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ABSTRACT

We use linked birth and education records for all children born in Florida between 1992 and 2002 to assess the effects of neonatal health on the identification of childhood disabilities. We find that several measures of neonatal health are associated with disability incidence, although birthweight plays the most empirically relevant role. Using large samples of siblings and twins, we find that infant health influences multiple measures of disability and grade repetition in school. The association between birthweight and disability holds throughout the distribution of birthweight and across a range of socioeconomic characteristics, including maternal education and race.

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I. Introduction

As described by the Individuals with Disabilities in Education Act (IDEA) of 1990, the overarching goal of special education services is to provide disabled children with the same educational opportunities as those children who do not have disabilities. Roughly 6.4 million public school students receive special education services in the United States, at an estimated annual cost of nearly $40 billion (National Center for Education Statistics, 2015).

In light of the prevalence and associated costs of childhood disability, numerous researchers have attempted to assess its underlying causes. For example, low birthweight has been linked to autism (Hultman et al, 2002; Larsson et al, 2005), intellectual disability (Hack, Klein and Taylor, 1996), and specific learning disabilities such as ADHD and dyslexia (Almond and Mazumder, 2011; Avchen, Scott and Mason, 2001; Bhutta et al, 2002; Grunau, Whitfield and Davis, 2002). In addition, congenital anomalies have been linked to several categories of childhood disabilities (Galaburda et al, 2006; Hultman et al, 2002; Larsson, 2005; Nelson, 2000). Although these findings ostensibly suggest that many childhood disabilities are functions of a child's health endowments, the intertwined relationship between health and family socioeconomic status (SES) has made it difficult to separately identify the roles of these two factors.[1] Moreover, the data sources used in previous studies have lacked sufficient sample sizes to study relatively rare health conditions and disability classifications.

Several studies have also linked birthweight to long-run human capital outcomes, including test scores (Figlio, Guryan, Karbownik and Roth, 2014; Chatterji, Kim and Lahiri, 2014, Lin and Liu, 2009), educational attainment (Behrman and Rosenzweig, 2004; Black, Devereux and Salvanes, 2007; Oreopoulos, Stabile, Walld and Roos, 2008; Royer, 2009),

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[1] See, e.g., Feinstein (1993) and Bradley and Corwyn (2002) for reviews of this literature.

earnings and wealth in adulthood (Almond and Mazumder, 2010; Black, Devereux and Salvanes, 2007), and intelligence test scores (Lawlor et al, 2006). However, the mechanisms through which birthweight affects these long run outcomes remain unclear.

In this paper, we use data from the State of Florida that links K-12 education records to birth certificate records in order to assess the effects of neonatal health on childhood disabilities, as measured by special education identification in elementary school. These data are uniquely well suited to studying the relationship between neonatal health and childhood disability because they provide detailed information about both SES and children's health conditions at birth. Moreover, the birth records include maternal identifiers, allowing us to abstract from the confounding effects of economic factors that vary across families.

In addition to disentangling the effects of neonatal health and SES, we conduct three novel analyses. First, we consider the roles of a number of measures of maternal and infant health at birth that are potentially important predictors of disability, whereas most previous studies considered birthweight or gestational age alone. Second, because our data include large samples of students, we are able to investigate the effects of health on individual disability categories, including arguably objective physical disabilities (which include vision, hearing, and orthopedic disabilities) and potentially more malleable disability classifications, such as the "specific learning disability" category that includes dyslexia and dyscalculia.[2] Finally, we investigate whether the gradient of disability with respect to neonatal health varies by a host of child and family characteristics, with a specific focus on whether these effects are strongest among economically disadvantaged populations.

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[2] Dyslexia is a condition that involves difficulty in learning to read despite normal intelligence, while dyscalculia involves difficulty in learning or comprehending arithmetical calculations.

We find that neonatal health, as measured by a number of characteristics available on birth records, is strongly associated with the incidence of disability.[3] For example, a congenital anomaly is associated with an 11.5 percentage-point increase in disability incidence in Kindergarten, a large estimate relative to the baseline incidence of 10.0 percent. This implies that one important channel through which birthweight affects human capital outcomes is through disability in childhood. Still, among those characteristics associated with disability identification, we find that birthweight plays by far the most empirically relevant role.

Across all of the individual disability categories that we consider, we find large and statistically significant estimated effects of birthweight. For example, in our preferred specifications that include sibling fixed effects, the estimates imply an elasticity of identification with respect to birthweight of -4.8 and -6.4 for fourth grade intellectual and physical disabilities, respectively. The analogous elasticity for the aggregated "any disability" classification is -0.8. In every category, the point estimates and elasticities are larger in models that include sibling fixed effects than in those that do not. Moreover, in a novel finding, we show that the association between birthweight and disability is strong even among infants in the "normal" birthweight range of over 2500 grams.

We also find that the powerful gradient of disability with respect to birthweight holds across a wide range of socioeconomic categories, including those defined by maternal education, marital status, and race. Mean disability rates vary widely across the subgroups that we consider (from 8.8 percent to 22.2 percent in fourth grade), but the estimated effect of a 10 percent

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[3] We use "special education identification" and "disability" synonymously throughout, following studies such as Avchen, Scott, and Mason (2001). Florida's special education classifications capture the conventional definitions of disability used in epidemiological and medical literatures, with one exception: asthma and other breathing conditions are sometimes defined as disabilities but do not typically lead to special education identification (see, e.g., Houtrow et al., 2014). Nonetheless, Stingone and Claudio (2006) argue that although asthma does not constitute a special education category itself, children with asthma are 60 percent more likely to enroll in special education than are children without asthma.

increase in birthweight on those rates varies considerably less, from -1.0 to -1.4 percentage points. Similarly, the estimates are roughly constant with respect to SES for most of the disability categories we consider, although there is some evidence that the effects of birthweight on intellectual disabilities and speech and language impairments combined with autism spectrum disorder (SLI / ASD) are largest in the lowest socio-economic groups. Importantly, we find that poor neonatal health substantially increases the likelihood of later disability regardless of socioeconomic status, suggesting that parental inputs may not fully offset the effects of early health shocks.

Our central goal is to use the unique Florida data to improve upon existing analyses of the impacts of infant health on later life disability. Although our primary identification strategy based on within-sibling comparisons arguably achieves this goal, remaining unobservable time-varying factors may influence both neonatal health and childhood disability. We have conducted several auxiliary analyses that suggest that we are capturing the causal effects of birthweight, in particular, on disability. First, we re-estimate our central specifications using a subsample of twins. Although the twins estimates suffer from a lack of precision, are based on only modest variation in intrauterine environment (and are thus missing potentially important variation in infant health), and may not be generalizable to a broader population, they allow us to sidestep concerns stemming from time-varying unobservable factors. The twins-based estimates are initially smaller than the sibling-based estimates, but the two sets of estimates become nearly identical when we adjust for attrition due to participation in the McKay Scholarship Program, a voucher program for disabled students to attend private schools. Even without such an adjustment, the twins-based estimates indicate that the relationship between birthweight and disability is large.

Second, we estimate models in which we allow the estimated birthweight gradients to vary by the age difference between siblings. If unobserved changes in family circumstances or parental behaviors drive the within-family association between birthweight and disability, we would expect the estimated gradients to grow as the sibling age gap widens. Instead, our estimates are remarkably constant across sibling age gaps. Third, we consider whether the estimated gradients in the full sample vary by whether siblings have the same father, i.e., by whether they are half- or full-siblings. We find that the estimates are nearly identical across the two groups, despite the fact that a change in father represents a significant change in family circumstances. In sum, our estimates are invariant to observable measures of the degree of similarity in siblings' family circumstances. While we cannot rule out biases stemming from time-varying unobservables in the full sample, these findings suggest that such biases are likely to be small.

II. Background

The medical literature has linked low birthweight to several types of disabilities. For example, low birthweight is associated with autism (Hultman et al, 2002; Larsson et al, 2005), intellectual disability (Hack, Klein and Taylor, 1996) and specific learning disabilities such as ADHD and dyslexia (Almond and Mazumder, 2011; Avchen, Scott and Mason, 2001; Bhutta et al, 2002; Grunau, Whitfield and Davis, 2002; Linnet et al, 2006). In addition, congenital anomalies are associated with several categories of childhood disabilities, such as dyslexia, autism and intellectual disability (Galaburda et al, 2006; Hultman et al, 2002; Larsson et al., 2005; Nelson, 2000). However, these associational studies often rely on relatively small clinical samples and are unable to account for the confounding influences of socioeconomic status and other unobserved determinants of disability. Typically, studies in the medical literature also are limited to investigating the role of birthweight, while ignoring other measures of infant health – including maternal health conditions, birth complications, and fetal abnormalities – that could confound the relationship between birthweight and disability status. In addition, these studies typically only examine a single disability type.

A number of studies relate birthweight to human capital outcomes but are unable to shed light on the underlying mechanisms, one of which could be disability. Black, Devereux and Salvanes (2007) compare twins and find that lower birthweight translates into lower earnings, educational attainment and IQ. Similarly, Behrman and Rosenzweig (2003) compare monozygotic twins and find that birthweight has a strong relationship with educational attainment, earnings, BMI and height. Royer (2009) also compares twins from California and finds an association between birthweight and both educational attainment and the birthweight of the next generation. Oreopoulos, Stabile, Walld and Roos (2008) compare twins and siblings in Canada and find that birthweight predicts high school completion, labor force outcomes, and mortality through age 17, even for higher birthweight categories. Figlio, Guryan, Karbownik and Roth (2014) compare twins from Florida to identify the effects of birthweight on test scores. Lin and Liu (2009) also compare twins from Taiwan and find that low birthweight predicts lower grades. Finally, Chatterji, Kim and Lahiri (2014) use an instrumental variables approach that makes use of multilevel panel data and finds that lower birthweight also predicts lower test scores.

Less is known about how childhood disability causally influences human capital attainment. A key study in this literature is Almond and Mazumder (2010), who find that prenatal exposure to Ramadan among Arab mothers in Iraq and Uganda results in lower birthweight babies who are more likely to have cognitive disabilities and a lower likelihood of home ownership. Nevertheless, it is unclear whether maternal fasting during pregnancy might produce disability in children through a different mechanism than low birthweight due to preterm labor, which is more common in the U.S.

III. Data and Descriptive Statistics

Our data include a unique merger of information from the Florida Education Data Warehouse, maintained by the Florida Department of Education, and birth records from Florida's Bureau of Vital Statistics. The linked records include all children born in the state of Florida from 1992 to 2002 who were enrolled at any time from the 1995-96 through 2012-13 school years. These data were merged based on last name, first name, date of birth, and Social Security Number, and all records were de-identified before being provided to the research team. Ultimately, 80.7% of birth records were later matched to a record in the education data. Figlio et al. (2014) and Autor et al. (2015) provide further details on the match quality and matching algorithm. Both of these studies compare the matched data to information in the American Community Survey and the Census of Population from 2000 to 2009 and find that the match rates are close to the proportion of students born in Florida who subsequently enroll in public schools in Florida (80.9%).[4]

In total, the data includes 1.6 million individual students. However, we restrict our analysis samples to include only those students who are in the data when they are enrolled in both Kindergarten and 4th grade in order to be able to track patterns of identification and de-

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[4] Note that the denominator in the Census / ACS analysis does not include children who were born in Florida but subsequently left the country, while the denominator in the Florida analysis necessarily does, as we do not know where Florida-born children live if they are not enrolled in public schools in Florida. As a result, the two groups are not identical.

identification as students advance through elementary school. This restriction reduces our sample to just under 870,000 students, including about 366,000 children with siblings and 21,804 twins. Our data do not allow us to determine zygosity; based on population estimates indicating that roughly 1 in 11 twin pairs are monozygotic in the U.S., our twins sample likely contains roughly 2,000 monozygotic twins.

Using these rich data, we focus on characteristics of children at birth, including both health and economic variables, along with detailed data on the identification of students for special education services under various categorizations.[5] The birth certificate data include a wealth of information about both child and maternal health status at birth and during the pregnancy. This information includes birthweight, gestational age, APGAR scores (a test of a newborn's responsiveness at one and five minutes after birth), whether the child was part of a plural birth, the mother's prior births, and diagnosis codes for congenital anomalies, abnormal conditions, complications during delivery, and the mother's pregnancy-related health diagnoses. Previous studies have shown that these variables are associated with increased incidence and severity of disability (Eaton et al, 2001; Glasson et al, 2004; Hultman, Sparen and Cnattingius, 2002; Larsson et al, 2005). We include analyses of both twins and singleton births with siblings.

The birth records also include demographic and economic characteristics of both the child and the mother, which we use to control for endowments. These characteristics include child gender, month and year of birth, mother's marital status, mother's educational attainment, mother's race, mother's immigration status, language spoken at home, presence of the father at birth, and the mother's zip code of residence when the child was born.[6]

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[5] We define a student as being in special education if he or she has an Individualized Education Plan (IEP) under the Individuals with Disabilities in Education Act.

[6] All of these variables come from the birth records except for home language, which comes from school records. We drop zip code indicators and time-invariant maternal variables from sibling and twin fixed-effects models.

We utilize information on the child's special education identification in each year from Kindergarten to fourth grade. Figure 1 shows a listing of the disability categories used by the Florida Department of Education during our sample period. Because many of these conditions are relatively rare, we aggregate them into six larger categories. Intellectual disabilities include codes A ("educable mentally handicapped"), B ("trainable mentally handicapped"), and N ("profoundly mentally handicapped"), all of which were reorganized into a single "intellectual disability" code in 2009.[7] Physical disabilities include codes C ("orthopedically impaired"), H ("deaf or hard of hearing"), and I ("visually impaired"). Speech and language impairments combined with autism spectrum disorder (SLI / ASD) include codes F ("speech impaired"), G ("language impaired"), and P ("autistic"). Specific learning disabilities (SLD), which include disorders such as dyslexia, correspond to code K. Developmental delays correspond to code T. Finally, we aggregate all remaining classifications apart from "gifted" status (which we do not study) into a single "other" category, which includes attention deficit hyperactivity disorder.

Table 1 presents summary statistics for all of the variables used in the analyses below. As noted above, the data include the population of children born in the state of Florida from 1992 to 2002 who were enrolled in public schools at any time from the 1995-96 through 2012-13 school years; because the 2002 birth cohort has not reached fifth grade by the 2012-2013 school year, we limit our analysis samples to grades K-4.[8] We further limit to students observed in both Kindergarten and fourth grade to ensure our sample is balanced across these focus grades. If

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[7] In addition to changes in category definitions, diagnoses of disorders themselves have changed over time (King and Bearman, 2009). For example, a child who may have once been diagnosed with a speech or language impairment might more recently have received a diagnosis of autism. We combine categories in order to account for these changing diagnostic trends and criteria over time (such as combining speech and language impairments with autism).

[8] Florida law specifies that children must be five years of age on or before September 1 to be eligible to enter Kindergarten in that school year. As a result, children born after September 1, 2002 were not legally eligible to enter Kindergarten until the 2008-2009 school year, and the majority of these children were in fourth grade in the 2012-2013 school year.

students show up multiple times in a grade (due to retention, for example) we only use their first time in that grade. The top panel of the table shows means of the disability measures in Kindergarten and fourth grade. Across all years, 10.0 percent of Kindergarteners and 15.0 percent of fourth graders received special education services for a disability or impairment. By far the most common classification in Kindergarten was SLI / ASD, with 7.8 percent of all students placed in this category. Less than 1 percent of students were placed in each of the other classifications. In nearly all cases, the data provide information only on the student's "primary" disability, implying that students receive at most one exceptionality code.[9]

By fourth grade, SLD was the most common disability category. Apart from SLI / ASD and developmental delay, all of the categories are more prevalent in fourth grade than in Kindergarten. Many students diagnosed with speech and language impairments in Kindergarten transition out of special education by fourth grade, typically due to a resolution of the impairment. Following the IDEA amendments of 1997, the developmental delay category is defined only for children ages 3-9, but in practice, virtually no students in Florida maintain this designation beyond first grade. Hence, we do not analyze developmental delays beyond first grade.[10]

The next panel in the table shows the incidence of grade retention. Approximately 7 percent of students repeated kindergarten, while 21.6 percent of students repeated at least one grade by the time they reached fourth grade. The remaining rows of the table show summary statistics of health and SES characteristics measured at birth. The birth records include detailed measures of abnormal conditions such as the need for assisted ventilation – separated into a

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[9] Students can be listed as having a "secondary" disability, but this field is only valid when the student has vision or hearing disabilities. Given the rareness of these conditions, we restrict to primary disabilities.

[10] See, e.g., IDEA's amendments for the definition of "developmental delays": https://www2.ed.gov/policy/speced/leg/idea/brief7.html.

"short-term" category of less than 30 minutes and a more severe long-term category – as well as delivery complications such as the presence of meconium in the amniotic fluid, premature membrane rupture, and breech presentation. The data also include detailed information about the mother, including health complications during pregnancy such as anemia, hypertension, and diabetes. We turn next to assessing how these health measures affect the likelihood of later disability diagnoses.

IV. Empirical Specifications

To measure the effects of neonatal and SES characteristics on disability incidence, we start with simple linear probability models that relate child-level special education indicators to the characteristics described above. Consider the following model:

$$(1) \qquad Y_{ijg} = \boldsymbol{X_{ijg}B_g} + \boldsymbol{H_{ijg}\Gamma_g} + \varepsilon_{ijg},$$

where Y_{ijg} is an indicator for whether student *i* in school *j* is classified as disabled when enrolled in grade g. The vector $\boldsymbol{X}$ denotes the socioeconomic characteristics of the student derived from birth certificate and schooling data, the vector $\boldsymbol{H}$ denotes health characteristics at birth of both the mother and infant, and ε_{ijg} represents unobservable determinants of disability identification.

Given that socioeconomic factors might lead to delayed diagnoses in some categories, we begin with the results for fourth grade. Table 2 reports linear probability estimates of the coefficients $\boldsymbol{\Gamma_g}$ from model (1). In the first column, we include only a parsimonious set of controls in the vector $\boldsymbol{X_{ijg}}$: month and year of birth, gender, parity, a quadratic in the mother's age at birth, and an indicator for missing APGAR scores. Column (2) adds controls for mother's immigration status, education level, marital status, and the child's race and indicators for zip code of residence at birth, which are potentially informative measures of SES.

The estimates in column (1) of Table 2 show that a number of factors are significantly associated with identification in fourth grade, including birthweight, APGAR scores, assisted ventilation, maternal health issues, labor and delivery complications, and congenital anomalies. All of the estimated coefficients are of the expected sign, indicating that worse health conditions at birth are correlated with higher disability rates. For example, a 0.1 log-point increase in birthweight is associated with a 0.81 percentage-point reduction in identification. Maternal health conditions are also important; diabetes is associated with a 2.7 percentage-point increase in identification while hypertension and other pregnancy complications (excluding anemia) are both associated with 1.3 percentage-point increases. These conditions are relatively common, occurring in over 25 percent of pregnancies in our data. Breech births, which occur in 3 percent of all births, are associated with a 1.0 percentage-point increase in disability. On the other hand, the other statistically significant factors occur in relatively few births. An infant with a five-minute APGAR score below 7 (the excluded category) is 4.9 percentage points more likely to be identified than an infant with a score of 9 or 10, but only 1 percent of children have five-minute APGAR scores below 7. Congenital anomalies and assisted ventilation for more than 30 minutes are associated with 10.9 and 3.2 percentage-point increases in disability rates, respectively, but fewer than 0.1% of children have either of these characteristics.[11] Throughout, we cluster standard errors at the level of the first district in which students enroll.

All of the estimates are insensitive to the inclusion of socioeconomic controls and zip code fixed effects, as shown in column (2). Further, Table 3 shows that this stability holds in

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[11] Online Appendix Table A1 presents analogous results for Kindergarteners. The point estimates in columns (1)-(3) are smaller in magnitude than those in Table 2, which is expected because disability rates are lower in Kindergarten than in fourth grade, but the specific conditions that are significant and the patterns across columns are similar in both grades. Again, the effect of birthweight increases markedly with the inclusion of maternal fixed effects, from 0.050 to 0.086, while the coefficients for maternal health conditions attenuate markedly.

each of the disability categories, further suggesting that basic economic factors have little confounding effect on the relationships between neonatal health and disability identification.

Column (3) shows estimates from specifications that include sibling fixed effects for the full sample, along with the baseline controls. These are our preferred specifications, as they eliminate a substantial portion (though likely not all) of the unobserved SES differences between children. While the estimates for congenital anomalies, labor and delivery complications, assisted ventilation, and five-minute APGAR scores are similar in columns (2) and (3), estimates for all of the mother's health measures attenuate substantially or even switch signs. At the same time, the role of birthweight becomes more important, with the point estimate increasing by 44 percent in absolute value, from -0.078 to -0.112.

A comparison of the estimates including and excluding maternal fixed effects implies that the within-family association between birthweight and development of disabilities later in life is stronger than the corresponding between-family association. While it is unclear why this is the case, one possible explanation is that while birthweight is a powerful measure of infant health, the mapping from birthweight to health varies across families. For example, some of the between-family variation in birthweight likely captures variation in family stature: relatively small parents have relatively small children, on average. Indeed, there is considerable evidence that stature is itself a large driver of birthweight (e.g., Morrison et al, 1991; Griffiths, et al, 2007). Such variation is essentially noise if it is unrelated to underlying child health, and the estimates in column (3) (and in column (4)) of Tables 2 and A1 eliminate this source of variation.[12]

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[12] If some of the between-family variation in birthweight represents genetic differences in stature, then variation across children born to the same mothers but different fathers would also capture some of this variation. We have estimated specifications with sibling fixed effects in which the effects of birthweight are allowed to differ by

Finally, column (4) presents the results based on the twins sample. The resulting point estimate on birthweight is -0.055, roughly half as large as the analogous point estimate in the sibling fixed-effect model. There are several reasons why the estimates for twins might differ from those of siblings. First, as we discuss below in the context of Table 3, the twins estimate becomes much closer to the siblings estimate when we include in the sample students who attend private school via a voucher program for disabled students. Second, because twins share nearly identical prenatal environments, most of the between-twin differences in birthweight stem from genetic factors (for dizygotic twins), slight differences in the location of the placenta that affect nutrient uptake, or external shocks that differentially affect one child and not the other, e.g., physical impacts that transmit more to one child than the other. As a result, estimates for twins capture only a portion of the potential for the intrauterine environment to influence development in ways that affect disability identification – such as through maternal health or birth complications. By examining both within-sibling and within-twin variation, we are able to investigate the potential roles of these factors. Third, as noted by Oreopoulos, Stabile, Walld and Roos (2008), the use of a broader sibling-based approach helps to alleviate concerns that twins represent a non-representative sample of the population.

Because the estimates in Tables 2 and A1 imply that birthweight is the most practically and statistically significant determinant of disability, we focus primarily on birthweight hereafter. However, we view birthweight as a summary statistic that proxies for infant health more generally. Figure 2 plots semi-parametric estimates of the relationship between birthweight and identification with any disability in fourth grade, showing estimates from models that include 21 dummy variables corresponding to 200-gram birthweight bins (with 2500-2699g as

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whether the children had the same father. We find small and statistically insignificant differences in the estimates for siblings with the same fathers versus those with different fathers.

the reference bin). We present estimates from two models: one including the baseline and SES controls, and one including baseline controls and sibling fixed effects (our preferred specification, for which we include 95 percent confidence interval bands). The figure is consistent with the linear-in-log birthweight specifications used above, as there is a concave relationship between birthweight and identification. The rate of disability increases precipitously in the smallest birthweight categories, but the negative relationship remains even into birthweight ranges beyond 2500g. There is some separation between the lines at both low and high birthweights, although those differences are not statistically distinguishable.[13]

Figure 3 shows the relationship between birthweight and disability in fourth grade for those children born above the "low birthweight" threshold of 2500g. The association between birthweight and disability is strong even in this range: infants weighing more than 3700g have between 3 and 5 percentage-point lower likelihoods of disability than those in the 2500-2699g bin. Estimates that include sibling fixed effects imply a stronger gradient than in models that do not, though the difference is not statistically significant.

We turn next to analyzing the effects of birthweight on the identification of each of the disaggregated disability categories. Table 3 shows estimates for fourth grade for the full sample in Panel A and for the twins sample in Panel B, with column (1) including estimates for the aggregated "any disability" measure, as in Tables 2 and A1. The estimates in each row refer to separate linear probability regressions, with specification "A" corresponding to models that include the baseline control set, specification "B" adding zip code fixed effects and the SES controls, and specification "C" replacing the controls and zip code fixed effects in "B" with

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[13] When we estimate models like those shown in Table 3 restricting to births of less than 2500 grams, adding sibling fixed effects reduces the estimate from -0.172 (0.005) to -0.201 (0.029); similarly, when we restrict to births greater than or equal to 2500 grams, the inclusion of sibling fixed effects reduces the estimate from -0.056 (0.007) to -0.073 (0.008).

sibling / twin indicators. These three specifications are similar to those in columns (1)-(3) of Table 2, except here log birthweight is the only neonatal health variable included. For example, the estimate in column (1) in specification C of Panel A, -0.120, is comparable to the estimate of -0.112 in column (3) of Table 2; this difference is solely due to the exclusion of the neonatal health characteristics.[14]

Before focusing on the impacts on different categories of disabilities, we consider specification D, in which we show estimates for "any disability" by including McKay Scholars in our estimation sample. The McKay Scholarship Program for Students with Disabilities began in 1999, roughly in the middle of our sample period, and provides students with disabilities the opportunity to attend a participating private school or a different public school than the student's default option. In our main sample, we drop students who take up the scholarship to attend a private school, as we do not directly observe data on them when enrolled in the private school. Nonetheless, we can observe whether a student is a recipient, and it is reasonable to infer that those on a scholarship have some identified disability given the program rules. Hence, in specification D we present the results of an analysis in which we include in the estimation sample all children who are on the McKay scholarship, assigning them a disability. Because we cannot observe the child's relevant disability category, we only show estimates in Column (1) for this specification.

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[14] As Angrist and Pischke (2008) note, linear probability models produce consistent estimates of average partial effects in binary outcome models with a large number of incidental parameters. Nonetheless, we have assessed the sensitivity of our results to functional form assumptions by estimating logit models analogous to the specifications in Table 3. For example, the marginal effect from a logit model corresponding to column (1) of Specification C for grade 4 is -0.117 (0.006), compared to the OLS estimate of -0.120 (0.006). It is computationally infeasible to estimate conditional logit models with a very large number of fixed effects. Thus, for the maternal fixed effects specifications we instead first demean all of our control variables by subtracting from each variable its mean value across all children born to that mother, and then estimate logit models using these demeaned values as control variables. In all cases, our conclusions are unchanged regardless of estimation method.

While the estimated effect of log birthweight is unchanged by the inclusion of the McKay scholars in the sibling sample, for the twins sample the resulting point estimate becomes much larger than the baseline estimate – and comparable in magnitude for that in the sibling sample. Hence, this particular type of attrition for disabled twins could explain the considerably smaller estimates we find in twin samples.

Turning next to the analyses of specific disability categories, columns (2)-(6) show the effects of log birthweight on the likelihood of identification in in each of the six disability categories. In the top panel, the estimates from the models that include sibling fixed effects (specification C) are larger in absolute value than the corresponding estimates without sibling fixed effects (specifications A and B). Focusing on specification C, a 10 percent increase in birthweight is estimated to decrease the probability of placement into SLI / ASD in fourth grade by 0.19 percentage points, which is roughly 3.6 percent of the corresponding sample mean of 5.3 percent (shown in brackets at the bottom of the panel), implying an elasticity of -0.36. Column (7) shows the effects of birthweight on the likelihood of repeating a grade at some point between Kindergarten and fourth grade. The estimate implies that a 10 percent increase in birthweight decreases the probability of repeating a grade by 1.16 percentage points. Online Appendix Table A2 presents analogous results for Kindergarten.

For all of the categories listed in Panel A of the table, the effects of birthweight on disability incidence are both practically and statistically significant.[15] The largest point estimate

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[15] Table 3 and several of the tables discussed below include outcomes that are mechanically correlated because the “any disability” indicator is the sum of the indicators across the specific disability categories. This introduces the possibility of incorrectly rejecting true null hypotheses at higher rates than nominal significance levels would imply. One method of incorporating family-wise error rate controlling procedures is to use Bonferroni corrections, which amount to performing hypothesis tests using a significance level of α / m, where α is the chosen nominal significance level and m is the total number of hypotheses tested. If the five disability category-specific estimates across columns are viewed as a family, the Bonferroni correction would imply that a researcher who wishes to use a nominal significance level of, say, 0.05 should reject individual null hypotheses only if individual p-values are less than 0.01 (=0.05 / 5).

corresponds to specific learning disabilities, in which a 10 percent increase in birthweight is estimated to decrease the likelihood of disability by 0.42 percentage points. The point estimates for the less common classifications of intellectual and physical disabilities are smaller in absolute magnitude but are large relative to the underlying incidence of these disabilities. For intellectual disabilities, the point estimate of -0.027 implies an elasticity with respect to birthweight of -3.9. The implied elasticity for physical disabilities is -5.6. In sum, identification in the rarer – and arguably more severe – categories is particularly sensitive to birthweight.

Panel B shows the results for the twins sample. Focusing again on the specifications that include twin fixed effects, the category-specific estimates are typically slightly smaller than those in Panel A. However, the estimates are relatively imprecise due to smaller sample sizes, and as a result are typically statistically insignificant. The largest discrepancy between the sibling- and twins-fixed-effect estimates is for intellectual and physical disabilities; these are the only categories in which in which the two sets of estimates are statistically distinguishable.

Thus far, we have argued that birthweight is the most relevant measure of neonatal health for predicting disability because for every disability category, the estimated effects of birthweight are both large and insensitive to the inclusion of additional measures of neonatal health. Table 4 provides further evidence of this phenomenon by showing the estimated effects on fourth grade disabilities of birthweight and gestational age in three different models. The first includes birthweight as the sole measure of neonatal health (shown in the top row), the second includes gestational age, and the third includes both of these measures. All models include the baseline controls and sibling fixed effects, using the full sample.

The table shows striking evidence that it is not prematurity *per se*, but birthweight that influences disability.[16] The estimated effect of birthweight in the "any disability" column barely changes, from -0.120 to -0.121, when gestational age is included. In contrast, the estimated effect of gestational age declines from -0.066 to 0.001 when birthweight is included; a similar decline occurs in each of the disaggregated disability categories (the estimate becomes marginally significantly positive in the case of specific learning disabilities). For each disability category, the estimated effects of birthweight are robust to the inclusion of gestational age. Appendix Table A3 shows analogous results for Kindergarteners. The findings match those shown in Table 4: the effects of birthweight are insensitive to the inclusion of gestational age for every category, while the inclusion of birthweight dramatically reduces the implied effects of gestational age.

Table 4 also sheds light on what might drive the differences between the siblings and twins estimates. The siblings estimates capture variation in birthweight due to both sibling differences in gestational age and intrauterine growth rates (IUGR), while the twins estimates necessarily capture only IUGR differences. As Table 4 shows, variation in gestational age does not account for the differences between the siblings and twins estimates, suggesting that the differences stem from other factors. Hereafter, we focus on the siblings estimates for the reasons described above, namely that they are substantially more precise, potentially more generalizable, and likely capture a broader measure of variation in the intrauterine environment than do twins estimates.

We have only focused on fourth grade and Kindergarten to this point. However, in Table 5 we show estimates for each grade from K-4, using our preferred specification with sibling

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[16] This finding is consistent with the results of Garfield et al. (2017), who show that while extremely premature children are disproportionately low-performers in school, a large fraction of extremely premature children perform within the typical range found among full-term infants.

fixed effects. We use a balanced sample of all students observed in all grades, which reduces our sample size to 746,623. The estimated effect of birthweight on any disability grows steadily as children progress through elementary school, although when normed by the grade-specific disability rates shown in brackets, the point estimates are roughly constant from first grade to fourth grade. For example, the implied elasticities are -0.80 (= -0.097 / 0.122) and -0.82 (= -0.124 / 0.152) in first and fourth grade, respectively.

Table 5 also shows that there is substantial heterogeneity in the temporal patterns across categories. The estimated effects of birthweight on SLI / ASD decline from Kindergarten to fourth grade (although not monotonically), along with the underlying incidence of these categories. Speech disabilities are typically treated in early grades, and children often exit the special education system once their speech improves. The estimated effects on specific learning disabilities, intellectual disabilities, and “other” disabilities grow over time, while the effects on physical disabilities are essentially constant. The most dramatic growth – for both the underlying incidence and the estimated effects of birthweight – is for specific learning disabilities, which becomes the most prevalent disability category by fourth grade. These disabilities often go undiagnosed until mid/late elementary grades, but still manifest themselves through classroom behaviors at early ages.[17]

The broad patterns in Table 5 suggest that, among those disabilities that become more common as children progress through school, the effects of birthweight grow in absolute terms.

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[17] Previous evidence suggests that a child’s likelihood of being diagnosed with a specific learning disability is related to their performance relative to their classmates in school. For example, Elder and Lubotsky (2009) find that learning disabilities are more commonly diagnosed in students who are relatively young in the within-classroom age distribution. Elder (2010) and Evans and Morrill (2010) find that the age-disability relationship is particularly strong for ADHD – which is sometimes categorized as a specific learning disability (though typically not in Florida) – resulting in systematic long-term differences between the youngest and oldest children in a classroom in the use of stimulants prescribed to treat ADHD.

In contrast, the effects of birthweight either shrink or remain constant for those disabilities that are commonly identified in Kindergarten or earlier, such as SLI / ASD and physical disabilities.

We have primarily focused on models that impose homogenous effects of birthweight, but there could be interactions between birthweight and other neonatal health and maternal health outcomes. In Table A4 in the Online Appendix, we present the results of an analysis that interacts the log of birthweight with a set of bins for gestational age in weeks. The omitted category is 39-40 weeks of gestation, corresponding to a “full term” infant. The estimates show that the effects of birthweight on the identification of any disability grow monotonically as gestational age declines, although the only significant interaction estimate is for children born at less than 31 weeks.

Next, in Table A5 we present estimates from models that interact log birthweight with the following characteristics of the child, mother, and labor/delivery in separate models: anemia, Apgar scores, assisted ventilation (both less than and greater than 30 minutes), breech birth, congenital anomalies, maternal drinking during pregnancy, maternal diabetes, maternal hypertension, meconium, premature membrane rupture, other abnormalities, other labor/delivery complications, other mother’s health conditions, and maternal smoking during pregnancy. In most cases, the interaction effects are small and statistically insignificant, with a few exceptions. First, the birthweight effects are smaller for children with Apgar scores of 9 or 10 (the highest scores). This interaction effect is driven by impacts on intellectual disabilities and physical disabilities (not shown), suggesting that low birthweight is less of a problem for these severe types of disabilities if the child has good vital signs at birth. The birthweight effects are also larger if the birth is breech and in the presence of a congenital anomaly. Finally, birthweight effects are larger if there is a premature membrane rupture. In sum, the effects of birthweight vary by the presence of other health conditions at birth or maternal health / behavior, but the association between birthweight and disability is large regardless of the presence of these factors.

V. Heterogeneity in the Effects of Birthweight by Child and Family Characteristics

Because our data include large samples of students in a racially and economically diverse state – for example, in 2013, 40 percent of Florida students were non-Hispanic white, 23 percent were non-Hispanic black, and 32 percent were Hispanic – we are able to investigate whether the effects of birthweight on disability vary by a host of child and family characteristics. We are particularly interested in assessing whether the effects of birthweight are strongest among economically disadvantaged populations, which might be the case if disadvantaged groups are those most at risk for developing disabilities.

Table 6 presents the estimated effects of birthweight on fourth grade disability categories for several subgroups. All estimates come from our preferred specification with sibling fixed effects using the full sample. The top panel of the table shows estimates by gender; specifically, we interact a “female” indicator with birthweight and report both the main effect of birthweight and the interaction effect. We estimate a separate regression for each panel, i.e., we include separate regressions for gender, race / ethnicity, maternal education, and so on.

The top panel shows that boys have slightly larger effects of birthweight on the identification of “any disability” (-0.136 versus -0.104), but the gender differential varies across disability categories. Specifically, the estimated effects of birthweight are larger for boys than for girls in all categories except for SLI / ASD, with the difference most pronounced for the specific learning disability category.

The next panel shows results separately by race / ethnicity. For non-Hispanic whites, non-Hispanic blacks, and Hispanics, there are large effects of birthweight on all disability categories. Moreover, we find that that the effects of birthweight are not obviously related to the underlying incidence across groups: among the five disability categories, the group with the largest underlying incidence has the largest point estimate in two cases (for brevity, we do not report the incidence rates in the table).

The next two panels show results by four categories of maternal education and by two categories of maternal marital status, respectively. The results exhibit the same general patterns as in the top two panels, in that birthweight strongly impacts disability for all groups, and the variation in the point estimates across groups is small. For SLI / ASD and intellectual disabilities, the relationship between birthweight and disability is somewhat stronger for children whose mothers did not attend college, or whose mothers are not married. In the case of physical disabilities, the relationship between birthweight and disability is strongest for children whose mothers have a college degree.

In the last two panels of the table, we limit our estimation samples to sibling pairs in order to consider variation in the birthweight gradient by the degree of similarity in siblings' family circumstances. The panel labeled "Siblings with Different Fathers" presents estimates by whether the siblings shared the same father, i.e., by whether they were half- or full-siblings. The "any disability" point estimates are nearly identical for the two groups, and the point estimates for half-siblings are larger in absolute value for two of the disaggregated categories, smaller in three categories, and roughly identical for the "other" category. There is also only a small, statistically insignificant difference for the grade repetition measure.

The final panel presents estimates from models in which the natural log of birthweight is interacted with the age gap between sibling pairs; these models also include the age gap itself as a control. In all cases, the coefficient on the interaction term is small relative to the main effect of birthweight; for example, the estimated birthweight gradient for "any disability" is -0.111 (= -0.115 + 0.004) for siblings born one year apart and -0.103 for siblings born three years apart.

Importantly, the estimates in the bottom two panels of Table 6 are potentially informative about whether *any* of our within-sibling estimates have a causal interpretation. Specifically, if unobserved changes over time in family circumstances or parental behaviors influence both neonatal health and disability, then the estimates from models that include maternal fixed effects would fail to capture the causal effects of birthweight. In this scenario, we would expect the estimated gradients to grow as the sibling age gap widens, under the assumption that the impacts of time-varying factors are more salient as more time elapses between sibling births. However, five of the six estimates on the "ln(birthweight) × age gap" interaction terms are positive, implying that the gradient weakens as the age gap increases.

To illustrate these patterns further, Figure 4 plots the estimated birthweight gradient by nine sibling age-difference bins. The estimated effect of log birthweight on the identification of any disability is roughly -0.055 for twins but grows to between -0.148 and -0.165 for age gaps of 9-12 and 12-18 months, respectively, which are both much larger than the full-sample estimate of -0.120 shown in Table 3. While we are wary of drawing strong inferences from the figure given the imprecision of the estimates, overall we find that the estimated birthweight gradients do not appear to be systematically related to the degree to which siblings share similar family circumstances.

A related issue is that neonatal health in one sibling could influence the disability status of other siblings through spillovers, possibly through parental responses. Black et al. (2017) estimate the impacts of disability status on siblings' educational achievement and find significant spillover effects. In estimates available by request, we follow the strategy used in that study by restricting to three-child families and estimating the impacts on the oldest two children's disability status as a function of "exposure time" to the youngest sibling (the time between when the youngest child is born and an older child reaches fourth grade) and the interaction between that exposure time and the birthweight of the youngest sibling. We find small and statistically insignificant effects of the exposure time × birthweight interaction on the disability status of the older sibling, suggesting that sibling spillover effects are unlikely to be contaminating our disability estimates. However, consistent with the findings of Black et al. (2017), we find significant negative effects of the interaction variable on grade retention.

Taken as a whole, our findings show that the powerful association between birthweight and disability holds across a wide range of socioeconomic categories – including those defined by maternal education, marital status, and race – and across disability categories. We find mixed evidence for the existence of heterogeneity in birthweight's effects: while the point estimates are typically largest for groups with the highest incidence of underlying disability, the implied elasticities are smallest in those groups. Moreover, these patterns are not consistent across disability categories. For intellectual disability, a relatively rare classification, the birthweight gradient is positively related to the underlying group-specific incidence regardless of how we cut the data. For the more common classifications of SLI / ASD and specific learning disabilities, there are no clear patterns across the panels of Table 6, although the relationship between birthweight and SLI / ASD is strongest for children whose mothers have less than a high school education or who are unmarried.

The heterogeneous effects of birthweight with respect to intellectual disabilities are particularly interesting, given that Figlio et al. (2014) find that the effects of birthweight on student outcomes are, if anything, slightly stronger for high-SES families than for low-SES families. One possible source of this apparent discrepancy could stem from variation across SES in baseline levels of measured cognitive skills. For example, if the effects of birthweight on measured IQ are constant in the population, and if identification of intellectual disabilities is primarily driven by a binary measure of whether a child's IQ is lower than a given threshold, the effects of birthweight on intellectual disabilities will be larger among those groups that have IQ distributions with relatively more mass near that threshold among "normal weight" babies. While this is a simplification of the disability identification process, it is arguably a reasonable approximation to reality in the U.S. before 2009, when intellectual disabilities were defined primarily by whether a child scored below 75 on standardized IQ tests.[18] Thus, our findings for intellectual disability are not necessarily inconsistent with those of Figlio et al. (2014), who concluded that neonatal health and parental inputs are modestly complementary.

VI. Endogenous Mobility

We argued above that the linked birth-education data are representative of the population of children born in Florida who attend public schools in Florida. However, students with disabilities might nonrandomly attend private schools or move out of the state. To investigate

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[18] The 2009 revision of IDEA fundamentally changed the identification process for intellectual disabilities, requiring as a necessary condition for identification that a child exhibits "significant deficits in the ability to function independently." Thus, measured IQ scores are no longer necessary nor sufficient conditions for the identification of intellectual disabilities.

this issue, we estimated models that examine whether birthweight has an impact on being included in our main estimation samples. We find that there is no association between log birthweight and attendance at a public Florida Kindergarten in either the within-sibling or the within-twin models: the coefficients are less than 0.002 and *t*–statistics are less than 0.5 in both cases. Nonetheless, we do find evidence of selective attrition when we restrict to those enrolled in both Kindergarten and fourth grade. Specifically, we estimate that a 1 log-point increase in birthweight is correlated with a 3.1 percentage-point increase (standard error of 0.003) in the likelihood of being observed in fourth grade in the within-sibling models, and a 2.5 percentage-point (0.009) increase in the within-twins models. Thus, it does appear that low birthweight children are disproportionately less likely to be observed in our estimation samples, and we cannot observe the extent to which this attrition involves out-of-state moves versus enrollment into private schools.

To gauge the extent of bias caused by nonrandom attrition, in Online Appendix Table A6 we present the results of a bounding analysis that assigns disability status based on birthweight for students not observed in the education data. Specifically, in column (2), we assign a disability to all children of low birthweight (< 2500g) who are not observed in both Kindergarten and fourth grade. This exercise would plausibly serve as an upper bound on the relationship between birthweight and disability. Column (3) repeats this exercise, except it limits the imputation to those of very low birthweight (< 1500g). These results suggest that, in the absence of attrition, the impact of birthweight on disability could be considerably larger – nearly double those of our main estimates, though these bounds are conservative by design.

Column (4) represents a lower bound, as it instead assumes that no low-birthweight children missing in either Kindergarten or fourth grade are disabled. The resulting estimates here are, by design, smaller in absolute value than the baseline estimates for both siblings and twins; importantly, they are still large and significantly different from zero. We view the assumptions underlying column (4) as unusually conservative – it is highly unlikely that none of the missing low-birthweight infants are identified with a disability – so these results provide further support for a strong association between infant health and later disability.

VII. Discussion and Conclusions

Using a unique merger of birth and education records from Florida, we present estimates of the effects of neonatal health on special education identification. We find that childhood disability is strongly associated with several measures of neonatal health – including lengthy assisted ventilation, APGAR scores, breech presentation, congenital anomalies, and meconium in amniotic fluid – but that birthweight plays an especially large role. This implies *ex post* that studies that only have access to birthweight data are likely to have a solid first approximation of neonatal health, at least when studying determinants of disability.

Children with lower birthweights are disproportionately likely to be diagnosed with disabilities throughout elementary school, and this relationship holds across socioeconomic categories. The estimated effects grow monotonically from Kindergarten to fourth grade, whereas the associated elasticities decline because the underlying incidence of identified disabilities increases as children age. Our central specifications include sibling fixed effects, allowing us to separate the effects of neonatal health from confounding factors due to family-level socioeconomic endowments. We consistently find that the implied effects of birthweight are larger in these models than in those without maternal fixed effects, and we argue that this phenomenon may stem from between-family variation in birthweight that is unrelated to underlying neonatal health. Overall, we find that a 10 percent increase in birthweight reduces disability rates in fourth grade by 1.2 percentage points, implying an elasticity of -0.8. We find somewhat smaller and imprecisely estimated effects in specifications using twins, but we argue that this is likely due to the different nature of intrauterine effects on disability between twins and siblings and attrition of disabled twins into private schooling via vouchers. Adjusting for the latter issue provides estimates similar to those from the sibling models, which are themselves unaffected by the exclusion of voucher students.

Because our estimation samples are much larger than those used in previous analyses of the determinants of special education identification, we are able to assess the effects of birthweight on individual disability categories, including relatively rare conditions such as intellectual disabilities. Across all of the categories that we consider, we find large and statistically significant effects of birthweight. The sensitivity of identification to birthweight is especially pronounced for relatively rare categories. These categories (including physical and intellectual disabilities) are also arguably more objectively defined than other classifications, such as specific learning disabilities or speech and language disorders.

Our data also allow us to shed light on the extent of heterogeneity in the effects of birthweight across a variety of child and family characteristics. These analyses reveal two important findings. First, the estimated effects of birthweight are large across a wide range of socioeconomic groups, even though disability incidence varies substantially across those groups. The estimated effects of a 10 percent increase in birthweight on overall fourth grade disability rates fall in a relatively tight window across groups: from -0.98 to -1.36 percentage points.

Finally, our estimates suggest that poor neonatal health affects children regardless of their economic endowments. We find no evidence that the birthweight / disability gradient is strongest among the most economically disadvantaged populations.

Our findings that neonatal health strongly influences disability even among families with substantial economic endowments suggests that in many cases, parental inputs are only partially effective in offsetting the effects of early health shocks. Although this finding is disheartening, it provides clear directions for future research. Priorities include investigating whether interventions aimed at improving neonatal health – such as improvements in maternal nutrition – will result in reductions in childhood disability. Additionally, because we know little about the impact of special education identification on later outcomes, there is a need for studies of the effects of such interventions to assess whether they are effective tools for ameliorating the effects of poor neonatal health on adult outcomes.

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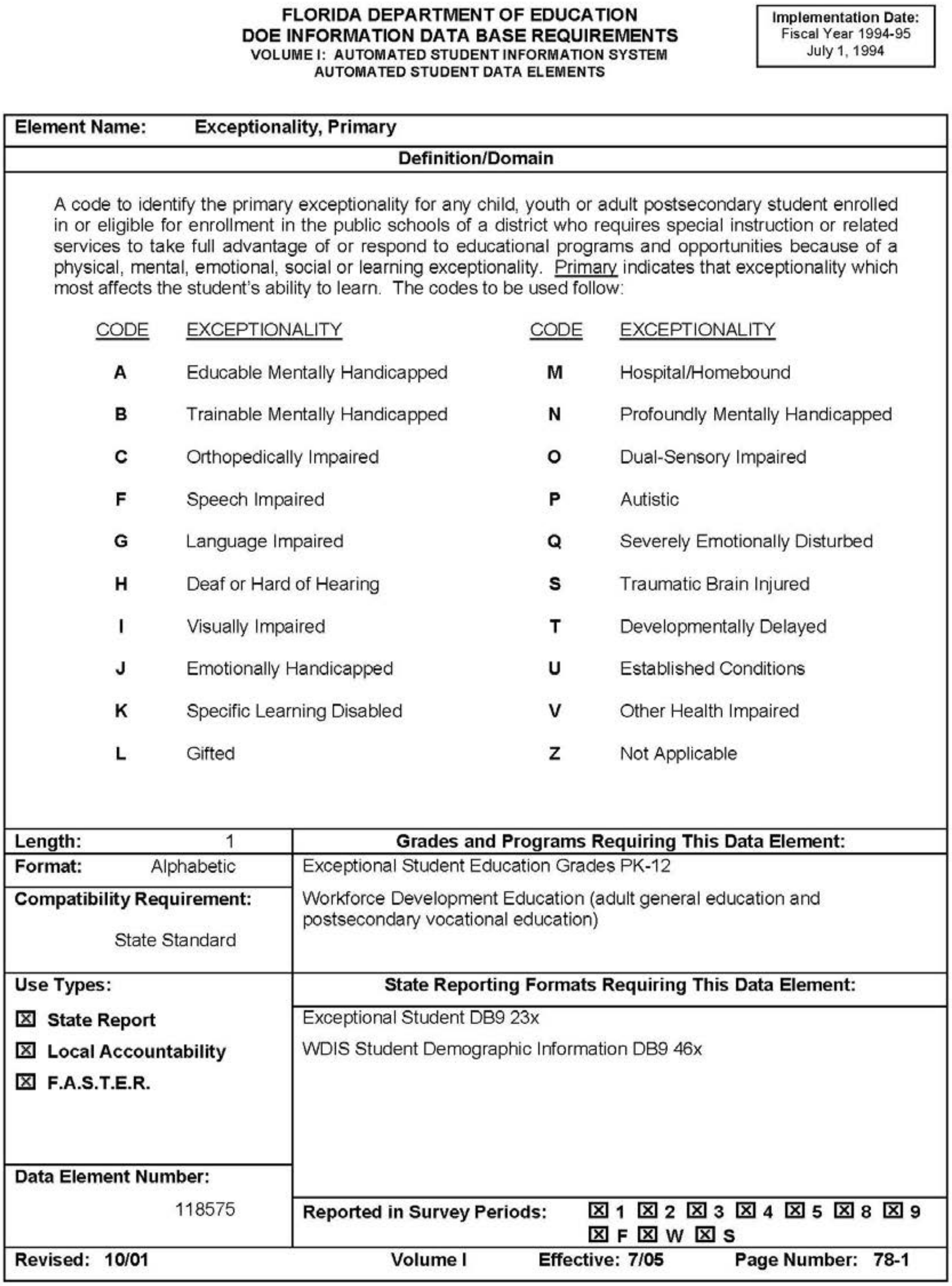
Figure 1: Special Education Categories Used by Florida Department of Education



FLORIDA DEPARTMENT OF EDUCATION
DOE INFORMATION DATA BASE REQUIREMENTS
VOLUME I: AUTOMATED STUDENT INFORMATION SYSTEM
AUTOMATED STUDENT DATA ELEMENTS

Implementation Date:
Fiscal Year 1994-95
July 1, 1994

Element Name: **Exceptionality, Primary**

Definition/Domain

A code to identify the primary exceptionality for any child, youth or adult postsecondary student enrolled in or eligible for enrollment in the public schools of a district who requires special instruction or related services to take full advantage of or respond to educational programs and opportunities because of a physical, mental, emotional, social or learning exceptionality. Primary indicates that exceptionality which most affects the student's ability to learn. The codes to be used follow:

CODE	EXCEPTIONALITY	CODE	EXCEPTIONALITY
A	Educable Mentally Handicapped	**M**	Hospital/Homebound
B	Trainable Mentally Handicapped	**N**	Profoundly Mentally Handicapped
C	Orthopedically Impaired	**O**	Dual-Sensory Impaired
F	Speech Impaired	**P**	Autistic
G	Language Impaired	**Q**	Severely Emotionally Disturbed
H	Deaf or Hard of Hearing	**S**	Traumatic Brain Injured
I	Visually Impaired	**T**	Developmentally Delayed
J	Emotionally Handicapped	**U**	Established Conditions
K	Specific Learning Disabled	**V**	Other Health Impaired
L	Gifted	**Z**	Not Applicable

Length: 1

Format: Alphabetic

Compatibility Requirement:
State Standard

Grades and Programs Requiring This Data Element:

Exceptional Student Education Grades PK-12

Workforce Development Education (adult general education and postsecondary vocational education)

Use Types:

☒ **State Report**
☒ **Local Accountability**
☒ **F.A.S.T.E.R.**

State Reporting Formats Requiring This Data Element:

Exceptional Student DB9 23x

WDIS Student Demographic Information DB9 46x

Data Element Number:
118575

Reported in Survey Periods: ☒ **1** ☒ **2** ☒ **3** ☒ **4** ☒ **5** ☒ **8** ☒ **9** ☒ **F** ☒ **W** ☒ **S**

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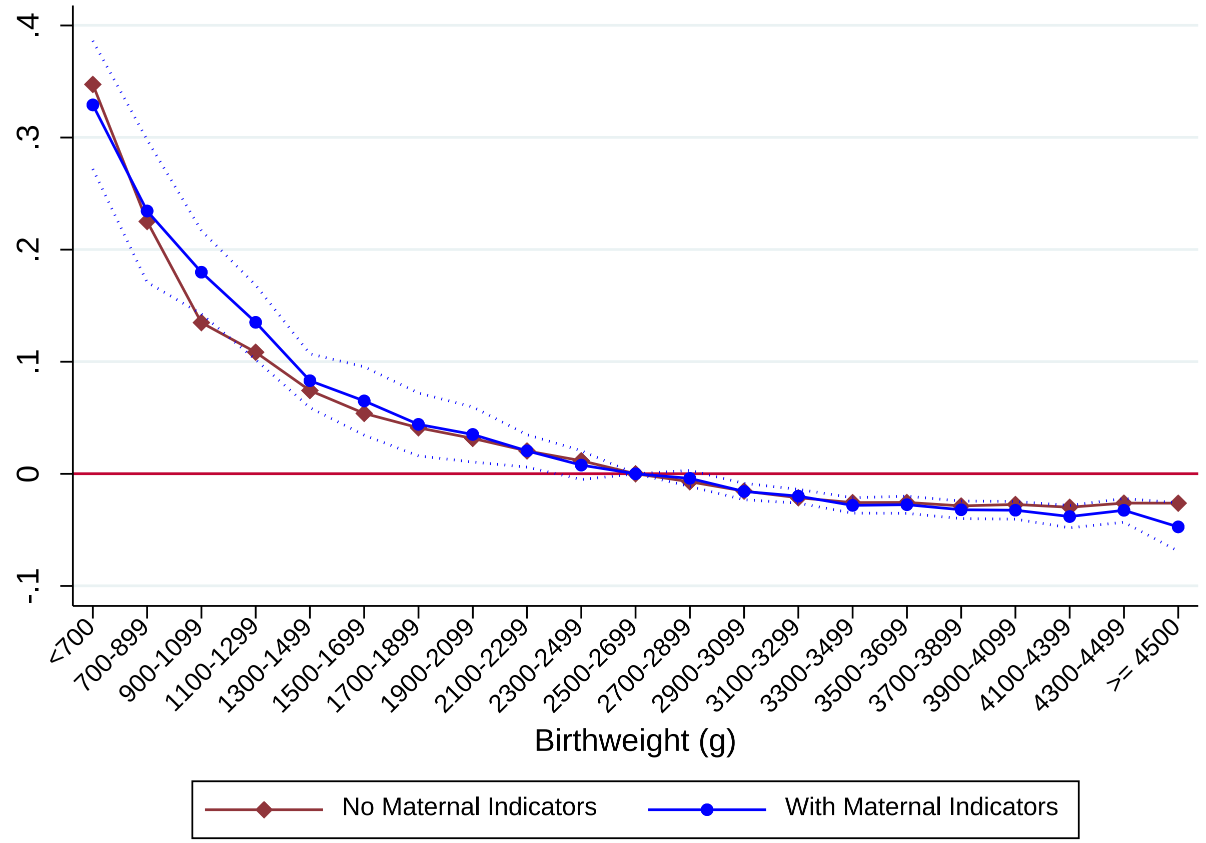
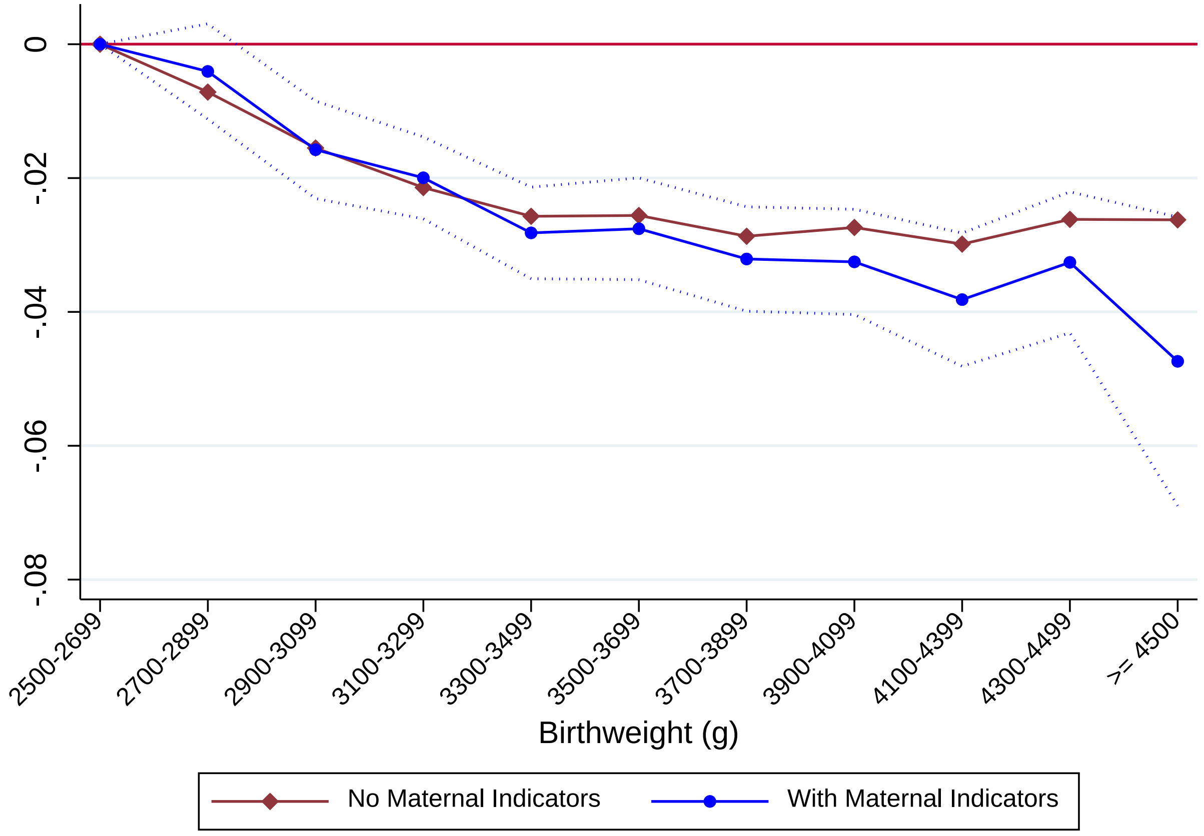
Figure 2: The Relationship between Birthweight and Identification of Any Disability in Grade 4



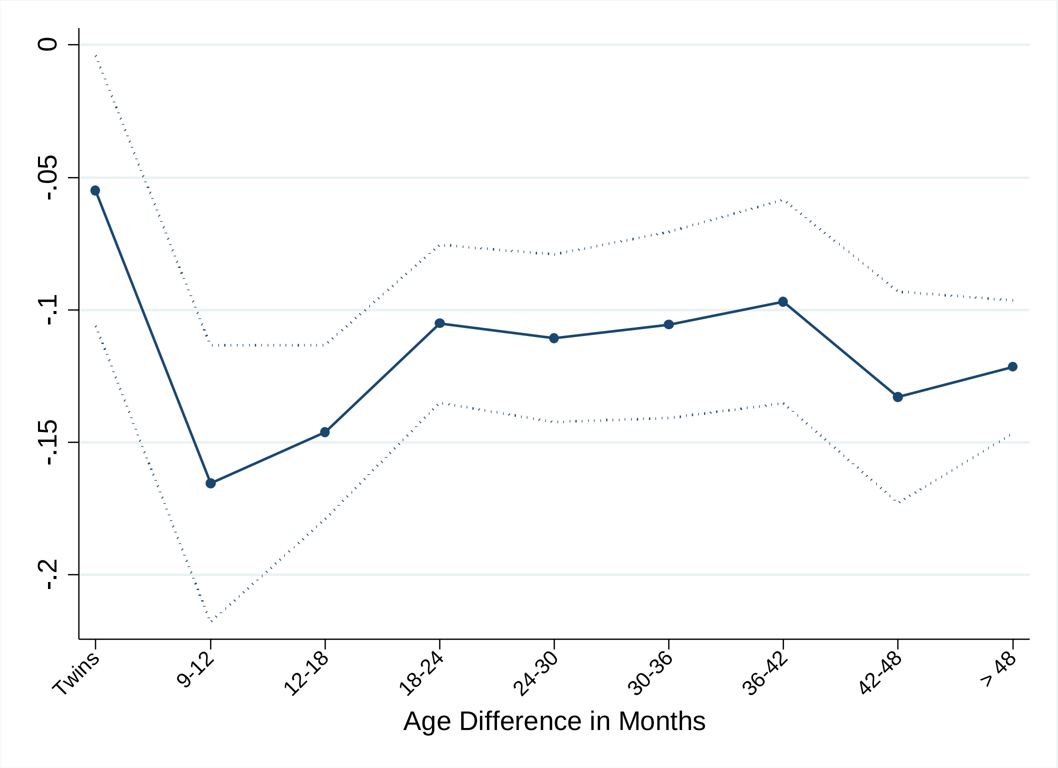
Notes: the y-axis represents the probability of diagnosis in birthweight bins relative to the 2500-2699g bin. All models include controls for birth order, gender, year of birth, and month of birth. Economic controls include mother's education, immigration status, a quadratic in mother's age, and race of child. 95% confidence intervals (based on standard errors clustered by first district attended) for estimates from the model that includes maternal indicators are shown with dotted lines.

Figure 3: The Relationship between Birthweights above 2500g and Identification of Any Disability in Grade 4



Notes: the y-axis represents the probability of diagnosis in birthweight bins relative to the 2500-2699g bin. All models include controls for birth order, gender, year of birth, and month of birth. Economic controls include mother's education, immigration status, a quadratic in mother's age, and race of child. 95% confidence intervals (based on standard errors clustered by first district attended) for estimates from the model that includes maternal indicators are shown with dotted lines.

Figure 4: Heterogeneity in the Effect of Birthweight on the Identification of Any Disability in Grade 4 by the Age Difference between Siblings



Notes: the y-axis represents the estimated effect of log birthweight on the probability of diagnosis in sibling pairs whose ages differ by the values listed in the x-axis. All models include controls for birth order, gender, year of birth, and month of birth, as well as maternal indicators. 95% confidence intervals (based on standard errors clustered by first district attended) are shown with dotted lines.

Table 1: Summary Statistics of Measures of Disability, Neonatal Health and SES

	Kindergarten	Grade 4
Disability Measures		
Any Disability	0.100	0.150
	(0.301)	(0.357)
Speech/Language Impairment (SLI) or Autism Spectrum Disorder (ASD)	0.078	0.053
	(0.268)	(0.225)
Specific Learning Disability	0.008	0.068
	(0.088)	(0.252)
Developmental Delay	0.005	-
	(0.070)	-
Intellectual Disability	0.004	0.007
	(0.059)	(0.082)
Physical Disability	0.003	0.003
	(0.050)	(0.058)
Other Impairment	0.004	0.018
	(0.063)	(0.133)
Retention		
Retained at Any Time Up to Given Grade	0.070	0.216
	(0.255)	(0.411)
Birth Characteristics and SES Characteristics		
Birthweight (grams)	3327	
	(557)	
Birthweight Differences (grams)		
Within Siblings	384	
	(356)	
Within Twins	263	
	(253)	
Gestational Age at Birth (weeks)	38.8	
	(2.0)	
Apgar 1 Score = 7 or 8	0.412	
	(0.492)	
Apgar 1 Score = 9 or 10	0.526	
	(0.499)	
Apgar 5 Score = 7 or 8	0.062	
	(0.242)	
Apgar 5 Score = 9 or 10	0.929	
	(0.257)	

Table 1: Summary Statistics of Measures of Disability, Neonatal Health and SES (cont'd)

Abnormality - Assisted Ventilation < 30 mins	0.019
	(0.137)
Abnormality - Assisted Ventilation > 30 mins	0.007
	(0.085)
Abnormality - Other	0.035
	(0.184)
Maternal Health - Anemia	0.026
	(0.160)
Maternal Health - Diabetes	0.027
	(0.163)
Maternal Health - Hypertension	0.044
	(0.205)
Maternal Health - Other	0.183
	(0.387)
L&D Complication - Meconium	0.054
	(0.226)
L&D Complication - Premature Membrane Rupture	0.021
	(0.144)
L&D Complication - Breech	0.032
	(0.175)
L&D Complication - Other	0.217
	(0.412)
Congenital Anomaly - Any	0.007
	(0.085)
Parity - 1st Born	0.406
	(0.491)
Parity - 2nd Born	0.338
	(0.473)
Parity - 3rd Born	0.162
	(0.369)
Parity - 4th or Higher Born	0.093
	(0.291)
Mother Married	0.614
	(0.487)
Mother's Age	27.239
	(6.254)
Mother is Immigrant	0.226
	(0.418)
Mother HS Dropout	0.215
	(0.463)

Mother HS Graduate	0.383
	(0.495)
Mother Some College	0.235
	(0.392)
Mother College Graduate	0.164
	(0.370)

Notes:

Entries in each cell are sample means of the variables listed in the first column, with standard deviations shown in parentheses. The sample size is 869,179, except for the “birthweight differences” samples, which have *n* = 366,066 for siblings and *n* = 21,854 for twins.

Table 2: The Association between Neonatal Health Conditions and Any Special Education Identification in Grade 4

	Dependent Variable: Any Disability			
	(1)	(2)	(3)	(4)
Ln(Birthweight) (grams)	-0.081***	-0.078***	-0.112***	-0.055**
	(0.005)	(0.003)	(0.007)	(0.026)
Gestational Age at Birth (weeks)	-0.000	-0.001**	0.000	-
	(0.000)	(0.000)	(0.001)	-
Apgar 1 Score = 7 - 8	-0.009***	-0.009***	-0.002	0.007
	(0.002)	(0.002)	(0.005)	(0.010)
Apgar 1 Score = 9 - 10	-0.018***	-0.012***	-0.004	0.001
	(0.004)	(0.003)	(0.005)	(0.012)
Apgar 5 Score = 7 - 8	-0.038***	-0.038***	-0.033**	-0.042
	(0.006)	(0.005)	(0.013)	(0.041)
Apgar 5 Score = 9 - 10	-0.049***	-0.049***	-0.041***	-0.069*
	(0.005)	(0.005)	(0.013)	(0.039)
Abnormality - Assisted Ventilation < 30 mins	-0.000	0.007**	0.003	-0.010
	(0.005)	(0.003)	(0.005)	(0.040)
Abnormality - Assisted Ventilation > 30 mins	0.032***	0.033***	0.034***	0.035
	(0.006)	(0.006)	(0.010)	(0.033)
Abnormality - Other	0.015***	0.013***	0.014***	-0.019
	(0.003)	(0.003)	(0.005)	(0.021)
Maternal Health - Anemia	0.002	0.000	0.006	-
	(0.004)	(0.003)	(0.004)	-
Maternal Health - Diabetes	0.027***	0.026***	0.003	-
	(0.003)	(0.002)	(0.007)	-
Maternal Health - Hypertension	0.013***	0.012***	-0.009**	-
	(0.002)	(0.002)	(0.004)	-

Maternal Health - Other	0.013***	0.008***	-0.002	-
	(0.002)	(0.001)	(0.002)	-
L&D Complication - Meconium	0.005***	0.006***	0.008**	-
	(0.002)	(0.001)	(0.003)	-
L&D Complication - Premature Membrane Rupture	-0.001	-0.002	-0.009	-
	(0.003)	(0.003)	(0.006)	-
L&D Complication - Breech	0.010***	0.008***	0.010**	-
	(0.002)	(0.002)	(0.004)	-
L&D Complication - Other	0.004**	0.003**	0.002	-
	(0.002)	(0.001)	(0.002)	-
Congenital Anomaly - Any	0.109***	0.107***	0.092***	0.102*
	(0.008)	(0.008)	(0.011)	(0.053)
Baseline controls	X	X	X	X
Socioeconomic controls		X		
Zip code of birth fixed effects		X		
Sibling fixed effects			X	
Twin fixed Effects				X

Notes: All estimates are from linear probability models of a binary measure of disability. Column (1) uses a sample of 869,179 children, including 366,064 with siblings. Due to missing data, sample sizes for columns (2) and (3) drop slightly to 866,708. Column (4) is restricted to multiple births and includes 20,542 child observations. Standard errors, clustered by first district attended, are listed in parentheses. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively. "Baseline controls" include month of birth, year of birth, gender, parity, controls for missing APGAR scores, and a quadratic in mother's age. For twins fixed effects models, only missing APGAR scores, gender, and parity are included in these controls. "Socioeconomic controls" include mother's immigration status, mother's education level, mother's marital status, and child's race.

Table 3: Estimated Effects of Birth Weight on Special Education Identification and Grade Retention By Grade 4

	Any Disability (1)	SLI & ASD (2)	Specific Learning Disability (3)	Intellectual (4)	Physical (5)	Other (6)	Repeat Any Grade KG - 4 (7)
				Panel A: Full Sample			
A: No SES Controls or FE	-0.102***	-0.009***	-0.040***	-0.022***	-0.014***	-0.016***	-0.164***
	(0.004)	(0.003)	(0.004)	(0.002)	(0.001)	(0.001)	(0.009)
B: Add Zip code FE and SES Controls	-0.099***	-0.012***	-0.038***	-0.020***	-0.015***	-0.013***	-0.118***
	(0.003)	(0.002)	(0.003)	(0.002)	(0.001)	(0.001)	(0.005)
C: Add Sibling FE to specification A	-0.120***	-0.019***	-0.042***	-0.027***	-0.017***	-0.015***	-0.116***
	(0.006)	(0.004)	(0.006)	(0.002)	(0.002)	(0.003)	(0.007)
D: Include McKay Scholars in specification C as disabled	-0.120*** (0.005)						
Dependent Var Mean	[0.150]	[0.053]	[0.068]	[0.007]	[0.003]	[0.018]	[0.216]
				Panel B: Twins Sample			
A: No SES Controls or FE	-0.148***	-0.031***	-0.052***	-0.026***	-0.021***	-0.017***	-0.138***
	(0.009)	(0.010)	(0.010)	(0.004)	(0.004)	(0.005)	(0.014)
B: Add Zip code FE and SES Controls	-0.144***	-0.031***	-0.051***	-0.024***	-0.022***	-0.016***	-0.115***
	(0.010)	(0.010)	(0.011)	(0.004)	(0.004)	(0.005)	(0.013)
C: Add Sibling FE to specification A	-0.055**	-0.016	-0.030	-0.004	0.010	-0.016**	-0.060***
	(0.026)	(0.019)	(0.020)	(0.007)	(0.007)	(0.008)	(0.023)
D: Include McKay Scholars in specification C as disabled	-0.102*** (0.026)						
Dependent Var Mean	[0.208]	[0.088]	[0.087]	[0.010]	[0.005]	[0.018]	[0.241]

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on log(birthweight). For Panel A, the controls in specifications A, B, and C match those in columns (1), (2), and (3) of Table 2, respectively; in Panel B, the controls in specifications A, B, and C match those in columns (1), (2) and (4) of Table 2, respectively. The full sample includes 869,179 children, including 366,066 with siblings, though due to missing data, sample sizes for specification B drop slightly to 866,708. Including McKay Scholars increases the sample size in specification D to 956,764. The twins sample has 20,542 child observations excluding and 28,728 observations including McKay Scholars. Standard errors clustered by first district attended in parentheses, with dependent variable means in brackets. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table 4: Estimated Effects of Birth Weight and Gestational Age on Special Education Identification and Retention By Grade 4 - Sibling Fixed Effects Models

	Any Disability (1)	SLI & ASD (2)	Specific Learning Disability (3)	Intellectual (4)	Physical (5)	Other (6)	Repeat Any Grade KG - 4 (7)
(A) Log Birth Weight Only	-0.120***	-0.019***	-0.042***	-0.027***	-0.017***	-0.015***	-0.116***
(From Table 3)	(0.006)	(0.004)	(0.006)	(0.002)	(0.002)	(0.003)	(0.007)
(B) Gestational Age Only	-0.0066***	-0.0012***	-0.0018***	-0.0015***	-0.0012***	-0.0009***	-0.0065***
	(0.0005)	(0.0003)	(0.0005)	(0.0001)	(0.0001)	(0.0002)	(0.0003)
(C) *Including Both Log Birth Weight and Gestational Age*							
Log Birth Weight	-0.121***	-0.016***	-0.048***	-0.028***	-0.015***	-0.014***	-0.125***
	(0.007)	(0.005)	(0.006)	(0.003)	(0.002)	(0.003)	(0.008)
Gestational Age	0.0001	-0.0003	0.0008*	0.0001	-0.0004***	-0.0001	0.0012**
	(0.0006)	(0.0004)	(0.0005)	(0.0002)	(0.0001)	(0.0003)	(0.0006)
Dependent Variable Mean	[0.150]	[0.053]	[0.068]	[0.007]	[0.003]	[0.018]	[0.216]

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on log birth weight. Controls include month of birth, year of birth, gender, parity, controls for missing APGAR scores, a quadratic in mother's age, and sibling fixed effects. All models have sample sizes of 869,179 children, including 366,066 with siblings. Standard errors clustered by first district attended in parentheses with dependent variable means in brackets. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table 5: Estimated Effects of Log Birth Weight on Disability for All Grades K-4 - Sibling Fixed Effects Models

	Any Disability	SLI & ASD	Specific Learning Disability	Developmental Delay	Intellectual	Physical	Other	Repeat Listed Grade
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Grade Level								
Kindergarten	-0.097***	-0.026***	-0.013***	-0.015***	-0.019***	-0.018***	-0.006***	-0.059***
	(0.005)	(0.005)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)	(0.007)
	[0.101]	[0.078]	[0.008]	[0.005]	[0.004]	[0.002]	[0.004]	[0.068]
1st	-0.097***	-0.018***	-0.024***	-0.001	-0.025***	-0.017***	-0.012***	-0.031***
	(0.006)	(0.006)	(0.005)	(0.001)	(0.003)	(0.002)	(0.002)	(0.004)
	[0.122]	[0.083]	[0.023]	[0.000]	[0.005]	[0.003]	[0.008]	[0.063]
2nd	-0.105***	-0.016***	-0.032***	-	-0.026***	-0.018***	-0.013***	-0.007*
	(0.005)	(0.005)	(0.005)	-	(0.004)	(0.002)	(0.002)	(0.004)
	[0.140]	[0.077]	[0.043]	-	[0.006]	[0.003]	[0.011]	[0.036]
3rd	-0.117***	-0.016***	-0.040***	-	-0.027***	-0.018***	-0.016***	-0.032***
	(0.007)	(0.005)	(0.006)	-	(0.004)	(0.002)	(0.003)	(0.005)
	[0.146]	[0.065]	[0.057]	-	[0.007]	[0.003]	[0.015]	[0.068]
4th	-0.124***	-0.021***	-0.043***	-	-0.027***	-0.017***	-0.016***	-0.006*
	(0.006)	(0.004)	(0.007)	-	(0.003)	(0.002)	(0.003)	(0.003)
	[0.152]	[0.053]	[0.070]	-	[0.007]	[0.003]	[0.018]	[0.015]

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on log birth weight. All specifications include the baseline controls and maternal fixed effects with standard errors clustered by first district attended in parentheses and mean group-specific disability rates in brackets. N = 746,623. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table 6: Heterogeneity in the Effects of Birthweight on 4th Grade Disability

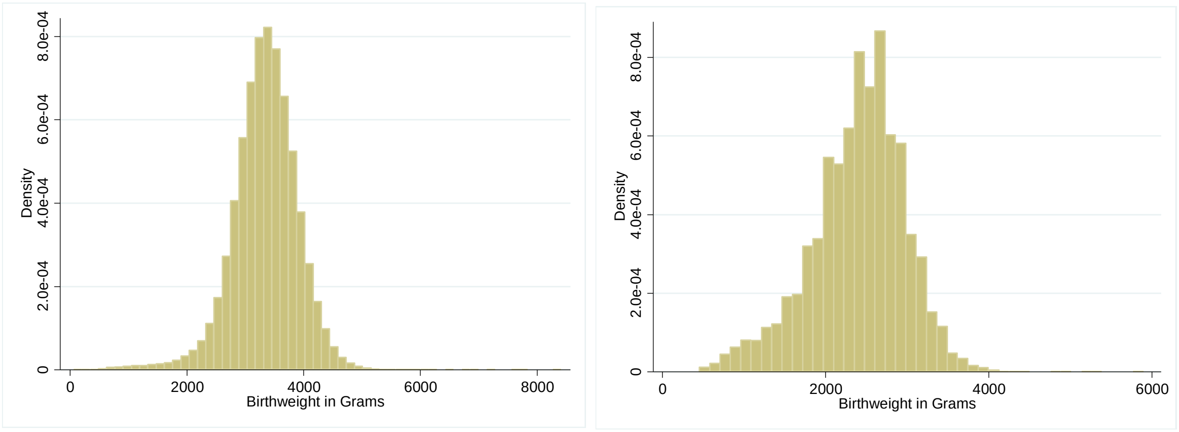
	Any Disability (1)	SLI & ASD (2)	Specific Learning Disability (3)	Intellectual (4)	Physical (5)	Other (6)	Repeat Any Grade KG - 4 (7)
Child's Gender							
Ln(Birthweight)	-0.136***	-0.011*	-0.055***	-0.030***	-0.018***	-0.022***	-0.132***
	(0.009)	(0.006)	(0.007)	(0.003)	(0.002)	(0.005)	(0.009)
Ln(BW)×Female	0.032***	-0.016**	0.026***	0.006**	0.003	0.014**	0.033***
	(0.010)	(0.008)	(0.006)	(0.003)	(0.002)	(0.005)	(0.007)
Observations	869179	869179	869179	869179	869179	869179	869179
Mother's Race/Ethnicity							
Ln(Birthweight)	-0.108***	-0.013**	-0.032***	-0.024***	-0.020***	-0.019***	-0.109***
	(0.010)	(0.005)	(0.006)	(0.003)	(0.003)	(0.003)	(0.010)
Ln(BW)×Non-Hispanic Black	-0.022*	-0.013	-0.013	-0.011**	0.008*	0.006	-0.007
	(0.013)	(0.008)	(0.009)	(0.005)	(0.005)	(0.005)	(0.012)
Ln(BW)×Hispanic	-0.026**	0.002	-0.033***	0.005	-0.003	0.003	-0.041**
	(0.013)	(0.010)	(0.009)	(0.004)	(0.007)	(0.006)	(0.018)
Ln(BW)×Other Non-White	0.096*	0.058	0.001	-0.005	0.023***	0.018*	0.081
	(0.058)	(0.054)	(0.021)	(0.019)	(0.006)	(0.011)	(0.054)
Observations	847801	847801	847801	847801	847801	847801	847801
Maternal Education							
Ln(Birthweight)	-0.125***	-0.025***	-0.036***	-0.039***	-0.013***	-0.013***	-0.129***
	(0.008)	(0.007)	(0.009)	(0.005)	(0.003)	(0.004)	(0.010)
Ln(BW)×HS Graduate	-0.008	0.002	-0.016	0.014***	-0.004	-0.004	0.014
	(0.011)	(0.006)	(0.011)	(0.005)	(0.003)	(0.006)	(0.014)
Ln(BW)×Some College	0.027***	0.009	0.003	0.017***	-0.003	0.001	0.010
	(0.010)	(0.011)	(0.011)	(0.005)	(0.004)	(0.005)	(0.013)
Ln(BW)×College Grad	0.013	0.023**	-0.007	0.022***	-0.015*	-0.009	0.035**

	(0.017)	(0.011)	(0.009)	(0.006)	(0.008)	(0.006)	(0.013)
Observations	866708	866708	866708	866708	866708	866708	866708
Mother's Marital Status							
Ln(Birthweight)	-0.126***	-0.028***	-0.044***	-0.029***	-0.015***	-0.011***	-0.123***
	(0.008)	(0.007)	(0.007)	(0.003)	(0.002)	(0.003)	(0.009)
Ln(BW)×Married	0.012	0.018**	0.004	0.003	-0.005	-0.008**	0.012
	(0.009)	(0.008)	(0.006)	(0.003)	(0.003)	(0.003)	(0.010)
Observations	866708	866708	866708	866708	866708	866708	866708
Siblings with Different Fathers							
Ln(Birthweight)	-0.112***	-0.020***	-0.033***	-0.023***	-0.020***	-0.016***	-0.117***
	(0.008)	(0.005)	(0.007)	(0.002)	(0.003)	(0.003)	(0.008)
Ln(BW)×Different Father	0.002	0.021*	-0.012	-0.012*	0.006	0.000	0.013
	(0.021)	(0.011)	(0.013)	(0.006)	(0.006)	(0.005)	(0.019)
Observations	727797	727797	727797	727797	727797	727797	727797
Age Gap for Younger Siblings†							
Ln(Birthweight)	-0.115***	-0.014	-0.020	-0.038***	-0.016***	-0.027***	-0.108***
	(0.018)	(0.010)	(0.015)	(0.007)	(0.005)	(0.007)	(0.016)
Ln(BW)×Age Gap in Years	0.004	0.001	-0.006	0.005***	0.001	0.003*	0.008
	(0.006)	(0.003)	(0.004)	(0.002)	(0.002)	(0.002)	(0.005)
Observations	869179	869179	869179	869179	869179	869179	869179

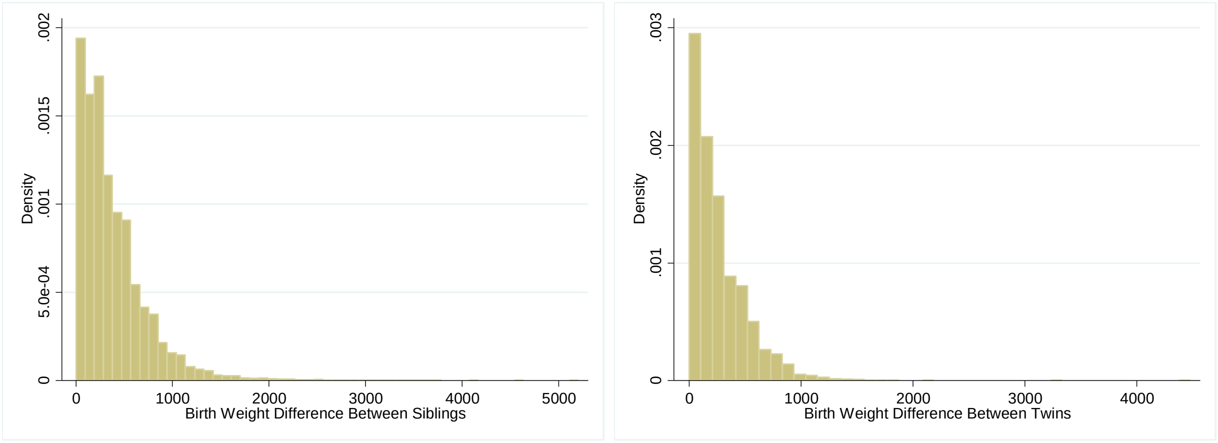
Notes: The entries in each column and panel represent estimates from a regression of a binary measure of disability on ln(birthweight) interacted with the characteristics listed in that panel. The main effects for the variables interacted with birthweight are also included (but not shown). Standard errors clustered by first district attended in parentheses. All specifications include baseline controls and sibling fixed effects. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively. † The model for "age gap for younger siblings" includes main effects and interaction effects with an indicator for being an older sibling (not shown).

Online Appendix: Not for Publication

Figure A1: Birthweight Distributions of Siblings and Twins


A. Birthweights – Siblings

B. Birthweights – Twins


C. Birthweight Differences – Siblings

D. Birthweight Differences – Twins

Table A1: The Association between Neonatal Health Conditions and Special Education Identification in Kindergarten

	Dependent Variable: Any Disability			
	(1)	(2)	(3)	(4)
Ln Birthweight (grams)	-0.040***	-0.050***	-0.086***	-0.035
	(0.003)	(0.003)	(0.006)	(0.024)
Gestational Age at Birth (weeks)	-0.002***	-0.002***	-0.000	
	(0.000)	(0.000)	(0.000)	-
Apgar 1 Score = 7 - 8	-0.008***	-0.009***	-0.010***	0.010
	(0.002)	(0.002)	(0.003)	(0.009)
Apgar 1 Score = 9 - 10	-0.021***	-0.012***	-0.010***	0.003
	(0.006)	(0.002)	(0.003)	(0.013)
Apgar 5 Score = 7 - 8	-0.043***	-0.044***	-0.023**	-0.007
	(0.005)	(0.005)	(0.010)	(0.033)
Apgar 5 Score = 9 - 10	-0.054***	-0.055***	-0.029***	-0.027
	(0.005)	(0.005)	(0.009)	(0.033)
Abnormality - Assisted Ventilation < 30 mins	0.006	0.006*	-0.002	-0.016
	(0.005)	(0.003)	(0.005)	(0.023)
Abnormality - Assisted Ventilation > 30 mins	0.028***	0.027***	0.016	0.038*
	(0.005)	(0.005)	(0.010)	(0.020)
Abnormality - Other	0.011***	0.010***	0.006	0.018
	(0.004)	(0.002)	(0.004)	(0.019)
Maternal Health - Anemia	0.007	-0.004*	-0.006	-
	(0.006)	(0.002)	(0.004)	-
Maternal Health - Diabetes	0.015***	0.013***	-0.009*	-
	(0.003)	(0.002)	(0.005)	-
Maternal Health - Hypertension	0.008***	0.004*	-0.005	-
	(0.002)	(0.002)	(0.004)	-

Maternal Health - Other	0.013***	0.004***	-0.000	-
	(0.003)	(0.001)	(0.002)	-
L&D Complication - Meconium	-0.003*	-0.001	-0.001	-
	(0.002)	(0.001)	(0.003)	-
L&D Complication - Premature Membrane Rupture	0.003	0.003	0.005	-
	(0.003)	(0.003)	(0.006)	-
L&D Complication - Breech	0.007***	0.005***	0.005	-
	(0.002)	(0.002)	(0.003)	-
L&D Complication - Other	0.002	0.002**	0.001	-
	(0.002)	(0.001)	(0.002)	-
Congenital Anomaly - Any	0.115***	0.112***	0.101***	0.071
	(0.008)	(0.007)	(0.011)	(0.044)
Baseline controls	X	X	X	X
Socioeconomic controls		X		
Zip code of birth fixed effects		X		
Sibling fixed effects			X	
Twin fixed effects				X

Notes: All estimates are from linear probability models of a binary measure of disability. Columns (1) and (4) have sample sizes of 869,179 children, including 366,064 with siblings. Due to missing data, sample sizes for columns (2) and (3) drop slightly to 866,708. Column (5) is restricted to multiple births and includes 20,542 child observations. Standard errors clustered by first district attended are listed in parentheses. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively. "Baseline controls" include month of birth, year of birth, gender, parity, controls for missing APGAR scores, and a quadratic in mother's age. For the twin fixed effect models, only missing APGAR scores, gender, and parity are included in these controls. "Socioeconomic controls" include mother's immigration status, mother's education level, mother's marital status, and child's race.

Table A2: Estimated Effects of Birthweight on Special Education Identification and Grade Retention by KG

	Any Disability (1)	SLI & ASD (2)	Specific Learning Disability (3)	Developmental Delay (4)	Intellectual (5)	Physical (6)	Other (7)	Repeat KG (8)
				Panel A: Full Sample				
A: No SES Controls or FE	-0.071***	-0.010***	-0.012***	-0.012***	-0.014***	-0.015***	-0.007***	-0.070***
	(0.003)	(0.002)	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)	(0.007)
B: Add Zip code FE and SES Controls	-0.077***	-0.017***	-0.012***	-0.012***	-0.014***	-0.016***	-0.007***	-0.060***
	(0.003)	(0.002)	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)	(0.006)
C: Add Sibling FE to specification A	-0.097***	-0.025***	-0.013***	-0.014***	-0.019***	-0.019***	-0.007***	-0.063***
	(0.005)	(0.004)	(0.003)	(0.003)	(0.002)	(0.001)	(0.002)	(0.007)
	[0.100]	[0.078]	[0.008]	[0.005]	[0.004]	[0.003]	[0.004]	[0.070]
D: Include McKay Scholars in specification C as disabled	-0.106***							
	(0.005)							
				Panel B: Twins Sample				
A: No SES Controls or FE	-0.131***	-0.026*	-0.024***	-0.033***	-0.018***	-0.023***	-0.008**	-0.072***
	(0.013)	(0.016)	(0.007)	(0.007)	(0.004)	(0.005)	(0.003)	(0.011)
B: Add Zip code FE and SES Controls	-0.129***	-0.027*	-0.024***	-0.031***	-0.017***	-0.024***	-0.007**	-0.065***
	(0.011)	(0.014)	(0.008)	(0.007)	(0.004)	(0.005)	(0.003)	(0.010)
C: Add Sibling FE to specification A	-0.035	-0.009	-0.017*	0.004	-0.003	0.002	-0.012	-0.048***
	(0.023)	(0.023)	(0.009)	(0.008)	(0.005)	(0.007)	(0.007)	(0.018)
	[0.168]	[0.125]	[0.015]	[0.012]	[0.006]	[0.005]	[0.005]	[0.087]
D: Include McKay Scholars in specification C as disabled	-0.049**							
	(0.019)							

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on ln(birthweight). For Panel A, the controls. The controls in specifications A, B, and C match those in columns (1), (2), and (3) of Table 2, respectively. In Panel B, the controls in specifications A, B, and C match those in columns for panel A and (1), (2) and (4) of Table 2, respectively for panel B. *N* = 869,179 in the full sample. The full sample includes 869,179 children, including 366,066 with siblings, though due to missing data, sample sizes for specification B drops slightly to 866,708. Including McKay Scholars increases the sample size in D to 956,764. The twins sample has 20,542 child observations excluding and 28,728 observations including McKay Scholars. Standard errors clustered by first district attended in parentheses with dependent variable means in brackets. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table A3: Estimated Effects of Birthweight and Gestational Age on Special Education Identification in Kindergarten

	Any Disability	SLI & ASD	Specific Learning Disability	Developmental Delay	Intellectual	Physical	Other	Repeat KG
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(A) Ln(Birthweight) Only	-0.097***	-0.025***	-0.013***	-0.014***	-0.019***	-0.019***	-0.007***	-0.063***
(From Table 3)	(0.005)	(0.004)	(0.003)	(0.003)	(0.002)	(0.001)	(0.002)	(0.007)
(B) Gestational Age Only	-0.0057***	-0.0011***	-0.0008***	-0.0010***	-0.0011***	-0.0013***	-0.0004***	-0.0032***
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0005)
(C) *Including Both Ln(Birthweight) and Gestational Age*								
Ln(Birthweight)	-0.093***	-0.028***	-0.012***	-0.012***	-0.019***	-0.016***	-0.007***	-0.068***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.007)
Gestational Age	-0.0005	0.0005	-0.0001	-0.0003***	-0.0001	-0.0004***	0.0000	0.0006
	(0.0004)	(0.0003)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0004)
Dependent Variable Mean	[0.100]	[0.078]	[0.008]	[0.005]	[0.004]	[0.003]	[0.004]	[0.070]

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on log birthweight. Controls include month of birth, year of birth, gender, parity, controls for missing APGAR scores, a quadratic in mother's age, and sibling fixed effects. All models have sample sizes of 869,179 children, including 366,066 with siblings. Standard errors clustered by first district attended in parentheses with dependent variable means in brackets. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table A4: The Association between Birthweight, Gestation Length, and Special Education Identification in Grade 4

Dependent Variable:	Any Disability (1)	SLI/ASD (2)	SLD (3)	Intellectual Disability (4)	Physical Disability (5)	Other Impairment (6)	Repeat Any Grade K - 4 (7)
Log Birthweight (grams)	-0.084***	-0.014***	-0.037***	-0.018***	-0.007***	-0.007*	-0.127***
	(0.008)	(0.005)	(0.007)	(0.003)	(0.001)	(0.004)	(0.011)
Log Birthweight * <31 Weeks Gestation	-0.118***	0.008	-0.019	-0.036***	-0.046***	-0.026*	-0.003
	(0.021)	(0.018)	(0.017)	(0.009)	(0.010)	(0.015)	(0.029)
Log Birthweight * 31-32 Weeks Gestation	-0.063	-0.022	-0.031	-0.011	-0.004	0.004	-0.035
	(0.040)	(0.022)	(0.037)	(0.014)	(0.008)	(0.012)	(0.045)
Log Birthweight * 33-34 Weeks Gestation	-0.035	-0.029	0.006	-0.002	-0.013	0.003	-0.019
	(0.036)	(0.022)	(0.021)	(0.009)	(0.008)	(0.015)	(0.041)
Log Birthweight * 35-36 Weeks Gestation	-0.030	0.002	0.003	-0.013	-0.006*	-0.017*	0.010
	(0.031)	(0.016)	(0.017)	(0.010)	(0.003)	(0.009)	(0.021)
Log Birthweight * 37-38 Weeks Gestation	-0.009	0.004	-0.010	-0.008*	0.006***	-0.001	0.020
	(0.012)	(0.008)	(0.008)	(0.004)	(0.001)	(0.005)	(0.012)
Log Birthweight * 39-40 Weeks Gestation	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
Log Birthweight * 41-42 Weeks Gestation	-0.016	-0.003	-0.016	0.007	0.000	-0.005	-0.046*
	(0.020)	(0.012)	(0.016)	(0.006)	(0.004)	(0.006)	(0.024)

Log Birthweight * > 42 Weeks Gestation	-0.169	-0.139	-0.028	0.001	0.022	-0.025	-0.573***
	(0.217)	(0.154)	(0.130)	(0.086)	(0.019)	(0.054)	(0.198)
<31 Weeks Gestation	0.430	-0.220	-0.080	0.186	0.322***	0.223**	-0.230
	(0.352)	(0.183)	(0.222)	(0.119)	(0.074)	(0.103)	(0.351)
33-34 Weeks Gestation	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
35-36 Weeks Gestation	-0.213	0.059	-0.274	-0.071	0.070	0.004	-0.113
	(0.458)	(0.195)	(0.365)	(0.119)	(0.079)	(0.111)	(0.453)
37-38 Weeks Gestation	-0.248	-0.183	-0.250	0.017	0.013	0.155	-0.323
	(0.291)	(0.183)	(0.260)	(0.112)	(0.060)	(0.121)	(0.313)
39-40 Weeks Gestation	-0.421	-0.198	-0.144	-0.023	-0.083	0.027	-0.406
	(0.278)	(0.183)	(0.257)	(0.102)	(0.059)	(0.081)	(0.328)
41-42 Weeks Gestation	-0.490	-0.172	-0.226	-0.084	-0.032	0.023	-0.239
	(0.299)	(0.168)	(0.282)	(0.108)	(0.063)	(0.091)	(0.345)
> 42 Weeks Gestation	-0.359	-0.149	-0.095	-0.142	-0.036	0.062	0.140
	(0.288)	(0.237)	(0.239)	(0.131)	(0.065)	(0.078)	(0.450)
Baseline controls	X	X	X	X	X	X	X
Sibling fixed effects	X	X	X	X	X	X	X

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on log birthweight. Controls include month of birth, year of birth, gender, parity, controls for missing APGAR scores, a quadratic in mother's age, and sibling fixed effects. All models have sample sizes of 869,179 children, including 366,066 with siblings. Standard errors clustered by first district attended in parentheses with dependent variable means in brackets. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table A5: Birthweight Effects Interacted with Other Health Measures - Any Disability, Grade 4

Health Condition:	Anemia	Apgar of 7 or 8	Apgar of 9 or 10	Assisted Ventilation < 30 mins	Assisted Ventilation > 30 mins	Breech	Congenital Anomaly	Drank While Pregnant
	(1)	(2)		(3)	(4)	(5)	(6)	(7)
Ln(Birthweight)	-0.121***	-0.161***		-0.121***	-0.112***	-0.113***	-0.118***	-0.120***
	(0.006)	(0.020)		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Ln(BW)×Health Condition	0.030	0.029	0.060***	0.015	-0.025	-0.070***	-0.081*	-0.042
	(0.023)	(0.022)	(0.020)	(0.023)	(0.018)	(0.020)	(0.044)	(0.047)
Health Condition Main Effect	-0.233	-0.261	-0.522***	-0.117	0.245*	0.577***	0.750**	0.338
	(0.188)	(0.176)	(0.159)	(0.188)	(0.136)	(0.163)	(0.355)	(0.374)

	Maternal Diabetes	Maternal Hyper-tension	Meconium	Premature Membrane Rupture	Other Abnormalities	Other Labor/ Delivery Complications	Other Mother's Health Conditions	Smoked While Pregnant
	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Ln(Birthweight)	-0.120***	-0.121***	-0.121***	-0.116***	-0.114***	-0.117***	-0.120***	-0.119***
	(0.005)	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)
Ln(BW)×Health Condition	0.015	0.007	0.020	-0.053***	-0.022	-0.007	-0.001	-0.003
	(0.028)	(0.017)	(0.024)	(0.017)	(0.016)	(0.011)	(0.009)	(0.018)
Health Condition Main Effect	-0.115	-0.065	-0.154	0.414***	0.201	0.062	0.004	0.029
	(0.229)	(0.137)	(0.196)	(0.134)	(0.130)	(0.091)	(0.074)	(0.141)

Notes: The entries in each column represent estimates from a regression of a binary measure of having any disability by grade 4 on ln(birthweight) interacted with the characteristics listed in that panel. Standard errors clustered by first district attended in parentheses. Controls include month of birth, year of birth, gender, parity, and a quadratic in mother's age. All specifications include baseline controls and sibling fixed effects. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Table A6: Bounds for Sample Attrition

	Baseline Estimate (From Table 3) (1)	Assign as Disabled in G4 if Low Birthweight (< 2500 g) and Observed in KG (2)	Assign as Disabled in G4 if Very Low Birthweight (< 1500 g) and Observed in KG (3)	Assign as Non-Disabled in G4 if Low Birthweight (< 2500 g) and Observed in KG (4)
		Panel A: Full Sample		
Ln(Birthweight)	-0.120***	-0.265***	-0.180***	-0.069***
	(0.006)	(0.006)	(0.005)	(0.005)
Observations	869,179	972,155	959,326	972,155
		Panel B: Twins Sample		
Ln(Birthweight)	-0.055**	-0.207***	-0.135***	-0.040*
	(0.026)	(0.021)	(0.024)	(0.023)
Observations	20,542	32,444	29,272	32,444

Notes: Each entry in the table represents an estimate from a separate regression of a binary measure of disability on log birthweight. The controls in Panel A and B match those in columns (4) and (5) of Table 2, respectively. Standard errors clustered by first district attended in parentheses. *, **, and *** denote statistical significance at the 10%, 5% and 1% level, respectively.