955	0.71	118	12.36	0.0085
No	132699	98.82	13021	9.81	
Missing	635	0.47	66	10.39	
Prior adverse birth outcome					
Yes	937	0.70	299	31.91	<.0001
No	133352	99.30	12906	9.68	
Failed Math					
Yes	16705	12.44	2228	13.34	<.0001
No	117439	87.45	10956	9.33	
Missing	145	0.11	21	14.48	
Failed Reading					
Yes	12255	9.13	1588	12.96	<.0001
No	121905	90.78	11606	9.52	
Missing	129	0.10	11	8.53	
Failed English/Language Arts					
Yes	20663	15.39	2580	12.49	<.0001
No	113456	84.49	10611	9.35	
Missing	170	0.13	14	8.24	

A.2. Distribution of poverty quintiles by covariates.

	Overall		Q1		Q2		Q3		Q4		Q5		
	n	%	n	%	n	%	n	%	n	%	n	%	
	134289	100.00	26944	20.06	26784	19.95	26859	20.00	26887	20.02	26815	19.97	
Sex													
Male	67852	50.53	13554	19.98	13625	20.08	13593	20.03	13599	20.04	13481	19.87	
Female	66437	49.47	13390	20.15	13159	19.81	13266	19.97	13288	20.00	13334	20.07	
Child's race													
White	62250	46.36	20143	32.36	16858	27.08	11933	19.17	8994	14.45	4322	6.94	[a]
Black	45040	33.54	2529	5.62	5077	11.27	8434	18.73	11483	25.50	17517	38.89	
Hispanic	17806	13.26	2065	11.60	2898	16.28	4508	25.32	4550	25.55	3785	21.26	
Other	9193	6.85	2207	24.01	11951	21.22	1984	21.58	1860	20.23	1191	12.96	
Mother's age													
≤ 17	5446	4.06	372	6.83	698	12.82	999	18.34	1282	23.54	2095	38.47	[a]
18-19	10148	7.56	830	8.18	1414	13.93	2076	20.46	2470	24.34	3358	33.09	
20-24	32755	24.39	3113	9.50	52223	15.95	6822	20.83	8169	24.94	9428	28.78	
25-29	36779	27.39	7082	19.26	8005	21.77	7732	21.02	7514	20.43	6446	17.53	
30-34	31740	23.64	9666	30.45	7414	23.36	6115	19.27	4924	15.51	3621	11.41	
35-39	14851	11.06	5053	34.02	3445	23.20	2661	17.92	2160	14.54	1532	10.32	
≥ 40	2570	1.91	828	32.22	585	22.76	454	17.67	368	14.32	335	13.04	
Mother's race													
White	66763	49.72	20964	31.40	17822	26.69	12874	19.28	10065	15.08	5038	7.55	[a]
Black	45404	33.81	2602	5.73	5135	11.31	8537	18.80	11542	25.42	17588	38.74	
Hispanic	16577	12.34	1816	10.95	2656	16.02	4233	25.54	4290	25.88	3582	21.61	
Other	5545	4.13	1562	28.17	1171	21.12	1215	21.91	990	17.85	607	10.95	
Mother's marital status													
Unmarried	45086	33.57	3065	6.80	5506	12.21	8381	18.59	11247	24.95	16887	37.46	[a]
Married	89156	66.39	23868	26.77	21267	23.85	18466	20.71	15632	17.53	9923	11.13	
Missing	47	0.03	11	23.40	11	23.40	12	25.53	8	17.02	5	10.64	
Mother's education													
Less than 12th grade	28178	20.98	1957	6.95	3681	13.06	5614	19.92	7138	25.33	9788	34.74	[a]
HS Diploma/GED	40508	30.16	5292	13.06	7643	18.87	8550	21.11	9099	22.46	9924	24.50	
Some College	27633	20.58	5641	20.41	6147	22.25	5860	21.21	5725	20.72	4260	15.42	
College Graduate	35147	26.17	13602	38.70	8858	25.20	6208	17.66	4330	12.32	2149	6.11	
Missing	2823	2.10	452	16.01	455	16.12	627	22.21	595	21.08	694	24.58	

[a]: significant p-value (<0.05)

(Table A.2 continued)

	Overall		Q1		Q2		Q3		Q4		Q5		
	n	%	n	%	n	%	n	%	n	%	n	%	
	134289	100.00	26944	20.06	26784	19.95	26859	20.00	26887	20.02	26815	19.97	
Missing father's information													
Yes	17927	13.35	1118	6.24	1982	11.06	2995	16.71	42222	23.55	7610	42.45	[a]
No	116362	86.65	25826	22.19	24802	21.31	23864	20.51	22665	19.48	19205	16.50	
Tobacco use													
Yes	9299	6.92	1180	12.69	1900	20.43	2011	21.63	2077	22.34	2131	22.92	[a]
No	124364	92.61	25633	20.61	24759	19.91	24719	19.88	24683	19.85	24570	19.76	
Missing	626	0.47	131	20.93	125	19.97	129	20.61	127	20.29	114	18.21	
Alcohol use													
Yes	955	0.71	267	27.96	186	19.48	151	15.81	138	14.45	213	22.30	[a]
No	132699	98.82	26545	20.00	26470	19.95	26575	20.03	26622	20.06	26487	19.96	
Missing	635	0.47	132	20.79	128	20.16	133	20.94	127	20.00	115	18.11	
Prior adverse birth outcome													
Yes	937	0.70	277	29.56	228	24.33	159	16.97	144	15.37	129	13.77	[a]
No	133352	99.30	26667	20.00	26556	19.91	26700	20.02	26743	20.05	26686	20.01	
Failed Math													
Yes	16705	12.44	1306	7.82	2352	14.08	3310	19.81	4245	25.41	5492	32.88	[a]
No	117439	87.45	25620	21.82	24388	20.77	23528	20.03	22611	19.25	21292	18.13	
Missing	145	0.11	18	12.41	44	30.34	21	14.48	31	21.38	31	21.38	
Failed Reading													
Yes	12255	9.13	997	8.14	1765	14.40	2442	19.93	3114	25.41	3937	32.13	[a]
No	121905	90.78	25932	21.27	24999	20.51	24396	20.01	23734	19.47	22844	18.74	
Missing	129	0.10	15	11.63	20	15.50	21	16.28	39	30.23	34	26.36	
Failed English/Language Arts													
Yes	20663	15.39	1986	9.61	3202	15.50	4238	20.51	5103	24.70	6134	29.69	[a]
No	113456	84.49	24933	21.98	23549	20.76	22593	19.91	21741	19.16	20640	18.19	
Missing	170	0.13	25	14.71	33	19.41	28	16.47	43	25.29	41	24.12	

A.3. Distribution of racial composition quintiles (percent black) by covariates.

	Overall		Q1		Q2		Q3		Q4		Q5		missing		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
	134289	100.00	26670	19.86	26659	19.85	26565	19.78	26708	19.89	26603	19.81	1084	0.81	
Sex															
Male	67852	50.53	13599	20.04	13331	19.65	13415	19.77	13475	19.86	13455	19.83	577	0.85	
Female	66437	49.47	13071	19.67	13328	20.06	13150	19.79	13233	19.92	13148	19.79	507	0.76	
Child's race															
White	62250	46.36	22053	35.43	18445	29.63	13073	21.00	6911	11.10	799	1.28	969	1.56	[a]
Black	45040	33.54	1009	2.24	2612	5.80	5653	12.55	12044	26.74	23720	52.66	2	0.00	
Hispanic	17806	13.26	2093	11.75	3296	18.51	5476	30.75	5544	31.14	1314	7.38	83	0.47	
Other	9193	6.85	1515	16.48	2306	25.08	2363	25.70	2209	24.03	770	8.38	30	0.33	
Mother's age															
≤ 17	5446	4.06	537	9.86	709	13.02	932	17.11	1252	22.99	1995	36.63	21	0.39	[a]
18-19	10148	7.56	1174	11.57	1466	14.45	1863	18.36	2528	24.91	3080	30.35	37	0.36	
20-24	32755	24.39	4116	12.57	5197	15.87	6722	20.52	7989	24.39	8571	26.17	160	0.49	
25-29	36779	27.39	7228	19.65	7642	20.78	7861	21.37	7444	20.24	6294	17.11	310	0.84	
30-34	31740	23.64	8610	27.13	7446	23.46	6156	19.40	4971	15.66	4159	13.10	398	1.25	
35-39	14851	11.06	4264	28.71	3653	24.60	2558	17.22	2179	14.67	2057	13.85	140	0.94	
≥ 40	2570	1.91	741	28.83	546	21.25	473	18.40	345	13.42	447	17.39	18	0.70	
Mother's race															
White	66763	49.72	22897	34.30	19416	29.08	14245	21.34	8088	12.11	1117	1.67	1000	1.50	[a]
Black	45404	33.81	1036	2.28	2685	5.91	5716	12.59	12164	26.79	23800	52.42	3	0.01	
Hispanic	16577	12.34	1820	10.98	3007	18.14	5177	31.23	5196	31.34	1310	7.90	67	0.40	
Other	5545	4.13	917	16.54	1551	27.97	1427	25.73	1260	22.72	376	6.78	14	0.25	
Mother's marital status															
Unmarried	45086	33.57	3431	7.61	4910	10.89	7409	16.43	11480	25.46	17748	39.36	108	0.24	[a]
Married	89156	66.39	23232	26.06	21736	24.38	19143	21.47	15220	17.07	8849	9.93	976	1.09	
Missing	47	0.03	0	0.00	7	14.89	13	27.66	13	27.66	8	17.02	6	12.77	
Mother's education															
Less than 12th grade	28178	20.98	3126	11.09	4162	14.77	5944	21.09	7552	26.80	7262	25.77	132	0.47	[a]
HS Diploma/GED	40508	30.16	6445	15.91	7010	17.31	8062	19.90	9032	22.30	9702	23.95	257	0.63	
Some College	27633	20.58	5427	19.64	5499	19.90	5283	19.12	5175	18.73	6043	21.87	206	0.75	
College Graduate	35147	26.17	11247	32.00	9417	26.79	6467	18.40	4318	12.29	3222	9.17	476	1.35	
Missing	2823	2.10	425	15.05	571	20.23	809	28.66	631	22.35	374	13.25	13	0.46	

[a]: significant p-value (<0.05)

(Table A.3 Continued)

	Overall		Q1		Q2		Q3		Q4		Q5		missing		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
	134289	100.00	26670	19.86	26659	19.85	26565	19.78	26708	19.89	26603	19.81	1084	0.81	
Missing father's information															
Yes	17927	13.35	1239	6.91	1762	9.83	2768	15.44	4406	24.58	7714	43.03	38	0.21	[a]
No	116362	86.65	25431	21.86	24897	21.40	23797	20.45	22302	19.17	18889	16.23	1046	0.90	
Tobacco use															
Yes	9299	6.92	2046	0.85	2071	22.00	2115	22.27	1662	22.74	1326	17.87	79	0.85	[a]
No	124364	92.61	24506	19.71	24457	19.67	24318	19.55	24920	20.04	25160	20.23	1003	0.81	
Missing	626	0.47	118	18.85	131	20.93	132	21.09	126	20.13	117	18.69	2	0.32	
Alcohol use															
Yes	955	0.71	279	29.21	183	19.16	158	16.54	128	13.40	199	20.84	8	0.84	[a]
No	132699	98.82	26269	19.80	26344	19.85	26274	19.80	26448	19.93	26289	19.81	1075	0.81	
Missing	635	0.47	122	19.21	132	20.79	133	20.94	132	20.79	115	18.11	1	0.16	
Prior adverse birth outcome															
Yes	937	0.70	266	28.39	200	21.34	167	17.82	145	15.47	143	15.26	16	1.71	[a]
No	133352	99.30	26404	19.80	26459	19.84	26398	19.80	26563	19.92	26460	19.84	1068	0.80	
Failed Math															
Yes	16705	12.44	1641	9.82	2240	13.41	3186	19.07	4401	26.35	5185	31.04	52	0.31	[a]
No	117439	87.45	25009	21.30	24385	20.76	23341	19.87	22275	18.97	21399	18.22	1030	0.88	
Missing	145	0.11	20	13.79	34	23.45	38	26.21	32	22.07	19	13.10	2	1.38	
Failed Reading															
Yes	12255	9.13	1165	9.51	1659	13.54	2530	20.64	3208	26.18	3644	29.73	49	0.40	[a]
No	121905	90.78	25488	20.91	24975	20.49	24005	19.69	23469	19.25	22933	18.81	1035	0.85	
Missing	129	0.10	17	13.18	25	19.38	20	23.26	31	24.03	26	20.16	0	0.00	
Failed English/Language Arts															
Yes	20663	15.39	2370	11.47	3032	14.67	4295	20.79	5306	25.68	5546	26.84	114	0.55	[a]
No	113456	84.49	24272	21.39	23594	20.80	22229	19.59	21367	18.83	21024	18.53	970	0.85	
Missing	170	0.13	28	16.47	33	19.41	41	24.12	35	20.59	33	19.41	0	0.00	

A.4. Distribution of deprivation index quintiles by covariates.

	Overall		Q1		Q2		Q3		Q4		Q5		missing		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
	134289	100.00	26878	20.02	26845	19.99	26932	20.06	26812	19.97	26821	19.97	1	0.00	
Sex															
Male	67852	50.53	13473	19.86	13673	20.15	13645	20.11	13608	20.06	13452	19.83	1	0.00	
Female	66437	49.47	13405	20.18	13172	19.83	13287	20.00	13204	19.87	13369	20.12	0	0.00	
Child's race															
White	62250	46.36	20551	33.01	17003	27.31	12540	20.14	9047	14.53	3109	4.99	0	0.00	[a]
Black	45040	33.54	1839	4.08	5234	11.62	9070	20.14	10727	23.82	18169	40.34	1	0.00	
Hispanic	17806	13.26	2213	12.43	2682	15.06	3512	19.72	5023	28.21	4376	24.58	0	0.00	
Other	9193	6.85	2275	24.75	1926	20.95	1810	19.69	2015	21.92	1167	12.69	0	0.00	
Mother's age															
≤ 17	5446	4.06	287	5.27	680	12.59	1056	19.39	1275	23.41	2148	39.44	0	0.00	[a]
18-19	10148	7.56	691	6.81	1349	13.29	2195	21.63	2499	24.63	3414	33.64	0	0.00	
20-24	32755	24.39	2682	8.19	5272	16.10	7016	21.42	8275	25.26	9510	29.03	0	0.00	
25-29	36779	27.39	6740	18.33	8144	22.14	7817	21.25	7627	20.74	6451	17.54	0	0.00	
30-34	31740	23.64	10120	31.89	7515	23.68	5828	18.36	4789	15.09	3487	10.99	1	0.00	
35-39	14851	11.06	5459	36.76	3323	22.38	2597	17.49	1982	13.35	1490	10.03	0	0.00	
≥ 40	2570	1.91	899	34.98	562	21.87	423	16.46	365	14.20	321	12.49	0	0.00	
Mother's race															
White	66763	49.72	21357	31.99	17955	26.89	13520	20.25	10122	15.16	3809	5.71	0	0.00	[a]
Black	45404	33.81	1928	4.25	5294	11.66	9118	20.08	10832	23.86	18231	40.15	1	0.00	
Hispanic	16577	12.34	1964	11.85	2449	14.77	3296	19.88	4714	28.44	4154	25.06	0	0.00	
Other	5545	4.13	1629	29.38	1147	20.69	998	18.00	1144	20.63	627	11.31	0	0.00	
Mother's marital status															
Unmarried	45086	33.57	2612	5.79	5342	11.85	8710	19.32	11174	24.78	17248	38.26	0	0.00	[a]
Married	89156	66.39	24255	27.21	21493	24.11	18211	20.43	15628	17.53	9568	10.73	1	0.00	
Missing	47	0.03	11	23.40	10	21.28	11	23.40	10	21.28	5	10.64	0	0.00	
Mother's education															
Less than 12th grade	28178	20.98	1697	6.02	3533	12.54	5441	19.31	7280	25.84	10227	36.29	0	0.00	[a]
HS Diploma/GED	40508	30.16	4503	11.12	7698	19.00	9105	22.48	9351	23.08	9851	24.32	0	0.00	
Some College	27633	20.58	5342	19.33	6294	22.78	6214	22.49	5531	20.02	4252	15.39	0	0.00	
College Graduate	35147	26.17	14881	42.34	8817	25.09	5653	16.08	3983	11.33	1812	5.16	1	0.00	
Missing	2823	2.10	455	16.12	503	17.82	519	18.38	667	23.63	679	24.05	0	0.00	

[a]: significant p-value (<0.05)

(Table A.4 continued)

	Overall		Q1		Q2		Q3		Q4		Q5		missing		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
	134289	100.00	26878	20.02	26845	19.99	26932	20.06	26812	19.97	26821	19.97	1	0.00	
Missing father's information															
Yes	17927	13.35	1023	5.71	1913	10.67	3075	17.15	4218	23.53	7698	42.94	0	0.00	[a]
No	116362	86.65	25855	22.22	24932	21.43	23857	20.50	22594	19.42	19123	16.43	1	0.00	
Tobacco use															
Yes	9299	6.92	927	9.97	1952	20.99	2326	25.01	2157	23.20	1937	20.83	0	0.00	[a]
No	124364	92.61	25816	20.76	24762	19.91	24473	19.68	24536	19.73	24776	19.92	1	0.00	
Missing	626	0.47	135	21.57	131	20.93	133	21.25	119	19.01	108	17.25	0	0.00	
Alcohol use															
Yes	955	0.71	312	32.67	168	17.59	144	15.08	120	12.57	211	22.09	0	0.00	[a]
No	132699	98.82	26430	19.92	26544	20.00	26653	20.09	26568	20.02	26503	19.97	1	0.00	
Missing	635	0.47	136	21.42	133	20.94	135	21.26	124	19.53	107	16.85	0	0.00	
Prior adverse birth outcome															
Yes	937	0.70	299	31.91	197	21.02	180	19.21	135	14.41	126	13.45	0	0.00	[a]
No	133352	99.30	26579	19.93	26648	19.98	26752	20.06	26677	20.01	26695	20.02	1	0.00	
Failed Math															
Yes	16705	12.44	1162	6.96	2395	14.34	3285	19.66	4290	25.68	5573	33.36	0	0.00	[a]
No	117439	87.45	25696	21.88	24417	20.79	23611	20.11	22497	19.16	21217	18.07	1	0.00	
Missing	145	0.11	20	13.79	33	22.76	36	24.83	25	17.24	31	21.38	0	0.00	
Failed Reading															
Yes	12255	9.13	831	6.78	1730	14.12	2422	19.76	3223	26.30	4049	33.04	0	0.00	[a]
No	121905	90.78	26034	21.36	25094	20.59	24481	20.08	23564	19.33	22731	18.65	1	0.00	
Missing	129	0.10	13	10.08	21	16.28	29	22.48	25	19.38	41	31.78	0	0.00	
Failed English/Language Arts															
Yes	20663	15.39	1691	8.18	3135	15.17	4176	20.21	5357	25.93	6304	30.51	0	0.00	[a]
No	113456	84.49	25163	22.18	23686	20.88	22714	20.02	21426	18.89	20466	18.04	1	0.00	
Missing	170	0.13	24	14.12	24	14.12	42	24.71	29	17.06	51	30.00	0	0.00	

B. Distribution of failing each CRCT by covariates.

	Overall		Math			Reading			English/Language Arts		
	n	%	n	%	p-value	n	%	p-value	n	%	p-value
	134289	100.00	16705	12.44		12255	9.13		20663	15.39	
Sex											
Male	67852	50.53	9414	13.87	<.0001	7788	11.48	<.0001	12754	18.80	<.0001
Female	66437	49.47	7291	10.97		4467	6.72		7909	11.90	
Child's race											
White	62250	46.36	4124	6.62	<.0001	2984	4.79	<.0001	5873	9.43	<.0001
Black	45040	33.54	8605	19.11		5915	13.13		9104	20.21	
Hispanic	17806	13.26	3287	18.46		2783	15.63		4733	26.58	
Other	9193	6.85	689	7.49		573	6.23		953	10.37	
Mother's age											
≤ 17	5446	4.06	1194	21.92	<.0001	874	16.05	<.0001	1418	26.04	<.0001
18-19	10148	7.56	1903	18.75		1413	13.92		2352	23.18	
20-24	32755	24.39	5511	16.82		4100	12.52		6738	20.57	
25-29	36779	27.39	4135	11.24		3038	8.26		5232	14.23	
30-34	31740	23.64	2513	7.92		1799	5.67		3186	10.04	
35-39	14851	11.06	1223	8.24		867	5.84		1454	9.79	
≥ 40	2570	1.91	226	8.79		164	6.38		283	11.01	
Mother's race											
White	66763	49.72	4671	7.00	<.0001	3438	5.15	<.0001	6633	9.94	<.0001
Black	45404	33.81	8640	19.03		5905	13.01		9104	20.05	
Hispanic	16577	12.34	3081	18.59		2613	15.76		4458	26.89	
Other	5545	4.13	313	5.64		299	5.39		468	8.44	
Mother's marital status											
Unmarried	45086	33.57	9091	20.16	<.0001	6618	14.68	<.0001	10483	23.25	<.0001
Married	89156	66.39	7610	8.54		5633	6.32		10172	11.41	
Missing	47	0.03	4	8.51		4	8.51		8	17.02	
Mother's educational status											
Less than 12th grade	28178	20.98	6275	22.27	<.0001	4893	17.36	<.0001	7908	28.06	<.0001
HS Diploma/GED	40508	30.16	6141	15.16		4461	11.01		7451	18.39	
Some College	27633	20.58	2630	9.52		1755	6.35		3132	11.33	
College Graduate	35147	26.17	1192	3.39		742	2.11		1500	4.27	
Missing	2823	2.10	467	16.54		404	14.31		672	23.80	
Missing father's information											
Yes	17927	13.35	4138	23.80	<.0001	3047	17.00	<.0001	4633	25.84	<.0001
No	116362	86.65	12567	10.80		9208	7.91		16030	13.78	

(Table B continued)

	Overall		Math			Reading			English/Language Arts		
	n	%	n	%	p-value	n	%	p-value	n	%	p-value
	134289	100.00	16705	12.44		12255	9.13		20663	15.39	
Tobacco use											
Yes	9299	6.92	1497	16.10	<.0001	1166	12.54	<.0001	1930	20.75	<.0001
No	124364	92.61	15128	12.16		11034	8.87		18642	14.99	
Missing	626	0.47	80	12.78		55	8.79		91	14.54	
Alcohol use											
Yes	955	0.71	96	10.05	0.0248	72	7.54	0.0856	129	13.51	0.1048
No	132699	98.82	16530	12.46		12127	9.14		20443	15.41	
Missing	635	0.47	79	12.44		56	8.82		91	14.33	
Prior adverse birth outcome											
Yes	937	0.70	101	10.78	0.1194	71	7.58	0.0988	128	13.66	0.1374
No	133352	99.30	16604	12.45		12184	9.15		20535	15.40	
Preterm											
Yes	13205	9.83	2228	16.87	<.0001	1588	12.03	<.0001	2580	19.54	<.0001
No	121084	90.17	14477	11.96		10667	8.81		18083	14.93	
Poverty											
Q1	26944	20.06	1306	4.85	<.0001	997	3.70	<.0001	1986	7.37	<.0001
Q2	26784	19.95	2352	8.78		1765	6.59		3202	11.95	
Q3	26859	20.00	3310	12.32		2442	9.09		4238	15.78	
Q4	26887	20.02	4245	15.79		3114	11.58		5103	18.98	
Q5	26815	19.97	5492	20.48		3937	14.68		6134	22.88	
Percent Black											
Q1	26670	19.86	1641	6.15	<.0001	1165	4.37	<.0001	2370	8.89	<.0001
Q2	26659	19.85	2240	8.40		1659	6.22		3032	11.37	
Q3	26565	19.78	3186	11.99		2530	9.52		4295	16.17	
Q4	26708	19.89	4401	16.48		3208	12.01		5306	19.87	
Q5	26603	19.81	5185	19.49		3644	13.70		5546	20.85	
Missing	1084	0.81	52	4.80		49	4.52		114	10.52	
Deprivation Index											
Q1	26878	20.02	1162	4.32	<.0001	831	3.09	<.0001	1691	6.29	<.0001
Q2	26845	19.99	2395	8.92		1730	6.44		3135	11.68	
Q3	26932	20.06	3285	12.20		2422	8.99		4176	15.51	
Q4	26812	19.97	4290	16.00		3223	12.02		5357	19.98	
Q5	26821	19.97	5573	20.78		4049	15.10		6304	23.50	
Missing	1	0.00	0	0		0	0.00		0	0.00	

C. Stratified analysis for interaction tests.

C.1. Stratified analysis comparing risk differences for the test for additive interaction.

	Failed Math				Failed Reading				Failed English/Language Arts			
	Term	Preterm	Expected	Interaction?	Term	Preterm	Expected	Interaction?	Term	Preterm	Expected	Interaction?
Poverty												
Q1	0.00	1.97	17.19	Yes	0.00	1.02	11.77	Yes	0.00	2.11	17.33	Yes
Q2	3.81	7.03			2.73	5.38			4.36	8.70		
Q3	7.12	12.38			5.12	8.76			8.15	12.49		
Q4	10.61	15.47			7.66	10.75			11.36	15.62		
Q5	15.22	20.35			10.75	13.58			15.22	19.32		
Percent Black												
Q1	0.00	1.27	14.06	Yes	0.00	1.10	10.13	Yes	0.00	2.14	13.68	Yes
Q2	2.08	5.38			1.76	3.94			2.41	5.54		
Q3	5.50	10.53			4.98	8.02			7.09	11.38		
Q4	9.91	14.98			7.38	10.79			10.72	15.08		
Q5	12.79	18.17			9.03	12.31			11.54	16.58		
Deprivation												
Q1	0.00	1.53	17.50	Yes	0.00	0.91	12.65	Yes	0.00	1.82	18.70	Yes
Q2	4.43	7.61			3.23	5.35			5.26	8.27		
Q3	7.48	12.65			5.61	9.23			8.85	14.02		
Q4	11.32	16.10			8.70	11.74			13.45	17.37		
Q5	15.97	21.27			11.74	14.81			16.88	21.29		

C.2. Stratified analysis comparing risk ratios for the test for multiplicative interaction.

	Failed Math				Failed Reading				Failed English/Language Arts			
	Term	Preterm	Expected	Interaction?	Term	Preterm	Expected	Interaction?	Term	Preterm	Expected	Interaction?
Poverty												
Q1	1.00	1.42	6.03	No	1.00	1.28	5.09	No	1.00	1.29	4.02	No
Q2	1.81	2.50			1.75	2.49			1.60	2.21		
Q3	2.52	3.64			2.41	3.42			2.13	2.73		
Q4	3.26	4.30			3.12	3.97			2.58	3.17		
Q5	4.25	5.34			3.97	4.75			3.11	3.68		
Percent Black												
Q1	1.00	1.21	3.77	No	1.00	1.26	3.91	No	1.00	1.25	2.90	No
Q2	1.34	1.89			1.41	1.92			1.28	1.64		
Q3	1.91	2.74			2.16	2.87			1.81	2.31		
Q4	2.64	3.48			2.72	3.52			2.23	2.73		
Q5	3.11	4.00			3.11	3.88			2.32	2.90		
Deprivation												
Q1	1.00	1.36	6.54	No	1.00	1.30	6.36	No	1.00	1.30	4.85	No
Q2	2.05	2.81			2.07	2.77			1.86	2.34		
Q3	2.78	4.00			2.86	4.06			2.44	3.28		
Q4	3.69	4.82			3.88	4.89			3.19	3.82		
Q5	4.79	6.05			4.89	5.90			3.74	4.46		

D. Binomial-Identity Models (RD)

D.1. Binomial RD model: preterm birth and poverty on risk of failing math CRCT

	Model 1 [a]				Model 2 [b]			
	β	95% CI		AIC	β	95% CI		AIC
Intercept	-0.015	-0.020	-0.009	88848	-0.017	-0.023	-0.011	88747
Preterm	0.021	0.015	0.027					
Poverty								
Q1					*ref*	*ref*	*ref*	
Q2					0.006	0.003	0.008	
Q3					0.011	0.007	0.014	
Q4					0.020	0.015	0.025	
Q5					0.033	0.027	0.038	
Preterm*Poverty								
Q1								
Q2								
Q3								
Q4								
Q5								
Covariates								
Sex	0.015	0.013	0.018		0.015	0.013	0.018	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.078	0.073	0.082		0.070	0.066	0.075	
Hispanic	0.048	0.042	0.054		0.045	0.038	0.051	
Other	-0.002	-0.006	0.001		-0.002	-0.005	0.000	
Mother's Age								
≤ 17	-0.021	-0.032	-0.009		-0.019	-0.031	-0.007	
18-19	-0.012	-0.020	-0.004		-0.011	-0.020	-0.003	
20-24	0.005	0.000	0.009		0.004	-0.001	0.008	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.001	-0.004	0.001		0.000	-0.003	0.002	
35-39	-0.001	-0.004	0.002		0.001	-0.002	0.004	
≥ 40	0.002	-0.005	0.009		0.004	-0.003	0.011	
Mother's Marital Status	0.025	0.020	0.030		0.023	0.017	0.028	
Mother's Education								
Less than 12th grade	0.138	0.131	0.145		0.131	0.124	0.138	
HS Diploma/GED	0.075	0.071	0.080		0.071	0.066	0.075	
Some College	0.030	0.026	0.034		0.027	0.024	0.031	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.041	0.033	0.048		0.039	0.032	0.047	
Prior Adverse Outcome	0.001	-0.011	0.012		0.007	-0.005	0.019	

[a]: Model 1 – preterm only
[b]: Model 2 – poverty only

(Table D.1 continued)

	Model 3 [c]				Model 4 [d]			
	β	95%CI		AIC	β	95% CI		AIC
Intercept	-0.017	-0.023	-0.012	88692	-0.017	-0.023	-0.011	88662
Preterm	0.020	0.014	0.026		0.002	-0.004	0.009	
Poverty								
Q1	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Q2	0.005	0.002	0.008		0.005	0.002	0.008	
Q3	0.010	0.007	0.014		0.009	0.005	0.012	
Q4	0.020	0.015	0.024		0.018	0.014	0.023	
Q5	0.032	0.026	0.038		0.030	0.024	0.036	
Preterm*Poverty								
Q1					*ref*	*ref*	*ref*	
Q2					0.010	-0.002	0.022	
Q3					0.037	0.022	0.052	
Q4					0.030	0.014	0.047	
Q5					0.041	0.024	0.058	
Covariates								
Sex	0.015	0.012	0.017		0.015	0.013	0.018	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.069	0.064	0.074		0.069	0.064	0.073	
Hispanic	0.045	0.039	0.051		0.045	0.039	0.052	
Other	-0.003	-0.006	0.000		-0.003	-0.006	0.000	
Mother's Age								
≤ 17	-0.019	-0.031	-0.008		-0.020	-0.031	-0.008	
18-19	-0.011	-0.020	-0.003		-0.011	-0.019	-0.003	
20-24	0.003	-0.001	0.008		0.004	-0.001	0.008	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	0.000	-0.003	0.002		0.000	-0.003	0.002	
35-39	0.001	-0.002	0.004		0.001	-0.002	0.004	
≥ 40	0.004	-0.003	0.010		0.004	-0.003	0.011	
Mother's Marital Status	0.023	0.017	0.028		0.022	0.017	0.028	
Mother's Education								
Less than 12th grade	0.130	0.123	0.137		0.130	0.123	0.137	
HS Diploma/GED	0.070	0.066	0.075		0.070	0.066	0.075	
Some College	0.027	0.023	0.031		0.027	0.024	0.031	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.039	0.032	0.046		0.039	0.031	0.046	
Prior Adverse Outcome	0.003	-0.008	0.014		0.004	-0.007	0.014	

[c]: Model 3 – preterm and poverty
[d]: Model 4 – preterm, poverty, and cross-product of preterm and poverty

D.2. Binomial RD model: preterm birth and percent black on risk of failing math CRCT

	Model 1 [a]				Model 2 [b]			
	β	95% CI		AIC	β	95% CI		AIC
Intercept	-0.015	-0.021	-0.009	888469	-0.017	-0.022	-0.011	88464
Preterm	0.021	0.015	0.027					
Percent Black								
Q1					*ref*	*ref*	*ref*	
Q2					0.003	0.001	0.006	
Q3					0.006	0.003	0.010	
Q4					0.019	0.014	0.024	
Q5					0.012	0.006	0.019	
Preterm*Percent Black								
Q1								
Q2								
Q3								
Q4								
Q5								
Covariates								
Sex	0.015	0.013	0.018		0.015	0.013	0.018	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.077	0.073	0.082		0.071	0.066	0.077	
Hispanic	0.048	0.042	0.054		0.044	0.037	0.050	
Other	-0.003	-0.006	0.001		-0.005	-0.008	-0.002	
Mother's Age								
≤ 17	-0.021	-0.033	-0.009		-0.021	-0.033	-0.009	
18-19	-0.012	-0.021	-0.004		-0.013	-0.021	-0.004	
20-24	0.005	0.000	0.009		0.004	0.000	0.009	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.001	-0.004	0.001		-0.001	-0.004	0.001	
35-39	-0.001	-0.004	0.002		-0.001	-0.004	0.003	
≥ 40	0.002	-0.005	0.009		0.002	-0.005	0.009	
Mother's Marital Status	0.025	0.020	0.030		0.024	0.019	0.030	
Mother's Education								
Less than 12th grade	0.139	0.132	0.145		0.138	0.131	0.144	
HS Diploma/GED	0.076	0.072	0.080		0.075	0.071	0.079	
Some College	0.030	0.027	0.034		0.030	0.026	0.033	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.041	0.033	0.048		0.041	0.033	0.048	
Prior Adverse Outcome	0.001	-0.011	0.013		0.004	-0.009	0.017	

[a]: Model 1 – preterm only
[b]: Model 2 – percent black only

(Table D.2 continued)

	Model 3 [c]				Model 4 [d]			
	β	95%CI		AIC	β	95% CI		AIC
Intercept	-0.017	-0.023	-0.012	888405	-0.017	-0.023	-0.011	88378
Preterm	0.021	0.015	0.027		0.004	-0.003	0.011	
Percent Black								
Q1	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Q2	0.004	0.001	0.006		0.003	0.001	0.006	
Q3	0.006	0.003	0.010		0.005	0.002	0.009	
Q4	0.019	0.014	0.023		0.017	0.012	0.022	
Q5	0.013	0.006	0.019		0.010	0.003	0.016	
Preterm*Percent Black								
Q1					*ref*	*ref*	*ref*	
Q2					0.008	-0.005	0.021	
Q3					0.024	0.008	0.039	
Q4					0.035	0.018	0.051	
Q5					0.043	0.026	0.059	
Covariates								
Sex	0.015	0.012	0.018		0.015	0.013	0.018	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.070	0.065	0.076		0.069	0.064	0.075	
Hispanic	0.044	0.038	0.050		0.044	0.038	0.051	
Other	-0.005	-0.009	-0.002		-0.005	-0.008	-0.002	
Mother's Age								
≤ 17	-0.022	-0.034	-0.010		-0.022	-0.034	-0.009	
18-19	-0.012	-0.021	-0.004		-0.012	-0.020	-0.004	
20-24	0.004	0.000	0.009		0.004	0.000	0.009	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.001	-0.004	0.002		-0.001	-0.004	0.001	
35-39	0.000	-0.003	0.003		0.000	-0.004	0.003	
≥ 40	0.002	-0.005	0.009		0.002	-0.005	0.009	
Mother's Marital Status	0.024	0.019	0.030		0.024	0.019	0.029	
Mother's Education								
Less than 12th grade	0.137	0.130	0.143		0.137	0.130	0.143	
HS Diploma/GED	0.074	0.070	0.079		0.074	0.070	0.079	
Some College	0.029	0.026	0.033		0.030	0.026	0.033	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.040	0.033	0.048		0.040	0.033	0.047	
Prior Adverse Outcome	0.000	-0.010	0.011		0.000	-0.010	0.011	

[c]: Model 3 – preterm and percent black
[d]: Model 4 – preterm, percent black, and cross-product of preterm and percent black

D.3 Binomial RD model: preterm birth and deprivation on risk of failing math CRCT

	Model 1 [a]				Model 2 [b]			
	β	95% CI		AIC	β	95% CI		AIC
Intercept	-0.015	-0.020	-0.009	88848	-0.017	-0.023	-0.012	88757
Preterm	0.021	0.015	0.027					
Deprivation								
Q1					*ref*	*ref*	*ref*	
Q2					0.008	0.005	0.011	
Q3					0.011	0.007	0.015	
Q4					0.022	0.017	0.026	
Q5					0.033	0.026	0.039	
Preterm*Deprivation								
Q1								
Q2								
Q3								
Q4								
Q5								
Covariates								
Sex	0.015	0.013	0.018		0.015	0.013	0.018	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.078	0.073	0.082		0.070	0.065	0.075	
Hispanic	0.048	0.042	0.054		0.044	0.037	0.050	
Other	-0.002	-0.006	0.001		-0.003	-0.005	0.000	
Mother's Age								
≤ 17	-0.021	-0.032	-0.009		-0.019	-0.031	-0.007	
18-19	-0.012	-0.020	-0.004		-0.011	-0.020	-0.003	
20-24	0.005	0.000	0.009		0.004	-0.001	0.008	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.001	-0.004	0.001		0.000	-0.002	0.002	
35-39	-0.001	-0.004	0.002		0.001	-0.002	0.004	
≥ 40	0.002	-0.005	0.009		0.005	-0.002	0.012	
Mother's Marital Status	0.025	0.020	0.030		0.023	0.017	0.028	
Mother's Education								
Less than 12th grade	0.138	0.131	0.145		0.130	0.124	0.137	
HS Diploma/GED	0.075	0.071	0.080		0.070	0.066	0.075	
Some College	0.030	0.026	0.034		0.027	0.023	0.031	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.041	0.033	0.048		0.039	0.032	0.047	
Prior Adverse Outcome	0.001	-0.011	0.012		0.007	-0.005	0.019	

[a]: Model 1 – preterm only
[b]: Model 2 – deprivation only

(Table D.3 continued)

	Model 3 [c]				Model 4 [d]			
	β	95%CI		AIC	β	95% CI		AIC
Intercept	-0.018	-0.024	-0.012	88702	-0.017	-0.023	-0.011	88672
Preterm	0.020	0.015	0.026		0.002	-0.004	0.008	
Deprivation								
Q1	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Q2	0.007	0.005	0.010		0.007	0.004	0.010	
Q3	0.010	0.006	0.014		0.009	0.005	0.012	
Q4	0.021	0.016	0.026		0.019	0.014	0.024	
Q5	0.032	0.026	0.038		0.030	0.023	0.036	
Preterm*Deprivation								
Q1					*ref*	*ref*	*ref*	
Q2					0.013	0.000	0.026	
Q3					0.033	0.018	0.048	
Q4					0.035	0.018	0.051	
Q5					0.042	0.025	0.059	
Covariates								
Sex	0.015	0.012	0.017		0.015	0.012	0.017	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.069	0.064	0.074		0.068	0.063	0.073	
Hispanic	0.044	0.038	0.050		0.044	0.038	0.051	
Other	-0.003	-0.006	0.000		-0.003	-0.006	0.000	
Mother's Age								
≤ 17	-0.019	-0.031	-0.007		-0.020	-0.031	-0.008	
18-19	-0.011	-0.019	-0.003		-0.011	-0.019	-0.003	
20-24	0.004	-0.001	0.008		0.004	-0.001	0.008	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	0.000	-0.002	0.003		0.000	-0.002	0.003	
35-39	0.002	-0.002	0.005		0.001	-0.002	0.005	
≥ 40	0.005	-0.002	0.012		0.005	-0.002	0.012	
Mother's Marital Status	0.023	0.017	0.028		0.023	0.017	0.028	
Mother's Education								
Less than 12th grade	0.130	0.123	0.136		0.130	0.123	0.136	
HS Diploma/GED	0.069	0.065	0.074		0.070	0.065	0.074	
Some College	0.026	0.023	0.030		0.027	0.023	0.030	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.039	0.032	0.047		0.039	0.032	0.046	
Prior Adverse Outcome	0.003	-0.008	0.014		0.004	-0.007	0.014	

[c]: Model 3 – preterm and deprivation
[d]: Model 4 – preterm, deprivation, and cross-product of preterm and deprivation

D.4 Binomial RD model: preterm birth and poverty on risk of filing English/language arts CRCT

	Model 1 [a]				Model 2 [b]			
	β	95% CI		AIC	β	95% CI		AIC
Intercept	-0.015	-0.021	-0.009	101029	-0.016	-0.022	-0.010	101018
Preterm	0.021	0.015	0.027					
Poverty								
Q1					*ref*	*ref*	*ref*	
Q2					0.003	0.000	0.006	
Q3					0.008	0.004	0.011	
Q4					0.015	0.010	0.020	
Q5					0.020	0.014	0.026	
Preterm*Poverty								
Q1								
Q2								
Q3								
Q4								
Q5								
Covariates								
Sex	0.046	0.043	0.050		0.046	0.043	0.050	
Child's Race								
White					*ref*	*ref*	*ref*	
Black	0.053	0.048	0.058		0.049	0.044	0.053	
Hispanic	0.078	0.070	0.085		0.076	0.068	0.083	
Other	-0.004	-0.008	-0.001		-0.005	-0.009	-0.002	
Mother's Age								
≤ 17	-0.029	-0.042	-0.016		-0.028	-0.041	-0.015	
18-19	-0.010	-0.019	-0.001		-0.010	-0.019	-0.001	
20-24	0.005	0.000	0.010		0.004	-0.001	0.009	
25-29					*ref*	*ref*	*ref*	
30-34	-0.003	-0.006	0.000		-0.002	-0.005	0.001	
35-39	-0.001	-0.005	0.003		0.000	-0.004	0.003	
≥ 40	-0.001	-0.008	0.006		-0.002	-0.009	0.006	
Mother's Marital Status	0.027	0.022	0.033		0.026	0.020	0.032	
Mother's Education								
Less than 12th grade	0.179	0.171	0.186		0.174	0.166	0.182	
HS Diploma/GED	0.096	0.091	0.100		0.093	0.088	0.098	
Some College	0.038	0.034	0.042		0.036	0.032	0.041	
College Graduate					*ref*	*ref*	*ref*	
Missing Father's Information	0.034	0.026	0.041		0.033	0.025	0.040	
Prior Adverse Outcome	0.009	-0.006	0.024		0.014	-0.002	0.029	

[a]: Model 1 – preterm only
[b]: Model 2 – poverty only

(Table 4 continued)

	Model 3 [c]				Model 4 [d]			
	β	95%CI		AIC	β	95% CI		AIC
Intercept	-0.017	-0.023	-0.011	100967	-0.016	-0.023	-0.010	100956
Preterm	0.021	0.014	0.027		0.006	-0.002	0.014	
Poverty								
Q1	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Q2	0.003	0.000	0.006		0.003	0.000	0.006	
Q3	0.007	0.003	0.011		0.006	0.002	0.010	
Q4	0.015	0.010	0.020		0.014	0.009	0.019	
Q5	0.020	0.014	0.026		0.018	0.012	0.025	
Preterm*Poverty								
Q1					*ref*	*ref*	*ref*	
Q2					0.010	-0.005	0.025	
Q3					0.030	0.014	0.046	
Q4					0.023	0.006	0.041	
Q5					0.029	0.011	0.047	
Covariates								
Sex	0.046	0.043	0.049		0.046	0.043	0.049	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.047	0.042	0.052		0.047	0.042	0.052	
Hispanic	0.076	0.068	0.083		0.076	0.068	0.083	
Other	-0.006	-0.009	-0.003		-0.006	-0.009	-0.003	
Mother's Age								
≤ 17	-0.028	-0.041	-0.015		-0.028	-0.041	-0.015	
18-19	-0.010	-0.019	-0.001		-0.010	-0.019	-0.001	
20-24	0.004	-0.001	0.009		0.004	-0.001	0.009	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.001	-0.004	0.002		-0.002	-0.005	0.001	
35-39	0.000	-0.003	0.004		0.000	-0.003	0.004	
≥ 40	-0.002	-0.010	0.005		-0.002	-0.010	0.006	
Mother's Marital Status	0.026	0.020	0.032		0.026	0.020	0.032	
Mother's Education								
Less than 12th grade	0.173	0.166	0.181		0.173	0.166	0.181	
HS Diploma/GED	0.092	0.087	0.097		0.092	0.087	0.097	
Some College	0.036	0.032	0.040		0.036	0.032	0.040	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.033	0.025	0.040		0.032	0.025	0.040	
Prior Adverse Outcome	0.009	-0.006	0.024		0.009	-0.005	0.024	

[c]: Model 3 – preterm and poverty
[d]: Model 4 – preterm, poverty, and cross-product of preterm and poverty

D.5 Binomial RD model: preterm birth and percent black on risk of failing English/language arts CRCT

	Model 1 [a]				Model 2 [b]			
	β	95% CI		AIC	β	95% CI		AIC
Intercept	-0.015	-0.021	-0.009	100411	-0.016	-0.022	-0.009	100428
Preterm	0.020	0.014	0.027					
Percent Black								
Q1					*ref*	*ref*	*ref*	
Q2					0.001	-0.002	0.003	
Q3					0.005	0.001	0.009	
Q4					0.015	0.009	0.020	
Q5					0.005	-0.001	0.011	
Preterm*Percent Black								
Q1								
Q2								
Q3								
Q4								
Q5								
Covariates								
Sex	0.047	0.043	0.050		0.047	0.043	0.050	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.053	0.048	0.058		0.050	0.045	0.056	
Hispanic	0.077	0.070	0.085		0.074	0.067	0.082	
Other	-0.004	-0.008	-0.001		-0.006	-0.009	-0.002	
Mother's Age								
≤ 17	-0.029	-0.042	-0.017		-0.029	-0.042	-0.016	
18-19	-0.011	-0.020	-0.001		-0.011	-0.020	-0.002	
20-24	0.005	0.000	0.010		0.005	0.000	0.010	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.002	-0.005	0.001		-0.002	-0.005	0.001	
35-39	-0.001	-0.004	0.003		-0.001	-0.004	0.003	
≥ 40	-0.001	-0.008	0.006		-0.002	-0.009	0.006	
Mother's Marital Status	0.027	0.022	0.033		0.027	0.021	0.033	
Mother's Education								
Less than 12th grade	0.179	0.171	0.186		0.178	0.170	0.185	
HS Diploma/GED	0.096	0.091	0.101		0.095	0.090	0.100	
Some College	0.039	0.035	0.043		0.038	0.034	0.042	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.034	0.026	0.041		0.034	0.026	0.042	
Prior Adverse Outcome	0.009	-0.006	0.024		0.013	-0.003	0.028	

[a]: Model 1 – preterm only
[b]: Model 2 – percent black only

(Table 5 continued)

	Model 3 [c]				Model 4 [d]			
	β	95%CI		AIC	β	95% CI		AIC
Intercept	-0.017	-0.023	-0.010	100379	-0.016	-0.022	-0.009	100359
Preterm	0.020	0.014	0.026		0.007	-0.001	0.016	
Percent Black								
Q1	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Q2	0.001	-0.002	0.004		0.001	-0.002	0.004	
Q3	0.005	0.001	0.009		0.004	0.000	0.008	
Q4	0.014	0.009	0.020		0.013	0.008	0.018	
Q5	0.005	-0.001	0.011		0.003	-0.003	0.008	
Preterm*Percent Black								
Q1					*ref*	*ref*	*ref*	
Q2					-0.001	-0.014	0.013	
Q3					0.020	0.002	0.037	
Q4					0.027	0.009	0.044	
Q5					0.039	0.022	0.056	
Covariates								
Sex	0.046	0.043	0.049		0.046	0.043	0.050	
Child's Race								
White	*ref*	*ref*	*ref*					
Black	0.049	0.043	0.054		0.048	0.043	0.053	
Hispanic	0.074	0.067	0.082		0.074	0.067	0.082	
Other	-0.006	-0.009	-0.003		-0.006	-0.009	-0.003	
Mother's Age								
≤ 17	-0.029	-0.042	-0.016		-0.029	-0.042	-0.016	
18-19	-0.011	-0.020	-0.001		-0.011	-0.020	-0.001	
20-24	0.005	0.000	0.010		0.005	0.000	0.010	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.002	-0.005	0.001		-0.002	-0.005	0.001	
35-39	0.000	-0.004	0.003		-0.001	-0.004	0.003	
≥ 40	-0.002	-0.009	0.005		-0.002	-0.009	0.005	
Mother's Marital Status	0.027	0.021	0.033		0.027	0.021	0.032	
Mother's Education								
Less than 12th grade	0.177	0.169	0.184		0.177	0.169	0.184	
HS Diploma/GED	0.095	0.090	0.099		0.095	0.090	0.100	
Some College	0.038	0.034	0.042		0.038	0.034	0.042	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.034	0.026	0.041		0.034	0.026	0.041	
Prior Adverse Outcome	0.008	-0.007	0.023		0.009	-0.006	0.024	

[c]: Model 3 – preterm and percent black
[d]: Model 4 – preterm, percent black, and cross-product of preterm and percent black

D.6 Binomial RD model: preterm birth and deprivation on risk of failing English/language arts CRCT

	Model 1 [a]				Model 2 [b]			
	β	95% CI		AIC	β	95% CI		AIC
Intercept	-0.015	-0.021	-0.009	101028	-0.016	-0.023	-0.010	100951
Preterm	0.021	0.015	0.027					
Deprivation								
Q1					*ref*	*ref*	*ref*	
Q2					0.005	0.002	0.008	
Q3					0.010	0.006	0.015	
Q4					0.026	0.021	0.032	
Q5					0.028	0.021	0.034	
Preterm*Deprivation								
Q1								
Q2								
Q3								
Q4								
Q5								
Covariates								
Sex	0.046	0.043	0.050		0.046	0.043	0.049	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.053	0.048	0.058		0.045	0.041	0.050	
Hispanic	0.078	0.070	0.085		0.073	0.066	0.081	
Other	-0.004	-0.008	-0.001		-0.006	-0.009	-0.003	
Mother's Age								
≤ 17	-0.029	-0.042	-0.016		-0.028	-0.041	-0.015	
18-19	-0.010	-0.019	-0.001		-0.010	-0.020	-0.001	
20-24	0.005	0.000	0.010		0.004	-0.001	0.009	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	-0.003	-0.006	0.000		-0.001	-0.004	0.002	
35-39	-0.001	-0.005	0.003		0.000	-0.003	0.004	
≥ 40	-0.001	-0.008	0.006		0.000	-0.008	0.007	
Mother's Marital Status	0.027	0.022	0.033		0.025	0.020	0.031	
Mother's Education								
Less than 12th grade	0.178	0.171	0.186		0.171	0.163	0.178	
HS Diploma/GED	0.096	0.091	0.100		0.090	0.085	0.095	
Some College	0.038	0.034	0.042		0.035	0.031	0.039	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.034	0.026	0.041		0.033	0.025	0.040	
Prior Adverse Outcome	0.009	-0.006	0.024		0.014	-0.002	0.030	

[a]: Model 1 – preterm only
[b]: Model 2 – deprivation only

(Table 6 continued)

	Model 3 [c]				Model 4 [d]			
	β	95%CI		AIC	β	95% CI		AIC
Intercept	-0.017	-0.024	-0.011	100901	-0.017	-0.023	-0.010	100880
Preterm	0.020	0.014	0.027		0.005	-0.002	0.011	
Deprivation								
Q1	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Q2	0.005	0.002	0.008		0.005	0.002	0.008	
Q3	0.010	0.006	0.014		0.008	0.004	0.012	
Q4	0.026	0.021	0.032		0.025	0.020	0.031	
Q5	0.028	0.021	0.034		0.025	0.019	0.032	
Preterm*Deprivation								
Q1					*ref*	*ref*	*ref*	
Q2					0.008	-0.005	0.022	
Q3					0.035	0.019	0.051	
Q4					0.025	0.007	0.042	
Q5					0.036	0.018	0.054	
Covariates								
Sex	0.045	0.042	0.049		0.046	0.042	0.049	
Child's Race								
White	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Black	0.044	0.039	0.049		0.044	0.039	0.049	
Hispanic	0.073	0.066	0.081		0.073	0.066	0.081	
Other	-0.006	-0.009	-0.004		-0.006	-0.009	-0.003	
Mother's Age								
≤ 17	-0.027	-0.040	-0.015		-0.028	-0.041	-0.015	
18-19	-0.010	-0.019	-0.001		-0.010	-0.019	-0.001	
20-24	0.004	-0.001	0.009		0.004	-0.001	0.009	
25-29	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
30-34	0.000	-0.003	0.002		-0.001	-0.004	0.002	
35-39	0.001	-0.002	0.004		0.001	-0.003	0.004	
≥ 40	-0.001	-0.008	0.007		0.000	-0.008	0.007	
Mother's Marital Status	0.025	0.020	0.031		0.025	0.019	0.031	
Mother's Education								
Less than 12th grade	0.170	0.162	0.178		0.170	0.162	0.177	
HS Diploma/GED	0.089	0.084	0.094		0.089	0.084	0.094	
Some College	0.034	0.030	0.038		0.035	0.031	0.039	
College Graduate	*ref*	*ref*	*ref*		*ref*	*ref*	*ref*	
Missing Father's Information	0.033	0.025	0.040		0.032	0.025	0.040	
Prior Adverse Outcome	0.009	-0.006	0.024		0.010	-0.005	0.025	

[c]: Model 3 – preterm and deprivation
[d]: Model 4 – preterm, deprivation, and cross-product of preterm and deprivation