When Does a Preterm Birth Lead to an Educational Disadvantage Later in Life? Heterogeneous Effects Across Families and Schools

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Abstract

Although preterm births are the leading cause of perinatal morbidity and mortality in developed countries, evidence about the consequences of such births later in life, and how the consequences vary by degrees of preterm severity, is limited. Using Swedish population register data on cohorts born 1982-1994 (N=939,225), we examine the effects of preterm births on school grades using sibling fixed effect models. 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 effects of parental compensatory strategies. Our results indicate that school environment may reduce the disadvantage resulting from preterm births, including the extreme preterm category.

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Introduction

Recent years have seen a growing interest in the long-term consequences of early life disadvantage. 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 et al. 2018; Barclay and Myrskylä 2018; Boardman et al. 2002; Torche 2018). The long-term consequences of being born with low birth weight have attracted a particularly large degree of research attention (Black et al. 2007; Cook and Fletcher 2015; Goisis et al. 2017). High quality data and sophisticated 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 and Rosenzweig 2004; Black et al. 2005; Black et al. 2007; Conley and 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 given that preterm birth rates have increased dramatically across high-income countries (Beck et al. 2010). For example, in the United States preterm birth rates rose by over 15% between 1989 and 2000, and despite a brief period of stagnation between 2007-2014, this upward trend has continued in recent years (Ananth et al. 2005; Martin and Osterman 2018). Preterm births have significant consequences for health care costs as they are the leading cause of perinatal morbidity and mortality in high-income countries (Fell et al. 2015; Goldenberg et al. 2008) and require considerable support from the health services (Frey and Klebanoff 2016; Mangham et al. 2009; Petrou 2005). Infants born preterm have immature organ systems and they are therefore more likely to suffer from respiratory distress syndrome, a compromised immune system, hearing and vision problems, and neurodevelopmental disability in comparison to full-term newborns (Behrman and Butler 2006).

Neurodevelopmental disorders that arise as a consequence of premature birth 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 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 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 and 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).

This study provides a rich examination of the consequences of preterm births for educational disadvantage. 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, comparing the outcomes of children born at full-term (37 weeks of gestation) to children born extremely (<28 weeks), very (28-32 weeks), or moderately (32-37 weeks) preterm. To do this we use sibling fixed effects in order to adjust for unobserved confounding by parental factors associated with both the risk of preterm birth and child outcomes. Since gestational age is closely associated with birth weight and mode of delivery, we also examine whether preterm births are associated with school grades net of low birth weight and Caesarian section (C-section) delivery. Finally, we extend the existing literature by examining heterogeneity in the effects of preterm birth on school grades by family resources and school characteristics, including maternal education, parental employment, household income, maternal country of origin, mean school grades, and within-school grade inequality. This allows us to determine the extent to which it is possible for the postnatal environment to compensate for any potential negative effects of preterm births on school grades, and the extent to which the negative effects of preterm birth are concentrated amongst disadvantaged families.

Previous Research on the Effect of Preterm Birth on Educational Disadvantage

Although the associations between preterm births and adverse health outcomes early in life are well documented, premature birth 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 et al. 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 et al. 2005), as well as assessments of arithmetic and reading ability (Anderson et al. 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 et al. 2010; Lindström et al. 2007; Stjernqvist and Svenningsen 1999; Swamy et al. 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 (Mathiasen et al. 2009a). 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 et al. 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; Mathiasen et al. 2009b). 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 having a failing score on high school grade point average (GPA) 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.

Although the paper by D'onofrio et al. (2013) sheds important light on the relationship between preterm birth and educational achievement by adjusting for unobserved factors shared by siblings, there is a still a risk for significant bias from birth weight and mode of delivery, which were not considered in that study. While pregnancy duration and fetal growth are interrelated, they are still conceptually distinct entities (Behrman and Butler 2006). Infants with low birth weight are a mix of a group whose growth in utero was suboptimal, a group whose growth trajectory was normal but who were delivered too early, as well as a group too small for genetic reasons unrelated to the length of gestation (Savitz et al. 2002). Much research has conflated prematurity with low birth weight, neglecting to separate these conceptually distinct dimensions of perinatal health status, partly due to a focus by the World Health Organization on low birth weight until the 2000s (Kajantie et al. 2019; Katz et al. 2013).

Mode of delivery is another important potential confounding factor for the relationship between preterm birth and educational disadvantage. 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). In high-income countries a substantial proportion of preterm births are attributable to C-sections, either due to maternal or fetal indications or because of other, non-medical reasons. For example, a recent assessment of late preterm births in the USA suggested that more than one third of preterm births that resulted from caesarean sections were done in the absence of a well-defined medical indication (Gyamfi-Bannerman et al. 2011). These types of deliveries are associated with higher maternal age, higher maternal education attainment, and multiparity, which may indicate the role of maternal preferences for the delivery type (Reddy et al. 2009). Since decisions about caesarean section deliveries can be affected by both parental preferences and health-related behaviors, we take the confounding role of caesarean sections into account in our analyses.

Potential Compensation by Parental Resources

The disadvantages attributable to premature births may also be reduced by parental compensatory behavior (Bharadwaj et al. 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 and 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 and 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 and 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 compensatory effects were not observed amongst children born very or extremely preterm. Studies examining low birth weight also suggest that the effects of early life disadvantage may differ by family socioeconomic status. For example, Figlio et al. (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 in the United States, which the authors speculated might be due to assisted reproductive technologies. Another study, however, examining the effects of birth weight in Chile, found the opposite (Torche and 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 UK.

In this paper, we compare the effects of preterm births on children born into families with different levels of socioeconomic and social resources, proxied by parental education, employment, and income, as well as country of origin. Parental employment and income may also be moderators of 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.

We also expect that parents with less education and parents from immigrant groups may face more barriers in fostering their children’s educational opportunities. Parents who were born abroad may be less fluent in the language of the country of destination, and they may have less knowledge and experience with the Swedish school system. This may limit parental opportunities for providing children with encouragement, practical help with schoolwork, and support with educational choices (Jonsson and 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.

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). High quality education has been identified as a particularly important way to reduce disadvantage stemming from adverse early life conditions (Currie and Rossin-Slater 2015; Sylva 2014).

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.

Data and Methods

We draw upon Swedish register data available at the Umeå SIMSAM Lab combining information from several administrative registers (Lindgren et al. 2016). We selected cohorts of children born in Sweden between 1982 and 1994. For these cohorts, we can access all the relevant 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 full biological siblings and to specify the sibling fixed effects models it is necessary to have information on the identification numbers of both biological 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: 28 to 32 weeks, and moderate to late preterm 32 to 37 weeks. Births after 37 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 achieved in 16 subjects across the disciplines of natural sciences, social sciences, mathematics and English language available in the Grade-9 Register. The Grade-9 Register provides information on the school grades achieved in the last year of compulsory schooling (i.e. around at the age of 16 years). 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, the outcome variable varies between 0 and 320 points, with the average being just over 209 points. In the analyses, we use scores that were standardized separately for each birth cohort. Hence, our outcome measure reflects deviations from cohort-specific mean number of points achieved in the last year of compulsory schooling.

About 4.6% children in our sample miss the sum of the grades either because they attended a special school (in Swedish, särskola), or because they failed to pass the core subjects and hence did not obtain school certificates. A marginal proportion of children (684 cases, i.e. 0.05% of our sample) completed their education abroad. We examined the association between being born preterm and missing a grade because of attending a special school or a school failure. The results suggest that that being born preterm raises the risk of being placed in a special school. While 3.3% children born at term attend a special school, among children who experienced an extremely preterm birth this proportion amounts to 15.2%, and for very or moderately preterm born children it amounts to 7.3% and 4.7%, respectively. At the same time, the proportion of children failing to complete the compulsory school amounts to 1-1.3% in all groups as distinguished by gestational age. The only downside of our data is that we don't observe children in 'special needs', because if these children had attended standard schools the observed disadvantage of children born preterm would likely be greater. This is especially important in estimating the effect of extremely preterm births.

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 more effectively for shared genetic predispositions and the early life environment. We also control for factors that may vary amongst siblings and have been shown to affect educational outcomes. Specifically, we control for maternal age (Myrskylä et al. 2013), children's sex, parity, and year of birth (Barclay 2015), multiple births, as well as adoptions (Bhalotra and Clarke 2018). We control for delivery type, which distinguishes between children born with and without caesarean sections. 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.

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) as well as children from 'blended families'. Hence, our analytical sample included 939,225 full siblings. In order to investigate whether the effects of preterm birth are weaker among families with less restricted socioeconomic resources, we carry out analyses interacting preterm births with maternal education, parental employment status, quintiles of disposable income, as well as maternal country of birth. The analytical sample for each of these additional analyses varies slightly due to some missing information on parental characteristics[1]. Information on the sample for each analysis can be found in the supplementary information.

We also compare these effects across schools with different average levels of grades and within-school grade inequality. We calculated school-specific average grade scores for all the schools attended by children in our selected cohorts. Next, we divided the schools according to average grades into quintiles. Our measure of school quality is based on average test scores, which may have several weaknesses. However, the available evidence (Chetty et al. 2011) suggests that measures of school quality based on average test scores correlate strongly with later life outcomes

[1] Most importantly, the information on parental education, employment status and income is missing for earliest years, so the analyses including these variables are restricted to birth cohorts 1986-1992.

such as college attendance rates or earnings. Our measure of within-school grade inequality is a Gini coefficient calculated within each school. We then calculate quintiles in the Gini coefficient distribution across schools and interact our variable for preterm birth by these quintiles.

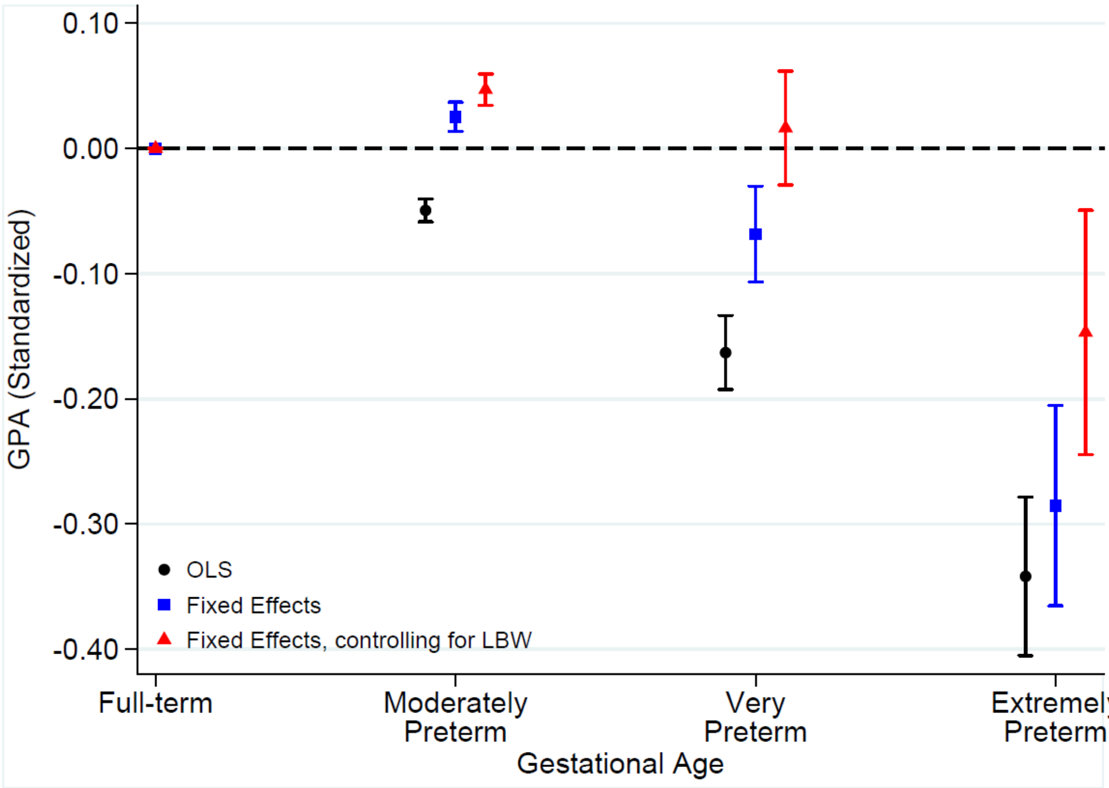
Results

The results from sibling models are displayed in Figure 1. In the first step we estimate OLS models to examine the association between categories of preterm birth and grade scores. This model includes 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.

According to our results displayed in Figure 1, individuals who were born extremely preterm end up with scores 0.32 standard deviations lower in comparison to individuals born at full-term. This effect decreases to 0.29 standard deviations after controlling for shared family-specific factors used 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. The results from Model 4 show that the effects of being born extremely preterm are strongly related to birth weight. When extremely premature births were accompanied by extremely or very low birth weight, the effect size amounts to 0.4 or 0.18 standard deviations, respectively. When extremely preterm births were associated with less pronounced birth weight deficiencies, they did not have statistically significant effects on school grades. However, we should note that this was very rarely the case. In our data, the number of infants born extremely preterm with normal or low birth weight amounted to 26 cases (3%) and 15 cases (1.7%), respectively. A vast majority of preterm infants had extremely low birth weight (480 cases or 56%), or very low birth weight (336 cases or 39.2%).

While the effect of being born extremely preterm is strong and robust, the disadvantage of other categories of preterm birth is less clear. Individuals who were born very preterm achieve scores that are 0.13 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. Also, the results from Model 4 indicate that the effects of being born very preterm are not observed among individuals who were born with normal weight. The disadvantage in educational attainment observed amongst individuals who were moderately preterm born is almost equal to zero. After controlling for family-specific factors, it disappears and individuals born moderately preterm turn out to have scores 0.03 standard deviations higher than individuals who were born after 37 weeks of gestation. Controlling for birth weight among these individuals increases this difference to 0.06 standard deviations. Interestingly, the advantage in educational attainment observed among individuals who were born moderately preterm is restricted to those who had a normal birth weight. This does not come from sample size limitations, as there are 825 cases of infants born moderately preterm with very low birth weight, and 17,758 with low birth weight.

Figure 1. Differences in grade scores according to gestational age at birth – results from sibling comparison



Source: Swedish register data. 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 (OLS model), (ii) maternal age and child characteristics as well as shared family-specific factors (FE model), and (iii) all of the above and low birth weight (FE +LBW).

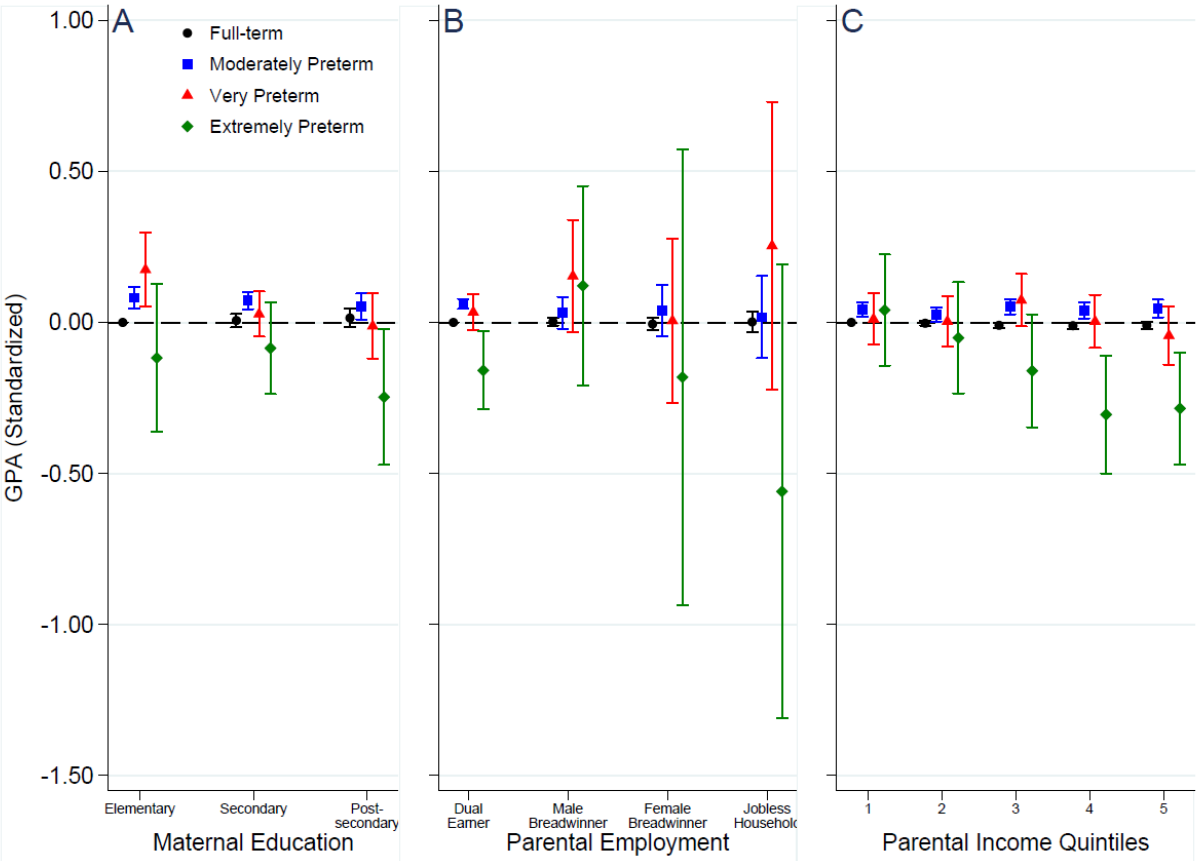
Next, we investigated whether the effects of preterm births vary according to the level of socioeconomic resources in the family that individuals were raised in. We compared the magnitude of the effects of preterm births according to maternal education, employment status of parents, parental income and maternal country of birth. For all these analyses, we used the full model specification adjusting for both maternal and child characteristics, and controlling for unobserved shared family-specific factors. Models with maternal education, employment status of parents and parental income included interactions between these variables and preterm births. Models with maternal country of birth were estimated in stratified samples, because this variable is not time varying and hence cannot be included in fixed effects models.

Our results displayed on Figure 2 indicate that children born extremely preterm in families with greater socioeconomic resources are not better off than children born extremely preterm in families whose resources are more restricted. In fact, we observe the opposite pattern. For example, the negative effects of extremely preterm births are greatest amongst individuals whose mothers completed postsecondary education. According to the results presented in Figure 2, the negative effects of extremely preterm births are also strongest amongst children born in families where both parents were working and had incomes in the top quintile.

Regarding the heterogeneity of the effects of other categories of preterm births, we observe the same pattern of relatively better educational outcomes among children with lower educated mothers among very and moderately preterm born individuals. However, the differences are much smaller in magnitude and the confidence intervals for the point estimates overlap. We also observe that parental employment has no moderating impact on the effects of very preterm births. The effects of moderately preterm births are not statistically significant from zero except for the group of individuals whose parents were both working. The results presented in Figure 2 reveal no clear income gradient in the effects of very or moderately preterm births.

In sum, it does not seem that parental resources reduce the disadvantage of children born prematurely. Somewhat surprisingly, the effects of extremely preterm births are actually relatively stronger in families with higher socioeconomic status. As for other categories of preterm births, family resources have little overall impact.

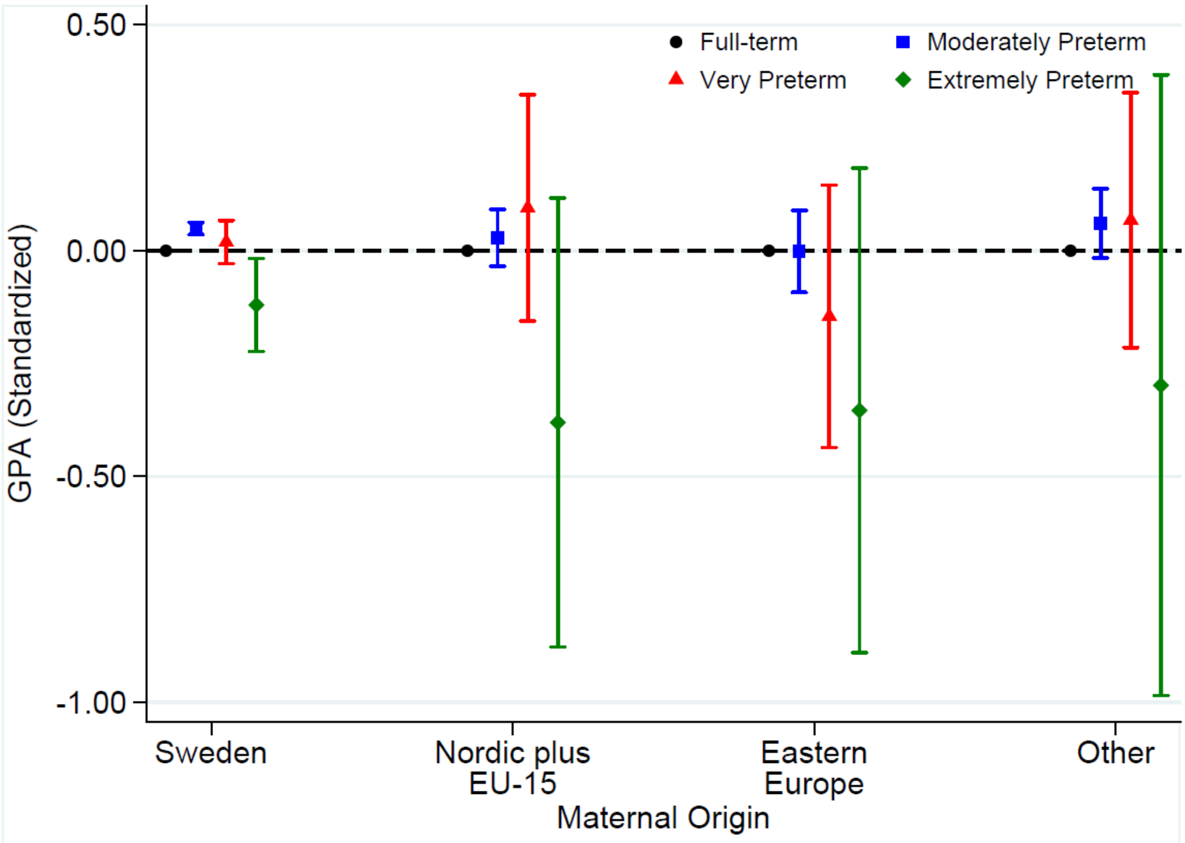
Figure 2. Differences in grade scores according to gestational age at birth and parental SES – results from sibling comparisons.



Source: Swedish register data. 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.

Finally, we considered maternal country of birth as a potential moderator (see Figure 3). We compared the magnitude of the effects of preterm births among families with mothers born in Sweden, Western Europe, Eastern Europe and immigrant mothers from the rest of the world. The effects of extremely preterm and very preterm births did vary across country groups. Among individuals whose mothers were born outside of Sweden, the point estimates for negative effects of extremely preterm births are larger, but these differences are not statistically significant. We do observe some heterogeneity in the effects of moderately preterm births, which appear positive and statistically significant only among individuals whose mothers were born in Sweden, but not amongst individuals whose mothers had immigrated to Sweden.

Figure 3. Differences in grade scores according to gestational age at birth and maternal country of birth – results from sibling comparisons.

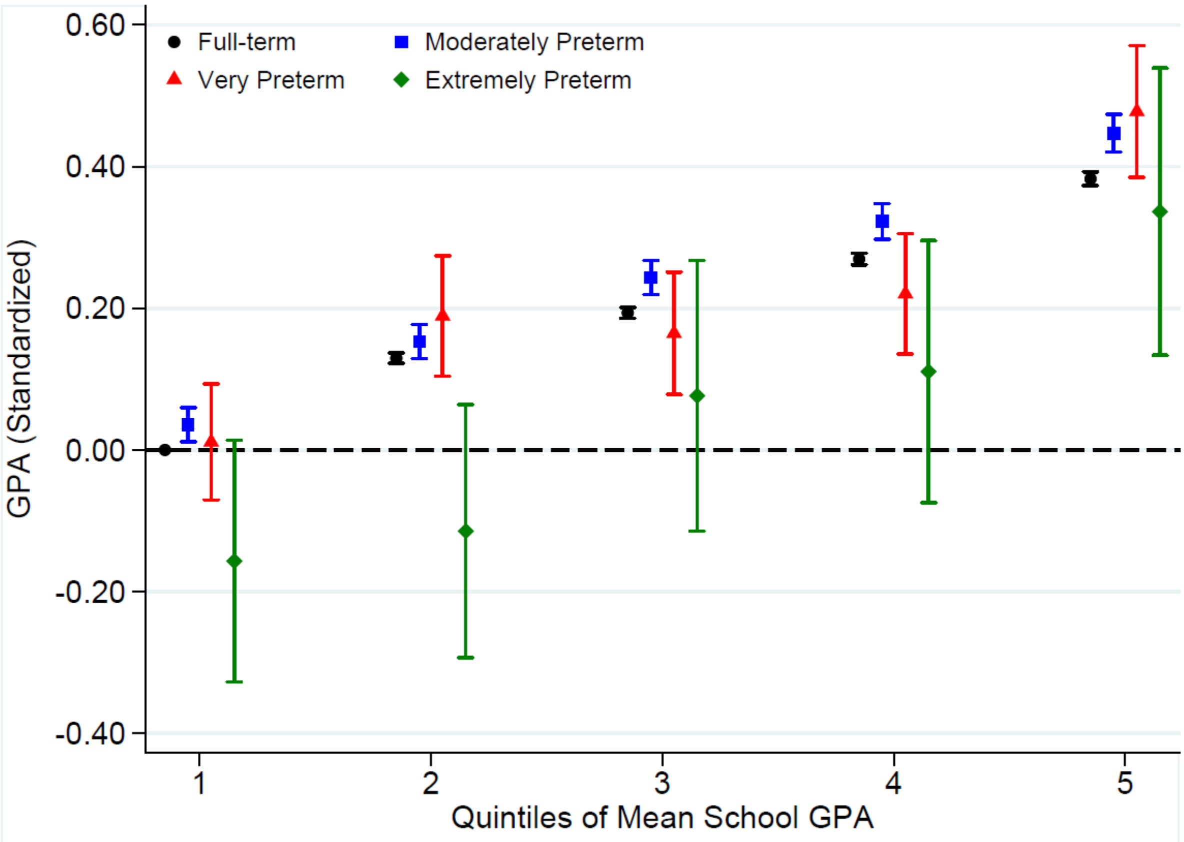


Source: Swedish register data. Notes: As for Figure 2.

Differences across schools

We investigated whether the type of school attended by children affects the degree to which a preterm birth may lead to a disadvantage in educational attainment. To this end, we estimated models with interactions between preterm birth categories and quantiles of school-specific average grades. Our results presented on Figure 4 indicate that higher school quality related to improved school grades among all individuals, but the relative gains from attending a school with better average grades are slightly larger among extremely preterm born individuals. While extremely preterm born individuals who attended schools in the bottom quantile have grades that are 0.16 standard deviation lower than their peers born fullterm in similar schools, extremely preterm born individuals who attended schools in the top quantile have grades that are 0.34 standard deviation higher than the reference category. Hence, choosing the "right" school for extremely preterm born children could improve their educational outcomes by up to 0.5 standard deviations. The difference in the effects of very preterm births between individuals who attended schools in the bottom and top grade quintiles amounts to 0.47 standard deviations of grades. The difference in the effect size of moderately preterm births amounts to 0.41 standard deviations.

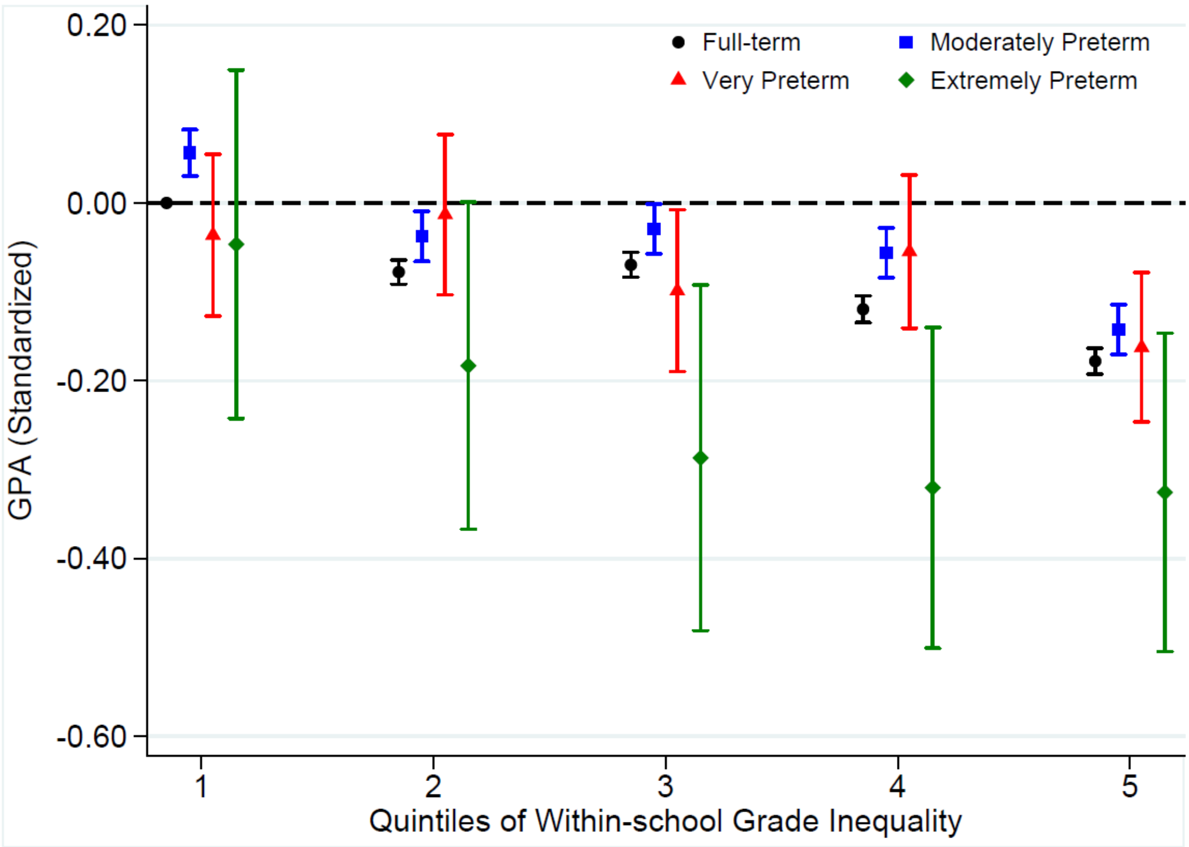
Figure 4. Differences in grade scores according to gestational age at birth and school quality – results from sibling comparisons.



Source: Swedish register data. Notes: As for Figure 2.

We also examined whether the within-school inequality in grades affects the degree to which a preterm birth may lead to an educational disadvantage. Our results presented on Figure 5 indicate that lower within-school inequality is related to better school grades among all children, but the relative benefits from attending a school with better average grades are slightly larger among extremely and moderately preterm born individuals. While individuals born at term who attended schools in the most unequal quintile have grades that are 0.18 standard deviation lower than children in least unequal schools, extremely preterm born individuals who attended most unequal schools have grades that are 0.28 standard deviation lower than extremely preterm born children in least unequal schools. The difference in the effects of very preterm births between individuals who attended schools in the bottom and top grade quintiles of overall within-school inequality amounts to 0.12 standard deviations. The difference in the effect size of moderately preterm births amounts to 0.20 standard deviations. If we compare children from the least unequal schools, there are no statistically significant differences between grades of preterm born children and children born at term.

Figure 5. Differences in grade scores according to gestational age at birth and within-school inequality – results from sibling comparisons.



Source: Swedish register data. Notes: As for Figure 2.

Discussion

Overall, our results show that there is a non-linear relationship between gestational age and school grades. Our results 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 preterm or even very preterm will not be likely to suffer any adverse long-term consequences if they were not born with low birth weight. We also show that the impact of preterm births is above and beyond the disadvantage exerted by low birth weight as documented in earlier studies (Conley and Bennett 2000; Goisis et al. 2017).

Furthermore, after accounting for unobserved and unmeasured factors within the sibling group, the long-term consequences of moderately preterm and very preterm 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 suggests 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.

To our surprise, parental socioeconomic resources do not seem to reduce the disadvantage resulting from extremely preterm births. In fact, we observe that the long-term effects of extremely preterm births are more severe amongst children born in high socioeconomic status families than in low socioeconomic status families. This puzzling pattern might be related to differential rates of *in utero* selection; mothers of low socioeconomic status have higher rates of stillbirth and perinatal mortality than mothers with high socioeconomic status in the Nordic region (Jørgensen et al. 2008; Rom et al. 2012) and this pattern may also hold for spontaneous abortion. If this were indeed the case, we might expect extremely preterm children born to low socioeconomic status mothers to be relatively more physically robust than extremely preterm children born to high socioeconomic status mothers, with corresponding consequences for development during childhood as well as long-term educational achievement. At less extreme levels of preterm birth status, the socioeconomic status of the parents does not seem to play any role in moderating the effects of preterm birth. For example, the effects of moderately preterm births do not vary across families with different socioeconomic status. This is important as it suggests that differential compensation effects are unlikely to be driving our results concerning non-linear effects of preterm births across gestational age.

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. Our findings suggest that in schools, where children have better grades on average and where there is less overall inequality of grades, children born preterm tend to deviate less from the rest of their peers. Hence, the overall quality of schools and also the way that schools handle the needs of the most disadvantaged children may alleviate the negative effects of being born preterm. This underscores the role of schools as institutions that may either reduce or reinforce the early life course disadvantage. Further research is needed to shed more light on which specific factors beyond high average grades and low inequality of grades 'closes the gap' between preterm born children and their healthier peers. Identifying these factors could be helpful for improving the design of educational policies addressing the needs of the most vulnerable groups of children.

Although this study has many strengths, including the use of full population register data, sibling fixed effects models that control for unobserved confounding, and additional adjustment for birth weight and mode of delivery, there are certainly some 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. 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 2018 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.

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	890	4,102	46,220	891,049	942,261
	%	83.49	91.4	94.31	95.7	95.6
Attended a special school	N	162	328	2,284	30,692	33,466
	%	15.2	7.31	4.66	3.3	3.4
Failed to pass	N	14	58	503	9,345	9,920
	%	1.31	1.29	1.03	1	1.01
Total	N	1,066	4,488	49,007	931,086	985,647
	%	100	100	100	100	100

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

Table A2. Sample structure.

		Gestational Age at Birth				Total
		Extremely preterm	Very preterm	Moderately preterm	Term delivery	
N		857	4,026	45,940	888,402	939,225
Mean Grade Scores		-0.3	-0.15	-0.03	0.01	0.01
Female	%	51.34	46.97	45.7	48.84	48.68
Birth order	Mean	1.91	1.87	1.86	1.90	1.90
Multiple births	%	25.09	27.02	18.14	1.52	2.46
Adopted children	%	0.23	0.05	0.03	0.02	0.02
Year of Birth	Mean	1988.96	1988.7	1988.13	1988.18	1988.18
C-sections	%	50.41	64.43	31.11	9.31	10.65
N by Birth Weight	Extremely low-birth weight	480	289	49	118	936
	Very low-birth weight	336	1,858	825	183	3,202
	Low-birth weight	15	1,805	17,758	11,436	31,014
	Normal birth weight	26	74	27,308	876,665	904,073
Mean Grade Scores by Birth Weight	Extremely low-birth weight	-0.34	-0.23	0.02	0.16	-0.22
	Very low-birth weight	-0.27	-0.14	-0.09	-0.10	-0.14
	Low-birth weight	-0.10	-0.15	-0.04	-0.14	-0.09
	Normal birth weight	-0.03	-0.07	-0.03	0.01	0.01
N by Maternal Age	up to 19	9	71	583	7,925	8,588
	20-24	142	733	8,496	152,321	161,692
	25-29	279	1,428	17,025	351,212	369,944
	30-34	263	1,089	12,818	263,463	277,633
	35-39	136	597	5,878	97,639	104,250
	40-44	27	100	1,087	15,287	16,501
	45+	1	8	53	555	617
Mean Grade Scores by Maternal Age	up to 19	-1.24	-0.60	-0.63	-0.61	-0.61
	20-24	-0.27	-0.40	-0.27	-0.24	-0.25

	25-29	-0.32	-0.12	-0.02	0.00	0.00
	30-34	-0.29	-0.04	0.07	0.13	0.12
	35-39	-0.15	-0.10	0.08	0.16	0.15
	40-44	-0.58	-0.12	0.01	0.12	0.11
	45+	-3.16	0.07	0.16	-0.00	0.01
N by Maternal Education	Elementary	115	483	5,428	91,725	97,751
	Secondary	384	1,737	17,971	351,328	371,420
	Post-secondary	142	712	7,763	164,974	173,591
Mean Grade Scores by Maternal Education	Elementary	-0.67	-0.60	-0.50	-0.48	-0.48
	Secondary	-0.30	-0.16	-0.07	-0.06	-0.06
	Post-secondary	0.13	0.38	0.46	0.47	0.47
N by Parental Employment	Dual Earner	594	2,749	29,129	567,619	600,091
	Male Breadwinner	46	193	2,030	40,947	43,216
	Female Breadwinner	17	83	878	15,402	16,380
	Jobless Household	12	37	393	7,203	7,645
Mean Grade Scores by Parental Employment	Dual Earner	-0.27	-0.08	0.01	0.04	0.04
	Male Breadwinner	-0.30	-0.47	-0.38	-0.24	-0.25
	Female Breadwinner	-0.93	-0.49	-0.29	-0.23	-0.24
	Jobless Household	-0.86	-0.78	-0.54	-0.39	-0.40
N by Parental Income	1 Income Quintile	185	822	9,820	186,203	197,030
	2 Income Quintile	164	820	9,914	192,697	203,595
	3 Income Quintile	163	765	9,592	186,096	196,616
	4 Income Quintile	161	824	8,844	173,466	183,295
	5 Income Quintile	182	781	7,626	147,435	156,024
Mean Grade Scores by Parental Income	1 Income Quintile	-0.34	-0.37	-0.24	-0.15	-0.16
	2 Income Quintile	-0.32	-0.29	-0.11	-0.07	-0.07
	3 Income Quintile	-0.40	-0.16	-0.05	-0.01	-0.02
	4 Income Quintile	-0.28	-0.07	0.03	0.06	0.06

	5 Income Quintile	-0.14	0.14	0.28	0.30	0.30
N by Maternal Country of Birth	Sweden	757	3,580	41,427	804,654	850,418
	Nordic+EU-15	38	180	2,112	40,336	42,666
	Eastern Europe	39	138	1,112	20,985	22,274
	Other	23	128	1,289	22,427	23,867
Mean Grade Scores by Maternal Country of Birth	Sweden	-0.27	-0.14	-0.02	0.02	0.02
	Nordic+EU-15	-0.61	-0.34	-0.13	-0.07	-0.07
	Eastern Europe	-0.44	-0.17	-0.20	-0.15	-0.16
	Other	-0.51	-0.18	-0.09	-0.10	-0.10
N by School Quality	1 Quintile of school GPA	208	862	9,496	176,765	187,331
	2 Quintile of school GPA	174	787	9,389	178,655	189,005
	3 Quintile of school GPA	147	847	9,200	178,906	189,100
	4 Quintile of school GPA	176	789	9,047	178,018	188,030
	5 Quintile of school GPA	152	741	8,808	176,058	185,759
Mean Grade Scores by School Quality	1 Quintile of school GPA	-0.62	-0.51	-0.41	-0.36	-0,36
	2 Quintile of school GPA	-0.39	-0.27	-0.18	-0.12	-0,13
	3 Quintile of school GPA	-0.38	-0.20	-0.05	-0.01	-0,01
	4 Quintile of school GPA	-0.22	-0.06	0.10	0.13	0,12
	5 Quintile of school GPA	0.25	0.34	0.40	0.42	0,42
N by Within-School Inequality	1 Quintile of Gini Coef.	159	781	8,837	176,597	186,374
	2 Quintile of Gini Coef.	177	773	8,990	179,809	189,749
	3 Quintile of Gini Coef.	159	759	9,165	177,854	187,937
	4 Quintile of Gini Coef.	175	815	9,488	178,897	189,375
	5 Quintile of Gini Coef.	187	898	9,460	175,245	185,790
Mean Grade Scores by Within-School Inequality	1 Quintile of Gini Coef.	0.11	0.13	0.23	0.27	0,27
	2 Quintile of Gini Coef.	-0.30	-0.03	0.03	0.07	0,07
	3 Quintile of Gini Coef.	-0.33	-0.24	-0.05	-0.01	-0,01
	4 Quintile of Gini Coef.	-0.39	-0.19	-0.11	-0.08	-0,08

5 Quintile of Gini Coef.	-0.51	-0.40	-0.26	-0.20	-0,20

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

Table A3. Differences in grade scores according to gestational age at birth – results from sibling comparison

	OLS Model			FE Model			FE Model		
	Coef.	95%CI		Coef.	95%CI		Coef.	95%CI	
Gestational age at birth									
Term delivery (ref.)									
Extremely preterm	-0.34	-0.41	-0.28	-0.29	-0.37	-0.21	-0.15	-0.24	-0.05
Very preterm	-0.16	-0.19	-0.13	-0.07	-0.11	-0.03	0.02	-0.03	0.06
Moderately preterm	-0.05	-0.06	-0.04	0.03	0.01	0.04	0.05	0.03	0.06
Maternal age									
Up to 19 (ref.)									
20-24	0.44	0.42	0.46	0.01	-0.02	0.03	0.01	-0.02	0.03
25-29	0.79	0.77	0.81	0.00	-0.02	0.03	0.00	-0.02	0.03
30-34	1.00	0.98	1.02	0.00	-0.02	0.03	0.01	-0.02	0.03
35-39	1.11	1.09	1.13	0.02	-0.02	0.05	0.02	-0.02	0.05
40-44	1.15	1.12	1.17	0.02	-0.02	0.07	0.02	-0.02	0.07
45+	1.15	1.07	1.22	-0.01	-0.13	0.11	-0.01	-0.13	0.11
Gender									
Men (ref.)									
Women	0.40	0.39	0.40	0.39	0.38	0.39	0.39	0.38	0.39
Birth order									
1st born (ref.)									
2nd	-0.29	-0.29	-0.28	-0.17	-0.17	-0.16	-0.17	-0.17	-0.16
3rd	-0.46	-0.46	-0.45	-0.28	-0.29	-0.27	-0.28	-0.29	-0.27
4th	-0.64	-0.65	-0.63	-0.36	-0.38	-0.34	-0.36	-0.38	-0.34
5th	-0.81	-0.83	-0.79	-0.45	-0.48	-0.42	-0.45	-0.48	-0.42
6th	-0.90	-0.94	-0.86	-0.51	-0.56	-0.47	-0.52	-0.56	-0.47
7th	-0.94	-1.00	-0.89	-0.56	-0.64	-0.49	-0.57	-0.64	-0.49
Multiple births	0.11	0.10	0.13	0.07	0.05	0.09	0.09	0.07	0.11
Adopted children	-0.34	-0.47	-0.22	-0.01	-0.30	0.28	-0.01	-0.30	0.28
C-sections	-0.06	-0.07	-0.05	-0.01	-0.02	0.00	0.00	-0.01	0.01
Birth weight									
Normal (ref.)									
Extremely low-birth weight							-0.18	-0.27	-0.09
Very low-birth weight							-0.11	-0.16	-0.06
Low-birth weight							-0.07	-0.08	-0.06
Constant	-0.75	-0.77	-0.73	-0.12	-0.15	-0.09	-0.12	-0.15	-0.09
N	939225			939225			939225		

Source: Swedish register data, birth cohorts 1982-1994. Fixed effects for birth cohorts included, results not displayed.

Table A4. 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	-0.02	0.03						
Term delivery # postsecondary	0.01	-0.02	0.05						
Extremely preterm # elementary	-0.12	-0.36	0.13						
Extremely preterm # high school	-0.09	-0.24	0.07						
Extremely preterm # postsecondary	-0.25	-0.47	-0.02						
Very preterm # elementary	0.17	0.05	0.30						
Very preterm # high school	0.03	-0.05	0.10						
Very preterm # postsecondary	-0.01	-0.12	0.10						
Moderately preterm # elementary	0.08	0.05	0.12						
Moderately preterm # high school	0.07	0.04	0.10						
Moderately preterm# postsecondary	0.05	0.01	0.10						
Term delivery # dual earner (ref.)									
Term delivery # male breadwinner				0.00	-0.01	0.01			
Term delivery # female breadwinner				-0.01	-0.03	0.02			
Term delivery # jobless household				0.00	-0.03	0.04			
Extremely preterm # dual earner				-0.16	-0.29	-0.03			
Extremely preterm # male breadwinner				0.12	-0.21	0.45			
Extremely preterm # female breadwinner				-0.18	-0.94	0.57			
Extremely preterm # jobless household				-0.56	-1.31	0.19			
Very preterm # dual earner				0.03	-0.03	0.09			
Very preterm # male breadwinner				0.15	-0.03	0.34			
Very preterm # female breadwinner				0.01	-0.27	0.28			
Very preterm # jobless household				0.25	-0.22	0.73			
Moderately preterm # dual earner				0.06	0.04	0.08			
Moderately preterm # male breadwinner				0.03	-0.02	0.08			

Moderately preterm # female breadwinner				0.04	-0.05	0.12			
Moderately preterm # jobless household				0.02	-0.12	0.15			
Term delivery # income quintile (1 ref.)									
Term delivery # 2 income quintile							0.00	-0.01	0.00
Term delivery # 3 income quintile							-0.01	-0.02	0.00
Term delivery # 4 income quintile							-0.01	-0.02	0.00
Term delivery # 5 income quintile							-0.01	-0.02	0.00
Extremely preterm # 1 income quintile							0.04	-0.14	0.22
Extremely preterm # 2 income quintile							-0.05	-0.24	0.13
Extremely preterm # 3 income quintile							-0.16	-0.35	0.03
Extremely preterm # 4 income quintile							-0.31	-0.50	-0.11
Extremely preterm # 5 income quintile							-0.28	-0.47	-0.10
Very preterm # 1 income quintile							0.01	-0.07	0.10
Very preterm # 2 income quintile							0.00	-0.08	0.09
Very preterm # 3 income quintile							0.07	-0.01	0.16
Very preterm # 4 income quintile							0.00	-0.08	0.09
Very preterm # 5 income quintile							-0.04	-0.14	0.05
Moderately preterm # 1 income quintile							0.04	0.02	0.07
Moderately preterm # 2 income quintile							0.03	0.00	0.05
Moderately preterm # 3 income quintile							0.05	0.03	0.08
Moderately preterm # 4 income quintile							0.04	0.01	0.07
Moderately preterm # 5 income quintile							0.05	0.02	0.08
Maternal age									
Up to 19 (ref.)									
20-24	0.02	-0.02	0.05	0.02	-0.01	0.06	0.00	-0.02	0.03
25-29	0.01	-0.02	0.05	0.02	-0.02	0.06	0.00	-0.02	0.03
30-34	0.01	-0.03	0.06	0.02	-0.02	0.06	0.01	-0.02	0.04
35-39	0.02	-0.03	0.07	0.02	-0.02	0.07	0.02	-0.02	0.05
40-44	0.03	-0.03	0.09	0.03	-0.03	0.09	0.02	-0.02	0.07
45+	-0.05	-0.22	0.12	-0.08	-0.25	0.09	-0.01	-0.13	0.11
Gender									

Men (ref.)									
Women	0.39	0.38	0.39	0.39	0.38	0.39	0.39	0.38	0.39
Birth order									
1st born (ref.)									
2nd	-0.17	-0.17	-0.16	-0.16	-0.17	-0.16	-0.17	-0.17	-0.16
3rd	-0.28	-0.29	-0.26	-0.27	-0.29	-0.26	-0.28	-0.29	-0.27
4th	-0.36	-0.39	-0.34	-0.35	-0.38	-0.33	-0.36	-0.38	-0.34
5th	-0.46	-0.50	-0.42	-0.44	-0.48	-0.40	-0.45	-0.48	-0.42
6th	-0.53	-0.60	-0.46	-0.50	-0.56	-0.43	-0.52	-0.56	-0.47
7th	-0.58	-0.68	-0.48	-0.56	-0.66	-0.47	-0.57	-0.64	-0.49
Multiple births	0.06	0.03	0.08	0.06	0.04	0.09	0.09	0.07	0.11
Adopted children	0.10	-0.41	0.60	0.12	-0.32	0.56	-0.01	-0.30	0.27
C-sections	0.00	-0.01	0.02	0.00	-0.01	0.02	0.00	-0.01	0.01
Birth weight									
Normal (ref.)									
Extremely low-birth weight	-0.18	-0.30	-0.07	-0.19	-0.31	-0.08	-0.18	-0.27	-0.09
Very low-birth weight	-0.09	-0.15	-0.03	-0.10	-0.16	-0.04	-0.11	-0.16	-0.06
Low-birth weight	-0.07	-0.09	-0.05	-0.06	-0.08	-0.04	-0.07	-0.08	-0.06
Constant	-0.07	-0.11	-0.03	-0.08	-0.12	-0.05	-0.12	-0.14	-0.09
N	642762			6673 32			93656 0		

Source: Swedish register data, birth cohorts 1982-1994. Fixed effects for birth cohorts included, results not displayed.

Table A5. Differences in grade scores according to gestational age at birth and maternal country of birth – results from sibling comparisons.

	FE Model Sweden			FE Model EU15+Nordic			FE Model Eastern Europe			FE Model Rest of the world		
	Coef.	95%CI		Coef.	95%CI		Coef.	95%CI		Coef.	95%CI	
Gestational age at birth												
Term delivery (ref.)												
Extremely preterm	-0.12	-0.22	-0.02	-0.38	-0.88	0.12	-0.35	-0.89	0.18	-0.30	-0.99	0.39
Very preterm	0.02	-0.03	0.07	0.09	-0.16	0.35	-0.15	-0.44	0.15	0.07	-0.21	0.35
Moderately preterm	0.05	0.04	0.06	0.03	-0.03	0.09	0.00	-0.09	0.09	0.06	-0.02	0.14
Maternal age												
Up to 19 (ref.)												
20-24	-0.02	-0.04	0.01	0.04	-0.06	0.15	0.03	-0.07	0.12	0.08	-0.03	0.18
25-29	-0.02	-0.05	0.01	0.06	-0.06	0.19	0.06	-0.07	0.18	0.09	-0.03	0.22
30-34	-0.02	-0.05	0.01	0.07	-0.07	0.22	0.02	-0.15	0.19	0.05	-0.11	0.22
35-39	0.00	-0.04	0.04	0.07	-0.10	0.24	-0.04	-0.25	0.18	-0.02	-0.23	0.18
40-44	0.01	-0.04	0.05	0.17	-0.04	0.38	-0.12	-0.41	0.18	-0.06	-0.33	0.21
45+	-0.06	-0.18	0.07	0.41	-0.07	0.89	0.14	-0.83	1.11	0.24	-0.88	1.35
Gender												
Men (ref.)												
Women	0.39	0.39	0.39	0.40	0.38	0.42	0.36	0.33	0.39	0.33	0.30	0.36
Birth order												
1st born (ref.)												
2nd	-0.17	-0.18	-0.16	-0.15	-0.18	-0.12	-0.16	-0.20	-0.11	-0.13	-0.17	-0.09
3rd	-0.29	-0.30	-0.27	-0.25	-0.31	-0.19	-0.22	-0.30	-0.14	-0.22	-0.30	-0.15
4th	-0.37	-0.39	-0.35	-0.29	-0.38	-0.20	-0.31	-0.43	-0.18	-0.27	-0.38	-0.15
5th	-0.48	-0.51	-0.45	-0.31	-0.44	-0.17	-0.31	-0.49	-0.13	-0.18	-0.35	-0.01
6th	-0.53	-0.58	-0.48	-0.42	-0.62	-0.21	-0.40	-0.67	-0.13	-0.55	-0.84	-0.26
7th	-0.63	-0.71	-0.55	-0.30	-0.59	-0.01	0.24	-0.22	0.69	-0.22	-0.71	0.27
Multiple births	0.08	0.06	0.10	0.10	0.00	0.20	0.22	0.07	0.38	0.09	-0.05	0.23
Adopted children	-0.04	-0.33	0.24	0.00	0.00	0.00	1.30	-0.80	3.41	0.00	0.00	0.00
C-sections	0.00	-0.01	0.01	-0.01	-0.06	0.04	-0.04	-0.12	0.04	0.02	-0.05	0.09

Birth weight												
Normal (ref.)												
Extremely low-birth weight	-0.17	-0.26	-0.08	0.06	-0.44	0.56	-0.44	-0.95	0.06	-0.54	-1.11	0.02
Very low-birth weight	-0.10	-0.15	-0.05	-0.21	-0.47	0.05	-0.16	-0.50	0.19	-0.26	-0.55	0.02
Low-birth weight	-0.07	-0.09	-0.05	-0.03	-0.11	0.04	-0.09	-0.20	0.01	-0.09	-0.18	0.00
Constant	-0.09	-0.11	-0.06	-0.21	-0.33	-0.09	-0.33	-0.44	-0.22	-0.41	-0.55	-0.27
N	850418			42666			22274			23867		

Source: Swedish register data, birth cohorts 1982-1994. Fixed effects for birth cohorts included, results not displayed.

Table A6. Differences in grade scores according to gestational age at birth and school characteristics – results from sibling comparisons.

	FE Model			FE Model		
	Coef.	95%CI		Coef.	95%CI	
Term delivery # 1 Quintile of school (ref.)						
Term delivery # 2 Quintile of school GPA	0.13	0.12	0.14			
Term delivery # 3 Quintile of school GPA	0.19	0.19	0.20			
Term delivery # 4 Quintile of school GPA	0.27	0.26	0.28			
Term delivery # 5 Quintile of school GPA	0.38	0.37	0.39			
Extremely preterm # 1 Quintile of school GPA	-0.16	-0.33	0.01			
Extremely preterm # 2 Quintile of school GPA	-0.11	-0.29	0.06			
Extremely preterm # 3 Quintile of school GPA	0.08	-0.11	0.27			
Extremely preterm # 4 Quintile of school GPA	0.11	-0.07	0.30			
Extremely preterm # 5 Quintile of school GPA	0.34	0.13	0.54			
Very preterm # 1 Quintile of school GPA	0.01	-0.07	0.09			
Very preterm # 2 Quintile of school GPA	0.19	0.10	0.27			
Very preterm # 3 Quintile of school GPA	0.16	0.08	0.25			
Very preterm # 4 Quintile of school GPA	0.22	0.14	0.31			
Very preterm # 5 Quintile of school GPA	0.48	0.39	0.57			
Moderately preterm # 1 Quintile of school GPA	0.04	0.01	0.06			
Moderately preterm # 2 Quintile of school GPA	0.15	0.13	0.18			
Moderately preterm # 3 Quintile of school GPA	0.24	0.22	0.27			
Moderately preterm # 4 Quintile of school GPA	0.32	0.30	0.35			
Moderately preterm # 5 Quintile of school GPA	0.45	0.42	0.47			
Term delivery # Quintile of Gini Coef. (1 ref.)						
Term delivery # 2 Quintile of Gini Coef.				-0.08	-0.09	-0.06
Term delivery # 3 Quintile of Gini Coef.				-0.07	-0.08	-0.06
Term delivery # 4 Quintile of Gini Coef.				-0.12	-0.13	-0.10
Term delivery # 5 Quintile of Gini Coef.				-0.18	-0.19	-0.16
Extremely preterm # 1 Quintile of Gini Coef.				-0.05	-0.24	0.15
Extremely preterm # 2 Quintile of Gini Coef.				-0.18	-0.37	0.00
Extremely preterm # 3 Quintile of Gini Coef.				-0.29	-0.48	-0.09
Extremely preterm # 4 Quintile of Gini Coef.				-0.32	-0.50	-0.14
Extremely preterm # 5 Quintile of Gini Coef.				-0.33	-0.50	-0.15
Very preterm # 1 Quintile of Gini Coef.				-0.04	-0.13	0.05
Very preterm # 2 Quintile of Gini Coef.				-0.01	-0.10	0.08
Very preterm # 3 Quintile of Gini Coef.				-0.10	-0.19	-0.01
Very preterm # 4 Quintile of Gini Coef.				-0.05	-0.14	0.03
Very preterm # 5 Quintile of Gini Coef.				-0.16	-0.25	-0.08
Moderately preterm # 1 Quintile of Gini Coef.				0.06	0.03	0.08
Moderately preterm # 2 Quintile of Gini Coef.				-0.04	-0.07	-0.01
Moderately preterm # 3 Quintile of Gini Coef.				-0.03	-0.06	0.00
Moderately preterm # 4 Quintile of Gini Coef.				-0.06	-0.08	-0.03
Moderately preterm # 5 Quintile of Gini Coef.				-0.14	-0.17	-0.11

Maternal age						
Up to 19 (ref.)						
20-24	0.01	-0.01	0.03	0.01	-0.02	0.03
25-29	0.01	-0.01	0.04	0.01	-0.02	0.03
30-34	0.01	-0.02	0.04	0.01	-0.02	0.04
35-39	0.02	-0.02	0.05	0.02	-0.02	0.05
40-44	0.02	-0.02	0.06	0.03	-0.02	0.07
45+	-0.02	-0.14	0.10	-0.01	-0.12	0.11
Gender						
Men (ref.)						
Women	0.38	0.38	0.39	0.39	0.38	0.39
Birth order						
1st born (ref.)						
2nd	-0.17	-0.17	-0.16	-0.17	-0.17	-0.16
3rd	-0.28	-0.29	-0.27	-0.28	-0.29	-0.27
4th	-0.35	-0.37	-0.34	-0.36	-0.38	-0.34
5th	-0.44	-0.47	-0.41	-0.45	-0.48	-0.42
6th	-0.50	-0.55	-0.45	-0.51	-0.56	-0.47
7th	-0.54	-0.61	-0.47	-0.56	-0.64	-0.49
Multiple births	0.09	0.07	0.11	0.09	0.07	0.11
Adopted children	-0.02	-0.30	0.27	0.00	-0.29	0.29
C-sections	0.00	-0.01	0.01	0.00	-0.01	0.01
Birth weight						
Normal (ref.)						
Extremely low-birth weight	-0.18	-0.27	-0.10	-0.18	-0.27	-0.10
Very low-birth weight	-0.11	-0.15	-0.06	-0.11	-0.16	-0.06
Low-birth weight	-0.07	-0.08	-0.05	-0.07	-0.08	-0.05
Constant	-0.33	-0.35	-0.30	-0.03	-0.06	0.00
N	939225			939225		

Source: Swedish register data, birth cohorts 1982-1994. Fixed effects for birth cohorts included, results not displayed.

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