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# Birth Order and Health of Newborns: What Can We Learn from Danish Registry Data?

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# What Can We Learn from Danish Registry Data?

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**Abstract**

Research has shown a strong negative correlation between birth order and cognitive test scores, IQ, and educational outcomes. We ask whether birth order differences in health are present at birth using matched administrative data for more than 1,000,000 children born in Denmark between 1981 and 2010. Using family fixed effects models, we find a positive and robust birth order effect; earlier born children are less healthy at birth. Looking at the potential mechanisms, we find that during earlier pregnancies women have higher labor market attachment, behave more risky in terms of smoking, receive more prenatal care, and are diagnosed with more medical pregnancy complications. Yet, none of these factors explain the birth order differences at birth. Combining our results with findings from the medical literature, we propose that biology is driving the early life advantage (nature). Finally, we show that these birth order differences at birth do not explain the negative birth order effect in educational performance, suggesting that nurture rather than nature is an important player later in life.

JEL classification: I10, I12, J12, J13

Keywords: Birth order, parity, child health, fetal health, health at birth, education

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# 1 Introduction

The negative association between birth order and cognitive test scores, IQ, and educational outcomes is well established in the economic and psychological literature. To explain the observed birth order effect, the empirical literature has mainly focused on the social environment.[1] However, some researchers have postulated the hypothesis that birth order differences might also, in part, be explained by health endowments and thus have a biological dimension as well.[2] The "nature versus nurture" debate is particularly crucial for policy makers if they aim for equality, meaning that birth order differences are unwanted from a welfare point of view. Albeit to date, consistent evidence on such early life birth order differences is missing.

In this paper, we use Danish Registry Data that cover over 1,000,000 children to investigate whether a birth order effect is already present at birth. We look at birth differences within families, focusing on different measures of health at birth. In addition to the analysis of the existence of an effect, we study the potential mechanisms through which birth order differences at birth operate. Essentially, we ask whether the social environment (nurture) or biology (nature) is driving the effect. While we cannot directly test for the latter, we can extensively account for the social environment. Combining the analysis with evidence from the medical literature, we discuss the role of nature as a mechanism of the birth order differences at birth. Moreover, in light of our findings, we assess the role of health at birth in the negative relationship between birth order and educational performance at age 15–16 years.

Our results are three-fold. *First*, we increase our understanding of the existence of birth order differences. We show that later born children have a health advantage around birth that is robust to numerous definitions of health at birth and apparent in different subpopulations. *Second*, as the positive birth order effect at birth clearly stands in contrast to the negative birth order effects found in education, we test several specification to understand the positive birth order effect at birth. We find that, during earlier pregnancies, women have higher labor market attachment; behave more risky in terms of smoking; visit more often their general practitioner (GP), their midwife, or a specialist; and have higher rates of hospitalizations for medical pregnancy

[1] See for instance Price (2008), de Haan (2010), Lehmann et al. (2014), de Haan et al. (2014), and Buckles and Kolka (2014).

[2] See for instance Behrman and Taubman (1986), Ejrnæs and Pörtner (2004), and Hotz and Pantano (2015)

complications. Because we focus on a country with universal health care, concerns about heterogeneity in the access to care are limited. However, the social and behavioral mechanisms cannot explain the positive birth order effect at birth. Based on our empirical results and evidence from the medical literature, we suggest that biology is driving the early life advantage (nature). *Third*, in contrast to the literature, health at birth does not explain the negative birth order effects in education later in life. In line with Black et al. (2011), controlling for health at birth increases the negative magnitude of the birth order coefficients in educational performance. Likewise, health at birth does not affect the accumulation of human capital differently across birth orders. Given our findings, we suggest that behavior (nurture) is an important determinant of the negative birth order effect in educational performance. We thereby strengthen the results of previous studies that have, among others, looked at allocation of time (Price 2008), financial resources (de Haan 2010) and intellectual stimulation (Lehmann et al. 2014; Hotz and Pantano 2015). However, our results also illustrate that the role of nurture for the birth order effects in education is understated if health at birth is not accounted for. Furthermore, our results have important implications for any future research that focuses on connecting early life differences within families with later life outcomes.

The rest of the paper is organized as follows: Section 2 summarizes the mechanisms of the birth order effects in education that have been discussed in the literature. Section 3 describes the data and our empirical strategy. Section 4 presents our main birth order estimates for health at birth, studies the mechanisms of these birth order differences and looks at how these health at birth differences affect educational performance. Finally, Section 5 concludes.

# 2 Mechanisms of the Birth Order Effect

Studies on birth order effects find a strong negative correlation between the birth order (or parity of a child) and cognitive test scores (Heiland 2009; Monfardini and See 2012; Lehmann et al. 2014; Hotz and Pantano 2015), schooling outcomes (Behrman and Taubman 1986; Conley and Glauber 2006; Kantarevic and Mechoulan 2006; Booth and Kee 2008; de Haan 2010; Mechoulan and Wolff 2015), and IQ scores (Kristensen and Bjerkedal 2007; Sulloway 2007;

Black et al. 2011).[3] Broadly, to explain birth order effects in schooling, IQ, and cognition (in the following: birth order effects in education), previous studies have discussed potential mechanisms by differentiating between those addressing the social environment and those addressing differences at birth. We will discuss them in the following to establish our contribution.

**Social Environment**

Negative birth order effects in education might be the result of strains on time and financial resources. Price (2008) finds that parents give the same amount of time to each child at any point in time, while the amount of parental quality time spent with each child decreases with the oldest child's age. Complementary, de Haan (2010) documents a negative correlation between birth order and the amount of money received from parents as adult. This finding is consistent with the idea of resource dilution (Parish and Willis 1993); if parents are poor planners, each additional child dilutes per-child financial resources causing strains in the budget. This holds, though, only for parents who are credit constrained or whose income does not increase proportionally with each child. If financial and time resources are critical inputs in the human capital production function, the existence of differences in these variables gives rise to negative birth order effects in education.

The stimulating environment is another important mechanism identified in the literature. The confluence model by Zajonc (1976) predicts that higher birth order children are born into an overall lower intellectual environment than earlier-borns, because existing children deteriorate the intellectual environment. However, the intellectual levels of the children increase with age and can ultimately reach these of parents (or grow even beyond). With large enough gaps between siblings, the birth order effect can, therefore, be nullified (or even reversed). Moreover, the confluence model incorporates that older children gain from teaching and instructing their younger siblings and hypothesizes that an active participation in an intellectual process is more effective than a passive participation. The stimulating environment might also be actively influenced by the parents. Lehmann et al. (2014) find that higher parity children receive less

[3] Ejrnæs and Pörtner (2004) and de Haan et al. (2014) show a positive relationship between birth order and educational outcomes. In contrast to the studies just mentioned, their evidence comes from developing countries, constituting an important but also quite different context to the one studied here.

cognitive support in early life. Hotz and Pantano (2015) show that parents are less stringent with later-born children, for instance, with respect to parental monitoring regarding homework. Finally, there may be cultural factors favoring earlier born children (Horton 1988).

**Health Endowments**

Research has suggested that birth order effects in education are already present at birth. Theoretically, the economic literature has argued that higher birth order children should show worse health at birth (Behrman and Taubman 1986; Behrman 1988; Horton 1988; Ejrnæs and Pörtner 2004; Hotz and Pantano 2015). The underlying argument is the natural correlation between parity and maternal age, for which the latter is assumed to be negatively associated with health at birth. Tests of this relationship are found mainly in the empirical medical literature that shows, *opposite* to the predictions of the studies just mentioned, a positive relationship between birth order and health at birth.[4] Good health at birth is an indicator for better later life outcomes and, therefore, the results from the medical literature stand in contrast to the negative birth order effects found at older ages (see e.g. Behrman and Rosenzweig (2004), Case et al. (2005), Cunha and Heckman (2007), and Figlio et al. (2013)). However, medical studies mostly do not account for socio-economic factors or between family heterogeneity. We will later show that such controls, to some extent, affect the relationship between birth order and health at birth.

Empirical economic studies on this topic are missing to date. However, Black et al. (2011) and Lehmann et al. (2014) provide some indication that higher birth order children are better off at birth. While Black et al. (2011) focus on men only and do not report any estimation results, Lehmann et al. (2014) find, in line with the medical literature that higher birth order children show better health at birth, such as higher birth weight, which is commonly used as a proxy for in utero conditions as well as neonatal health. Unfortunately, the results of Lehmann et al. (2014) are based on a small sample and are partly imprecisely estimated.

Hence, until now consistent evidence answering whether and why birth order differences in health at birth exist is still missing. Importantly, if birth order differences are present at birth,

[4] For references to the medical literature, see Camilleri and Cremona (1970), Swamy et al. (2012), and Hinkle et al. (2014).

it will be essential to understand what drives these differences. A priori, they might be the result of changes in the in utero social environment across birth orders (nurture) or the result of biological changes (nature). Differently put, we differentiate between actively influencing birth order differences (nurture) and mechanisms that are beyond the control of the mother or others (nature). In the following, we will refer to birth order differences in health at birth caused by nature as *health endowment* differences.

**Contribution**

Our study contributes to the literature as follows. First, we have a battery of measures of health at birth for over 1,000,000 children in our final sample. Given the large sample size, the data provides precise estimates and we show, using family fixed effects estimation, that the results are not specific to the way we measure health at birth and hold in different subpopulations. *Second*, we are able to study the role of socio-economic variables, behavioral measures, and pregnancy complications to address the mechanisms and to provide an answer to the "nature versus nurture" question of these health at birth differences. *Third*, our data enables us to link health at birth with school performance at age 15–16 years. Thus, we can test whether differences at birth play a role in the relationship between birth order and educational performance. To our knowledge, we are the first to study these important relationships in such detail. Our results may furthermore enable a vitally important link for any future research that focuses on connecting early life differences within families with later life outcomes.

# 3 Data and Empirical Strategy

Our data comes from administrate files, covering the universe of all children born in Denmark between 1981 and 2010. The advantage of the data, compared to micro-level data from other countries, is that we can map each child to his or her parents; can follow it from birth to adulthood; and have a final sample of more than 1,000,0000 children with information that is not self-reported but observed by professionals in the health care sector or reported by different authorities in the public sector. To give two examples, the sample size is comparable to a 1 percent random sample of the US National Vital Statistics, but, in comparison to the US data, we are able to link each child to its siblings and to its parents. That allows us to include a wider range of family controls and more importantly, to include family fixed effects. By contrast, our data is about 100 times larger than the Children Sample of the National Longitudinal Survey of Youth 1979 (NLSY79). Moreover, our administrative data is complete in the sense that it provides information on each person every year. Therefore, we only experience attrition in the rare case of out-migration or death.

Our sample is based on seven different administrative registries. (1) The fertility registry (*Fertilitetsdatabasen*) links every child to his or her mother and father. From this, a full replication of the family's fertility history can be derived and additional registries can be merged. (2) The birth registry (*det Medicinske Fødselsregister*) gives detailed information about child health at birth. (3) The national patient registry (*Landspatientregistret*) gives us hospitalization diagnoses for the mother during pregnancy and for the child at birth. (4) The school marks registry (*Folkeskolekarakterer*) reports grades obtained at the end of ninth grade. (5) The population (*Befolkningsregistret*), (6) income (*Indkomstregistret*), and (7) education (*Uddannelsesregistret*) registries provide information on parental characteristics.

## 3.1 Demographic Characteristics

To construct the sample for analysis, we use the following restrictions. We restrict the sample to mothers who conceived their first child in 1980 or later, because the registries on parental characteristics started in that year. We exclude families with at least one multiple birth (e.g. twins) as birth orders are more difficult to assign in these families. We keep only families with more than one child and families where the mother has given birth to children who all have the same father (biological siblings) and where we have at least two non-missing observations on perinatal death or two non-missing observations for our other main outcomes for health at birth. Given the small frequency of families with five or more children, we exclude those families.

Panel a) of Table 1 shows the frequencies of children with birth order 1, 2, 3, and 4. Having two children constitutes the most popular family size. The average child in the sample lives in a family with 2.4 children with a median of 2 children. Given the low frequency of parents with four children, only 2 percent of all children are of birth order 4.[5] The share of boys and girls is equal in the sample.

[Table 1 about here.]

## 3.2 Birth Outcomes

The birth registry contains a rich set of variables measuring different dimensions of child health at birth. Table 1 summarizes the variables for child health at birth.

Birth weight for gestational age z-score relates the birth weight of a child at a given gestational age at birth to what would be expected from a healthy child at same gestational age. We prefer to use the birth weight z-score rather than birth weight, because the latter cannot differentiate between variation in gestational length and fetal growth. Put differently, children can be born premature and for that reason have a low birth weight (but are otherwise perfectly healthy) or children can be born with low birth weight even though they are in the range of a normal gestational age; the latter would reflect fetal growth restriction. We define birth weight for gestational age z-score using Scandinavian fetal growth curves based on ultrasonically estimated fetal weights in uncomplicated pregnancies (Marsál et al. 1996).[6] The mean z-score in the sample of about zero implies that, on average, the birth weight of each offspring coincides with the reference for uncomplicated pregnancies. As a robustness check, we will later also look at birth weight in natural logarithms, a measure previous studies have used (Black et al. 2007; Figlio et al. 2013).

Moreover, we focus on children at different parts of the birth weight distribution. Of all children, 3.1 percent are small for gestational age (SGA), an indicator taking the value 1 if the birth weight z-score falls below $-2$ standard deviations and 0 otherwise. In comparison, the same share is born large for gestational age (LGA), an indicator taking the value 1 if the birth weight z-score exceeds $+2$ standard deviations and 0 otherwise. These shares are as expected

[5] Birth order is assigned based on children born alive and children dying before birth but with presumed gestation of 28 weeks or more. For the latter group, birth information is not available. That is why the number of first and second born children differ despite our sample restriction at the family level.

[6] For each gestational age and gender, we calculate the z-score as: $\frac{\text{Birth weight}-\text{Birth weight from reference}}{\text{Standard deviation from reference}}$.

given that the z-scores are normally distributed. While SGA is a commonly used indicator for poor neonatal health, LGA is associated with an increased risk of infant mortality, injuries during delivery, and potentially long-term adverse health effects (Surkan et al. 2004).

In addition, we look at a severe form of intrauterine growth restriction. Symmetrical growth restriction is a global growth restriction meaning that the fetus has developed slowly throughout the whole pregnancy. By contrast, in the case of asymmetric growth, the child is also growth restricted but the head has continued to grow at a (nearly) normal rate. Robinson (2013) finds that while symmetric and asymmetric growth restriction impairs physical health, brain sparing is found only for the asymmetric growth restricted offspring. Symmetrical growth restriction can, hence, be understood, as a more severe form of SGA. We define being symmetrical growth restricted (SGR) as an indicator equal to 1 if a child is SGA and lean where leanness is based on the ponderal index z-score.[7] About half of SGA children are SGR.

As a complement to the anthropometric measures, we also consider the 5-Minute Apgar score.[8] With an average of 9.86, the average nearly corresponds to 10, the maximum score possible. Given the highly skewed distribution of the Apgar score, we define the variable low Apgar score (Apgar score $< 7$), which is associated with higher infant mortality and severe neurological morbidity (Thorngren-Jerneck and Herbst 2001). Less than 1 percent of all children are classified with a low Apgar score.[9]

Given the large number of outcome measures and the potential concern of finding spurious correlations, we define a summary index following Kling et al. (2007) that is an equally weighted average of the following components: birth weight z-score, SGA, LGA, SGR, and low Apgar score. To construct the index, each component is standardized by subtracting the

[7] More precisely, we calculate the ponderal index, defined as the ratio between weight (in kg) and height (in ccm) and the equivalent z-score based on Lykke et al. (2012). Leanness is ponderal index z-score below -1 standard deviation. Children that are SGA and not lean are, hence, asymmetric growth restricted; we do not study this group further, as we already look at SGA.

[8] The 5-Minute Apgar score is a diagnostic test measured five minutes after birth and based on five criteria: heart rate, respiratory effort, muscle tone, reflex irritability, and color. For each criteria 0, 1 or 2 points are assigned with the score ranging between 0 and 10. The Apgar score has been found to be highly correlated with cognitive ability, health and behavioral problems in later childhood (Almond et al. 2005) and has been used in several economic studies to measure health at birth (Chay and Greenstone 2003; Almond et al. 2009; Black et al. 2007; Almond et al. 2010; Black et al. 2011, among others).

[9] Given the low prevalence of low Apgar score, we used alternative specifications where we increased the cut-off to 8 Apgar score points and where we looked at Apgar score as a continuous variable. The results remain unchanged.

mean and dividing it by its standard deviation. The standardized components are then summed with the sign of each component reflecting whether the component is associated with better or worse child health.[10] The index is constructed with a mean of 0 and a standard deviation of 1; a higher value on the score reflects better health at birth.[11]

## 3.3 In Utero Environment

Our data contains an unusual rich set of maternal characteristics measured in utero, summarized in Panel c) of Table 1.

The top of panel c) shows summary statistics for socio-economic characteristics of the mother during pregnancy. The variables working, student, unemployed, and out of the labor force measure labor force participation during pregnancy and are based on the main source of income in the year before birth.[12] Working can affect child health at birth through stress, as stress during pregnancy is negatively related to birth outcomes (Aizer and Cunha 2012; Black et al. 2014; Persson and Rossin-Slater 2014). However, not working may also relate to stress, i.e. through anxiety over future employment prospects (Wüst 2014). Parental wage income is the total sum of before tax labor earnings of both parents and is measured the year before birth. The socio-economic status of the parents, i.e. income, affects the timing of birth and neonatal health (Buckles and Hungerman 2013; Figlio et al. 2013). Of all women, 79 percent work during pregnancy; parental wage income is around 500,000 DKK in 2011 prices.[13]

The middle part of panel c) summarizes measures of maternal behavior. Information about whether the mother smoked at her first midwife visit is available since 1991.[14] Smoking during pregnancy reduces birth weight and increases the probability of a low Apgar score (Thorngren-Jerneck and Herbst 2001). Prenatal care is grouped into visits at the GP, the midwife, and the specialist. While prenatal care has an important policy dimension, the effect on neonatal health is controversial (Fiscella 1995; Lu et al. 2003). The pregnancy interval measures the time

[10]Negative sign is given to SGA, LGA, SGR, and low Apgar score, while a positive sign is given to the birth weight z-score.

[11]Using principal components analysis instead reveals very similar results in the analysis.

[12]Not in the labor force means that mothers are neither working, nor student, nor unemployed.

[13]67,000 EUR or 75,700 USD as of September 2015.

[14]The first midwife visit is scheduled at the end of the first trimester or beginning of the second trimester.

between the previous birth and the date of conception of the subsequent pregnancy.[15] Very long pregnancy intervals are associated with impaired child health at birth (Stephansson et al. 2003). About 17 percent of all women smoked at the time of the first midwife visit. Pregnant women see a GP about twice during pregnancy, the midwife 5 times, and a specialist a little more than 3 times.[16] The mean pregnancy interval is 31 months.

The bottom part of panel c) shows summary statistics for variables attributable to maternal health, two of which are maternal age and gestational diabetes. Maternal age at birth is on average 29 years. Gestational diabetes is an indicator equal to 1 if the mother was hospitalized for gestational diabetes and 0 otherwise. Hospitalizations for pregnancy complications constitute a very important dimension of maternal health, because they capture actual complications that need to be diagnosed in the hospital and are, thus, registered for every affected woman.[17] Gestational diabetes is a form of diabetes in women without previously diagnosed diabetes; it is associated with excessive fetal size that is translated into an increased prevalence of LGA (Casey et al. 1997). A family history of diabetes contributes to the probability of gestational diabetes. Risk factors that are not be captured by family fixed effects and may, hence, vary by birth order are pregnancy factors (i.e. high blood pressure), maternal age, prepregnancy weight, preganancy weight gain, and obesity (Ben-Haroush et al. 2004). About 1 percent of all women were diagnosed with gestational diabetes.[18]

The third and fourth measure of maternal health are indicators for hospitalizations for gestational hypertension and preeclampsia, which are both blood pressure disorders developing at near term. To be diagnosed with preeclampsia, the woman needs to have both gestational hypertension and proteinuria (large amount of protein in the urine). In our measure of preeclampsia, we consider mild and severe preeclampsia, eclampsia and the HELLP (Haemolysis, Elevated

[15]For the mean of the actual birth interval (time between birth), we would have to add, on average, 9 months to our mean of 31. The result is in line with Buckles and Munnich (2012) who report a mean of 40.8 for the time between two birth.

[16]The practice has naturally changed over time. Today, the standard for an uncomplicated pregnancy is about 3 visits at the GP, 6 visits at the midwife and 2 visits at the specialist.

[17]Diagnoses are based on the International Statistical Classification of Disease and Related Health Problems, $8^{th}$ and $10^{th}$ Revisions (ICD-10 and ICD-8). The reporting standard changed in 1994 from ICD-8 to the ICD-10 codes. However, we can still use information for all diagnoses in our sample, using the recoding of the old ICD-8 codes from Lykke et al. (2012) to merge with the ICD-10 codes.

[18]Casey et al. (1997) reports that between 1–3 percent of all pregnancies in the US are diagnosed with gestational diabetes.

Liver enzyme levels, Low Platelet count) syndrome. The HELLP syndrome and eclampsia can be the consequence of a severe preeclampsia and unfold in higher rates of cesarean sections as well as increased maternal and perinatal morbidities and mortality (Sibai 2003). Causes of preeclampsia can be related to biological factors of the mother (systolic blood pressure) but also relate to behavior during pregnancy (smoking, obesity) (Sibai et al. 1995). We define gestational hypertension conditional on not experiencing preeclampsia, as women with preeclampsia are necessarily also diagnosed with gestational hypertension in the same pregnancy. With this condition, we ensure that we do not capture an intermediate diagnoses for women who develop preeclampsia later in the same pregnancy. Less than 1 percent of all women are diagnosed with gestational hypertension, however, almost 3 percent experience preeclamspsia.[19]

## 3.4 Empirical Strategy

We now turn to our econometric model to examine the relationship between birth order and child health.

The following linear model is to be estimated:

$$Y_{iftm} = \alpha + \sum_{j=2}^{n} 1(\text{Birth order}_i = j)\beta_j + X'_{itm}\gamma + \theta_f + \varepsilon_{iftm}, \tag{1}$$

where $Y_{iftm}$ is the outcome of child $i$, born in family $f$, conceived in year $t$ and month $m$. The sum represents a set of dummies for birth order, $1(\text{Birth order}_i = j)$ for $j = 2,3,$ and 4 where $1(\cdot)$ is the indicator function. Children of birth order 1 represent the omitted category so that $\beta_j$, our coefficients of interest, capture differences with respect to birth order 1. $X_{itm}$ is a vector of controls including year of conception by month of conception dummies and gender of the child. We prefer *year by month of conception* effects to *year by month of birth* effects to accurately map in utero conditions specific to pregnancies with the same expected time of delivery (Buckles and Hungerman 2013; Almond and Mazumder 2011). This is especially

[19] If women experiencing preeclampsia are counted, the figure would increase to 4 percent. Sibai (2003) notes a prevalence of 6–17 percent for nulliparous women and 2–4 percent for multiparous women. These numbers fit in line with the 4 percent given that we have 43 percent nulliparous and 60 percent multiparous births in our sample.

relevant given the variation in gestational age, meaning that children with the same birth date are not necessarily conceived the same date. $\theta_f$ are family fixed effects. Identification is based on comparing second, third, and fourth born children who are conceived across different years and months to firstborns within the same family. While family fixed effects control for any time-invariant observable and unobservable heterogeneity within families (i.e. family size, maternal age at first birth, genetic endowments), month and year of conception capture cohort and seasonal trends in the outcome variable. Finally, $\varepsilon_{iftm}$ is the error term. Given the grouped structure of our data, standard errors are clustered at the family level to account for possible correlation of errors within families as suggested by Moulton (1990) and Pepper (2002).

$\beta_j$ gives the causal effect of being born later within the family. This effect, however, is a combined effect, covering changes in the social and biological environment across birth orders. Hence, in equation 1, we cannot differentiate between the different channels, through which the sign of the $\beta_j$ may be explained. We explore the unusual richness of our underlying data to disentangle the channels. We do so by gradually accounting for distinct measures of the social environment in equation 1. The part of $\beta_j$ that is invariant to controlling for the social environment, will provide an indication for the role of the biological environment.

Our proposed result regarding the role of the social and the biological environment may still be the product of an unobserved time-variant heterogeneity across siblings.[20] While we cannot prove that this is not the case, we will argue that we have addressed relevant measures of the social environment. An advantage of focusing on health at birth and, thus, in utero conditions, is that we are not facing the difficulty of measuring parent-child interactions that have challenged the literature on birth order effects on educational outcomes or IQ; these types of interactions will not be shaped until after birth.

[20] We considered the possibility of applying quasi-experimental events. Kristensen and Bjerkedal (2007) use death of a sibling to generate allegedly exogenous variation in social and biological birth order. We considered the possibility of a similar approach exploiting miscarriages as an instrument for social and biological birth order. However, miscarriages might have negative obstetric consequences for following pregnancies (Hathout et al. 1982; Bhattacharya et al. 2008). At the same time, experiencing a miscarriage might change behavior during a following pregnancy, possibly at the favor of the unborn child. Hence, applying this approach will not be superior to our within family approach. In contrast, the impossibility of disentangling the consequences of a miscarriage might even confound the results.

# 4 The Birth Order Relationship in Health Endowments

In this section, we present our statistical estimates. We begin with a graphical analysis of the relationship between birth order and child health at birth before we show the empirical estimation results. Having established the relationship between birth order and child health at birth, we turn to the potential mechanisms. Finally, we derive implications from our results for the birth order effects in education by showing how the birth order effect in educational performance is affected by accounting for health at birth.

## 4.1 Main Results

Figure 1 plots the mean of the health at birth measures by birth order and family size together with the 95 percent confidence interval. This approach allows us to show how health differences by family size evolve across birth orders. In graphs (a) and (f), higher values reflect better health, while the opposite is the case for the remaining graphs. The non-parametric comparisons in Figure 1 show that birth order is positively correlated with birth weight z-score (a) and negatively correlated with SGA (b), SGR (d), and low Apgar score (e), thereby Figure 1 reflects that higher birth order is associated with improved health outcomes at birth. In contrast, the positive relationship between birth order and LGA (c) indicates that for some children the positive effect on birth weight exceeds the value of what is considered healthy. However, in general, these results point towards better health with increasing birth order. That is, furthermore, supported by the positive correlation between the health index (which encompasses all these individual measures) and birth order (f). The difference between first and third born children exceeds 0.2 standard deviations indicating a nontrivial effect.

[Figure 1 about here.]

We note three things regarding the shape of the birth order gradient. (1) The biggest change in health happens between first- and second born children. (2) The relationship between birth order and health at birth slightly reverts at the fourth parity for SGA and SGR. However, the whiskers for the 95 percent confidence interval indicate that this slight reversion of the trend at birth order 4 is not significant. (3) Consistent with correlations shown in other studies, we find level differences between the three family sizes with children of larger families doing generally worse. The association between birth order and the measures of health, however, follow the same trend irrespective of family size. Therefore, in the following, we pool all children but control for family size effects. As a robustness check, we will later also show the results by family size.

[Table 2 about here.]

We now test whether the positive correlation between birth order and child health also holds within an econometric framework. Table 2 panel a) presents the results of estimating equation 1 without family fixed effects but including controls for family size. For convenience, we only report the estimates of our key-explanatory variables. Remarkably, the simple correlations previously discussed are robust to any time effects and controls for gender, and all coefficients are statistically significant from zero at the 1 percent level. Birth order is clearly positively associated with better health at birth. The only exception is LGA.

To account for unobserved family heterogeneity, we include family fixed effects in Table 2 panel b). Family fixed effects account for time-invariant observable and unobservable differences within families, including maternal age at first birth, genetic endowments, and also family size. This is why the family size dummies drop out in this specification.

The positive pattern observed in panel a) remains when we account for family fixed effects. However, the birth order coefficients clearly increase in magnitude. The birth weight z-score is on average 0.393, 0.544 and 0.658 standard deviations higher for birth order 2, 3, and 4 compared to firstborns in the same family [column (1)]. The coefficients are jointly significantly different from zero and the increase for each additional birth order is significant at the 1 percent level. This result is translated into a reduced risk of being SGA [column (2)] and a quantitative similar increase in risk of being LGA [column (3)]. The probability of SGR is reduced by 1.2 to 1.9 percentage points [column (4)]. Hence, more later born children are too large for their gestational age at birth, but fewer children are growth restricted, resulting in a decrease in the more unfavorable outcome of SGR. The positive association between birth order and child health unfolds furthermore in the decrease in the prevalence of a low Apgar score [column (5)].

Again, the effect is increasing by birth order with the F-test rejecting equal pair coefficients and joint equal coefficients at the 1 percent level.

The results in column (1)–(5) are translated into a higher score in the standardized health index for birth order 2, 3, and 4 compared to firstborns [column (6)]. The effect is sizable, as it implies more than a quarter of a standard deviation increase in each of the index components on average for second-borns, more than a third of a standard deviation increase on average for third-borns, and almost half of a standard deviation increase on average for fourth-borns. In other words, the increase for birth order 4 is equivalent to moving someone from the middle of the health distribution (50th percentile) to the 70th percentile.

#### Additional Measures of Health at Birth and Mortality

To explore the richness of our data, we focus on an even wider scope of measures of health at birth. These include the natural logarithm of birth weight and birth length, an indicator for being premature (i.e. birth before 37 weeks of gestation at delivery), head circumference, and an indicator for being diagnosed for a condition relating to the perinatal period. Table A1, column (1)–(5) presents these results. The positive relationship between birth order and child health is clearly not driven by the way we define health at birth.[21]

Our findings might be the result of higher mortality at higher parities. If the children who survive are positively selected, our proposed relationship between birth order and child health might be driven from a 'culling of the weakest'. We can test this hypothesis by looking at the relationship between birth order and perinatal death, in column (6) of Table A1. Perinatal death is defined as fetal deaths occurring with a stated or presumed gestation of 28 weeks or more or deaths occurring within the first 7 days of life.[22] As the coefficients in column (6) shows, birth order and perinatal death are negatively related. Consequently, these results suggest that the findings in Table 2 reflect a lower bound of the true birth order effect in health at birth.

[21] We prefer our previously used measures over the ones presented in Table A1 for the health index. Birth length, birth weight, and prematurity are cruder measures of health at birth and are encompassed in our main measures. Moreover, information about head circumference and diagnoses for perinatal conditions are not collected before 1997 and 1994 respectively.

[22] These children are grouped on the assumption that similar factors have caused the death (Barfield 2011). The definition is furthermore the official definition for perinatal death used by the National Center for Health Statistic and the World Health Organization. Notice that we have more observations for perinatal deaths than for our other outcomes, as not all children dying in the perinatal period have information on these other outcomes.

### Heterogeneity Analysis

The birth order estimates presented so far are average effects. We want to ask whether the birth order effect in health at birth holds within different subsamples and across the entire health-at-birth-distribution.

As noted earlier, family fixed effects account for differences in family size preferences and realized family size as of 2010 (our last observed period). However, heterogeneity in the birth order effect by family size could be at play, although we did not detect such heterogeneity in the descriptive figures. Hence, we estimate all regressions separately by family size in Table A2. To rule out families with incomplete family size, we restrict the sample to families where the mother is at least 38 in December 2010.[23] Table A2 reveals that birth order differences exist in all three family sizes and are remarkably similar. Consequently, we present the pooled results in the remaining analysis. Moreover, as the health index reflects the pattern of the individuals components very accurately, we will focus on the health index henceforth.

We next study the heterogeneity by maternal age at first birth. In the previous specification, maternal age at first birth is captured by the family fixed effect. To see whether the birth order effect is affected by age at first birth, we interact the birth order coefficients with five indicators for maternal age (in years) at first birth: $<$22, 22–25, 26–29, 30–33, and $>$33. Figure 2 depicts the results of this estimation. No remarkable heterogeneity in the birth order effect evolves for mothers younger than 34. However, women who give birth to their first child at age 34 or later show larger birth order differences. This result becomes more apparent when we isolate the age groups 26–29 and $>33$ in Figure 2 b).[24] In general, though, we see birth order effects across all groups of maternal age at first birth.

[Figure 2 about here.]

While innate ability of the mother is fixed within a family, it could give rise to heterogeneity in the birth order effect. Currie and Moretti (2003) show that maternal education positively

[23] This is a reasonable cut-off, as 91 percent of all women who were above 45 years in 2010 got their last child before the age of 38.

[24] The standard error for the birth order coefficient at the fourth child is inflated for women in the age group older than 33. Women that give birth to their first child after age 33 and end up giving birth to four children are relatively few in our sample.

affects fetal health and reduces risky behavior. As a proxy for innate ability, we use the length of the mother's highest completed education. On average, women in our sample have completed more than 14 years of education. Figure 3 shows that birth order differences evolve very similar across the different education groups. However, women with low education show significantly larger birth order differences; they are less able to equalize in utero resources across their offspring. Following the argumentation of Currie and Moretti (2003), this finding would be consistent with lower educated women behaving more risky at every pregnancy than women with higher education. Yet again, birth order effects are apparent in all groups.

[Figure 3 about here.]

We now consider heterogeneous effects at different parts of the health-at-birth distribution. For example, we might see a positive relationship between birth order and child health at some parts of the distribution but a negative relationship at other parts of the distribution. To explore this, we estimate quantile regressions for the health index at the $5^{th}$, $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$, $90^{th}$, and $95^{th}$ percentiles. Figure 6 plots the quantile estimates by birth order. The results suggest substantial effects at the lower end of the health distribution. However, the birth order effect is not solely driven by improvements at the lower end. We still see large birth order differences at the $10^{th}$ to $75^{th}$ percentiles; the improvements at the upper end of the health distribution are less pronounced, although still existing.[25] Overall, we suggest that the birth order effect at birth is present across the entire health-at-birth distribution. This is a very important result, because when we want to understand what drives the birth order effect at birth, we need to find factors that address the entire health-at-birth distribution. We aim to identify these factors in the following.

[Figure 4 about here.]

[25]Table A3 lists the coefficients of the quantile model as well as the OLS and fixed effects coefficients for a comparison. The OLS and fixed effects estimates reported in Table A3 differ slightly from those reported in column (6) Table 6 as we were unable to fit month by year of conception effects in the quantile model. Instead we control for month of conception dummies and a month by year of conception trend, squared, and cubic. That produces very similar coefficients.

## 4.2 What Explains the Positive Relationship?

Given we find a substantial birth order effect in health at birth, the objective is now to understand the mechanisms. We look at the role of maternal age, pregnancy intervals, socio-economic characteristics, maternal behavior, and maternal health to explain the within family differences by birth order. More precisely, we are interested in whether the social environment (nurture) or the biological environment (nature) is driving the birth order effect at birth. In a first step, we show how variables that have been found or discussed to affect fetal health (see section 3.3), change with birth order. We then account for these variables in equation 1 to assess their role. A highly relevant mechanism explains as much as 100 percent of the birth order differences. A variable that does not change the birth order coefficients at all can be rejected as a mechanism.

### Maternal Age and Pregnancy Interval

We first focus on maternal age at birth. Some studies have suggested a negative relationship between birth order and child health at birth due to the natural correlation between birth order and maternal age (Behrman and Taubman 1986; Horton 1988; Ejrnæs and Pörtner 2004, among others). We have already established a birth order effect at different ages at first birth. However, while maternal age at first birth is captured by the family fixed effect, we still see variation in the increase in maternal age at birth at higher parities.

In the data, women are on average, 26.5 years old at the birth of their first child. At the fourth birth, average maternal age increases to 33.4 years. We observe substantial differences by family size at a given parity. Women with four children are younger at the birth of their first child (23.9 years) than women with three children (25.5) and women with two children (27.0 years). This pattern remains for second and third births.

The analysis of an increase in maternal age at higher order births is closely related to an analysis of the interval between two pregnancies. In our sample, the mean pregnancy interval is increasing by birth order: from around 19 months between the first and second pregnancy to 32 months between the second and third pregnancy to 35 months between the third and fourth pregnancy.

### Socio-Economic Characteristics

A positive birth order effect in health at birth could also be the result of differences in labor force participation across birth orders or might be the result of socio-economic status. For example, while a woman works during the first pregnancy and leaves for maternity leave only a few weeks prior to the scheduled birth, she may decide to stay at home after the birth of the first child. Women may also increase their labor market participation with higher order births when financial constraints are present or when a transition from higher education to the labor market occurs. Holding labor force participation constant, we might also see changes in the socio-economic status, i.e. income, which varies over the life cycle and, thus, with birth order.

[Table 3 about here.]

To demonstrate how socio-economic characteristics evolve across birth orders, we estimate equation 1 with the outcome being either one of four indicators for labor force participation (working, student, unemployed, out of the labor force) or income during pregnancy.[26] Table 3 shows the result of these estimations. Women reduce working during pregnancy, on average, by 7.8 percentage points (almost 10 percent of the mean) at the second pregnancy and by 24.5 percentage points (more than 30 percent of the mean) at the fourth pregnancy compared to the first one. The probability to be a student decreases by 0.4–0.5 percentage points (20–25 percent of the mean) at the second and third pregnancy compared to first one; we see a small but imprecisely estimated increase at the fourth parity. The probability to be unemployed or out of the labor force is positively associated with birth order. Thus, with higher order pregnancies, mothers tend to shift their time from the labor market to the household. Parental wage income during pregnancy is negatively associated with birth order, the decrease compared to the mean is 8.6 percent, 15 percent, and 29.8 percent for birth order 2, 3, and 4 compared to birth order 1 - about 1.0, 1.7 and 3.5 average monthly wages for birth order 2, 3, and 4, respectively.

### Maternal Behavior

The relationship between birth order and health at birth might also be the result of changes in maternal behavior reflecting mothers' risk perceptions. The idea is that women learn from

[26]We omit the gender dummy from this specification.

experiences of previous pregnancies and change behavior accordingly during subsequent pregnancies. This experience may unfold in a different information set that alters the beliefs about the risk or the uncertainty associated with prenatal investments.

Viscusi et al. (1986) and Lillard (2015) show that the stock of information about product hazards produces precautionary behavior. For example, if a woman smokes during her first pregnancy, she will be exposed to a midwife advising her to quit smoking. If this alters the woman's information stock, we should observe better health outcomes for higher birth orders through a reduction in smoking at higher order pregnancies.

Prenatal checkups may change with birth order if the uncertainty perception with respect to the effectiveness of medical care changes with the experience of the first pregnancy. Based on Arrow (1963), Dardanoni and Wagstaff (1990) show theoretically that the demand for medical care falls if uncertainty about the effectiveness of medical care decreases or if individuals become better informed about health outcomes, i.e. due to greater confidence in self-diagnosis. For prenatal checkups, this implies that demand falls (1) if checkups in the first pregnancy provide increased knowledge about their effectiveness and (2) if a woman learns about her own health and child health at birth through observations during the first pregnancy. As we use data from a country with universal health insurance, concerns about heterogeneity in access to care are limited. Moreover, it also makes it much less likely that financial constraints play a different role across birth orders in terms of prenatal care.[27]

[Table 4 about here.]

Table 4 shows how maternal behavior changes with birth order. We estimated again equation 1 with the outcome being prenatal checkups (at the GP, the midwife, or the specialist) or an indicator for smoking during pregnancy. All types of prenatal checkups decrease with higher order pregnancies. For prenatal checkups at the GP and the midwife, the quantities relate, on average, to about 3 percent of the mean for birth order 2, 6 percent of the mean for birth order 3, and 10 percent of the mean for birth order 4. The effects are smaller for checkups at the specialist and economically not meaningful. Our findings are in line with Buckles and Kolka

[27] While labor force participation and income might also encompass behavioral aspects, smoking and prenatal checkups present choices of the mother that are more clearly the result of the mother's perceptions about risks. We acknowledge, however, that prenatal checkups also reflect maternal health in general.

(2014) and Lehmann et al. (2014). However, while they focus on prenatal care within the first months of pregnancy, we draw on their results by differentiating between the types of checkups and by focusing on the entire pregnancy period. Our results suggest that women reduce prenatal checkups associated largely with mental preparation and consulting (GP and midwife), while they do not strongly change prenatal checkups associated with medical procedures (specialist). The probability to smoke is decreasing between 2.7 and 3.3 percentage points after the first pregnancy. While the effect is increasing between birth order 2 and 3, the difference between birth order 3 and 4 is insignificant.[28]

**Hospitalizations for Medical Pregnancy Complications**

As a fourth group of variables, we assess the role of hospitalizations for severe pregnancy complications as a measure of impaired maternal health. To the extent that maternal health is affected by behavior, changes in maternal health reflect this behavioral change. At the same time, changes in maternal health might reflect physiological changes (nature). Gluckman and Hanson (2004) argue that higher order pregnancies face lower constraints; this should unfold in reduced hospitalizations for severe pregnancy complications.

[Table 5 about here.]

Table 5 shows the result of regressing birth order on diagnoses for gestational diabetes, gestational hypertension, and preeclampsia. The coefficients reveal a strong positive association between maternal health and birth order, i.e. a significant reduction in suffering from any of the three conditions with higher order pregnancies. The results for diabetes also suggest that the increase in LGA is not the result of an increase in the prevalence of diabetes and, hence, not the result of an impaired maternal health environment.[29] The reduction in hospitalizations for severe pregnancy complications at higher order pregnancies is furthermore in line with reduced perinatal mortality at higher order pregnancies as reported earlier.

[28] This finding is consistent with Black et al. (2015) but opposite to Lehmann et al. (2014). Yet, while Lehmann et al. (2014) look at a subsample of their data with previous smokers, our results are based on the entire sample.

[29] While the coefficients are significantly increasing with parity for gestational hypertension and peeclampsia, the coefficients for gestational diabetes at the fourth parity is smaller than at the third parity, however, still negative and highly significant.

### The Role of the In Utero Environment

In summary, we find systematic changes in the in utero environment with higher order pregnancies. With increasing birth order, we observe an increase in maternal age with similar changes in the pregnancy interval; a lower maternal labor market attachment and parental wage income during pregnancy; a reduction in risky behavior in terms of smoking; a reduced number of visits at the GP, the midwife, or a specialist; and reduced rates of hospitalizations for medical pregnancy complications. We now ask how much of the birth order effect in health at birth can be explained by these variables and how much remains unexplained. Thereafter, we examine whether improvements are still present at the entire health distribution or whether the effects are specific to certain parts of the distribution.

[Table 6 about here.]

Table 6 depicts the role of the previously discussed mechanisms by sequentially controlling for the in utero environment in equation 1. As a baseline, column (1) shows the birth order coefficient for the health index from our main specification that controlled for year by month of conception effects, gender, and family fixed effects [identical to Table 2 panel b), column (6)].

We begin with adding maternal age at birth in column (2). Maternal age at birth is measured in intervals to account for a potential non-linearity in the effect of maternal age on child health as shown by Swamy et al. (2012). A comparison between column (1) and (2) reveals that accounting for maternal age slightly increases the birth order coefficient. The change, however, is very small in magnitude (less than 1 percent) and we do not consider it economically meaningful.[30] We conclude that maternal at age at birth is neither a mechanism nor does it increase the birth order effect in health at birth.

[Table 7 about here.]

To assess the effects of the pregnancy interval, we use the small sample of 3–4 child families and drop all firstborns, as no interval is defined for children of birth order 1 by definition. Birth order 2 now constitutes the reference group. Table 7 shows the birth order effect for this smaller

[30] In alternative specifications, we also accounted for maternal age linear and squared with the result being unchanged.

sample where we account for the same variables as in column (2) of Table 6. Column (2) in Table 7 adds the pregnancy interval. To account again for a possible non-linearity in the effect of the pregnancy interval (Stephansson et al. 2003), we add 6 dummies with the pregnancy interval 18–23 months being the reference group. The birth order effect in column (2) is nearly unchanged compared to column (1) and not statistically different; the pregnancy interval does not affect the relationship between birth order and health at birth.

Accounting for labor force participation and wage income during pregnancy does neither alter the positive relationship between birth order and health at birth either [Table 6, column (3)]. Even though the decrease is statistically significant, the difference is again not economically meaningful (relative changes of about 1 percent). The associations between socio-economic variables and child health at birth are not strong; though, we do not attempt to interpret the coefficients of labor force participation and income, as they are likely endogenously determined.

We account for smoking and prenatal checkups in columns (4) and (5) of Table 6. The birth order coefficients slightly decrease by up to 2.1 percent when adding smoking and slightly increase by 1.1–2.1 percent when adding prenatal checkups. However, the change in smoking and checkups across pregnancies does again not alter substantially the relationship between birth order and child health at birth.

Controlling for hospitalizations for medical pregnancy complications in the relationship between birth order and child health reduces the birth order coefficients by 3–4 percent [Table 6, column (6)]. The magnitude of the birth order coefficients, however, remains sizable. Compared to firstborns, second-, third-, and fourth-borns score 0.259, 0.371, and 0.457 standard deviations higher on the health index.

*Overall*, the coefficients are reduced by 2.6, 1.9 and 2.1 percent for birth order 2, 3, and 4 comparing column (1) and (6) of Table 6. Albeit this difference is statistically significant, it is close to zero. Thus, the findings that higher birth order children show better health at birth is persistent.

[Figure 5 about here.]

Figure 5 summarizes the role of socio-economic, behavioral, and hospitalization variables. The light gray bars are the predicted values for the health index at birth taking into account the parity specific in utero environment: maternal age, socio-economic characteristics, maternal behavior, and hospitalization for pregnancy complications. The dark gray bars are the predicted values had birth order 2, 3, and 4 been exposed to the in utero environment of the firstborn in the family (*as if* values). Consistent with our results in Table 6, the measures of in utero conditions do not strongly alter the positive relationship between birth order and child health. Although the *as if* values slightly reduce the predicted birth order differences, the large birth order effect at birth still prevails. Therefore, this analysis clearly shows that accounting for socio-economic variables, behavior, and maternal pregnancy complications does not have strong explanatory power for the observed birth order pattern.

[Figure 6 about here.]

Figure 6 plots the quantile estimates by birth order accounting for socio-economic, behavioral, and hospitalization variables measured in utero. This stands in contrast to Figure 4 where we did not control for the in utero environment.[31] The estimates at the $10^{th}$ to $95^{th}$ percentiles closely resemble the estimates depicted in Figure 4. However, we see a large reduction in the estimates at the $5^{th}$ percentile; albeit the birth order differences at the $5^{th}$ percentile are still the largest in magnitude, they are reduced by about 0.4 standard deviations for birth order 2, 3 and 4 when we account for the in utero environment. This result suggest that our variables for the in utero environment explain part of the birth order differences (roughly 40–50 percent) for those at the very low end of the health-at-birth distribution. Yet, the overall prevalence of the birth order coefficients at all percentile underlines once more the persistence of the health differences at birth.

### Nature

The persistent positive relationship between birth order and child health suggest that unobservable factors are the underlying cause of the birth order effect in health at birth. As discussed earlier, while a change in hospitalizations for severe pregnancy complications across birth orders may be the result of underlying maternal behavior, complications also relate to maternal

[31] Table A4 lists the estimates and shows also the OLS and fixed effects results for a comparison.

physiology unrelated to behavior. Hence, the decrease in the birth order coefficients observed between columns (5) and (6) in Table 7 may also be a prove of the nature channel. While hospitalization rates for pregnancy complications are highly informative about improvements in maternal health, they can only speak for the bottom part of the maternal-health distribution. General improvements in health, i.e. a shift of the health distribution, will not be detected by the hospitalization variables. Improvements at upper parts of the distribution might even go unnoticed by the mother. As mentioned earlier, the medical literature argues that later pregnancies face lower maternal constraints that influence fetal growth (Gluckman and Hanson 2004). Put differently, the medical literature suggests that later pregnancies are more efficient because first pregnancies prime the body (Hinkle et al. 2014).

The general understanding is that changes in physiological factors necessary for fetal development during the first pregnancy do not fully return to their baseline value (before the first pregnancy). Consequently, higher order children profit from this incomplete reversal, namely, at the entire health-at-birth distribution. These physiological changes encompass the uterine blood supply (Hafner et al. 2000; Hollis et al. 2003; Khong et al. 2003; Prefumo et al. 2004) and an enlargement of the uterus (Woessner and Brewer 1963; Sørnes and Bakke 1989), both of which affect nutrient supply to the fetus (Gluckman and Hanson 2004). It has also been suggested that maternal sensitization to paternal antigens that occur at the first pregnancy affect birth weight of later born children (Warburton and Naylor 1971; Chakraborty et al. 1975).

All this evidence suggests that the positive relationship between birth order and child health is largely a biological effect, determined by nature and represents, thus, an endowment effect. While we do not have the possibilities to detect the nature mechanism with our data, we are confident that the persistence of the birth order effect to controls for the social environment is an indication for the existence of the role of biology. Of course behavioral changes might unfold in other dimensions but smoking and prenatal checkups. For example, social values of the parents may change with higher order pregnancies. However, given the in utero environment is not shaped by parent-child interactions, the inability to control for social values should not affect our results. Hence, our findings that neither maternal age, socio-economic characteristics, behavioral aspects, nor hospitalization rates for pregnancy complications explained the positive birth order effect, are consistent with the nature thesis.[32]

### 4.3 Implications for the Birth Order Effects in Education

We end this section with implications of our findings for the birth order effects in education and ask what role the relationship between birth order and health at birth plays for the birth order effect in educational performance. We build upon findings by Black et al. (2011) who have addressed this issue similarly for Norwegian men in terms of IQ. Given our findings that higher birth order children are better endowed at birth and given findings from the literature that children with better endowments fare better, we expect that birth order differences in education increase in magnitude when accounting for health at birth. We test this in the following.

[Table 8 about here.]

A unique feature of the administrative data is that we are able to match birth information with performance in school for almost a quarter of the sample; these children were in ninth grade between 2002 and 2011.[33] We estimate equation 1 with our outcome of interest being grade point average (GPA) of all grades at the end of ninth grade (Table 8).[34] The grades are composed of the teachers' assessment of the student's performance throughout the year and grades given from national exams. They are given in almost all subjects (but not in sports) and cover oral presentation, written presentation, hand writing, and reading comprehension.

We note four results. *First,* in line with the previous literature, the positive birth order effect in educational performance has reversed after completion of childhood [Table 8, column (1)]. Children of birth order 2, 3, and 4 score on average 0.163, 0.237, and 0.285 standard deviations lower on ninth grade GPA compared to firstborns in the same family. These results indicate a nontrivial birth order effect. *Second*, we add birth weight z-score, SGA, LGA, SGR, and low

[32] The role of biology is probably underestimated as hospitalizations for pregnancy complications have a biological dimension as well. Notice also that the reduction in prenatal care is then not based on a purely behavioral framework but also encompass these fewer maternal constraints, i.e. a reduced need to see a doctor.

[33] We have tested whether a birth order effect in health at birth exists in this subsample. The birth order coefficients are all of the same sign as in Table 2 and statistically different from zero at the 1 percent level. The magnitudes of the coefficients for birth order 2 and 3 are slightly smaller than in Table 2, while the coefficient for birth order 4 is not different from the birth order 2 coefficients.

[34] Schooling in Denmark starts at age six with one year of pre-school, followed by nine years of primary education so that children are normally 15–16 years at the end of ninth grade.

Apgar Score [column (2)] as well as the health index itself [column (5)] and find, consistent with previous research, that better health at birth is positively correlated with educational performance.[35] *Third*, including health at birth significantly increases the magnitude of the birth order coefficients [column (3) and (6)], even though the difference is not large. This finding is in line with Black et al. (2011). *Fourth*, to account for family size effects, we additionally estimate the model separately for family size 2, 3, and 4 (Table 9). The size of the coefficients are remarkably similar with only the coefficients for birth order 2 in 4-child families being slightly smaller.

[Table 9 about here.]

While the initial advantage of later-borns does not translate into later life, it might be that the returns to health at birth differ by birth order. Combining findings from the genetics and neuroscience literature, Cook and Fletcher (2015) show that the effect of birth weight on adult cognition and wages is heterogeneous with part of the population not being affected by variation in birth weight. However, the authors provide no indication that this heterogeneity is linked to birth order. Acknowledging that birth order differences at birth are driven by biology, studies in the medical literature have suggested parity-specific birth weight references to accurately map endowments at birth (Hinkle et al. 2014).

We are not aware of empirical research that tests heterogeneous returns to health at birth by birth order and we, therefore, do so next. We include interactions between birth order and the measures of child health at birth [column (4)] and between birth order and the health index [column(7)]. The coefficients of the interaction terms, not reported, are in all but two cases not statistically significant. The interactions between birth order 2 and 3 with LGA, however, show positive and significant coefficients (0.110 [0.033], 0.108 [0.041]), suggesting that being LGA

[35] Birth weight z-score has a positive and significant effect on GPA. Being too small or too large for a given gestational age at birth significantly reduces GPA. While the coefficient of low Apgar score is imprecisely estimated, the sign of the coefficient is as expected. The coefficient for symmetrical growth restriction goes in the opposite direction from our expectation and is also very imprecisely estimated. That is most likely due to the small cases of SGR in the sample for educational performance. We note that these coefficients do not measure the causal effect of child health at birth on educational performance and we do not attempt to stress the interpretation of these coefficients.

is less harmful for later-borns than for firstborns.[36] This is an important finding given LGA is the only variable that indicated that higher birth order children might be less healthy. The results here imply, that "being too heavy" is less harmful for later born children, at least with respect to school performance in ninth grade. Otherwise, the returns to health do not differ by birth order.

The conclusion of this final analysis is that birth endowments are not a channel of the negative relationship between birth order and educational performance, but that birth endowments increase birth order differences in educational performance. We cannot rule out that birth order differences in educational performance are not the result of the social environment after birth (nurture) and strengthen previous research, discussed in section 2.

# 5 Conclusions

Our study provides new evidence on the relationship between birth order and child health at birth, and the role of health at birth differences in the negative relationship between birth order and educational performance. Using family fixed effects model, we find large birth order differences in health at birth that are robust to the way we define health at birth and hold irrespective of family size. While the socio-economic environment, risk behavior of the mother, and hospitalizations for pregnancy complications differ by birth order, these factors cannot explain the health advantage of later born children. Combining findings from the medical literature with our results, we suggest that birth order differences in health at birth have a biological dimension (nature) being the result of first pregnancies changing maternal physiology in favor of later-borns. Observing the children again at age 15–16, we find that these endowment differences do not explain the negative relationship between birth order and educational performance. Consistent with previous literature, we conclude that birth order differences in education are the product of social determinants (nurture) that are most likely connected to parental-child interactions after birth. The role of nurture for the birth order effects in education, however, is understated if health at birth is not accounted for.

[36]For fourth-borns, however, the coefficient is negative and very imprecisely estimated (-0.042 [0.082]). In the analysis by family size the positive interaction between birth order and LGA holds for birth order 2 in 2– and 4–children families and for birth order 3 in 3-child families.

Our results raise important questions for future research focusing on within family differences. The *positive* birth order effect in health at birth clearly stands in contrast to the *negative* birth order effects in education found in previous research. We extrapolate that the social environment shapes the negative birth order effects in education while biology shapes the positive birth order effect in health at birth. Moreover, it appears like the social environment does not affect the birth order effect in health at birth, but we do not know anything about whether biology plays a role beyond birth. Initial health differences may have latent effects that simply do not show up in tests of cognition (GPA) but that do show up in other dimensions of human capital. For example, in a recent working paper, Black et al. (2015) show that health differences by birth order in adulthood exist. The pattern, however, is mixed, showing that there is no clear firstborn disadvantage or advantage. To understand how birth order differences in health evolve over childhood is therefore a necessary next step.

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**Table 1**

Child and Mother's Charactersitics

| **Panel a: Demographic Characteristics** | | | |
|---|---|---|---|
| Variable | Mean | S.D. | N |
| Number of Children | 2.437 | 0.621 | 1,097,934 |
| Birth Order 1 | 0.431 | 0.495 | 1,097,934 |
| Birth Order 2 | 0.434 | 0.496 | 1,097,934 |
| Birth Order 3 | 0.117 | 0.322 | 1,097,934 |
| Birth Order 4 | 0.018 | 0.133 | 1,097,934 |
| Child is Male | 0.514 | 0.500 | 1,097,934 |
| Month of Conception | 6.708 | 3.424 | 1,097,934 |
| Year of Conception | 1980–2010 | | 1,097,934 |
| **Panel b: Birth Outcomes** | | | |
| Variable | Mean | S.D. | N |
| Birth Weight Z-Score | -0.070 | 1.078 | 1,063,934 |
| Small for Gestational Age (SGA) | 0.031 | 0.173 | 1,063,934 |
| Large for Gestational Age (LGA) | 0.032 | 0.175 | 1,063,934 |
| Symmetrical Growth Restricted (SGR) | 0.014 | 0.117 | 1,063,934 |
| 5-Minute Apgar Score $< 7$ (Low Apgar Score) | 0.007 | 0.081 | 1,063,934 |
| Health Index | 0.001 | 0.996 | 1,063,934 |
| **Panel c: Maternal Characteristics During Pregnancy** | | | |
| Variable | Mean | S.D. | N |
| Working | 0.786 | 0.410 | 1,097,934 |
| Student | 0.022 | 0.148 | 1,097,934 |
| Unemployed | 0.044 | 0.206 | 1,097,934 |
| Not in the Labor Force | 0.147 | 0.354 | 1,097,934 |
| Parental Wage Income (in 100,000 DKK) | 4.933 | 2.727 | 1,097,624 |
| Education (Years) | 14.376 | 2.451 | 1,083,410 |
| Smoking | 0.164 | 0.370 | 721,488 |
| Prenatal Checkup General Practitioner (GP) | 2.142 | 1.452 | 992,064 |
| Prenatal Checkup Midwife | 4.853 | 1.994 | 1,070,855 |
| Prenatal Checkup Specialist | 3.613 | 3.154 | 991,083 |
| Pregnancy Interval (Spacing) | 31.182 | 20.833 | 624,658 |
| Maternal Age (Years) | 28.683 | 4.461 | 1,063,934 |
| Gestational Diabetes | 0.011 | 0.102 | 1,097,934 |
| Gestational Hypertension | 0.008 | 0.088 | 1,097,934 |
| Preeclampsia | 0.029 | 0.167 | 1,097,934 |

**Notes**: Panel a): Included in the sample are all observations of families with at least two children with non-missing observations on all variables used to construct the health index or on perinatal death. Panel b): Included in the sample are all observations of families with at least two children with non-missing observations on all variables used to construct the health index. Panel c): Parental wage income is observed the year before birth and is in 2011 prices and in 100,000 DKK (100,000 DKK corresponds to about 15,020 USD). Labor force participation variables (working, student, unemployed, not in the labor force) are based on main source of income in the year before birth. Education is the length of the mother's highest completed education. Smoking is available since 1991. Pregnancy interval is the time between previous birth and conception and not defined for birth order 1.

**Table 2**
Birth Order Effects at Birth, Child Health

**Panel a) Without Family Fixed Effects**

| | (1) Birth Weight Z-Score | (2) SGA | (3) LGA | (4) SGR | (5) Low Apgar Score | (6) Health Index |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.340*** | -0.020*** | 0.022*** | -0.008*** | -0.003*** | 0.199*** |
| | (0.002) | (0.000) | (0.000) | (0.000) | (0.000) | (0.002) |
| Birth Order 3 | 0.430*** | -0.019*** | 0.035*** | -0.007*** | -0.005*** | 0.232*** |
| | (0.003) | (0.001) | (0.001) | (0.000) | (0.000) | (0.003) |
| Birth Order 4 | 0.496*** | -0.019*** | 0.043*** | -0.007*** | -0.005*** | 0.254*** |
| | (0.007) | (0.001) | (0.002) | (0.001) | (0.001) | (0.007) |
| N | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 |
| Mean | -0.07 | 0.03 | 0.03 | 0.01 | 0.01 | 0.00 |
| Joint Test | 14836.73 | 1042.32 | 2008.42 | 336.6 | 125.66 | 3722.77 |
| P>F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Panel b) With Family Fixed Effects**

| | (1) Birth Weight Z-Score | (2) SGA | (3) LGA | (4) SGR | (5) Low Apgar Score | (6) Health Index |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.393*** | -0.028*** | 0.023*** | -0.012*** | -0.007*** | 0.266*** |
| | (0.003) | (0.001) | (0.001) | (0.000) | (0.000) | (0.004) |
| Birth Order 3 | 0.544*** | -0.037*** | 0.037*** | -0.016*** | -0.013*** | 0.378*** |
| | (0.006) | (0.001) | (0.001) | (0.001) | (0.001) | (0.008) |
| Birth Order 4 | 0.658*** | -0.046*** | 0.045*** | -0.019*** | -0.018*** | 0.467*** |
| | (0.010) | (0.002) | (0.002) | (0.002) | (0.001) | (0.013) |
| N | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 |
| Mean | -0.07 | 0.03 | 0.03 | 0.01 | 0.01 | 0.00 |
| Joint Test | 6719.40 | 792.29 | 487.76 | 270.29 | 133.04 | 2166.98 |
| P>F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Notes**: Panel (a) shows the results of pooled OLS models. Panel (b) shows the results of family fixed effects models. Each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception and gender of the child. Models in panel (a), additionally control for family size effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 3**
Effects of Birth Order on Maternal Labor Force Participation and Parental Wage Income

| | (1) Working | (2) Student | (3) Unemployed | (4) Not in the Labor Force | (5) Parental Wage Income |
|---|---|---|---|---|---|
| Birth Order 2 | -0.078*** | -0.004*** | 0.025*** | 0.056*** | -0.422*** |
| | (0.001) | (0.000) | (0.001) | (0.001) | (0.006) |
| Birth Order 3 | -0.147*** | -0.005*** | 0.035*** | 0.118*** | -0.743*** |
| | (0.003) | (0.001) | (0.002) | (0.002) | (0.013) |
| Birth Order 4 | -0.245*** | 0.003* | 0.045*** | 0.197*** | -1.473*** |
| | (0.005) | (0.002) | (0.003) | (0.004) | (0.024) |
| N | 1,097,934 | 1,097,934 | 1,097,934 | 1,097,934 | 1,097,934 |
| Mean | 0.79 | 0.02 | 0.04 | 0.15 | 4.93 |
| Joint Test | 1341.97 | 63.06 | 389.25 | 932.85 | 1751.23 |
| Prob > F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Notes**: The table shows the results of family fixed effects models; each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception and age of the mother at birth. Parental wage income is in 2011 prices and in 100,000 DKK (100,000 DKK about 15,020 USD). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 4**
Effects of Birth Order on Maternal Behavior

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Number of Prenatal Checkups at | | | |
| | GP | Midwife | Specialist | Smoking |
| Birth Order 2 | -0.073*** | -0.204*** | 0.004 | -0.027*** |
| | (0.003) | (0.006) | (0.007) | (0.001) |
| Birth Order 3 | -0.130*** | -0.319*** | -0.048*** | -0.034*** |
| | (0.006) | (0.012) | (0.014) | (0.002) |
| Birth Order 4 | -0.217*** | -0.461*** | -0.069*** | -0.033*** |
| | (0.010) | (0.021) | (0.024) | (0.004) |
| N | 992,064 | 1,070,855 | 991,083 | 721,488 |
| Mean | 2.14 | 4.85 | 3.15 | 0.16 |
| Joint Test | 238.60 | 434.97 | 18.00 | 293.83 |
| Prob > F | 0.00 | 0.00 | 0.00 | 0.00 |

**Notes**: The table shows the results of family fixed effects models; each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception and age of the mother at birth. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 5**
Effects of Birth Order on Hospitalizations for Medical Pregnancy Complications

| | (1) Gestational Diabetes | (2) Gestational Hypertension | (3) Preeclampsia |
|---|---|---|---|
| Birth Order 2 | -0.005*** | -0.006*** | -0.028*** |
| | (0.000) | (0.000) | (0.001) |
| Birth Order 3 | -0.011*** | -0.007*** | -0.034*** |
| | (0.001) | (0.001) | (0.001) |
| Birth Order 4 | -0.009*** | -0.009*** | -0.037*** |
| | (0.001) | (0.001) | (0.002) |
| N | 1,097,934 | 1,097,934 | 1,097,934 |
| Mean | 0.01 | 0.01 | 0.03 |
| Joint Test | 67.47 | 116.29 | 1081.35 |
| Prob > F | 0.00 | 0.00 | 0.00 |

**Notes**: The table shows the results of family fixed effects models; each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception and age of the mother at birth. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 6**

Mechanisms of the Birth Order Relationship in Health Endowments

| | (1)<br>Health Index | (2)<br>Health Index | (3)<br>Health Index | (4)<br>Health Index | (5)<br>Health Index | (6)<br>Health Index |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.266*** | 0.268*** | 0.266*** | 0.265*** | 0.268*** | 0.259*** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Birth Order 3 | 0.378*** | 0.382*** | 0.378*** | 0.375*** | 0.383*** | 0.371*** |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Birth Order 4 | 0.467*** | 0.469*** | 0.462*** | 0.459*** | 0.470*** | 0.457*** |
| | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) |
| **Maternal Age at Birth** | | | | | | |
| Maternal Age 18 | | 0.011 | 0.008 | 0.004 | 0.012 | 0.015 |
| | | (0.034) | (0.034) | (0.034) | (0.034) | (0.034) |
| Maternal Age 18-21 | | -0.004 | -0.004 | -0.006 | -0.002 | -0.000 |
| | | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) |
| Maternal Age 22-25 | | 0.006 | 0.005 | 0.005 | 0.007 | 0.007 |
| | | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| Maternal Age 30-33 | | -0.003 | -0.003 | -0.003 | -0.003 | -0.003 |
| | | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Maternal Age 34-37 | | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 |
| | | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Maternal Age $>$ 37 | | 0.025* | 0.024* | 0.022* | 0.022* | 0.023* |
| | | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) |
| **Socio-Economic Characteristics** | | | | | | |
| Student | | | 0.027*** | 0.027*** | 0.028*** | 0.028*** |
| | | | (0.007) | (0.007) | (0.007) | (0.007) |
| Unemployed | | | 0.010 | 0.010 | 0.011 | 0.011 |
| | | | (0.007) | (0.007) | (0.007) | (0.007) |
| Not in the Labor Force | | | 0.014*** | 0.015*** | 0.015*** | 0.014*** |
| | | | (0.004) | (0.004) | (0.004) | (0.004) |
| Parental Wage Income | | | -0.003*** | -0.003*** | -0.003*** | -0.003*** |
| | | | (0.001) | (0.001) | (0.001) | (0.001) |
| **Maternal Behavior** | | | | | | |
| Smoking | | | | -0.050*** | -0.050*** | -0.051*** |
| | | | | (0.006) | (0.006) | (0.006) |
| Prenatal Checkups GP | | | | | 0.023*** | 0.024*** |

**Table 6** continued

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | (0.002) | (0.002) | |
| Prenatal Checkups Midwife | | | | | 0.010*** | 0.009*** | |
| | | | | | (0.001) | (0.001) | |
| Prenatal Checkups Specialist | | | | | 0.015*** | 0.015*** | |
| | | | | | (0.001) | (0.001) | |
| **Hospitalizations for Medical Pregnancy Complications** | | | | | | | |
| Gestational Diabetes | | | | | | 0.013 | |
| | | | | | | (0.014) | |
| Gestational Hypertension | | | | | | -0.148*** | |
| | | | | | | (0.018) | |
| Preeclampsia | | | | | | -0.325*** | |
| | | | | | | (0.011) | |
| **Differences in Birth Order Coefficients** | | | | | | | |
| △ Birth Order 2 | | 0.002*** | -0.002*** | -0.001*** | 0.003*** | -0.009*** | **-0.007***** |
| △ Birth Order 3 | | 0.004*** | -0.005*** | -0.003*** | 0.008*** | -0.012*** | **-0.007***** |
| △ Birth Order 4 | | 0.002*** | -0.007*** | -0.003*** | 0.011*** | -0.013*** | **-0.010***** |
| N | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | |
| Mean | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Joint Test | 2166.98 | 2098.94 | 2052.77 | 2029.35 | 2058.76 | 1914.59 | |
| Prob > F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |

**Notes**: The table shows the results of family fixed effects models; each column represents a separate regression. Dependent variable is health index at birth. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include year by month of conception dummies and a dummy for gender of the child. Omitted category in column (3)–(6) is working in the year before birth. Parental wage income is observed the year before birth and is in 2011 prices and in 100,000 DKK (100,000 DKK corresponds to about 15,020 USD). Missing observations are mainly due to different reporting schemes over the sample period. To account for any potential underlying systematic scheme, we account for missing values by including indicator variables for missing values. The triangle (△) is the difference between the birth order coefficients in the two enclosed columns for birth order 2, 3 and 4, respectively. The bold differences in the last column compare column (1) with column (6). The test for the differences is based on a Wald test. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 7**

The Role of the Pregnancy Interval in the Birth Order Relationship in Health Endowments

| | (1) Health Index | (2) Health Index |
|---|---|---|
| Birth Order 3 | 0.128*** | 0.128*** |
| | (0.007) | (0.008) |
| Birth Order 4 | 0.224*** | 0.223*** |
| | (0.014) | (0.017) |
| Pregnancy Interval $<$ 11 months | | 0.030*** |
| | | (0.008) |
| Pregnancy Interval 12–17 months | | -0.007 |
| | | (0.007) |
| Pregnancy Interval 24-29 months | | -0.001 |
| | | (0.007) |
| Pregnancy Interval 30–37 months | | -0.003 |
| | | (0.007) |
| Pregnancy Interval 38–51 month | | -0.012 |
| | | (0.008) |
| Pregnancy Interval $>$51 months | | 0.005 |
| | | (0.010) |
| △ Birth Order 3 | 0.000 | |
| △ Birth Order 4 | -0.001 | |
| N | 265,128 | 265,128 |
| Mean | 0.11 | 0.11 |
| Joint Test | 176.39 | 121.94 |
| Prob $>$ F | 0.00 | 0.00 |

**Notes**: The table shows the results of family fixed effects model; each column represents a separate regression. Dependent variable is health index at birth. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1 and pregnancy interval 18–23 months. All regressions include dummies for year by month of conception, gender of the child, and age of the mother at birth. The triangle (△) is the difference between the birth order coefficients for birth order 3 and 4, respectively. The test for the differences is based on a Wald test. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 8**
Birth Order Effects on Ninth Grade GPA

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Birth Order 2 | -0.163*** | | -0.172*** | -0.174*** | | -0.166*** | -0.166*** |
| | (0.007) | | (0.007) | (0.007) | | (0.007) | (0.007) |
| Birth Order 3 | -0.237*** | | -0.248*** | -0.250*** | | -0.241*** | -0.242*** |
| | (0.014) | | (0.014) | (0.014) | | (0.014) | (0.014) |
| Birth Order 4 | -0.285*** | | -0.297*** | -0.298*** | | -0.289*** | -0.289*** |
| | (0.024) | | (0.024) | (0.025) | | (0.024) | (0.024) |
| Birth Weight Z-Score | | 0.019*** | 0.029*** | 0.032*** | | | |
| | | (0.003) | (0.003) | (0.004) | | | |
| SGA | | -0.053*** | -0.055*** | -0.042** | | | |
| | | (0.016) | (0.016) | (0.020) | | | |
| LGA | | -0.036*** | -0.043*** | -0.127*** | | | |
| | | (0.014) | (0.014) | (0.029) | | | |
| SGR | | 0.027 | 0.029 | 0.010 | | | |
| | | (0.022) | (0.022) | (0.028) | | | |
| Low Apgar Score | | -0.034 | -0.039 | -0.038 | | | |
| | | (0.025) | (0.025) | (0.039) | | | |
| Health Index | | | | | 0.014*** | 0.019*** | 0.019*** |
| | | | | | (0.002) | (0.002) | (0.003) |
| Interaction Birth Order | – | – | No | Yes | – | No | Yes |
| N | 232,830 | 232,830 | 232,830 | 232,830 | 232,830 | 232,830 | 232,830 |
| Mean | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |

**Notes**: The table shows the results of family fixed effects models; each column represents a separate regression. Dependent variable is Ninth grade GPA. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception, gender of the child, age of the mother at birth, and year of graduation. Column (4) adds interactions between the birth order dummies and birth weight z-score, LGA, SGA, SGR, and low Apgar score. Column (7) adds interactions between the birth order dummies and the health index. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 9**

Birth Order Effects on Ninth Grade GPA - by Family Size

| **Panel a)** | 2–Child Family | | | | 3–Child Family | | | | 4–Child Family | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Birth Order 2 | -0.166$^{***}$ | | -0.176$^{***}$ | -0.178$^{***}$ | -0.163$^{***}$ | | -0.172$^{***}$ | -0.175$^{***}$ | -0.140$^{***}$ | | -0.147$^{***}$ | -0.153$^{***}$ |
| | (0.010) | | (0.010) | (0.010) | (0.010) | | (0.010) | (0.010) | (0.019) | | (0.019) | (0.020) |
| Birth Order 3 | | | | | -0.267$^{***}$ | | -0.277$^{***}$ | -0.281$^{***}$ | -0.263$^{***}$ | | -0.271$^{***}$ | -0.266$^{***}$ |
| | | | | | (0.022) | | (0.022) | (0.022) | (0.036) | | (0.036) | (0.036) |
| Birth Order 4 | | | | | | | | | -0.348$^{***}$ | | -0.356$^{***}$ | -0.354$^{***}$ |
| | | | | | | | | | (0.055) | | (0.055) | (0.055) |
| Birth Weight Z-Score | | 0.022$^{***}$ | 0.030$^{***}$ | 0.034$^{***}$ | | 0.017$^{***}$ | 0.028$^{***}$ | 0.030$^{***}$ | | 0.022$^{**}$ | 0.029$^{***}$ | 0.023 |
| | | (0.004) | (0.004) | (0.005) | | (0.005) | (0.005) | (0.007) | | (0.009) | (0.009) | (0.015) |
| SGA | | -0.043$^{**}$ | -0.041$^{*}$ | -0.021 | | -0.082$^{***}$ | -0.087$^{***}$ | -0.099$^{**}$ | | -0.015 | -0.017 | -0.011 |
| | | (0.021) | (0.021) | (0.025) | | (0.028) | (0.028) | (0.039) | | (0.055) | (0.054) | (0.082) |
| LGA | | -0.043$^{**}$ | -0.045$^{**}$ | -0.146$^{***}$ | | -0.039$^{*}$ | -0.047$^{**}$ | -0.109$^{**}$ | | -0.016 | -0.021 | -0.074 |
| | | (0.020) | (0.020) | (0.037) | | (0.021) | (0.021) | (0.049) | | (0.039) | (0.039) | (0.110) |
| SGR | | 0.016 | 0.015 | -0.003 | | 0.055 | 0.058 | 0.051 | | 0.002 | 0.007 | -0.038 |
| | | (0.030) | (0.029) | (0.035) | | (0.037) | (0.037) | (0.051) | | (0.076) | (0.075) | (0.114) |
| Low Apgar Score | | -0.022 | -0.025 | -0.012 | | -0.061 | -0.067 | -0.098 | | -0.023 | -0.029 | -0.041 |
| | | (0.034) | (0.034) | (0.047) | | (0.042) | (0.042) | (0.075) | | (0.073) | (0.072) | (0.172) |
| Interaction Birth Order | – | – | No | Yes | – | – | No | Yes | – | – | No | Yes |
| N | 129,246 | 129,246 | 129,246 | 129,246 | 81,627 | 81,627 | 81,627 | 81,627 | 21,957 | 21,957 | 21,957 | 21,957 |
| Mean | 0.12 | 0.12 | 0.12 | 0.12 | 0.10 | 0.10 | 0.10 | 0.10 | -0.08 | -0.08 | -0.08 | -0.08 |

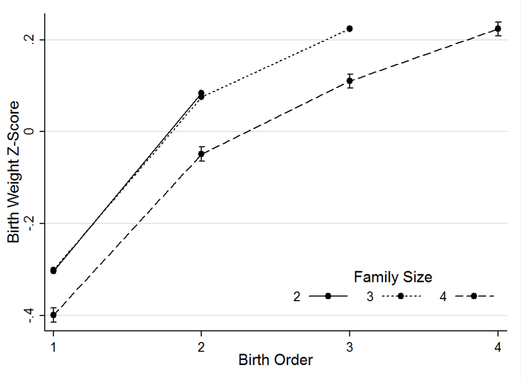
**Table 9** continued

| **Panel b)** | 2–Child Family | | | | 3–Child Family | | | | 4–Child Family | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | | (4) | (5) | (6) | | (7) | (8) | (9) |
| Birth Order 2 | | | -0.169*** | -0.169*** | | | -0.167*** | -0.167*** | | | -0.142*** | -0.141*** |
| | | | (0.010) | (0.010) | | | (0.010) | (0.010) | | | (0.019) | (0.019) |
| Birth Order 3 | | | | | | | -0.272*** | -0.272*** | | | -0.265*** | -0.267*** |
| | | | | | | | (0.022) | (0.022) | | | (0.036) | (0.036) |
| Birth Order 4 | | | | | | | | | | | -0.349*** | -0.350*** |
| | | | | | | | | | | | (0.055) | (0.055) |
| Health Index | | 0.015*** | 0.017*** | 0.017*** | | 0.016*** | 0.022*** | 0.025*** | | 0.013* | 0.016** | 0.014 |
| | | (0.003) | (0.003) | (0.004) | | (0.004) | (0.004) | (0.005) | | (0.008) | (0.008) | (0.011) |
| Interaction Birth Order | – | – | No | Yes | – | – | No | Yes | – | – | No | Yes |
| N | | 129,246 | 129,246 | 129,246 | | 81,627 | 81,627 | 81,627 | | 21,957 | 21,957 | 21,957 |
| Mean | | 0.12 | 0.12 | 0.12 | | 0.10 | 0.10 | 0.10 | | -0.08 | -0.08 | -0.08 |

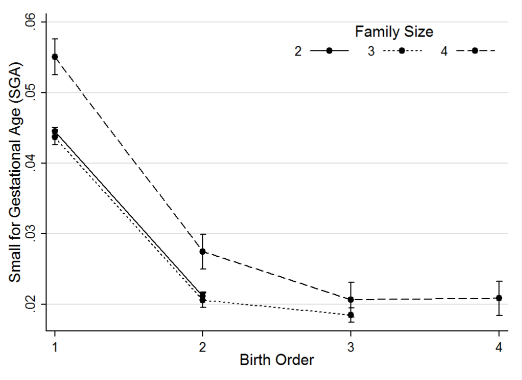
**Notes**: The table shows the results of family fixed effects model; each column represents a separate regression. Dependent variable is ninth grade GPA. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception, gender of the child, age of the mother at birth, and year of graduation. Column (4) adds interactions between the birth order dummies and birth weight z-score, LGA, SGA, SGR, and low Apgar score. Column (7) adds interactions between the birth order dummies and the health index. Column (4), (8), (12), panel a) adds interactions between the birth order dummies and birth weight z-score, LGA, SGA, SGR, and low Apgar score. Column (3), (6) and (9), panel b) adds interactions between the birth order dummies and the health index. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Figure 1**
Birth Outcomes by Birth Order

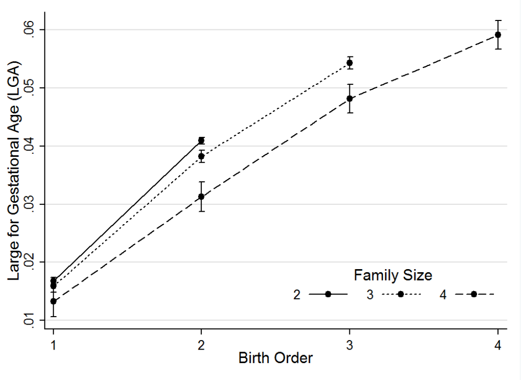
**(a)** Birth Weight Z-Score



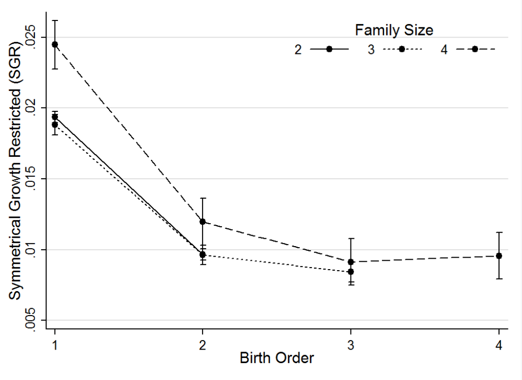

**(b)** Small for Gestational Age (SGA)



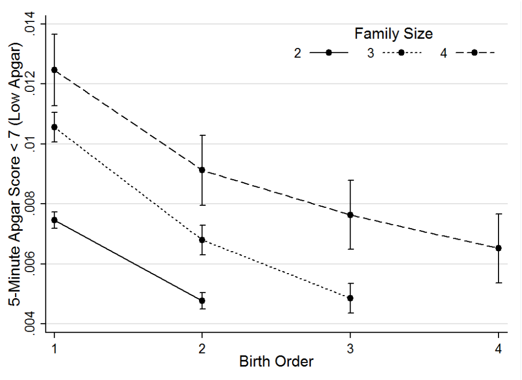

**(c)** Large for Gestational Age (LGA)



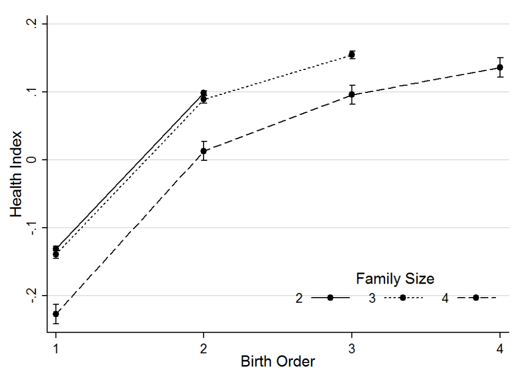

**(d)** Symmetrical Growth Restricted (SGR)




**(e)** 5-Minute Apgar Score < 7 (Low Apgar Score)



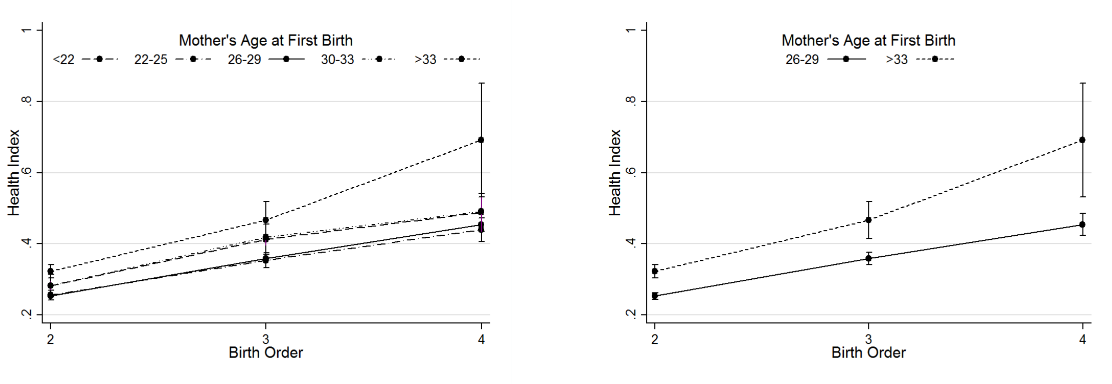

**(f)** Health Index




**Notes**: Figure 1 plots the mean of the variable by birth order and family size. The whiskers represent the 95 percent confidence interval.

**Figure 2**
Birth Order Effect by Age at First Birth

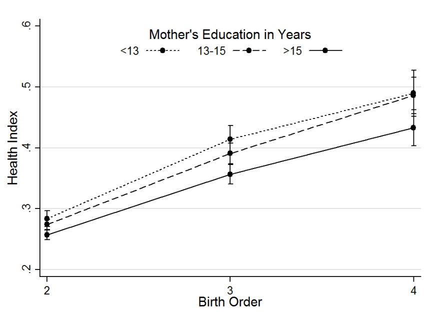
**(a)** Alle Age Groups **(b)** Age Group 26–29 and >33



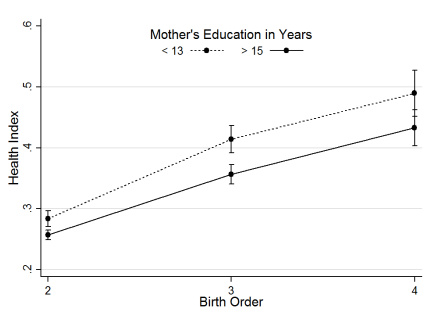

**Notes**: Figure 2 plots the interaction between birth order and maternal age at first birth in the family fixed effects model, including dummies for year by month of conception, gender of the child, and age of the mother at birth. The whiskers indicate the 95 percent confidence interval.

**Figure 3**
Birth Order Effect by Maternal Education

**(a)** All Education Groups

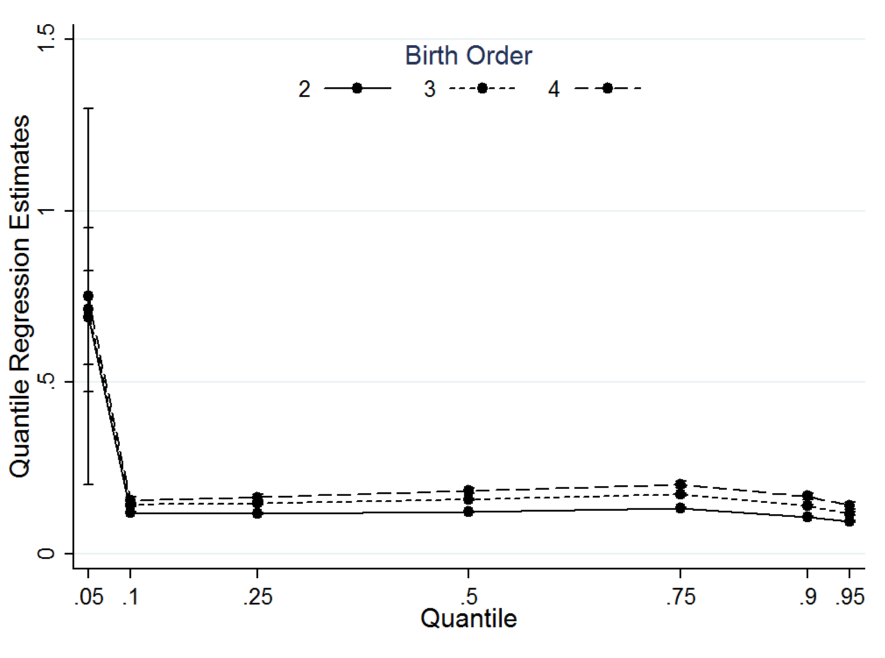



**(b)** Education Groups $< 13$, $>15$




**Notes**: Figure 3 plots the interaction between birth order and education in the family fixed effects model, including dummies for year by month of conception, gender of the child, and age of the mother at birth. The whiskers indicate the 95 percent confidence interval.

**Figure 4**
Quantile Regression Estimates




**Notes**: Figure 5 plots the predictions for health index. Predictions are based on family fixed effects estimation. Dependent variable is health index at birth. The sample includes families with 2–4 children. The model includes month and year of conception trend, squared and cubic; dummies for month of conception, family size, maternal age at first birth, education of the mother, and gender of the child

**Figure 5**

Predictions Health Index by Birth Order and Controls

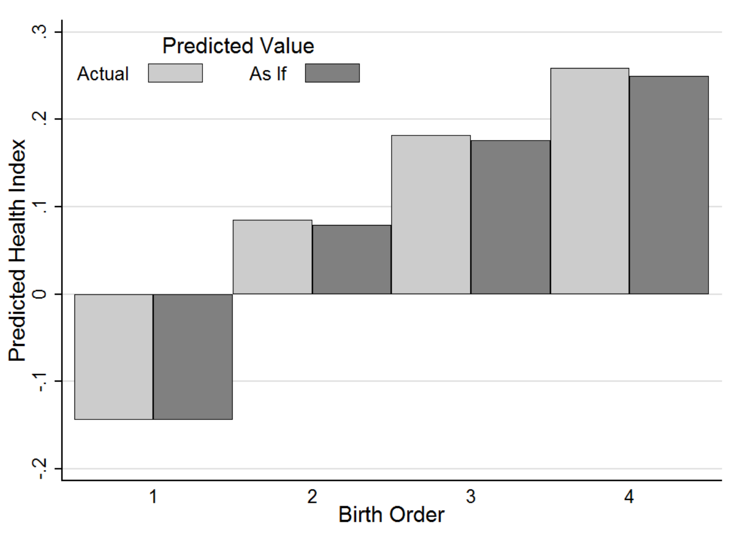
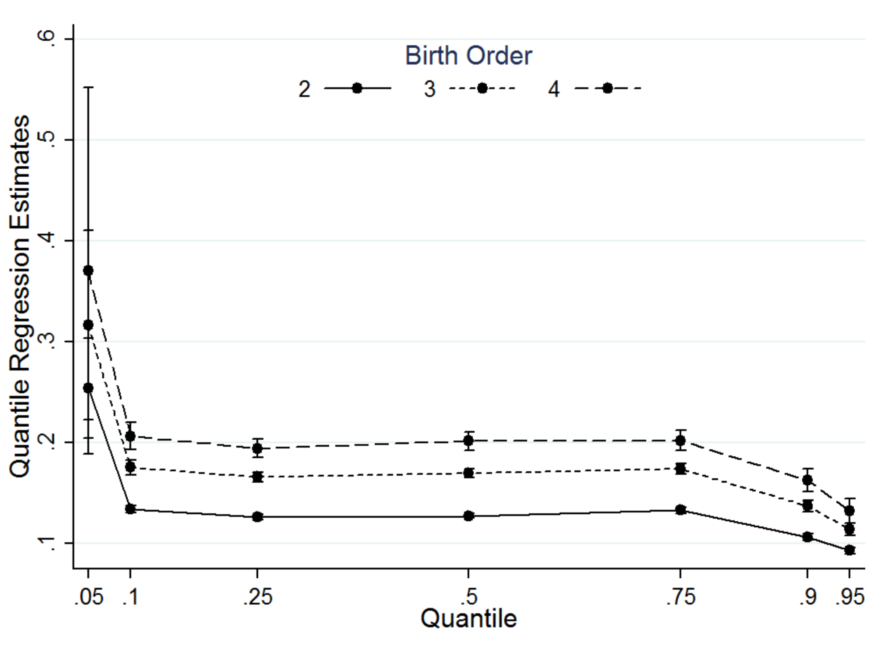



Figure 5 plots the predictions for health index. Predictions are based on family fixed effects estimation. Dependent variable is health index at birth. The sample includes families with 2–4 children. The model includes dummies for year by month of conception; gender of the child; maternal age at birth; labor force participation; smoking during pregnancy; hospitalizations for gestational diabetes, gestational hypertension, and preeclampsia; controls for parental wage income; number of prenatal checkups at the GP, the midwife, and the specialist. The dark gray bars use the value of all controls for birth order 1 for the prediction. Confidence intervals were too small to be depicted.

**Figure 6**
Quantile Regression Estimates With In Utero Environment Controls




**Notes**: Figure 5 plots the predictions for health index. Predictions are based on family fixed effects estimation. Dependent variable is health index at birth. The sample includes families with 2–4 children. The model includes month and year of conception trend, squared and cubic; dummies for month of conception, family size, maternal age at first birth, education of the mother, gender of the child, maternal age at birth, labor force participation, smoking during pregnancy, hospitalizations for gestational diabetes, gestational hypertension, and preeclampsia; controls for parental wage income; number of prenatal checkups at the GP, the midwife, and the specialist.

**Table A1**

Birth Order Effects at Birth, Child Health - Additional Measures

| | (1) ln(Birth Weight) | (2) ln(Birth Length) | (3) Premature | (4) Head Circumference | (5) Perinatal Conditions | (6) Perinatal Death |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.054*** | 0.010*** | -0.022*** | 0.365*** | -0.083*** | -0.013*** |
| | (0.001) | (0.000) | (0.001) | (0.009) | (0.002) | (0.000) |
| Birth Order 3 | 0.075*** | 0.015*** | -0.029*** | 0.546*** | -0.109*** | -0.033*** |
| | (0.001) | (0.000) | (0.001) | (0.018) | (0.004) | (0.001) |
| Birth Order 4 | 0.088*** | 0.017*** | -0.029*** | 0.669*** | -0.123*** | -0.052*** |
| | (0.002) | (0.001) | (0.002) | (0.030) | (0.006) | (0.001) |
| N | 1,063,934 | 1,063,934 | 1,063,934 | 474,728 | 632,287 | 1,097,930 |
| Mean | 8.16 | 3.95 | 0.04 | 35.17 | 0.14 | 0.003 |
| Joint Test | 4665.48 | 1619.48 | 432.11 | 666.20 | 930.59 | 693.04 |
| P>F | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Notes**: The table shows the results of family fixed effects model; each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception and gender of the child. Prematurity is defined as gestational age less than 37 weeks. Head circumference is in cm and reported since 1997. Perinatal condition indicates the diagnosis of a condition originating in the perinatal period and is based on the ICD-10 codes P00–P96. We exclude the codes P05–P08 since these indicate birth weight and gestational age and we look at these outcomes already separately. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table A2**

Birth Order Effects at Birth, Child Health – by Family Size

**Panel a) 2–Child Families**

| | Birth Weight Z-Score | SGA | LGA | SGR | Low Apgar Score | Health Index |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.39*** | -0.027*** | 0.024*** | -0.012*** | -0.004*** | 0.253*** |
| | (0.004) | (0.001) | (0.001) | (0.001) | (0.000) | (0.006) |
| N | 670,572 | 670,572 | 670,572 | 670,572 | 670,572 | 670,572 |
| Mean | -0.11 | 0.03 | 0.03 | 0.01 | 0.01 | -0.02 -0.02 |

**Panel b) 3–Child Families**

| | Birth Weight Z-Score | SGA | LGA | SGR | Low Apgar Score | Health Index |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.389*** | -0.028*** | 0.022*** | -0.011*** | -0.009*** | 0.270*** |
| | (0.005) | (0.001) | (0.001) | (0.001) | (0.001) | (0.006) |
| Birth Order 3 | 0.560*** | -0.037*** | 0.039*** | -0.015*** | -0.018*** | 0.403*** |
| | (0.009) | (0.002) | (0.002) | (0.001) | (0.001) | (0.011) |
| N | 318,333 | 318,333 | 318,333 | 318,333 | 318,333 | 318,333 |
| Mean | 0.00 | 0.03 | 0.04 | 0.01 | 0.01 | 0.04 |

**Panel c) 4–Child Families**

| | Birth Weight Z-Score | SGA | LGA | SGR | Low Apgar Score | Health Index |
|---|---|---|---|---|---|---|
| Birth Order 2 | 0.350*** | -0.031*** | 0.016*** | -0.013*** | -0.009*** | 0.271*** |
| | (0.010) | (0.002) | (0.002) | (0.002) | (0.001) | (0.013) |
| Birth Order 3 | 0.507*** | -0.045*** | 0.030*** | -0.016*** | -0.017*** | 0.405*** |
| | (0.015) | (0.003) | (0.003) | (0.002) | (0.002) | (0.019) |
| Birth Order 4 | 0.624*** | -0.051*** | 0.039*** | -0.017*** | -0.026*** | 0.498*** |
| | (0.022) | (0.005) | (0.005) | (0.003) | (0.003) | (0.027) |
| N | 75,029 | 75,029 | 75,029 | 75,029 | 75,029 | 75,029 |
| Mean | -0.02 | 0.03 | 0.04 | 0.01 | 0.01 | 0.01 |

**Notes**: The table shows the results of family fixed effects models; each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include dummies for year by month of conception and gender of the child. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table A3**

Quantile Regression, OLS, and Fixed Effects Estimates for Health Index

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Quantile | | | | | | |
| | 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 0.9 | 0.95 | OLS | Family FE |
| Birth Order 2 | 0.689*** | 0.120*** | 0.118*** | 0.122*** | 0.133*** | 0.109*** | 0.095*** | 0.204*** | 0.266*** |
| | (0.070) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.004) |
| Birth Order 3 | 0.713*** | 0.145*** | 0.148*** | 0.159*** | 0.174*** | 0.141*** | 0.119*** | 0.242*** | 0.378*** |
| | (0.122) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.008) |
| Birth Order 4 | 0.750*** | 0.156*** | 0.165*** | 0.184*** | 0.203*** | 0.169*** | 0.141*** | 0.268*** | 0.466*** |
| | (0.279) | (0.006) | (0.004) | (0.004) | (0.004) | (0.005) | (0.005) | (0.007) | (0.012) |
| N | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 |

**Notes**: Column (1)–(7) show the quantile regression estimates . Column (6) shows the result of a pooled OLS model and column (7) that of a family fixed effects model. Each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include month and year of conception trend, squared and cubic; dummies for month of conception, and gender of the child. Column (1)–(8) additionally control for family size effects, maternal age at first birth, and education of the mother. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

**Table A4**

Quantile Regression, OLS, and Fixed Effects Estimates for Health Index With In Utero Environment Controls

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Quantile | | | | | | |
| | 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 0.9 | 0.95 | OLS | Family FE |
| Birth Order 2 | 0.254*** | 0.134*** | 0.126*** | 0.127*** | 0.132*** | 0.106*** | 0.092*** | 0.217*** | 0.258*** |
| | (0.025) | (0.002) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.002) | (0.004) |
| Birth Order 3 | 0.317*** | 0.175*** | 0.165*** | 0.169*** | 0.174*** | 0.137*** | 0.114*** | 0.278*** | 0.369*** |
| | (0.048) | (0.004) | (0.003) | (0.002) | (0.003) | (0.003) | (0.003) | (0.005) | (0.008) |
| Birth Order 4 | 0.370*** | 0.206*** | 0.194*** | 0.201*** | 0.202*** | 0.162*** | 0.132*** | 0.329*** | 0.455*** |
| | (0.093) | (0.007) | (0.005) | (0.005) | (0.005) | (0.006) | (0.006) | (0.009) | (0.013) |
| N | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 | 1,063,934 |

**Notes**: Column (1)–(7) show the quantile regression estimates . Column (6) shows the result of a pooled OLS model and column (7) that of a family fixed effects model. Each column represents a separate regression. Standard errors, clustered at the family level, are in parentheses. The sample includes families with 2–4 children. The omitted category is birth order 1. All regressions include month and year of conception trend, squared and cubic; dummies for month of conception, gender of the child, maternal age at birth, labor force participation, smoking during pregnancy, hospitalizations for gestational diabetes, gestational hypertension, and preeclampsia; controls for parental wage income; number of prenatal checkups at the GP, the midwife, and the specialist. Column (1)–(8) additionally control for family size effects, maternal age at first birth, and education of the mother. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$