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Medium-term consequences of low birth weight on health and behavioral deficits – is there a catch-up effect?

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Abstract: A number of studies have documented negative long term effects of low birth weight. Yet, not much is known about the dynamics of the process leading to adverse health and educational outcomes in the long-run. While some studies find effects of the same size at both school age and young adulthood, others find a diminishing negative effect over time due to a catching-up process. The purpose of this paper is to try to resolve this puzzle by analyzing the medium term consequences of low birth weight measured as various child outcomes at ages 6 months, 3, 7 and 11, using data from the Danish Longitudinal Survey of Children. Observing the same children at different points in time allows us to chart the evolution of health and behavioral deficits among children born with low birth weight and helps inform the nature and timing of interventions.

Keywords: low birth weight, medium term effects, health and behavioral outcomes, longitudinal child-mother survey
JEL-codes: I12

1. INTRODUCTION

Low birth weight is a problem that developing and even developed societies must contend with. More than 60% of low birth weight babies are born preterm, and in recent years, there has been a rise in the number of premature infants in the population. In the U.S., the proportion of births occurring before 37 weeks gestation has risen from 11% in 1995 to 12.1% in 2002 (U.S. National Center for Health Statistics), while in Norway, premature births have gone from 7.5% in 1995 to 8.5% in 2002 (Medical Birth Registry of Norway). In Denmark, there has been a 22% increase in preterm deliveries between 1995 and 2004, and as much as 51% in the same period within first-time mothers of singletons delivered spontaneously, a group otherwise considered as low-risk (Langhoff-Roos et al., 2006). A rise in multiple births, the greater use of IVF and increased obstetric intervention are cited as contributing factors, but, overall, they explain only a small portion of the rise.

A number of studies have documented *long term* effects of low birth weight (LBW)[1], for example heightened risks of diseases in adulthood (Barker, 1999; Eriksson et al, 2001), worse self-reported health at ages 23 and 33 (Currie and Hyson, 1999), significantly lower rates of high-school completion (Conley and Bennett, 2000) and effects on health and IQ which translate into long-run labor market outcomes such as educational attainment and earnings (Behrman and Rosenzweig, 2001; Currie and Moretti, 2005; Black et al., 2007). On the other hand, due to advances in neonatal intensive care technology in industrialized countries, risks of higher mortality or poorer health in the first years of a child's life due to adverse birth outcomes have been greatly diminished. To date, there is very little knowledge about the possible *medium-term* consequences of LBW, where medium-term is interpreted as the time span between infancy/toddlers and adults. This is because until recently few child longitudinal surveys existed which were able to track children's cognitive and non-cognitive development throughout childhood.

In this paper, we access a large-scale representative survey from Denmark of approximately 6,000 children born in 1995 and followed over time until 2007. Children's outcomes are recorded at different ages—6 months, 3, 7 and 11—allowing an understanding of the evolution of health and behavioral deficits among children born with low birth weight which in turn will help inform the

[1] The standard definition of LBW is <2,500 gms.

nature and timing of interventions during this critical period of human capital formation (Carneiro and Heckman, 2003, Doyle et al. 2009).

The objective is to analyze the medium term effect of LBW on child outcomes. In particular, we bring new evidence concerning an unsolved puzzle in the literature on the existence of a catch-up effect. Breslau et al. (2004) find deficits in academic achievement test scores among LBW children compared to NBW (normal birth weight) children at age 17 which persisted with little change from age 11. On the other hand, a recent study by Samuelson et al. (2006) find that while VLBW (very low birth weight) children showed deficits at 9 years of age compared to NBW children in reading and comprehension skills, by 15 years of age these gaps were no longer significant. Similarly, Boardman et al. (2002) use 6 waves of the NLSY between 1986 and 1996 and find that LBW effects on math and reading scores for children between 6-14 years of age decline with child age.

Thus, there is scope to re-examine whether a catch-up effect exists or not. Extending the previous literature, we explore the catch-up effect on anthropomorphic measures of health as well as of *behavioral development* as measured on the psychosocial scale SDQ, bringing new evidence to the analysis of medium-term effects of LBW which so far has mainly been focused on cognitive development. As a series of recent papers show, non-cognitive development is a highly necessary pre-requisite for cognitive development, and furthermore, has been linked to future labor market success, independent of cognitive achievement (Heckman et al., 2006; Cunha and Heckman, 2008; Segal, 2006). More recently work by Currie and Stabile has shown the long-run negative test score and labor market outcomes of an ADHD diagnosis and our findings will have bearing for this discussion as well (Currie and Stabile, 2009).

As LBW itself may be a product of family structure and low socioeconomic status, we study the effects of LBW which arise net of these factors, and in some specifications, also via these factors.
The effect of birth weight on the outcome measures described above are found by estimating simple regression models on a very rich longitudinal survey which was administered to 6,011 Danish children born in 1995 implying that a fairly large sample of LBW children can be obtained compared to previous studies. The survey data is supplemented by register data from which a reliable measure of birth weight (from hospital records) can be obtained.

The paper is organized as follows: Section 2 reviews existing literature in the field, while section 3 presents data and the various outcome measures. Section 4 discusses the methodological framework, and results are found in Section 5. Finally, section 6 concludes the paper.

2. PREVIOUS RESEARCH

LBW has been linked to a number of adverse long-run developmental outcomes but only a relatively new strand of literature has begun to focus on cognitive and behavioral difficulties of LBW infants at school age (McCormick et al., 1992; Hack et al., 1995; Bhutta et al., 2002). As recent medical advances have been very successful in minimizing health problems of LBW children, the focus seems to have changed from looking only at health outcomes to investigating the extent of, primarily, learning disabilities. Even fewer studies look at behavioral deficits for example, attention deficiency (Breslau et al., 1996, is one exception). The more recent studies have benefited from the availability of child longitudinal data sets, allowing for follow-ups during various stages of childhood.

A puzzle exists in the literature regarding the existence of a catch-up effect, with studies reporting contradictory findings. A study by Klebanov et al. 1998 based on a small sample (n=374) of LBW children from the Infant Health and Development Program and focusing on the very early childhood period, find that the negative effect of birth weight on cognitive functioning decreased significantly between the ages of 1 and 3. Controlling for a rich set of socioeconomic characteristics and family risk factors including teen birth, mother's depression and neighborhood poverty, they found a significant negative effect at ages 1 which then disappeared at ages 2 and 3. The sample, however, only consisted of LBW infants.

Breslau et al. (2004) estimate the effect of LBW on academic achievement (reading and mathematics) in two racially and socio-economically disparate communities i.e. the inner city of Detroit and nearby middle-class suburbs. Standardized tests of reading and mathematics are administered at ages 11 and 17 to representative samples of LBW and NBW children (n=773). The results show that LBW children scored 3 to 5 points lower in age-standardized academic achievement tests at age 17, and that these deficits persisted almost unchanged since age 11. Moreover, these gaps arise in both urban and suburban communities, independently of family

factors and are associated with LBW-related differences in cognitive abilities (proxied by IQ scores) at age 6.

Differing evidence is again provided by Samuelson et al. (2006), who focus on reading skills among very low birth weight children (VLBW), a group that should be severely disadvantaged in comparison to NBW children. This study also investigate to what extent reading difficulties at 9 years of age persisted, became better or worse by 15 years of age. Fifty-six VLBW and 52 NBW children are evaluated on their word decoding, word recognition, and reading comprehension skills at 9 and 15 years of age. The results show that while VLBW children showed deficits in reading skill at 9 years of age, by 15 years of age, these gaps are no longer significant. In fact, VLBW children improve their reading comprehension between 9 and 15 years of age more than NBW children, and when controlling for individual differences in IQ, VLBW children improve both reading comprehension and word-recognition skills. These results seem to suggest that VBLW children improve their reading skills over time, i.e. the existence of a catch-up effect at least in terms of reading skills.

Similar recent evidence is also brought to this debate by Boardman et al. (2005) who use six waves of the NLSY Child Data (1986-1996) and estimate the impact of LBW on PIAT Math and Reading-Recognition test scores on a large sample of children aged 6 to 14. While LBW is significantly related to lower test scores in both types of tests and this relationship is robust to the inclusion of social and economic controls, the gaps in test scores between LBW and NBW children decrease in magnitude over time, indicative of a catch-up effect. The authors also find that other factors such as maternal education and race/ethnicity are much more important in explaining test scores than birth weight differences.

Another recent aspect to emerge from this literature is that there could be possible sex differences in the impact of LBW on disabilities. Johnson and Breslau (2000) investigate this issue on randomly selected samples of LBW and NBW children who were born in an urban and suburban hospital in southeast Michigan. These children are evaluated at ages 6 and 11 in terms of their reading and math disabilities according to the Wechsler Intelligence Scale and the Woodcock-Johnson Battery-Revised test. Their results show that LBW was associated with an increased risk for learning

disabilities among male children but not female children and is consistent with previous findings of the greater vulnerability of male children to pregnancy and birth complications.

Yet, McCallister Prichett, Astone and Guyer (2004) using a large cross-sectional sample of children (3,586) up to the age of 12 from the PSID 1997 Child Development Supplement find that birth weight is more important for outcomes among girls than boys, and that lower birth weight girls have more behavior problems, health problems and lower verbal and math scores while for boys, a relationship is found only for birth weight and health problems. The authors suggest two explanations which may be behind this unexpected finding: first, differential mortality of boy and girl infants may have resulted in the sickest girls having survived or, alternatively, that the incidence of twins is higher among LBW boys, and twins may exhibit more of a catch-up effect.

Our aim is to assess the impact of LBW on children's health and behavioral outcomes net of other birth, health, family structure and socioeconomic factors. Our paper adds to the literature in this area in at least four important ways. First, while many previous studies have been hampered by small samples of LBW cases and NBW controls often drawn from local populations, we use a large, nationally representative longitudinal sample of children who are followed for over a decade which allows an understanding of the dynamic processes involved in producing adverse outcomes over the full age-span of childhood as well as allowing for estimating separate impacts for boys and girls. Second, the richness of our data allows us to simultaneously assess impacts of LBW on health, as well as a multifaceted measure of psychosocial well-being instead of narrowly focusing on reading or math skills. Behavioral outcomes have been argued to be more important for child development than academic outcomes and have been shown to be the necessary prerequisites for learning academic skills. Third, our birth weight measure is highly accurate as it is based on the actual registered weight in child medical records rather than on the mother's self report, which is the case in the NLSY and other U.S. data sets (Boardman et al., 2005), so our estimates should not suffer from misreporting bias. Finally, unlike most previous studies, we have a very rich set of socioeconomic and family structure controls many of which are merged to the survey from highly reliable administrative registers including parallel information on both parents with respect to labor force status, household income, detailed educational type as well as unique survey information on parental mental illness and hospitalization for diseases. Allowing for a complete set of

socioeconomic and family factors will minimize bias in LBW impacts arising from the confounding effects of these factors.

3. DATA

The data we use in the analysis are drawn from the Danish Longitudinal Survey of Children (DALSC). This survey follows children born between September 15 and October 31 in the 1995 cohort, and is representative of children born in Denmark in that period. The survey data has been merged with register data from Statistics Denmark from 1995 to 2005. The aim of the DALSC study was to track children's physical and mental development, along with supplying basic information on other aspects of children's development, their family background and their daily family life. Typically, it was the mother who completed the questionnaire (in a few cases, where the mother was not present, the father completed it). In addition to the standard questionnaire, a special health questionnaire was administered in 2003 collecting exact health information from the first 7 years of the children's lives. The register data link-up gives us information about family structure and about the educational level and employment status of the parents.

A total of 6,011 children were randomly drawn for the DALSC in 1995. The first wave of the DALSC was carried out in 1996 when the children were about 6 months old, and included interviews with 5,428 mothers. Of these, 5,288 mothers participated in the second wave in 1999 when the children were 3½ years old, 4,971 mothers took part in the third wave in 2003 when the children were 7½ years old, and 4,802 mothers took part in the fourth wave in 2007 when the children were 11 years old. The response rate in 2007 was 80% of the original sample. Although this response rate is very high, analyses have shown that families with low socioeconomic status (e.g., single mothers) are under-represented in the 2007 sample. This means that the prevalence of children in less-privileged circumstances is lower than in the population at large, a condition that we need to keep in mind when interpreting the results.

In the analysis, data from the four waves of DALSC is used and is merged with register data from Statistics Denmark. More specifically, children's birth weight is from the first wave, while the outcome measures come from the second, third and fourth waves when the children's ages are 3½ years, 7½ years and 11 years respectively. The explanatory variables are defined on the basis of both the survey and the register data. Children with missing information on either the outcome

variables or the explanatory variables are dropped from the sample. So are the (few) children who are developmentally retarded. These deletions reduce the sample to 4,783 children: 2,297 girls and 2,486 boys.

Birth weight

The primary variable of interest in the analysis is the birth weight of the children, see Table 1. On average, the children weighed about 3,500 gms at birth – boys a little more than that, and girls a little less. The threshold for low birth weight is defined at 2,500 gms, as in other studies of low birth weight.[2] About 5% of girls and 4% of boys belong to this low weight group with an average weight of 2,000 gms. From Table 1 it can be seen that the mean birth weight in the DALSC does not differ from the cohort mean for either boys or girls. The share of LBW is slightly lower in the DALSC compared to the cohort mean possibly due to the under-sampling of mothers of low socio-economic status.

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Table 1 about here

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Outcome measures

Child outcomes include health as measured by anthropomorphic measures (z-scores for weight and height), and the psychosocial scale SDQ. The outcomes are measured at different points in time – in 1999 (when the children are 3½ years old), in 2003 (when the children are 7½ years old) and in 2007 when they are 11 years old. Means of the outcome variables are presented in Table 2.

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Table 2 about here

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[2] The threshold at 2,500 gms is the standard definition of LBW. This cutoff has been criticized for not taking into account racial/ethnic differences in maternal height, weight etc. (Rooth, 1980). Also, while most studies use the threshold measure, Barker (1999) finds a linear relationship between birth weight and adult risk of diseases and argues for exploiting the full distribution. Because of these objections, we apply several other definitions in the sensitivity analyses.

Weight and *height* are defined as z-scores, i.e. the measures are standardized by the median and standard deviation for girls and boys respectively.[3] These variables are all obtained from the special health questionnaire. At all ages, children from the low birth weight group weigh less on average and are shorter, although the raw data indicates catch-up until the age of 7 (2003).

The *SDQ*-scale is a psychosocial measure based on the Strength and Difficulties Questionnaire. The SDQ-scale ranges from 0-40, where a higher score indicates more difficulties in four areas: emotional symptoms, misconduct symptoms, hyperactivity, and peer problems. In addition to these sub-categories, a sub-category measures pro-social behavior (see www.sdqinfo.com for a thorough description). Although the Strengths and Difficulties Questionnaire is a relatively new instrument, it has already seen widespread use as a psychiatric screening of children and adolescents (Goodman, 1997; Goodman, 1999; Goodman and Scott, 1999; Mathai et al., 2002). Psychologists use the SDQ-scale for categorizing children in terms of fewer or more difficulties than what is considered normal, given the child's age. In this paper, however, we apply the continuous scale. The SDQ-questions are included in the 2003- and the 2007-questionnaire, but not in the 1999-questionnaire. However, in a previous paper, Andersen, Deding and Lausten (2007) have calculated a pseudo-SDQ score for the 3 year-olds based on similar questions about difficulties in the 1999-questionnaire. The two scales are not directly comparable, but in both cases a higher score indicates more psychosocial difficulties. LBW children score higher than average on the pseudo-SDQ scale in 1999 and on the SDQ scale (meaning worse behavior) in 2003 and 2007 in all dimensions except pro-social behavior where they are rated lower, but note that here higher values indicate better behavior.

Explanatory variables

The data include a wealth of variables in different areas taken from the four surveys. Some questions recur in all waves of the survey, while others change more or less over time. The explanatory variables used in this paper can be grouped into four categories: 1) birth variables 2) health of the mother, as a proxy for the intrauterine environment, 3) family structure, and 4) socioeconomic factors. These four groups will be described in turn.

[3] The definition of the z-score for weight is: (weight – median weight for the group)/standard deviation for the group, and likewise for the z-score for height.

The "birth" variables include LBW, the *average birth weight for siblings*, a *dummy for having no siblings*, and a *dummy for missing birth weight for siblings*. These three variables are taken from a special Fertility database at Statistics Denmark 1979-2005. The average of siblings' birth weight is included to capture an unobserved effect common to all children in the family, for example genetics. The effect of LBW on child outcome may be biased if shared family characteristics which are potentially correlated with LBW are not taken into account. For singletons, this is set to missing, and the dummy variable for missing birth weight of siblings is included as well.[4]

Information about "health" is from all four waves of the survey. For children, we observe the presence of a *physical handicap*, defined as reduced hearing, sight or completely deafness or blindness, as well as severe speech defects or being physically handicapped; and *bad child health*, defined as any kind of diagnosed illness. Having a physical handicap is time-invariant, whereas the dummy variable for bad child health can change between waves. For all waves of the survey, we have self reported information about whether the mother has been *mentally ill* since the last interview and also whether the mother has suffered from bad health in terms of having been *hospitalized* since the last interview.

The "family structure variables" exist for all four years and include whether the child is the *firstborn* and *number of siblings.* By definition, the children either live with their mother and father or with a single mother in 1996 – a *two parent family* or *single mother*.[5] As the children grow older, more of the parents divorce and in some cases the mother remarries, so that the child lives with the *mother and stepfather*. Danish municipalities are categorized according to level of urbanization. This variable, originating from the registers, groups geographical locations into three groups: *Copenhagen* (the metropolitan area), *urban areas* and *rural areas*.

The final group of variables is the socioeconomic factors. These variables are all taken from the register data. *Log household income* is defined as (log) disposable income of all household members. In addition, *family level of employment* is defined as a 0, 1, 2 variable, counting whether the mother, the father or both have been employed most of the year. Education is the highest

[4] While we have access to siblings' birth weight, unfortunately we lack information on outcome variables for siblings to allow sibling-difference estimation. Moreover, information on only 69 twin pairs is present in the survey, including NBW and LBW.

[5] We are not able to identify biological fathers other than as the man living with the child at the time of the first survey (when the child is 3-6 months old).

educational level attained and is grouped in six categories: *no education, high school, vocational education, short post-secondary education, medium post-secondary education, long post-secondary education,* and *education unknown.* Thus *family level of education* is the sum of the mother's and the father's educational level, making a categorical variable going from 0 to 12, where 0 indicates no education at all in the family and 12 indicates to parents with long post-secondary educations. Finally, dummies for missing mother or father's education are included under socioeconomic factors.[6]

Means of variables

The means of the time-invariant variables are presented in Table 3, the means of time-varying variables from the first wave (1996) in Table 4, and from the last wave (2007) in Table 5 (means for the other waves are available from authors upon request). From Table 3 we see that the birth weight for siblings is around 3,500 gms on average but approximately 2,800 gms for LBW children. Also, 40% of the children are firstborn. This number is higher for girls and boys in the LBW groups probably reflecting the fact that children of higher birth order tend to be heavier. LBW children, not unexpectedly, have a higher incidence of physical handicaps. *Mother's age at birth* is about 29 years on average, while the *father's age at birth* is 31 on average.

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Table 3 about here

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In terms of the time-varying explanatory variables, comparing 1995/96 to 2007 (Tables 4 and 5) which are the first and last years of our sample period we see naturally that the number of siblings increases over time, while the fraction of two parent families tend to decline and share of single mothers increase. More mothers are coded as mentally ill over time. Bad child health falls for the LBW children going from 1995/96 to 2007. Finally, family income (measured in levels in current prices) increases. Levels of the other variables remain stable over time.

[6]For the first wave only, we have information about smoking. First of all, there is information about whether the mother smokes. Second, we know whether smoking in the house is taking place on a regular basis, and third, we know if this is smoking with the child present. However, these variables are highly correlated with the incidence of low birth weight and therefore both cannot be included together in the regression. The smoking variables also exist for 1999, but not for the 2003 or the 2007 waves.

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Table 4 about here

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Table 5 about here

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4. RESULTS

The aim is to assess the impact of LBW net of other birth, health, family structure and socioeconomic factors on the outcomes mentioned in Section 3.[7] A condensed version of the results is shown in Table 6, where only the coefficients to the dummy for low birth weight are included. Separate estimations are generated for girls and boys. Thus, each cell in this table reports the coefficient to LBW in a child outcome regression.

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Table 6 about here

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The results show that z-scores for weight and height are the outcomes that are affected the most by low birth weight (< 2,500 gms). Compared to children with a birth weight higher than 2,500 gms, girls and boys with low birth weight have a z-score for weight (height) in 1996 of around 1.3 (1.2) standard deviations lower than the mean for girls and 1.5 (1.5) standard deviations lower than mean for boys. These effects diminish over time, and by 2003, LBW children indeed "catch-up" with respect to their z-scores on weight and height. For girls the weight (height) disadvantage reduces to 0.2 (0.2) standard deviations below the mean and for boys to 0.6 (0.6) standard deviations below the mean. Thus girls make up about 5/6ths of the disadvantage while boys regain more than two thirds of the deficit. Between 2003 and 2007, LBW boys continue to catch up to their NBW counterparts especially in terms of weight, whereas for girls there is a slight increase in the weight disadvantage.

[7] In a previous version of the paper, sets of variables were entered in succession, but this did not appear to affect the results.

There is no effect from low birth weight on the psychosocial measure, SDQ, in 1999 when the children are 3 years old or in 2003 when the children are 7 years old. Interestingly, there is a positive and significant effect in 2007 for the boys i.e. boys seem to have more psychosocial difficulties than average at the age of 11 if their birth weight was lower than 2,500 gms. On the other hand, there is no significant effect for the girls at age 11. When disaggregating SDQ into its sub-domains, we find that while LBW girls show significant emotional behavior symptoms at age 7, by age 11 this changes so LBW girls begin to display significantly more conduct disorders. In contrast, LBW boys show significant hyperactivity/inattention at age 7 which only intensifies by age 11 which may be the explanation for boy's greater learning disabilities (Johnson and Breslau, 2000). These findings can thus resolve the debate in this area between findings of McCallister et al. (2004) who find that mainly girls develop behavioral problems, and Johnson and Breslau (2000) who find that boys are more vulnerable to learning disabilities, as our results show that both girls and boys are affected but by different problems.

In Table 6, we suppressed the control variables. These are shown instead in Appendix Table GX1-GX3 (girls) and Table BX1-BX3 (boys) for the outcomes weight, height and SDQ respectively.[8] These results show that physical handicap and bad child health are consistently associated with negative outcomes, be they health or behavioral. Mothers' health through mental illness or hospitalization affects only SDQ. Boys are only affected by mothers' mental illness, whereas girls are affected both by maternal mental illness and by maternal hospitalization. The birth weight of siblings only affects the weight and height outcomes. The higher the average birth weight of siblings, the higher is the z-score for both weight and height for both boys and girls.

Family structure variables also affect child outcomes. Generally, the larger the family size, the worse the outcomes. Boys tend to be more affected by birth order than girls. Being first born increases their height and weight and at the same time also produces better behavior in terms of SDQ and its domains, except for pro-social behavior. First born girls on the other hand display mixed behavioral outcomes. The most striking result in this area is that of maternal age at birth. The higher the mother's age at birth, the better are child behavioral outcomes such as the overall SDQ score, hyperactivity and emotional behavior symptoms for boys, and all of these plus conduct problems for girls. Maternal age also has a positive and significant effect on child height. The

[8]Coefficients on the other control variables in the domain-specific SDQ regressions are available on request.

observed family structure of mother and step-father tends to accompany negative behavioral outcomes, particularly for boys. Both boys and girls in Copenhagen (the metropolitan area) seem to have more psychosocial difficulties than boys and girls in other areas.

The socioeconomic variables do not affect z-scores for weight or height as much as they affect the SDQ. The SDQ is significantly lower the higher is the family education level. This is true for both boys and girls. In addition, for boys, there are strong positive (improving) effects of household income and family employment on overall behavior and its sub-domains.

The results above underscore the importance of socioeconomic factors on children's health and behavioral outcomes. Could parental socioeconomic background mitigate the impact of LBW on child outcomes? For example, more educated families have better jobs and higher income which they can use to invest in sickly children's health. Or it could be that educated parents have greater health knowledge and are able to make more efficient health investments which improve the health of LBW children? Or even that educated families have healthier habits and different preferences for discounting and risk-aversion which are health-preserving (Case et al., 2002; Cutler and Lleras-Muney, forthcoming).[9] These theories would indicate that the impact of LBW on child health in particular would be lower the greater the family level of education. To test this hypothesis, LBW effects are interacted with family level of education in Table 7 below. The results show that for girls in particular, there is some evidence of an attenuating effect of family education of LBW effects on SDQ, hyperactivity and conduct problems, while for boys, hardly any significant interaction effects are seen. For girls' health, however, family education tends to be associated with lower weight and height z-scores which may be indicative of some selection, i.e. that educated families experience higher survival rates of the smaller LBW children.[10]

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Table 7 about here

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[9] Another linkage could be that education changes fertility choices towards a preference for quality rather than quantity of children, but our models control for family size and birth order.

[10] Interactions of LBW with other explanatory variables in our models have been tried, such as family concurrent employment, family structure (single mother, mother with stepfather) etc., but only in the case of family education do we minimize concerns of endogeneity as parental education is typically completed prior to birth and shows little change over the sample period, see means of parental education variables over time in Tables 4 and 5.

Thus, the results show some consistent patterns in all of these estimations. Similar to Hack et al. (1995), Boardman et al. (2006), we find, however, that although LBW does produce negative effects and some of which worsen over time, many other social factors produce just as large if not larger effects, in particular, whether the mother was mentally ill, was hospitalized for an illness, maternal age, family educational level and family level of employment. And, as other researchers in this area, we are able to maximally explain about 13% of the variation in outcomes with the best fitting model. A positive finding is that LBW and the other variables included explain a larger share of the observed variation in outcomes in the earliest year of the sample (1996) and that the explanatory power of the model declines with each year thereafter which we interpret as the declining importance over time of a bad start in life.[11]

5. SENSITIVITY ANALYSIS

In the following, the sensitivity of the findings is tested to different ways of defining the sample and the variables. First, we explore whether changing cutoffs for LBW, to <2,400 gms and <2,600 gms, and then reverting back to <2,500 gms but omitting the HBW (<4,500 gms), change our findings. The 2,400 threshold is presented in table 8, while the other two are available from authors upon request. These results lend further credence to our findings as in no case are the results affected appreciably. Of course there are small differences. The results get sharper respectively weaker, when the cutoff is placed at <2,400 gms versus at <2,600 gms or when the HBW are removed from the sample.

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Table 8 about here

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An alternative to using a specific threshold for defining low birth weight is to use birth weight as a continuous variable in the analyses. In these estimations, we allow birth weight to affect outcomes across the whole distribution. The result (presented in table 9) show very similar results although all

[11] We have information on whether the mother smoked in 1996, but this is likely to reflect whether she smoked previous to or during the pregnancy and therefore cannot be considered exogenous to the child outcome.

coefficients now have the opposite sign. In general, our results seem very robust to specification of the low birth weight variable.

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Table 9 about here

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Next, when the models are estimated using gestation (in weeks) instead of the dummy for low birth weight, number of gestation weeks as expected significantly affect girls' SDQ in 2003, i.e. the fewer the gestation weeks the more psychosocial difficulties girls have. On the other hand, boys' problems with hyperactivity are insignificant in this specification. All other results on gestation weeks correspond to the results of low birth weight.

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Table 10 about here

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We have also replaced LBW by fetal growth which is measured by birth weight for gestation age. By defining LBW as those children who are small for gestational age, we identify those children who are small for genetic/maternal/placental/environmental reasons as opposed to those who born low-weight because of incomplete gestation. The first group should experience more severe neurological and psychosocial difficulties and less catch-up. The findings indeed confirm our supposition and show stronger and more significant effects compared to Table 6.

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Table 11 about here

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In our final specification test, we look at the effect of attrition in the survey. In Section 3 it was mentioned that although the DALSC was representative in the first wave, families with low socioeconomic status (e.g., single mothers) become under-represented over time, i.e., differential attrition from the sample. To check that our results are not being driven by a compositional effect,

the models for each year are estimated on the balanced sample of the mothers who are present in all waves (results are available from authors upon request). Although significance suffers due to the smaller sample size, 777 girls and 802 boys, the results remain essentially the same. Thus, differences in the sample composition over time do not affect our findings.

6. DISCUSSION AND CONCLUSIONS

We use a large, representative, longitudinal sample of Danish children born in 1995 and followed through 2006 to study the medium-term consequences of low birth weight and to bring new evidence to the recent literature on whether a catch-up effect exists in LBW effects on child outcomes over time. We extend this literature by considering both health and behavioral outcomes, and by exploiting an especially rich and highly reliable set of measures. Our findings show that low birth weight children exhibit a significant catch-up with respect to their physical growth although the catch-up effect slackens at age 11. However, over time, behavioral problems increase. For LBW children significant psychosocial problems appear at the age of school start. However, when looking at behavioral sub-domains, we see that the kinds of problems LBW girls and boys face are different. While LBW girls initially face emotional behavioral symptoms which manifest themselves later as conduct disorders, LBW boys suffer from hyperactivity/inattention problems at an early age, which only intensify with time. Thus, interventions must start early, and must be focused on somewhat different areas for the two genders.

Furthermore, we build in interactions of the birth weight measure and family education and find some evidence of an attenuating effect of family education on LBW effects for girls. A comprehensive set of sensitivity checks, experimenting with different LBW measures and sample composition support the robustness of the findings.

Overall, however, LBW effects, while independent of family structure and mother's socioeconomic characteristics, explain only a small fraction of the variation in child outcomes. Furthermore, our results show that mother's mental and physical health, the structure of the family, the family's educational attainment and labor market situation produce at least as strong or even stronger effects on child outcomes. Thus, we join the group of researchers, Hack et al. (1995) and Boardman et al.

(2006), in concluding that the biological disadvantage generated by a low birth weight plays only a minor role in explaining the inequities in outcomes that start early in life.

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Table 1. Distribution of birth weight among children born in 1995

	Girls			Boys		
	Cohort	Sample	LBW	Cohort	Sample	LBW
Average weight	3,420	3,461	2,002	3,550	3,583	2,012
(std dev)	(567)	(578)	(425)	(603)	(601)	(423)
Share of low weight children	5.42	5.09		4.20	4.14	
Number of children	33,617	2,297	117	35,591	2,486	103

Table 2. Outcomes, 1996, 1999, 2003, and 2007 (standard deviations in parentheses)

	Girls		Boys	
	All	LBW	All	LBW
1996				
Weight (z-score)	-0.07 (1.00)	-1.38 (1.12)	0.02 (1.00)	-1.56 (1.13)
Height (z-score)	0.01 (1.00)	-1.29 (1.11)	-0.08 (1.00)	-1.61 (1.10)
1999				
Weight (z-score)	0.14 (1.00)	-0.34 (1.06)	0.01 (1.00)	-0.84 (0.82)
Height (z-score)	0.12 (1.00)	-0.32 (0.96)	-0.12 (1.00)	-0.98 (1.09)
SDQ (pseudo)	9.32 (5.11)	9.95 (5.85)	10.33 (5.58)	10.58 (6.12)
2003				
Weight (z-score)	0.03 (1.00)	-0.23 (1.10)	0.22 (1.00)	-0.33 (0.86)
Height (z-score)	0.02 (1.00)	-0.24 (1.09)	0.01 (1.00)	-0.58 (1.11)
SDQ	6.04 (4.68)	7.03 (5.72)	6.80 (5.10)	7.51 (5.40)
--Pro-social behavior	9.06 (1.26)	9.04 (1.46)	8.45 (1.62)	8.42 (1.80)
--Peer relationship problems	0.64 (1.13)	0.71 (1.32)	0.81 (1.34)	0.77 (1.23)
--Hyperactivity/inattention	2.19 (2.26)	2.54 (2.59)	2.83 (2.61)	3.35 (2.92)
--Emotional behavior symptoms	1.92 (1.96)	2.35 (2.42)	1.80 (1.91)	2.03 (2.14)
--Conduct disorder	1.29 (1.41)	1.44 (1.44)	1.37 (1.48)	1.37 (1.34)
2007				
Weight (z-score)	0.10 (1.00)	-0.23 (0.98)	0.13 (1.00)	-0.22 (0.89)
Height (z-score)	-0.07 (1.00)	-0.35 (1.06)	0.01 (1.00)	-0.51 (1.00)
SDQ	5.57 (4.68)	6.87 (6.03)	6.36 (5.03)	7.33 (5.84)
--Pro-social behavior	9.27 (1.11)	9.05 (1.35)	8.83 (1.32)	9.02 (1.25)
--Peer relationship problems	0.80 (1.33)	1.09 (1.68)	0.95 (1.47)	1.04 (1.59)
--Hyperactivity/inattention	1.83 (2.05)	2.13 (2.42)	2.67 (2.43)	3.38 (2.72)
--Emotional behavior symptoms	2.07 (2.00)	2.41 (2.43)	1.82 (1.92)	1.88 (2.05)
--Conduct disorder	0.87 (1.14)	1.23 (1.46)	0.92 (1.19)	1.03 (1.19)

Table 3. Time-invariant explanatory variables (standard deviations in parentheses)

	Girls				Boys			
	All		LBW		All		LBW	
Average birth weight for siblings[1]	3,521	(561)	2,826	(669)	3,490	(551)	2,801	(643)
Dummy for no siblings	0.09	(0.29)	0.09	(0.28)	0.11	(0.31)	0.15	(0.35)
Missing birth weight for siblings	0.01	(0.10)	0.03	(0.16)	0.01	(0.10)	0.01	(0.10)
Dummy for being firstborn	0.40	(0.49)	0.49	(0.50)	0.41	(0.49)	0.49	(0.50)
Dummy for physical handicap	0.05	(0.23)	0.12	(0.33)	0.07	(0.25)	0.12	(0.32)
Mother's age at birth	29.32	(4.63)	29.35	(5.73)	29.46	(4.50)	30.30	(4.92)
Father's age at birth	30.59	(8.17)	29.46	(10.86)	30.36	(8.77)	30.33	(9.36)

[1] Summary for all siblings, 1980-2001, excluding zeros for singletons

Table 4. Time-varying explanatory variables, 1995-1996 (standard deviations in parentheses)

	Girls				Boys			
	All		LBW		All		LBW	
Health variables:								
Dummy for bad child health (1996)	0.03	(0.16)	0.08	(0.27)	0.04	(0.19)	0.10	(0.30)
Mother mentally ill (1996)	0.02	(0.14)	0.06	(0.24)	0.02	(0.15)	0.01	(0.10)
Family structure:								
Number of siblings (1996)	0.83	(0.88)	1.00	(0.95)	0.81	(0.86)	1.00	(0.93)
Two parent family (1996)	0.97	(0.18)	0.93	(0.25)	0.96	(0.20)	0.95	(0.22)
Single mother (1996)	0.03	(0.18)	0.07	(0.25)	0.04	(0.20)	0.05	(0.22)
Copenhagen (1996)	0.29	(0.45)	0.37	(0.48)	0.31	(0.46)	0.35	(0.48)
Urban area (1996)	0.35	(0.48)	0.34	(0.48)	0.35	(0.48)	0.32	(0.47)
Rural area (1996)	0.36	(0.48)	0.29	(0.46)	0.34	(0.47)	0.33	(0.47)
Family income (1996)	240,109	(76,075)	223,710	(77,427)	237,817	(73,846)	227,216	(59,632)
Family employment (1996)	1.65	(0.57)	1.54	(0.64)	1.64	(0.58)	1.68	(0.56)
Family level of education (1996)	5.44	(2.04)	4.95	(1.91)	5.40	(2.02)	5.10	(1.84)
Mother’s education unknown (1996)	0.00	(0.07)	0.00	(0.00)	0.00	(0.06)	0.00	(0.00)
Father’s education unknown (1996)	0.01	(0.11)	0.02	(0.13)	0.02	(0.13)	0.04	(0.19)

Table 5 Time-varying explanatory variables, 2007[1] (standard errors in parentheses)

	Girls				Boys			
	All		LBW		All		LBW	
Health variables:								
Dummy for bad child health (2007)	0.05	(0.21)	0.06	(0.24)	0.04	(0.20)	0.07	(0.25)
Mother mentally ill (2003)	0.20	(0.40)	0.18	(0.39)	0.19	(0.39)	0.15	(0.35)
Mother hospitalised (2003)	0.16	(0.36)	0.19	(0.39)	0.15	(0.35)	0.14	(0.34)
Family structure:								
Number of siblings (2005)	1.32	(0.88)	1.43	(0.92)	1.24	(0.95)	1.22	(0.80)
Two parent family (2005)	0.76	(0.43)	0.68	(0.47)	0.76	(0.43)	0.72	(0.45)
Single mother (2005)	0.15	(0.35)	0.17	(0.38)	0.14	(0.35)	0.18	(0.39)
Mother and stepfather (2005)	0.10	(0.29)	0.15	(0.36)	0.10	(0.30)	0.10	(0.30)
Copenhagen (2005)	0.27	(0.44)	0.36	(0.48)	0.29	(0.45)	0.32	(0.47)
Urban area (2005)	0.32	(0.47)	0.31	(0.46)	0.32	(0.47)	0.33	(0.47)
Rural area (2005)	0.40	(0.49)	0.32	(0.47)	0.38	(0.49)	0.34	(0.48)
Socioeconomic variables:								
Family income (2005)	416,800	(333,917)	382,435	(133,817)	419,421	(370,723)	386,015	(137,834)
Family employment (2005)	1.67	(0.58)	1.56	(0.68)	1.65	(0.58)	1.64	(0.54)
Family level of education (2005)	5.44	(2.17)	4.92	(2.15)	5.45	(2.15)	5.20	(1.92)
Mother's education unknown (2005)	0.02	(0.15)	0.03	(0.18)	0.03	(0.17)	0.02	(0.14)
Father's education unknown (2005)	0.01	(0.07)	0.00	(0.00)	0.00	(0.07)	0.00	(0.00)

[1] Note, that not all information is available for the year 2007. In this case, we use information from the latest year available

Table 6. Effect of low birth weight (< 2,500 gms) on child outcomes

Girls	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.291	***	-0.426	***	-0.239	**	-0.313	***
Height (z-score)	-1.224	***	-0.388	***	-0.199	**	-0.196	*
SDQ[1]			0.550		0.617		0.701	
--Pro-social behavior					0.025		-0.180	
--Peer relationship problems					-0.030		0.134	
--Hyperactivity/inattention					0.215		0.092	
--Emotional behavior symptoms					0.333	*	0.198	
--Conduct disorder					0.099		0.277	**
Boys	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.534	***	-0.871	***	-0.603	***	-0.394	***
Height (z-score)	-1.473	***	-0.929	***	-0.626	***	-0.523	***
SDQ			0.094		0.640		0.903	*
--Pro-social behavior					-0.078		0.176	
--Peer relationship problems					-0.100		0.046	
--Hyperactivity/inattention					0.541	**	0.755	***
--Emotional behavior symptoms					0.179		-0.012	
--Conduct disorder					0.020		0.114	

[1] Note that in 1999, the outcome is pseudo-SDQ.

Table 7. Interaction between LBW and family education on child outcomes

Girls		1996		1999		2003		2007	
Child outcome:		Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	Lbw	-1.070	***	0.335		0.072		-0.310	
	lbwfamedc	-0.044		-0.145	*	-0.061		0.000	
Height (z-score)	Lbw	-1.135	***	0.081		0.232		0.209	
	lbwfamedc	-0.017		-0.090		-0.082	*	-0.077	
SDQ	Lbw			1.127		1.719		3.904	***
	lbwfamedc			-0.114		-0.214		-0.613	**
--Pro-social behavior	lbw					-0.072		0.041	
	lbwfamedc					0.019		-0.042	
--Peer relationship problems	lbw					0.319		0.658	
	lbwfamedc					-0.068		-0.100	
--Hyperactivity/inattention	lbw					0.260		1.171	*
	lbwfamedc					-0.009		-0.207	*
--Emotional behavior symptoms	lbw					0.645		1.048	*
	lbwfamedc					-0.061		-0.163	
--Conduct disorder	lbw					0.495		1.028	***
	lbwfamedc					-0.077		-0.144	**

Boys		1996		1999		2003		2007	
Child outcome:		Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	lbw	-1.121	***	-0.486		-1.083	***	-0.433	
	lbwfamedc	-0.080		-0.073		0.091	*	0.007	
Height (z-score)	lbw	-1.936	***	-0.640		-0.872	***	-0.961	***
	lbwfamedc	0.087		-0.053		0.047		0.083	
SDQ	lbw			1.118		-0.453		1.562	
	lbwfamedc			-0.200		0.207		-0.124	
--Pro-social behavior	lbw					0.461		0.299	
	lbwfamedc					-0.102		-0.023	
--Peer relationship problems	lbw					-0.661	*	-0.168	
	lbwfamedc					0.106		0.040	
--Hyperactivity/inattention	lbw					0.417		0.765	
	lbwfamedc					0.023		-0.002	
--Emotional behavior symptoms	lbw					-0.394		0.531	
	lbwfamedc					0.109		-0.102	
--Conduct disorder	lbw					0.185		0.434	
	lbwfamedc					-0.031		-0.060	

Table 8. Sensitivity test with birth weight <2,400 gms

Girls	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.446	***	-0.572	***	-0.357	***	-0.364	***
Height (z-score)	-1.390	***	-0.510	***	-0.350	***	-0.220	*
SDQ			0.541		0.923	*	1.003	*
--Pro-social behavior					0.058		-0.145	
--Peer relationship problems					0.028		0.085	
--Hyperactivity/inattention					0.296		0.228	
--Emotional behavior symptoms					0.414	**	0.303	
--Conduct disorder					0.186		0.387	***
Boys	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.709	***	-0.912	***	-0.651	***	-0.439	***
Height (z-score)	-1.556	***	-0.993	***	-0.714	***	-0.596	***
SDQ			0.106		0.740		0.841	
--Pro-social behavior					0.038		0.179	
--Peer relationship problems					-0.126		-0.059	
--Hyperactivity/inattention					0.545	*	0.724	**
--Emotional behavior symptoms					0.283		0.004	
--Conduct disorder					0.038		0.171	

Table 9. Sensitivity test with linear birth weight (bw/1,000)

Girls	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (zscore)	0.875	***	0.623	***	0.385	***	0.292	***
Height (zscore)	0.849	***	0.552	***	0.372	***	0.297	***
SDQ			-0.501	**	-0.387	**	-0.269	
--Prosocial behavior					-0.020		-0.025	
--Peer relationship problems					0.040		0.040	
--Hyperactivity/inattention					-0.257	***	-0.217	***
--Emotional behavior symptoms					-0.118		0.041	
--Conduct disorder					-0.052		-0.133	***
Boys	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (zscore)	0.865	***	0.634	***	0.452	***	0.344	***
Height (zscore)	0.836	***	0.519	***	0.437	***	0.387	***
SDQ			-0.353	*	-0.498	***	-0.506	***
--Prosocial behavior					0.066		-0.017	
--Peer relationship problems					0.030		-0.017	
--Hyperactivity/inattention					-0.343	***	-0.336	***
--Emotional behavior symptoms					-0.078		-0.077	
--Conduct disorder					-0.107	**	-0.076	*

Table 10: Sensitivity test med gestation age dummy for gestation age < 35 weeks

Girls	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.477	***	-0.431	**	-0.055		-0.022	
Height (z-score)	-1.326	***	-0.493	***	-0.183		-0.143	
SDQ			0.864		1.191	**	0.625	
--Pro-social behavior					0.093		-0.106	
--Peer relationship problems					0.123		-0.064	
--Hyperactivity/inattention					0.433		0.085	
--Emotional behavior symptoms					0.426	*	0.275	
--Conduct disorder					0.209		0.328	**
Boys	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.441	***	-0.593	***	-0.466	***	-0.317	**
Height (z-score)	-1.464	***	-0.772	***	-0.556	***	-0.454	***
SDQ			-0.467		0.191		0.238	
--Pro-social behavior					-0.097		0.128	
--Peer relationship problems					0.039		0.162	
--Hyperactivity/inattention					-0.078		0.259	
--Emotional behavior symptoms					0.197		-0.103	
--Conduct disorder					0.033		-0.080	

Table 11: Sensitivity test med fetal growth = ((bw/1,000)/gestation age)

Girls	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.327	***	-0.584	***	-0.403	***	-0.333	***
Height (z-score)	-1.234	***	-0.504	***	-0.355	***	-0.247	**
SDQ			0.040		0.930	**	0.799	*
--Pro-social behavior					0.087		-0.057	
--Peer relationship problems					0.049		0.060	
--Hyperactivity/inattention					0.331		0.267	
--Emotional behavior symptoms					0.354	**	0.160	
--Conduct disorder					0.196		0.311	***
Boys	1996		1999		2003		2007	
Child outcome:	Coef.		Coef.		Coef.		Coef.	
Weight (z-score)	-1.530	***	-0.965	***	-0.660	***	-0.479	***
Height (z-score)	-1.448	***	-0.963	***	-0.695	***	-0.568	***
SDQ			-0.261		0.321		0.939	*
--Pro-social behavior					0.184		0.300	**
--Peer relationship problems					-0.201		-0.057	
--Hyperactivity/inattention					0.420		0.846	***
--Emotional behavior symptoms					0.060		0.086	
--Conduct disorder					0.043		0.063	

APPENDIX

Table GX1. OLS estimation of z-score for weight. Girls

	1996		1999		2003		2007	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	0.581	(0.969)	1.529	(1.524)	0.575	(0.910)	0.927	(1.051)
Birth variables:								
Low birth weight	-1.291	(0.095) ***	-0.426	(0.144) ***	-0.239	(0.099) **	-0.313	(0.110) ***
Average siblings birth weight	0.000	(0.000) ***	0.000	(0.000) **	0.000	(0.000)	0.000	(0.000) **
Missing birth weight for siblings	0.045	(0.216)	0.064	(0.322)	-0.259	(0.229)	-0.083	(0.259)
Health variables:								
Physical handicap	-0.224	(0.090) **	-0.098	(0.134)	-0.020	(0.096)	0.085	(0.105)
Bad child health	-0.202	(0.124)	0.029	(0.141)	-0.057	(0.105)	-0.046	(0.103)
Mother mentally ill	-0.102	(0.137)	-0.059	(0.099)	0.010	(0.056)	-0.023	(0.060)
Mother hospitalized			-0.012	(0.094)	-0.099	(0.060) *	-0.054	(0.065)
Family structure:								
Firstborn	0.019	(0.061)	0.053	(0.078)	-0.128	(0.053) **	-0.099	(0.055) *
Number of siblings	-0.010	(0.035)	-0.066	(0.050)	-0.095	(0.032) ***	-0.077	(0.029) ***
Single mother	-0.264	(0.196)	0.274	(0.176)	0.035	(0.102)	-0.187	(0.114)
Mother and stepfather			0.535	(0.241) **	-0.047	(0.093)	0.052	(0.086)
Copenhagen	0.218	(0.052) ***	0.013	(0.078)	-0.059	(0.057)	0.125	(0.061) **
Rural area	0.000	(0.048)	-0.014	(0.071)	0.029	(0.052)	0.188	(0.055) ***
Mothers age at birth	0.003	(0.006)	0.002	(0.008)	0.005	(0.006)	0.004	(0.006)
Fathers age at birth	-0.005	(0.005)	0.002	(0.005)	-0.008	(0.003) **	-0.010	(0.003) ***
Family socioeconomic variables:								
Log household income	-0.076	(0.081)	-0.167	(0.125)	-0.016	(0.073)	-0.028	(0.084)
Family level of employment	-0.004	(0.042)	0.150	(0.081) *	-0.050	(0.056)	-0.082	(0.065)
Family educational level	0.019	(0.012)	0.026	(0.018)	-0.002	(0.013)	-0.039	(0.015) ***
Missing level of education for mother	0.193	(0.302)	-0.107	(0.590)	0.038	(0.413)	-0.330	(0.446)
Missing level of education for father	0.339	(0.192) *	-0.335	(0.582)	0.382	(0.283)	-0.084	(0.319)
R-squared	0.111		0.014		0.011		0.024	

Table GX2. OLS estimation of z-score for height. Girls

	1996			1999			2003			2007		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Intercept	-0.953	(1.103)		0.950	(1.276)		-0.604	(0.919)		0.045	(1.049)	
Birth variables:												
Low birth weight	-1.224	(0.113)	***	-0.388	(0.123)	***	-0.199	(0.099)	**	-0.196	(0.109)	*
Average siblings birth weight	0.000	(0.000)	***	0.000	(0.000)	***	0.000	(0.000)	***	0.000	(0.000)	***
Missing birth weight for siblings	0.245	(0.249)		0.048	(0.257)		0.060	(0.224)		-0.063	(0.259)	
Health variables:												
Physical handicap	-0.050	(0.105)		-0.145	(0.115)		-0.148	(0.096)		-0.199	(0.107)	*
Bad child health	-0.203	(0.149)		0.140	(0.123)		-0.196	(0.105)	*	-0.216	(0.103)	**
Mother mentally ill	0.195	(0.165)		-0.043	(0.082)		-0.021	(0.056)		-0.008	(0.060)	
Mother hospitalized				0.031	(0.079)		-0.061	(0.060)		0.017	(0.064)	
Family structure:												
Firstborn	-0.001	(0.072)		0.107	(0.066)		0.022	(0.052)		-0.037	(0.055)	
Number of siblings	-0.013	(0.043)		-0.070	(0.042)	*	-0.072	(0.032)	**	-0.089	(0.029)	***
Single mother	-0.417	(0.240)	*	-0.035	(0.148)		0.128	(0.103)		0.036	(0.112)	
Mother and stepfather				0.207	(0.208)		0.041	(0.093)		0.217	(0.086)	**
Copenhagen	-0.004	(0.059)		-0.072	(0.067)		-0.075	(0.057)		0.132	(0.061)	**
Rural area	-0.132	(0.055)	**	-0.050	(0.060)		-0.042	(0.052)		0.040	(0.055)	
Mothers age at birth	0.010	(0.007)		0.024	(0.007)	***	0.006	(0.006)		0.004	(0.006)	
Fathers age at birth	-0.005	(0.005)		-0.004	(0.004)		-0.001	(0.003)		-0.002	(0.003)	
Family socioeconomic variables:												
Log household income	0.044	(0.092)		-0.139	(0.105)		0.019	(0.074)		-0.046	(0.084)	
Family level of employment	-0.040	(0.049)		0.082	(0.067)		0.014	(0.057)		0.120	(0.064)	*
Family educational level	0.001	(0.014)		0.001	(0.015)		0.023	(0.013)	*	0.005	(0.014)	
Missing level of education for mother	0.197	(0.363)		0.178	(0.502)		0.073	(0.412)		-0.381	(0.447)	
Missing level of education for father	0.285	(0.233)		0.550	(0.338)		0.114	(0.283)		0.104	(0.336)	
R-squared	0.107			0.020			0.009			0.018		

Table GX3. OLS estimation of SDQ. Girls

	1999			2003			2007		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Intercept	20.473	(5.216)	***	16.752	(3.979)	***	20.373	(4.533)	***
Birth variables:									
Low birth weight	0.550	(0.507)		0.617	(0.432)		0.701	(0.474)	
Average siblings birth weight	0.000	(0.000)		0.000	(0.000)		0.000	(0.000)	
Missing birth weight for siblings	-1.474	(1.098)		-1.206	(0.977)		-1.022	(1.199)	
Health variables:									
Physical handicap	1.824	(0.479)	***	2.331	(0.419)	***	1.876	(0.459)	***
Bad child health	2.416	(0.504)	***	2.522	(0.454)	***	2.569	(0.449)	***
Mother mentally ill	0.593	(0.335)	*	1.237	(0.242)	***	0.545	(0.259)	**
Mother hospitalized	0.286	(0.332)		0.663	(0.259)	**	0.263	(0.278)	
Family structure:									
Firstborn	-0.229	(0.279)		0.346	(0.227)		0.290	(0.236)	
Number of siblings	-0.005	(0.165)		-0.121	(0.136)		-0.021	(0.125)	
Single mother	-1.166	(0.560)	**	-0.541	(0.441)		-0.957	(0.484)	**
Mother and stepfather	-0.681	(0.782)		0.419	(0.396)		1.045	(0.369)	***
Copenhagen	1.119	(0.279)	***	0.344	(0.246)		0.236	(0.265)	
Rural area	-0.148	(0.258)		-0.137	(0.225)		-0.052	(0.236)	
Mothers age at birth	-0.164	(0.029)	***	-0.087	(0.025)	***	-0.046	(0.027)	*
Fathers age at birth	-0.004	(0.016)		-0.007	(0.014)		-0.005	(0.014)	
Family socioeconomic variables:									
Log household income	-0.419	(0.431)		-0.520	(0.320)		-0.856	(0.365)	**
Family level of employment	-0.040	(0.261)		-0.288	(0.243)		-0.477	(0.276)	*
Family educational level	-0.271	(0.064)	***	-0.303	(0.057)	***	-0.317	(0.062)	***
Missing level of education for mother	1.745	(1.777)		0.400	(1.595)		1.068	(2.008)	
Missing level of education for father	-1.600	(1.269)		-2.264	(1.261)	*	-3.339	(1.370)	**
R-squared	0.060			0.099			0.085		

Table BX1. OLS estimation of z-score for weight. Boys

	1996		1999		2003		2007	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	-1.037	(0.927)	1.780	(1.378)	1.469	(0.957)	1.774	(1.009) *
Birth variables:								
Low birth weight	-1.534	(0.098) ***	-0.871	(0.149) ***	-0.603	(0.104) ***	-0.394	(0.114) ***
Average siblings birth weight	0.000	(0.000) ***	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
Missing birth weight for siblings	0.456	(0.204) **	-0.027	(0.421)	0.485	(0.222) **	-0.023	(0.246)
Health variables:								
Physical handicap	-0.324	(0.076) ***	0.012	(0.118)	-0.006	(0.082)	0.078	(0.089)
Bad child health	-0.037	(0.101)	0.001	(0.151)	0.102	(0.098)	-0.087	(0.108)
Mother mentally ill	-0.079	(0.129)	0.054	(0.091)	-0.018	(0.055)	0.045	(0.060)
Mother hospitalized			0.078	(0.089)	-0.075	(0.059)	0.029	(0.063)
Family structure:								
Firstborn	-0.076	(0.058)	0.025	(0.074)	0.031	(0.051)	0.047	(0.053)
Number of siblings	-0.113	(0.033) ***	-0.026	(0.046)	-0.068	(0.034) **	-0.059	(0.025) **
Single mother	0.193	(0.178)	-0.014	(0.158)	0.062	(0.099)	-0.009	(0.103)
Mother and stepfather			-0.402	(0.280)	0.050	(0.089)	0.128	(0.081)
Copenhagen	0.200	(0.048) ***	0.017	(0.075)	0.031	(0.054)	0.075	(0.058)
Rural area	0.025	(0.046)	0.014	(0.068)	0.036	(0.051)	0.057	(0.054)
Mothers age at birth	-0.006	(0.006)	0.000	(0.009)	0.013	(0.006) **	0.011	(0.006) *
Fathers age at birth	0.008	(0.004) *	-0.003	(0.005)	-0.003	(0.003)	0.003	(0.003)
Family socioeconomic variables:								
Log household income	0.067	(0.077)	-0.152	(0.113)	-0.126	(0.078)	-0.157	(0.082) *
Family level of employment	-0.008	(0.040)	0.055	(0.074)	0.042	(0.054)	0.076	(0.060)
Family educational level	0.000	(0.012)	0.010	(0.018)	-0.006	(0.013)	-0.040	(0.014) ***
Missing level of education for mother	0.180	(0.314)	-0.525	(0.995)	0.431	(0.338)	-0.220	(0.586)
Missing level of education for father	0.123	(0.160)	0.041	(0.339)	-0.328	(0.282)	-0.017	(0.355)
R-squared	0.135		0.023		0.018		0.014	

Table BX2. OLS estimation of z-score for height. Boys

	1996			1999			2003			2007		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Intercept	-1.733	(1.068)		-0.042	(1.128)		0.128	(0.957)		-0.576	(0.998)	
Birth variables:												
Low birth weight	-1.473	(0.119)	***	-0.929	(0.122)	***	-0.626	(0.105)	***	-0.523	(0.114)	***
Average siblings birth weight	0.000	(0.000)	***	0.000	(0.000)	**	0.000	(0.000)	**	0.000	(0.000)	*
Missing birth weight for siblings	0.365	(0.242)		0.160	(0.294)		0.014	(0.232)		-0.013	(0.238)	
Health variables:												
Physical handicap	-0.166	(0.088)	*	-0.017	(0.096)		-0.061	(0.083)		-0.048	(0.090)	
Bad child health	0.119	(0.132)		0.056	(0.118)		0.010	(0.099)		-0.182	(0.109)	*
Mother mentally ill	-0.282	(0.158)	*	-0.053	(0.075)		-0.009	(0.055)		-0.077	(0.060)	
Mother hospitalized				-0.039	(0.073)		0.051	(0.060)		0.016	(0.063)	
Family structure:												
Firstborn	0.002	(0.067)		0.195	(0.062)	***	0.113	(0.051)	**	0.045	(0.053)	
Number of siblings	-0.003	(0.040)		-0.064	(0.037)	*	-0.081	(0.033)	**	-0.047	(0.025)	*
Single mother	-0.407	(0.218)	*	0.030	(0.132)		0.009	(0.099)		0.085	(0.103)	
Mother and stepfather				-0.168	(0.216)		0.141	(0.090)		0.113	(0.080)	
Copenhagen	-0.081	(0.055)		0.039	(0.062)		-0.011	(0.054)		0.124	(0.058)	**
Rural area	0.003	(0.052)		0.017	(0.057)		-0.015	(0.051)		-0.023	(0.054)	
Mothers age at birth	0.010	(0.007)		0.021	(0.007)	***	0.017	(0.006)	***	0.014	(0.006)	**
Fathers age at birth	-0.015	(0.005)	***	-0.003	(0.004)		-0.005	(0.003)	*	0.001	(0.003)	
Family socioeconomic variables:												
Log household income	0.118	(0.089)		-0.068	(0.093)		-0.050	(0.078)		-0.013	(0.081)	
Family level of employment	0.013	(0.047)		0.021	(0.060)		0.047	(0.054)		0.104	(0.059)	*
Family educational level	0.016	(0.014)		0.017	(0.015)		0.006	(0.013)		0.007	(0.014)	
Missing level of education for mother	-0.536	(0.426)		0.053	(0.705)		0.206	(0.337)		0.392	(0.582)	
Missing level of education for father	-0.114	(0.209)		-0.163	(0.280)		-0.015	(0.282)		-0.276	(0.352)	
R-squared	0.113			0.042			0.022			0.021		

Table BX3. OLS estimation of SDQ. Boys

	1999			2003			2007		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Intercept	14.271	(5.033)	***	24.923	(4.543)	***	23.579	(4.698)	***
Birth variables:									
Low birth weight	0.094	(0.578)		0.640	(0.498)		0.903	(0.531)	*
Average siblings birth weight	0.000	(0.000)		0.000	(0.000)		0.000	(0.000)	
Missing birth weight for siblings	0.722	(1.196)		-0.370	(1.080)		-0.266	(1.164)	
Health variables:									
Physical handicap	1.228	(0.450)	***	0.656	(0.389)	*	1.222	(0.416)	***
Bad child health	1.769	(0.572)	***	1.718	(0.471)	***	2.097	(0.500)	***
Mother mentally ill	0.654	(0.342)	*	1.230	(0.261)	***	0.846	(0.281)	***
Mother hospitalized	0.321	(0.348)		0.140	(0.281)		0.038	(0.300)	
Family structure:									
Firstborn	-0.658	(0.293)	**	-0.088	(0.240)		-0.553	(0.249)	**
Number of siblings	-0.024	(0.176)		0.075	(0.157)		0.050	(0.119)	
Single mother	-0.429	(0.580)		-1.695	(0.467)	***	-1.403	(0.482)	***
Mother and stepfather	0.521	(0.828)		1.439	(0.413)	***	0.966	(0.381)	**
Copenhagen	1.175	(0.285)	***	0.949	(0.254)	***	0.156	(0.273)	
Rural area	0.167	(0.277)		0.171	(0.239)		-0.205	(0.252)	
Mothers age at birth	-0.130	(0.031)	***	-0.143	(0.027)	***	-0.098	(0.028)	***
Fathers age at birth	-0.014	(0.017)		-0.010	(0.013)		-0.019	(0.014)	
Family socioeconomic variables:									
Log household income	0.183	(0.414)		-0.862	(0.370)	**	-0.801	(0.379)	**
Family level of employment	-0.386	(0.268)		-0.710	(0.257)	***	-0.796	(0.278)	***
Family educational level	-0.255	(0.070)	***	-0.331	(0.063)	***	-0.332	(0.067)	***
Missing level of education for mother	2.982	(2.259)		0.338	(1.646)		-1.507	(2.850)	
Missing level of education for father	-1.483	(1.153)		-1.274	(1.374)		0.605	(1.628)	
R-squared	0.041			0.090			0.078		

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