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HIGH BIRTH WEIGHT AND COGNITIVE OUTCOMES

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ABSTRACT

While the effects of low birth weight have long been explored, those of high birth weight have been essentially ignored. Economists have analyzed the negative effects that low birth weight might have on subsequent school outcomes, while taking into account unobserved characteristics that may be common to families with low birth weight babies and negative outcomes in terms of school test scores when children, in addition to labor market income when adults. Today, however, with increasing obesity rates in the United States, high birth weight has become a potential concern, and has been associated in the medical literature with an increased likelihood of becoming an overweight child, adolescent, and subsequently an obese adult. Overweight and obesity, in turn, are associated with a host of negative effects, including lower test scores in school and lower labor market prospects when adults. If studies only focus on low birth weight, they may underestimate the effects of ensuring that mothers receive adequate support during pregnancy. In this study we find that cognitive outcomes are adversely affected not only by low birth weight (<2500 grams) but also by high birth weight (>4500 grams). Our results have policy implications in terms of provision of support for pregnant women.

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I. INTRODUCTION

While the effects of low birth weight have long been explored, those of high birth weight have been essentially ignored. Economists have analyzed the negative effects that low birth weight might have on subsequent school outcomes, while taking into account unobserved characteristics that may be common to families with low birth weight babies and negative outcomes in terms of school test scores when children, in addition to labor market income when adults. Today, however, with increasing obesity rates in the United States, high birth weight is of potential concern, and has been associated in the medical literature with an increased likelihood of becoming an overweight child, adolescent, and subsequently an obese adult. Overweight and obesity, in turn, are associated with a host of negative effects, including lower test scores in school and lower labor market prospects when adults. We analyze the effects that high birth weight may have on subsequent test scores for children and adolescents in order to fill this gap in the literature. We find that the relationship between birth weight and cognitive outcomes is quadratic in nature. While low birth weight is of primary concern, high birth weight should not be ignored and can also lead to adverse cognitive outcomes.

Two main national-level data sets are used in this paper. The first, the Child-Young Adult National Longitudinal Survey of Youth, is a comprehensive data set for the United States that follows individuals who were 14-22 years of age in 1979 until the present. Starting 1984, children of these individuals were included in the Child-Young Adult version of the data set. It is ideal because detailed demographic information on the mothers of the children, including data on weight, height, and education, is available. The second data set is the Early Childhood Longitudinal Survey (Kindergarten), another panel data set which follows the same students from kindergarten onwards. The survey began in the 1998-1999 school year and continues to the present. Both data sets are panel data sets and allow for the tracking of specific individuals over time.

II. LITERATURE REVIEW

There is an extensive literature on the effect of low birth weight (LBW) on a variety of adverse outcomes. Relatively little research has been conducted on the possible negative effects of high birth weight (HBW). For mothers, higher birth weight has been linked to gestational diabetes and maternal obesity or weight gain during pregnancy (Gunn Eide 2005). Inherited genes for obesity could explain the association between maternal obesity, high birth weight, and subsequent obesity in offspring, which may reflect a postnatal environment with unfavorable dietary and activity habits (Gunn Eide 2005). Others have found that a high, but not low, birth weight is a risk factor for increased emergency visits during childhood. The risk increases linearly beyond a birth weight of 4.5 kilograms (Don et al. 2004). Danielzik et al. (2004) find that parental overweight, a low socioeconomic status, and a high birth weight are the strongest independent risk factors of overweight and obesity in children.

Studies of the effect of birth weight on cognitive outcomes have generally focused on low birth weight. Kirkegaard et al. (2006), taking gestation into account, find that children with a birth weight of 2500 to 2999 grams had nearly twice the risk of reading difficulties than children with a birth weight of 3500 to 3999 grams. The association between birth weight and reading difficulties seemed to have a U-shaped pattern with a decreasing risk with increasing birth weight until 3500 grams and an increasing risk of having reading difficulties above this weight. They find no association between gestational age and arithmetic difficulties. Children with a birth weight of 2500 grams had four times the risk of arithmetic difficulties compared with children who weighed between 3500 and 3999 grams. As was the case with reading and spelling problems, the decreasing frequency of arithmetic difficulties was seen with increasing birth weight, although at 3500 grams, and subsequently at 3999 grams, the frequency of arithmetic difficulties again increased.

Using data from Danish conscripts born between 1973 and 1975, Sorensen et al. (1997) find the score from the "Boerge Prien" test, taken around age 20, increases from a birth weight of 1900 grams to one of 4200 grams. There is a slight decrease after a birth weight of 4200 grams, again pointing to the nonlinear relationship between birth weight and test scores. Richards et al. (2001) explore cognitive function at ages 8, 11, 15, 26, and 43 years. They find that birth weight is significantly associated with cognitive function at age 8 years, with cognitive scores increasing across the four lowest birth weight categories, and then declining at the highest birth weight category. These studies indicate that birth weight may be nonlinear in cognitive outcomes, and that perhaps there needs to be more attention paid to high birth weight in addition to low birth weight.

III. DATA – NLSY

The 1979 cohort of the National Longitudinal Survey of Youth (NLSY79) is a nationally representative sample of 12,686 young men and women who were 14-22 years old when they were first surveyed in 1979. These individuals were interviewed annually through 1994 and are currently interviewed on a biennial basis. In 1986, a separate survey of all children born to NLSY79 female respondents began (the Child-Young Adult National Longitudinal Survey, or the NLS-CYA), with survey questions on assessment as well as additional demographic and development information collected from either the mother or child. For children aged ten and older, information has been collected from the children biennially since 1988 on a variety of factors including child-parent interaction, attitudes toward schooling, dating and friendship patterns, religious attendance, health, substance use, and home responsibilities. Out of 6,283 females in the NLSY79, 5,418 were interviewed in 1986, of which 2,922 were mothers. These mothers had 5,255 in 1986, 4,971 of which were interviewed. In 2002, 7,467 children or young adults were interviewed. A detailed description of the data is provided at the NLS website at http://www.bls.gov/nls. Summary statistics are presented in Table 1.

Dependent Variables

Assessment data include responses to questions on test scores related to the Peabody Picture Vocabulary Test (PPVT) for those aged three and older, and the Peabody Individual Achievement Test (PIAT) for those aged five and older, which includes assessments on math, reading comprehension, and reading recognition. The PPVT measures the child's hearing vocabulary of Standard American English. The PIAT assessments measure ability in mathematics and oral reading and the ability to derive meaning from printed words. The standardized scores for these tests were used in our analysis, with a mean for the whole NLS sample of approximately 100.

Explanatory Variables

Birth weight, and particularly HBW, defined as a baby born weighing more than 4500 grams, is the variable of interest in this paper. Information on characteristics of both the child and mother are included as additional explanatory variables. Mean birth weight in the NLS sample is 3366 grams (Table 1). About two percent of children in the NLS-CYA are born with a HBW while the prevalence of LBW, defined as having a birth weight of less than 2500 grams, is approximately seven percent.

Control variables include family income, race/ethnic background, age, gender, height, weight, number of siblings, mother's body mass index (BMI) at the time the child was delivered, mother's age at time of birth of child, mother's education, mother's age, whether the child was breastfed, gender, birth order,[1] and region of residence. Since extensive information on the mother is given and since there are many siblings in the NLS-CYA, we cluster regressions by mother's ID to account for unobservable characteristics common to siblings and to the same individuals over time. In addition to these controls, we exploit the information available on the mother during pregnancy and include the following variables as excluded instruments in our instrumental variables models: whether the mother used prenatal care, gestation, how much weight the mother gained during pregnancy, whether the mother was a teenager at the time the child was born, and whether the mother was over 30 years of age at the time the child was born.[2]

IV. DATA – ECLS-K

The Early Childhood Longitudinal Study Kindergarten Cohort (ECLS-K), designed and collected by the US Department of Education, is a nationally representative data set with more than 20,000 children from about 1,000 different schools, starting kindergarten in 1998. At the time this was written, a total of six rounds of data collection have been conducted, held in the fall of and spring of kindergarten, fall and spring of first grade, spring of third grade, and spring of fifth grade. The full sample was interviewed in all rounds except the fall of first grade.[3] ECLS-K data provide a wide range of information on student backgrounds, allowing us to have a rich set of control variables for the analysis. The data contain a substantial amount of information on demographic characteristics and parental background. A detailed description of the data is provided at the ECLS website http://nces.ed.gov/ecls.

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[1] First-borns may have an educational advantage over their siblings (Kantarevic and Mechoulan 2006).
[2] Occupational stress has been found to affect birth weight (Chen et al. 2000) and type of occupation may affect cognitive outcomes. We therefore also ran regressions including controls for mother's Census industry of occupation as explanatory variables. The qualitative nature of our results does not change. Results are available upon request.
[3] Only a 30 percent subsample interviewed in the fall of first grade.

Due to the nature of the data, based on repeated observations of the same group of people over time, attrition between the rounds is unavoidable. Attrition is mainly due to children who move between rounds. Only about 50 percent of the children who move are followed by ECLS. Additionally, minority groups are oversampled to meet the study's precision goals. ECLS created both longitudinal and cross sectional weights for each round to make it possible to conduct analysis based on nationally representative data.

We restrict our sample to students who are eligible in the fifth grade. By restricting the sample to the students who are eligible in the fifth grade, we are better able to follow the changes and patterns over time. We can particularly observe whether the magnitudes of the coefficients with respect to birth weight change over time. Hence our sample size is reduced to 11,813 students who are eligible in the fifth grade. Summary statistics are presented in Table 2.

Dependent Variables

Reading and math standardized test scores are the outcome variables of interest with respect to academic achievement of the children. Calculations of reading and math tests are based on Item Response Theory (IRT), using the patterns of correct and incorrect answers to obtain estimates that are comparable across different assessment forms.[4] Test scores are calculated based on a full set of assessment items in reading and math. Even though the assessments undertaken are not identical in different times, IRT scoring enables tracking the longitudinal trends in children's learning. The reading test is based on the evaluation of the following skills: letter recognition, beginning and ending sounds, sight words, comprehension of

[4] Children were tested in two steps. In the first step they were asked common questions. Based on their performance in the first step, second step questions were selected. Students ended up answering to different questions based on their performance in the first step. In order to make the results comparable to each other, the scores were calculated using Item Response Theory (IRT), using patterns of right, wrong, and missing answers in addition to the difficulty of questions to calculate children's score on a continuous ability scale. The computed IRT score is an estimate of the number of questions the child would have correctly answered if he was asked all available questions.

words in context, extrapolation, evaluation, and evaluating non-fiction. The math test is based on the evaluation of the following skills: number and shape, relative size, ordinality and sequence, addition and subtraction, division and multiplication, place value, rate and measurement, fractions, area, and volume. The mathematics IRT average test score increased from about 33 in spring semester of kindergarten to about 113 in the spring semester of fifth grade. The reading IRT average test score likewise increased from 41 to 139 in the mentioned period.

ECLS-K data includes standardized math and reading t-scores which are normalized to have an average of 50 and a standard deviation of 10. Standardized t-scores measure children's success relative to that of others. We prefer to use standardized t-scores to facilitate comparisons over time.

Explanatory Variables

Mean birth weight in the ECLS sample is 3355 grams (Table 2). Similarly to the NLS, about two percent of children in the ECLS-K sample are born with HBW while the prevalence of LBW is approximately seven percent.

Child and family background and neighborhood characteristics are included as additional explanatory variables. In our specifications, a large set of control variables, many of which are commonly used in the literature, are included in regressions. While information on dependent variables is collected in each round, most information with respect to explanatory variables are collected with less frequency. In addition to the time-invariant nature of some variables such as birth weight and racial/ethnic category of the child, information on family and neighborhood characteristics collected at most once in a school year since variation in these variables, such as parents' socioeconomic status, within a year is very unlikely. Child-level background variables are child's age in years, race and gender. Average child age is 6.23 years in the spring of kindergarten and 11.20 five years later in the spring of fifth grade. Family-level background variables are the composite socioeconomic status (SES) of child's family, mother's age at time of her first birth, mother's WIC participation status during the pregnancy,[5] number of children's books in the home, and the number of siblings at home. The SES measure, which reflects the socioeconomic status of the child's family, is computed by ECLS at the household level for those parents who finished the parent interview in the related school year. Father's or male guardian's education, mother's or female guardian's education, father of male guardian's occupation, mother or female guardian's occupation, and household income are the components used in the creation of SES composite measure. SES is available in both categorical and continuous composite form. The categorical SES measure is calculated on a scale of 1 to 5. Average categorical SES measure is close to 3.20 and does not change much over time. Neighborhood-level background variables are regional dummies and urban area size dummies.

Similarly to the NLS-CYA, one of the important characteristics of ECLS-K data is that variation over time is very limited for explanatory variables. Hence, even though we have data for the same individuals over time, because of the lack of variation in the explanatory variables, the use of fixed effects estimation techniques is limited. Furthermore, even if there were variation in the explanatory variables, because birth weight is a fixed variable, fixed effects panel data estimation techniques are not feasible to employ for our analysis.

[5] Women, Infants and Children (WIC) is a program providing Federal grants to States for supplemental foods, health care referrals, and nutrition education for low-income pregnant, breastfeeding, and non-breastfeeding postpartum women, and to infants and children up to age five who are found to be at nutritional risk.

V. EMPIRICAL IMPLEMENTATION

For both data sets, our dependent variables of interest are cognitive outcomes. To investigate the effect that birth weight has on various measures of cognitive outcomes, the following equation is estimated:

$$CognitiveOutcome = \alpha_0 + \alpha_1 BirthWeight + \alpha_2 BirthWeight^2 + \overline{\alpha_3} X + \overline{\alpha_4}(region) + \varepsilon \quad (1)$$

where *CognitiveOutcome* represents one of the following: PPVT score, math score, or reading score; *X* includes personal, parental, and demographic characteristics; *region* represents indicators for Census region of residence; and ε is an error term. A quadratic term for birth weight is included to account for the likelihood that an additional unit at higher levels will have less of an effect on the dependent variable as that of an additional unit at lower levels. Our hypothesis is that at a birth weight of approximately 4500 grams, cognitive outcomes may start to decrease with increasing birth weight. Sampling weights are not employed in regressions as exogenous stratification obviates the need for them (DuMouchel and Duncan 1983; Maddala 1983), yet the qualitative nature of the results does not change when weights are employed.

A potential concern with estimating equation (1) is that unobserved characteristics common to both birth weight and cognitive outcomes are not controlled for; in particular, birth weight may be strongly correlated with the error term ε. In order to address this, we use an instrumental variables approach and exploit information on the mother's behavior during pregnancy with the child in the NLSY-CYA. Gestational age has rarely been considered in previous studies. (Thus, the effect of intrauterine growth retardation cannot be disentangled from that of preterm delivery.) We consider gestation in our IV regressions, in addition to information on prenatal care,[6] mother's weight gain during pregnancy[7] and mother's age at the time the child was born.

There are two common sources of endogeneity undermining the credibility of ordinary least squares (OLS) estimates. The first one is reverse causality, or structural endogeneity, which is not relevant to the nature of our analysis since it is not possible for test scores of an individual to determine his or her birth weight (BW). The second is omitted variables bias that arises due to unobserved heterogeneity, or statistical endogeneity. That is, when a third unobservable factor related to someone's personal characteristics such as SES but not included in the estimations, determines both the variable of interest and the dependent variable, OLS may lead to biased estimates. In our case, if personal characteristics are affecting a child's BW as well as test outcomes, then our results would be biased. The literature examining the impact of LBW on various outcomes stresses that LBW is correlated with low SES. Hence, studies which do not control for the endogeneity of LBW may lead to biased estimates.

Aside from IV approaches, one method used in dealing with endogeneity with respect to the impact of LBW is to use a monogenic twin sample. Since it is assumed that monogenic twins share identical background characteristics, the difference in their BW, caused by their random positioning in the womb, determines their access to nutrition during gestation. The lucky twin has a better position in the womb and receives better nutrition and therefore is born with a higher BW. Hence, if an estimate of twin fixed effects of the difference in BW is statistically significant with a positive sign, then this shows that LBW babies are disadvantaged in

[6] There is evidence that selection bias in estimating the effect of prenatal care on birth weight does not operate in the expected direction; i.e., OLS underestimates the effects of prenatal care and there is evidence of adverse selection in this context (Joyce 1994).

[7] Weight gain during pregnancy has been found to be associated with complications during pregnancy (Kiel et al. 2007) and may lead to gestational diabetes, which increases the probability of high birth weight.

comparison to HBW babies. Another way to deal with this particular problem is to undertake a sibling fixed methodology, which makes similar assumptions for the siblings.

Certain limitations make it difficult to utilize such methodologies for our study using the ECLS-K, which has limited information on mothers compared to the NLS-CYA. A twin sample is particularly uninteresting for our purposes since twins on average are born with a lower BW than non-twins. Therefore, the prevalence of HBW among twins is very low. Similar problems arise when we consider a sibling fixed effects methodology. The prevalence of HBW is low and a sibling sample is quite small in the NLS-CYA; moreover, it is difficult using the ECLS-K in obtaining a sibling sample.[8] The resulting limited sample size would not offer enough variation to undertake such analyses.

If the factors determining HBW are the same as the factors determining LBW, which is strongly correlated with low SES status, then OLS estimates with respect to the impact of HBW will be biased. However, if HBW is determined by other factors and somewhat free from SES, then OLS estimates may be reliable. Our instruments reflect determinants of LBW, but even using IV approaches, Hausman endogeneity tests indicate that OLS estimates are consistent for the most part. Appendix B shows the relationship between categorical SES, and HBW and LBW status. For LBW as SES category increases, the prevalence of LBW decreases. For HBW the relationship is unclear. Prevalence of HBW oscillates as SES category changes. Using categories of education for the NLS-CYA sample, we see a similar pattern emerge: a steadily declining percentage of those with LBW as education category increases but an unclear relationship for HBW. Thus, HBW does not seem to be correlated with SES. This suggests that

[8] ECLS-K consists of a cohort of students followed over time. Unless there are a few grade repeating students, the only way for any two students to have the same mother is to have a twin sibling. Therefore, a sibling fixed methodology is impossible to undertake using ECLS-K data.

the source of endogeneity for LBW may not be as major a concern for HBW as the independent variable.

These findings have two important implications. First, for our purposes, relying on OLS estimates may not be a bad strategy since the presence of HBW appears to be free of classical sources of endogeneity. Second, an endeavor to uncover the determinants of HBW would produce a meaningful contribution to the literature.

VI. RESULTS

Table 3 presents OLS results for the NLS-CYA. For all outcomes, positive and significant effects can be found associated with increasing birth weight at 2500 grams. While lower in magnitude, these positive effects continue at the mean birth weight. Once we evaluate the effect at a birth weight of 4500 grams, however, the effect becomes negative and significant for all outcomes. In particular, an increase in birth weight at 4500 grams of 100 grams decreases the average Piat math score by 0.0337 (column 2) and the average Piat reading recognition score by 0.0388 (column 4). Breastfeeding and being a firstborn are associated with positive cognitive outcomes, while being other than white, having a single or divorced mother, having many siblings at home, and having a mother with a high BMI are associated with adverse cognitive outcomes.

Results for instrumental variables regressions are reported in Table 4. These results are qualitatively similar for the most part to the OLS ones, yet slightly higher magnitudes are found at the 4500 gram threshold, and mixed results are seen at mean birth weight. In particular, an increase in birth weight at 4500 grams of 100 grams decreases the average Piat math score by 0.682 (column 2) and the average Piat reading recognition score by 1.395 (column 4). Overidentification tests suggest that instruments pass the standard test for exclusion restrictions.

Endogeneity tests suggest that OLS results are consistent for these two variables. Moreover, the underlying distribution of actual and predicted birth weight appears to be very similar: Average birth weight is 3290 grams, while average predicted birth weight is 3283 grams. At the 20th percentile of the distribution, actual birth weight is 2863 grams while predicted birth weight is 3055 grams; at the 80th percentile, actual birth weight is 3770 grams while predicted birth weight is 3545 grams. First-stage results can be seen in Appendix A.

Table 5 presents results for the ECLS-K where the math test t-score is the outcome variable. Similarly to the NLS, positive and significant effects can be found associated with increasing birth weight at 2500 grams. Again, while lower in magnitude, these positive effects continue at the mean birth weight. Once we evaluate the effect at a birth weight of 4500 grams, however, the effect again becomes negative and significant. In particular, an increase in birth weight at 4500 grams of 100 grams decreases the average IRT math t-score by 0.0182 (kindergarten) to 0.0633 (1st grade). A higher SES, having more books at home, and expecting to go far in education are associated with positive math t-scores, while being other than white or Asian, being female, having many siblings at home, and having a mother who received WIC are associated with adverse math t-scores.

Table 6 presents results for the ECLS-K where the reading test t-score is the outcome variable. Similar results emerge for birth weight. We find that an increase in birth weight at 4500 grams of 100 grams decreases the average IRT reading t-score by 0.0286 (1st grade) to 0.0731 (3rd grade). A higher SES, having more books at home, and expecting to go far in education are associated with positive reading t-scores, while being other than white or Asian, being male, having many siblings at home, and having a mother who received WIC are associated with adverse reading t-scores.

VII. DISCUSSION

Taking the potential endogenous nature of birth weight into account, our study provides some new evidence on the relationship between high birth weight and cognitive outcomes. Using two different data sets, the children of the 1979 cohort of the National Longitudinal Survey of Youth (NLSY-CYA) and the kindergarten cohort of the Early Childhood Longitudinal Study (ECLS-K), we find that while not as pressing a need as low birth weight, high birth weight should not be ignored when determining the effect of birth weight on subsequent outcomes.[9] In particular, we find that if birth weight were increased by a standard deviation from the mean (approximately 500 grams) at a birth weight of 4500 grams, math scores would decrease by 0.168 (NLS-CYA) and 0.135 (ECLS-K, pooled sample) and reading scores would decrease by 0.194 (NLS-CYA) and 0.255 (ECLS-K, pooled sample). Policies aimed at reducing low birth weight prevalence may also reduce high birth weight prevalence if they encourage mothers to seek proper care and nutrition during pregnancy, and thus the current benefits of these policies may be underestimated.

[9] HBW prevalence is still lower than LBW prevalence, at two percent versus seven percent in our samples. Appendix C reveals that HBW is more of a concern for males and for races other than African-Americans.

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Table 1: NLS-CYA DESCRIPTIVE STATISTICS

Variable	Obs	Mean	Std.
Peabody Vocabulary	14398	95.56	18.17
Math	22316	102.27	13.51
Reading Comprehension	18658	102.89	13.63
Reading Recognition	22207	105.42	14.48
Birth Weight in Grams	35672	3366.35	597.88
Child Breastfed	35672	0.53	0.50
Female	35672	0.48	0.50
Child's Age	35672	7.49	4.11
Less than High School	35672	0.13	0.33
High School	35672	0.47	0.50
Some College	35672	0.23	0.42
Graduate Degree	35672	0.17	0.38
White	35672	0.78	0.41
Non-Hispanic black	35672	0.15	0.36
Hispanic	35672	0.07	0.26
Single	35672	0.09	0.28
Divorced	35672	0.18	0.39
Mother's Age	35672	32.85	4.86
Family Income	35672	54.58	88.96
Birth Order	35672	1.83	0.99
Child's Height in Feet	35672	3.94	1.88
Child's Weight in Pounds	35672	31.20	39.66
Data N/A: Child Height	35672	0.04	0.19
Data N/A: Child Weight	35672	0.46	0.50
Number of Children	35672	2.41	1.11

Note: NLS sample person weights are used in calculating the mean and standard deviation. Education and marital status pertain to the mother.

Table 2: ECLS-K BASELINE DESCRIPTIVE STATISTICS (SPRING K)

Variable	Obs	Mean	St.
Birth Weight	11813	3355.14	580.30
Mother's Age at B.	11813	24.49	5.03
Premature for 2	11813	0.16	0.37
WIC when Pregnant	11813	0.35	0.48
Data N/A: WIC	11813	0.02	0.14
Teen mother at 1st bir.	11813	0.18	0.38
Mother over 30 at 1st	11813	0.11	0.31
Data N/A: Age at 1st	11813	0.13	0.34
White	11813	0.57	0.50
Black	11813	0.11	0.32
Hispanic	11813	0.19	0.39
Asian	11813	0.07	0.25
Other Race	11813	0.06	0.23
Female	11813	49.34%	0.50
Math IRT t-score	11363	51.26	9.77
Reading IRT t-score	10896	51.17	9.69
Categorical SES	11338	3.14	1.41
Continuous SES	11813	0.04	0.78
Data N/A SES	11813	0.04	0.20
Children's Book*10	11813	75.59	55.73
Data N/A: Child Book	11813	0.14	0.35
# of Siblings	11813	1.49	1.13
Data N/A: # of	11813	0.00	0.00
Expected Degree	11813	4.12	1.01
Data N/A: Exp.	11813	0.14	0.35
Child's Age	11813	6.23	0.36
Data N/A: Child's	11813	0.02	0.15
Child's Height	11813	45.95	2.27
Data N/A: Child's	11813	0.04	0.18
Child's Weight	11813	49.69	9.88
Data N/A: Child's	11813	0.03	0.16

Table 3: Effect of Birth Weight on Cognitive Outcomes, OLS, NLS-CYA

	(1) PPVT	(2) Math	(3) Reading Comprehension	(4) Reading Recognition
Birth weight in grams	0.4004**	0.4648***	0.4502***	0.5394***
	[0.1625]	[0.1142]	[0.1063]	[0.1090]
Birth weight in grams squared	-0.0049*	-0.0055***	-0.0056***	-0.0064***
	[0.0025]	[0.0018]	[0.0016]	[0.0017]
Breastfed	2.5191***	1.5544***	1.6652***	1.4467***
	[0.4649]	[0.3295]	[0.3360]	[0.3801]
Female child	0.4526	-0.2038	1.3844***	2.5523***
	[0.3463]	[0.2572]	[0.2587]	[0.2957]
Age of child	2.3004***	1.6827***	-4.6496***	-1.3275***
	[0.1978]	[0.2204]	[0.2976]	[0.2471]
Age of child squared	-0.1079***	-0.0976***	0.1441***	0.0345***
	[0.0112]	[0.0108]	[0.0140]	[0.0124]
Less than high school-mother	-3.3985	-5.3292***	-3.4816	-3.1355
	[6.6788]	[1.6356]	[2.2473]	[3.7653]
High school-mother	2.0618	-2.3493	-0.0763	0.4495
	[6.6670]	[1.6175]	[2.2292]	[3.7594]
Some college-mother	5.2882	0.0488	2.4914	3.5639
	[6.6873]	[1.6438]	[2.2404]	[3.7738]
College plus-mother	8.9437	3.0151*	4.7167**	5.7794
	[6.7025]	[1.7012]	[2.2876]	[3.8029]
Non-Hispanic black	-12.5102***	-5.3817***	-3.8617***	-3.0102***
	[0.5890]	[0.4340]	[0.4410]	[0.5014]
Hispanic	-9.7556***	-4.1927***	-1.7495***	-1.6724***
	[0.6915]	[0.4616]	[0.4646]	[0.5402]
Single	-3.3718***	-1.2770***	-2.2558***	-2.0312***
	[0.6537]	[0.4745]	[0.4689]	[0.5637]
Divorced	-1.3999***	-0.4449	-0.8629**	-0.6570
	[0.5130]	[0.3537]	[0.3642]	[0.4136]
Age of mother	-0.1791	-0.4781	-1.0915***	-0.9489***
	[0.3978]	[0.2980]	[0.3240]	[0.3235]
Age of mother squared	0.0047	0.0102**	0.0172***	0.0175***
	[0.0061]	[0.0043]	[0.0047]	[0.0047]
Real family income	0.0434***	0.0369***	0.0239***	0.0317***
	[0.0081]	[0.0052]	[0.0049]	[0.0057]
Real family income squared	-0.0000***	-0.0000***	-0.0000***	-0.0000***
	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Birth order	-1.5704***	-0.7225***	-1.2469***	-1.3027***
	[0.2323]	[0.1693]	[0.1762]	[0.1977]
Child Height in Feet	-0.0281	0.0223	0.0418	0.0850

	[0.0714]	[0.0757]	[0.0727]	[0.0698]
Child Weight in Pounds	0.0102	0.0069	0.0086	0.0064
	[0.0084]	[0.0051]	[0.0055]	[0.0059]
Number of Children	-1.6636***	-0.5695***	-0.6274***	-0.7791***
	[0.2304]	[0.1514]	[0.1524]	[0.1767]
Mother's delivery BMI	-0.1937***	-0.1438***	-0.1413***	-0.1848***
	[0.0509]	[0.0356]	[0.0376]	[0.0417]
Observations	13,655	21,197	17,714	21,088
F test p-value	0.00367	7.94e-08	2.47e-06	2.13e-09
Value at BW=4500	-0.0392	-0.0337	-0.0551	-0.0388
Value at mean BW	0.07134	0.09164	0.07191	0.10657
Value at BW=2500	0.156	0.188	0.169	0.218
R-squared	0.318	0.194	0.257	0.177

Note: Dependent variables pertain to standardized scores for the Peabody Picture Vocabulary Test (PPVT), the Piat math test, the Piat reading comprehension test, and the Piat reading recognition test. Robust standard errors are shown in brackets. Controls for Census region and missing information on child's height and weight are included in all regressions. F-test p-value refers to the joint significance of birth weight and birth weight squared. Regressions are clustered by mother's ID. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table 4: Effect of Birth Weight on Cognitive Outcomes, IV, NLS-CYA

	(1) PPVT	(2) Math	(3) Reading Comprehension	(4) Reading Recognition
Birth weight in grams	0.7104	1.5864*	2.1570**	2.8719**
	[1.3319]	[0.9625]	[1.0414]	[1.1824]
Birth weight in grams squared	-0.0095	-0.0252	-0.0366**	-0.0474**
	[0.0232]	[0.0168]	[0.0181]	[0.0206]
Breastfed	2.3850***	1.5037***	1.6871***	1.4007***
	[0.4701]	[0.3366]	[0.3501]	[0.3991]
Age of child	2.3285***	1.6881***	-4.5855***	-1.2896***
	[0.1995]	[0.2258]	[0.3029]	[0.2521]
Age of child squared	-0.1086***	-0.0992***	0.1387***	0.0299**
	[0.0115]	[0.0111]	[0.0143]	[0.0127]
Less than high school-mother	-3.5222	-4.6841***	-2.9570	-2.7031
	[7.4749]	[1.7532]	[2.3597]	[4.4294]
High school-mother	1.7852	-1.7497	0.4520	0.9224
	[7.4617]	[1.7342]	[2.3417]	[4.4258]
Some college-mother	5.0697	0.7613	3.1635	4.1962
	[7.4805]	[1.7583]	[2.3517]	[4.4377]
College plus-mother	8.6839	3.6408**	5.3028**	6.2518
	[7.4912]	[1.8144]	[2.4024]	[4.4677]
Non-Hispanic black	-12.4951***	-5.7471***	-4.5684***	-3.7385***
	[0.7337]	[0.5438]	[0.5575]	[0.6348]
Hispanic	-9.7986***	-4.3925***	-2.1075***	-2.1311***
	[0.7395]	[0.4957]	[0.4980]	[0.5763]
Single	-3.4372***	-1.3886***	-2.4433***	-2.3330***
	[0.6542]	[0.4841]	[0.4849]	[0.5886]
Divorced	-1.3936***	-0.5073	-0.9919***	-0.8944**
	[0.5183]	[0.3622]	[0.3787]	[0.4391]
Age of mother	-0.2890	-0.5773*	-1.1292***	-1.0407***
	[0.3951]	[0.2996]	[0.3335]	[0.3344]
Age of mother squared	0.0064	0.0117***	0.0178***	0.0190***
	[0.0061]	[0.0044]	[0.0048]	[0.0049]
Real family income	0.0438***	0.0373***	0.0249***	0.0315***
	[0.0082]	[0.0052]	[0.0051]	[0.0059]
Real family income squared	-0.0000***	-0.0000***	-0.0000***	-0.0000***
	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Birth order	-1.5598***	-0.6095***	-1.0683***	-1.0838***
	[0.2633]	[0.1990]	[0.2108]	[0.2385]
Child Height in Inches	-0.0332	0.0361	0.0759	0.1171
	[0.0711]	[0.0832]	[0.0880]	[0.0835]

Child Weight in Pounds	0.0088	0.0099*	0.0148**	0.0131*
	[0.0091]	[0.0058]	[0.0062]	[0.0068]
Number of Children	-1.6712***	-0.5337***	-0.5567***	-0.7060***
	[0.2328]	[0.1555]	[0.1603]	[0.1848]
Mother's delivery BMI	-0.1950***	-0.1147***	-0.0871**	-0.1268***
	[0.0566]	[0.0396]	[0.0440]	[0.0485]
Observations	13482	20956	17528	20848
F test p-value	0.0340	0.00370	0.0679	0.00189
Value at BW=4500	-0.148	-0.682	-1.134	-1.395
Value at mean BW	0.06768	-0.11178	-0.30682	-0.32193
Value at BW=2500	0.233	0.326	0.329	0.502
Endogeneity chi-square	1.077	1.451	6.329	4.367
Endogeneity p-value	0.584	0.484	0.0422	0.113
Over-identification chi-square	2.874	0.749	1.106	0.403
Over-identification p-value	0.412	0.862	0.776	0.940
R-squared	0.317	0.179	0.220	0.124

Note: Dependent variables pertain to standardized scores for the Peabody Picture Vocabulary Test (PPVT), the Piat math test, the Piat reading comprehension test, and the Piat reading recognition test. Robust standard errors are shown in brackets. Controls for Census region and missing information on child's height and weight are included in all regressions. F-test p-value refers to the joint significance of birth weight and birth weight squared. Regressions are clustered by mother's ID. Excluded instruments used pertain to prenatal care, gestation, mother's age at pregnancy, and BMI increase during pregnancy. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table 5: Effect of Birth Weight on Math Outcomes, ECLS-K

	(1) Spring K	(2) Spring 1st	(3) Spring 3rd	(4) Spring 5th	(5) Pooled
Birth Weight	0.3412***	0.4083***	0.4103***	0.3545***	0.4101***
	[0.0751]	[0.0755]	[0.0757]	[0.0738]	[0.0668]
Birth Weight Squared	-0.0040***	-0.0052***	-0.0052***	-0.0042***	-0.0049***
	[0.0012]	[0.0012]	[0.0012]	[0.0011]	[0.0010]
Family SES	2.5597***	2.5013***	2.7683***	2.8385***	1.3230***
	[0.1257]	[0.1276]	[0.1300]	[0.1254]	[0.0700]
Mother Received WIC	-1.7592***	-1.4399***	-1.8905***	-1.6394***	-2.9285***
	[0.1952]	[0.1976]	[0.1981]	[0.1937]	[0.1675]
Mother was a Teenager	-0.7541***	-0.8418***	-0.9752***	-1.0075***	-1.6401***
	[0.2246]	[0.2264]	[0.2269]	[0.2217]	[0.1974]
Mother was above 30	0.6959***	0.6177**	0.6949***	1.0228***	1.6457***
	[0.2576]	[0.2599]	[0.2621]	[0.2562]	[0.2285]
# of Children's Books	0.6573***	0.0526***	0.0418***	0.0377***	0.0194***
	[0.0565]	[0.0085]	[0.0079]	[0.0075]	[0.0033]
# Children's Books Squared	-0.0227***	-0.0001***	-0.0002***	-0.0001***	-0.0000***
	[0.0025]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Number of Siblings	-0.4268***	-0.2394***	-0.2392***	-0.2306***	-0.0902**
	[0.0709]	[0.0714]	[0.0738]	[0.0699]	[0.0411]
Highest Expected Degree	0.6582***	0.8722***	1.3524***	1.7412***	0.3608***
	[0.0801]	[0.0796]	[0.0852]	[0.0820]	[0.0303]
Child's Age in Years	55.9266***	73.5418***	56.6366***	34.4220***	11.9269***
	[4.9385]	[7.7251]	[9.7015]	[3.8228]	[0.3179]
Child's Age Squared	-4.0085***	-4.8017***	-2.9371***	-1.4917***	-0.4945***
	[0.3915]	[0.5319]	[0.5236]	[0.1681]	[0.0138]
Child's Height in Inches	0.2599***	0.3119***	0.3188***	0.2787***	0.0929***
	[0.0489]	[0.0450]	[0.0408]	[0.0344]	[0.0204]
Child's Weight in Pounds	-0.0213**	-0.0348***	-0.0218***	-0.0191***	-0.0109***
	[0.0106]	[0.0080]	[0.0052]	[0.0036]	[0.0023]
Race: Black	-2.9714***	-4.2231***	-5.2980***	-5.5256***	-5.0049***
	[0.2852]	[0.2829]	[0.2830]	[0.2765]	[0.2434]
Race: Hispanic	-2.6903***	-2.3059***	-2.4971***	-2.1129***	-3.1692***
	[0.2515]	[0.2458]	[0.2459]	[0.2387]	[0.2070]
Race: Asian	1.8640***	0.1615	1.0109***	1.5498***	0.7191**
	[0.3548]	[0.3395]	[0.3370]	[0.3269]	[0.2902]
Race: Other	-1.7022***	-2.4139***	-2.6236***	-2.0477***	-2.5487***
	[0.3510]	[0.3533]	[0.3555]	[0.3480]	[0.3101]
Female	-0.1743	-0.5054***	-1.6698***	-2.3360***	-1.0492***
	[0.1549]	[0.1562]	[0.1566]	[0.1541]	[0.1374]
Observations	11,363	11,364	11,306	11,269	45,302
F test p-value	0.000	0.000	0.000	0.000	0.000

Value at BW=4500	-0.0182	-0.0633	-0.0566	-0.0205	-0.0269
Value at mean BW	0.07321	0.05671	0.06221	0.07488	0.08427
Value at BW=2500	0.142	0.146	0.151	0.146	0.167
R-squared	0.309	0.250	0.291	0.315	0.292
Number of children					11769

Note: Dependent variable pertains to standardized t-scores for the IRT math test. Robust standard errors are shown in brackets. Controls for Census region, urban area size, and missing information on child's birth weight are included in all regressions. F-test p-value refers to the joint significance of birth weight and birth weight squared. Pooled regressions are clustered by ID. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table 6: Effect of Birth Weight on Reading Outcomes, ECLS-K

	(1) Spring K	(2) Spring 1st	(3) Spring 3rd	(4) Spring 5th	(5) Pooled
Birth Weight	0.3675***	0.2933***	0.3042***	0.2117***	0.3229***
	[0.0795]	[0.0773]	[0.0752]	[0.0735]	[0.0657]
Birth Weight Squared	-0.0045***	-0.0036***	-0.0042***	-0.0028**	-0.0042***
	[0.0012]	[0.0012]	[0.0012]	[0.0011]	[0.0010]
Family SES	2.6614***	2.6253***	3.1087***	3.1416***	1.6432***
	[0.1331]	[0.1301]	[0.1284]	[0.1248]	[0.0748]
Mother Received WIC	-1.5976***	-1.7332***	-1.7835***	-1.5544***	-2.8646***
	[0.2088]	[0.2021]	[0.1962]	[0.1928]	[0.1656]
Mother was a Teenager	-0.9526***	-0.9844***	-1.1579***	-1.2144***	-1.7853***
	[0.2414]	[0.2317]	[0.2251]	[0.2207]	[0.1946]
Mother was above 30	1.0942***	0.4674*	1.0202***	1.3049***	1.8364***
	[0.2690]	[0.2626]	[0.2590]	[0.2551]	[0.2246]
# of Children's Books	0.6221***	0.0493***	0.0521***	0.0535***	0.0272***
	[0.0604]	[0.0086]	[0.0073]	[0.0074]	[0.0036]
# Children's Books Squared	-0.0227***	-0.0001***	-0.0002***	-0.0001***	-0.0001***
	[0.0026]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Number of Siblings	-0.8820***	-0.6328***	-0.6746***	-0.6168***	-0.3744***
	[0.0759]	[0.0729]	[0.0734]	[0.0696]	[0.0440]
Highest Expected Degree	0.6892***	0.9810***	1.3622***	1.6845***	0.4742***
	[0.0858]	[0.0816]	[0.0845]	[0.0817]	[0.0338]
Child's Age in Years	43.8613***	55.2200***	42.6511***	29.0934***	7.0011***
	[5.2262]	[7.8550]	[9.6243]	[3.8247]	[0.3450]
Child's Age Squared	-3.1612***	-3.6062***	-2.1995***	-1.2564***	-0.2756***
	[0.4141]	[0.5408]	[0.5194]	[0.1682]	[0.0153]
Child's Height in Inches	0.2267***	0.2158***	0.2213***	0.2617***	0.1346***
	[0.0519]	[0.0458]	[0.0404]	[0.0342]	[0.0220]
Child's Weight in Pounds	-0.0407***	-0.0280***	-0.0110**	-0.0118***	-0.0055**
	[0.0112]	[0.0081]	[0.0051]	[0.0035]	[0.0025]
Race: Black	-0.8724***	-1.9677***	-3.8750***	-4.4266***	-3.3221***
	[0.2980]	[0.2857]	[0.2809]	[0.2751]	[0.2396]
Race: Hispanic	-0.9252***	-1.7616***	-2.8705***	-2.7601***	-3.0708***
	[0.2705]	[0.2525]	[0.2434]	[0.2376]	[0.2049]
Race: Asian	3.0186***	1.7481***	-0.3177	-0.9344***	0.4116
	[0.3697]	[0.3427]	[0.3328]	[0.3252]	[0.2854]
Race: Other	-0.7927**	-1.5690***	-2.6153***	-2.4805***	-2.2747***
	[0.3652]	[0.3561]	[0.3553]	[0.3464]	[0.3046]
Female	1.9803***	1.8414***	1.5395***	0.8965***	1.6783***
	[0.1641]	[0.1589]	[0.1551]	[0.1533]	[0.1351]

Observations	10896	11134	11243	11260	44533
F test p-value	1.73e-10	2.01e-07	3.21e-05	0.00139	1.02e-09
Value at BW=4500	-0.0363	-0.0286	-0.0731	-0.0370	-0.0509
Value at mean BW	0.06638	0.05328	0.02289	0.02629	0.04418
Value at BW=2500	0.143	0.114	0.0946	0.0736	0.115
R-squared	0.245	0.232	0.303	0.325	0.309
Number of children					11764

Note: Dependent variable pertains to standardized t-scores for the IRT reading test. Robust standard errors are shown in brackets. Controls for Census region, urban area size, and missing information on child's birth weight are included in all regressions. F-test p-value refers to the joint significance of birth weight and birth weight squared. Pooled regressions are clustered by ID. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Appendix A: First State Regressions for Birth Weight (NLS Table 3)

	(1) Birth Weight	(2) Birth Weight Squared
Mother Visited Medical Person for Prenatal care	0.9889*	49.6143
	[0.5416]	[34.0751]
Length of gestation in weeks	1.2940***	71.6697***
	[0.0346]	[1.9020]
Weight gain during pregnancy	-0.3208***	-21.2926***
	[0.0267]	[1.7738]
Teenage mother	0.0488	1.1101
	[0.2093]	[13.3842]
Mother over 30	-0.5134**	-34.7751**
	[0.2535]	[16.7857]
Breastfed	0.5798***	34.8688***
	[0.1471]	[9.9395]
Male child	1.1816***	83.7144***
	[0.1144]	[7.4822]
Age of child	-0.1082***	-6.8569***
	[0.0334]	[2.1752]
Age of child squared	0.0019*	0.1231*
	[0.0010]	[0.0677]
Less than high school-mother	-1.0144	-65.8314
	[0.6202]	[44.1109]
High school-mother	-0.5247	-35.5225
	[0.6161]	[44.0233]
Some college-mother	-0.2044	-18.1086
	[0.6264]	[44.6810]
College plus-mother	-0.0299	-7.6564
	[0.6476]	[46.1596]
Non-Hispanic black	-1.5628***	-104.9216***
	[0.1878]	[12.3576]
Hispanic	-0.4063**	-31.9638**
	[0.2024]	[13.4852]
Single	-0.7919***	-48.7357***
	[0.2283]	[14.5243]
Divorced	-0.6454***	-41.4674***
	[0.1374]	[9.0316]
Age of mother	-0.0882	-5.8588
	[0.0657]	[4.3188]
Age of mother squared	0.0020**	0.1324**
	[0.0009]	[0.0603]

Real family income	0.0040**	0.2434**
	[0.0017]	[0.1142]
Real family income squared	-0.0000**	-0.0002**
	[0.0000]	[0.0001]
Birth order	0.3131***	23.7350***
	[0.0794]	[5.1670]
Child's height in inches	0.0439**	2.9612**
	[0.0214]	[1.4119]
Child's weight in pounds	0.0103***	0.6820***
	[0.0018]	[0.1165]
Number of children	0.1189**	7.7757**
	[0.0574]	[3.6681]
Mother's delivery BMI	0.1512***	10.1949***
	[0.0163]	[1.0970]
Observations	47,509	47,509
F-statistic for Excluded Instruments	355.52	361.12
Joint Significance of Instruments	0.00000	0.00000
R-squared	0.326	0.272

Note: Controls for Census region and missing information on child's height and weight are included. Regressions are clustered by mother's ID. Excluded instruments used pertain to prenatal care, gestation, mother's age at pregnancy, and BMI increase during pregnancy. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Appendix B: High and Low Birth Weight SES Relationship

ECLS-K						
SES Category	SES-1	SES-2	SES-3	SES-4	SES-5	Total
LBW Percentage	8.62%	7.38%	7.21%	6.16%	5.90%	6.92%
HBW Percentage	1.78%	1.73%	1.96%	2.59%	2.31%	2.11%
NLS-CYA						
Education Category	Less than HS	HS	Some college	College		Total
LBW Percentage	10.78%	7.22%	6.18%	5.49%		7.14%
HBW Percentage	1.96%	2.05%	1.70%	2.89%		2.11%

Appendix C: Prevalence of HBW By Race and Gender

	Female	**Male**
All Races		
NLS	1.105%	3.051%
ECLS	1.098%	2.891%
Race: White		
NLS	1.168%	3.360%
ECLS	1.215%	3.695%
Race: Black		
NLS	0.732%	1.963%
ECLS	0.900%	1.333%
Race: Hispanic		
NLS	1.255%	2.073%
ECLS	0.809%	2.469%