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Preterm birth and educational disadvantage: Heterogeneous effects

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*Although preterm birth is the leading cause of perinatal morbidity and mortality in advanced economies, evidence about the consequences of prematurity in later life is limited. Using Swedish registers for cohorts born 1982–94 (*N *= 1,087,750), we examine the effects of preterm birth on school grades at age 16 using sibling fixed effects models. We further examine how school grades are affected by degree of prematurity and the compensating roles of family socio-economic resources and characteristics of school districts. Our results show that the negative effects of preterm birth are observed mostly among children born extremely preterm (<28 weeks); children born moderately preterm (32–<37 weeks) suffer no ill effects. We do not find any evidence for a moderating effect of parental socio-economic resources. Children born extremely preterm and in the top decile of school districts achieve as good grades as children born at full term in an average school district.*

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Keywords: premature births; gestational age; school districts; educational disadvantage; parental effects; sibling models; register-based research

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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. The long-term consequences of low birthweight have attracted a substantial degree of research attention. High-quality data and carefully designed methods for causal inference have been used to reveal that children with low birthweight achieve lower grades in school and lower scores on cognitive ability tests, leading to lower final educational attainment; they also experience worse outcomes in the labour market and poorer health in adulthood (Behrman and Rosenzweig 2004; Black et al. 2007; Risnes et al. 2011). However, a factor which in most cases causes low birthweight—preterm birth—has been studied less extensively and few researchers have used statistical methods that reduce residual confounding and allow for the identification of any long-term consequences of preterm birth. Since prematurity can be seen as an antecedent to low birthweight, we need more knowledge on preterm birth to understand better the causes of disadvantage originating from health at birth.

The relative lack of attention devoted to the long-term consequences of preterm birth is surprising for three reasons. First, the incidence of prematurity is high. Across 184 countries in 2010, between 5 and 18 per cent 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 since 1990 (Beck et al. 2010). Third, and most importantly, preterm birth may have significant consequences for individuals and societies. Preterm birth is the leading cause of perinatal morbidity and mortality in high-income countries (Goldenberg et al. 2008; Fell et al. 2015) and premature babies require considerable support from health services (Petrou 2005; Frey and Klebanoff 2016). 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 (Behrman and Butler 2006).

Neurodevelopmental disorders that arise from premature birth are crucial for understanding the link between preterm birth and educational disadvantage. Children born preterm exhibit deficiencies in both white and grey brain matter, which can be attributed to the fact that grey matter volume normally increases threefold 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 et al. 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 have shown that the brains of children born prematurely exhibit lower levels of maturation and are of lower volume at term-equivalent age (e.g. at age five weeks for a child born five weeks early) than the brains of children born at full term (Lind et al. 2011), and these differences are still evident at ages 7–15 (Counsell and Boardman 2005). Compared with children born at 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 and behaviour (Keunen et al. 2016). Therefore, the increasing incidence of preterm births is not only a challenge for the children and parents directly affected but is also likely to have implications at the population level, for healthcare costs and educational attainment.

This study provides a rich examination of the consequences of preterm birth for educational disadvantage. First, using Swedish population data with information on school grades measured at age 16, we examine whether the potential adverse 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 birth on school grades by family resources and school district characteristics. Specifically, we consider parental education and employment, household income, and average grades for school districts, all of which proxy the social and financial resources that foster positive educational outcomes for children (Bischoff and Owens 2019). This allows us to determine the extent to which the negative effects of preterm birth are concentrated among children raised in disadvantaged families or who attend schools where social and financial resources are more restricted (lowering the overall quality of schooling that children can receive). Thus, our study recognizes both that early-life disadvantage can shape educational outcomes and that the postnatal environmental and socio-economic conditions experienced by individuals may moderate or compensate for the harmful effects of early-life disadvantage.

Previous research

Previous studies have found that preterm birth is associated with a host of poor long-term outcomes, in areas ranging from socio-economic attainment to health and fertility. However, we focus on outcomes related to educational disadvantage. A 2002 meta-analysis of 15 studies found that children born preterm displayed lower cognitive performance than children born at full term; they were also twice as likely to have been diagnosed with attention disorders (Bhutta et al. 2002; Cheong et al. 2017), which have themselves been linked to educational outcomes. Since 2002, several other studies have also suggested that children born preterm, particularly those born extremely preterm, exhibit marked disadvantages in performance on general cognitive ability assessments (Marlow et al. 2005) and assessments of arithmetic and reading ability (Anderson and Doyle, 2003).

Research in the Nordic region has shown mixed results regarding the consequences of preterm birth for educational attainment. For example, in Norway and Sweden, children born prematurely display lower educational attainment and cognitive competence (Lindström et al. 2007; Ekeus et al. 2010), although active perinatal care may 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 of the child completing the most basic level of education (Mathiasen et al. 2009). However, using data from Finland, another study has found that premature birth was no longer associated with educational attainment after adjusting for maternal socio-demographic characteristics (Härkönen et al. 2012).

Although many studies have examined the correlation between gestational age and educational outcomes, few have used a causal identification strategy to examine the long-term consequences of preterm birth for educational achievement. In addition, previous research on the long-term consequences of preterm birth has focused largely on first-born children and used statistical methods that compare children across families, with relatively limited adjustment for the factors that vary between families (Lindström et al. 2007; Delobel-Ayoub et al. 2009; Mathiasen et al. 2009; Ekeus et al. 2010; Garfield et al. 2017). Consequently, in many previous studies, the relationships between preterm birth and long-term outcomes are confounded by factors related to both the risk of preterm birth and long-term educational outcomes, including—critically—the health, educational level, and socio-economic circumstances of the mothers who give birth to these preterm children.

The only study that we are aware of to examine the effects of preterm birth on educational achievement net of shared family background factors is by D'Onofrio et al. (2013), who used Swedish population data on cohorts born 1973–82. The authors found after comparing siblings in the same family that the relationship between gestational age and failure to pass high school persisted only for those born extremely preterm. The effects of preterm birth on educational outcomes measured after age 16 were not statistically significant. However, that study did not consider whether the consequences of preterm birth vary by parental socio-economic status (SES) or across different types of school districts. This question is at the centre of our paper. We also study more recent birth cohorts—those born in the 1980s and 1990s—where the effects of preterm birth are likely to differ due to advances in the technology used by neonatal intensive care units.

Potential compensation by parental resources

The educational disadvantages attributable to premature birth may be reduced by parental compensatory behaviour (Bharadwaj et al. 2018). Parents may pursue a variety of strategies to achieve this goal. For example, they may provide more cognitive stimulation for preterm infants than for their siblings and make additional investments in improving educational attainment for children born prematurely. Whether parents pursue such compensatory strategies or not may depend on the overall resources that families have at their disposal. On one hand, compensatory strategies may be more common in better-off families who can easily afford these additional expenses (Bernardi 2014; Gil-Hernández 2019). On the other hand, some studies have suggested that better-resourced families focus investment on children exhibiting the highest levels of ability in infancy (Grätz and Torche 2016), who are more likely to be siblings not born prematurely.

Some research on compensation for adverse life events (such as parental divorce or death) by parental SES has suggested that having parents with greater socio-economic resources may constrain any negative impact (Grätz 2015; Kalil et al. 2016; Prix and Erola 2017). However, other studies have observed an equalizing effect of parental divorce, where the negative consequences appear to be worse for children from higher-SES families (Bernardi and Radl 2014; Erola and Jalovaara 2017). Additionally, some research has found no clear or consistent socio-economic variation in the impact of parental death on child outcomes (Barclay and Hällsten 2022). Nevertheless, the systematic variation in patterns by country suggests that the importance of parental SES for compensating for disadvantage may be conditional on contextual conditions, such as school systems and the extent of the welfare state (e.g. see Bernardi and Radl 2014).

To date, very few studies have investigated how the effects of preterm birth vary across social strata. One of the few exceptions, a study by Ekeus et al. (2010), showed that the association between moderately preterm birth and cognitive competence was smaller among children born to parents with higher SES. Conversely, similar moderating effects were not observed among children born before 32 weeks of gestation. Gisselmann et al. (2011) showed that shorter gestational age was associated with lower chances of achieving high grades only among children from families in which none of the parents had completed tertiary education.

In this paper, we compare the effects of preterm birth on children born into families with different levels of socio-economic resources, proxied by parental education, employment, and income. We expect parents with less education to face more barriers in fostering their children's educational opportunities. Parents with lower education may also have limited opportunities for encouraging children or providing practical help with schoolwork and support with educational choices (Jonsson and Rudolphi 2011). Parental support—or lack thereof—may be disproportionally consequential for children in greater need of it, for instance due to worse early-life health. Parental employment and income may also moderate the impact of preterm birth 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 district characteristics

Although 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 crucial for child development and educational achievement. From a policy perspective, it is also valuable to understand which types of institutions or interventions may mitigate the effects of early-life disadvantage. Financial and social resources available in school districts have been identified as crucial for diminishing the inequality of opportunities between children (Bischoff and Owens 2019). School districts are administrative units that determine education funding, which affects the quality of teaching and school management, as well as the locally available facilities and extracurricular offerings for children. In the Swedish context the school district (*rektorsområde*) corresponds to what could be translated directly as a 'principal's district' (Fredriksson et al. 2013). Principals of school districts in Sweden have a high degree of control and responsibility, and this has been the case particularly since the decentralization reforms in the early 1990s (Skolverket 1998, 2015). Principals decide how financial resources from the central budget (allocated first across regions to municipalities in which school districts are embedded) should be used for different goals and how they should be redistributed within school districts. The division of resources differs substantially between school districts and municipalities (Von Greiff 2009), including with regard to how resources related to supporting children from less advantaged families or with special needs are allocated. The use of structural resources (in Swedish *strukturtillägg*, additional resources relating to the number of students whose parents have e.g. lower educational attainment or immigrant backgrounds, or are unemployed) and also resources for students in need of special support is relatively common, although this corresponds to a rather small proportion of the overall budget (Skolverket 2009a).

The better environment a school district can provide, the more they may be able to reduce disadvantages stemming from adverse early-life conditions (Sylva 2014; Currie and Rossin-Slater 2015). School districts also determine the social resources that are present in children's environments. Due to peer effects (Sacerdote 2011), children's outcomes may be shaped by the characteristics and behaviours of other children in the school district. In addition, peers and the parents of peers may influence local authorities and advocate for better personnel or budgetary decisions and improved access to extracurricular activities that benefit all children attending schools in the district (Bischoff and Owens 2019). The evidence suggests that contextual measures of schooling quality based on average grades correlate strongly with later-life outcomes, such as college attendance rates or earnings (Chetty et al. 2011), including in the Swedish context (Jonsson and Mood 2008).

While social and financial resources in school districts improve schooling outcomes, the benefits from these resources may vary across children. For example, in districts with schools that are more selective, teachers may set relatively higher demands on children and focus on the best-performing students instead of allocating additional resources to support vulnerable pupils. In addition, there is emerging evidence to suggest that attending elite schools may negatively affect children's perceptions of their own academic abilities (Dicke et al. 2018), a problem which may be particularly relevant for children with poor health. At the same time, self-belief is crucial for academic achievement (Huang 2011). From this perspective, we could argue that school districts with higher average grades may reinforce rather than compensate for early-life disadvantage related to poor health at birth.

To date, the resources available at school district level remain a theoretically well-developed but empirically unexplored potential mechanism affecting educational opportunities for children (Bischoff and Owens 2019). In particular, there is little evidence on how the characteristics of school districts moderate the effects of poor early-life health. To the best of our knowledge the only study related to this topic, focusing on low birthweight, was conducted by Figlio et al. (2014). That study found that while high-quality schools improve the average outcomes of all children, they do not reduce the gaps between children with low birthweight and those with normal birthweight. More research is needed to 'bring schools back in' to the discussion about how learning environments outside the home can enhance children's educational chances, especially for those disadvantaged by worse health in early life. This paper fills that gap.

The Swedish compulsory schooling system

In Sweden, compulsory education consists of elementary and lower-secondary school and typically covers schooling at ages 7–16. The vast majority of schools providing compulsory education are run by the state. 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 natural sciences, social sciences, mathematics, Swedish, and English language. The way that teachers assign grades was subject to reform during the 1990s. The purpose of the reform was to achieve a goal-oriented system with fixed standards. From 1998 onwards, children earned grades according to their fulfilment of the learning outcomes defined in the curriculum established at 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 (16×20) points.

Although the grading is based on a common curriculum and national guidelines, grades are not standardized. When assessing pupils' knowledge and skills, teachers consider the results from national tests, which are meant to help teachers follow common standards to make grades comparable across the country. Although grades are partly based on national standardized tests, these tests aim to assist teachers in their final assessments, to ensure fair, standardized, and reliable assessment practices (Rudolphi 2014). Most pupils receive the same final grade as that indicated by the result from the national test, but some teachers interpret grading criteria differently or adopt grading practices that deviate from the national criteria. Specifically, apart from assessing subject-specific knowledge and skills when assigning grades, some teachers take account of aspects such as pupils' effort, interest, and motivation (Lekholm and Cliffordson 2008). Hence, GPA has a shortcoming as a measure of actual knowledge, due to the subjective nature of grade assignments. Surprisingly, one study comparing the results from national tests with final grades from schools providing compulsory education has shown that grading is more restrictive in schools where high-performing students dominate compared with schools where many students tend to receive lower grades (Skolverket 2009b).

Nevertheless, GPA is regarded as a valid measure for studies of educational inequalities because it reflects both ability and sustained effort. It is used as a selection instrument in competition for further study programmes (Rudolphi 2014). For instance, where there is a shortage of places in the study programmes in highest demand in upper-secondary schools, the selection of students is based on GPA. Therefore, GPA not only reflects children's educational performance but also shapes further schooling opportunities. Indeed, as an instrument for predicting future educational success, grades from the previous educational level provide greater validity than standardized tests (Thorsen and Cliffordson 2012). GPA from compulsory schooling is also predictive of future labour market success, because it is correlated with the level of returns to education (Wikström and Wikström 2011), suggesting that it reflects individual ability and productivity.

From an international perspective, many aspects of the educational system in Sweden follow egalitarian principles. Compared with many European educational systems, there are few administrative barriers to pursuing further education, even for children with less advantaged backgrounds. However, this does not mean that educational inequalities are low: some estimates reveal that in international comparisons ranking the correlation of parental and children education attainment, Sweden is relatively close to the median rank (Hertz et al. 2008; Pfeffer 2008). Some studies have linked these educational inequalities to a set of reforms implemented in the early 1990s, which included privatization and decentralization of education (see e.g. Böhlmark et al. 2016). New ways of working in schools and new teaching practices have emerged (Carlgren et al. 2006). Teacher-led instruction for the whole class has diminished in favour of more individualistic, child-centred teaching practices and independent work, where 'students have to rely on their ability to search for knowledge and reach the curriculum goals' (Skolverket 2009b, p. 28). Some researchers have contended that these new teaching practices are more beneficial for children from more privileged families but less well suited to more vulnerable pupils, such as those in need of special educational support (Giota et al. 2009; Giota and Emanuelsson 2011). Hence, overall, despite the egalitarian principles underlying Sweden's educational system, we can still expect substantial educational inequalities between children depending on their health and family background.

Data and methods

We draw on Swedish register data that combine information from several administrative registers (Lindgren et al. 2016). We select children born in Sweden between 1982 and 1994, who were observed until

2010. For these cohorts, we can access a rich set of parental and infant characteristics from the Medical Birth Register, and we obtain associated data on school grades at age 16 from the Grade-9 Register. To identify siblings and specify the sibling fixed effects models, the identification numbers of both parents are needed. These are available in the Swedish Multi-Generation Register. All variables used in the analyses are summarized in Table A1, supplementary material.

Preterm births

The World Health Organization gives the following definitions for the different stages of preterm birth based on gestational age (WHO 2013): 'extremely preterm' refers to a gestational age of under 28 weeks, 'very preterm' refers to gestation of between 28 and 32 weeks, and 'moderately preterm' refers to gestational age over 32 weeks (up to term i.e. 37 weeks). Births after 37 completed weeks of gestation are not considered preterm. We use these four categories in our analyses. In our data from the Medical Birth Register, gestational age is assessed according to maternal reports of the last menstrual period and clinical judgment by the attending paediatrician.

GPA in last year of compulsory schooling

To measure educational attainment, we use the sum of the grades in the last year of compulsory schooling (i.e. GPA at age 16, available in the Grade-9 Register). The original outcome variable varies between 0 and 320 points, with an average score of 211 points. In the analyses, we standardize scores separately for each birth cohort in order to control for grade inflation. Hence, our final outcome measure reflects deviations from the 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 per cent of children in our selected cohorts) completed their education abroad. About 1 per cent of children in our sample are missing information on GPA, 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 with missing GPA according to gestational age (see Table A2, supplementary material). In the sample of over 1 million observations, only 20 children born extremely preterm (1.92 per cent of all extremely preterm), 73 children born very preterm (1.49 per cent), and 710 children born moderately preterm (1.29 per cent) received no grades. Therefore, we believe that our estimates are not severely biased due to missing grades.

Control variables

We control for factors that may vary between siblings and have been shown to affect educational outcomes. Specifically, we control for maternal age, children's sex and birth order, and multiple births. We also control for delivery type, distinguishing between children born by caesarean section and those born by vaginal delivery. Descriptive statistics of these covariates are provided in Table A1, supplementary material. We present distributions of key covariates across categories of preterm birth for the total sample and also for the subsample of children in families with at least one child born preterm.

Parental SES

To investigate whether the consequences of preterm birth are greater among families with restricted socio-economic resources, we carry out analyses comparing the effects of preterm birth across parental education, parental employment status, and quintiles of disposable income. Our parental education variable uses the educational attainment (elementary, secondary, or tertiary) of either the mother or father, whichever is higher. Parental employment status is a categorical variable that distinguishes between families where both parents are employed, families where a father is employed and a mother is not, families where a mother is employed and a father is not, and jobless households. Disposable income combines the incomes of both parents after social transfers and taxes, and this measure is not adjusted for consumption units; after adjusting for inflation, it is divided into quintiles. All these variables capturing different dimensions of parental socio-economic resources are measured one year before the birth of a child. In models including interactions between gestational age and parental SES, each measure of parental SES is included in a separate specification.

School districts

We calculate average grade scores by school district for all children in the selected cohorts based on identifiers of school districts (*rektorsområde*). We stratify the analysis according to deciles of these average grades. The distribution of mean GPA according to school district decile and gestational age at birth is presented in Table A3, supplementary material.

Statistical methods

To estimate the relationship between premature birth and educational outcomes, we use ordinary least squares (OLS) and linear regression with sibling fixed effects. Comparing the outcomes for 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 $i = 1, \ldots N$ refers to the family and $j = 0, 1, \ldots M$ refers to the first and *Mth* siblings, we 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 birth; X_{ij} is a set of control variables (listed shortly); 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.

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 from our data set (we carried out additional analyses to compare grades among only children and children with siblings; the results are discussed in the Sensitivity analyses subsection). 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 analytical sample (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 across children are still not captured in our analysis, a point which we have tried to address by including a set of control covariates. Finally, the effects may be biased if preterm births potentially result in family resources being diverted from siblings born at full term to the sibling born preterm. We carried out additional analyses to address the possible consequences of these limitations for the interpretation of our results, and we return to this point in the Sensitivity analyses subsection.

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 in 1986–92. The models comparing the effects of preterm birth across families with diverging socio-economic resources include dummies representing different combinations of preterm birth categories and parental SES categories. Following our previous notation, our model can be written:

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

where $P_{ij} \times SES_{ij}$ is a set of dummies capturing the combinations of preterm birth and parental SES categories. In the model where we compare the effects of preterm birth across three levels of maternal education, the vector $P_{ij} \times SES_{ij}$ includes 12 possible combinations, and children born at full term to mothers with elementary education constitute the reference category. In the model where we compare the effects of preterm birth across four categories of parental employment, the vector $P_{ij} \times SES_{ij}$ includes 16 possible combinations, and children born at full term in dual-earner households are the reference category. For interactions with quintiles of parental income, altogether $P_{ij} \times SES_{ij}$ includes 20 possible combinations, with children born at full term in families with incomes in the bottom quintile as the reference category.

We also compare these effects across groups of school districts with different average grade levels. The models comparing the effects of preterm birth across school districts include all possible combinations of preterm birth categories and deciles of mean school district GPA. More specifically, using similar notation as before, our model can be written:

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

where $P_{ij} \times S_{ij}$ is a set of dummies capturing combinations of different categories of preterm birth and deciles of mean school district GPA. Children born at full term in school districts in the bottom decile are the reference category. Note that although with our analytical approach it is not possible to estimate the effects of variables that do not vary across siblings, we can still estimate the interactions of such covariates with preterm birth (Collischon and Eberl 2020; Giesselmann and Schmidt-Catran 2020).

Results

We start with a descriptive analysis of our data. The results from models examining the association between preterm birth categories and individuals' 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 second step, we estimate sibling fixed effects models that additionally control for any unobserved shared family-specific factors.

As can be seen in Figure 1, the disadvantage in school grades observed among individuals born moderately preterm is almost equal to zero (the OLS coefficient implies scores that are 0.05 standard deviations lower than those found among children born at full term). After controlling for family-specific factors using sibling fixed effects, individuals born moderately preterm turn out to achieve scores 0.02 standard deviations higher than individuals born after 37 weeks of gestation. Individuals born very preterm achieve scores that are 0.15 standard deviations lower than for individuals born at full term. However, this effect halves after controlling for family-specific factors. While we find no evidence for an educational disadvantage among moderately or very preterm births, the effect of being born extremely preterm is strong and robust. Individuals born extremely preterm end up with scores 0.33 standard deviations lower than for individuals born at full term. This effect decreases to 0.28 standard deviations after controlling for shared family-specific factors. Overall, our analysis reveals that preterm birth does not always result in educational disadvantage but that individuals born extremely preterm constitute a particularly vulnerable group that needs more attention.

Next, we investigate whether the effects of preterm birth vary according to the level of socioeconomic resources in the family that individuals are raised in. We compare the magnitude of the effects of preterm birth by parental education, employment status, and income. For all these analyses, we use the full model specification, adjusting for maternal age and child characteristics and

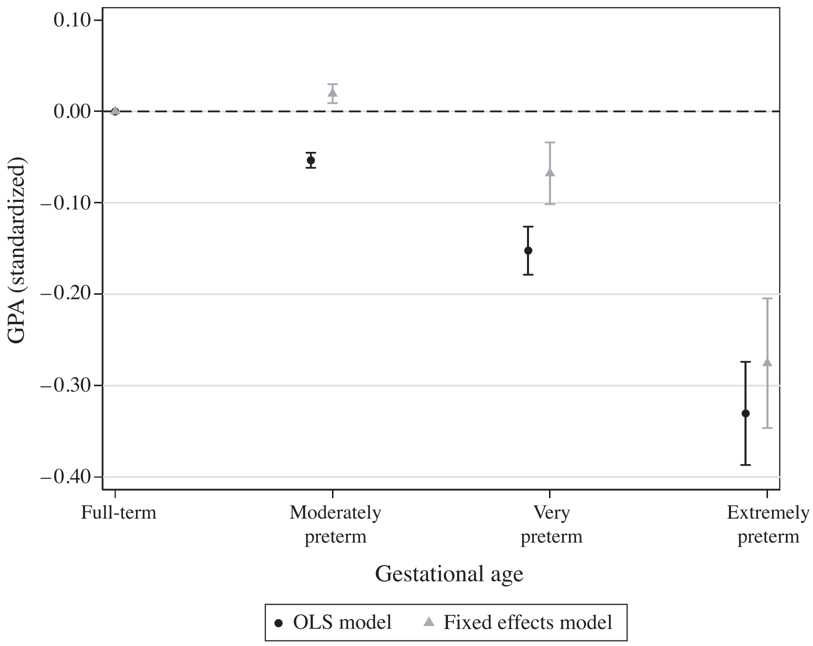

Figure 1 Differences in GPA at age 16 by gestational age at birth: results from sibling comparisons for individuals born in Sweden in 1982–94

Notes: The figure shows the relationship between categories of gestational age at birth and grade point average (GPA) scores as measured by the coefficients from sibling models adjusting for: (i) maternal age and child characteristics (OLS); and (ii) maternal age and child characteristics, as well as shared family-specific factors (fixed effects). Children born at full term are the reference category in the models. Vertical lines show 95 per cent confidence intervals. Full results are presented in Table A4, supplementary material.

Source: Swedish register data, 1982–94 birth cohorts.

controlling for unobserved shared family-specific factors.

The results displayed in Figure 2 indicate that children born extremely preterm in families with greater socio-economic resources are not consistently better off than children born extremely preterm in families whose resources are more restricted. Contrary to our expectations, higher parental education is not associated with smaller school grade differences between children born very or extremely preterm and those born at full term (Figure 2(a)). There is weak evidence that parental employment matters, as the point estimates suggest that for children born extremely preterm the difference from children born at full term is smallest in dual-earner families and largest in jobless households (Figure 2(b)). The differences, however, are not significant. Moreover, there is similarly weak evidence running in the opposite direction, as the point estimates of Figure 2(c) suggest that the differences in school grades between children born extremely preterm and those born at full term may be largest in the highest-income families. The confidence intervals, however, are wide and we are not able to conclude that parental socio-economic resources would reduce the educational disadvantage resulting from extremely preterm birth. Note that analyses drawing on comparisons *across* sibling groups (i.e. sibling models with random effects) showed that the negative effects of preterm birth tend to be weaker in families with higher SES (compare Table A6, supplementary material). However, as shown in Figure 2, after controlling for unobserved family characteristics in fixed effects models that use comparisons *within* sibling groups, this SES-related gradient disappears. This means that parental SES is a marker of family resources that can close the gap originating from early-life health, but it is not parental SES per se that operates as an equalizer.

Differences across school districts

We also examine whether the characteristics of school districts affect the degree to which a preterm birth leads to a disadvantage in school

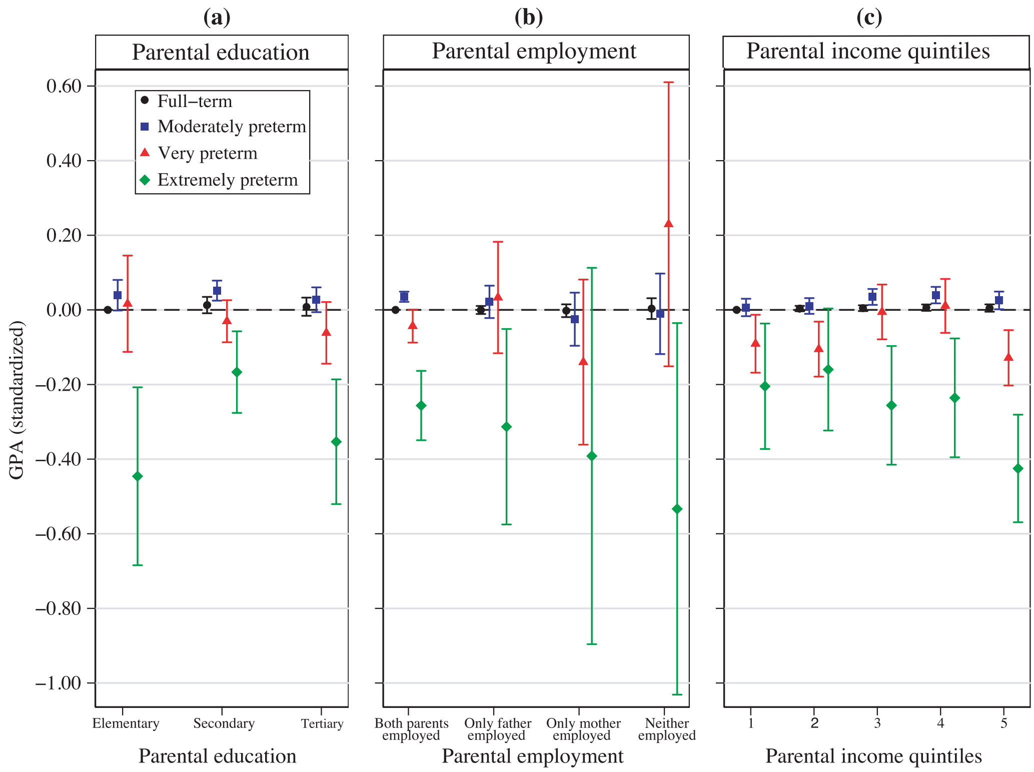

Figure 2 Differences in GPA at age 16 by gestational age at birth and parental SES: results from sibling comparisons for individuals born in Sweden in 1986–92

Notes: The figure shows the relationship between categories of gestational age at birth and grade point average scores (GPA) as measured by the coefficients from sibling models adjusting for maternal age and child characteristics and shared family-specific factors. Vertical lines show 95 per cent confidence intervals. For parental income quintiles, '1' represents the lowest income and '5' the highest. Full results are presented in Table A5, supplementary material.

Source: Swedish register data, 1986–92 birth cohorts.

grades. To this end, we estimate models comparing the effects of preterm birth across deciles of average grades in school districts (see Figure 3).

The results in Figure 3 show that schooling quality is an important determinant of grades, but the school district category does not necessarily moderate the preterm birth effect. On one hand, individuals born moderately preterm achieve grades that are almost equal to the grades of their peers born at full term, regardless of their school district category. Similarly, the differences between individuals born very preterm and those born at full term remain very small across the deciles of school district grades and are not statistically significant at the 5 per cent level (with the exception of the seventh decile). On the other hand, individuals born extremely preterm tend to achieve lower school grades than their peers born at full term in the same school districts. Thus, it appears that the within-school differences between children born preterm and at full term persist independently of school district. This, however, does not mean that school district does not matter: children who are born extremely preterm and who are in the top decile of school districts achieve as good grades as those born at full term who attend schools in an average district. However, good school districts appear to lift scores for all groups, and as a result, that gap between children born extremely preterm and at full term remains also in the best school districts. This suggests that attending schools in districts with better average grades, where the demands and pressure might be higher, does not make children born extremely preterm more disadvantaged. Thus, our results suggest that better social and financial resources in school districts increase the likelihood that children born very or extremely preterm can catch up with their *average* peers born at full term, *averaged* across all schools that children go to.

Sensitivity analyses

We carried out three additional analyses to evaluate the robustness of our results. First, using model specifications as defined in equation (1), we estimated a linear probability model to examine the impact of gestational age on school grades in a sample

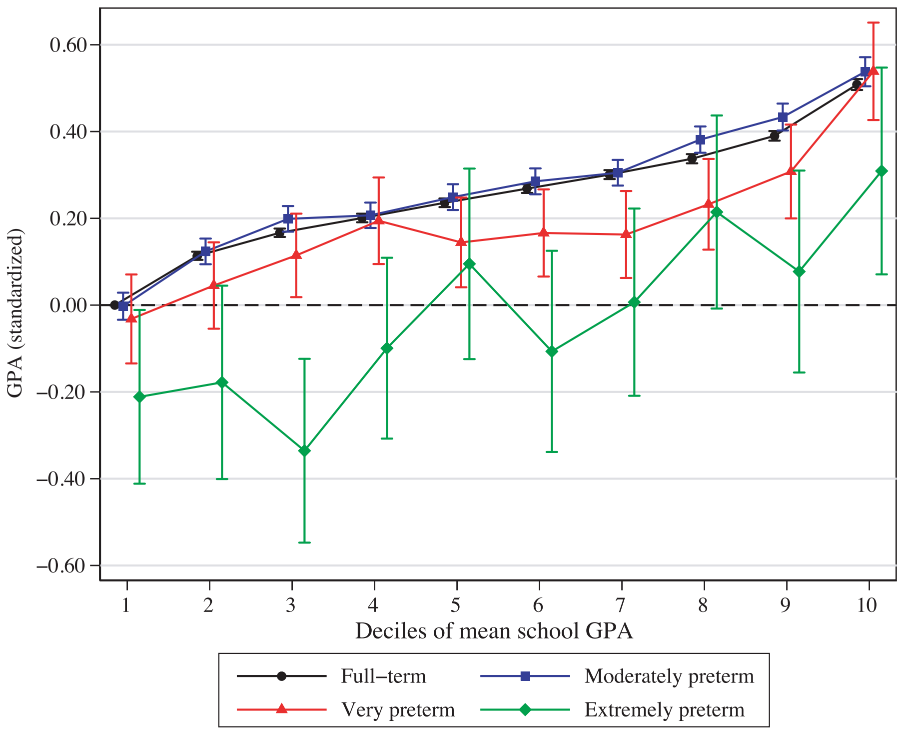

Figure 3 Differences in GPA at age 16 by gestational age at birth and mean school district GPA: results from sibling comparisons for individuals born in Sweden in 1986–92

Notes: The figure shows the relationship between categories of gestational age at birth and grade point average scores (GPA) as measured by the coefficients from sibling models adjusting for maternal age and child characteristics and shared family-specific factors. Vertical lines show 95 per cent confidence intervals. For mean school GPA deciles, '1' represents the lowest grade and '10' the highest. Full results are presented in Table A7, supplementary material.

Source: As for Figure 2.

including only children, not just those with siblings (see Table A8, supplementary material). Next, we carried out Wald tests for differences in coefficients corresponding to different categories of gestational age between the model presented in Figure 1 and the additional model estimated using the full sample. The results (not shown) indicated that none of these differences were statistically significant at the 5 per cent level (p–values were 0.37 for those born extremely preterm, 0.07 for the very preterm, and 0.72 for the moderately preterm). Hence, we conclude that it is unlikely that excluding only children from our analytical sample affects our results.

Second, we assessed the potential bias from maternal health in pregnancy. Blencowe et al. (2012) emphasized that the risk factors for preterm birth include poor maternal health. Our register data includes indicators of maternal diseases: chronic kidney disease, diabetes, epilepsy, Crohn's disease, systemic lupus erythematosus, and hypertension. Generally, in our data there is little overlap between these conditions and preterm births (distributions are presented in Figure A1, supplementary material). Thus, we created a dummy variable, which takes a value of one if any of these health conditions were reported by pregnant women and zero otherwise. The results, reported in Table A9 (supplementary material), showed that controlling for this additional variable did not change our results.

Finally, we also tested for potential bias related to parental repartnering. In principle, a parent's marital status might be affected by the strain of raising a child born preterm, in which case repartnering is a collider and should not be controlled for (Elwert and Winship 2014). We re-estimated our sibling comparison models using data where we excluded children raised by repartnered parents. The results, presented in Table A10 (supplementary material), were almost identical to the estimates presented in Figure 1.

Discussion

Overall, our results show a non-linear relationship between gestational age and school grades. Our findings indicate that preterm birth leads to substantial disadvantage only among individuals born extremely early (i.e. <28 weeks gestation). This welcome finding suggests that most children born moderately preterm or even very preterm are unlikely to suffer any adverse long-term consequences. At the population level, preterm birth is unlikely to have broader consequences for educational attainment because the adverse effects are observed only for extremely preterm births, which amount to only 2 per cent of all preterm births and 0.1 per cent of all births.

Our results also show that after accounting for common unobserved and unmeasured factors within a sibling group, the consequences of moderately preterm and very preterm birth for educational disadvantage are less severe than previously documented in the literature. This pattern is consistent with our knowledge about *in utero* brain development trajectories, which suggests that children born extremely preterm suffer most severely. The findings showing a lack of disadvantage among children born moderately preterm suggest that any special needs among these children can be met with due attention, and any health problems related to moderate prematurity can be compensated for by additional support from the parents and schools.

To our surprise, parental socio-economic resources do not seem to reduce the disadvantage resulting from preterm birth consistently. This suggests that differential compensation by parental resources is unlikely to be driving the non-linear effects of preterm birth at different gestational ages. In fact, we observe the opposite pattern for some measures of parental resources. For example, somewhat stronger effects of extremely preterm birth on GPA are observed among children born to parents with incomes in the top quintile. In contrast, we observe some expected modifications based on parental employment. In families where both parents are employed, the school grade gap between children born extremely preterm and at full term 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 are in line with previous literature suggesting that while better-off families can easily afford the additional expenses related to compensatory strategies (Bernardi 2014; Gil-Hernández 2019), some better-resourced families might instead adopt reinforcement strategies, focusing their investments on children who exhibit the highest levels of ability in infancy (Grätz and Torche 2016).

As well as analysing in detail the possible compensating role of parental resources, we examined heterogeneous effects of preterm birth across different categories of school districts. According to our findings, individuals born moderately preterm achieve grades almost equal to their peers born at full term regardless of the type of school district. The differences between individuals born very preterm and those born at full term remain minimal across the deciles of average school district grades and disappear in the top decile. Individuals born extremely preterm achieve consistently lower school grades than their peers born at full term in the same school districts. However, children born extremely preterm who attend schools in the top decile of school districts achieve as good grades as those born at full term in an average school district. This suggests that school districts with better average grades, where the demands and pressure might be higher than in other school districts, do not make children born extremely preterm more disadvantaged. Thus, our results suggest that higher-quality schooling resources increase the likelihood of children born very or extremely preterm catching up with the average outcomes of their peers born at full term in school districts with average-quality resources. Still, because districts with high-quality schooling show improved grades for *all* children, the gap between children born extremely preterm and at full term can be observed even in the best school districts. Overall, our findings imply that the schooling environment may be a relevant factor for reducing the educational disadvantage of children who suffer from health problems. The quality of social and financial resources is relevant for schooling, and how school districts handle the needs of the most disadvantaged children may affect the negative effects of being born preterm.

It is unclear what mechanisms are at play in school districts that support high achievement for children born extremely preterm. The mechanisms driving our results could be related to peer effects, differentials in schools' socio-economic status, specific pedagogical approaches, or municipality policies that are particularly helpful for disadvantaged children. For example, research on children's resilience has suggested that social support from peers, caring teacher–student relationships, and high-quality extracurricular offerings in schools may help children to surmount adversity related to early-life disadvantage (Noltemeyer and Bush 2013). Disentangling the specific contributions of these factors could help to improve the design of educational policies addressing the needs of the most vulnerable groups of children suffering from health problems.

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, limiting the extent to which we can generalize our findings to the entire population. Another limitation of our study is that information on school grades is missing for children who attended special schools or failed core courses in high school. As a result, they are excluded from our analytical sample. Only around 1 per cent of the population is missing school grade information, but due to the impact of premature birth on brain development, children born preterm are over-represented among 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 children born extremely preterm. Another limitation of our study is the subjective nature of GPA, which means that neither individual- nor school-level grades are measured without error. However, given that grading is more restrictive in schools with many high-performing pupils (Skolverket 2019), we believe it is unlikely that our results showing the benefits from school districts with higher GPAs are driven by less restrictive grading practices.

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

Finally, while our analysis based on sibling fixed effects models reduces bias from individual-level confounders, there may be selection into school districts with higher average grades. Although our models control for children's parental background, not all these selectivity effects can be removed by controlling for family-specific SES.

Our study was carried out with high-quality register data from Sweden, but we should question the degree to which our conclusions are generalizable to other national contexts. The Swedish welfare state provides substantial support for families with children. Both healthcare and educational systems are designed to ensure that the needs of children are met, regardless of their background. The Swedish healthcare system compares favourably with those of many other advanced economies regarding the availability of services across the country and across social strata. Sweden has been a forerunner in reducing child morbidity and mortality. In addition, the educational system in Sweden aims to promote both children's educational progress and high equality in educational opportunities. This is reflected in international comparisons, which show that Swedish students experience relatively low dropout rates, low grade repetition, and low levels of educational inequality more generally (OECD 2011). Therefore, it remains an open question whether the lack of educational disadvantage observed among children born moderately preterm is a broader phenomenon in countries where policies do not as strongly support the most vulnerable groups or tackle barriers related to early-life health.

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No potential conflict of interest was reported by the authors.

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