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Abstract

Although preterm births are the leading cause of perinatal morbidity and mortality in advanced economies, evidence about the consequences of such births later in life is limited. Using Swedish population register data on cohorts born 1982-1994 (N=1,087,750), we examine the effects of preterm births on school grades using sibling fixed effect models which compare individuals with their non-preterm siblings. We test for heterogeneous effects by degree of prematurity, as well as whether family socioeconomic resources and school characteristics can compensate for any negative effects of premature births. Our results show that preterm births can have negative effects on school grades, but these negative effects are largely confined to children born extremely preterm (<28 weeks of gestation, i.e. born at least 10 weeks earlier). Children born moderately preterm (i.e. born up to 5 weeks early) suffer no ill effects. We do not find any evidence for the moderating effect of parental socioeconomic resources. Our results indicate that school environment is very important for the outcomes of preterm born children, such that those born extremely preterm that are in the top decile of schools have as good grades as those born full-term that are in an average school. However, good schools appear to lift scores for all groups, and as a result that gap between extremely preterm and full-term children remains also in the best schools. This highlights the role of schools as institutions that may either reduce or reinforce the early life course disadvantage.

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Introduction

Recent years have seen a growing interest in the long-term consequences of early life disadvantage, including health and developmental outcomes. Most of this research has focused upon factors such as environmental exposures during childhood, socioeconomic circumstances in the family of origin, sociodemographic factors such as parental age at the time of birth and birth order, as well as the long-term impact of perinatal health (Almond, Currie, & Duque, 2018; Barclay & Myrskylä, 2018; Boardman, Powers, Padilla, & Hummer, 2002; Torche, 2018). The long-term consequences of being born with low birth weight have attracted a particularly large degree of research attention (Black, Devereux, & Salvanes, 2007; Cook & Fletcher, 2015; Goisis, Özcan, & Myrskylä, 2017). High quality data and carefully designed methods for causal inference have been marshalled to reveal that children born with low birth weight have lower grades in school, lower scores on cognitive ability tests, lower final educational attainment, worse outcomes in the labor market, as well as poorer health in adulthood (Behrman & Rosenzweig 2004; Black, Devereux, & Salvanes, 2005; Black et al., 2007; Conley & Bennett, 2000; Risnes et al., 2011). However, a factor closely related to low birth weight, preterm birth, has been studied less extensively, particularly with statistical methods that reduce residual confounding and allow for the identification of the long-term consequences of preterm birth.

The relative lack of attention devoted to the long-term consequences of preterm births is surprising for three reasons. First, the prevalence of prematurity is high. Across 184 countries in 2010, between 5% and 18% of children were born premature, defined as being born before 37 weeks gestation (Blencowe et al., 2012). Second, preterm birth rates have increased across many high-income countries (Beck et al., 2010). In the United States preterm birth rates rose by over 15% from 10.6% in 1989 to 12.5% in 2000, and despite a brief period of stagnation between 2007-2014, an upward trend has been observed again in recent years (Ananth, Joseph, Oyelese, Demissie, & Vintzileos, 2005; Martin & Osterman, 2018). Many other high-income countries show a similar pattern (Zeitlin et al., 2013). In Sweden, however, the proportion of preterm births stabilized at a low level, 6%, between 1996-2008 (Zeitlin et al., 2013) but has recently declined to 4.7% (Richards et al., 2016). Third, and most importantly, preterm births may have significant consequences for individuals and societies. Preterm births are the leading cause of perinatal morbidity and mortality in high-income countries (Fell et al., 2015; Goldenberg, Culhane, Iams, & Romero, 2008) and require considerable support from the health services (Frey & Klebanoff, 2016; Mangham, Petrou, Doyle, Draper, &

Marlow, 2009; Petrou, 2005). Infants born preterm have immature organ systems and relative to full-term newborns they are more likely to suffer from respiratory distress syndrome, a compromised immune system, hearing and vision problems, and neurodevelopmental disability (R. Behrman & Butler, 2006).

Neurodevelopmental disorders that arise as a consequence of premature births are particularly important for understanding the link between preterm birth and educational disadvantage. Children born preterm exhibit deficiencies in both white and gray brain matter, which can be attributed to the fact that grey matter volume normally increases three-fold between 29 weeks of gestation and full-term (Kuban et al., 1999), and white matter in the brain also increases substantially after 29 weeks of gestation (Kinney, Brody, Kloman, & Gilles, 1988). As such, children born extremely preterm (i.e. <28 weeks of gestation) are particularly likely to suffer long-term consequences related to educational disadvantage. Brain imaging studies show that the brains of children born prematurely exhibit lower levels of maturation, and have lower volumes at term-equivalent-age (e.g. at age 5 weeks for a child born 5 weeks early) than children born at full-term (Lind et al., 2011), and these differences are still evident at ages 7-15 (Constable et al., 2008; Counsell & Boardman, 2005). In comparison with children born full-term, children born preterm exhibit both macro- and microstructural brain abnormalities (Nosarti et al., 2002). These differences in neurodevelopment by gestational age have also been correlated with later cognition, behavior, as well as neuromotor performance (Keunen et al., 2016). The increasing prevalence of preterm births is therefore not only a challenge for the children and parents directly affected, but is also likely to have implications at the population-level for health care costs and educational attainment.

This study provides a rich examination of the consequences of preterm births for educational disadvantage. First, using Swedish population data with information on school grades measured at age 16, we examine whether the potential negative effects of preterm birth on achievement vary according to degree of prematurity. Second, we use sibling fixed effects that adjust for unobserved confounding by parental factors associated with both the risk of preterm birth and child outcomes. Finally, we extend the existing literature by examining heterogeneity in the effects of preterm births on school grades by family resources and school characteristics. Specifically, we consider maternal education, parental employment, household income and proxies for school quality. This allows us to determine the extent to which the negative effects of preterm births are concentrated amongst children raised in disadvantaged families or attending lower quality schools. Thus, our study recognizes both that early life disadvantage can shape educational outcomes as well as the fact that the postnatal environmental and socioeconomic conditions experienced by individuals may moderate or compensate for the negative effects of early life disadvantage.

Previous Research

Although the associations between preterm births and adverse health outcomes early in life are well documented, premature births may also have long-term consequences. However, empirical evidence on these long-term impacts is limited. Previous studies have found that preterm birth is associated with a host of poor long-term outcomes, ranging from socioeconomic attainment, to health, to fertility, but here we focus our attention on outcomes related to educational disadvantage. A 2002 meta-analysis of 15 studies found that children born preterm had lower cognitive performance than children born full-term, and they were also twice as likely to have been diagnosed with attention disorders (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Cheong et al., 2017), which have also been linked to educational outcomes. Since 2002 a number of other studies have also suggested that children born preterm, and particularly extremely preterm, exhibit marked disadvantages in performance on general cognitive ability assessments (Marlow, Wolke, Bracewell, & Samara, 2005), as well as assessments of arithmetic and reading ability (Anderson, Doyle, & Group, 2003).

Research in the Nordic region also suggests that preterm birth has negative consequences for educational achievement and attainment. In Norway and Sweden, for example, children born prematurely have lower educational attainment and cognitive competence (Ekeus, Lindström, Lindblad, Rasmussen, & Hjern, 2010; Lindström, Winbladh, Haglund, & Hjern, 2007; Stjernqvist & Svenningsen, 1999; Swamy, Østbye, & SkjŠrven, 2008), though active perinatal care may be able to mitigate these developmental disadvantages (Serenius et al., 2016). Research using Danish data has also reported that the lower the gestational age at the time of birth, the lower the likelihood is of the child completing the most basic level of education (R. Mathiasen, B. M. Hansen, A.-M. Nybo Anderson, & G. Greisen, 2009). However, other studies, using data from Finland, have found that premature birth was no longer associated with educational attainment after adjusting for maternal sociodemographic characteristics (Härkönen, Kaymakçalan, Mäki, & Taanila, 2012).

Although many studies have examined the correlation between gestational age and educational outcomes, few studies have used a causal identification strategy to examine the long-term consequences of preterm birth for educational achievement. Previous research on the long-term consequences of preterm birth has largely focused on first-born children, and employed statistical methods that compare children across families with relatively limited adjustment for the factors that vary between families (Delobel-Ayoub et al., 2009; Ekeus et al., 2010; Lindström et al., 2007; R. Mathiasen, B. M. Hansen, A. M. NYBO ANDERSON, & G. Greisen, 2009). As a consequence, many previous studies on the relationship between preterm birth and long-term outcomes are confounded by factors that are related to the risk of preterm birth as well as long-term educational outcomes, critically including the health, educational level, and socioeconomic circumstances of the mothers who gave birth to these preterm children.

The only study that we are aware of examining the effects of preterm birth on educational achievement using a causal identification strategy is a paper by D'onofrio et al. (2013), which used Swedish population data on cohorts born 1973-1982. D'onofrio et al. (2013) found that the relationship between gestational age and a failure to pass in high school only persisted for those born extremely preterm after comparing siblings in the same family, while the effects of preterm births on educational outcomes measured after age 16 was no longer statistically significant in the sibling comparison models. However, the study by D'Onofrio et al. (2013) did not consider whether the consequences of preterm birth vary by the parental socioeconomic status or across different types of schools. This question is at the center of our paper. We also study more recent birth cohorts, born in the 1980s and 1990s, where the effects of preterm births are likely to differ due to advances in the technology employed by neonatal intensive care units.

Potential Compensation by Parental Resources

The educational disadvantages attributable to premature births may be reduced by parental compensatory behavior (Bharadwaj, Eberhard, & Neilson, 2018). Parents may pursue a number of strategies to achieve this goal. They may provide more cognitive stimulation for preterm infants as compared to their siblings, and they may also make additional investments in educational attainment of children born prematurely (Miles & Holditch-Davis, 1995). Whether such compensatory strategies are pursued by parents or not may depend on the overall resources that families have at their disposal. On the one hand, compensatory strategies may be more common in better-off families who can easily afford these additional expenses (Bernardi, 2014; Conley, 2004). On the other hand, some studies suggest that better resourced families focus investment in children who exhibit the highest levels of ability in infancy (Grätz & Torche, 2016), which are more likely to be siblings who are not born prematurely. Although parents may provide gifts or bequests at later ages to the less able child in order to reduce economic inequalities among siblings (Becker & Tomes, 1976), this would not reduce a potential gap in school educational achievement.

Very few studies to date have investigated how the effects of preterm births vary across social strata. One of the few exceptions, a study by Ekeus et al. (2010), has shown that the association between a moderately preterm birth and cognitive competence was smaller amongst children born to parents with higher socioeconomic status. Similar moderating effects were not observed amongst children born very or extremely preterm. Gisselmann, Koupil, and De Stavola (2011) have shown that shorter gestational age is associated with lower chances of achieving high grades only among children from families in which none of the parents had tertiary education. The literature related to our topic, i.e. studies examining low birth weight, provides mixed findings regarding the effects of early life disadvantage according to family socioeconomic status. Somewhat surprisingly, a few studies have observed greater differences between children born with low birth weight and children born with normal weight among families with higher socioeconomic status (Hack, Klein, & Taylor, 1995). For example, Figlio, Guryan, Karbownik, and Roth (2014) reported that the negative effects of low birth weight on educational outcomes were stronger among children that grew up in families with higher socioeconomic status, which the authors speculated might be due to assisted reproductive technologies. Another study, however, examining the effects of birth weight, found the opposite (Torche & Echevarría, 2011). Currie and Hyson (1999) found no moderating effect of parental socioeconomic status for the effects of birth weight on educational attainment and labor market outcomes.

In this paper, we compare the effects of preterm births on children born into families with different levels of socioeconomic resources, proxied by parental education, employment and income. We expect that parents with less education may face more barriers in fostering their children's educational opportunities. Parents with lower education may also have limited opportunities for providing children with encouragement, practical help with schoolwork, and support with educational choices (Jonsson & Rudolphi, 2011). Parental support – or lack thereof - may be disproportionally consequential for children who are in greater need of it, for instance due to worse early-life health. Parental employment and income may also moderate the impact of preterm births on educational outcomes, since involvement in paid work provides economic and social resources that may be used to mitigate the potential negative consequences of premature birth.

Potential Compensation by School Characteristics

While previous research has engaged with the role that family resources can play in compensating for early life disadvantage, the role of public resources has received much less attention. This is an important omission, because resources available at public institutions such as schools are important for child development and educational achievement. From a policy perspective it is also valuable to understand which types of institutions or interventions may be able to mitigate the effects of early life disadvantage (Figlio et al., 2014). On the one hand, high quality education has been identified as a particularly important way to reduce disadvantage stemming from adverse early life conditions (Currie & Rossin-Slater, 2015; Sylva, 2014). On the other hand, more selective and elitist schools may set relatively higher demands on children and focus on best performing students instead of allocating additional resources to support vulnerable pupils. In addition, there is an emerging evidence suggesting that attending elite schools may have negative effects on the perception of one's own academic abilities (Dicke et al., 2018), a problem which may be particularly relevant for children with poor health. At the same time, self-beliefs are crucial for academic achievements (Huang, 2011). Hence, schools with higher average grades may reinforce rather than compensate for early life disadvantage related to poor health at birth.

To date, there is little evidence on how the characteristics of schools moderate the effects of poor neonatal health. To the best of our knowledge the only study on this topic, focusing on low birth weight, was conducted by Figlio et al. (2014). Figlio and colleagues found that while high quality schools improve the average outcomes of all children, they do not reduce the gaps between children with low birth weight and those with normal birth weight. Other studies investigated the moderating role of early education and care (Hall et al., 2009). This research has shown that some measures of pre-school quality such as the ratio of teachers to children offsets the otherwise negative effects of low birth weight on cognitive development. Nevertheless, more research is needed to 'bring schools back in' to the discussion about how learning environments outside the home can enhance the child's educational chances, especially for those children disadvantaged by worse health in early-life. This paper fills that gap.

Swedish compulsory school system

In Sweden, compulsory education consists of elementary and lower secondary schools and typically covers schooling from age 7 until the age of 16. A vast majority of compulsory schools are public. Other types of schools, such as schools for pupils with special needs, international schools, Christian-community or private schools used to be very uncommon before reforms in 1992 and 1996 (Halldén, 2008). As a result of these reforms, the proportion of students attending independent schools increased from 1.6-3.1 percent in 1998-2001 (Bjorklund, Clark, Edin, Fredricksson, & Krueger, 2006) to about 11 percent in 2009 (Böhlmark & Lindahl, 2015).

In the final year of compulsory schooling, students are assigned a grade point average (GPA), which is considered a crucial educational performance measure (Rudolphi, 2014). GPA is the sum of the grades achieved in 16 subjects across the disciplines of natural sciences, social sciences, mathematics, and Swedish and English language. The way that teachers assign grades has been subject to reform. From 1998 onwards, children earned grades according to their fulfillment of the learning outcomes defined in the curriculum established at the national level. For each subject, teachers graded the students' knowledge and skills using the following scale: 0, fail; 10, pass; 15, pass with distinction; 20, pass with special distinction. Hence, GPA varies between 0 and 320 (16 x 20) points. While the grading is based on a common curriculum and national guidelines, grades are not standardized.

GPA is regarded as reflecting both ability and sustained effort and it is utilized as a selection instrument in competition for further study programs (Rudolphi, 2014). Upper secondary schools offer approximately 20 programs. According to legal regulations, Swedish municipalities are obliged to consider the students' choices when planning the number of places available in the different programs. However, municipalities can face limitations such as availability of teachers or resources necessary to offer these study programs. Where there is a shortage of places in the most demanded study programs in upper secondary schools, the selection of students is based upon GPA. Therefore, GPA does not only reflect children's educational performance, but also shapes further schooling opportunities. Indeed, previous research suggests that a large portion of the overall inequality in educational opportunity in Sweden is explained by GPA in the ninth grade (Rudolphi, 2013).

Data and Methods

We draw upon Swedish register data combining information from several administrative registers (Lindgren, Nilsson, de Luna, & Ivarsson, 2016). We selected cohorts of children born in Sweden between 1982 and 1994, who are observed until 2010. For these cohorts, we can access a rich set of parental and child characteristics during pregnancy and birth from the

Medical Birth Register, and obtain associated data on school grades from the Grade-9 Register. To identify siblings and to specify the sibling fixed effects models it is necessary to have information on the identification numbers of both parents. These variables are available in the Swedish Multigenerational Register.

Preterm Births

The World Health Organization gives the following definitions for the different stages of preterm birth based upon gestational age (WHO, 2013): extremely preterm refers to less than 28 weeks, very preterm refers to gestational age between 28 and less than 32 weeks, and moderately preterm refers to gestational age between 32 to less than 37 weeks. Births after 37 completed weeks of gestation are no longer considered preterm. In our data gestational age is assessed in the Medical Birth Register according to maternal reports of last menstrual period and clinical judgment by the attending pediatrician (Socialstyrelsen, 2003).

High School GPA

In order to measure educational attainment, we use the sum of the grades in the last year of compulsory schooling (GPA) available in the Grade-9 Register. The original outcome variable varies between 0 and 320 points, with the average of 211 points. In the analyses, we standardized scores separately for each birth cohort in order to control for grade inflation. Hence, our final outcome measure reflects deviations from cohort-specific mean number of points achieved in the last year of compulsory schooling.

A marginal proportion of children (684 cases, i.e. overall 0.05% of children in our selected cohorts) completed their education abroad. About 1% children in our sample having missing information on the sum of the grades either because they attended a school for students with special needs or because they failed to pass the core subjects and hence did not obtain school certificates. We examined the distribution of children missing a grade according to gestational age (see Table A1 in the Appendix). In the sample of over one million observations, only 20 extremely preterm (1.92% of all extremely preterm), 74 very preterm (1.51%) and 714 moderately preterm born children (1.30%) received no grades. Therefore, we believe that our estimates are not severely biased due to missing grades.

Statistical Methods

To estimate the relationship between premature birth and educational outcomes we employ ordinary least squares and linear regression with sibling fixed effects. Comparing the outcomes of full siblings, i.e. children sharing the same biological parents, allows us to adjust for unobserved family characteristics that are shared among siblings. More specifically, if $i = 1,..N$ refers to the family, and $j = 0,1,..M$ refer to the first and M sibling, one can estimate a model as follows:

$$y_{ij} = \gamma_0 + \gamma_1 P_{ij} + \gamma_2 X_{ij} + \delta_i + \varepsilon_{ij} \quad (1)$$

where y_{ij} refers to school grades, P_{ij} is a set of dummies capturing different categories of preterm births, X_{ij} is a set of control variables (listed below) and δ_i captures the impact of shared family-specific factors that could otherwise bias the estimates of γ_1 , which retrieves the effect of prematurity on grades.

We control for factors that may vary amongst siblings and have been shown to affect educational outcomes. Specifically, we control for maternal age (Myrskylä, Silventoinen, Tynelius, & Rasmussen, 2013), children's sex, birth order, multiple births, as well as adoptions (Bhalotra & Clarke, 2018). We control for delivery type, which distinguishes between children born with and without caesarean sections. Recent summaries of research on preterm births highlight that both prevalence and consequences of premature births in high-income countries are crucially dependent on the trends associated with increased caesarean sections (Blencowe et al., 2012). Therefore, we take the confounding role of caesarean sections into account in our analyses. In additional specifications, we also include measures of birth weight in order to examine the effect of preterm birth net of low birth weight. We distinguish between extremely low-birth weight for infants weighting up to 1000g, very low-birth weight for infants between 1000g and 1500g, low birth weight for infants between 1500g and 2500g and normal birthweight of more than 2500g. We include this variable in additional specifications because we aim to show to what degree the impact of a preterm birth exceeds the effects of low birth weight documented in previous research.

Sibling fixed effects models are based on within-family variation rather than variation between children from different families. As a consequence, we drop all children without siblings in our dataset (i.e. only-children)[1]. Hence, our analytical sample includes 1,087,750 siblings. Sibling fixed-effects models have some limitations as an analytical strategy. First, the results from fixed-effects models are not generalizable beyond the analytic sample

[1] The number of only-children excluded from our analysis amounts to 176,685 observations. Among only children the proportion of preterm births amounts to 5.72%, whereas it is 5.52% in our sample. We carried out additional analyses to compare grades among single children and children with siblings, the results are discussed in the section describing sensitivity analyses.

(Allison, 2009). Second, and related to the first point, restrictions imposed on our sample in order to have at least two siblings in each family mean that we cannot estimate our fixed effects models on the full population. However, since we use register data, the sample is still very large even after these restrictions and hence the estimates tend to be very precise. Third, unobserved factors that vary over children are still not captured in our analysis, a point which we tried to address by including a rich set of control covariates. Finally, the effects may be biased if preterm births potentially result in family resources being diverted from the sibling born at full-term to the sibling born preterm. We carried out additional analyses to address the possible consequences for the interpretation of our results, and we return to this point in the section describing sensitivity analyses.

In order to investigate whether the consequences of preterm birth are larger among families with restricted socioeconomic resources, we carry out analyses comparing the effects of preterm births across maternal education, parental employment status, and quintiles of disposable income. Maternal education distinguishes between elementary, secondary and postsecondary education. Parental employment status is a categorical variable that distinguishes between dual earner couples, male breadwinner (where a father receives income from paid work and a mother does not), female breadwinner (where a mother receives income from paid work and a father does not) and jobless households. Disposable income combines incomes of both parents after social transfers and taxes[2]. After adjusting for inflation, it is divided into quintiles. All these variables capturing different dimensions of parental socioeconomic resources are measured one year before the birth of a child. The analytical sample for each of these additional analyses varies slightly due to some missing information on parental characteristics. Most importantly, the information on parental education, employment status and income is not available for earlier periods, so the analyses including these variables are restricted to children born 1986-1992. The models comparing the effects of preterm births across families with diverging socioeconomic resources includes dummies representing different combinations of preterm birth categories and measures of parental socioeconomic status. Following our previous notation, our model can be written:

$$y_{ij} = \gamma_0 + \gamma_1 P_{ij} \times SES_{ij} + \gamma_2 X_{ij} + \delta_i + \varepsilon_{ij} \quad (2)$$

[2] This measure is not adjusted for consumption units. Statistics Sweden calculates measures of disposable income per consumption unit, this specific measure is however not available in our data.

where $P_{ij} \times SES_{ij}$ is a set of dummies capturing combinations of categories of preterm births and categories of parental socioeconomic status. In the model where we compare the effects of preterm births across three levels maternal education, the vector $P_{ij} \times SES_{ij}$ includes twelve possible combinations, and children born at full-term whose mothers had elementary education constitute the reference category. In the model where we compare the effects of preterm births across four categories of parental employment, the vector $P_{ij} \times SES_{ij}$ includes sixteen possible combinations, and children born at full-term in dual earner households are the reference category. In case of interactions with quantiles of parental income, altogether $P_{ij} \times SES_{ij}$ includes twenty possible combinations, with children born at full-term in families with incomes in the bottom quantile as a reference category.

We also compare these effects across groups of schools with different average levels of grades. This measure may capture high quality of schooling resulting from better resources allocated by the local authorities (for instance, resulting in better working conditions of teachers or lower pupil-to-teacher ratios), higher socioeconomic status of schools (resulting in better dialogue between parents and teachers) or stronger peer effects among pupils attending the school. The available evidence suggests that measures of school quality based on average grade scores correlate strongly with later life outcomes such as college attendance rates or earnings (Chetty et al., 2011). We calculated school-specific average grade scores for all the schools attended by children in our selected cohorts[3]. Next, we divided the schools according to average grades into deciles.

The models comparing the effects of preterm births across school quality includes combinations of preterm birth categories and deciles of mean school GPA. More specifically, using similar notation as before, our model can be written:

$$y_{ij} = \gamma_0 + \gamma_1 P_{ij} \times S_{ij} + \gamma_2 X_{ij} + \delta_i + \varepsilon_{ij} \tag{3}$$

where $P_{ij} \times S_{ij}$ is a set of dummies capturing combinations of different categories of preterm births and deciles of mean school GPA. Children born at full-term and attending schools in the bottom decile are the reference category.

Results

[3] Our data do not include school identifiers. Instead, the school code identifies the so called 'rektorsområde', which can be translated as 'school area'. According to Söderström (2006), in the period when individuals in our sample participated in compulsory education there where 1.5 lower secondary schools per 'rektorsområde'.

We start with a descriptive analysis of our data (Table 1). In our sample, 94.48% individuals were born at full-term, the proportion of individuals born moderately preterm amounted to 4.98%, while the shares of very and extremely preterm births amounted to 0.44% and 0.09%, respectively. A comparison of mean GPA across these four categories of gestational age reveals that among individuals born at term average GPA amounts to 211, individuals born moderately preterm have a GPA of 208 (i.e. just 0.01 standard deviations lower than full-term), whereas the grades of individuals born very and extremely preterm amounted to 202 and 193 (i.e. 0.09 and 0.24 standard deviations lower than full-term), respectively.

This descriptive analysis already suggests that while the grades of individuals born moderately preterm are similar to the grades among their full-term born peers, the grades of individuals born extremely preterm lag behind the grades of the full-term born. Nevertheless, the statistics presented in Table 1 indicate that individuals born preterm deviate from individuals born at full-term in a number of respects, and these differences may to some degree contribute to the gap in grades. For example, preterm births are more likely to be multiple and delivered by cesarean sections. There is a strong link between preterm births and birth weight, as would be expected. Individuals born preterm are more likely to have mothers who have not attained postsecondary education and who were not involved in paid work before giving birth. The risk of preterm birth increases with age of the mother, and with parental disposable income. The association with income may be related to high-income being correlated with maternal age. There are no strong differences in parental employment across the gestational age. At the same time, individuals born preterm are more likely than their full-term born peers to attend schools with somewhat lower average grades. Overall, some of the characteristics that are more common among preterm born individuals, may also contribute to their educational disadvantage. Therefore, in the next step we turn to multivariate analysis, which takes individual heterogeneity into account.

- Table 1 -

The results from models examining the association between categories of preterm birth and grade scores are displayed in Figure 1. In the first step we estimate OLS models that include the full set of control variables. In the next step, we estimated sibling fixed effects models that additionally control for any unobserved shared family-specific factors. Next, we estimated models that show the effects of gestational age net of low birth weight, which is included as an additional covariate.

As can be seen in Figure 1, the disadvantage in school grades observed amongst individuals who were born moderately preterm is almost equal to zero (the coefficient implies scores that are 0.05 standard deviation lower than those found among children born full-term). After controlling for family-specific factors, this difference disappears and individuals born moderately preterm turn out to have scores 0.02 standard deviations higher than individuals who were born after 37 weeks of gestation. Controlling for birth weight corroborates our conclusions that children born moderately preterm are not at risk of educational disadvantage. Individuals who were born very preterm achieve scores that are 0.15 standard deviations lower than individuals born at full-term. However, this effect halves after controlling for family-specific factors and becomes statistically non-significant in models controlling for low birth weight. While we find no evidence for an educational disadvantage amongst moderately or very preterm births, the effect of being born extremely preterm is strong and robust. Individuals who were born extremely preterm end up with scores 0.33 standard deviations lower in comparison to individuals born at full-term. This effect decreases to 0.28 standard deviations after controlling for shared family-specific factors using sibling fixed effects. After we introduce low birth weight as a covariate in our models, the effect size is further reduced to 0.15 standard deviations, but remains statistically significant. Overall, our analysis reveals that preterm births do not always result in educational disadvantage, but that individuals born extremely preterm constitute a particularly vulnerable group which needs more attention.

- Figure 1 -

Next, we investigated whether the effects of preterm births vary according to the level of socioeconomic resources in the family that individuals were raised in. We compared the magnitude of the effects of preterm births by maternal education, employment status of parents, and parental income. For all of these analyses, we used the full model specification adjusting for both maternal and child characteristics, and controlling for unobserved shared family-specific factors (but excluding the measures of birth weight).

The results displayed in Figure 2 indicate that children born extremely preterm in families with greater socioeconomic resources are not consistently better off than children born extremely full-term preterm in families whose resources are more restricted. Contrary to our expectations, higher maternal education is not associated with smaller school grade differences between the very or extremely preterm born children and full-term born children (Figure 2 Panel A). There is weak evidence that parental employment may matter, as the point estimates suggest that for extremely preterm born children the difference to full-term born children is smallest in dual-earner families and largest in jobless households (Figure 2 Panel B). The differences, however, are not significant. Moreover, there is similarly weak evidence running to the opposite direction, as the point estimates of Figure 2 Panel C suggest that the differences in school grades between the extremely preterm and full-term children may be largest in the highest-income families. The confidence intervals, however, are wide and we are not able to conclude that parental socioeconomic resources would reduce educational disadvantage resulting from extremely preterm births[4].

- Figure 2 -

Differences across schools

We also examined whether the characteristics of the schools that children attended affects the degree to which a preterm birth leads to a disadvantage in school grades. To this end, we estimated models comparing the effects of preterm birth across deciles of average school grades, which proxy school quality. The results presented in Figure 3 show how higher school quality modifies the effects of preterm births.

The results of Figure 3 show that school quality is an important determinant of grades, but the school quality does not necessarily moderate the preterm birth effect. Individuals born moderately preterm have grades that are almost equal to the grades of their peers born at full-term regardless of the level of school quality. The differences between individuals born very preterm and those born at full-term remains very small across the deciles of school grades and are not statistically significant at the 5% level (with the exception of the 7th decile). Individuals born extremely preterm, on the other hand, have consistently lower school grades than their full-term born peers in the same schools. Thus it appears that the within-school differences between preterm and full-term born children persists independently of the school quality. This, however, does not mean that schools would not matter: children that are born extremely preterm that are in the top decile of schools have as good grades as those born full-term that are in an average school. However, good schools appear to lift scores for all groups, and as a result that gap between extremely preterm and full-term children remains also in the best schools. This suggests that attending schools with better average grades, where the

[4] The analyses drawing on comparisons *across* sibling groups show that the negative effects of preterm births tend to be weaker in families with higher socioeconomic status, corroborating the findings of Gisselmann et al. (2011). However, as shown on Figure 2, after controlling for unobserved family characteristics this SES-related gradient disappears. The results from the comparisons across sibling groups are presented in Table A7 in the Appendix.

demands and pressure might be higher than in other schools, does not make extremely preterm born children more disadvantaged. Thus, our results suggest that attending a higher quality school increases the likelihood that children born very or extremely preterm may be able to catch up with their *average* peers born at full-term, *averaged* across all schools to which children go.

- Figure 3-

Sensitivity analyses

We also carried out additional analyses to evaluate the robustness of our results. First, we tested how the exclusion of only children from the sample may affect our results. Using model specifications as defined in Eq. 1, we estimated a linear probability model to examine the impact of gestational age on school grades in a sample which does not exclude only children. Next, we carried out Wald tests for differences in coefficients corresponding to different categories of gestational age between the model presented on Figure 1 and the additional model estimated based on full sample. The results indicate that none of these differences were statistically significant at the 5% level (the p–value for extremely preterm born was 0.34, for very preterm it was 0.07 and for moderately preterm it amounted to 0.75). Hence, we conclude that it is unlikely that excluding only children from our analytical sample affects our results.

We have also considered the possibility of negative spillovers from preterm births. If a preterm birth causes distress among parents and drains parental resources, having a sibling born preterm may have a negative impact on the school grades of even those siblings who were not born preterm. In such cases, children in the reference category in our models may have relatively lower grades due to the presence of preterm born siblings, and this could lead us to underestimate the educational disadvantage of children born preterm (Sjölander & Zetterqvist, 2017). To address this problem, we constructed indicators distinguishing children whose siblings were born preterm. Since the presence of a sibling born preterm in a family does not vary across siblings, in order to be able to identify the potential spillover effects in sibling fixed effects modeling framework, we added separate dummies for older siblings were born preterm and those who had younger siblings born preterm. The reference category was children whose siblings were born at full-term. Then, we excluded siblings born preterm from the sample, so that the regression coefficients indicate the effects of having preterm born siblings on educational disadvantage among full-term born children. We found no evidence for the negative spillover effects of having a younger or an older sibling who was born preterm (cp. Table A6 in the Appendix)[5].

Finally, we ran additional analyses related to heterogeneous effects across schools. Following Jonsson and Mood (2008), we first limited the sample to children attending schools run by municipalities, and we excluded schools with less than 20 children in the same cohort. The results from these analyses are similar to those presented in Figure 3 (see Table A5 in the Appendix).

Discussion

Overall, our results show that there is a non-linear relationship between gestational age and school grades. Our findings indicate that a preterm birth leads to a substantial disadvantage only among individuals who were born extremely early, i.e. after less than 28 weeks' gestation. This welcome finding suggests that many children who were born moderately preterm or even very preterm will not be likely to suffer any adverse long-term consequences, especially if they were not born with low birth weight. Our results imply that at the population level, preterm births are unlikely to have broader consequences for educational attainment in the society because the negative effects are observed only for the extremely preterm births.

We also show that the impact of preterm births is above and beyond the disadvantage exerted by low birth weight that has been documented in earlier studies (Conley & Bennett, 2000; Goisis et al., 2017). Furthermore, after accounting for common unobserved and unmeasured factors within a sibling group, the consequences of moderately preterm and very preterm births for educational disadvantage are less severe than previously documented in the literature even without accounting for birth weight. This pattern is consistent with our knowledge about *in utero* brain development trajectories, which suggest that children born extremely preterm should suffer most severely. These findings are particularly heartening given that advances in medical science mean that the provisions available for treating preterm children today are far more sophisticated than they were in the 1980s and 1990s.

We carried out additional analyses to examine what factors modify the effects of preterm births. To our surprise, parental socioeconomic resources do not seem to consistently reduce the disadvantage resulting from preterm births. This suggests that differential compensation by parental resources is unlikely to be driving the non-linear effects of preterm births at

[5] Interestingly, we do observe negative spillovers in a sample where siblings born preterm are not excluded. This suggests that when children's health problems accumulate in a family, this may drain family resources and increase the educational disadvantage of children born preterm.

different gestational ages. In fact, for some measures of parental resources we observe the opposite pattern, with somewhat stronger effects of extremely preterm births observed among individuals whose mothers had completed postsecondary education and amongst children born in families where parents had incomes in the top quintile. On the other hand, we observe some expected modification based on parental employment, such that in families in which both parents are employed, the school grade gap between extreme- and full-term born children is somewhat smaller than in jobless households. The statistical uncertainty in these estimates is, however, high and does not allow for strong conclusions. Our results indicating a lack of consistent compensating role of parental socioeconomic resources are in line with the findings from previous studies on the heterogeneous effects of perinatal health (Figlio et al., 2014; Hack et al., 1995).

Apart from a detailed analysis of the possible compensating role of parental resources, we examined heterogeneous effects of preterm births across different categories of schools. According to our findings, individuals born moderately preterm have grades that are almost equal to the grades of their peers born at full-term regardless of the level of school quality. The differences between individuals born very preterm and those born at full-term remain very small across the deciles of average school grades and disappear in the top decile. Individuals born extremely preterm have consistently lower school grades than their full-term born peers in the same schools. However, children that are born extremely preterm and attend schools in the top decile of school quality have as good grades as those born full-term that are in an average school. This suggests that attending schools with better average grades, where the demands and pressure might be higher than in other schools, does not make extremely preterm born children more disadvantaged. Thus, our results suggest that attending a higher quality school increases the likelihood that children born very or extremely preterm may be able to catch up with the average outcomes of their peers born at full-term attending schools with average quality. Still, because high quality schools improve grades for all the children, the gap between extremely preterm and full-term children can be observed also in the best schools. Overall, our findings imply that the school environment may be a relevant factor which diminishes the educational disadvantage of children who suffer from health problems. The quality of schools and the way that schools handle the needs of the most disadvantaged children may reduce the negative effects of being born preterm. These results are also interesting because children born preterm tend to be overrepresented in schools were the average grades tend to be somewhat lower.

It is unclear what mechanism are at play in good schools that support high achievement for the extremely preterm born children. The mechanisms driving our results could be related to peer effects, differential socioeconomic status of schools, or specific pedagogical approaches that are particularly helpful for disadvantaged children. For example, emerging research on children's resilience suggests that social support from peers, caring teacher-student relationships, as well as high quality extracurricular offerings in schools may help children to surmount adversity related to early life disadvantage (Noltemeyer & Bush, 2013). Disentangling the specific contributions of these factors could be helpful for improving the design of educational policies addressing the needs of the most vulnerable groups of children suffering from health problems. Nevertheless, it appears that these schools are able to support both the needy and less needy, as full-term born children also do very well in these schools, such that the gap between the full-term and extremely preterm children does not disappear.

Previous research on public interventions that aim at reducing the negative consequences of early-life disadvantage have focused on policies such as prenatal care, public health insurance, vouchers for purchases of healthy food, family leave, and nurse home visiting programs (Currie & Rossin-Slater, 2015). School-based interventions have received much less attention. At the same time, studies that evaluate programs focused on school-aged children tend to focus on the global effects observed among all the children who were enrolled into those programs. We know too little about the benefits of these policies for children who are disadvantaged due to health-related problems. Developing further insight in this area is crucial, and particularly if educational systems are meant not only to improve overall levels of educational attainment in the population, but also to make educational opportunities more equal.

Although this study has many strengths, including the use of full population register data and sibling fixed effects models that control for unobserved confounding, it is important to highlight a few limitations. First, our use of sibling fixed effects models means that we exclude only children from our analytical sample, and this limits the extent to which we can generalize our findings to the full population. Second, given the rise in the mean age at childbearing in Sweden and other OECD countries since the 1970s, only children are more likely to be born to older mothers, who may also be more likely to have births with poor perinatal outcomes such as low birth weight and preterm birth. Another limitation of our study is that children who attended special schools or failed core courses in high school have missing information on school grades. As a result, they are excluded from our analytical sample. However, only around 1% of the population are missing information on school grades. Due to the impact of premature birth on brain development, children born preterm are overrepresented amongst children attending special schools or failing core courses in school. Therefore, our findings may underestimate the negative effects of preterm birth on educational achievement, especially for the extremely preterm born children.

In order to study school grades, we needed to examine cohorts born considerably before the present day. This time lag means that we must be cautious in generalizing our findings to those who are born preterm in the 2010s, for two reasons. First, the increased incidence of preterm births means that the average characteristics of the children who are born preterm, and their families, may well be different today to the 1980s and 1990s. However, the increasing incidence of preterm births suggests that these families are, on average, likely to be less disadvantaged than before, as they are an increasingly less selected group. Second, advances in medical science mean that children born preterm in 2019 are likely to have a better prognosis than children born preterm in the 1980s. In conclusion, we may therefore cautiously suggest that the long-term consequences of preterm birth are less severe than was previously feared, and also that the long-term disadvantages for preterm birth for children born today may be less pronounced than they were in earlier birth cohorts.

Our study has been carried out with high quality register data from Sweden, which calls for a question on the degree to which our conclusions could be generalizable to other country contexts. The Swedish welfare state provides substantial support for families with children, and both healthcare and educational systems are designed to ensure that the needs of children are met regardless of their background. The Swedish health care system compares favorably with those of many other advanced economies in terms of the availability of services across the country and social strata. Sweden has been a forerunner in reducing levels of child morbidity and mortality (Sandin, Sparrman, & Sjöberg, 2012). In addition, the educational system in Sweden aims at promoting not only educational progress of children, but also high equality of educational opportunities. This is reflected in international comparisons, which show that Swedish students have a relatively low dropout rates, low grade retention, and low levels of educational inequality more generally (Daun & Hansson, 2006; Jonsson & Erikson, 2000; OECD, 2011). It therefore remains an open question as to whether a lack of educational disadvantage observed among moderately preterm children is a broader phenomenon that would also be observed in countries where policies are not as strongly oriented towards supporting the most vulnerable groups and tackling barriers related to early life health.

Appendix

Table A1. The impact of gestational age on attending a special school or failing at school as compared to completing a standard compulsory school.

		Extremely preterm	Very preterm	Moderately preterm	Term delivery	Total
Received a grade	N	1023	4818	54201	1027708	1087750
	%	98.08	98.49	98.7	98.77	98.76
Attended a special school or failed to pass	N	20	74	714	12818	13626
	%	1.92	1.51	1.3	1.23	1.24
Total	N	1043	4892	54915	1040526	1101376
	%	100.00	100.00	100.00	100.00	100.00

Source: Swedish register data, birth cohorts 1982-1994.

Table A2. Differences in grade scores according to gestational age at birth – results from sibling comparisons.

	OLS Model			FE Model			FE Model		
	Coef.	95%CI		Coef.	95%CI		Coef.	95%CI	
Gestational age									
Term delivery (ref.)									
Extremely preterm	-0.33	-0.39	-0.27	-0.28	-0.35	-0.21	-0.15	-0.23	-0.06
Very preterm	-0.15	-0.18	-0.13	-0.07	-0.10	-0.04	0.01	-0.03	0.05
Moderately preterm	-0.05	-0.06	-0.05	0.02	0.01	0.03	0.04	0.03	0.05
Maternal age									
Up to 19 (ref.)									
20-24	0.44	0.43	0.46	0.03	0.01	0.05	0.03	0.01	0.05
25-29	0.79	0.78	0.81	0.05	0.03	0.07	0.05	0.03	0.07
30-34	1.01	0.99	1.02	0.07	0.05	0.09	0.07	0.05	0.09
35-39	1.11	1.09	1.12	0.10	0.08	0.13	0.10	0.08	0.13
40-44	1.14	1.12	1.16	0.14	0.10	0.17	0.14	0.10	0.17
45+	1.14	1.07	1.21	0.12	0.01	0.22	0.12	0.01	0.22
Gender									
Men (ref.)									
Women	0.37	0.37	0.37	0.36	0.36	0.37	0.36	0.36	0.37
Birth order									
1st born (ref.)									
2nd	-0.26	-0.27	-0.26	-0.14	-0.14	-0.14	-0.14	-0.15	-0.14
3rd	-0.40	-0.41	-0.40	-0.23	-0.23	-0.22	-0.23	-0.23	-0.22
4th	-0.57	-0.58	-0.56	-0.28	-0.29	-0.26	-0.28	-0.29	-0.27
5th	-0.72	-0.74	-0.70	-0.34	-0.36	-0.31	-0.34	-0.36	-0.31
6th	-0.79	-0.83	-0.76	-0.38	-0.42	-0.34	-0.38	-0.42	-0.34
7th	-0.85	-0.90	-0.80	-0.44	-0.50	-0.38	-0.44	-0.50	-0.38
Multiple births	0.09	0.07	0.10	0.07	0.05	0.09	0.08	0.06	0.10
Adopted children	-0.21	-0.29	-0.13	0.23	0.06	0.40	0.23	0.06	0.40
C-sections	-0.05	-0.06	-0.05	-0.01	-0.02	0.00	-0.00	-0.01	0.01
Birth weight									
Normal (ref.)									
Extremely							-0.18	-0.26	-0.10
Very							-0.10	-0.14	-0.05
Low							-0.06	-0.07	-0.05
Constant	-0.73	-0.74	-0.71	-0.07	-0.09	-0.05	-0.07	-0.09	-0.05
N	1087750			1087750			1087750		

Source: Swedish register data, birth cohorts 1982-1994.

Table A3. Differences in grade scores according to gestational age at birth and parental SES – results from sibling comparisons.

	FE Model			FE Model			FE Model		
	Coef.	95%CI		Coef.	95%CI		Coef.	95%CI	
Term delivery # elementary (ref.)									
Term delivery # high school	0.01	-0.01	0.03						
Term delivery # postsecondary	0.02	-0.01	0.05						
Extremely preterm # elementary	-0.23	-0.42	-0.04						
Extremely preterm # high school	-0.20	-0.31	-0.08						
Extremely preterm # postsecondary	-0.35	-0.54	-0.16						
Very preterm # elementary	0.01	-0.08	0.10						
Very preterm # high school	-0.03	-0.09	0.03						
Very preterm # postsecondary	-0.08	-0.18	0.01						
Moderately preterm # elementary	0.04	0.01	0.07						
Moderately preterm # high school	0.05	0.02	0.07						
Moderately preterm # postsecondary	0.04	-0.00	0.07						
Term delivery # dual earner (ref.)									
Term delivery # male breadwinner				-0.00	-0.01	0.01			
Term delivery # female breadwinner				-0.00	-0.02	0.01			
Term delivery # jobless household				0.00	-0.02	0.03			
Extremely preterm # dual earner				-0.26	-0.35	-0.16			
Extremely preterm # male breadwinner				-0.31	-0.58	-0.05			
Extremely preterm # female breadwinner				-0.39	-0.90	0.11			
Extremely preterm # jobless household				-0.53	-1.03	-0.04			
Very preterm # dual earner				-0.04	-0.09	-0.00			
Very preterm # male breadwinner				0.03	-0.12	0.18			
Very preterm # female breadwinner				-0.16	-0.38	0.06			
Very preterm # jobless household				0.23	-0.15	0.61			
Moderately preterm # dual earner				0.04	0.02	0.05			
Moderately preterm # male breadwinner				0.02	-0.02	0.07			
Moderately preterm # female breadwinner				-0.03	-0.10	0.05			
Moderately preterm # jobless household				-0.01	-0.12	0.10			
Term delivery # income quintile (1 ref.)									
Term delivery # 2 income quintile							0.00	-0.00	0.01
Term delivery # 3 income quintile							0.00	-0.00	0.01
Term delivery # 4 income quintile							0.01	-0.00	0.01
Term delivery # 5 income quintile							0.00	-0.00	0.01
Extremely preterm # 1 income quintile							-0.20	-0.37	-0.04
Extremely preterm # 2 income quintile							-0.16	-0.32	0.00

Extremely preterm # 3 income quintile							-0.26	-0.41	-0.10
Extremely preterm # 4 income quintile							-0.24	-0.40	-0.08
Extremely preterm # 5 income quintile							-0.42	-0.57	-0.28
Very preterm # 1 income quintile							-0.09	-0.17	-0.01
Very preterm # 2 income quintile							-0.11	-0.18	-0.03
Very preterm # 3 income quintile							-0.01	-0.08	0.07
Very preterm # 4 income quintile							0.01	-0.06	0.08
Very preterm # 5 income quintile							-0.13	-0.20	-0.05
Moderately preterm # 1 income quintile							0.01	-0.02	0.03
Moderately preterm # 2 income quintile							0.01	-0.01	0.03
Moderately preterm # 3 income quintile							0.03	0.01	0.06
Moderately preterm # 4 income quintile							0.04	0.02	0.06
Moderately preterm # 5 income quintile							0.03	0.00	0.05
Maternal age (ref.: up to 19)									
20-24	0.02	-0.01	0.04	0.02	-0.00	0.05	0.03	0.01	0.05
25-29	0.02	-0.01	0.05	0.03	-0.00	0.05	0.04	0.02	0.06
30-34	0.03	-0.01	0.06	0.03	0.00	0.06	0.07	0.04	0.09
35-39	0.04	-0.00	0.07	0.04	0.00	0.07	0.10	0.07	0.12
40-44	0.06	0.01	0.11	0.06	0.02	0.11	0.13	0.10	0.17
45+	-0.02	-0.17	0.13	-0.04	-0.19	0.11	0.12	0.01	0.22
Gender (ref.: Men)									
Women	0.36	0.36	0.36	0.36	0.35	0.36	0.36	0.36	0.37
Birth order (ref.: 1st born)									
2nd	-0.15	-0.15	-0.14	-0.14	-0.15	-0.14	-0.14	-0.15	-0.14
3rd	-0.24	-0.25	-0.23	-0.24	-0.25	-0.23	-0.23	-0.24	-0.22
4th	-0.31	-0.33	-0.29	-0.30	-0.32	-0.29	-0.28	-0.29	-0.27
5th	-0.38	-0.41	-0.35	-0.36	-0.39	-0.33	-0.34	-0.36	-0.32
6th	-0.43	-0.49	-0.38	-0.41	-0.46	-0.36	-0.39	-0.43	-0.35
7th	-0.53	-0.61	-0.44	-0.51	-0.59	-0.43	-0.44	-0.50	-0.38
Multiple births	0.05	0.02	0.07	0.05	0.03	0.08	0.07	0.05	0.09
Adopted children	0.17	-0.09	0.43	0.24	-0.00	0.47	0.22	0.05	0.40
C-sections	-0.00	-0.02	0.01	-0.01	-0.02	0.01	-0.01	-0.02	0.00
Constant	0.05	0.02	0.07	0.05	0.03	0.08	0.07	0.05	0.09
N		760433			790145			1084722	

Source: Swedish register data, birth cohorts 1982-1994.

Table A4. Differences in grade scores according to gestational age at birth and parental SES – results from sibling models with random effects.

	FE Model			FE Model			FE Model		
	Coef.	95%CI		Coef.	95%CI		Coef.	95%CI	
Term delivery # elementary (ref.)									
Term delivery # high school	0.36	0.36	0.37						
Term delivery # postsecondary	0.82	0.81	0.83						
Extremely preterm # elementary	-0.25	-0.38	-0.12						
Extremely preterm # high school	0.11	0.03	0.18						
Extremely preterm # postsecondary	0.43	0.30	0.56						
Very preterm # elementary	-0.04	-0.11	0.02						
Very preterm # high school	0.28	0.24	0.31						
Very preterm # postsecondary	0.72	0.66	0.78						
Moderately preterm # elementary	-0.01	-0.03	0.01						
Moderately preterm # high school	0.35	0.34	0.37						
Moderately preterm # postsecondary	0.81	0.79	0.83						
Term delivery # dual earner (ref.)									
Term delivery # male breadwinner				-0.13	-0.14	-0.12			
Term delivery # female breadwinner				-0.19	-0.20	-0.18			
Term delivery # jobless household				-0.27	-0.29	-0.25			
Extremely preterm # dual earner				-0.30	-0.37	-0.24			
Extremely preterm # male breadwinner				-0.38	-0.58	-0.18			
Extremely preterm # female breadwinner				-0.80	-1.13	-0.47			
Extremely preterm # jobless household				-0.77	-1.11	-0.44			
Very preterm # dual earner				-0.10	-0.13	-0.07			
Very preterm # male breadwinner				-0.25	-0.36	-0.15			
Very preterm # female breadwinner				-0.42	-0.58	-0.26			
Very preterm # jobless household				-0.42	-0.67	-0.17			
Moderately preterm # dual earner				-0.01	-0.02	-0.00			
Moderately preterm # male breadwinner				-0.23	-0.26	-0.19			
Moderately preterm # female breadwinner				-0.27	-0.32	-0.22			
Moderately preterm # jobless household				-0.42	-0.49	-0.35			
Term delivery # 1 income quintile (ref.)									
Term delivery # 2 income quintile							0.04	0.03	0.04
Term delivery # 3 income quintile							0.06	0.05	0.06
Term delivery # 4 income quintile							0.09	0.09	0.10
Term delivery # 5 income quintile							0.20	0.20	0.21
Extremely preterm # 1 income quintile							-0.30	-0.42	-0.18
Extremely preterm # 2 income quintile							-0.19	-0.31	-0.06

Extremely preterm # 3 income quintile							-0.24	-0.36	-0.12
Extremely preterm # 4 income quintile							-0.19	-0.31	-0.07
Extremely preterm # 5 income quintile							-0.24	-0.34	-0.13
Very preterm # 1 income quintile							-0.15	-0.20	-0.09
Very preterm # 2 income quintile							-0.14	-0.19	-0.08
Very preterm # 3 income quintile							-0.03	-0.09	0.02
Very preterm # 4 income quintile							-0.01	-0.06	0.05
Very preterm # 5 income quintile							0.07	0.02	0.12
Moderately preterm # 1 income quintile							-0.05	-0.07	-0.04
Moderately preterm # 2 income quintile							-0.00	-0.02	0.01
Moderately preterm # 3 income quintile							0.05	0.03	0.07
Moderately preterm # 4 income quintile							0.08	0.06	0.09
Moderately preterm # 5 income quintile							0.19	0.17	0.21
Maternal age (ref.: up to 19)									
20-24	0.18	0.16	0.20	0.35	0.34	0.37	0.30	0.29	0.32
25-29	0.35	0.33	0.37	0.62	0.60	0.64	0.55	0.53	0.56
30-34	0.46	0.44	0.48	0.82	0.80	0.84	0.72	0.70	0.73
35-39	0.52	0.50	0.54	0.94	0.92	0.96	0.82	0.81	0.84
40-44	0.56	0.54	0.58	1.01	0.98	1.03	0.88	0.86	0.90
45+	0.56	0.48	0.63	1.01	0.93	1.08	0.90	0.83	0.97
Gender (ref.: Men)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Women	0.36	0.36	0.37	0.36	0.36	0.37	0.37	0.36	0.37
Birth order (ref.: 1st born)									
2nd	-0.21	-0.22	-0.21	-0.25	-0.25	-0.24	-0.24	-0.24	-0.24
3rd	-0.33	-0.33	-0.32	-0.40	-0.40	-0.39	-0.41	-0.41	-0.40
4th	-0.42	-0.43	-0.41	-0.54	-0.55	-0.53	-0.56	-0.57	-0.55
5th	-0.50	-0.52	-0.48	-0.66	-0.68	-0.64	-0.71	-0.72	-0.69
6th	-0.55	-0.58	-0.51	-0.74	-0.77	-0.70	-0.81	-0.84	-0.78
7th	-0.60	-0.66	-0.54	-0.82	-0.88	-0.76	-0.93	-0.98	-0.88
Multiple births	0.06	0.04	0.07	0.07	0.06	0.08	0.07	0.06	0.09
Adopted children	-0.04	-0.15	0.07	-0.09	-0.20	0.02	-0.15	-0.23	-0.06
C-sections	-0.03	-0.04	-0.02	-0.04	-0.05	-0.03	-0.04	-0.04	-0.03
Constant	-0.73	-0.75	-0.71	-0.57	-0.59	-0.55	-0.59	-0.60	-0.57
N	760433			790145			1084722		

Source: Swedish register data, birth cohorts 1982-1994.

Table A5. Differences in grade scores according to gestational age at birth and school quality – results from sibling comparisons.

	FE Model (Full sample)			FE Model (Municipality schools)			FE Model (Municipality schools >20 in a cohort)		
	Coef.	95%CI		Coef.	95%CI		Coef.	95%CI	
Term delivery # 1 Decile of school GPA (ref.)									
Term delivery # 2 Decile of school GPA	0.11	0.10	0.12	0.11	0.10	0.12	0.09	0.08	0.10
Term delivery # 3 Decile of school GPA	0.17	0.16	0.18	0.16	0.15	0.17	0.15	0.14	0.16
Term delivery # 4 Decile of school GPA	0.20	0.19	0.21	0.20	0.19	0.21	0.18	0.17	0.19
Term delivery # 5 Decile of school GPA	0.24	0.23	0.25	0.23	0.22	0.24	0.21	0.20	0.22
Term delivery # 6 Decile of school GPA	0.27	0.26	0.28	0.27	0.26	0.28	0.25	0.24	0.26
Term delivery # 7 Decile of school GPA	0.30	0.29	0.31	0.30	0.29	0.31	0.28	0.27	0.29
Term delivery # 8 Decile of school GPA	0.34	0.33	0.35	0.34	0.32	0.35	0.31	0.30	0.32
Term delivery # 9 Decile of school GPA	0.39	0.38	0.40	0.39	0.38	0.40	0.37	0.35	0.38
Term delivery # 10 Decile of school GPA	0.51	0.50	0.52	0.50	0.48	0.51	0.47	0.45	0.48
Extremely preterm # 1 Decile of school GPA	-0.22	-0.42	-0.02	-0.21	-0.42	-0.00	-0.20	-0.42	0.02
Extremely preterm # 2 Decile of school GPA	-0.18	-0.40	0.05	-0.20	-0.43	0.02	-0.19	-0.42	0.04
Extremely preterm # 3 Decile of school GPA	-0.34	-0.55	-0.12	-0.34	-0.55	-0.12	-0.34	-0.56	-0.12
Extremely preterm # 4 Decile of school GPA	-0.10	-0.31	0.11	-0.10	-0.31	0.11	-0.15	-0.36	0.06
Extremely preterm # 5 Decile of school GPA	0.10	-0.12	0.31	0.09	-0.13	0.31	0.07	-0.15	0.29
Extremely preterm # 6 Decile of school GPA	-0.11	-0.34	0.13	-0.11	-0.34	0.13	-0.14	-0.37	0.10
Extremely preterm # 7 Decile of school GPA	0.01	-0.21	0.22	0.01	-0.21	0.23	-0.00	-0.23	0.22
Extremely preterm # 8 Decile of school GPA	0.21	-0.01	0.44	0.20	-0.03	0.43	0.18	-0.04	0.41
Extremely preterm # 9 Decile of school GPA	0.08	-0.16	0.31	0.07	-0.18	0.32	0.01	-0.25	0.26
Extremely preterm # 10 Decile of school GPA	0.31	0.07	0.55	0.26	-0.03	0.55	0.27	-0.03	0.57
Very preterm # 1 Decile of school GPA	-0.04	-0.14	0.07	-0.01	-0.11	0.09	-0.04	-0.15	0.07
Very preterm # 2 Decile of school GPA	0.05	-0.05	0.14	0.05	-0.05	0.15	0.04	-0.06	0.14
Very preterm # 3 Decile of school GPA	0.11	0.02	0.21	0.11	0.02	0.21	0.10	0.01	0.20
Very preterm # 4 Decile of school GPA	0.19	0.09	0.29	0.19	0.08	0.29	0.16	0.06	0.26
Very preterm # 5 Decile of school GPA	0.14	0.04	0.25	0.15	0.04	0.25	0.14	0.03	0.24
Very preterm # 6 Decile of school GPA	0.17	0.07	0.27	0.15	0.05	0.26	0.12	0.02	0.23
Very preterm # 7 Decile of school GPA	0.16	0.06	0.26	0.16	0.06	0.26	0.15	0.05	0.26
Very preterm # 8 Decile of school GPA	0.23	0.13	0.34	0.24	0.13	0.35	0.22	0.12	0.33
Very preterm # 9 Decile of school GPA	0.30	0.20	0.41	0.28	0.17	0.39	0.26	0.14	0.37
Very preterm # 10 Decile of school GPA	0.53	0.42	0.64	0.48	0.35	0.60	0.44	0.31	0.56
Moderately preterm # 1 Decile of school GPA	-0.00	-0.03	0.03	-0.00	-0.04	0.03	-0.00	-0.04	0.03
Moderately preterm # 2 Decile of school GPA	0.13	0.10	0.15	0.12	0.09	0.15	0.11	0.08	0.14
Moderately preterm # 3 Decile of school GPA	0.20	0.17	0.23	0.20	0.17	0.23	0.18	0.15	0.21

Moderately preterm # 4 Decile of school GPA	0.21	0.18	0.24	0.21	0.18	0.24	0.18	0.16	0.21
Moderately preterm # 5 Decile of school GPA	0.25	0.22	0.28	0.25	0.22	0.28	0.23	0.20	0.26
Moderately preterm # 6 Decile of school GPA	0.28	0.25	0.31	0.28	0.25	0.31	0.26	0.23	0.29
Moderately preterm # 7 Decile of school GPA	0.31	0.28	0.34	0.30	0.27	0.33	0.28	0.25	0.31
Moderately preterm # 8 Decile of school GPA	0.38	0.35	0.41	0.37	0.34	0.40	0.35	0.32	0.38
Moderately preterm # 9 Decile of school GPA	0.43	0.40	0.46	0.43	0.40	0.46	0.40	0.37	0.44
Moderately preterm # 10 Decile of school GPA	0.54	0.50	0.57	0.53	0.50	0.57	0.50	0.46	0.54
Maternal age (ref.: up to 19)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20-24	0.04	0.02	0.05	0.04	0.02	0.05	0.04	0.02	0.05
25-29	0.06	0.04	0.08	0.06	0.04	0.08	0.06	0.04	0.08
30-34	0.08	0.06	0.10	0.08	0.06	0.10	0.08	0.06	0.10
35-39	0.11	0.09	0.14	0.11	0.09	0.14	0.11	0.08	0.14
40-44	0.14	0.11	0.17	0.14	0.11	0.17	0.14	0.11	0.18
45+	0.12	0.02	0.23	0.11	0.01	0.22	0.12	0.01	0.23
Gender (ref.: Men ref.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Women	0.36	0.35	0.36	0.36	0.35	0.36	0.36	0.35	0.36
Birth order (ref.: 1st born)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2nd	-0.14	-0.14	-0.13	-0.14	-0.14	-0.13	-0.14	-0.14	-0.13
3rd	-0.22	-0.23	-0.21	-0.22	-0.23	-0.21	-0.22	-0.23	-0.21
4th	-0.27	-0.28	-0.25	-0.26	-0.28	-0.25	-0.26	-0.28	-0.25
5th	-0.32	-0.34	-0.29	-0.32	-0.34	-0.29	-0.32	-0.34	-0.29
6th	-0.36	-0.40	-0.32	-0.36	-0.40	-0.32	-0.36	-0.40	-0.32
7th	-0.41	-0.47	-0.35	-0.41	-0.47	-0.35	-0.41	-0.47	-0.35
Multiple births	0.07	0.05	0.09	0.07	0.05	0.09	0.07	0.05	0.09
Adopted children	0.24	0.07	0.41	0.21	0.04	0.39	0.23	0.05	0.41
C-sections	-0.01	-0.02	0.00	-0.01	-0.02	0.00	-0.01	-0.02	0.00
Constant	-0.34	-0.36	-0.32	-0.34	-0.36	-0.32	-0.32	-0.34	-0.29
N		1087750				1058806		1044422	

Source: Swedish register data, birth cohorts 1982-1994.

Table A6. The impact of siblings' preterm births – the results from sibling comparisons.

	FE Model		
	Coef.	95%CI	
Older sibling born preterm			
Extremely preterm	0.02	-1.83	1.87
Very preterm	0.20	-1.39	1.79
Moderately preterm	0.08	-0.05	0.21
Younger sibling born preterm			
Extremely preterm	0.20	-1.64	2.03
Very preterm	0.21	-1.38	1.80
Moderately preterm	0.07	-0.06	0.20
Maternal age (ref.: up to 19)	0.00	0.00	0.00
20-24	0.03	0.02	0.05
25-29	0.05	0.03	0.08
30-34	0.08	0.06	0.10
35-39	0.11	0.09	0.14
40-44	0.14	0.11	0.18
45+	0.09	-0.02	0.20
Gender (ref.: Men)	0.00	0.00	0.00
Women	0.36	0.36	0.37
Birth order (ref.: 1st born)	0.00	0.00	0.00
2nd	-0.14	-0.15	-0.14
3rd	-0.23	-0.24	-0.22
4th	-0.28	-0.30	-0.27
5th	-0.35	-0.37	-0.32
6th	-0.39	-0.43	-0.34
7th	-0.45	-0.51	-0.38
Multiple births	0.07	0.05	0.10
Adopted children	0.27	0.08	0.45
C-sections	-0.01	-0.02	0.01
Constant	-0.07	-0.10	-0.05
N		1027708	

Source: Swedish register data, birth cohorts 1982-1994, children born preterm excluded from the sample.

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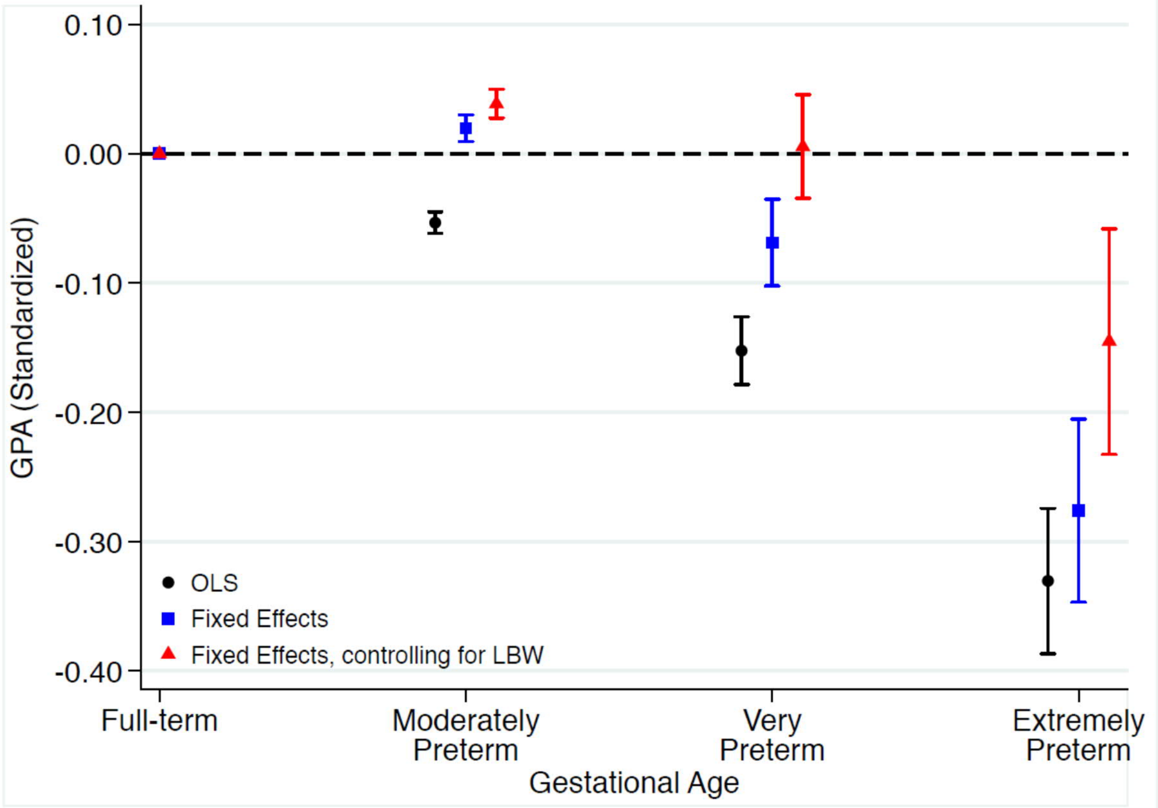
Tables and figures

Table 1. Sample structure.

		Gestational Age at Birth				
		Extremely preterm	Very preterm	Moderately preterm	Term delivery	Total
N		1023	4818	54201	1027708	1087750
GPA (unstandardized)		193	202	208	211	211
Female, %		50	47	46	49	49
Birth order		1.86	1.83	1.83	1.86	1.86
Multiple births, %		25	28	19	2	3
Adopted, %		0.29	0.12	0.06	0.05	0.05
C-sections, %		51	64	31	9	11
Birth Weight, %	Extremely low	57	7	0	0	0
	Very low	39	46	2	0	0
	Low	2	45	39	1	3
	Normal	3	2	59	99	96
	Total	100	100	100	100	100
Maternal Age, %	up to 19	2	2	2	1	1
	20-24	19	20	21	20	20
	25-29	32	36	37	39	39
	30-34	28	26	26	28	28
	35-39	15	14	12	10	10
	40-44	3	2	2	2	2
	45+	0	0	0	0	0
	Total	100	100	100	100	100
Maternal Education, %	Elementary	20	20	20	17	17
	Secondary	59	59	58	58	58
	Post-secondary	21	21	22	25	25
	Total	100	100	100	100	100
Parental Employment, %	Dual Earner	85	88	89	89	89
	Male Breadwinner	8	7	7	7	7
	Female Breadwinner	3	3	3	3	3
	Jobless Household	3	1	1	1	1
	Total	100	100	100	100	100
Parental Income*		1326	1326	1331	1308	1312
Mean school GPA (unstandardized)		206	206	207	207	208

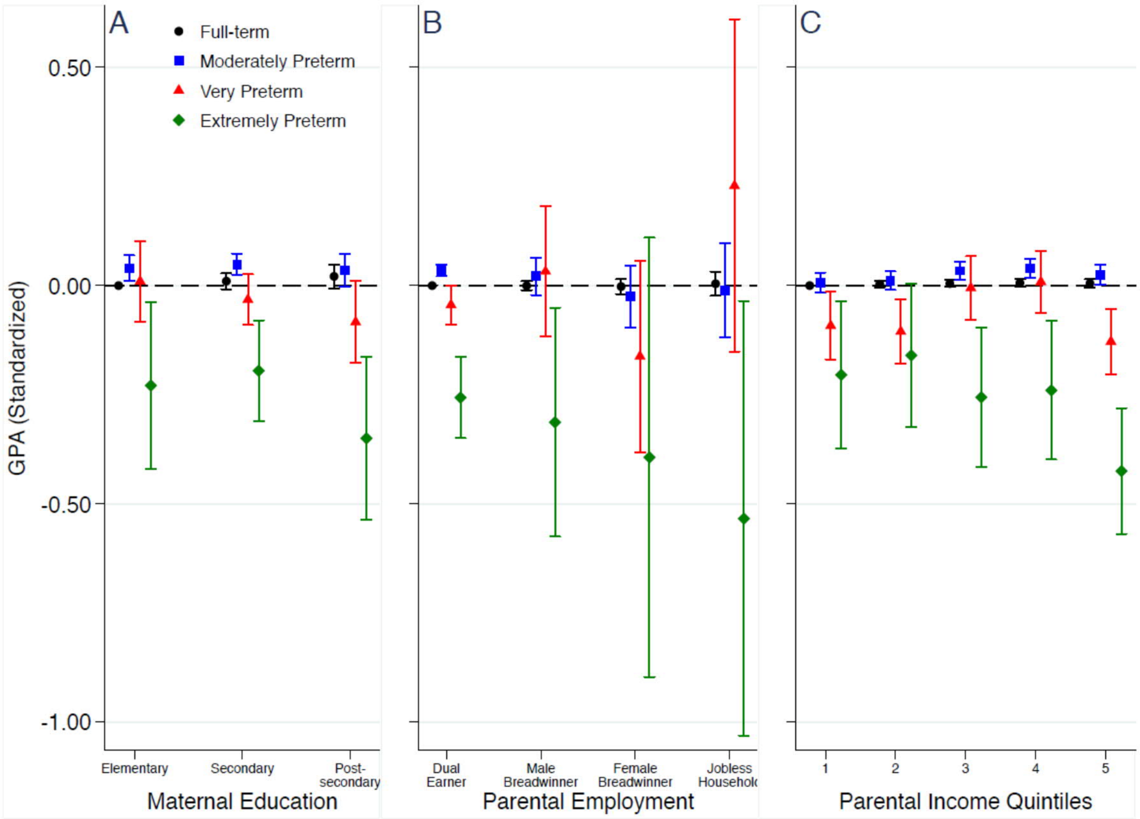
Source: Swedish register data, birth cohorts 1982-1994. Notes: Parental income is measured as a sum of annual disposable incomes of both parents (in hundreds SEK, prices as of 2010).

Figure 1. Differences in grade scores by gestational age at birth – results from sibling comparisons.



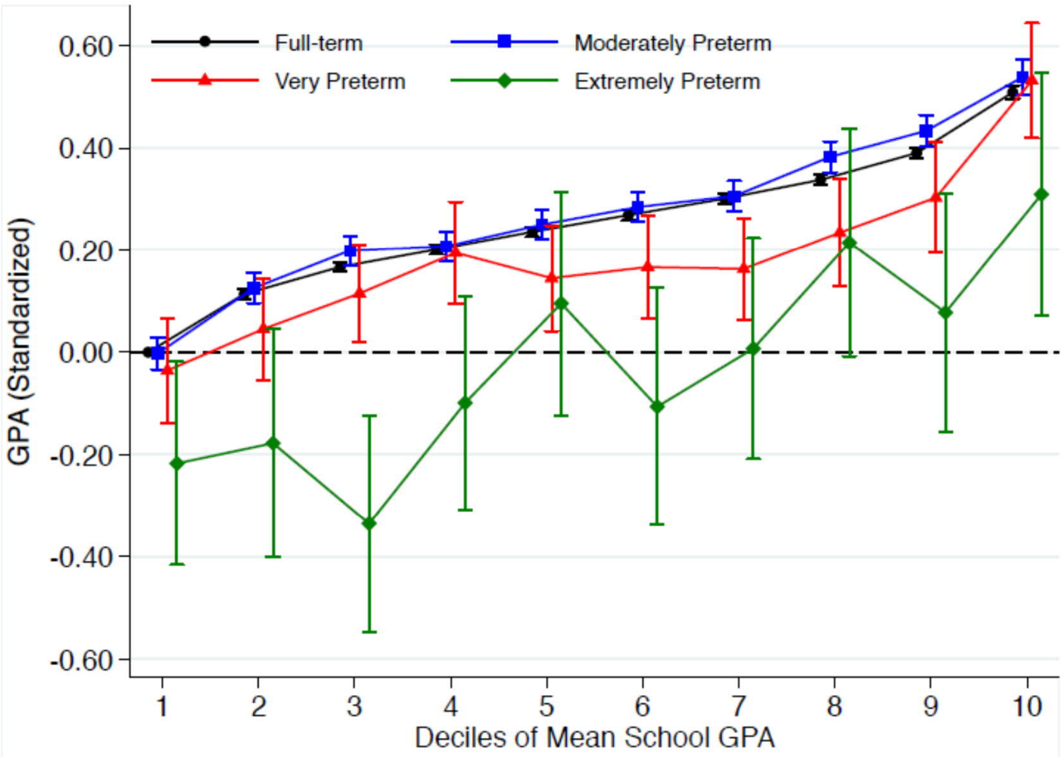
Source: Swedish register data, birth cohorts 1982-1994. Notes: The figure shows the relationship between categories of gestational age at birth and grade scores as measured by the coefficients from sibling models adjusting for: (i) maternal age and child characteristics, (ii) maternal age and child characteristics as well as shared family-specific factors, and (iii) all of the above in addition to low birth weight. Full table of results presented in Table A2 in the Appendix.

Figure 2. Differences in grade scores by gestational age at birth and parental SES – results from sibling comparisons.



Source: Swedish register data, birth cohorts 1986-1992. Notes: The figure shows the relationship between categories of gestational age at birth and grade scores as measured by the coefficients from sibling models adjusting for maternal age and child characteristics, shared family-specific factors as well as low birth weight. Full results table presented in Table A3 in the Appendix.

Figure 3. Differences in grade scores by gestational age at birth and school quality – results from sibling comparisons.



Source: Swedish register data. Notes: As for Figure 2. Full results are presented in Table A5 in the Appendix.