Socioeconomic implications of adverse birth outcomes

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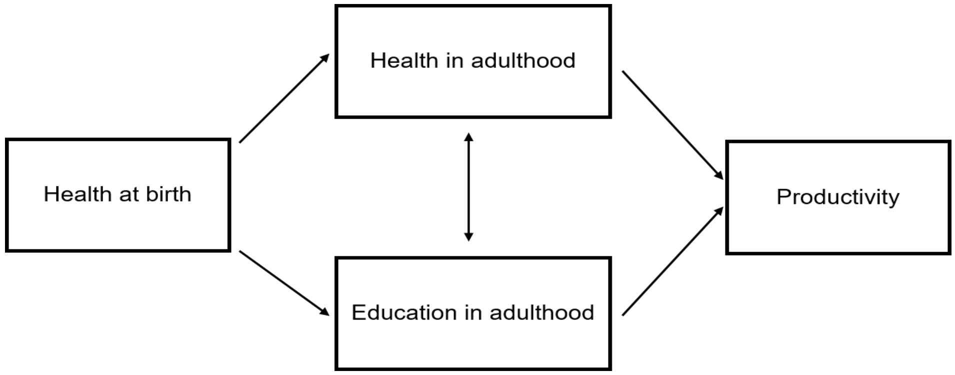
1 Introduction

This dissertation studies the socioeconomic implications of adverse birth outcomes, which include measures related to birth weight (low birth weight), gestational age (preterm birth), or both combined (small for gestational age). All these concepts are well-established indicators for the health endowment of a child at birth (Ashorn et al., 2020; Blencowe et al., 2019; Chawanpaiboon et al., 2019; Conti et al., 2020). From an economic perspective, these health endowments at birth could be interpreted as part of the initial health capital stock of a newborn individual (Baguet & Dumas, 2019; Grossman, 2017; Schneider-Kamp, 2021). Adverse birth outcomes as part of this capital stock could have lasting consequences for the future health of an individual (Crump, 2020; Luu et al., 2017), which may translate into reduced future productivity (Arora, 2001; Lenhart, 2019; Riphahn, 1999). In addition to that, individual long-term productivity could be impaired due to educational drawbacks caused by adverse birth outcomes (Allen et al., 2019; Blumenshine et al., 2010; Johnson & Schoeni, 2011; Trickett et al., 2022; Twilhaar et al., 2020). Consequently, adverse birth outcomes might be linked to losses in future productivity, as illustrated in Figure 1.1. These theoretical considerations imply that policies to improve the health of newborn children or mitigate the socioeconomic consequences of adverse birth outcomes could increase future productivity. Such policies are efficient as long as their induced productivity gains in the population exceed their total costs.

For the year 2020, the WHO and UNICEF report that 13.4 million babies were born preterm and 19.8 million were born with low birth weight. Country-specific estimates for the rate of low birth weight range from less than 5% to more than 20%, with the highest rates in developing countries in which large proportions of the population live in absolute poverty. The picture is similar, given the concept of preterm birth (UNICEF, 2023; WHO, 2023). Due to the fact that a large population of newborn children is affected by adverse birth outcomes, potential welfare gains linked to the reduction of adverse birth outcomes and the consequences later in life might be meaningful on aggregate.

Figure 1.1: Health at birth and future productivity



The diagram illustrates the potential relationship between health at birth and future productivity.

It is important to mention that newborn children are not responsible for their health at birth, as it is mostly shaped by the prenatal environment and predetermined conditions (Mitku et al., 2021; Moss & Harris, 2014). Given the idea of equality of opportunity, individual success should be shaped mainly by factors affected by the individual. This could be interpreted as another reason to study the individual causes and consequences of adverse birth outcomes and to derive suitable policy measures to either improve the health status of newborns or mitigate the long-term impact of adverse birth outcomes. Moreover, it should be emphasised that the returns on investments in human capital are comparably high in early childhood (Heckman, 2000).

In the following chapters, I present research on potential risk factors for adverse birth outcomes and their implications for the socioeconomic status of the newborn in later life. Beyond that, I study the economic consequences for the parents of a newborn child with adverse birth outcomes. Except for the second chapter, all chapters have an applied econometric approach and statistically analyse observational data from Germany and the United Kingdom. The analyses are interdisciplinary and focus on the explanation of the assumptions required to causally interpret the results and address the limitations of the analyses.

The main body of this dissertation is structured into five chapters. In Chapter 2, I present an extensive literature review of empirical articles that study the influence of measures related to infant health during pregnancy (prenatal) or health at birth and health in early childhood (perinatal) on the intergenerational transmission of socioeconomic status (e.g., income, education, social status, wealth, and related concepts). The literature review is split into three parts and focuses on studies attempting to identify causal effects. The first part discusses whether poor parental socioeconomic status is related to an increased risk of adverse birth outcomes for the child. While the results in most developing countries indicate that socioeconomic status is an important variable to explain the incidence of adverse birth outcomes, the evidence for more developed countries is mixed. It is important to mention in this context that many of the developed countries considered provide conditional cash transfers to families or mothers during pregnancy. Furthermore, these countries have a comparably sophisticated system of prenatal health care and strong social institutions, which effectively improve birth outcomes, as shown by the literature presented. The second part covers literature studying the implications of adverse prenatal and perinatal conditions for individual socioeconomic status later in life. Even though a majority of studies find a significant impact of adverse birth outcomes on education in childhood and adolescence, some studies indicate that the relevance of adverse birth outcomes is diminishing over the life course (especially in developed countries). The third part presents literature that directly studies the relevance of predetermined endowments of a child (which are transmitted during pregnancy) for the intergenerational transmission of social status. Here, a large proportion of the literature is based on studies comparing biological and adopted children. Most of the reviewed articles suggest that endowment effects (e.g., education of biological parents) are significantly related to the educational attainment of the next generation, even if the child was not raised by its biological parents. Very few articles explicitly study the relevance of adverse birth outcomes for measures of intergenerational mobility. They show that higher incidences of adverse birth outcomes could be associated with reductions in intergenerational mobility. The literature review is based on joint work with Daniel Schnitzlein and Sakarai Lemola, which is forthcoming in the following handbook article: Voit, F. A. C., Lemola, S., & Schnitzlein, D. D. (forthcoming). Pre- and perinatal influences on intergenerational transmission of inequality. In E. Kilpi-Jakonen, J. Blanden, J. Erola & L. Macmillan (Eds.), *Research Handbook on Intergenerational Inequality.* Edward Elgar.

The third chapter (Chapter 3) studies risk factors for adverse birth outcomes and aims to answer the question of whether maternal mental health during pregnancy is related to adverse birth outcomes using two survey datasets from Germany, the Socio-Economic Panel (SOEP) and the National Educational Panel Study (NEPS). Even though the literature presented in the chapter suggests that in-utero conditions (e.g., maternal stress, mental health) could be related to the birth outcomes of the child using data from different countries (Aizer et al., 2016; Hayes et al., 2012; Persson & Rossin-Slater, 2018; Staneva et al., 2015), there is no evidence for the case of Germany. This chapter fills this gap and is also one of the first analysis to study the association between maternal mental health during pregnancy and birth outcomes. To quantify the relationship, we estimate OLS models, logit models, mother fixed effects models, and matching models. The results suggest that poor maternal mental health during pregnancy is a significant risk factor for low birth weight and preterm birth. Results from the main analysis using the SOEP data indicate that poor maternal mental health is associated with an 8.6 to 14.4 percentage point higher risk for preterm birth and a 4.6 to 13.0 percentage point higher risk for low birth weight. The results are robust to various specifications and various sub-samples applying different estimation strategies. The results from the matching and mother fixed effects models suggest that the estimated relationship has a causal component. In various studies, the external validity of the estimates is not considered. In our analysis, the relation between maternal mental health and adverse birth outcomes (LBW, PT) is found in both datasets, the SOEP and the NEPS. From a policymaker perspective, the evidence suggests that preventing and moderating maternal mental health issues during pregnancy could contribute to reductions in the incidence of preterm birth and low birth weight. The chapter is a joint work with Eero Kajantie, Sakari Lemola, Katri Räikkönen, Dieter Wolke, and Daniel Schnitzlein and is based on the following published article: Voit, F. A. C., Kajantie, E., Lemola, S., Räikkönen, K., Wolke, D., & Schnitzlein, D. D. (2022). Maternal mental health and adverse birth outcomes. *PLoS ONE*, *17*(8), e0272210.

Previous literature suggests that a) preterm birth has lasting consequences for educational attainment in adolescence (Simms et al., 2013; Trickett et al., 2021; Twilhaar et al., 2018) and b) preschool skills are important predictors for later educational attainment (Duncan et al., 2007; Heckman, 2006; Heckman et al., 2013). Therefore, it is straightforward to ask whether preschool Mathematics and Literacy skills mitigate the association between preterm birth and educational achievement in adolescence. Accordingly, Chapter 4 aims to answer this question. Using data from the Avon Longitudinal Study of Parents and Children (ALSPAC) and estimating logit models, we find that preschool skills in Mathematics and Literacy are an important predictor of the probability of passing the GCSEs in the respective subject for both preterm- and term-born children. Interestingly, the association is more pronounced for preterm-born individuals in both subjects, English/Literacy (OR: 1.57, 95% CI: 1.10-2.25) and Mathematics (OR: 1.51, 95% CI: 1.14-2.00). The results are robust to multiple performed sensitivity analyses. It is noteworthy that the estimated odd ratios for the interactions 'preterm * preschool skills' are also positive but not significant in a dataset with imputed missing values applying multiple imputation by chained equations (MICE). Nevertheless, the evidence from the main analysis suggests that interventions to improve preschool education among preterm-born individuals might be effective to compensate for the negative implications of preterm birth on educational attainment in adolescence. In addition, preterm-born individuals with poor preschool skills are at a higher risk of not achieving a sufficient score in the GCSEs at age 16 compared to their term-born counterparts. Here, the negative implications of preterm birth and poor preschool skills seem to reinforce each other. The chapter is based on an article that is a joint work with Nicole Baumann, Dieter Wolke, Hayley Trower, Ayten Bilgin, Eero Kajantie, Katri Räikkönen, Kati Heinonen, Daniel Schnitzlein, and Sakari Lemola and is published as: Baumann, N., Voit, F., Wolke, D., Trower, H., Bilgin, A., Kajantie, E., Räikkönen, K., Heinonen, K., Schnitzlein, D. D., & Lemola, S. (2023). Preschool Mathematics and Literacy Skills and Educational Attainment in Adolescents Born Preterm and Full Term. *The Journal of Pediatrics*, 113731.

In Chapter 5, I analyze the implications of adverse birth outcomes (LBW, PT) for parental labor market outcomes (household income, working hours, labor income) using SOEP data to estimate OLS regression models. Most of the presented literature focuses on the effect of adverse birth outcomes on the socioeconomic status or cognitive skills of the individual later in life (Black et al., 2007; Figlio et al., 2014; Maruyama & Heinesen, 2020; Wolke et al., 2019). In contrast, this chapter emphasizes the consequences of adverse birth outcomes for parents rather than for the child. Descriptive evidence suggests that families of children with adverse birth outcomes earn lower gross and net household incomes after birth. However, this is also the case in the pre-birth period. The panel structure of the SOEP data allows to control for the influence of pre-birth labor market outcomes of the parents while estimating the relationship between adverse birth outcomes and parental labor market outcomes after birth. The results show that adverse birth outcomes are not significantly related to the most considered parental labor market outcomes after birth. Preterm birth and low birth weight are both not significantly related to fathers' income or labor market outcomes. Nevertheless, there is some evidence for a negative relationship between adverse birth outcomes and maternal working hours as well as maternal income after birth. On aggregate, they are not large enough to cause differences in household income. Another important finding of this chapter is the fact that it is not sufficient to account for the influence of general measures of socioeconomic status after birth, such as education. It is comparably important to control for the pre-birth measures of the respective labor market outcome of interest while analyzing the consequences following events related to birth. A version of this chapter is available as the following discussion paper: Voit, F. A. C. (2023). *Adverse birth outcomes and parental labor market participation after birth.* Hannover Economic Papers, No. 710.

Chapter 6 provides an extensive conclusion, given all the previous chapters of this dissertation. The findings are contextualised to various noteworthy aspects, which are important to evaluate research on adverse birth outcomes and their socioeconomic implications. These aspects should be taken into consideration when designing specific measures to reduce the risk of adverse birth outcomes or mitigate the consequences followed by their incidence. Moreover, I cover potential pathways for future research on adverse birth outcomes and their causes and consequences.

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2 Pre- and perinatal influences on intergenerational mobility

Authors' contributions

The following chapter is based on an article that is a joint work with Daniel Schnitzlein and Sakari Lemola, and is forthcoming as Voit, F. A. C., Lemola, S., & Schnitzlein, D. D. (forthcoming). Pre- and perinatal influences on intergenerational transmission of inequality. In E. Kilpi-Jakonen, J. Blanden, J. Erola & L. Macmillan (Eds.), *Research Handbook on Intergenerational Inequality.* Edward Elgar. The authors' contributions toward the article are as follows:

- Statistical analysis: Methods and computing - None
- Literature research - Falk Voit
- Writing first draft - Falk Voit
- Revision - Falk Voit, Daniel Schnitzlein, Sakari Lemola
- Supervision - Falk Voit, Daniel Schnitzlein

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Abstract

Many researchers argue that children in poorer households are at a higher risk of adverse conditions in-utero and shortly after birth, which in turn could affect their later life outcomes negatively. In this chapter, we present a summary of recent articles that contributed to a better understanding of the relevance of prenatal and perinatal outcomes for the process of intergenerational transmission of socioeconomic status. The focus of the summary is on articles conducting empirical analysis. We also discuss whether results could be causally interpreted and cover articles studying a wide range of countries with different institutional arrangements.

2.1 Introduction

The intergenerational transmission of economic or social status is an important driver of inequality around the world. Understanding the processes behind intergenerational transmission is key to derive appropriate policy consequences. This chapter focuses on the role of the prenatal environment and perinatal outcomes as potential channels through which socioeconomic status (SES) is transmitted across generations. If prenatal and perinatal factors are important determinants of intergenerational inequality, this would have immediate policy implications. Measures designed to improve women's environment during pregnancy and reduce the socioeconomic gradient in adverse birth outcomes would not only improve the individual situation of mothers and children but also contribute to a general reduction in inequality across generations.

But why should prenatal and perinatal factors matter for intergenerational processes? Within the economic theory of skill formation (Cunha & Heckman, 2007; Heckman, 2006), a worse birth outcome can be interpreted as a shock to skill formation in early life, leading to a lower initial stock of human capital for the child. Health shocks at birth have a strong impact on the human capital stock, assuming that the marginal return to human capital is highest in the early years of life.

Neurological and psychological research shows that adverse birth outcomes are related to brain development, which emphasizes the potential importance of prenatal and perinatal factors for individual well-being (Garcia et al., 2018; Hedderich et al., 2021). Beyond that, the so-called Predictive Adaptive Response Hypothesis suggests that shocks in early development (e.g., mismatches between expected and actual environments) have strong implications for the later outcomes of individuals (Bateson et al., 2014; Gluckman & Hanson, 2011).

The main birth outcomes typically examined in the literature are length of gestation (e.g., (very) preterm birth (PT/VPT)) and/or birth weight (e.g., (very) low birth weight (LBW/VLBW)) and birth weight relative to gestational age (e.g., being small for gestational age (SGA)) (Ashorn et al., 2020; Blencowe et al., 2019; Chawanpaiboon et al., 2019).[1] The mother's risk of living in an unfavorable environment during pregnancy and experiencing poor birth outcomes appears to be higher in socioeconomically disadvantaged groups of society (Jardine et al., 2021; Manyeh et al., 2016; Snelgrove & Murphy, 2015).

Dimensions of socioeconomic inequality relate to education, social status, employment, income, or economic wealth. Therefore, it can be argued that parental socioeconomic disadvantage increases the risk of negative prenatal and perinatal conditions, which in turn have lasting effects on children and lead to the reproduction of socioeconomic inequality

[1] In addition, Conti et al. (2020) argue that measures related to fetal ultrasounds (e.g., head or abdominal circumference during pregnancy) could improve the understanding of the in-utero environment.

across generations (Aizer & Currie, 2014).

In this chapter, we review the empirical literature that contributes to a better understanding of the relationship between the intergenerational transmission of SES and prenatal and perinatal factors. The chapter is organized as follows: Section 2.2 reviews the literature examining the effects of parental SES on pregnancy- and birth-related outcomes. It also discusses potential mechanisms which could explain how maternal SES might influence the prenatal environment and maternal perinatal outcomes. Section 2.3 covers studies that explore whether socioeconomic disadvantage later in life can be explained by pregnancy-related variables and birth outcomes. In Section 2.4, we describe the main idea of the research, which combines these two strands of literature to evaluate the importance of in-utero and birth-related factors in explaining patterns of intergenerational mobility. Section 2.5 summarizes the findings from the literature discussed in this chapter and provides a brief conclusion, highlighting implications for policymakers and prospects for future research. Table 2.1 at the end of the chapter provides a detailed summary of the articles discussed, organized by sections.

2.2 Parental socioeconomic status and prenatal and perinatal factors

Is low SES a relevant risk factor for an adverse prenatal and perinatal environment? And if so, what are the main mechanisms explaining this relationship? Even if we find evidence of a socioeconomic gradient, this does not mean that birth- or pregnancy-related factors explain intergenerational mobility. If these factors play a role in the intergenerational transmission of SES, there has to be evidence that parental SES influences pregnancy- and birth-related outcomes as well. Otherwise, measures to reduce the impact of SES on pregnancy- and birth-related outcomes are unlikely to affect the intergenerational transmission of SES.

Indeed, several studies point to the importance of economic conditions and SES as relevant predictors of birth- and pregnancy-related outcomes (Bushnik et al., 2017; Campbell et al., 2018; Case et al., 2002; Jardine et al., 2021; Manyeh et al., 2016; Morgen et al., 2008; Snelgrove & Murphy, 2015), with the clear majority of studies showing a negative association between poor SES and infant health at birth regardless of the country or birth outcome considered (Blumenshine et al., 2010). With this strong empirical pattern in mind, we focus on studies that attempt to decipher the causal component of these associations.[2]

Many approaches to estimate the impact of SES rely on variables related to parents'

[2] Another important question is whether the correlation between socioeconomic status and infant health persists over time. Recent research suggests that the socioeconomic gap between children with and without adverse birth outcomes persists and even widens over time in some countries, highlighting the importance of this issue (Craig et al., 2002; Gissler et al., 2009; Glinianaia et al., 2013; Rahman et al., 2019; Wilding et al., 2019).

educational status. A commonly used technique to isolate the causal effect of education on birth outcomes is to examine the impact of compulsory schooling laws on infant health using an instrumental variable estimation strategy (Arendt et al., 2021; Chevalier & O'Sullivan, 2007; Chou et al., 2010; Güneş, 2015; Lindeboom et al., 2009; Silles, 2015). For example, the reform of national compulsory schooling in Turkey in 1997 extended compulsory schooling from five to eight years, increasing the likelihood that mothers attended school for at least eight years of schooling. This, in turn, had a significant impact on their children's birth outcomes. Affected mothers had a lower risk of giving birth to a child with VLBW (Güneş, 2015). Consistent with this, Chou et al. (2010) use data from Taiwan to demonstrate that a reform that increased the number of years of compulsory schooling had a positive effect on the health at birth of children from affected parents. The increase in maternal schooling caused by the reform reduced the proportion of VLBW children, neonatal mortality, postnatal mortality, and infant mortality.

In contrast to these results, studies based on compulsory schooling reforms in European countries find little or no effect on infant health. Chevalier and O'Sullivan (2007) show that the 1944 Education Act in the UK did not substantially improve birth outcomes for children of affected mothers. The risk of low birth weight was not altered by the reform. However, they find a significant effect when birth weight is considered as a continuous variable.[3] Arendt et al. (2021) confirm this finding using Danish data. To summarize, the evidence shows that the results of the above studies need to be contextualized because of differences between countries. It should also be noted that the effects identified are so-called local average treatment effects and, as such, only apply to the part of the population that is actually affected by the reform (mothers with low levels of education) and cannot easily be generalized to the population as a whole.[4]

Another indicator of inferior socioeconomic status is parental unemployment. Surprisingly, the existing literature suggests no consistent positive association between unemployment and adverse offspring outcomes. Dehejia and Lleras-Muney (2004) analyze regional unemployment rates in the US and present evidence that higher regional unemployment rates were associated with lower rates of infant mortality and (V)LBW births. This positive association between regional unemployment and birth outcomes was also found in Sweden (van den Berg et al., 2020).

In contrast, recent articles examining the impact of the 2007-2009 financial crisis suggest an impairment on birth outcomes for women who were pregnant during this period

[3] Lindeboom et al. (2009) study the same reform in the UK and also find no effect of education on birth outcomes.

[4] Another strand of literature focuses on the natural variation in schooling due to regulations for age at school entry and minimum school leaving age. Overall, no consistent and/or only small effects of maternal education on low birth weight, preterm birth, or infant death are found (McCrary & Royer, 2011). If present, these do not appear to operate through changes in years of schooling but through changes in maternal age at birth (Fredriksson et al., 2021).

(Margerison-Zilko et al., 2017; Noelke et al., 2019). Studies based on individual rather than regional data also have mixed results. While some authors show that parental unemployment is associated with adverse birth outcomes (Lindo, 2011; Scharber, 2014), Mörk et al. (2020) find no evidence of this relationship.

In addition, measures related to parents' financial situation (income or wealth) can be used as indicators of socioeconomic status (Apouey & Geoffard, 2013). In several countries, conditional cash transfers are provided to pregnant women to improve the use of prenatal and perinatal care services and to prevent adverse birth outcomes and their consequences as much as possible. Most of the literature confirms that these programs were successful in improving health outcomes for the children of mothers who received such transfers (Barber & Gertler, 2008; Duflo, 2000; Gertler, 2004; Glassman et al., 2013; Hunter et al., 2017; Lucas et al., 2022; Ramos et al., 2021; Rawlings, 2005).

One approach to explain the socioeconomic gradient in health status at birth is based on the idea that education helps to minimize the consequences of adverse parental conditions and promotes a favorable environment for the infant during pregnancy and early childhood. In particular, maternal health behaviors (smoking, alcohol abuse) (Beard et al., 2009; Cnattingius, 2004; Räisänen et al., 2013; van den Berg et al., 2013), access to or lack of access to and use of prenatal care services, and maternal malnutrition are identified as important health-related variables (Almond & Mazumder, 2011; Kader & Perera, 2014; Lane et al., 2013). In addition, maternal stress and domestic violence during pregnancy (Aizer, 2011; Caprara et al., 2020; Ferdos & Rahman, 2017; Persson & Rossin-Slater, 2018), as well as pollution and environmental factors (Bergstra et al., 2021; Currie et al., 2013; do Nascimento et al., 2022; Flynn & Marcus, 2021), are highlighted as important mechanisms influencing the association between parental social status and infant health.

2.3 Prenatal and perinatal influences on the later life outcomes of the child

The research discussed in this section is based on the idea that developmental processes are initiated during pregnancy (Almond & Mazumder, 2011; Currie & Hyson, 1999; Hartman & Belsky, 2018; Pluess & Belsky, 2011). Consequently, in-utero shocks increase the risk of complications during pregnancy and adverse birth outcomes, which then have lasting consequences throughout the life cycle. Several meta-studies, as well as early descriptive evidence, have failed to reject this hypothesis, as poor infant health is a strong predictor of future SES (Bilgin et al., 2018; Moster et al., 2008; Twilhaar et al., 2018; Wolke et al., 2019).

It is conceivable that unobserved individual and parental characteristics correlate with both infant health and SES later in life. Although descriptive analyses are relevant for quantifying the overall association, the estimates obtained cannot be interpreted causally because they also capture the potential effect of any relevant factors not directly included in the models. Identification strategies to remove potential bias due to unobserved characteristics could be based on the comparison of siblings and/or twins (Almond et al., 2005; Black et al., 2007; Fletcher, 2011). Black et al. (2007) use data from Norway and compare OLS models with estimates based on variation between twins. In the twin model, a 10 percent increase in birth weight significantly increased the probability of high school graduation by one percentage point, and the effect persisted as it increased full-time earnings by about 1 percent. Fletcher (2011) suggests that low birth weight leads to a lower SES in the short term (e.g., learning disabilities, grade repetition), but that these negative effects do not persist in the long term (high school graduation, years of schooling), which is contrary to the findings of Black et al. (2007).

Other articles attempt to isolate the causal effect of infant and prenatal health on later SES by relying on exogenous events such as pandemics (Almond, 2006; Schwandt, 2017), famines (Scholte et al., 2015), or armed conflicts (Lee, 2014) that create an adverse environment for affected infants in the womb. These are of particular interest in the context of the COVID-19 pandemic and increasing armed conflicts worldwide. The articles reviewed generally find that infants exposed to adverse conditions in the womb had poorer SES outcomes in adulthood.

Various measures of infant health are based on sharp thresholds depending on gestational age (PT) or birth weight (LBW) (Saigal & Doyle, 2008). However, it is difficult to argue that newborns with a birth weight of 1501g are significantly healthier than those with a birth weight of 1499g. Nevertheless, a birth weight below the cut-off of 1500g is strongly associated with more intensive medical care. Therefore, it is possible to use this discontinuity in medical care to identify the causal effect of health interventions in (very) early childhood on SES in adulthood, provided that individuals around the cut-off do not differ extremely in terms of the unobserved variables that lead to this adverse birth outcome. Using a regression discontinuity design, Bharadwaj et al. (2013) show that individuals classified as VLBW achieved about 0.2 standard deviations better test scores and grades. Chyn et al. (2021) confirm these results on school achievement. In addition, they estimate that early interventions for LBW children saved social security spending of around 67,000 dollars by the age of 14.

Other articles use a Difference-in-Differences approach, estimating the effects of increased availability of health services for the child shortly after birth. Bütikofer et al. (2019) explicitly address the long-term effects of the opening and rollout of health care centres in Norway. Consistent with the evidence presented earlier, better access to these centres improved the educational attainment and increased the earnings of treated individuals later in life.

Over the past decade, an increasing number of data sources have included information on the gene pool of individuals. Recent studies used these gene-related variables to identify the effects of birth weight (Cook & Fletcher, 2015; Pehkonen et al., 2021). These studies argue that some parts of the gene pool may lead to a higher birth weight or be associated with a lower birth weight. Pehkonen et al. (2021) use Finnish data with genetic information and estimate that a one percent increase in birth weight leads to a one percent increase in income when males are considered. Interestingly, there was no effect of birth weight on income when only females were taken into account. Maruyama and Heinesen (2020) instead use a diagnosis of placenta praevia of the mother during pregnancy.[5] This diagnosis results in a shorter gestation period, may also require a cesarean section, and therefore may be associated with a reduction in birth weight. Using this information, the authors find no evidence of an effect on school grades or labor market outcomes.

From a policymaker's perspective, it is important to ask whether the effects of prenatal and perinatal health on later SES are permanent or whether they diminish over the life course (Basten et al., 2015; Johnson & Schoeni, 2011; Matsushima et al., 2018; Nakamuro et al., 2013; Odd et al., 2019). If, given the context and the state of development of existing institutions, the impact is diminishing, there is less reason to make (financial) efforts to improve this issue. Johnson and Schoeni (2011) estimate the association between low birth weight, education, and later life earnings. They show that the higher incidence of high school dropout and poor health among LBW adolescents did not disappear in adulthood. The earnings of LBW children were still significantly lower in adulthood compared to those born with an adequate birth weight. Basten et al. (2015) show that individuals born prematurely had lower wealth at age 42, which was mediated by lower mathematical skills in childhood. However, other authors find no persistent effect of measures related to birth weight and gestational age on long-term SES. Two studies from Japan suggest that individuals with low birth weight have no long-term disadvantages, even if they have slightly worse SES outcomes in childhood (Matsushima et al., 2018; Nakamuro et al., 2013). Moreover, evidence from the British ALSPAC data indicates that preterm-born individuals were able to compensate for most of the initial disadvantage even during their school career (Odd et al., 2019).

Some of the articles reviewed suggest that the effects are not long-lasting and, in particular, that they are absent or weak when individuals participate in the labor market. This does not necessarily mean that adverse birth outcomes do not have long-lasting effects, but could also be a consequence of the successful prevention of negative long-term effects through existing institutional arrangements.

[5] The fetus of pregnant women with the diagnosis of placenta praevia is not located in the upper part of the uterus, which is usually the case. This increases the risk of preterm birth and low birth weight (Adere et al., 2020; Kollmann et al., 2016).

2.4 Implications for intergenerational transmission

Most of the evidence presented so far emphasizes the importance of parental SES for prenatal and perinatal outcomes (section 2.2) and the effects of birth- and pregnancy-related variables on the future SES of the infant (Section 2.3). The combined findings suggest that prenatal and perinatal factors are important in shaping the process of intergenerational transmission of socioeconomic status (Aizer & Currie, 2014; Case & Paxson, 2006; Currie, 2009; Currie & Moretti, 2007).

Traditionally, there has been an ongoing scholarly debate about factors that possibly shape the intergenerational transmission of socioeconomic status: predetermined endowments (from the perspective of the child) on the one hand or individual investments on the other (Solon, 2009). Literature that attempts to separate intergenerational transmission into endowment effects and investment effects is often based on data from adopted children (Björklund et al., 2006; Halpern-Manners et al., 2020; Lundborg et al., 2018; Scheeren et al., 2017; Silles, 2017). The idea is simple: if parents who adopt a child do so shortly after birth, any investment effects could be attributed to their influence (including their social status), while the influence of biological parents is attributed to endowments. However, endowments are not only associated with genes but also capture the broader aggregate influence of biological parents before birth. The cumulative influence of biological parents before birth is interpreted as an endowment effect (for the child). Arguably, pregnancy plays a key role in this transmission because various endowments are passed to the next generation in this time span.

Using the technique described, Lundborg et al. (2018) estimate that each additional year of maternal education leads to 0.28 additional years of education for biological children. The effect is almost identical when paternal education is considered as the variable of interest. In the subsample of adopted children, the estimates were not that large. An additional year of maternal education was associated with an increase of 0.05 years of schooling for the child. The effect of paternal education was even smaller. The difference between the two results suggests that endowment-related aspects of biological parents are highly relevant for understanding patterns of intergenerational mobility. Scheeren et al. (2017) examine data from the Netherlands and confirm these results. They found only a small effect of parental education on the educational outcomes of adopted children, while the effect for biological children was generally large.

Björklund et al. (2006) analyzed a very unique dataset on adopted children from Sweden that included information on the educational status of a child's biological and adoptive parents. This allowed them to simultaneously identify and compare the relative effects of biological and adoptive parents within the same dataset. In general, all types of parental education mattered for the child, regardless of whether the parents were adoptive or biological. In addition, they decompose the aggregate pre-birth effect of biological parents on their children into pre-pregnancy and prenatal influences. This is based on the assumption that biological mothers influence their children up to the time of birth if they put their children up for adoption shortly thereafter, while fathers only matter up to the time of pregnancy, which is a strong assumption. Cardak et al. (2013) use a technique based on endowment and employment shocks to estimate the relative importance of endowment and investment effects. They show that two-thirds of the total intergenerational earnings elasticity was related to endowment effects, with the endowment effect being much larger than the investment effect when fathers´ earnings were at the lower end of the earnings distribution.

In addition to these articles using adoption data, there are other approaches to identify the importance of infant health in the intergenerational transmission process. Settele and van Ewijk (2018) show that a higher taxation of tobacco increased intergenerational mobility. Smoking was more common among low-SES parents and was associated with lower educational attainment for their children. In contrast to previous findings, Conley and Bennett (2000) found no effect of parental education on birth weight, even though birth weight was strongly related to individual educational attainment.[6]

Very few articles directly estimate the effects of prenatal and perinatal variables on measures of intergenerational mobility. An important exception is Heinonen et al. (2013), who use data from the Helsinki Birth Cohort Study from 1934-1944 to estimate the effects of preterm birth on measures of intergenerational mobility and conclude that individuals born prematurely have lower upward mobility but higher downward mobility. The result was independent of the measure of socioeconomic status used (occupation and income). O'Brien et al. (2018) show that high air pollution during pregnancy was associated with a lower later socioeconomic status of the infant if the child's parents themselves had a low socioeconomic status. Robertson and O'Brien (2018) analyze income rank-rank correlations and find that a 1 percentage point increase in regional rates of LBW could be associated with a 0.1 percentage point decrease in the intergenerational income correlation in those regions.

2.5 Discussion

Most of the evidence presented points to the importance of parental socioeconomic status on the prenatal environment (e.g., access to prenatal care) and perinatal outcomes (e.g., low birth weight). These adverse birth outcomes, if not addressed adequately, could translate into long-term socioeconomic disadvantage. Literature directly addressing mobility measures is scarce, but generally confirms that there are (small) effects on intergenera-

[6] Black et al. (2020) analyze the intergenerational transmission of wealth and conclude that biological factors play only a minor role.

tional mobility.

As noted by Wolke et al. (2019), much of the existing evidence comes from relatively high developed countries. We know little about the relationship between infant health and intergenerational mobility in social status in developing countries. However, less developed countries are relevant not only because of their comparatively high rates of adverse birth outcomes but also because their fertility rates are generally much higher than in more developed countries. Therefore, a large proportion of children who were exposed to an unfavorable prenatal environment and/or had unfavorable birth outcomes grow up in less developed countries. Furthermore, the impact of health status at birth on the process of intergenerational transmission is likely to be more pronounced in less developed countries, where the implications of these outcomes for social status in early life have not already been mitigated by existing institutions. Finally, if we do not find effects of birth- and pregnancy-related variables on the intergenerational transmission of social status, this does not mean that there are no effects. It could also imply that institutions are already sufficiently developed to address these issues accurately. Hence, a better understanding of the impact of perinatal and prenatal influences on the intergenerational transmission of socioeconomic status in less developed countries is crucial.

Table 2.1: Selected articles

Authors / Year	Country / Data	Research Question	Dependent Variables	Result
Section 2.2: Parental socioeconomic status (SES) and prenatal and perinatal factors				
Case et al. (2002)	USA National Health Interview Survey, Child Development and Nutrition Examination Survey.	Studies the association between family income and child health.	Health status at ages 0-3	Higher income increased the probability of very good or good health for the child.
Morgen et al. (2008)	Denmark Danish National Birth Cohort.	Studies the relationship between parental SES and PT.	PT	Low maternal education was significantly related to PT.
Snelgrove and Murphy (2015)	UK Millennium Cohort Study.	Studies the relation between parental SES and PT.	PT	Maternal unemployment and poor social support increased the risk of PT.
Manyeh et al. (2016)	Ghana Dodowa Health and Demographic Surveillance System.	What are the determinants of LBW?	LBW	Even mothers in poor households showed higher odds of a birth without LBW compared to the poorest mothers.
Jardine et al. (2021)	UK National Maternity and Perinatal Audit.	Attempts to quantify the relevance of SES as a risk factor for PT.	PT	Inequalities in SES were related to the incidence of PT.
Blumenshine et al. (2010)	Multiple countries Online databases for articles.	Systematic review of literature on the relationship between SES and adverse birth outcomes.	Adverse birth outcomes	Nearly all considered studies indicated that socioeconomic disadvantage is related to adverse birth outcomes.
Chevalier and O'Sullivan (2007)	UK National Child Development Study.	Studies the relationship between education and birth weight using the 1947 compulsory schooling reform as an instrumental variable.	Birth weight	Maternal education increased the birth weight of newborn children.
Lindeboom et al. (2009)	UK National Child Development Study.	Studies the relationship between education and birth weight using the 1947 compulsory schooling reform as an instrumental variable.	Birth outcomes	No significant effect of parental education on various adverse birth outcomes of newborn children.
Chou et al. (2010)	Taiwan Aggregated register data.	Studies the relationship between education and birth weight using the 1968 compulsory schooling reform as an instrumental variable.	LBW, neonatal deaths	Higher parental education reduced the incidence of LBW children and neonatal deaths.

Table 2.1: Selected articles (cont.)

Authors / Year	Country / Data	Research Question	Dependent Variables	Result
Güneş (2015)	Turkey Turkish Demographic and Health Survey.	Studies the relationship between education and birth weight using the 1997 compulsory schooling reform as an instrumental variable.	SGA *z*-score, VLBW	Higher parental education reduced the incidence of VLBW children and increased SGA *z*-scores.
Silles (2015)	UK Continuous Household Survey and General Household Survey.	Studies the impact of parental education on the long-term health outcomes of the child using various compulsory schooling reforms as an instrumental variable.	Long-term health status of the child	No robust effect of parental education on the long-term health status of the child.
Arendt et al. (2021)	Denmark Register data.	Studies the relationship between education and birth weight using the 1972 compulsory schooling reform as an instrumental variable.	Birth weight, LBW	No impact of parental education on (low) birth weight.
Dehejia and Lleras-Muney (2004)	USA Bureau of Labor Statistics for unemployment data, Vital Statistics Natality Records.	What is the relationship between regional unemployment rates and birth outcomes?	Regional rate of (V)LBW and neonatal morality	Higher regional unemployment rates were linked to reductions in regional rates of adverse birth outcomes.
van den Berg et al. (2020)	Sweden Register data.	Studies the relationship between parental unemployment and adverse birth outcomes.	VLBW, neonatal mortality	Local unemployment rates were associated with a reduced risk of VLBW and neonatal morality.
Margerison-Zilko et al. (2017)	USA National Center for Health Statistics, data from the Bureau of Labor Statistics.	Studies the relation between state-level unemployment rates in pregnancy and PT/LBW during the times of the 2007-2009 recession.	PT, LBW	The recession amplified the positive relationship between unemployment and adverse birth outcomes.
Noelke et al. (2019)	USA National Center for Health Statistics, data from the Bureau of Labor Statistics.	Studies the relationship between unemployment and PT.	PT	The magnitude of the relationship between unemployment in pregnancy and PT doubled during the recession.
Lindo (2011)	USA Panel Study of Income Dynamics.	Studies the relationship between individual job displacement and birth weight of the next generation.	Birth weight	Job displacement among husbands was linked to reductions in birth weight.
Scharber (2014)	USA Texas vital records.	Studies the relationship between self-reported unemployment and birth outcomes.	Birth weight, infant mortality	Unemployment was associated with reductions in birth weight and higher infant mortality.

Table 2.1: Selected articles (cont.)

Authors / Year	Country / Data	Research Question	Dependent Variables	Result
Mörk et al. (2020)	Sweden Population-wide administrative data.	Studies the consequences of parental job loss for the health of the next generation based on a matching approach.	Prenatal mortality, hospitalisation	No effect of parental job loss on child health.
Apouey and Geoffard (2013)	UK Families and Children Study.	Studies the effect of parental income on the general health of children at different stages of life.	General health at ages 0-1	No relation between average income and child health at ages 0-1. The income gradient emerged when the child was 2 years old.
Duflo (2000)	South Africa National Survey of South Africa.	Presents evidence on the impact of the expansion of the 1991 Old Age Pension program in South Africa on birth outcomes.	Height, Height-for-Age Z-scores	Newborn females affected by the program had improved birth outcomes. No effect on newborn males.
Gertler (2004)	Mexico Survey data from a randomized control trial Government of Mexico.	Evaluates the impact of the PROGRESA anti-poverty program on child outcomes.	Height, anemia, stunded	Positive impact of the program on child outcomes.
Barber and Gertler (2008)	Mexico Survey data from a randomized control trial in Mexican communities.	Evaluates the impact of the conditional cash transfer program Oportunidades on birth weight.	Birth weight, LBW	Exposure to the program increased birth weight and reduced the risk of LBW of newborn children.
Ramos et al. (2021)	Brazil 100 Million Brazilian Cohort.	Evaluates the impact of the Bolsa Família Program on childhood mortality.	Child mortality	Program exposure reduced child mortality. Larger coefficients for PT-born children.
Lucas et al. (2022)	Brazil 100 Million Brazilian Cohort.	Studies the long-term associations between maternal exposure to the Bolsa Família program and birth outcomes.	(V)LBW, (V)PT	Program exposure reduced the risk of adverse birth outcomes.
Section 2.3: Prenatal and perinatal influences on later life outcomes of the child				
Currie and Hyson (1999)	UK British National Child Development Survey.	Studies the relationship between LBW and SES over the life course.	O-levels passed, income at ages 23 and 33	Negative association between LBW and education as well as income later in life.
Moster et al. (2008)	Norway Register data.	Studies the socioeconomic consequences of PT.	Higher education, income, receipt of social security benefits	PT-born individuals had inferior educational outcomes, a lower income, and were more likely to receive social security benefits.

Table 2.1: Selected articles (cont.)

Authors / Year	**Country / Data**	**Research Question**	**Dependent Variables**	**Result**
Twilhaar et al. (2018)	Multiple countries Articles listed in PubMed, Web of Science, and PsycINFO.	Studies the academic performance of PT-born children.	Test scores	PT children achieved lower test scores in the considered studies.
Bilgin et al. (2018)	Multiple countries Articles listed in Medline, PubMed, PsycINFO, Web of Science and Embase.	Studies literature on the relationship between adverse birth outcomes and SES in adulthood.	Education, unemployment, receipt of social security	Adverse birth outcomes were related to lower odds of higher education and employment and higher odds of receiving social security benefits.
Almond et al. (2005)	USA Data from the Healthcare Cost and Utilization Project and National Center of Health Statistics.	Studies hospital costs associated with reduced birth weight.	Hospital costs	Reduced birth weight, especially VLBW, was related to excess hospital costs.
Black et al. (2007)	Norway Medical Birth Registry of Norway.	Studies the short- and long-term consequences of low birth weight.	High school completion, earnings, IQ	Higher birth weight corresponded to higher IQ scores, higher odds of high school completion, and higher earnings.
Fletcher (2011)	USA Add Health data.	Studies the relation between LBW and medium- and long-term educational outcomes.	Grade repetition, years of education	LBW was related to higher odds of grade repetition. No effect of LBW on years of education.
Almond (2006)	USA Census data.	Studies the consequences of the 1919 pandemic on the socioeconomic outcomes of individuals born in the pandemic.	High school graduation, income	The 1919 birth cohort was less likely to have a high school degree and earned less.
Schwandt (2017)	Denmark Birth records from Danish Medical Birth Register linked to Income, Population and National Patient Register.	Studies the consequences of seasonal influenza on the socioeconomic outcomes of individuals born in these seasons.	Income, receiving welfare benefits, being unemployed	Seasonal influenza during pregnancy was associated with lower earnings and higher odds of receiving welfare benefits.
Scholte et al. (2015)	Netherlands Municipal Personal Records Database from Statistics Netherlands.	Studies the impact of prenatal exposure to the Dutch famine in 1944-1945 on labor market outcomes.	Employment, income	Exposure to the famine in the first trimester of pregnancy reduced the odds of employment in later life. No effect on income.

Table 2.1: Selected articles (cont.)

Authors / Year	**Country / Data**	**Research Question**	**Dependent Variables**	**Result**
Lee (2014)	Korea 2% micro sample of the population census and data from Vital Statistics.	Studies the consequences of prenatal exposure to the Korean War in the 1950s on various measures of SES later in life.	Years of schooling, unemployment	Pregnancy in a region of conflict was associated with lower years of schooling and higher odds of unemployment for the child.
Bharadwaj et al. (2013)	Chile, Norway Administrative register data.	Studies the impact of prioritized early life medical care on education using a regression discontinuity design.	Grade point average, National exam scores	Being born below the threshold of 1,500g was associated with higher GPAs in Chile and better test scores in the Norwegian national exams.
Chyn et al. (2021)	USA Administrative data from Rhode Island.	Studies the impact of prioritised early life medical care on education using a regression discontinuity design.	Average test scores, collage enrolment, social program expenditures	Being born below the below the threshold of 1,500g was associated with higher test scores, higher odds of college enrolment and lower social program expenditures.
Bütikofer et al. (2019)	Norway Register data.	Studies the impact of the opening of health care centers on the long-term outcomes of individuals.	Years of education, earnings	Individuals with access to health care centers had more years of education and earned more.
Cook and Fletcher (2015)	USA Wisconsin Longitudinal Study.	Studies the long-term consequences of lower birth weight.	IQ in high school	Lower birth weight was associated with lower IQ scores.
Pehkonen et al. (2021)	Finland Survey data from the Young Finns Study linked to administrative data from Statistics Finland.	Studies the effect of birth weight on income later in life using polygenic scores as an instrumental variable.	Income	Given the sample of male individuals, higher birth weight leads to higher income later in life.
Maruyama and Heinesen (2020)	Denmark Administrative birth records.	Studies the effect of birth weight on education and income using the diagnosis of placenta praevia as an instrumental variable.	Income, average test scores	No significant effect of birth weight on test scores or income.
Johnson and Schoeni (2011)	USA Panel Study of Income Dynamics.	Studies the impact of poor health at birth on later educational attainment and labor market outcomes.	Earnings, school dropout	LBW was associated with lower earnings and higher odds of school dropout.
Nakamuro et al. (2013)	Japan Online survey data.	Studies the association between LBW and socioeconomic outcomes at age 15 and in subsequent years.	Student performance at age 15, years of schooling, earnings	Small effects of birth weight on student performance at age 15, but these were not lasting.

Table 2.1: Selected articles (cont.)

Authors / Year	Country / Data	Research Question	Dependent Variables	Result
Basten et al. (2015)	UK National Child Development Study.	Studies the direct and indirect effects of PT on SES later in life.	Wealth at age 42, education in childhood	PT was associated with lower math and reading scores in childhood and reduced wealth in adulthood.
Matsushima et al. (2018)	Japan Japanese Study of Age and Retirement.	Studies the relationship between LBW and SES over the life course.	Early life school performance, educational attainment, employment status at age 54	Individuals with LBW reported lower school performance. No association between LBW and educational attainment or employment status.
Odd et al. (2019)	Avon Longitudinal Study of Parents and Children.	Studies the implications of PT for educational trajectories.	Key stage scores	PT-born individuals scored lower in their key stages, which was driven by lower scores in the first years of schooling.
Section 2.4: Implications for intergenerational transmission				
Currie and Moretti (2007)	USA Individual birth records from California.	Studies implications of the intergenerational transmission of birth weight for the perpetuation of economic status.	Income, years of schooling	LBW in poorer regions was associated with lower income and lower years of education. In richer areas, the marginal effect was smaller.
Björklund et al. (2006)	Sweden Administrative register data.	Studies the intergenerational transmission of education and income from biological and adoptive parents.	Years of schooling	Shows that biological and adoptive parents were both relevant for the intergenerational transmission of social status.
Scheeren et al. (2017)	Netherlands Register data.	Studies the relevance of parental education for the educational success of biological and adopted children.	Educational attainment of the child	Only biological parents had a significant impact on the educational attainment of the child.
Silles (2017)	USA American Community Survey.	Studies the relevance of parental education for grade retention of adopted and biological children.	Grade retention	The education of biological parents was associated with lower odds of grade retention for biological children. For adopted children, the coefficients were smaller and not all significant.
Lundborg et al. (2018)	Sweden Linked Register data.	Compares the intergenerational transmission of education between adopted and biological children.	Years of schooling	Parental years of education increased the years of schooling of biological children. The coefficients for adoptive children were smaller.

Table 2.1: Selected articles (cont.)

Authors / Year	**Country / Data**	**Research Question**	**Dependent Variables**	**Result**
Halpern-Manners et al. (2020)	USA Early Growth and Development Study.	Studies the relevance of biological and adoptive parental education for the educational attainment of their children.	Letter-word identification, word attack, math fluency	Years of schooling of biological parents increased the letter-word identification and word attack scores and math fluency scores of children. Adoptive parents also matter.
Cardak et al. (2013)	USA Panel Study of Income Dynamics.	Studies the relative importance of endowment and investment effects for the intergenerational persistence of earnings.	Intergenerational earnings mobility	1/3 of the intergenerational persistence was explained by investments, and 2/3 by endowments.
Conley and Bennett (2000)	USA Panel Study of Income Dynamics.	Studies the association between parental income and LBW as well as LBW and later life income of individuals.	Parental income, LBW	Parental income during pregnancy was not related to LBW of the child. LBW reduced the chances of graduating from high school.
Heinonen et al. (2013)	Finland Helsinki Birth Cohort Study.	Studies associations between LBW of the child and the intergenerational mobility of SES.	Parental SES, late PT	Individuals born PT showed lower upward mobility and a higher degree of downward mobility.
Robertson and O'Brien (2018)	USA Regional data from the Equality of Opportunity Project combined with data from Vital Statistics.	Studies the association between regional rates of LBW and intergenerational income mobility.	Intergenerational income correlation	Increased regional rates of LBW were associated with higher intergenerational income persistence.

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3 Maternal mental health and adverse birth outcomes

Authors' contributions

The following chapter is based on an article, which is joint work with Daniel Schnitzlein, Sakari Lemola, Eero Kajantie, Katri Räikkönen, and Dieter Wolke and is published as Voit, F. A. C., Kajantie, E., Lemola, S., Räikkönen, K., Wolke, D., & Schnitzlein, D. D. (2022). Maternal mental health and adverse birth outcomes. *PLoS ONE*, *17*(8), e0272210. The authors' contributions toward the article are as follows:

- Statistical analysis: Methods and computing - Falk Voit, Daniel Schnitzlein
- Literature research - Falk Voit
- Writing first draft - Falk Voit
- Revision - Falk Voit, Eero Kajantie, Sakari Lemola, Katri Räikkönen, Dieter Wolke, Daniel Schnitzlein
- Supervision - Falk Voit, Daniel Schnitzlein

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Abstract

Recent research in economics emphasizes the role of in-utero conditions for the health endowment at birth and in early childhood and for social as well as economic outcomes in later life. This chapter analyzes the relationship between maternal mental health during pregnancy and the birth outcomes of the child. In particular, we analyze the relationship between maternal mental health during pregnancy and the probability of giving birth preterm (PT), having a newborn at low birth weight (LBW), or being small for gestational age (SGA). Based on large population-representative data from the German Socio-Economic Panel (SOEP) and cohort data from the National Educational Panel Study (NEPS), we present extensive descriptive evidence on the relationship between maternal mental health and preterm birth by carrying out OLS estimates controlling for a wide range of socioeconomic characteristics. In addition, we apply matching estimators and mother fixed effects

models, which bring us closer toward a causal interpretation of estimates. In summary, the results uniformly provide evidence that poor maternal mental health is a risk factor for preterm birth and low birth weight in offspring. In contrast, we find no evidence for a relationship between maternal mental health and small for gestational age at birth.

3.1 Introduction

Every year, approximately 15 million children are born preterm (PT) (<37 weeks gestation), and 20 million have low birth weight (LBW) (<2,500 g) (Blencowe et al., 2019; Chawanpaiboon et al., 2019). Being born PT or with LBW has lasting effects over the life cycle. Previous research has shown that these adverse birth outcomes are associated with lower education, fewer employment chances, health issues, lower socioeconomic status, and decreased economic prosperity (Bilgin et al., 2018; Heinonen et al., 2013; Jaekel et al., 2014). Psychologists argue that the last trimester of pregnancy is central to brain development, as substantial parts of the cerebral cortex are still developing in that period (Garcia et al., 2018). Altered brain development in preterm children involves alterations in brain volume, cortical folding, and impaired functional networks (Hedderich et al., 2021).

The WHO aims to reduce the incidence of low birth weight by 30% by 2025 (WHO, 2014). As PT birth is highly correlated with LBW, the World Health Organization states: *"An increased awareness of the long-term consequences of preterm birth (at all gestational ages) is required to fashion policies to support these survivors and their families as part of a more generalized improvement in quality of care for those with disabilities in any given country"* (WHO, 2012, p. 30). These long-term consequences lead to substantial direct and indirect costs. A study that investigates German data shows that early PT birth is associated with more than 72,000 € of additional health care spending per child in the first year after birth (Jacob et al., 2017), and a systematic review of articles indicates that the association between preterm birth and increased costs is prevalent in various other developed countries (Petrou et al., 2019).

Due to the challenges following preterm birth, increased efforts have been made to identify risks as well as protective and/or resilience factors for prematurity (Almond et al., 2018). Identifying and tackling these risk factors is central to suitably prevent or lower the incidence of preterm birth. Risk factors for having a PT-born baby include smoking during pregnancy, teenage pregnancy, an interval of fewer than 12 months after a prior birth, birth of twins/multiples, previous PT birth, maternal health, and fertility problems (DGGG, OEGGG, SGGG, 2019). Beyond that, the economic literature has analyzed the impact of diseases such as flu (Lin & Liu, 2014), malnutrition (Almond & Mazumder, 2011), pollution (Currie et al., 2013; Isen et al., 2017), and socioeconomic disadvantages (Lindo, 2011) as potential risk factors for infants' birth outcomes. In addition, it is controversially discussed whether economic crisis and unemployment are associated with increased rates of children with adverse birth outcomes (de Cao et al., 2022; Dehejia & Lleras-Muney, 2004; Taylor-Robinson et al., 2019). Moreover, intense physical exercise and maternal anxiety are further risk factors for having a PT-born baby (Della Rosa et al., 2021).

Maternal mental health during pregnancy might be a further relevant factor to explain adverse birth outcomes. The WHO pointed to poor maternal mental health as a possible risk factor for PT birth and suggested actions to improve the diagnosis and maintenance of maternal mental health problems during pregnancy by member states (WHO, 2012). In addition to PT birth and LBW, small for gestational age (SGA) birth is another frequently used indicator of the infant´s health endowment at birth (Eves et al., 2020; Osypuk et al., 2016). Accordingly, this article investigates whether poor maternal mental health during pregnancy is associated with a higher risk of LBW, PT, and SGA birth.

Previous research in health economics has mainly focused on maternal stress during pregnancy rather than analyzing the mental health of mothers. Since maternal stress during pregnancy is both difficult to measure in a valid way and arguably correlated with various unobserved characteristics, early research was rather descriptive (Dole et al., 2003; Rini et al., 1999). More recent contributions have used exogenous variation in stress levels to tackle selection problems. Torche (2011) studies the effects of stress on birth outcomes, which were exogenously induced by the 2005 Tarapaca earthquake. She reports that earthquake-induced stress significantly increased the incidence of low birth weight and reduced the average gestational age. Following a comparable approach, Currie and Rossin-Slater (2013) analyze US data on hurricane exposure during pregnancy. Using the geographical variation of hurricanes as a natural experiment for stress, the authors find descriptive evidence for increased abnormal conditions after birth (e.g., being on a ventilator for more than 30 minutes or meconium aspiration syndrome). However, the effects seem to diminish once causal models are applied.

One limitation of these articles is that they lack an objective stress measure and indirectly associate all the variation from these events with higher stress levels or rely on self-reported stress levels. In contrast, Aizer et al. (2016) use cortisol levels as a measure of stress. Applying sibling fixed effects, they show that maternal stress during pregnancy leads to lower-level educational outcomes for the offspring. Persson and Rossin-Slater (2018) study a large US dataset, which includes cortisol levels of mothers during pregnancy. They use the passing of a family member of the mother as an instrumental variable for stress (changes in cortisol levels) and find significant effects on preterm birth and low birth weight in the offspring.

Maternal mental health effects on infant health are still under debate. Whereas some authors report adverse effects of poor maternal mental health on birth outcomes (Hayes et al., 2012; Pesonen et al., 2016; Staneva et al., 2015), others do not (Andersson et al., 2004;

Benute et al., 2010). In an extensive review of psychological literature, only a quarter of all considered papers identify an adverse impact of maternal mental health problems on infant health at birth (Accortt et al., 2015). In addition, it remains unknown whether associations between maternal mental health and infant birth outcomes represent a causal relationship or are driven by reversed causality, omitted variables, or selection problems.

We contribute to this literature by investigating the effect of maternal mental health during pregnancy on the risk of PT, LBW, and SGA birth, controlling for a wide variety of socioeconomic, demographic, and health-related characteristics of both the mother and the child. This potential effect of maternal mental health during pregnancy could be seen as one aspect of the prenatal programming of postnatal plasticity (Pluess & Belsky, 2011) and the fetal origins hypothesis (Almond & Currie, 2011). Both hypotheses entail that maternal and family characteristics determine the child´s development, even if it is not yet born (Black et al., 2016; Currie, 2011; Currie et al., 2022).

Beyond that, we estimate matching and fixed effects models to account for potential endogeneity problems. We also evaluate the internal validity of our results by performing a specification curve analysis and the external validity by analyzing two different datasets from Germany with comparable survey instruments.

Our results show that maternal mental health problems during pregnancy are indeed a substantial risk factor for adverse birth outcomes. This result also holds after the inclusion of a wide range of socioeconomic characteristics as well as physical health measures of the mother and is robust given different identification strategies or data sources.

3.2 Data and descriptive evidence

We use two German datasets to estimate the relevance of mental health problems during pregnancy for the incidence of PT birth: the Socio-Economic Panel (SOEP), a representative household study, and the National Educational Panel Study (NEPS), a cohort study. Both offer highly comparable questions in their mother-newborn surveys but different target populations, giving us the opportunity to test for the external validity of the results obtained from one of the two datasets.

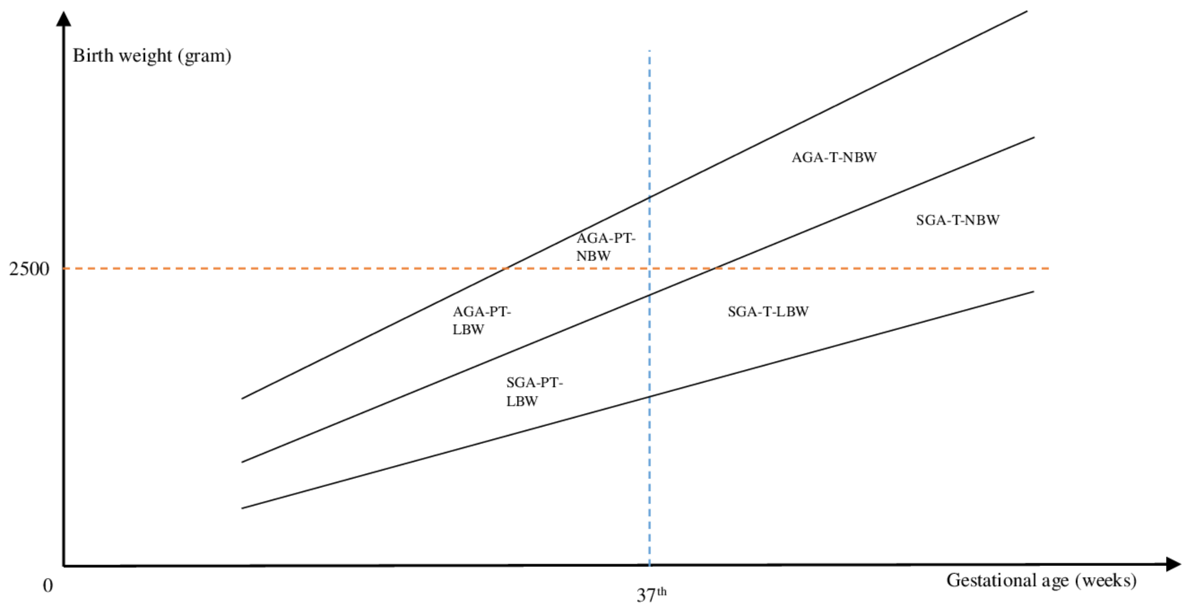
For our main analysis, we focus on the SOEP data. The NEPS is used to infer the external validity of the results. The first reason for using the SOEP as our data source for the main analysis is that the SOEP includes birth weight and gestational age as continuous variables. Hence, we could calculate SGA based on this information. With the NEPS data, this is not possible because birth weight and gestational age are assessed as categorical variables. Second, only the SOEP includes information on the mental health component score before birth, which is a very important and meaningful variable to balance in the matching procedure. Third and foremost, the SOEP is a panel dataset. It contains information from siblings, allowing us to estimate mother fixed effect models. The NEPS as a cohort dataset does not include any information on the birth outcomes of siblings of the individual included in the cohort.

The SOEP and the NEPS are two large, publicly funded German datasets intended for secondary analysis and widely used for scientific purposes. All participants were individually asked for their consent to participate in the study. In the case of minors, the consent was given by their legal representatives (usually their parents). All statements of consent are stored and archived by the German Institute for Economic Research (DIW) in Berlin for the SOEP data and by the Leibniz Institute for Educational Trajectories in Bamberg for the NEPS data and/or their respective field institutes. The SOEP data is accessible for researchers under permission. Permission is provided by the Scientific Advisory Board of DIW Berlin. In order to prevent harm to the respondents, the data may only be used for specific purposes (scientific research) and factually anonymized. Prior to any disclosure to new users, the institutional data protection officer verifies that the data are only shared for scientific use and are appropriately anonymized and/or protected. We can guarantee that on the participant side there is informed consent and voluntariness. The fact that participation is voluntary is explained to the participants each wave. The NEPS study is conducted under the supervision of the German Federal Commissioner for Data Protection and Freedom of Information (BfDI) and in coordination with the German Standing Conference of the Ministers of Education and Cultural Affairs (KMK) and – in the case of surveys at schools – the Educational Ministries of the respective Federal States. All data collection procedures, instruments and documents were approved by the data protection unit of the Leibniz Institute for Educational Trajectories (LIfBi). The necessary steps are taken to protect participants' confidentiality according to national and international regulations of data security. Participation in the NEPS study is voluntary and based on the informed consent of participants. This consent to participate in the NEPS study can be revoked at any time.

The SOEP is a representative household panel study that started in 1984 and has involved yearly assessments (SOEP, 2019). Data for newborns and their mothers has been collected from 2000 onwards. The sampling is based on the household, and every household member should be included in the SOEP data. The selection of households in the SOEP aims to be representative of the German population. The SOEP data in version 34 provides birth information for mothers with children born between 2000 and 2017. Our initial sample consists of 4,656 mother-child pairs with information on gestational age, which were observed before and after pregnancy. It also includes information on birth weight and information on maternal mental and physical health in the last third of the pregnancy. We analyze three outcome variables.

First, PT is assigned a value of one if a child was born before the completion of the 37th week of gestation and zero otherwise. LBW includes individuals with a birth weight below 2,500 grams, as defined by the WHO. Finally, we estimate the coefficient for mental health during pregnancy on a combined measure of both previous concepts: SGA. SGA assigns a value of one to everyone whose birth weight is below the first decile of a gender- and gestation-specific distribution of birth weight, as suggested by Voigt et al. (2014). Figure 3.1 visualizes the three concepts and their overlaps.

Figure 3.1: The relationship between PT, LBW, and SGA



The figure shows the relationship between the birth outcomes PT, LBW, and SGA. NBW = normal birth weight; LBW = low birth weight; T = term-born; PT = preterm-born; SGA = small for gestational age; AGA = appropriate for gestational age (Ashorn et al., 2020). It is possible that the SGA-line is crossing the PT-line above the intersection of the PT-line and LBW-line, which is dependent on the country- and time-specific definition of the measure SGA.

Our variable of interest is maternal mental health during pregnancy. In addition, we also include self-reported maternal physical health in our analysis. The exact wording of the survey question is:

"How were you feeling physically and mentally during the last third of your pregnancy and during the first three months after giving birth?"
(1 = very good, 2 = good, 3 = bad, 4 = very bad)

All mothers who gave birth in the year before the annual survey interview, which are already part of the study, were asked to provide information on their mental and physical health status. Responding mothers answer separate items for both health variables and both periods after they gave birth. The question has two parts: one asking for mental health status during pregnancy and the other for mental health after birth. We use the answer on the first item, which is the mental health status during the last third of pregnancy, and aggregate the four answer categories into an indicator variable, which takes the value one for a very bad or bad maternal mental health status and zero otherwise. The same transformation was applied to the physical health variable. We form the measure in this particular way because there is a clear change in meaning between categories two and three (from good to bad). To summarize, the procedure described above yields two indicator variables: one for inferior physical health and one for poor mental health during pregnancy. Figure 3.A.1 shows the distribution of both health variables, given the sample we use for OLS estimation later. Here, 14 % of all mothers report bad or very bad mental health, and 23% report bad or very bad physical health.

In addition to these variables, Table 3.A.1 summarizes potential risk factors as well as protective or resilience factors of the mother, which are used as control variables in the regression models. As socioeconomic and demographic characteristics, we include an indicator for higher education (high school diploma or better), average weekly working hours, migration status and marital status of the mother, logarithmic average household income (annually) before birth, household size, and an indicator for homeownership. For fertility aspects that are related to previous births, indicators for the child being an older sibling, having a preterm-born sibling, or having a twin brother or sister are included. To account for physical health and health behavior, we also include a variable indicating whether mothers ever smoked before birth, as well as the physical health indicator discussed previously. Finally, we control for the sex of the newborn. Excluding individuals with missing or implausible values in any of the variables (e.g., birth weight of 7,500g) yields a final sample of 1655 mothers and 2,141 children, of whom 207 children were born PT (9.67%), 149 had a LBW (6.96%), and 263 were SGA births (12.28%).

The main reason is that some of the 2,141 children are siblings (and some are twins or multiples) and thus share the same mother. Hence, we have fewer mothers than children in our sample. We decided to keep them in the OLS samples and address this by including information on siblings and twins as a control variables in the OLS models. Official German statistics report comparable rates of preterm birth (8.36%), low birth weight (7.03%), and small for gestational age (10.00%) (IQTIG, 2018). Children in our sample were born between the 24th and 45th weeks of gestation, and their birth weight ranged from 540 grams to 5,140 grams. We also included siblings (and twins) in the sample, and we use this information and include it as control variables in our OLS models. The only variables with a considerable amount of missing information are the variables "smoked before pregnancy" (2,171) and "working hours of the mother" (1,716).

Maternal mental and physical health differ significantly across the two categories of the LBW and preterm indicators. In the term-born group, 12% of mothers reported a poor mental health status during pregnancy, whereas 30% in the preterm-born group did so.

If we consider SGA as an outcome variable, we find no large differences in the share of mothers with bad or very bad mental health. Table 3.A.1 also shows the mean values of our control variables across our outcome categories (PT, LBW, and SGA). As expected, we observe that preterm-born individuals show a significantly higher rate of low birth weight but no higher risk of small for gestational age. Mothers with a preterm-born child are more likely to have smoked before birth. Moreover, they were slightly less educated in terms of a higher secondary degree and worked significantly more on average before childbirth took place. We observe higher rates of preterm birth given that mothers experienced multiple births or previous preterm births. Mothers with a preterm-born child live in smaller households and are less likely to own property. Preterm-born children live in households with lower logarithmic income. The observed differences in the data replicate the findings of previous research on risk factors for preterm birth. Turning to LBW or SGA, we observe comparable patterns with respect to significant differences in control variables, given a 10%-significance level.
The National Educational Panel Study (NEPS) is a multi-cohort study from Germany that mainly focuses on education and related topics. The newborn cohort data (SC-1) contain information on central birth outcomes comparable to those available in the SOEP, discussed above (Blossfeld & von Maurice, 2011). The NEPS also contains information on the central control variables or comparable alternatives to those we also use in the SOEP sample described previously. In particular, the question on maternal mental health in the NEPS questionnaire reads:

"How were you feeling mentally during the last trimester of your pregnancy?"
(1 = very good, 2 = rather good, 3 = rather bad, 4 = very bad)

After we exclude all cases with missing values in key variables summarized in Table 3.A.2, we arrive at a sample of 1,841 children born in 2012. Here, 16% of all mothers reported a bad or very bad mental health status, and 27% reported a bad or very bad physical health status. In the NEPS, which is a cohort design, most births took place in one particular year, whereas the SOEP includes birth information over a period of 18 years. The NEPS focuses on one specific birth cohort. The target population here are individuals born between February 2012 and July 2012, and only household members were surveyed if the baby was between six and eight months old by the time the interview should take place. The sample we use includes 121 (6.57%) preterm-born children and 107 (5.81%) with a low birth weight. In the NEPS, relative shares are slightly smaller, as reported by official statistics (IQTIG, 2018). Since birth weight information was reported as a categorical variable in the NEPS, we could generate the low birth weight indicator but are not able to calculate low birth weight for gestational age.

Table 3.A.2 presents descriptive statistics for the NEPS sample. In the NEPS, 40% of all mothers with preterm-born children reported poor mental health during pregnancy, and only 15% with a term-born child did so. This difference is also prevalent in the SOEP data, and the same is true for the case of low birth weight. Generally, mothers of children born preterm do not differ significantly from term-born children in this sample, except for the share of mothers who are homeowners. We only observe values reported shortly after birth. This explains the comparable small mean values in the working hour variable because most observed mothers in the NEPS should still be on maternity leave while surveyed. We use the NEPS sample to control for the external validity of the results we obtained in our main analysis with the SOEP data.

3.3 Empirical strategy

In the first step, we estimate OLS models to identify the coefficient of mental health on the three birth outcomes discussed previously. We run OLS regressions in both samples with and without control variables. Formally, the OLS model can be described as:

$$B_i = b_0 + b_1 MH_i + b_2' C_i + \epsilon_i \tag{3.1}$$

B_i consists of one of our three indicators (PT, LBW, and SGA). b_0 is a constant, and C_i is the matrix of control variables, which we discussed previously. ϵ_i denotes an idiosyncratic independently identically distributed (iid) error term. The parameter of interest is b_1, which yields the association between maternal mental health (MH_i) and the respective birth outcome. However, simple OLS estimates might be biased due to omitted variables. Unobservable characteristics could induce a risk of both mental health problems during pregnancy and adverse birth outcomes. One example would be the unobserved health behavior of the mother, which is related to a higher risk of depressive symptoms or mental health problems in general but also impairs birth outcomes. Nevertheless, OLS estimates are highly informative in terms of the total association between the concepts.

Since our dependent variables are binary, equation 3.1 represents a linear probability model (LPM). We decided to base our main analysis on estimated LPMs to ease the interpretation of coefficients. However, the results are virtually identical in a logit model (see Tables 3.A.3 and 3.A.4).

The SOEP data also enable us to identify the biological mothers of the children and estimate our parameter of interest, controlling for mother fixed effects. In the mother fixed effects model, we are able to control for all mother-specific unobservable characteristics that do not vary across different births, which brings us slightly closer toward a causal interpretation of estimates. This includes any constant genetic influence the mother has on the birth outcome of the child. A formal description of mother fixed effects models is:

$$B_{ij} = c_0 + c_1 MH_{ij} + c_2' C_{ij} + U_j + \psi_{ij} \tag{3.2}$$

Fixed effects models are essentially OLS models with an additional indicator variable U_j for each mother j of child i. Since we already control for all within-mother variation, we cannot identify coefficients for all variables, which are constant for the mother across births, because their influence is already captured by the fixed effect. C_{ij} is a matrix of control variables for mother j and child i, which are not constant across births. The coefficient of interest is c_1, which is the association between maternal mental health (MH_{ij}) and the respective birth outcome conditional on the included control variables and the mother fixed effect (U_j).

One other way to address potential biases is to apply a matching approach. Matching enables us to estimate the Average Treatment Effect on the Treated (ATT) and Average Treatment Effect (ATE) (Rosenbaum & Rubin, 1983). In our setting, ATT is the causal effect of maternal mental health on the respective birth outcome for mothers with poor mental health, and ATE is the effect of poor maternal mental health for all mothers.

The intuition behind a matching estimator can be imagined as a two-step approach. In the first step, we predict the probability (propensity score) of a poor mental health status for every mother with a set of socioeconomic and health-related covariates. Second, we compare rates of adverse birth outcomes among mothers with similar probabilities of a poor mental health status, which is our treatment. For reasons described later in the text, we apply a kernel-based matching model. Mothers of the treatment group are matched with mothers of the control group, such that they are comparable in terms of the included covariates, which are predicting the mental health status of the mother in the model.

If we compare mothers of the treatment group (t) with a weighted average of control group members (c), we estimate the potential counterfactual birth outcome ($\hat{B}$) given the following formula:

$$\hat{B}_c = \frac{\sum_{c \in MH=0} W(q) B_c}{\sum_{c \in MH=0} W(q)} \text{ with } q = \frac{p_t - p_c}{h} \tag{3.3}$$

Here, W denotes the weight of the kernel function we apply, p is the propensity score, and h is the bandwidth. For our purpose, we use two different kernel functions, Gaussian and Epanechnikov, with a fixed bandwidth h of 0.06:

$$W_{gau}(q) \propto exp\left(\frac{-q^2}{2}\right) \tag{3.4}$$

$$W_{epa}(q) \propto (1 - q^2) \text{ if } |q| < 1 \tag{3.5}$$

We decided to stick to the same bandwidth for both kernel matching functions in order to keep the results comparable. Differences between the two kernels should thus not represent differences in the bandwidth selection. The smaller the bandwidth, the stronger is the weighting of very similar observations of the treatment and control group, which could influence our results. We also estimated the models with alternative bandwidths (0.04 & 0.08). The results are similar to the results with a bandwidth of 0.06.
Given the procedure described above, we calculate the ATT and the ATE for mental health (MH), estimating the average treatment effect on the control group (ATC) as follows (Imbens, 2004):

$$ATT(MH) = \frac{1}{N_t} \sum\nolimits_t \left(B_t - \frac{\sum_c B_c W(q)}{\sum_c W(q)} \right) \tag{3.6}$$

$$ATC(MH) = \frac{1}{N_c} \sum\nolimits_c \left(\frac{\sum_t B_t W(q)}{\sum_t W(q)} - B_c \right) \tag{3.7}$$

$$ATE(MH) = \frac{N_t}{N} ATT(MH) + \frac{N_c}{N} ATC(MH) \tag{3.8}$$

If we include all relevant predictors for poor mental health status (conditional independence), we could interpret the ATT and the ATE causally (Angrist & Pischke, 2009). We computed our results using the software Stata 16 (StataCorp., 2019) and R (R Core Team, 2020), as well as the packages provided in those software applications.

3.4 Results

Even though OLS estimates may be biased, as argued above, they provide a benchmark for the underlying causal effect. Table 3.1 presents the results from OLS and mother fixed effects models for all three outcomes we mentioned previously (rows 1–6). The results show a clear pattern: poor maternal mental health in the last trimester of pregnancy significantly raises the risk of having a preterm-born child in all models presented in Table 3.1. The same is true for LBW, but not for SGA. In column (1), we show OLS without any controls included, whereas column (2) shows the OLS coefficients for maternal mental and physical health conditional on all variables discussed in Section 3.2. Even though the inclusion of further control variables helps to explain more of the variance in our outcomes (higher R^2), it does not change the coefficients for mental or physical health substantially. OLS only produces consistent estimates if the assumptions of the linear probability model hold and are only causally interpretable if the distribution of maternal mental health issues across term and preterm-born children is not affected by any other covariate, which is not included in our model.

If these assumptions hold, poor maternal mental health in the last trimester of pregnancy is related to a 9.5–12.7 percentage point increased risk for PT birth. Accordingly, poor maternal mental health is associated with a 7.8–9.7 percentage point higher risk for LBW. For the SGA outcome, we find no consistently significant maternal mental health coefficients. This might be because many children with low birth weight for gestational age are not born preterm and have no low absolute birth weight.

Table 3.1: OLS and FE models (SOEP)

	(1) OLS	(2) OLS	(3) FE	(4) FE
PT				
Poor Mental Health	0.127***	0.095***	0.097***	0.062***
	(0.024)	(0.027)	(0.022)	(0.018)
Poor Physical Health		0.046*		0.014
		(0.020)		(0.016)
LBW				
Poor Mental Health	0.097***	0.078***	0.063***	0.046*
	(0.021)	(0.023)	(0.018)	(0.018)
Poor Physical Health		0.037*		0.022
		(0.016)		(0.016)
SGA				
Poor Mental Health	0.019	0.007	0.035	0.048
	(0.021)	(0.023)	(0.024)	(0.026)
Poor Physical Health		-0.002		0.001
		(0.019)		(0.023)
Controls		Yes		Yes
Observations	2,141	2,141	2,119	2,119

The table presents OLS and mother fixed effects estimates for the relationship between maternal mental health and our birth outcomes (PT, LBW, and SGA) using the SOEP sample. OLS estimates are based on a full information sample of all individuals. Mother fixed effects models are based on the whole sample of mothers with at least two children, without conditioning on full information for all control variables and excluding all pregnancies with multiple births. In the OLS model with controls, we include maternal age at birth (and squared), maternal smoking before birth, average working hours of the mother before birth, marital status, education and migration background of the mother, homeownership, household size and income before birth, an indicator for previous preterm births, twin and multiple births, the presence of older siblings, the sex of the child, year and region fixed effects. The mother fixed effects model with controls includes the sex of the child as an indicator for previous preterm birth and one for the presence of an older sibling. Robust standard errors in parentheses. ***p<0.001, **p<0.01, *p<0.05.

For example, in our sample, 12.25% of term-born and 12.56% of preterm-born children were categorized as SGA. Various children born with low birth weight for gestational age are at the lower end of the gender-birth-week-specific birth weight distribution but are not born preterm, have no low birth weight, and hence might face no substantial developmental disadvantages at birth. The influence of the additional control variables is as expected (Table 3.A.5). With only a few exceptions, we see the same picture with respect to control variables regarding our other two birth outcomes (LBW and SGA).

Columns 3 and 4 present results from the mother fixed effects models, which allow us to control for constant but unobservable maternal characteristics. For the analysis, we drop all mothers who had only one child and all twin births since there was no variation in gestational age or the mental health of the mother during pregnancy.

Again, poor maternal mental health increases the risk of preterm birth, but the coefficients are smaller in comparison to those obtained in OLS models, which is what we would expect. This indicates that unobserved factors at the mother´s level influence both the child´s birth outcomes and the mental health condition of the mother accordingly. The same is true for the case of LBW and partly for SGA. Interestingly, physical health is not significant in the most comprehensive model (column 4) for any of the three outcomes. Here, we also include various birth-related variables that are correlated with maternal physical health. Poor maternal mental health still significantly increased the risk of preterm birth (6.2–9.7 percentage points) and low birth weight (4.6–6.3 percentage points). As is the case in OLS models, we do not find consistent significant coefficients of maternal mental health on the incidence of SGA at the child´s birth. Our fixed effects models show that the relationship between maternal mental health and the child´s birth outcomes (LBW and PT) is not entirely explained by mother-specific characteristics such as genetics (see also Table 3.A.6 for the full table of results).

In the absence of a suitable instrumental variable for the mental health status of the mother during pregnancy, we also apply matching estimators to get closer toward causality. We use kernel-based matching algorithms, Gaussian and Epanechnikov, and match on all covariates we used as control variables in our OLS models. Moreover, we also use the mental health component summary score (mcs) before birth as a covariate to balance our treatment and control groups. This score is calculated using multiple subscales representing different dimensions of mental health. The SOEP includes four subscales, which cover general mental health, emotional role, social functioning, and vitality. Higher mcs scores represent a better mental health condition. We compare birth outcomes for mothers with comparable mcs scores before birth. For our estimation, we use the same sample as in the OLS analysis, excluding observations with missing information on the mcs scores before birth.

The results are summarized in Table 3.2 (see also Table 3.A.7 for the full table of results). The estimates for the ATE and the ATT confirm our previous results. Mental health is a risk factor for PT and LBW, but not for SGA. We estimate the relationship based on kernel matching since we have better common support compared to nearest-neighbor matching. Predicting mental health via a Gaussian kernel always leads to perfect common support by design (see Stuart (2010) for more details on different matching techniques).

Table 3.2: Matching estimates for treatment effects (SOEP)

Treatment Effect	(1) GAU	(2) EPA
	PT	
ATE	0.113*	0.144***
	(0.057)	(0.034)
ATT	0.086**	0.093**
	(0.034)	(0.029)
	LBW	
ATE	0.130**	0.091**
	(0.055)	(0.036)
ATT	0.072**	0.065**
	(0.030)	(0.027)
	SGA	
ATE	0.031	-0.009
	(0.040)	(0.027)
ATT	0.003	-0.017
	(0.025)	(0.027)
Observations	2,134	2,134
Support	1	0.838

The table presents matching estimates for the Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT) of maternal mental health on our birth outcomes (PT, LBW, and SGA) using the SOEP sample. We matched all covariates presented in Table 3.A.8 as well as survey years, federal states and a squared term of maternal age (not indicated in Table 3.A.8). The sample size is different because the mcs scores are added as a covariate to match individuals. Bootstrapped standard errors in parentheses (100 replications). ***p<0.001, **p<0.01, *p<0.05.

Table 3.A.8 presents the pre- and after-matching differences for the variables we use in our estimation of mothers with poor mental health during pregnancy and those without. It is evident that both matching procedures drastically reduce the differences in almost all the considered variables.

In the sample, we analyzed 21% of the mothers with poor mental health during pregnancy who had a preterm-born child, whereas only 8% of those without mental health problems had a child born preterm. The estimated ATE of a poor maternal mental health status during pregnancy on the risk of preterm birth equals 11.3 percentage points given Gaussian kernel matching. The ATT indicates that for mothers with poor health, the risk of preterm birth is 8.6 percentage points higher. The second Panel shows the ATE and ATT for an Epanechnikov kernel matching approach. Again, we find a significant ATE indicating that poor maternal mental health increases the risk of preterm birth by 14.4 percentage points. The ATT remains significant using an Epanechnikov kernel, as it is the case for the Gaussian kernel, and indicates a 9.3 percentage point higher risk for preterm birth. If we now turn to the case of LBW, we see a comparable picture. The ATT and ATE of poor mental health status on LBW range between 6.5 and 13.0 percentage points. Again, SGA is not related to the mental health status of the mother in any of the models.

The differences in the results using the two kernels could be partly explained by their mechanics. Whereas the Gaussian kernel includes all observations in the estimation and

weighs them according to their differences in their estimated probability of having a poor mental health status, the Epanechnikov kernel excludes some that do not meet the support criteria. Excluding these distinct observations reduces the uncertainty in our estimates for the ATC since 16% of the control group and only 2% of the treatment group are affected. Because the control group only affects estimates for the ATE (via the ATC), the standard errors of the ATE are drastically reduced, but the ATT errors remain relatively stable.
The results are consistent with those presented previously. We find significant ATTs and ATEs for the outcomes preterm and LBW but not for SGA. In summary, propensity score matching suggests that there is a causal component within the estimates we obtained using OLS.

3.5 Robustness

An important feature of our study is the estimation of the association between maternal mental health and birth outcomes in two independently surveyed observational datasets. Both studies provide highly comparable measures of birth outcomes and control variables, which gives us the opportunity to compare estimates across two different samples from Germany.
Table 3.A.9 contains OLS estimates for mental and physical health for the NEPS sample. The results show the same clear pattern as in the SOEP sample. Mental and physical health are both significant risk factors for preterm birth. As in the SOEP data, the inclusion of control variables does not drastically alter either the coefficient size or significance. Reporting poor mental health is associated with a 9.3–11.2 percentage point higher risk for preterm birth, which is in the range of the OLS coefficients based on the SOEP sample presented above. Estimates for LBW are also very similar in the NEPS and the SOEP data. The poor mental health status of the mother is associated with a 6.5–7.3 percentage point higher risk of having a newborn with a low birth weight. In summary, OLS estimates in both samples are very comparable, which indicates that they are externally valid for the case of Germany. As discussed above, we cannot calculate the SGA because birth weight is a categorical variable in the NEPS, and we would need a continuous measure here.
In addition to selection issues and unobserved characteristics, we want to address another potential threat, which is reverse causality. In both datasets, mothers reported their mental health status in the last trimester of pregnancy in an interview after birth. Therefore, it might be the case that mothers reported poor mental health status because they had a child with a comparably low birth weight or one born preterm. To address this problem, we run an interaction model with another mental health measure, the mental health component summary score (mcs), before pregnancy and after birth using the SOEP data. Dimensions forming the mcs score are surveyed every second year in the SOEP (SOEP,

2019), so we could infer how mental health changes from the years before birth to those afterwards with a Difference-in-Differences (DiD) framework.
We exclude births for which we have only one observation, either from the period before pregnancy or after birth. Overall, our sample includes 605 mothers and 770 births (i), which are potentially surveyed every second year between 2002 and 2016 (t). For each birth, we analyzed at least two observations of the maternal mcs, one before pregnancy and one after birth. A single mother could be included multiple times if her mcs score was surveyed multiple times before and after birth and/or she had more than one child. The final sample consists of 3,123 mother-birth-year combinations, for which we estimate the following equation:

$$mcs_{it} = d_0 + d_1 * B_i + d_2 * Birth_i + d_3 * (Birth_i * B_i) + d_4' Controls_{it} + \omega_{it} \tag{3.9}$$

Given the adverse birth outcome considered is preterm birth, d_1 captures the average difference in the mcs score between mothers with preterm- and term-born babies, and d_2 the difference between mothers' mcs before and after pregnancy. The vector d_4 represents the influence of control variables included in the model. The coefficient of interest is d_3. It shows whether there is a systematic difference in the change of mcs scores between mothers of preterm- and term-born children from the period before birth to the period after birth. It helps to quantify the magnitude of the reverse causality problem in our estimates. We would expect a positive (negative) coefficient if mothers of preterm-born children have systematically higher (lower) mcs scores. If this is the case, mothers of preterm-born children would have a different mental health condition after birth, and our estimates for maternal mental health in the last trimester of pregnancy would represent this fact.
Table 3.A.10 summarizes coefficient estimates for d_1, d_2, and d_3 and the estimates for a set of controls, which we also use in the OLS models. The analysis is based on the full sample of mothers, in which we have information on the mcs, all control variables included in the final model, and on all birth outcomes we consider. We find no evidence of differences in changes of mothers' mental health from the period before pregnancy to the time after birth between mothers of preterm and term-born children. The coefficients are negative but insignificantly different from zero. Therefore, our results suggest that preterm birth is not associated with a worsened mental health score after birth. We do not find evidence for a reversed causality pattern in our data. Consequently, our estimates for maternal mental health status in the last trimester of birth seem not to be driven by reverse causality since the mental health of mothers with preterm-born children is not altered systematically after birth. In addition, the mcs score and our measure of subjective mental health during pregnancy are strongly related to each other. Before birth, the last observed mcs score

was 3.1 points ($p<0.01$) lower if mothers reported bad or very bad mental health during pregnancy than the mcs score of those who did not.

Furthermore, we want to address the selectivity of our results to the selection of control variables, the identification strategy, and to the selection of different subsamples based on SOEP data. To do so, we perform a specification curve analysis (Frey et al., 2021; Simonsohn et al., 2020) varying control parameter combinations, using different outcomes, identification strategies, and estimating the respective models in different subsamples. Afterward, we graph the estimates and confidence intervals, which enables us to infer on the robustness of our results with respect to the specification we choose.

Traditionally, it is to some degree the researcher's freedom to decide which specification to report within the article. The purpose of a specification curve analysis is to reduce the research degree of freedom and present the results of various specifications in an aggregated curve. Given the curve, it is straightforward to evaluate whether the reported results are similar to other specifications, which are not directly shown in the article. Proceeding in this manner, we avoid reporting only selected models, which generate significant estimates for our variable of interest.

First, we estimate the relationship between maternal mental health and our three birth outcomes. Moreover, we use the SGA calculated on the basis of international standards and an indicator using height at birth instead of the birth weight to calculate the SGA (Villar et al., 2014; Villar et al., 2016; Voigt et al., 2014). Again, we use both the German and international standards, while we consider the height at birth. We also vary five sets of control variables, five different samples, and identify the coefficients for maternal mental health by estimating fixed effects, matching, and OLS models. All aspects that could potentially vary (sample, identification, control variables, outcomes) are listed in Table 3.A.11.

Figure 3.A.2 graphs the specification curve. On the vertical axis of Figure 3.A.2 is a legend indicating which outcomes, estimation technique, sample, and control combinations the respective estimate represents. In total, the specification curve visualizes 1,110 estimates. Nearly all estimates that are insignificantly different from zero (485 of 1,110) are those that are related to the SGA as an outcome variable (477 of 740). For preterm birth, only four coefficients are not significant given a 5% threshold, whereas 181 coefficients are significant. LBW shows a comparable pattern, and nearly all estimates are significant and positive.

The specification curve analysis supports our main finding of a negative association between poor maternal mental health and the birth outcomes of the offspring if we consider LBW or PT. For SGA, we find no consistent evidence that maternal mental health is a risk factor.

3.6 Conclusion

Our main finding is that poor maternal mental health in the last trimester of pregnancy is associated with inferior birth outcomes (PT and LBW). The result is robust across many specifications and is prevalent in two different datasets from Germany. However, we find no consistent association once we consider SGA as an outcome. This leads us to the conclusion that associations between low birth weight and maternal mental health seem to work through associations between maternal mental health and gestational age. However, children affected by a poor maternal mental health status of the mother do not seem to be intrauterine growth retarded with respect to weight gain during pregnancy. Our results are consistent with the fetal origins hypothesis. Children exposed to poor maternal mental health in the womb have a higher risk of showing adverse birth outcomes. Their mothers are at higher risk of having a preterm-born child or a newborn with a low birth weight.

Our results suggest that maternal mental health should be prominently mentioned as a risk factor for preterm birth and low birth weight. Medical professionals should include the diagnosis of mental health problems of pregnant women as part of the recommended standard prenatal care examination. Our results emphasize the importance of the WHO recommendations, which already stated in 2012 that the improvement of mental health problems during pregnancy should be targeted to enhance the birth outcomes of the newborn. It is important to mention that additional capacities to improve mental health care during pregnancy must be financed by additional public spending, at least in countries with a public health care system.

However, current policy in Germany seems to target the difficulties of parents after they have a preterm-born child rather than the prevention of the incidence of preterm birth itself. For example, in 2020, the German parliament introduced a new law which increases the maximum time parental allowance is granted by a month if the child was born six weeks before the expected date of birth. While this is welcome support for families, given the substantial indirect and direct costs of adverse birth outcomes, this should be accompanied by efforts to prevent preterm births. Improving the mental health status of mothers during pregnancy could be an essential factor in this prevention. A better supply of midwife services throughout pregnancy with a special focus on the detection and maintenance of maternal mental health problems could be one part of such a prevention strategy. Moreover, one could think of prioritizing pregnant women for psychological services because they could be helpful not only for the mother but also for the child.

Our study has a number of limitations. First, we are not able to use any quasi-experimental variation in mental health to estimate causal effects on birth outcomes. Nevertheless, by applying fixed effects and propensity score matching models, we arguably remove some of the selection and endogeneity problems a purely descriptive analysis would suffer from.

Second, our study relies on observational samples from Germany. Even though estimates are similar in two independent datasets, it would be interesting to replicate our result with large administrative data. Analyzing administrative data is promising since the SOEP and the NEPS are two of the largest German datasets with birth outcomes and mental health measures included, and still the sample sizes are comparably small. One could think of linking medical records on mental health treatments in pregnancy to administrative data on birth outcomes to replicate our results. This leaves room for further research. Nevertheless, not all pregnant women with mental health problems will benefit from psychological care services or are willing to do so. Therefore, studying observational data will remain quite important in the context of mental health in the future. Analyzing both medical health treatment (e.g., therapy or psychopharmaca medication) and self-reported mental health status during pregnancy in one study would be of great interest to see how effective interventions are able to reduce the risk of adverse birth outcomes induced by mental health problems. Third, we could not control for all confounding variables that influence the relationship between maternal mental health and adverse birth outcomes. Even though we removed all time constant maternal confounders in the fixed effects models, we cannot capture all time variant variables which are important. In addition to that, it is important to emphasize that we did not control for any paternal confounders. We fully abstract from the influence of fathers.

To further infer the external validity of our results, it would be interesting to perform an international comparison. This could answer the question of whether our results could be generalized or whether they are driven by country-specific characteristics such as differences in public health care systems or cultural aspects. To perform an international analysis, it would be beneficial to have an international dataset with comparable measures of the most important variables, especially mental health. Nevertheless, it would be fruitful to consider the harmonization of national datasets and analyze the role of mental health during pregnancy for birth outcomes in an international context. One could consider analyzing multiple national datasets with a so-called individual participant data (IPD) meta-analysis, which is frequently used in social science. Despite the lack of an international context, our results for Germany indicate that mental health problems during pregnancy are a key risk factor for inferior birth outcomes.

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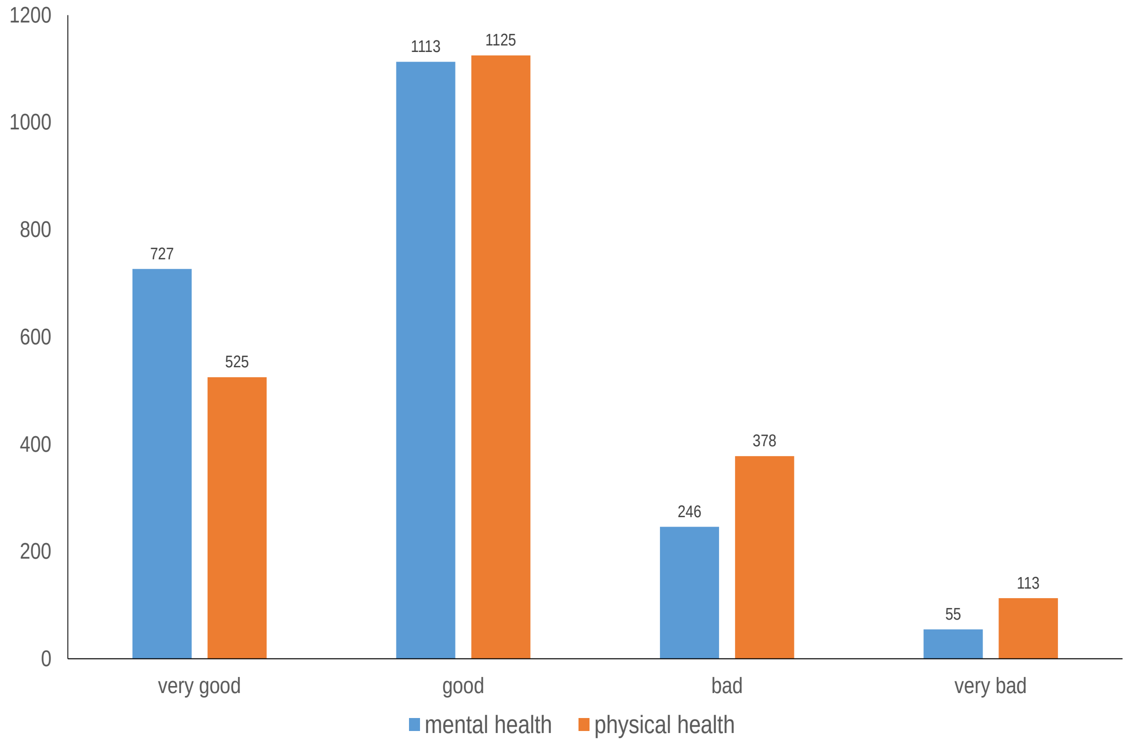
Appendix

Figure 3.A.1: Distribution of maternal mental and physical health (SOEP)



The figure shows the distribution of maternal mental and physical health in the last three months/last trimester of pregnancy. The number of observations is displayed above the graph.

Table 3.A.1: T-test for zero mean difference (SOEP)

Variables	No PT	PT	P	No LBW	LBW	P	AGA	SGA	P
PT	.	.	.	0.054	0.664	<0.001	0.096	0.099	0.900
.	.	.		(0.227)	(0.474)		(0.295)	(0.299)	
LBW	0.026	0.478	<0.001	.	.	.	0.039	0.285	<0.001
	(0.159)	(0.501)		.	.		(0.195)	(0.452)	
SGA	0.123	0.126	0.900	0.094	0.503	<0.001	.	.	.
	(0.328)	(0.332)		(0.292)	(0.502)		.	.	
Poor Mental	0.124	0.300	<0.001	0.128	0.309	<0.001	0.138	0.160	0.365
Health	(0.329)	(0.459)		(0.334)	(0.464)		(0.345)	(0.367)	
Poor Physical	0.219	0.411	<0.001	0.214	0.436	<0.001	0.225	0.259	0.247
Health	(0.407)	(0.493)		(0.410)	(0.498)		(0.418)	(0.439)	
Age mother	31.342	31.329	0.971	31.308	31.772	0.268	31.330	31.418	0.799
	(5.047)	(5.060)		(5.057)	(4.903)		(5.011)	(5.305)	
Smoked before	0.221	0.300	0.020	0.227	0.255	0.449	0.221	0.285	0.030
pregnancy	(0.415)	(0.459)		(0.419)	(0.437)		(0.415)	(0.452)	
Marital Status	0.625	0.647	0.517	0.623	0.671	0.237	0.635	0.570	0.049
	(0.484)	(0.479)		(0.485)	(0.471)		(0.482)	(0.496)	
Higher education	0.500	0.435	0.074	0.493	0.503	0.808	0.497	0.468	0.368
	(0.500)	(0.497)		(0.500)	(0.502)		(0.500)	(0.500)	
Working hours	34.063	36.093	0.005	34.032	37.289	<0.001	34.048	35.77	0.011
(mother)	(10.666)	(9.676)		(10.728)	(7.950)		(10.639)	(10.115)	
Sex	0.496	0.556	0.106	0.502	0.503	0.975	0.507	0.468	0.234
	(0.500)	(0.498)		(0.500)	(0.502)		(0.500)	(0.500)	
Older sibling	0.559	0.512	0.197	0.561	0.47	0.033	0.569	0.456	0.001
	(0.497)	(0.501)		(0.496)	0.501		0.495	0.499	
Previous PT	0.036	0.068	0.082	0.039	0.047	0.643	0.038	0.049	0.410
	(0.187)	(0.252)		(0.193)	(0.212)		(0.191)	(0.217)	
Twin (multiple birth)	0.020	0.135	<0.001	0.016	0.242	<0.001	0.019	0.118	<0.001
	(0.141)	(0.343)		(0.124)	(0.430)		(0.137)	(0.323)	
Migration background	0.237	0.271	0.299	0.244	0.181	0.058	0.244	0.209	0.192
	(0.425)	(0.445)		(0.430)	(0.386)		(0.430)	(0.407)	
Homeowner	0.351	0.295	0.094	0.345	0.349	0.929	0.347	0.335	0.687
	(0.477)	(0.457)		(0.476)	(0.478)		(0.476)	(0.473)	
Household size	2.814	2.662	0.054	2.825	2.450	<0.001	2.824	2.624	0.002
	(1.041)	(1.076)		(1.054)	(0.834)		(1.053)	(0.968)	
Household income	10.441	10.369	0.017	10.434	10.438	0.907	10.439	10.394	0.087
(log)	(0.407)	(0.406)		(0.407)	(0.412)		(0.408)	(0.399)	

The table shows the P-values given by t-tests for different means of important variables across the three birth outcomes (PT, LBW, and SGA) using SOEP v34. Standard deviations are in parenthesis. N=2,141.

Table 3.A.2: T-test for zero mean difference (NEPS)

Variables	No PT	PT	P	No LBW	LBW	P
PT	.	.	.	0.033	0.598	<0.001
	.	.		(0.178)	(0.493)	
LBW	0.025	0.529	<0.001	.	.	.
	(0.156)	(0.501)		.	.	
Poor Mental Health	0.147	0.397	<0.001	0.153	0.336	<0.001
	(0.354)	(0.491)		(0.360)	(0.475)	
Poor Physical Health	0.252	0.479	<0.001	0.257	0.43	0.001
	(0.434)	(0.502)		(0.437)	(0.497)	
Migration background	0.369	0.397	0.552	0.373	0.346	0.575
	(0.483)	(0.491)		(0.484)	(0.478)	
Working hours (mother)	2.689	2.545	0.864	2.698	2.374	0.687
	(8.667)	(8.886)		(8.720)	(8.012)	
Sex	0.495	0.545	0.289	0.500	0.477	0.641
	(0.500)	(0.500)		(0.500)	(0.502)	
Household income (log)	10.554	10.525	0.486	10.549	10.606	0.219
	(0.443)	(0.448)		(0.442)	(0.462)	
Age mother	40.396	39.496	0.105	40.365	39.879	0.419
	(5.942)	(5.862)		(5.935)	(6.031)	
Household size	3.576	3.570	0.942	3.574	3.598	0.735
	(0.820)	(0.773)		(0.823)	(0.712)	
Higher education	0.595	0.57	0.601	0.589	0.654	0.177
	(0.491)	(0.497)		(0.492)	(0.478)	
Homeowner	0.517	0.430	0.065	0.515	0.449	0.185
	(0.500)	(0.497)		(0.500)	(0.500)	

The table shows P-values given by t-tests for different means of important variables across the two birth outcomes (PT and LBW) using NEPS SC-1. Standard deviations are in parenthesis. N=1,841. We cannot calculate the SGA in the NEPS since birth weight is a categorical variable, and we would need a continuous measure to do so.

Table 3.A.3: Marginal effects at sample means given logit estimation (SOEP)

Variables	(1) PT	(2) PT	(3) LBW	(4) LBW	(5) SGA	(6) SGA
Poor Mental Health	0.127***	0.077**	0.097***	0.058**	0.019	0.006
SE	0.024	0.025	0.021	0.021	0.021	0.020
T	5.267	3.048	4.520	2.777	0.909	0.278
P	<0.001	0.002	<0.001	0.005	0.363	0.781
CI	0.080 - 0.175	0.027 - 0.126	0.055 - 0.139	0.017 - 0.099	-0.022 - 0.061	-0.034 - 0.046
Poor Physical Health	.	0.043*	.	0.032*	.	-0.000
SE	.	0.018	.	0.013	.	0.016
T	.	2.427	.	2.388	.	-0.018
P	.	0.015	.	0.017	.	0.986
CI	.	0.008 - 0.077	.	0.006 - 0.058	.	-0.033 - 0.032
Age Mother	.	0.002	.	0.002	.	0.002
SE	.	0.001	.	0.001	.	0.001
T	.	1.751	.	1.649	.	1.737
P	.	0.080	.	0.099	.	0.082
CI	.	0.000 - 0.005	.	0.000 - 0.003	.	0.000 - 0.005
Sex	.	0.019	.	0.001	.	-0.015
SE	.	0.012	.	0.008	.	0.013
T	.	1.681	.	0.124	.	-1.205
P	.	0.093	.	0.901	.	0.228
CI	.	-0.003 - 0.042	.	-0.015 - 0.017	.	-0.041 - 0.010
Twin (multiple birth)	.	0.264***	.	0.382***	.	0.351***
SE	.	0.068	.	0.077	.	0.067
T	.	3.874	.	4.985	.	5.272
P	.	<0.001	.	<0.001	.	<0.001
CI	.	0.131 - 0.398	.	0.232 - 0.533	.	0.221 - 0.482
Previous PT	.	0.080	.	0.044	.	0.079
SE	.	0.045	.	0.032	.	0.046
T	.	1.788	.	1.375	.	1.702
P	.	0.074	.	0.169	.	0.089
CI	.	-0.008 - 0.167	.	-0.019 - 0.107	.	-0.012 - 0.170
Older Sibling	.	-0.030	.	-0.019	.	-0.058**
SE	.	0.017	.	0.012	.	0.018
T	.	-1.740	.	-1.568	.	-3.238
P	.	0.082	.	0.117	.	0.001
CI	.	-0.064 - 0.004	.	-0.042 - 0.005	.	-0.093 - -0.023
Smoked before preg.	.	0.016	.	0.004	.	0.019
SE	.	0.015	.	0.010	.	0.018
T	.	1.062	.	0.408	.	1.093
P	.	0.288	.	0.683	.	0.274
CI	.	-0.013 - 0.045	.	-0.015 - 0.023	.	-0.015 - 0.054
Migration background	.	0.008	.	-0.016	.	-0.021
SE	.	0.014	.	0.009	.	0.014
T	.	0.588	.	-1.684	.	-1.488
P	.	0.556	.	0.092	.	0.137
CI	.	-0.019 - 0.035	.	-0.034 - 0.003	.	-0.049 - 0.007
Marital Status	.	0.016	.	0.014	.	-0.012
SE	.	0.012	.	0.008	.	0.015
T	.	1.299	.	1.692	.	-0.775
P	.	0.194	.	0.091	.	0.438
CI	.	-0.008 - 0.040	.	-0.002 - 0.031	.	-0.041 - 0.018
Higher Education	.	-0.009	.	-0.002	.	-0.004
SE	.	0.013	.	0.009	.	0.015
T	.	-0.729	.	-0.257	.	-0.283
P	.	0.466	.	0.797	.	0.777
CI	.	-0.034 - 0.015	.	-0.020 - 0.015	.	-0.034 - 0.025
Working hours mother	.	0.001*	.	0.001*	.	0.001
SE	.	0.001	.	0.000	.	0.001
T	.	2.270	.	2.255	.	1.227
P	.	0.023	.	0.024	.	0.220
CI	.	0.000 - 0.003	.	0.000 - 0.002	.	-0.001 - 0.002
Household income (log)	.	-0.031	.	-0.007	.	-0.034
SE	.	0.016	.	0.012	.	0.020
T	.	-1.915	.	-0.545	.	-1.739
P	.	0.056	.	0.586	.	0.082
CI	.	-0.063 - 0.001	.	-0.031 - 0.017	.	-0.073 - 0.004
Homeowner	.	-0.013	.	0.004	.	0.011
SE	.	0.013	.	0.010	.	0.016
T	.	-1.070	.	0.455	.	0.721
P	.	0.285	.	0.649	.	0.471
CI	.	-0.038 - 0.011	.	-0.014 - 0.023	.	-0.019 - 0.042
Household size	.	-0.004	.	-0.015*	.	-0.001
SE	.	0.008	.	0.006	.	0.007
T	.	-0.500	.	-2.541	.	-0.081
P	.	0.617	.	0.011	.	0.936
CI	.	-0.020 - 0.012	.	-0.026 - -0.003	.	-0.015 - 0.013
Year & Federal State		Yes		Yes		Yes
R^2	0.029	0.111	0.028	0.200	<0.001	0.068
N	2,141	2,128	2,141	2,141	2,141	2,141

Standard errors are in parentheses. N=13 individuals were excluded since one regional fixed effect predicts preterm perfectly. ***p<0.001, **p<0.01, *p<0.05. Controls are the same variables as in the OLS model (Table 3.1).

Table 3.A.4: Average marginal effects given logit estimation (SOEP)

Variables	**(1) PT**	**(2) PT**	**(3) LBW**	**(4) LBW**	**(5) SGA**	**(6) SGA**
Poor Mental Health	0.127***	0.080**	0.097***	0.067**	0.019	0.006
SE	0.024	0.025	0.021	0.022	0.021	0.022
T	5.267	3.255	4.520	3.114	0.909	0.278
P	<0.001	0.001	<0.001	0.002	0.363	0.781
CI	0.080 - 0.175	0.032 - 0.129	0.055 - 0.139	0.025 - 0.109	-0.022 - 0.061	-0.037 - 0.050
Poor Physical Health	.	0.046*	.	0.039*	.	-0.000
SE	.	0.019	.	0.015	.	0.018
T	.	2.479	.	2.517	.	-0.018
P	.	0.013	.	0.012	.	0.986
CI	.	0.010 - 0.082	.	0.009 - 0.069	.	-0.036 - 0.035
Age Mother	.	0.002	.	0.002	.	0.003
SE	.	0.001	.	0.001	.	0.002
T	.	1.803	.	1.674	.	1.663
P	.	0.071	.	0.094	.	0.096
CI	.	0.000 - 0.005	.	0.000 - 0.004	.	0.000 - 0.006
Sex	.	0.022	.	0.001	.	-0.017
SE	.	0.013	.	0.011	.	0.014
T	.	1.715	.	0.124	.	-1.208
P	.	0.086	.	0.901	.	0.227
CI	.	-0.003 - 0.046	.	-0.020 - 0.022	.	-0.045 - 0.011
Twin (multiple birth)	.	0.259***	.	0.370***	.	0.353***
SE	.	0.061	.	0.063	.	0.063
T	.	4.247	.	5.836	.	5.621
P	.	<0.001	.	<0.001	.	<0.001
CI	.	0.139 - 0.379	.	0.246 - 0.494	.	0.230 - 0.475
Previous PT	.	0.083	.	0.053	.	0.048
SE	.	0.044	.	0.036	.	1.755
T	.	1.889	.	1.457	.	0.079
P	.	0.059	.	0.145	.	0.048
CI	.	-0.003 - 0.170	.	-0.018 - 0.124	.	-0.010 - 0.177
Older Sibling	.	-0.033	.	-0.023	.	-0.063***
SE	.	0.019	.	0.014	.	0.019
T	.	-1.760	.	-1.631	.	-3.341
P	.	0.078	.	0.103	.	0.001
CI	.	-0.070 - 0.004	.	-0.052 - 0.005	.	-0.099 - -0.026
Smoked before pregnancy	.	0.018	.	0.005	.	0.021
SE	.	0.016	.	0.013	.	0.019
T	.	1.073	.	0.412	.	1.103
P	.	0.283	.	0.680	.	0.270
CI	.	-0.015 - 0.050	.	-0.019 - 0.030	.	-0.016 - 0.059
Migration background	.	0.009	.	-0.021	.	-0.023
SE	.	0.015	.	0.012	.	0.016
T	.	0.592	.	-1.668	.	-1.484
P	.	0.554	.	0.095	.	0.138
CI	.	-0.021 - 0.039	.	-0.045 - 0.004	.	-0.054 - 0.007
Marital Status	.	0.018	.	0.019	.	-0.013
SE	.	0.014	.	0.011	.	0.016
T	.	1.279	.	1.651	.	-0.781
P	.	0.201	.	0.099	.	0.435
CI	.	-0.009 - 0.045	.	-0.003 - 0.041	.	-0.044 - 0.019
Higher Education	.	-0.010	.	-0.003	.	-0.005
SE	.	0.014	.	0.012	.	0.016
T	.	-0.734	.	-0.258	.	-0.284
P	.	0.463	.	0.797	.	0.776
CI	.	-0.038 - 0.017	.	-0.026 - 0.020	.	-0.037 - 0.027
Working hours mother	.	0.002*	.	0.001*	.	0.001
SE	.	0.001	.	0.001	.	0.001
T	.	2.269	.	2.268	.	1.233
P	.	0.023	.	0.023	.	0.217
CI	.	0.000 - 0.003	.	0.000 - 0.002	.	-0.001 - 0.002
Household income (log)	.	-0.035	.	-0.009	.	-0.038
SE	.	0.018	.	0.016	.	0.022
T	.	-1.924	.	-0.545	.	-1.737
P	.	0.054	.	0.586	.	0.082
CI	.	-0.070 - 0.001	.	-0.040 - 0.023	.	-0.080 - 0.005
Homeowner	.	-0.015	.	0.006	.	0.012
SE	.	0.014	.	0.012	.	0.017
T	.	-1.067	.	0.457	.	0.722
P	.	0.286	.	0.648	.	0.470
CI	.	-0.043 - 0.013	.	-0.019 - 0.030	.	-0.021 - 0.046
Household size	.	-0.005	.	-0.019*	.	-0.001
SE	.	0.009	.	0.008	.	0.008
T	.	-0.499	.	-2.497	.	-0.081
P	.	0.618	.	0.013	.	0.936
CI	.	-0.023 - 0.013	.	-0.034 - -0.004	.	-0.016 - 0.015
Year & Federal State		Yes		Yes		Yes
R^2	0.029	0.111	0.028	0.200	<0.001	0.068
N	2,141	2,128	2,141	2,141	2,141	2,141

Standard errors are in parentheses. N=13 individuals were excluded since one regional fixed effect predicts preterm perfectly. ***p<0.001, **p<0.01, *p<0.05. Controls are the same variables as in the OLS model (Table 3.1).

Table 3.A.5: OLS estimates (SOEP)

Variables	(1) PT	(2) PT	(3) LBW	(4) LBW	(5) SGA	(6) SGA
Poor Mental Health	0.127***	0.095***	0.097***	0.078***	0.019	0.007
SE	0.024	0.027	0.021	0.023	0.021	0.023
T	5.265	3.531	4.519	3.414	0.909	0.290
P	<0.001	<0.001	<0.001	<0.001	0.363	0.772
CI	0.080 - 0.175	0.042 - 0.147	0.055 - 0.139	0.033 - 0.123	-0.022 - 0.061	-0.039 - 0.053
Poor Physical Health	.	0.046*	.	0.037*	.	-0.002
SE	.	0.020	.	0.016	.	0.019
T	.	2.322	.	2.239	.	-0.082
P	.	0.020	.	0.025	.	0.935
CI	.	. 0.007 - 0.085	.	0.005 - 0.069	.	-0.038 - 0.035
Age Mother	.	0.009	.	0.005	.	-0.011
SE	.	0.012	.	0.010	.	0.016
T	.	0.762	.	0.475	.	-0.704
P	.	0.446	.	0.635	.	0.482
CI	.	-0.014 - 0.031	.	-0.015 - 0.025	.	-0.041 - 0.020
Age Mother^2	.	0.000	.	0.000	.	0.000
SE	.	0.000	.	0.000	.	0.000
T	.	-0.571	.	-0.294	.	0.903
P	.	0.568	.	0.769	.	0.366
CI	.	0.000 - 0.000	.	0.000 - 0.000	.	0.000 - 0.001
Sex	.	0.022	.	0.000	.	-0.017
SE	.	0.013	.	0.010	.	0.014
T	.	1.762	.	-0.019	.	-1.203
P	.	0.078	.	0.985	.	0.229
CI	.	-0.002 - 0.047	.	-0.021 - 0.020	.	-0.045 - 0.011
Twin (multiple birth)	.	0.302***	.	0.454***	.	0.354***
SE	.	0.061	.	0.061	.	0.061
T	.	4.918	.	7.434	.	5.783
P	.	<0.001	.	<0.001	.	<0.001
CI	.	0.181 - 0.422	.	0.334 - 0.574	.	0.234 - 0.474
Previous PT	.	0.076	.	0.037	.	0.065
SE	.	0.042	.	0.028	.	0.039
T	.	1.807	.	1.333	.	1.668
P	.	0.071	.	0.183	.	0.096
CI	.	-0.006 - 0.158	.	-0.018 - 0.092	.	-0.011 - 0.142
Older Sibling	.	-0.033	.	-0.027	.	-0.062***
SE	.	0.018	.	0.014	.	0.019
T	.	-1.807	.	-1.878	.	-3.346
P	.	0.071	.	0.061	.	<0.001
CI	.	-0.069 - 0.003	.	-0.055 - 0.001	.	-0.098 - -0.026
Smoked before pregnancy	.	0.017	.	-0.002	.	0.021
SE	.	0.018	.	0.014	.	0.020
T	.	0.936	.	-0.125	.	1.064
P	.	0.349	.	0.901	.	0.288
CI	.	-0.018 - 0.051	.	-0.028 - 0.025	.	-0.018 - 0.059
Migration background	.	0.010	.	-0.022	.	-0.023
SE	.	0.016	.	0.013	.	0.016
T	.	0.654	.	-1.730	.	-1.435
P	.	0.513	.	0.084	.	0.152
CI	.	-0.021 - 0.041	.	-0.047 - 0.003	.	-0.055 - 0.009
Marital Status	.	0.016	.	0.015	.	-0.013
SE	.	0.014	.	0.012	.	0.016
T	.	1.140	.	1.299	.	-0.763
P	.	0.254	.	0.194	.	0.446
CI	.	-0.012 - 0.044	.	-0.008 - 0.038	.	-0.045 - 0.020
Higher Education	.	-0.008	.	0.001	.	-0.006
SE	.	0.014	.	0.012	.	0.016
T	.	-0.605	.	0.056	.	-0.369
P	.	0.545	.	0.955	.	0.712
CI	.	-0.035 - 0.019	.	-0.022 - 0.024	.	-0.038 - 0.026
Household income (log)	.	-0.030	.	-0.006	.	-0.038
SE	.	0.017	.	0.015	.	0.021
T	.	-1.746	.	-0.402	.	-1.793
P	.	0.081	.	0.688	.	0.073
CI	.	-0.063 - 0.004	.	-0.036 - 0.024	.	-0.080 - 0.004
Homeowner	.	-0.015	.	0.006	.	0.012
SE	.	0.014	.	0.012	.	0.016
T	.	-1.108	.	0.472	.	0.759
P	.	0.268	.	0.637	.	0.448
CI	.	-0.043 - 0.012	.	-0.018 - 0.029	.	-0.020 - 0.044
Household size	.	-0.004	.	-0.015**	.	-0.000
SE	.	0.008	.	0.005	.	0.008
T	.	-0.416	.	-2.700	.	-0.019
P	.	0.677	.	0.007	.	0.985
CI	.	-0.020 - 0.013	.	-0.025 - -0.004	.	-0.016 - 0.016
Year & Federal State		Yes		Yes		Yes
R^2	0.022	0.086	0.018	0.154	<0.001	0.060
N	2,141	2,141	2,141	2,141	2,141	2,141

***p<0.001, **p<0.01, *p<0.05. Controls are the same variables as in the OLS model (Table 3.1).

Table 3.A.6: Mother fixed effects estimates (SOEP)

Variables	(1) PT	(2) PT	(3) LBW	(4) LBW	(5) SGA	(6) SGA
Poor Mental Health	0.097***	0.062***	0.063***	0.046*	0.035	0.048
SE	0.022	0.018	0.018	0.018	0.024	0.026
T	4.370	3.382	3.554	2.501	1.445	1.858
P	<0.001	<0.001	<0.001	0.013	0.149	0.063
CI	0.054 - 0.141	0.026 - 0.098	0.028 - 0.097	0.010 - 0.082	-0.013 - 0.083	-0.003 - 0.100
Poor Physical Health	.	0.014	.	0.022	.	0.001
SE	.	0.016	.	0.016	.	0.023
T	.	0.852	.	1.361	.	0.038
P	.	0.394	.	0.174	.	0.969
CI	.	-0.018 - 0.045	.	-0.010 - 0.054	.	-0.044 - 0.046
Sex	.	0.016	.	-0.001	.	0.007
SE	.	0.011	.	0.011	.	0.016
T	.	1.497	.	-0.116	.	0.453
P	.	0.135	.	0.908	.	0.651
CI	.	-0.005 - 0.038	.	-0.023 - 0.020	.	-0.024 - 0.038
Previous PT	.	-0.745***	.	-0.226***	.	0.061
SE	.	0.026	.	0.026	.	0.037
T	.	-28.436	.	-8.562	.	1.631
P	.	<0.001	.	<0.001	.	0.103
CI	.	-0.796 - -0.694	.	-0.278 - -0.174	.	-0.012 - 0.134
Older Sibling	.	0.045***	.	0.002	.	-0.073***
SE	.	0.010	.	0.010	.	0.015
T	.	4.379	.	0.238	.	-4.917
P	.	<0.001	.	0.812	.	<0.001
CI	.	0.025 - 0.066	.	-0.018 - 0.023	.	-0.102 - -0.044
R^2-adjusted	0.174	0.523	0.253	0.300	0.276	0.289
N	2,119	2,119	2,119	2,119	2,119	2,119

***p<0.001, **p<0.01, *p<0.05. Controls are the same variables as in the mother fixed effect model (Table 3.1).

Table 3.A.7: Matching estimates for treatment effects (SOEP)

Variables	(1) PT	(2) PT	(3) LBW	(4) LBW	(5) SGA	(6) SGA
Poor mental Health	GAU	EPA	GAU	EPA	GAU	EPA
ATE	0.113*	0.144***	0.130**	0.091**	0.031	-0.009
SE	0.057	0.034	0.055	0.036	0.040	0.027
T	1.990	4.230	2.380	2.520	0.780	-0.610
P	0.047	<0.001	0.017	0.012	0.434	0.543
CI	0.002 - 0.224	0.077 - 0.210	0.023 - 0.236	0.020 - 0.162	-0.047 - 0.109	-0.070 - 0.037
ATT	0.086**	0.093**	0.072**	0.065**	0.003	-0.017
SE	0.034	0.029	0.030	0.027	0.025	0.027
T	2.580	3.270	2.420	2.420	0.130	1.300
P	0.010	0.001	0.015	0.016	0.895	0.193
CI	0.021 - 0.152	0.037 - 0.149	0.014 - 0.130	0.012 - 0.118	-0.046 - 0.053	-0.026 - 0.130
Support	1	0.838	1	0.838	1	0.838
N	2,134	2,134	2,134	2,134	2,134	2,134

The table presents matching estimates for the average treatment effect (ATE) and average treatment effect on the treated (ATT) of maternal mental health on our birth outcomes (PT, LBW, and SGA) using the SOEP sample. We matched all covariates presented in Table 3.A.8 as well as survey years and federal states (not indicated in Table 3.A.8). The sample size is different because the mcs scores are added as a covariate to match individuals. Bootstrapped standard errors (100 replications). ***p<0.001, **p<0.01, *p<0.05.

Table 3.A.8: Mean differences before and after matching (SOEP)

	Unbalanced (before matching)			Balanced (after matching)		
Variables	**Poor mental health**	**Good mental health**	**p**	**Poor mental health**	**Good mental health**	**p**
Poor Physical Health						
Gaussian	0.716	0.149	<0.001	0.716	0.716	0.980
Epanechnikov	0.716	0.149	<0.001	0.708	0.708	0.992
Maternal age at birth						
Gaussian	30.829	31.434	0.055	30.829	31.197	0.404
Epanechnikov	30.829	31.434	0.055	30.880	31.608	0.096
(Maternal age at birth)^2						
Gaussian	979.5	1012.9	0.091	979.5	1001.9	0.412
Epanechnikov	979.5	1012.9	0.091	982.4	1025.5	0.113
Sex						
Gaussian	0.528	0.499	0.349	0.528	0.570	0.297
Epanechnikov	0.528	0.499	0.349	0.529	0.562	0.423
Twin (multiple birth)						
Gaussian	0.047	0.029	0.099	0.047	0.048	0.929
Epanechnikov	0.047	0.029	0.099	0.048	0.051	0.883
Previous PT						
Gaussian	0.060	0.036	0.046	0.060	0.052	0.665
Epanechnikov	0.060	0.036	0.046	0.052	0.052	0.965
Older Sibling						
Gaussian	0.652	0.538	<0.001	0.652	0.647	0.899
Epanechnikov	0.652	0.538	<0.001	0.643	0.635	0.857
Smoked before pregnancy						
Gaussian	0.375	0.203	<0.001	0.375	0.396	0.589
Epanechnikov	0.375	0.203	<0.001	0.364	0.387	0.566
Migration background						
Gaussian	0.298	0.232	0.013	0.298	0.292	0.883
Epanechnikov	0.298	0.232	0.013	0.299	0.269	0.426
Marital Status						
Gaussian	0.605	0.632	0.384	0.605	0.605	0.492
Epanechnikov	0.605	0.632	0.384	0.608	0.622	0.737
Higher Education						
Gaussian	0.355	0.518	<0.001	0.355	0.372	0.661
Epanechnikov	0.355	0.518	<0.001	0.364	0.388	0.564
Working hours mother						
Gaussian	32.646	34.512	0.005	32.646	31.475	0.217
Epanechnikov	32.646	34.512	0.005	32.708	31.874	0.380
Household income (log)						
Gaussian	10.321	10.453	<0.001	10.321	10.316	0.890
Epanechnikov	10.321	10.453	<0.001	10.329	10.331	0.939
Homeowner						
Gaussian	0.314	0.352	0.205	0.314	0.316	0.975
Epanechnikov	0.314	0.352	0.205	0.313	0.339	0.505
Household size						
Gaussian	2.990	2.770	0.001	2.990	2.903	0.342
Epanechnikov	2.990	2.770	0.001	2.983	2.893	0.340
mcs						
Gaussian	46.274	49.383	<0.001	46.274	45.584	0.396
Epanechnikov	46.274	49.383	<0.001	46.588	45.738	0.298

T-test for zero mean differences across maternal mental health. The table shows (weighted) means before and after Gaussian and Epanechnikov matching.

Table 3.A.9: OLS Estimates (NEPS)

Variables	(1) PT	(2) PT	(3) LBW	(4) LBW
Poor Mental Health	0.112***	0.093***	0.073***	0.065**
SE	0.022	0.023	0.019	0.021
T	5.141	4.053	3.776	3.030
P	<0.001	<0.001	<0.001	0.002
CI	0.069 - 0.155	0.048 - 0.139	0.035 - 0.112	0.023 - 0.107
Poor Physical Health	.	0.042**	.	0.031*
SE	.	0.016	.	0.016
T	.	2.630	.	2.007
P	.	0.009	.	0.045
CI	.	0.011 - 0.074	.	0.001 - 0.062
Age Mother	.	-0.002	.	-0.004
SE	.	0.004	.	0.005
T	.	-0.560	.	-0.865
P	.	0.576	.	0.387
CI	.	-0.011 - 0.006	.	-0.014 - 0.005
(Age Morther)^2	.	0.000	.	0.000
SE	.	0.000	.	0.000
T	.	0.382	.	0.731
P	.	0.702	.	0.465
CI	.	0.000 - 0.000	.	0.000 - 0.000
Sex	.	0.013	.	-0.004
SE	.	0.011	.	0.011
T	.	1.174	.	-0.402
P	.	0.241	.	0.688
CI	.	-0.009 - 0.036	.	-0.026 - 0.017
Migration background	.	0.000	.	-0.010
SE	.	0.012	.	0.011
T	.	0.033	.	-0.921
P	.	0.974	.	0.357
CI	.	-0.023 - 0.024	.	-0.032 - 0.012
Higher Education	.	0.004	.	0.019
SE	.	0.012	.	0.011
T	.	0.385	.	1.687
P	.	0.700	.	0.092
CI	.	-0.018 - 0.027	.	-0.003 - 0.040
Working hours mother	.	0.000	.	0.000
SE	.	0.001	.	0.001
T	.	-0.269	.	-0.735
P	.	0.788	.	0.463
CI	.	-0.001 - 0.001	.	-0.002 - 0.001
Household income (log)	.	0.019	.	0.037*
SE	.	0.014	.	0.015
T	.	1.300	.	2.495
P	.	0.194	.	0.013
CI	.	-0.010 - 0.047	.	0.008 - 0.065
Homeowner	.	-0.016	.	-0.019
SE	.	0.012	.	0.012
T	.	-1.318	.	-1.619
P	.	0.188	.	0.106
CI	.	-0.039 - 0.008	.	-0.042 - 0.004
Household size	.	-0.004	.	-0.001
SE	.	0.007	.	0.006
T	.	-0.607	.	-0.131
P	.	0.544	.	0.896
CI	.	-0.017 - 0.009	.	-0.013 - 0.011
R^2	0.028	0.035	0.013	0.023
N	1,841	1,841	1,841	1,841

This table presents estimates based on the NEPS data, as described in the article. ***p<0.001, **p<0.01, *p<0.05.

Table 3.A.10: DiD with mcs and birth outcomes (SOEP)

Variables	(1) mcs	(2) mcs	(3) mcs	(4) mcs	(5) mcs	(6) mcs
PT	1.322	1.430	.	.	.	.
SE	0.805	0.774	.	.	.	.
T	1.643	1.847	.	.	.	.
P	0.101	0.065	.	.	.	.
CI	-0.256 - 2.900	-0.088 - 2.948	.	.	.	.
LBW	.	.	-0.353	-0.750	.	.
SE	.	.	0.975	0.982	.	.
T	.	.	-0.362	-0.764	.	.
P	.	.	0.717	0.445	.	.
CI	.	.	-2.265 - 1.559	-2.676 - 1.176	.	.
SGA	.	.	.	.	-0.986	-1.445*
SE	.	.	.	.	0.708	0.719
T	.	.	.	.	-1.392	-2.010
P	.	.	.	.	0.164	0.045
CI	.	.	.	.	-2.375 - 0.403	-2.854 - -0.035
PT * After Birth	-0.187	-0.446	.	.	.	.
SE	1.081	1.026	.	.	.	.
T	-0.173	-0.434	.	.	.	.
P	0.863	0.664	.	.	.	.
CI	-2.305 - 1.932	-2.457 - 1.566	.	.	.	.
LBW * After Birth	.	.	-0.094	-0.309	.	.
SE	.	.	1.353	1.355	.	.
T	.	.	-0.069	-0.228	.	.
P	.	.	0.945	0.820	.	.
CI	.	.	-2.747 - 2.559	-2.965 - 2.348	.	.
SGA * After Birth	.	.	.	.	1.186	1.538
SE	.	.	.	.	0.971	0.969
T	.	.	.	.	1.222	1.588
P	.	.	.	.	0.222	0.112
CI	.	.	.	.	-0.718 - 3.089	-0.361 - 3.438
After Birth	0.926**	-0.229	0.898**	-0.270	0.736*	-0.458
SE	0.354	0.605	0.346	0.603	0.360	0.609
T	2.619	-0.378	2.593	-0.448	2.046	-0.752
P	0.009	0.705	0.010	0.655	0.041	0.452
CI	0.233 - 1.620	-1.415 - 0.957	0.219 - 1.577	-1.452 - 0.912	0.031 - 1.441	-1.653 - 0.736
pcs	-0.141***	-0.133***	-0.143***	-0.137***	-0.143***	-0.135***
SE	0.027	0.027	0.027	0.027	0.027	0.027
T	-5.190	-4.871	-5.259	-4.974	-5.265	-4.954
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CI	-0.194 - -0.088	-0.187 - -0.080	-0.197 - -0.090	-0.191 - -0.083	-0.196 - -0.090	-0.189 - -0.082
Age Mother	.	-1.024***	.	-1.022***	.	-1.036***
SE	.	0.227	.	0.227	.	0.227
T	.	-4.509	.	-4.504	.	-4.566
P	.	<0.001	.	<0.001	.	<0.001
CI	.	-1.469 - -0.579	.	-1.466 - -0.577	.	-1.481 - -0.591
Age Mother^2	.	0.015***	.	0.015***	.	0.015***
SE	.	0.003	.	0.003	.	0.003
T	.	4.732	.	4.733	.	4.797
P	.	<0.001	.	<0.001	.	<0.001
CI	.	0.009 - 0.021	.	0.009 - 0.021	.	0.009 - 0.022
Sex	.	-0.950**	.	-0.938**	.	-0.950**
SE	.	0.328	.	0.328	.	0.328
T	.	-2.901	.	-2.856	.	-2.894
P	.	0.004	.	0.004	.	0.004
CI	.	-1.593 - -0.308	.	-1.582 - -0.294	.	-1.594 - -0.306
Twin (multiple birth)	.	0.184	.	0.989	.	0.724
SE	.	1.115	.	1.149	.	1.115
T	.	0.165	.	0.861	.	0.649
P	.	0.869	.	0.389	.	0.516
CI	.	-2.002 - 2.370	.	-1.264 - 3.243	.	-1.463 - 2.911
Previous PT	.	2.565***	.	2.690***	.	2.687***
SE	.	0.731	.	0.728	.	0.727
T	.	3.510	.	3.693	.	3.695
P	.	<0.001	.	<0.001	.	<0.001
CI	.	1.132 - 3.998	.	1.262 - 4.118	.	1.261 - 4.113
Older Sibling	.	-0.948*	.	-1.045**	.	-1.051**
SE	.	0.403	.	0.403	.	0.404
T	.	-2.352	.	-2.590	.	-2.604
P	.	0.019	.	0.010	.	0.009
CI	.	-1.739 - -0.158	.	-1.836 - -0.254	.	-1.843 - -0.260

Table 3.A.10: DiD with mcs and birth outcomes (SOEP) (cont.)

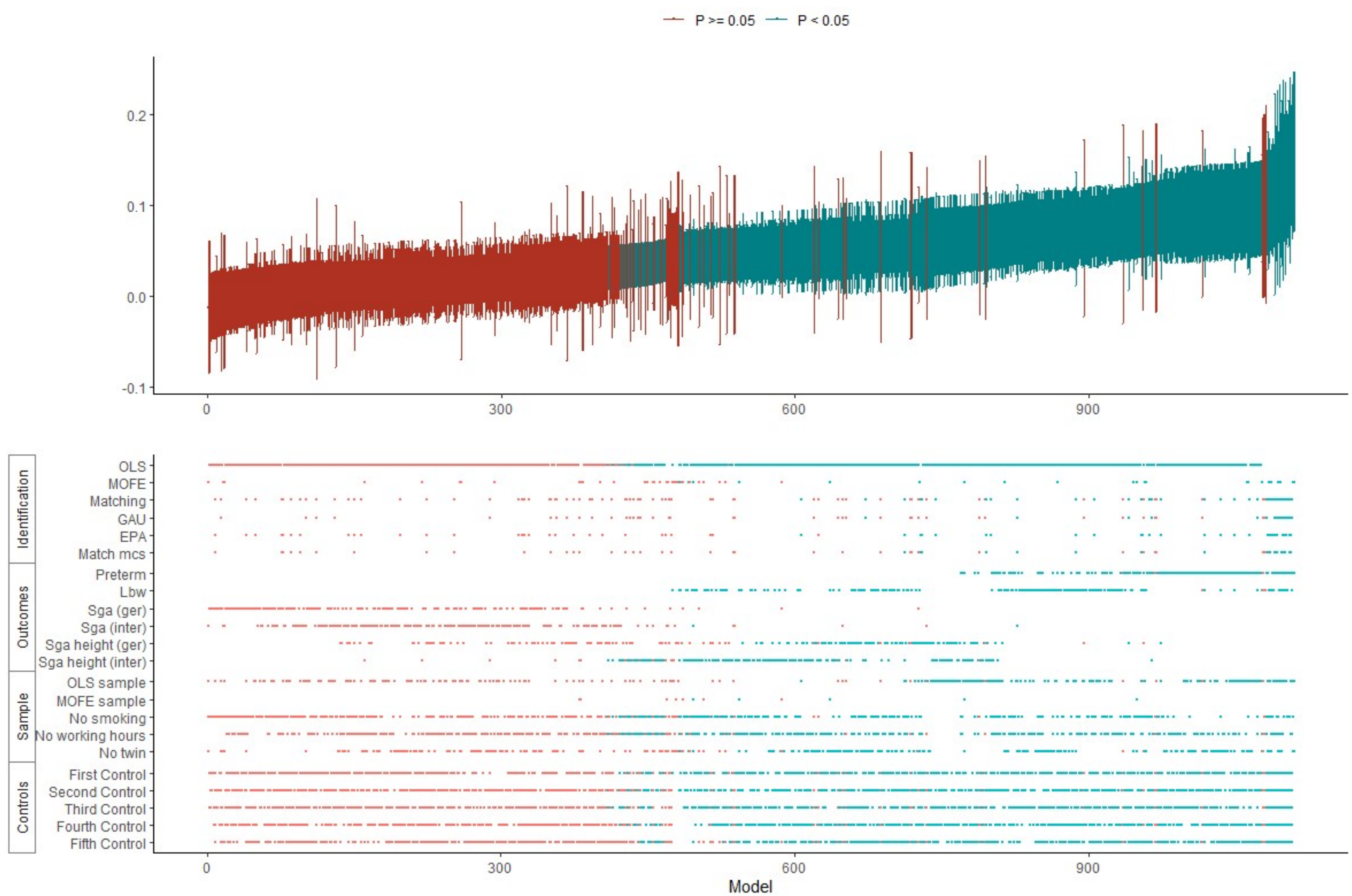
Variables	**(1) mcs**	**(2) mcs**	**(3) mcs**	**(4) mcs**	**(5) mcs**	**(6) mcs**
Smoked before pregnancy	.	-0.551	.	-0.519	.	-0.511
SE	.	0.395	.	0.396	.	0.396
T	.	-1.392	.	-1.312	.	-1.291
P	.	0.164	.	0.190	.	0.197
CI	.	-1.326 - 0.225	.	-1.295 - 0.257	.	-1.287 - 0.265
Migration background	.	0.958	.	0.946	.	0.940
SE	.	0.497	.	0.500	.	0.499
T	.	1.929	.	1.892	.	1.883
P	.	0.054	.	0.059	.	0.060
CI	.	-0.016 - 1.932	.	-0.034 - 1.926	.	-0.039 - 1.919
Marital Status	.	1.402***	.	1.418***	.	1.408***
SE	.	0.415	.	0.418	.	0.416
T	.	3.374	.	3.395	.	3.386
P	.	0.001	.	0.001	.	0.001
CI	.	0.587 - 2.216	.	0.599 - 2.237	.	0.593 - 2.224
Higher Education	.	-0.068	.	-0.144	.	-0.114
SE	.	0.360	.	0.359	.	0.359
T	.	-0.188	.	-0.402	.	-0.316
P	.	0.851	.	0.688	.	0.752
CI	.	-0.774 - 0.639	.	-0.849 - 0.560	.	-0.818 - 0.590
Working hours mother	.	-0.031*	.	-0.030*	.	-0.029
SE	.	0.015	.	0.015	.	0.015
T	.	-2.045	.	-1.981	.	-1.910
P	.	0.041	.	0.048	.	0.056
CI	.	-0.062 - -0.001	.	-0.061 - 0.000	.	-0.060 - 0.001
Household income (log)	.	2.041***	.	2.081***	.	2.058***
SE	.	0.429	.	0.429	.	0.429
T	.	4.759	.	4.855	.	4.802
P	.	<0.001	.	<0.001	.	<0.001
CI	.	1.200 - 2.882	.	1.241 - 2.921	.	1.218 - 2.898
Homeowner	.	-0.544	.	-0.583	.	-0.557
SE	.	0.373	.	0.373	.	0.373
T	.	-1.457	.	-1.561	.	-1.494
P	.	0.145	.	0.119	.	0.135
CI	.	-1.277 - 0.188	.	-1.315 - 0.149	.	-1.288 - 0.174
Household size	.	-0.300	.	-0.326	.	-0.315
SE	.	0.238	.	0.238	.	0.237
T	.	-1.262	.	-1.366	.	-1.327
P	.	0.207	.	0.172	.	0.185
CI	.	-0.766 - 0.166	.	-0.793 - 0.142	.	-0.780 - 0.150
Year & Federal State		Yes		Yes		Yes
$\mathbf{R^2}$	0.017	0.073	0.015	0.072	0.016	0.073
N	3,123	3,123	3,123	3,123	3,123	3,123

The table shows DiD estimates for the relationship between preterm birth and the mcs score of the mother after birth using the SOEP sample. We only included births with at least one non-missing maternal mcs score before and after birth. All models also include the physical health component score (pcs) as a control variable (not indicated below). Robust standard errors in parenthesis. ***p<0.001, **p<0.01, *p<0.05.

Table 3.A.11: Samples, controls, outcomes and methods for the specification curve analysis

Controls	
First_Control	• Maternal smoking • Region and year fixed effects
Second_Control	• Sex (child) • Maternal age at birth (and squared)
Third_Control	• Average maternal working hours before birth • Logarithmic average household income before birth • Higher education (mother)
Fourth_Control	• Marital status (mother) • Indirect migration background • Homeownership • Household size
Fifth_Control	• Older Sibling • Preterm Sibling • Twin/multiple birth
Outcomes	
Birth Outcomes	• Preterm birth (preterm) • Low birth weight (lbw) • Low birth weight for gestational age (German standard) (sga_ger) • Small for gestational age (German standard) (sga_height_ger) • Low birth weight for gestational age (intergrowth standard) (sga_inter) • Small for gestational age (intergrowth standard) (sga_height_inter)
Sample	
General samples	• Sample excluding all missing values (OLS_sample) • Sample excluding all missing values except of maternal smoking (no_smoking) • Sample excluding all missing values except of maternal working hours (no_working_hours) • Sample excluding all twin/multiple birth observations (no_twins)
MOFE sample	• Sample excluding all children without siblings and multiple births used for mother fixed effects models. (MOFE_sample)
Identification	
OLS	• Linear regression model
MOFE	• Mother fixed effect model
Matching	• Gaussian matching (GAU) • Epanechnikov matching (EPA) • Both matched with mcs score (mcs) before birth and without

Figure 3.A.2: Specification curve



The upper Panel shows point estimates and their respective 95% confidence intervals for the different models described below the table. Estimates are ordered from the smallest to the largest. Confidence intervals are calculated using heteroscedasticity robust standard errors.

4 Preschool skills and educational attainment in preterm-born adolescents

Authors' contributions

The following chapter is based on an article, which is joint work with Nicole Baumann, Eero Kajantie, Dieter Wolke, Hayley Trower, Ayten Bilgin, Eero Kajantie, Katri Räikkönen, Kati Heinonen, Daniel Schnitzlein, and Sakari Lemola, which is currently published as Baumann, N., Voit, F., Wolke, D., Trower, H., Bilgin, A., Kajantie, E., Räikkönen, K., Heinonen, K., Schnitzlein, D. D., & Lemola, S. (2023). Preschool Mathematics and Literacy Skills and Educational Attainment in Adolescents Born Preterm and Full Term. *The Journal of Pediatrics*, 113731. The authors' contributions toward the article are as follows:

- Statistical analysis: Methods and computing - Falk Voit, Nicole Baumann
- Literature research - Falk Voit, Nicole Baumann
- Writing first draft - Falk Voit, Nicole Baumann
- Revision - Falk Voit, Nicole Baumann, Eero Kajantie, Dieter Wolke, Hayley Trower, Ayten Bilgin, Eero Kajantie, Katri Räikkönen, Kati Heinonen, Daniel Schnitzlein and Sakari Lemola
- Supervision - Falk Voit, Nicole Baumann, Sakari Lemola

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Abstract

The objective of this chapter is to test whether preschool academic skills were associated with educational attainment in adolescence and whether associations differed between preterm- and term-born individuals.

This prospective cohort study comprised 6,924 individuals, including N=444 (6.4%) adolescents born preterm (<37 weeks of gestation, mostly 32-36 weeks of gestation) from the Avon Longitudinal Study of Parents and Children (ALSPAC). Preschool academic (Mathematics and Literacy) skills were rated by teachers at 4-5 years. Educational attainment at

16 years was informed by attaining a General Certificate of Secondary Education (GCSE) in key subjects Mathematics and English.

Logistic regressions assessed the association between preterm birth, preschool Mathematics and GCSE Mathematics, and between preterm birth, preschool Literacy and GCSE English. Similar numbers of preterm and term-born adolescents achieved a GCSE in Mathematics and English (53.6% vs. 57.4% and 59.5% vs. 63.9%, respectively; $p>0.05$). Higher preschool academic skill scores in Mathematics were associated with greater odds of attaining GCSE Mathematics, and preschool Literacy skills were associated with GCSE English. Adolescents born preterm with higher preschool Mathematics (OR 1.51, CI: 1.14, 2.00) and Literacy skills (OR 1.57, CI: 1.10, 2.25) were more likely to attain GCSEs in the respective subject than their term-born counterparts with equal levels of preschool skills. Preschool academic skills in Mathematics and Literacy are associated with the educational attainment of preterm- and term-born individuals in adolescence. Children born prematurely may benefit more from preschool Mathematics and Literacy skills for academic and educational success into adolescence than term-born individuals.

4.1 Introduction

Mathematical and reading difficulties in childhood can have far-reaching consequences into adult life and negatively influence educational attainment, earnings, wealth, and health (Basten et al., 2015; Crawford & Cribb, 2013; Desjardins et al., 2006; Nomura et al., 2009; OECD, 2017). Compared with their term-born peers, children born preterm (<37 weeks of gestation) are at an increased risk for learning difficulties and poorer academic attainment at school age, particularly in domains such as Mathematics and Reading (Aarnoudse-Moens et al., 2009; Allotey et al., 2018; de Jong et al., 2012; Martínez-Nadal & Bosch, 2020; McBryde et al., 2020; O'Nions et al., 2021; Quigley et al., 2012; Simms et al., 2013; Trickett et al., 2021; Twilhaar et al., 2018). Children born preterm and especially those born before 32 weeks of gestation (very preterm birth) are at increased risk for general cognitive difficulties that can co-occur with other neuropsychological processes, including executive function, attention, visual-spatial skills, and working memory, which have all been shown to be associated with learning difficulties in both Mathematics and Reading (Allen et al., 2019; Figlio et al., 2014; Johnson et al., 2016; Johnson et al., 2011; Mulder et al., 2010; Simms et al., 2013; Trickett et al., 2022; Twilhaar et al., 2020). Given the rising number of preterm births (Chawanpaiboon et al., 2019), there is an increasing need to provide education professionals with information and guidance allowing them to adequately support preterm children in their educational and academic needs (Johnson et al., 2015).

The years before formal schooling are important in a child's development. Early iden-

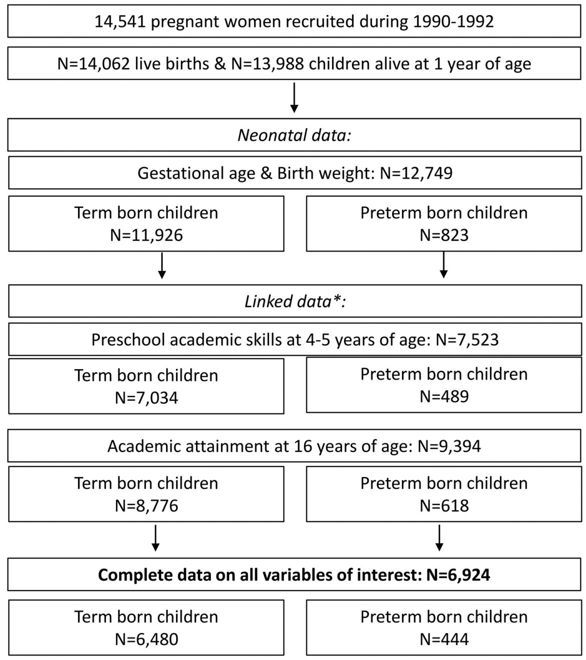
tification of academic weaknesses before formal schooling, early educational programmes and early intervention can positively affect children's cognitive and socio-emotional skills that are important for their medium- to long-term educational achievement and life outcomes (Duncan et al., 2007; Hasler & Akshoomoff, 2019). This is particularly true for those from disadvantaged backgrounds (Currie, 2001; Heckman, 2006; Heckman et al., 2013; McCormick et al., 2006; Melhuish, 2011; OECD, 2018; Sammons, 2010a, 2010b). There is evidence that school readiness and better early academic skills are associated with improvements in later academic and educational outcomes as well as with economic and societal advancement (Duncan et al., 2007; Heckman, 2006; Romano et al., 2010). However, studies that investigate the long-term associations between preschool academic skills and adolescent educational achievement in preterm populations are scarce.
Although preterm-born children have an elevated risk for learning problems and are less likely to achieve good grades in school compared with term-born peers, we hypothesised that good preschool Mathematics and Literacy skills would be associated with educational success in adolescence. The aim of this study was to investigate whether preschool academic skills in Mathematics and Literacy were associated with decreased risks of preterm birth on educational attainment in adolescence and to test whether associations between preschool academic skills and later educational attainment differ between preterm and term-born individuals. The study utilised data from a large nationally representative prospective cohort study in the United Kingdom with data on preterm birth status (i.e., gestational age) and with record linkage data on preschool Mathematics and Literacy abilities, and educational attainment in adolescence (i.e., the General Certificate of Secondary Education, GCSEs).

4.2 Methods

The current study used data from a large prospective longitudinal study, the Avon Longitudinal Study of Parents and Children (ALSPAC). ALSPAC recruited 14,541 pregnant women with expected delivery dates of April 1st, 1991 to December 31st, 1992. Of the initial pregnancies, there were 14,676 foetuses, resulting in 14,062 live births; 13,988 children were alive at 1 year of age (Boyd et al., 2013; Fraser et al., 2013).
Ethical approval was obtained from the ALSPAC Ethics and Law committee and the Local Research Ethics Committees (NHS Haydock REC: 10/H1010/70). Informed consent for the use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time. From the first trimester of pregnancy, parents completed postal questionnaires about themselves and the study child. Children were invited to annual assessment clinics, including face-to-face interviews, and psychological and physical tests from 7 years onwards. At age

18, study children were sent 'fair processing' materials describing ALSPAC's intended use of their health and administrative records and were given clear means to consent or object via a written form. Data were not extracted for participants who objected, or who were not sent fair processing materials. The study website contains details of all data available through a fully searchable data dictionary and variable search tool:
(http://www.bristol.ac.uk/alspac/researchers/our-data/)
We study two independent variables of interest, which are preterm birth and preschool skills. Information on gestational age was based on maternal reports of the last menstrual period. The first variable of interest is preterm birth, which was defined as birth at less than 37 weeks of gestation.
Teachers rated children's preschool academic skills in the first half of their first term in reception class, at ages 4 to 5 years. The Early Years Foundation Stage Profile and its predecessors were not in place at the time. However, a working group of heads, teachers, early-year advisers, and educational psychologists within the Local Education Authorities in the Avon area had developed a baseline observational assessment carried out by reception class teachers (Duckworth & Schoon, 2010; Meadows et al., 2007; Roulstone et al., 2011). Children were rated on a scale from two to seven on Mathematics, Reading, and Writing abilities, with higher scores indicating better skills. Scores for ALSPAC participants were obtained through parent-consented record linkage, which were available for 68% of children alive at 1 year of age (Chittleborough et al., 2014). For the current study, Reading and Writing scales were combined into a mean Literacy score. As a result, two preschool academic skill scores were available for the analyses: Mathematics and Literacy. Preschool skills are treated as continuous variables in the analyses.
The outcome variables studied are educational attainment at age 16 in the core subjects Mathematics and English. In the UK, the General Certificate of Secondary Education (GCSE) is the main qualification taken by the majority of pupils at age 16 when they complete the first stage of secondary school education (Key Stage 4). Data were obtained through linkage to the National Pupil Database (NPD) for England and were identified for 84% of children alive at 1 year (Chittleborough et al., 2014). The GCSE examinations include Mathematics, English, and additional subjects (Department for Education, 2017, 2018). Information on whether an adolescent achieved a passing grade (A*-C) in GCSE in Mathematics and English (i.e., passing grades that are considered a pre-requisite for advanced-level education and subsequent university access in the UK) was coded: 0 = no and 1 = yes, respectively.
Longitudinal data on all variables of interest were available for 6,924 participants (see Figure 4.1).

Figure 4.1: ALSPAC flow chart



The flow chart visualises of the ALSPAC data used in the main analyses. *Linked preschool and school data were available for 68% and 84% of children alive at 1 year of age, respectively.

Based on their association with the variables of interest (i.e., either preterm birth, early academic skills, or educational attainment), a number of covariates were considered (shown in Tables 4.1 and 4.A.1) (Alterman et al., 2022; Bornstein & Putnick, 2012; Jeong et al., 2017).

These covariates were child sex, child general health and development (milestones) (derived from the Denver Developmental Screening Test (Frankenburg & Dodds, 1967)), as well as the number of books owned by the child at age 18 months. Further covariates considered were child cognitive function (communicative and intelligibility; developed and adapted by the ALSPAC study team) at 38 months, child emotional, hyperactivity, conduct difficulties, and prosocial behaviour (derived from the Revised Rutter Parent Scale for Preschool Children (Elander & Rutter, 1996)) at 42 months, and child IQ (Wechsler Intelligence Scale for Children, WISC-III (Wechsler et al., 1992)) at age 8 years. Parent-related or social-environmental covariates included maternal smoking during pregnancy, marital status, breastfeeding, maternal and paternal age, maternal and paternal educational and occupational status, and parents' income. Group differences for covariates are presented in Tables 4.1 and 4.A.1. All analyses were conducted in Stata 16. Group differences were tested with chi-square tests for categorical variables and t-tests for continuous variables.

Associations between preschool academic skills and GCSEs in adolescence were tested using two separate logistic regression analyses: A) preschool Mathematics skills and GCSE Mathematics, and B) preschool Literacy skills and GCSE English. In the regression analysis, we also control for missing information in the covariates. To achieve this, we transformed all (quasi-)linear control variables coded into quintiles (categorical variables), which enabled us to include missing information as a separate category.

Table 4.1: Sample characteristics (ALSPAC)

	Term	**Preterm**	
	N=6,480	N=444	
	mean (SD) or %	mean (SD) or %	P-value
Neonatal/neurosensory variables			
Gestational age	39.52 (1.16)	34.40 (2.30)	<0.001
Birth weight	3436 (484)	2403 (627)	<0.001
Sex (male)	49.9%	57.7%	0.001
Predictors at preschool age			
Preschool academic skills			
Mathematics	5.30 (1.09)	5.01 (1.04)	<0.001
Literacy	4.99 (0.78)	4.86 (0.79)	<0.001
Outcomes in adolescents			
Educational achievement (GCSE)			
Mathematics	57.4%	53.6%	0.12
English	63.9%	59.5%	0.06

GCSE describes the achievement of a General Certificate of Secondary Education at age 16. Preschool skills are measured at the age of 4 to 5 years. N=6,924.

First, we tested associations between preschool academic skills and GCSEs in adolescence within preterm and term-born participants, separately. Second, we applied stepwise hierarchical logistic regression models to examine whether educational attainment (i.e., GCSEs in Mathematics and English) in adolescence was explained by preterm birth and preschool academic skills (i.e., Mathematics and Literacy) (model 1). To test whether the effect of preschool academic skills on achieved GCSEs was different between preterm and term-born adolescents, an interaction term 'preterm birth * preschool academic skills' was added to each of the two models A and B (model 2). In a final step, both regression models were adjusted for all covariates. Including both the matrix of control variables and the interaction term, the logit models we consider could be described with the following expression:

$$P(GCSE_i = 1|A = a_i) = F(\beta_0 + \beta_1 PT_i + \beta_2 S_i + \beta_3 (S_i * PT_i) + X_i \beta_4) \quad (4.1)$$

Given this model, $P(GCSE_i = 1|A = a_i)$ describes the probability of individual i to achieve a GCSE given the variables of interest, the interaction term, and a matrix of control variables, which all together are denoted by $A = a_i$. The variable PT_i is the indicator for preterm birth, S_i captures preschool skills, and X_i reflects the matrix of control variables described previously. In addition to that, model 2 also includes the interaction term 'preterm birth * preschool academic skills' ($S_i * PT_i$).
To infer the robustness of the results from the main analysis, we carried out three sets of sensitivity analyses. First, logistic regression models were repeated, excluding participants with neurosensory (i.e., visual, hearing, or learning (IQ<3SD)) impairments (N=41). Second, given that Mathematics and Literacy skills have been found to be correlated (Crawford & Cribb, 2013; Duncan et al., 2007), we repeated the main regression models for GCSE Mathematics and GCSE English and included both preschool Mathematics and preschool Literacy skills in each of the models. And third, as only 68% of the data on preschool Mathematics and Literacy skills and 84% of the school data were linked to the ALSPAC sample data, we carried out attrition analyses and performed multiple data imputation by chained equation (MICE) (Azur et al., 2011; van Buuren, 2007; White et al., 2011). Based on the sample with neonatal data (i.e., gestational age and birth weight) available for children alive at age 1 year (N=12,749; Figure 4.1), missing data were imputed on the outcomes (GCSE Mathematics and English), main predictors (preschool Mathematics and Literacy skills), and covariates.

4.3 Results

The group differences for the main predictors and outcome variables are presented in Table 4.1. As per the definition, preterm-born participants had a lower gestational age and birth weight (p<0.001). There were group differences in the distribution of sex, with preterm-born adolescents being more often of male sex (p=0.001). Compared with their term-born counterparts, preterm-born adolescents had lower preschool academic skill scores (all p<0.001). Similarly, the percentage of adolescents born preterm that achieved GCSEs was slightly lower than in term-born adolescents but did not reach statistical significance (p=0.06 to p=0.16 for Mathematics and English, respectively).
In terms of covariates (see Table 4.A.1), preterm-born children had a lower developmental score (p<0.001) and owned fewer books (p=0.001) at age 18 months. At age 38 months, preterm children had a lower intelligibility score (p=0.029) but a higher communicative (p=0.032) score, and at age 42 months, they had a lower prosocial score (p=0.014) compared to term-born children. Regarding social-environmental covariates, preterm children were less likely to have been breastfed (p=0.013). Furthermore, compared to parents of term-born children, fathers of preterm children were younger (p=0.007) and had a

lower social status (p=0.004), and mothers had achieved a lower educational attainment (p=0.009).

Table 4.2: Unadjusted and adjusted associations between preschool academic skills and GCSEs in adolescence

	A) GCSE Mathemathics Odds Ratio (95% CI)		**B) GCSE English Odds Ratio (95% CI)**	
Unadjusted models	Model 1	Model 2	Model 1	Model 2
Preterm birth	1.07 (0.88, 1.31)	0.14** (0.04, 0.57)	0.95 (0.77, 1.16)	0.11* (0.02, 0.61)
Preschool Mathematics	2.30*** (2.18, 2.43)	2.25*** (2.13, 2.39)	.	.
Interaction	.	1.51** (1.14, 2.00)	.	.
Preschool Literacy	.	.	3.48*** (3.21, 3.77)	3.39*** (3.12, 3.68)
Interaction	.	.	.	1.57* (1.10, 2.25)
Pseudo R^2	0.117	0.119	0.128	0.129
Adjusted models	Model 1	Model 2	Model 1	Model 2
Preterm birth	1.15 (0.92, 1.44)	0.19* (0.05, 0.83)	1.16 (0.92, 1.47)	0.09* (0.01, 0.64)
Preschool Mathematics	1.83*** (1.72, 1.95)	1.80*** (1.69, 1.92)	.	.
Interaction	.	1.43* (1.07, 1.93)	.	.
Preschool Literacy	.	.	2.38*** (2.17, 2.61)	2.30*** (2.10, 2.53)
Interaction	.	.	.	1.73** (1.14, 2.63)
Pseudo R^2	0.232	0.233	0.260	0.260

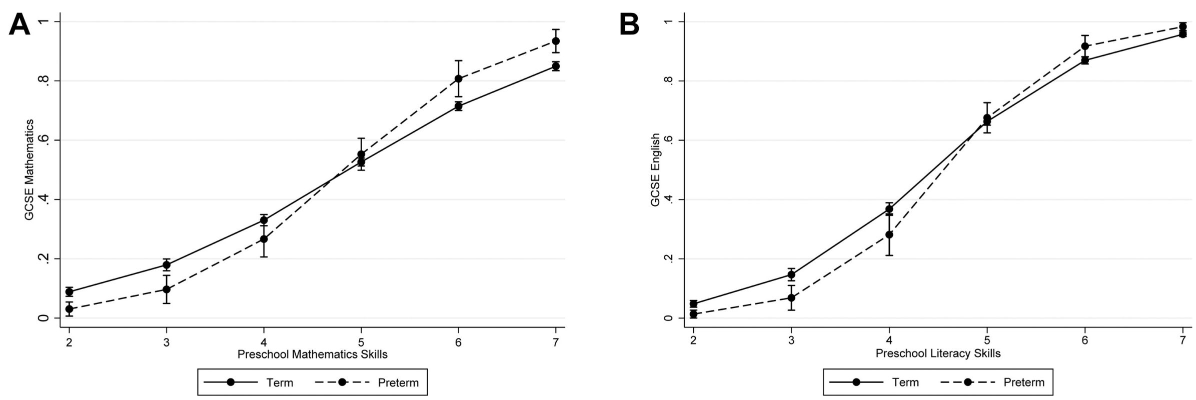
Adjusted for all covariates (child-related variables: child sex, child health, and developmental status at 18 months, books owned by the child at 18 months, the child's cognitive function (intelligibility, communication) at 38 months, child emotional, hyperactivity, conduct difficulties, and prosocial behaviour at 42 months, and child intelligence at 8 years; parent-related and social-environmental variables: breastfeeding, maternal and paternal age, maternal mental health, marital status, maternal and paternal educational attainment, employment status, and social status). N=6,924. ***p<0.001, **p<0.01, *p<0.05.

The results of the stepwise logistic regression analyses for both models, i.e., preschool Mathematics skills and attainment of GCSE Mathematics, and preschool Literacy skills and attainment of GCSE English, are presented in Table 4.2.

Model 1 shows that preterm birth was not associated with the attainment of a GCSE (short for A*-C GCSE) in Mathematics (OR: 1.07, 95% CI: 0.88-1.31) in adolescence. However, all individuals with higher preschool Mathematics scores were twice as likely to attain a GCSE in Mathematics (OR: 2.30, 95% CI: 2.18-2.43) compared to adolescents with lower preschool skill scores. Adding the interaction term 'preterm birth * preschool Mathematics skills' showed that children born preterm who achieved higher Mathematics skill scores in preschool were more likely to achieve a GCSE in Mathematics than term-born adolescents with similar preschool Mathematics scores (OR: 1.51, 95% CI: 1.14-2.00, Table 4.2 and Figure 4.2, Panel A). None of these associations changed significantly in adjusted models (see Table 4.2). Additional examinations within birth groups showed that term-born adolescents with higher preschool Mathematics skills were twice as likely to achieve a GCSE in Mathematics (OR: 2.25, 95% CI: 2.13-2.39). Within preterm-born individuals, this association increased to a three-fold higher likelihood (OR: 3.40, 95% CI: 2.58-4.48).

As with GCSE Mathematics, preterm birth was not associated with GCSE English (OR: 0.95, 95% CI: 0.77-1.16), but preschool Literacy skills were positively associated with a GCSE in English (OR: 3.48, 95% CI: 3.21-3.77). Again, adding the interaction term 'preterm birth * preschool Literacy skills' showed a significant association with GCSE in English (OR: 1.57, 95% CI: 1.10-2.25), indicating that adolescents born preterm who had higher preschool Literacy skill scores had a greater chance of attaining a GCSE in English, compared to term-born peers with equal preschool skill scores (see Figure 4.2, Panel B). All effects remained significant after adjusting for covariates (see Table 4.2). Within-group analysis showed that term-born children with higher preschool Literacy skills were three times more likely to achieve a GCSE in English (OR: 3.39, 95% CI: 3.12-3.68). In contrast, preterm-born individuals were five times more likely to achieve a GCSE in English (OR: 5.32, 95% CI: 3.76-7.53).

Figure 4.2: Preschool skills, preterm birth and educational achievement



The figures show the association between preschool skills and the probability of passing the GCSE for preterm-born and term-born individuals.

4.4 Sensitivity analyses

In order to assess whether neurosensory impairment influenced the associations between preschool skills, educational attainment in adolescence, and birth status, we omitted participants with neurosensory impairment. The results for both regression models did not change substantially (see Table 4.A.2).

As preschool Mathematics and Literacy skills were correlated (r=0.63, p<0.001), a second set of sensitivity analyses was carried out with both preschool academic skill variables, i.e., Mathematics and Literacy (see Table 4.A.3) included in each of the regression models. Again, the results of the models changed only marginally (see Table 4.2).

Finally, the attrition analysis (see Table 4.A.4) based on the sample with neonatal data (i.e., gestational age and birth weight) available for children alive at age 1 year (N=12,749; Figure 4.1) showed that adolescents born preterm who were not included in the complete case analysis were born at lower gestational age and birth weight compared to those included ($p=0.008$ and $p=0.01$, respectively). In the group of term-born adolescents, males were more likely not to have been included in the complete case analysis ($p=0.004$), and term-born adolescents that were lost to attrition were more likely to achieve a GCSE in Mathematics and in English compared to those with complete data ($p<0.001$). Repeating the regression models with multiple imputed data (see Table 4.A.5) showed that the main effects of preterm birth and preschool Mathematics skills on GCSE Mathematics and preschool Literacy on GCSE English were similar in their magnitude compared to the results of the main analyses (Table 4.2).

However, while the interaction term 'preterm birth * preschool Mathematics skills' remained statistically significant in the unadjusted model (OR: 1.28, 95% CI: 1.00-1.64), it was no longer significant after adjusting for covariates (OR: 1.25, 95% CI: 0.99-1.59). In contrast, the interaction term 'preterm birth * preschool Literacy skills' was not significantly associated with GCSE English, neither in the unadjusted (OR: 1.30, 95% CI: 0.84-2.00) nor in the adjusted model (OR: 1.36, 95% CI: 0.79-2.35). Both of these findings are mainly explained by the fact that term-born individuals excluded from the main analyses were more likely to attain GCSEs in adolescence.

4.5 Discussion

The findings of this study show that higher levels of preschool Mathematics and Literacy skills are associated with an improved likelihood of achieving educational qualifications (i.e., GCSEs in Mathematics and English) in adolescence. Preterm birth was associated with lower preschool academic skills in Mathematics and Literacy, but not with educational achievement at 16 years. Although preterm birth was not directly associated with educational attainment in adolescence, the findings of the current study demonstrate that children born preterm with higher preschool academic skill scores are more likely to achieve GCSEs in Mathematics and English than term-born individuals with the same level of preschool skills. Notably, these associations were independent of important covariates, including family socioeconomic status and child intelligence.

In accordance with previous work, the findings of this study demonstrate that preschool academic skills such as early Mathematics and Literacy skills have long-lasting benefits for educational attainment and academic success (Heckman, 2006; Sammons, 2010a). Confirming the findings of previous work (Allotey et al., 2018; de Jong et al., 2012; McBryde et al., 2020; Twilhaar et al., 2018), the current study showed that prematurity is associated with preschool academic skills, though an association between prematurity and educational achievement in adolescence could not be replicated. However, importantly, the current study detected a positive association between the interaction term 'preterm birth by preschool skill' and educational attainment. This suggests that, compared with their term-born counterparts, preterm-born individuals with higher levels of early academic skills in Mathematics and Literacy are more likely to accomplish important educational qualifications in adolescence. In other words, adolescents born preterm who accomplish higher levels of preschool skills benefit disproportionately in regard to later educational attainment, compared with term-born individuals who have achieved equal levels of preschool academic skills. This may suggest that preterm children may be more sensitive to positive environmental influences such as preschool education than those born term, as proposed by theories of differential susceptibility or vantage sensitivity (Ellis et al., 2011; Jaekel et al., 2014; Lionetti et al., 2018). Considering this finding, it may be speculated that individuals born very preterm might benefit equally or more from higher preschool academic skills compared with moderate to late preterm and term-born adolescents. However, we could not explore this possibility due to the small number of very preterm-born participants in the current study (n=47). Further, it is important to note that the magnitude of the tested associations did not change when we included Mathematics and Literacy in the same model as a sensitivity analysis. This suggests that both Mathematics and Literacy skills seem to be important core subjects for the academic attainment of children born preterm.

Prior evidence suggests that children born preterm not only have more academic difficulties than their term-born peers (Hasler & Akshoomoff, 2019; McBryde et al., 2020), but these difficulties also seem to persist into employment in adulthood (Allotey et al., 2018; Kovachy et al., 2015; Twilhaar et al., 2019). Therefore, early learning programmes, such as provisions of preschool education, that are tailored to the educational needs of children born preterm may be important in ensuring their academic success. Together with the rising number of preterm children worldwide (Chawanpaiboon et al., 2019) and the widening gap between preterm and term-born children in their academic performance over the past two decades (Cheong et al., 2017), fostering the early academic skills of preterm children, in particular Mathematics and Literacy skills, may be an important strategy to support these children and their families and enhance the long-term educational success and life chances of children born preterm (Jaekel et al., 2022).

The findings of this study may be of particular interest to parents, education professionals, and policymakers regarding the learning needs of children born preterm. Further, the findings may inform planning and setting up effective preschool programmes. Early education and preschool programmes for children born preterm may enhance learning in core school subjects and developmental outcomes, foster social participation, and improve their academic and educational proficiency. These may positively influence later well-being and success in education and employment (Melhuish, Sylva et al., 2008). However, it is not just the provision of preschool or early learning programmes that matters. Attendance, duration, and the quality of preschool provision have been found to be important factors that can influence the impact of early learning and education on children's later academic outcomes (OECD, 2018).

Other social environmental factors that directly or indirectly affect early learning, academic performance, and education are parent education and socioeconomic status, the home learning environment, cognitive and non-cognitive stimulation, and parenting behaviour (Breslau et al., 2004; Davis-Kean, 2005; Han et al., 2023; Heckman, 2006; Neel et al., 2018; OECD, 2020; Treyvaud et al., 2016; van Houdt et al., 2019; Wolke et al., 2013). In addition to these social-environmental provisions, it is important to foster motivation, interest, and enjoyment in early learning, as this can influence later learning, educational achievement, and wealth, independent of cognitive ability (Heckman, 2006; OECD, 2004). More research is needed to identify specific environmental and medical factors and to understand the role and association of these factors with early academic skills and the medium- to long-term educational achievement of children born preterm.

The strengths of this study are its longitudinal design and large sample that included children born across the full spectrum of gestational age. The study further provided a wide range of important measures and covariates representing family socioeconomic status and environment as well as children's mental and physical health, behaviour, and cognitive ability across different ages from preschool to school age. However, there are also limitations. Although home environment factors, such as social activities or activities that may provide learning opportunities (Melhuish, Phan et al., 2008), were not available in the present study, many variables that capture family socioeconomic status (i.e., parents' educational attainment, employment, and social status) as well as aspects of the home environment (e.g., the number of books owned by the child) were considered. Further, despite the demonstrated links between preschool skills, prematurity, and educational attainment, a causal relationship cannot be confirmed in this prospective cohort study. Therefore, residual confounding may still be possible, for example, through other environmental and social factors that may affect preschool skills or academic success and that were not included in the current study, such as parental support or maternal sensitivity (Jaekel et al., 2014; Wolke et al., 2013). Further, preschool skills were rated by teachers, and scores may therefore include assessor bias. In addition, despite the large sample size available for this study, attrition cannot be avoided in a longitudinal study. The current study was reliant on linkage data provided by schools and the National Pupil Database for England, which provides preschool academic skills and GCSE data for 68% and 84% of ALSPAC children alive at 1 year of age. Thus, attrition was substantial, and our attrition analysis (Table 4.A.4) showed a significant difference in achieved GCSEs between term-born adolescents included and excluded in the complete data analysis, i.e., more term-born adolescents without complete data achieved GCSEs in Mathematics and English. It may therefore be possible that the associations between preschool academic skills and achieved GCSEs have been underestimated in the term-born group, which in turn may mean that the beneficial effect of preschool skills is more equal between preterm- and term-born children.

Furthermore, ALSPAC includes children born between 1991 and 1992. Changes in reproductive medicine and improvements in neonatal care over the last decades have led to increased survival rates for babies born preterm, with larger numbers in the community. However, despite these improvements, rates of neurodevelopmental difficulties, including academic and educational difficulties, remain significantly higher compared with term-born peers in contemporary cohorts (Burnett et al., 2018; Cheong et al., 2017; Marlow et al., 2021). As a result, the need for educational support for children born preterm remains high.

Overall, our results not only suggest that attending preschool and doing well in subjects such as Mathematics and Literacy is important for later educational attainment for all children, but that early academic skills may be particularly important for preterm children's academic trajectory and educational success, over and above important developmental, cognitive, behavioural, and social-environmental influences. The findings of the current study therefore underpin and extend previous work advocating the provision of high-quality early education with the aim to foster and improve children's early developmental progress and academic proficiency and to reduce special educational needs and economic burden, in particular for disadvantaged and preterm-born children (Heckman, 2006; Melhuish, 2011; OECD, 2018; Sammons, 2010b).

Preschool academic skills are positively associated with long-term academic achievement. Preterm-born children may benefit disproportionately for their educational success from early learning and preschool programmes that promote Mathematics and Literacy skills. The findings highlight the importance of early learning and preschool programmes that foster all children's early academic performance to enhance their long-term educational success.

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Appendix

Table 4.A.1: Group differences of other covariates across term and preterm participants

		Term	**Preterm**	
		N=6,480	N=444	
	N	mean (SD) or %	mean (SD) or %	P-value
Covariates - Children:				
At age 18 months				
Developmental Score	5,672	81.67 (10.30)	75.46 (11.89)	<0.001
Health Status	5,646			0.070
Healthy no problems		45.6%	42.6%	
Few minor problems		49.5%	50.0%	
Sometimes ill		4.2%	5.7%	
Hardly ever well		0.7%	1.7%	
Number of books owned	5,677			0.001
None		1.0%	0.3%	
1-2 books		4.4%	8.5%	
3-9 books		29.6%	32.4%	
>10 books		65.0%	58.8%	
At age 38 months				
Cognitive function				
Intelligibility score	5,196	5.62 (0.86)	5.51 (0.89)	0.029
Communicative score	5,191	5.22 (1.08)	5.35 (1.16)	0.032
At age 42 months				
Emotional difficulties	5,179	2.55 (1.73)	2.61 (1.84)	0.48
Conduct difficulties	5,179	3.63 (2.34)	3.70 (2.44)	0.64
Hyperactivity	5,179	2.63 (1.79)	2.82 (1.84)	0.08
Prosocial	5,179	15.36 (3.52)	14.85 (3.64)	0.014
At age 8 years				
Fluid Intelligence (WISC)	3,572	91.31 (24.50)	88.69 (24.86)	0.12
Covariates – Parents:				
Maternal age	6,003	28.08 (4.71)	27.85 (4.64)	0.37
Paternal age	4,035	30.70 (5.69)	29.66 (4.79)	0.007
Maternal mental health	5,951	5.99 (4.72)	6.30 (5.31)	0.24
Maternal smoking (pregnancy)	6,013	20.2%	21.7%	0.50
Breastfeeding	5,650			0.013
Never		26.9%	34.9%	
<1 months		17.6%	17.4%	
1-3 months		16.3%	15.4%	
3-6 months		12.2%	11.7%	
>6 months		26.9%	20.6%	
Marital Status	4,964			0.55
Never married		11.5%	10.7%	
Widowed		0.3%	0.0%	
Divorced		5.3%	3.9%	
Separated		2.7%	2.6%	
Married once		72.3%	72.5%	
Marriage 2 or 3		8.0%	10.4%	

Table 4.A.1: Group differences of other covariates across term and preterm participants (cont.)

		Term	**Preterm**	
		N=6,480	N=444	
	N	mean (SD) or %	mean (SD) or %	P-value
Educational attainment mother	5,828			0.009
CSE		16.1%	22.4%	
Vocational		11.6%	12.6%	
O level		40.5%	32.4%	
A level		22.6%	23.5%	
Degree		9.3%	9.2%	
Educational attainment father	5,995			0.41
CSE		28.5%	31.5%	
Vocational		9.7%	9.4%	
O level		22.8%	22.4%	
A level		26.5%	27.4%	
Degree		12.6%	9.4%	
Employment status mother	4,829			0.044
Employer		0.6%	2.1%	
Self-employed, no employee		4.8%	3.5%	
Manager		5.9%	5.6%	
Supervisor		19.5%	19.4%	
Other employee		69.3%	69.4%	
Employment status father	5,220			0.19
Employer		4.0%	3.2%	
Self-employed, no employee		14.0%	15.8%	
Manager		11.4%	9.7%	
Supervisor		24.0%	29.0%	
Other employee		46.7%	42.3%	
Social status mother	4,829			0.90
Professional		2.5%	1.7%	
Managerial and technical		27.9%	28.1%	
Skilled non-manual		45.9%	46.2%	
Skilled manual		10.4%	9.0%	
Partly skilled		10.7%	11.8%	
Unskilled		2.7%	3.1%	
Social status father	5,220			0.004
Professional		6.0%	3.9%	
Managerial and technical		27.9%	25.2%	
Skilled non-manual		12.3%	12.3%	
Skilled manual		42.8%	52.9%	
Partly skilled		7.9%	4.2%	
Unskilled		3.2%	1.6%	

The table summarises all variables used in the main analysis and shows group differences between preterm- and term-born individuals.

Table 4.A.2: Associations between preschool academic skills, preterm birth, and GCSEs in adolescence, after excluding participants with a neurosensory impairment

	A) GCSE Mathemathics Odds Ratio (95% CI)		**B) GCSE English Odds Ratio (95% CI)**	
Adjusted models	Model 1	Model 2	Model 1	Model 2
Preterm birth	1.08 (0.87, 1.33)	0.14** (0.04, 0.57)	0.95 (0.77, 1.17)	0.10* (0.02, 0.58)
Preschool Mathematics	2.29*** (2.17, 2.42)	2.25*** (2.12, 2.38)	.	.
Interaction	.	1.51** (1.14, 2.01)	.	.
Preschool Literacy	.	.	3.46*** (3.19, 3.75)	3.37*** (3.10, 3.66)
Interaction	.	.	.	1.61** (1.11, 2.31)
Pseudo R^2	0.116	0.117	0.127	0.127

Adjusted for all covariates (child-related variables: child sex, child health, and developmental status at 18 months, books owned by the child at 18 months, the child's cognitive function (intelligibility, communication) at 38 months, child emotional, hyperactivity, conduct difficulties, and prosocial behaviour at 42 months, and child intelligence at 8 years; parent-related and social-environmental variables: breastfeeding, maternal and paternal age, maternal mental health, marital status, maternal and paternal educational attainment, employment status, and social status). N=6,883. ***p<0.001, **p<0.01, *p<0.05. Neurosensory impairment is defined as visual, hearing, or learning impairment (IQ<3SD).

Table 4.A.3: Associations between both preschool academic skills, preterm birth, and GCSEs in adolescence

	A) GCSE Mathemathics Odds Ratio (95% CI)		**B) GCSE English Odds Ratio (95% CI)**	
Adjusted models	Model 1	Model 2	Model 1	Model 2
Preterm birth	1.08 (0.88, 1.32)	0.18* (0.05, 0.70)	1.05 (0.85, 1.30)	0.12* (0.02, 0.68)
Preschool Mathematics	1.77*** (1.66, 1.89)	1.74*** (1.63, 1.86)	1.80*** (1.68, 1.93)	1.80*** (1.68, 1.93)
Interaction (Mathematics)	.	1.44* (1.09, 1.90)	.	.
Preschool Literacy	1.90*** (1.74, 2.08)	1.90*** (1.73, 2.07)	2.19*** (2.00, 2.41)	2.13*** (1.94, 2.35)
Interaction (Literacy)	.	.	.	1.58* (1.10, 2.26)
Pseudo R^2	0.139	0.140	0.163	0.163

Adjusted for all covariates (child-related variables: child sex, child health, and developmental status at 18 months, books owned by the child at 18 months, the child's cognitive function (intelligibility, communication) at 38 months, child emotional, hyperactivity, conduct difficulties, and prosocial behaviour at 42 months, and child intelligence at 8 years; parent-related and social-environmental variables: breastfeeding, maternal and paternal age, maternal mental health, marital status, maternal and paternal educational attainment, employment status, and social status). N=6,883. ***p<0.001, **p<0.01, *p<0.05.

Table 4.A.4: Attrition analysis: Sample characteristics

Available data (N=12,749)	**Term (N=11,926)**			**Preterm (N=823)**		
	mean (SD) or %	mean (SD) or %	P-value	mean (SD) or %	mean (SD) or %	P-value
	Complete Data	Attrition		Complete Data	Attrition	
Neonatal variables	N=6,480	N=5,446		N=444	N=379	
Gestational age	39.52 (1.16)	39.53 (1.17)	0.71	34.40 (2.30)	33.95 (2.47)	0.008
Birth weight	3435 (484)	3443 (481)	0.37	2399 (625)	2288 (599)	0.01
Sex (male)	49.9%	52.5%	0.004	57.7%	55.4%	0.52

Available data (N=7,523) (59%)	**Term (N=7,033/7,034)**			**Preterm (N=489/490)**		
	mean (SD) or %	mean (SD) or %	P-value	mean (SD) or %	mean (SD) or %	P-value
	Complete Data	Attrition		Complete Data	Attrition	
Preschool skills	N=6,480	N=553/554		N=444	N=46/45	
Mathematics	5.30 (1.09)	5.21 (1.17)	0.07	5.01 (1.04)	4.87 (1.15)	0.40
Literacy	4.99 (0.78)	4.96 (0.81)	0.43	4.86 (0.79)	4.73 (0.79)	0.31

Available data (N=9,394) (74%)	**Term (N=8,776)**			**Preterm (N=618)**		
	mean (SD) or %	mean (SD) or %	P-value	mean (SD) or %	mean (SD) or %	P-value
	Complete Data	Attrition		Complete Data	Attrition	
GCSE achieved	N=6,480	N=2,296		N=444	N=174	
Mathematics	57.4%	63.1%	<0.001	53.6%	55.2%	0.73
English	63.9%	71.1%	<0.001	59.5%	58.6%	0.85

The table summarises the results of the attrition analysis.

Table 4.A.5: Unadjusted and adjusted associations between preschool academic skills and GCSEs in adolescence with multiple imputed data

	A) GCSE Mathemathics Odds Ratio (95% CI)		**B) GCSE English Odds Ratio (95% CI)**	
Unadjusted models	Model 1	Model 2	Model 1	Model 2
Preterm birth	0.98 (0.82, 1.17)	0.29* (0.08, 0.97)	0.83 (0.64, 1.08)	0.24 (0.03, 2.21)
Preschool Mathematics	2.32*** (2.21, 2.43)	2.28*** (2.17, 2.41)	.	.
Interaction (Mathematics)	.	1.28* (1.00, 1.64)	.	.
Preschool Literacy	.	.	3.61*** (3.39, 3.85)	3.55*** (3.32, 3.80)
Interaction (Literacy)	.	.	.	1.30 (0.84, 2.00)
Adjusted models	Model 1	Model 2	Model 1	Model 2
Preterm birth	1.06 (0.87, 1.31)	0.35 (0.10, 1.16)	0.99 (0.73, 1.34)	0.22 (0.01, 3.47)
Preschool Mathematics	1.86*** (1.74, 1.98)	1.83*** (1.71, 1.97)	.	.
Interaction (Mathematics)	.	1.25 (0.99, 1.59)	.	.
Preschool Literacy	.	.	2.46*** (2.26, 2.69)	2.42*** (2.20, 2.65)
Interaction (Literacy)	.	.	.	1.36 (0.79, 2.35)

Adjusted for all covariates (child-related variables: child sex, child health, and developmental status at 18 months, books owned by the child at 18 months, the child's cognitive function (intelligibility, communication) at 38 months, child emotional, hyperactivity, conduct difficulties, and prosocial behaviour at 42 months, and child intelligence at 8 years; parent-related and social-environmental variables: breastfeeding, maternal and paternal age, maternal mental health, marital status, maternal and paternal educational attainment, employment status, and social status). N=6,883. ***p<0.001, **p<0.01, *p<0.05. Data was imputed by chained equations. N=12,749.

5 Adverse birth outcomes and parental labor market participation after birth

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Abstract

Numerous articles have looked at the connection between adverse birth outcomes (low birth weight or preterm birth) and an individual's later socioeconomic status. To this day, very few studies have been conducted that specifically address how delivery and adverse birth outcomes affect families and the homes where children grow up. In this study, I use data from the German Socio-Economic Panel (SOEP) to research the association between adverse birth outcomes and several parental labor market outcomes following childbirth. The analysis indicates that low birth weight and preterm birth are not associated with most of the considered parental labor market outcomes after birth. Initial disparities prior to childbirth account for a large extent of the negative relationship between adverse birth outcomes and labor market outcomes after birth.

5.1 Introduction

Why are some families economically successful whereas others are not? Studying the intragenerational determinants of individual income dynamics across the life course is a central question in both empirical (Bradbury, 2023) and theoretical research (Blundell, 2014) in economics. Generally, income trajectories are modelled as a function of family characteristics, education, demographics, macroeconomic conditions, external shocks, and crucial life events (Angelopoulos et al., 2020; Jäntti & Jenkins, 2015).

A large body of literature analyzes the impact of childbirth as one of these factors shaping income dynamics while affecting the labor market outcomes of parents. Angrist and Evans (1998) was one of the earliest articles attempting to quantify the causal impact of childbirth on maternal labor market outcomes with an instrumental variable approach, based on twin births and the gender distribution of earlier births. The results imply that childbirth caused income losses for mothers ranging between 1,300$ and 2,000$ per year. Other research that used various instrumental variable based approaches confirmed this finding of a detrimental effect of childbirth on maternal labor market outcomes (Agüero &

Marks, 2008, 2011; Bratti & Cavalli, 2014). Moreover, there is evidence that childbirth is not related to adverse labor market outcomes for fathers, which widens income differences between parents (Cools et al., 2017; Feldhoff, 2021; Kleven et al., 2019; Markussen & Strøm, 2022).

Even though the relationship between adverse perinatal or early life health and individual long-term outcomes is well established in the literature, very few articles address the resulting economic implications for parents and families. Some of the previous research suggests that mothers of children with adverse health and development outcomes after birth are less likely to be employed, and they work and earn less compared to mothers of children without these difficulties (Burton et al., 2017; Frijters et al., 2009; Laffërs & Schmidpeter, 2021). This study contributes to this literature and addresses the question of whether adverse birth outcomes have negative implications for the labor market outcomes of both parents and families after birth.

One exception that studies birth outcomes is the article by Luca and Sevak (2023). The authors sum multiple indicators of adverse neonatal outcomes and estimate the effects of this combined measure on maternal labor supply. They conclude, that the more of these adverse neonatal outcomes children are suffering from, the lower their mother´s labor market participation after birth.

Beyond the study of Luca and Sevak (2023), this study is one of the first to study the relationship between adverse birth outcomes and family income as well as labor market participation after birth, conditional on various pre-birth characteristics, including the pre-birth measures of the outcome variables. In the absence of a meaningful exogenous instrument for adverse birth outcomes, the analysis relies on a linear regression analysis (OLS models). The article analyzes German panel data. Therefore, I could also estimate Difference-in-Differences (DiD) models. However, some existing results suggest that low parental socioeconomic status before birth is related to increased risks of adverse birth outcomes (Güneş, 2015; Lindo, 2011). Hence, the treatment variables, which are adverse birth outcomes, would not be exogenous and Difference-in-Differences results and therefore could not be interpreted causally.

The second contribution of this article is methodological. The results from the regression analysis suggest that it is important to control for pre-birth measures of the specific labor market outcome studied. In many of the considered models, it is not sufficient to include more general measures of socioeconomic status, such as education, to account for socioeconomic differences before birth.

5.2 Data and empirical strategy

Do parents who have babies with adverse birth outcomes experience income losses, and do they reduce their labor supply after birth? To answer these questions, I perform the following linear regression and estimate the relationship between adverse birth outcomes and different labor market outcomes after birth:

$$Y_{i,t=1} = \beta_1 + B_i\beta_2 + X_{i,t}\beta_3 + Y_{i,t=-1}\beta_4 + \epsilon_{i,t} \tag{5.1}$$

The variable of interest (B_i) in equation 5.1 is either an indicator for preterm birth, which denotes a gestational age below 37 weeks, or an indicator for low birth weight, which equals one if the baby weighed less than 2,500g and zero otherwise. Beyond other variables, low birth weight and preterm birth are frequently studied measures of adverse birth outcomes (Aizer & Currie, 2014; Black et al., 2007; Conley & Bennett, 2000; Noelke et al., 2019). The variable $Y_{i,t=1}$ is the outcome, which consists of four measures of average income and average maternal and paternal working hours after childbirth i. The birth year is referred to as $t = 0$.

The control variables included in the model are represented by the matrix $X_{i,t}$. These variables include the age at birth, an indicator for higher education of both parents before birth, the migration background of both parents, an indicator for house ownership before birth, the average household size after birth, an indicator for households located in East Germany, the sex of the child, and the birth rank. The model also includes the respective average pre-birth measure of the outcome variable ($Y_{i,t=-1}$). All control variables could be potentially related to incidences of adverse birth outcomes and labor market outcomes of the parents after birth. In the presented model, the coefficient β_2 represents the marginal effect of the adverse birth outcome (B_i) on the considered economic outcome after birth ($Y_{i,t=1}$), conditional on differences before birth ($Y_{i,t=-1}$), and other included control variables ($X_{i,t}$).

To estimate equation 5.1, I used data from the German Socio-Economic Panel (SOEP). The SOEP is a representative household panel study that includes roughly 15,000 households with more than 30,000 individuals. It started in 1984 and is still running today (SOEP, 2019). More precisely, I use data from the mother-child survey, which started in 2000. This sub-sample includes information on various birth-related variables for 7,657 children born between 2000 and 2019, including the birth weight of newborn children and gestational age, which are the main variables of interest.

In order to capture differences in permanent income after delivery, the averages of all observations after birth for each child are examined as outcome variables (income and working hours). For the income variables under study, we considered the log of these averages. The same procedure was applied to observations before birth. To account for inflation time trends, all initial income observations are included in real terms of 2007. Moreover, a large share of parents, especially mothers, are likely to participate in paid parental leave during the period around the first year before and after birth. Observations from these years are not included in the analysis since they are not indicative of parents' long-term labor market performance. Household income variables refer to maternal household income if available and paternal household income otherwise. Excluding all individuals with missing information in any of the explanatory or outcome variables yields the final sample, which consists of 1,718 births from 1,380 biological mothers and 1,379 biological fathers born between 2002 and 2014. All relevant variables for families with and without low birth weight children are summarized in Table 5.A.1.

5.3 Results

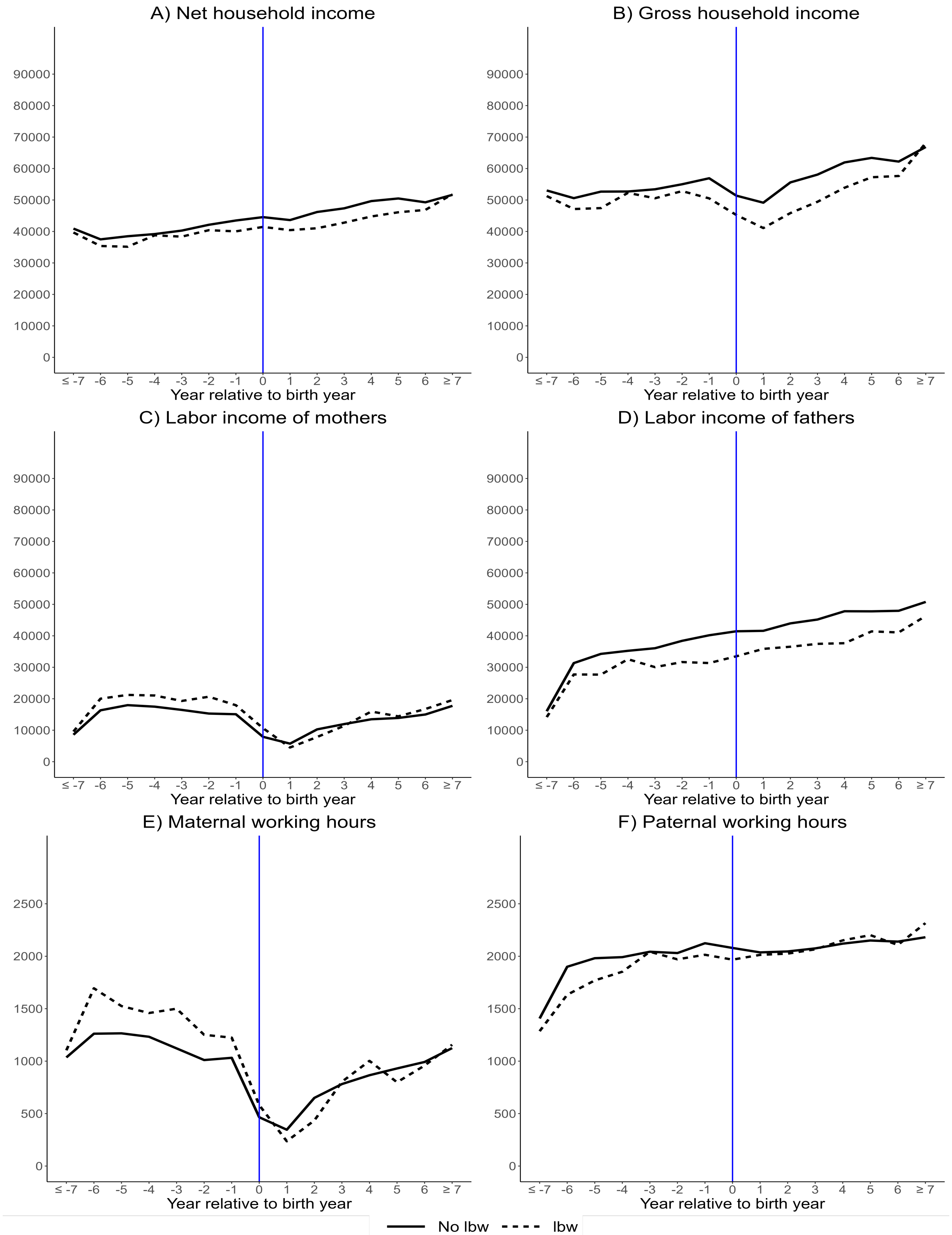
At first, I compare labor market outcomes between families with and without children suffering from adverse birth outcomes. Based on the final sample of 1,718 children, Figure 5.1 visualizes the trajectories of the yearly average of all labor market outcomes used in the analysis and compares families with and without low birth weight children.

In the graphs, annual averages are displayed, which is a different measure than the one used in the main analysis. However, if the results of the main analysis are robust, they should reflect the descriptive evidence presented in these graphs. The graphs show the annual averages for families with low birth weight children and those without, from 7 years before birth to 7 years after the birth of the respective child. It is evident that households with a low birth weight child have lower net and gross household incomes in many of the considered periods before and after birth (Panels A and B). Fathers of low birth weight children work and earn less before birth (Panels D and F). After birth, the income of fathers of low birth weight children remains lower (Panel D).

In contrast to that, it seems that mothers of children born with low birth weights are working more and earning a higher income before birth. After birth, these gradients tend to diminish (Panels C and E). The trajectories of parental labor market outcomes are comparable if preterm birth is used as an indicator for adverse birth outcomes (see Figure 5.A.1).

Results from the OLS regressions for model 1 are shown in Tables 5.1 and 5.2, which include the coefficients for the six outcomes under study. These are gross and net household income as well as parental labor income and working hours. In Table 5.1, low birth weight is used as a dependent variable. Table 5.2 shows the results for models which replace low birth weight with preterm birth.

Figure 5.1: Labor market outcomes of families with and without low birth weight children



The six panels show a time series of the annual average for the six labor market outcomes for parents with and without a low birth weight child based on the final sample of 1,718 births. Observations from more than 7 years before birth are assigned to 7 years before birth. Observations from more than 7 years after birth are assigned to 7 years after birth.

Table 5.1: OLS results - Low birth weight

A) Household income	Gross household income			Net household income		
LBW	-0.335**	-0.354**	-0.248**	-0.072*	-0.068**	-0.024
	(0.159)	(0.138)	(0.122)	(0.038)	(0.030)	(0.027)
Income			0.531***			0.610***
(before birth)			(0.084)			(0.032)
B) Labor income	Labor income of mothers			Labor income of fathers		
LBW	-0.639*	-0.774**	-0.640**	-0.386**	-0.396**	-0.269*
	(0.381)	(0.330)	(0.313)	(0.189)	(0.169)	(0.151)
Labor income			0.320***			0.422***
(before birth)			(0.032)			(0.058)
C) Working hours	Maternal working hours			Paternal working hours		
LBW	-115.276*	-147.107***	-155.866***	-20.256	-26.543	5.809
	(61.608)	(55.346)	(55.348)	(78.347)	(75.006)	(68.441)
Working hours			0.289***			0.447***
(before birth)			(0.025)			(0.029)
Controls	No	Yes	Yes	No	Yes	Yes
Observations	1718	1718	1718	1718	1718	1718

The table shows the coefficients for OLS regressions using the SOEP data. Control variables include parental age at birth, an indicator for higher education before birth, and the migration background of the mothers and fathers, an indicator for house ownership before birth, average household size after birth, an indicator for households located in East Germany, the sex of the child, and the birth rank. Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.10.

Table 5.2: OLS results - Preterm birth

A) Household income	Gross household income			Net household income		
PT	-0.294**	-0.217*	-0.162	-0.081**	-0.034	-0.003
	(0.135)	(0.120)	(0.104)	(0.038)	(0.030)	(0.026)
Income			0.534***			0.612***
(before birth)			(0.084)			(0.032)
B) Labor income	Labor income of mothers			Labor income of fathers		
PT	-0.401	-0.248	-0.128	-0.374**	-0.284*	-0.224
	(0.310)	(0.278)	(0.264)	(0.177)	(0.163)	(0.139)
Labor income			0.322***			0.423***
(before birth)			(0.032)			(0.057)
C) Working hours	Maternal working hours			Paternal working hours		
PT	-148.056***	-125.605***	-117.456***	-52.741	-27.555	-32.697
	(53.499)	(45.649)	(44.478)	(70.848)	(67.737)	(60.996)
Working hours			0.288***			0.447***
(before birth)			(0.025)			(0.029)
Controls	No	Yes	Yes	No	Yes	Yes
Observations	1718	1718	1718	1718	1718	1718

The table shows the coefficients for OLS regressions using the SOEP data. Control variables include parental age at birth, an indicator for higher education before birth, and the migration background of the mothers and fathers, an indicator for house ownership before birth, average household size after birth, an indicator for households located in East Germany, the sex of the child, and the birth rank. Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.10.

Families with a low birth weight child have a roughly 25% lower average gross household income after birth (Panel A of Table 5.1). Having a low birth weight child is associated with lower gross average household income, even after the inclusion of the pre-birth average as a control variable. Panel A of Table 5.1 also shows that net household income is not significantly lower in families with low birth weight children compared to those without, if the pre-birth income is included in the model. These findings indicate that governmental redistribution of income partly compensates for the negative association between low birth weight and the gross household income of the family after birth. The models with all control variables included in Panel B of Table 5.1 indicate that having a low birth weight child is significantly related to a decline in earnings for mothers (-64%) and fathers (-27%). The coefficient for mothers is more than double the size of the coefficient for fathers.

In all models presented in Panels A and B of Table 5.1, the inclusion of pre-birth income measures reduced the effect size of low birth weight on the considered income variable after birth. This indicates that it is not sufficient to control for general measures of pre-birth parental socioeconomic status, such as education.

Panel C of Table 5.1 indicates that mothers of low birth weight children work 156 hours (that is about 4 weeks) less annually after birth compared to mothers without a low birth weight child. This is partly driven by the fact that mothers of low birth weight children worked more before birth. Table 5.A.1 shows that mothers of children with a low birth weight worked 85 hours more annually before birth, even though this difference is not significant. For fathers, the models show no significant reduction in working time after the birth of a child with low birth weight compared to those without. It is important to note that mothers of low birth weight children work and earn more before birth in the analyzed sample. Even though this might be a surprising finding, it is not contrary to all previous evidence (Dehejia & Lleras-Muney, 2004; van den Berg et al., 2020).

Considering preterm birth as an indicator for an adverse birth outcome, the general picture is comparable to the results from the models including low birth weight instead of preterm birth (see Table 5.2). Panel A of Table 5.2 shows that preterm birth is not related to either gross or net household income after birth if the respective pre-birth outcome is included in the model. The same is the case for parental labor income (Panel B of Table 5.2). In contrast to that, models in Panel C of Table 5.2 indicate a significant negative relationship between preterm birth and maternal working hours after birth. Fathers of preterm-born children do not work significantly less after birth compared to those of term-born children (see Panel C of Table 5.2).

To summarize, OLS models suggest that low birth weight is related to lower gross household income, which is partly explained by the parental labor income gradient after birth. The coefficient sizes are larger for mothers than for fathers. In addition, mothers are working significantly less after having a low birth weight child compared to those without a low birth weight child. Low birth weight does not, however, negatively correlate with postpartum net household income, highlighting the relevance of governmental redistribution in this context. The association between low birth weight and family resources after birth is not that pronounced, especially if pre-birth resources are included as a control variable. If preterm birth is used as an indicator for adverse birth outcomes, the results are fairly similar. However, OLS models suggest no significant relationship between preterm birth and gross household income as well as maternal labor income. The results in Table 5.2 with preterm birth as a variable of interest support the previous findings from Table 5.1 using low birth weight as an independent variable. The analysis also shows that the pre-birth measures of the outcome variables are important control variables, and removing them from the model could lead to an omitted variable bias.

5.4 Robustness

The main analysis does not take full advantage of the panel structure of the SOEP. As a robustness test, I estimate the models presented before without averaging the outcome variables after birth. The models still control for the average pre-birth measure. In these models, different measurements of the dependent variables are used to estimate the OLS coefficients. If the results of these models contradict the findings from the main analysis, it could be attributed to measurement bias. Table 5.A.2 displays the coefficients for low birth weight and Table 5.A.3 for preterm birth. Overall, the results support the findings from the main analysis.

As already mentioned in the introduction, it is possible to use the panel structure of the SOEP to estimate Difference-in-Difference (DiD) models. These models use the full panel structure of the data to estimate the association between adverse birth and labor market outcomes. Moreover, these estimates could be causally interpreted if the required assumptions (especially common trends) are not violated. The DiD models are defined as the following:

$$Y_t = \beta_1 + B_i\beta_2 + T_i\beta_3 + (B_i * T_i)\beta_4 + X_{i,t}\beta_5 + \gamma_{i,t} \tag{5.2}$$

In this model, β_2 measures the average difference in the considered socioeconomic outcome between families with and without children with adverse birth outcomes. The coefficient β_3 refers to the average change of the outcome variables from the years before to those after birth. The coefficient of interest is β_4. It represents differences in the change of the considered labor market outcome across families with and without adverse birth outcomes from periods before birth to those after birth.

The coefficients from these models could only be interpreted under some crucial assumptions. One is the exogeneity of the treatments, which are adverse birth outcomes. As already stated, some literature suggests a relationship between parental socioeconomic status and adverse birth outcomes (Güneş, 2015; Lindo, 2011). On the other hand, other articles, mostly from highly developed countries like Germany, find no impact (Arendt et al., 2021; Lindeboom et al., 2009). Beyond exogenous treatment, the existence of parallel pre-treatment trends is an important assumption. Figure 5.1 illustrates that most outcome variables seem to meet that assumption, namely gross and net household income, as well as paternal working hours and income. An exception here is maternal working hours and income because the pre-birth time trends across both groups are not comparable.

Tables 5.A.4 and 5.A.5 summarize the results of these DiD models, which indicate that adverse birth outcomes have no impact on household income and do not negatively affect the income or labor market participation of fathers after birth. For mothers, the models suggest that coefficients are negative, which arguably stems from the fact that the parallel trend assumption is violated.

Combining matching estimators with Difference-in-Differences models is one frequently discussed approach to balance pre-treatment trends if the parallel trend assumption is violated. However, this strategy could not always improve the identification and, in some cases, introduce an additional bias (Daw & Hatfield, 2018; Lindner & McConnell, 2019; Roth et al., 2023).

In general, the evidence from the DiD models supports the findings from the main analysis. Adverse birth outcomes cannot be consistently related to negative labor market outcomes.

5.5 Conclusion

The main finding of this article is that labor market outcomes for families of children with adverse birth outcomes are not drastically worsening after birth. Preterm birth and low birth weight are not negatively correlated with fathers' income or labor market outcomes. For mothers, there is some evidence for a negative relationship between adverse birth outcomes and labor market outcomes after birth. However, it seems that these associations do not translate into losses in household income. The analysis also shows that it is important to control for pre-birth measures of the socioeconomic outcomes considered beyond other variables, which also try to capture the influence of socioeconomic status before birth.

The study has its limitations. The results should be interpreted cautiously with regard to causality because the analysis uses no source of exogenous variation to explain differences in the risk of adverse birth outcomes. Even though Difference-in-Differences models could be interpreted causally given a set of required assumptions, it is unlikely that the analyzed data could fully meet the underlying criteria. Especially pre-treatment trends differ across families with and without adverse birth outcomes for some of the labor market outcome variables under study.

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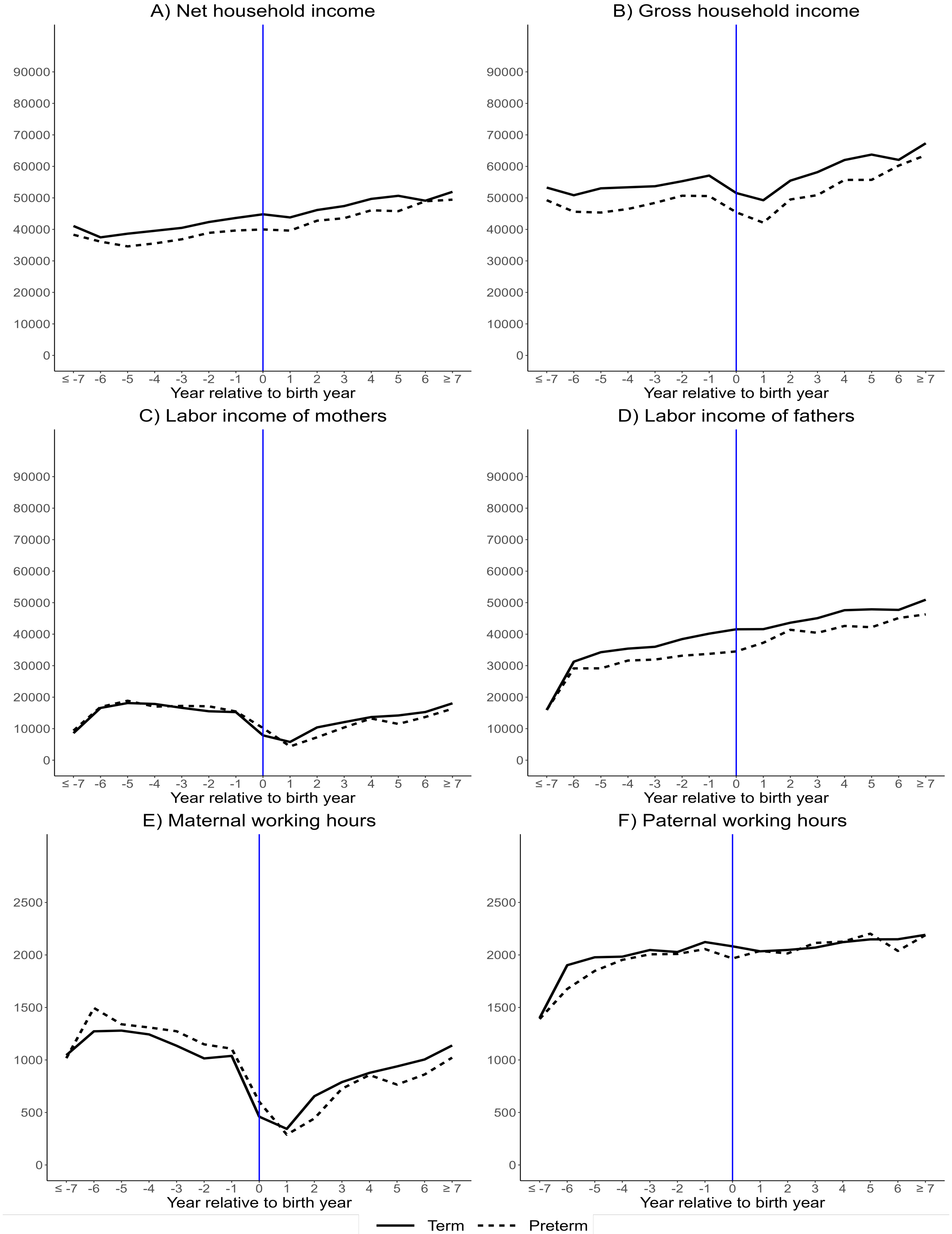
Appendix

Table 5.A.1: Mean differences

Variables	No low birth weight	low birth weight	P-value
Gross household income (after birth)	60303	52225	0.01
Gross household income (before birth)	53294	47097	0.01
Net household income (after birth)	48568	44365	0.02
Net household income (before birth)	41380	37927	<0.01
Maternal labor income (after birth)	13239	12221	0.41
Maternal labor income (before birth)	13947	13482	0.69
Paternal labor income (after birth)	46146	38232	<0.01
Paternal labor income (before birth)	33625	28356	0.01
Maternal working hours (after birth)	835	720	0.06
Maternal working hours (before birth)	1036	1121	0.24
Paternal working hours (after birth)	2054	2033	0.80
Paternal working hours (before birth)	1875	1802	0.34
Maternal higher education	0.47	0.41	0.19
Paternal higher education	0.47	0.48	0.86
Maternal age at birth	30.84	31.18	0.43
Paternal age at birth	33.89	33.88	0.98
Number of household members	3.32	3.28	0.77
East Germany	0.22	0.25	0.37
Paternal migration background	0.24	0.22	0.63
Maternal migration background	0.25	0.22	0.41
House ownership	0.37	0.36	0.86
Child sex	0.51	0.48	0.56
Birth rank	2.15	2.03	0.29

The table shows the mean differences between families with low birth weight children and those without using the SOEP data. P-values refer to a t-test on mean differences with unequal variances. N=1,718.

Figure 5.A.1: Labor market outcomes of families with and without preterm-born children



The six panels show a time series of the annual average for the six labor market outcomes for parents with and without a preterm-born child based on the final sample of 1,718 births. Observations from more than 7 years before birth are assigned to 7 years before birth. Observations from more than 7 years after birth are assigned to 7 years after birth.

Table 5.A.2: OLS results - Low birth weight (no average)

A) Household income	Gross household income			Net household income		
LBW	-0.100*	-0.177***	-0.071	-0.042**	-0.049***	-0.010
	(0.058)	(0.053)	(0.047)	(0.017)	(0.015)	(0.014)
Income			0.679***			0.467***
(before birth)			(0.047)			(0.015)
B) Labor income	Labor income of mothers			Labor income of fathers		
LBW	-0.122	-0.456***	-0.408**	-0.010	-0.062	0.009
	(0.185)	(0.175)	(0.171)	(0.069)	(0.065)	(0.061)
Labor income			0.349***			0.461***
(before birth)			(0.018)			(0.033)
C) Working hours	Maternal working hours			Paternal working hours		
LBW	-9.734	-70.682**	-90.958***	75.578**	44.140	56.708*
	(34.007)	(32.149)	(32.385)	(34.967)	(35.352)	(33.714)
Working hours			0.242***			0.416***
(before birth)			(0.013)			(0.015)
Controls	No	Yes	Yes	No	Yes	Yes
Observations	8,247	8,247	8,247	8,247	8,247	8,247

The table shows the coefficients for OLS regressions using the SOEP data. Control variables include parental age at birth, an indicator for higher education before birth and migration background of the mothers and fathers, an indicator for house ownership before birth, average household size after birth, an indicator for households located in East Germany, the sex of the child, and the birth rank. Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.10.

Table 5.A.3: OLS results - Preterm birth (no average)

A) Household income	Gross household income			Net household income		
PT	-0.142***	-0.122**	-0.085*	-0.047***	-0.023*	0.006
	(0.055)	(0.052)	(0.048)	(0.017)	(0.014)	(0.013)
Income			0.680***			0.468***
(before birth)			(0.047)			(0.015)
B) Labor income	Labor income of mothers			Labor income of fathers		
PT	-0.501***	-0.395***	-0.239	-0.085	-0.055	-0.074
	(0.160)	(0.149)	(0.145)	(0.073)	(0.071)	(0.067)
Labor income			0.348***			0.461***
(before birth)			(0.018)			(0.033)
C) Working hours	Maternal working hours			Paternal working hours		
PT	-107.106***	-83.722***	-78.521***	54.808*	51.158	17.525
	(29.007)	(26.258)	(25.926)	(31.485)	(31.225)	(29.191)
Working hours			0.241***			0.415***
(before birth)			(0.013)			(0.015)
Controls	No	Yes	Yes	No	Yes	Yes
Observations	8,247	8,247	8,247	8,247	8,247	8,247

The table shows the coefficients for OLS regressions using the SOEP data. Control variables include parental age at birth, an indicator for higher education before birth and migration background of the mothers and fathers, an indicator for house ownership before birth, average household size after birth, an indicator for households located in East Germany, the sex of the child, and the birth rank. Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.10.

Table 5.A.4: DiD results - Low birth weight

	Household income		Labor income		Working hours	
	Net	Gross	mothers	fathers	mothers	fathers
After birth	-0.242***	-0.141***	0.387***	0.022	-126.830***	-66.787***
	(0.037)	(0.012)	(0.122)	(0.065)	(26.561)	(24.487)
LBW	-0.199***	-0.060***	0.190	-0.248**	195.269***	-123.200***
	(0.059)	(0.018)	(0.193)	(0.102)	(42.150)	(38.858)
LBW * After birth	0.046	-0.001	-0.707***	0.207	-302.288***	188.456***
	(0.078)	(0.024)	(0.254)	(0.134)	(55.274)	(50.957)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,834	12,834	12,834	12,834	12,834	12,834

The table shows the coefficients for DiD regressions using the SOEP data. Control variables include parental age at birth, an indicator for higher education and migration background of the mothers and fathers, an indicator for house ownership, household size, an indicator for households located in East Germany, the sex of the child, and the birth rank. Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.10.

Table 5.A.5: DiD results - Preterm birth

	Household income		Labor income		Working hours	
	Net	Gross	mothers	fathers	mothers	fathers
After birth	-0.247***	-0.141***	0.394***	0.023	-124.894***	-69.122***
	(0.038)	(0.012)	(0.123)	(0.065)	(26.755)	(24.658)
PT	-0.156***	-0.029*	0.127	-0.130	137.819***	-77.472**
	(0.055)	(0.017)	(0.178)	(0.094)	(38.732)	(35.696)
PT * After birth	0.074	0.005	-0.624***	0.147	-240.633***	169.660***
	(0.070)	(0.022)	(0.227)	(0.120)	(49.601)	(45.713)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,834	12,834	12,834	12,834	12,834	12,834

The table shows the coefficients for DiD regressions using the SOEP data. Control variables include parental age at birth, an indicator for higher education and migration background of the mothers and fathers, an indicator for house ownership, household size, an indicator for households located in East Germany, the sex of the child, and the birth rank. Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.10.

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6 Conclusion

Do adverse birth outcomes have socioeconomic implications, and if so, what are these implications and how meaningful are they? As shown in the previous chapters, there is no universal answer to these questions. It rather depends on multiple aspects, as also shown in my literature review (Chapter 2).

Among others, these aspects include the birth outcome and socioeconomic outcome considered, the time period considered with respect to the time of birth and the country under study, as well as its historical, cultural, economic, and institutional context. All these factors could potentially influence associations between socioeconomic status and adverse birth outcomes across generations. Generally, the aim of policies in this context is to either reduce the incidence of adverse birth outcomes or mitigate their consequences. Beyond the societal demand to do so, it could also be economically efficient to provide suitable policy measures given the comparably high direct and indirect costs of adverse birth outcomes.

It is obvious that the characteristics of the country and its population have a large impact on the socioeconomic implications of adverse birth outcomes. This is especially true since various policy measures, like universal health care and special treatment for children with health difficulties at birth, are essentially designed to reduce the incidence of adverse birth outcomes and moderate the consequences following them. Hence, it is important to contextualize the results carefully. Empirical results always need to be interpreted given the country- and time-specific (institutional) characteristics. When evaluating policy in a national context with a causal design, the estimated effect sizes are still influenced by the existing set of institutions. One possibility to quantify the relevance of these aspects could be to compare data from multiple countries and study the aggregated country-specific influence on the socioeconomic implications of adverse birth outcomes.

However, even cross-country comparisons could only control the aggregate influence of institutional differences. The institutional development of a country is arguably correlated with the quantity and quality of data available to researchers, which is another problem here. For various developing countries there simply is no data which is suitable to answer research questions. Hence, many cross-country comparisons rely on data from rather developed countries. I think it is crucial to establish a better understanding of the country-specific developmental influences on the socioeconomic implications of adverse birth outcomes, which requires analyzing comparable data from developing and developed countries.

It is important to mention that the relationship between higher institutional or economic development and adverse birth outcomes is not linear. Higher development is not always linked to reductions in the incidence of adverse birth outcomes. On the one hand, improved access to medical care and economic resources could arguably lead to reductions in the incidence of various measures for adverse birth outcomes. This is especially true in the early stages of economic and institutional development. On the other hand, given the comparably sophisticated state of health care institutions in the analysed country, progress in prenatal care could lead to increased incidences of adverse birth outcomes. One reason for this is induced birth, which will be started artificially if continuing pregnancy is considered a risk for the health of the newborn and the consequences of the reduced gestational period could be mitigated. As a result, rates of (very) low birth weight and (very) preterm birth are rising while rates of stillbirth and/or neonatal motility might be declining or remaining constant.

It is not surprising that risk factors for adverse birth outcomes are country-specific. As the previous analysis has shown, stress or mental health is one of these factors in developed countries like Germany (see Chapter 3), whereas variables regarding the economic situation of the parents and access to prenatal care might be more important predictors of adverse birth outcomes in developing countries with no sophisticated public health care system. This does not imply that access to prenatal care is not important for the prevention of adverse birth outcomes in highly developed countries like Germany. Insufficient access to prenatal care during pregnancy is obviously not a meaningful risk factor because public institutions provide this access universally. However, as shown in Chapter 5, there is a significant socioeconomic gradient between families with and without adverse birth outcomes that is persistent but not widening after birth.

To this day, there is no universal measure or indicator for adverse birth outcomes that is widely used in research. Instead, research studying adverse birth outcomes often relies on various measures, which are based on gestational length (preterm birth), birth weight (low birth weight), or both combined (small for gestational age). Beyond that, neonatal mortality, the AGPAR score, the child´s height at birth, and the head circumference are frequently used variables to study adverse birth outcomes. Since there are various measures of adverse birth outcomes, it is, in many cases not straightforward to compare results across studies.

Accordingly, it might be fruitful to define a general adverse birth outcome score that in-

cludes multiple of the previous indicators as sub-scales. A good starting point for such a measure might be the AGPAR score, because it is already formed by five sub-scales which include breathing effort, heart rate, muscle tone, reflexes, and skin color. All these elements are either valued at 0, 1, or 2. Higher scores represent a better outcome. AGPAR scores above 7 are typically considered rather unproblematic.
However, the AGPAR score includes none of the measures considered in this dissertation, which are either based on birth weight or gestational age, and I believe that these indicators could easily be included in the AGPAR score as additional sub-scales:

[0] Very preterm-born, [1] Preterm-born, [2] Term-Born
[0] Very low birth weight, [1] Low birth weight, [2] Normal birth weight

Processing in this manner, one could define an Adverse Birth Outcome Score (ABOC), which in this simple form includes seven sub-scales and ranges from 0 to 14. It would also be possible to add further measures based on the head circumference or variables considering other aspects of the health status at birth (height, small for gestational age). This suggestion could be seen as a starting point towards a more general measure of adverse birth outcomes compared to those that exist and are used today. It is important to mention that all measures that contribute to the ABOC need to be included in one dataset, which is not the case in many frequently used survey datasets. This is also true for some of the datasets studied in this dissertation.
Beyond the advantages a general measure for adverse birth outcomes could have for empirical research, a general measure could also be important to consider for policymakers while allocating resources to special and intensive prenatal and perinatal care.
I think it is hard to argue that children born with a birth weight of almost 2,500g face significant health issues compared to children with a slightly higher birth weight. In many cases, both birth outcomes are not extremely adverse and are not likely to be correlated with major socioeconomic disadvantages over the life course. The opposite is true for children born with very low birth weight (<1,500g). A comparably large proportion of individuals around this threshold suffer from poor health status at birth. A similar logic applies to measures related to gestational age (preterm birth, very preterm birth). Interventions should not be based on these sharp and singular thresholds based on birth weight or gestational age but rather rely on multiple measures of newborn health.
On aggregate, babies born with a low birth weight or born preterm face more adverse health outcomes at birth compared to those who are not. It is important to mention that the magnitude and significance of these differences are dependent on the distribution of birth weight (for low birth weight) and gestational age (for preterm birth) in the considered population. In the analyses of this dissertation, the share of late preterm-born children is

comparably high, and the share of babies with very low birth weight is low. Therefore, the indicators of preterm birth and low birth weight in this study could be interpreted as not very adverse compared to studies with a high share of very low birth weight or very preterm-born children within the population of low birth weight or preterm-born individuals analyzed. In many cases, it is not possible to derive valid statistical results for the sub-group of very low birth weight or very preterm-born children because the numbers of observations in these sub-populations are not sufficiently large.

From a methodical perspective, it is important to emphasize that none of the conducted analyses could be interpreted causally without caution, and the analyses are not based on (quasi-)experimental variation in the variables of interest. However, barely any empirical research in social science could be interpreted causally without caution. Most frequently used estimation techniques impose assumptions on the data in order to be interpreted causally. These assumptions could never be fully classified as valid. Nevertheless, it is possible to collect evidence that the required assumptions are likely to not be violated and point out the limitations of the results, which is a strong focus of all analyses in this dissertation. The empirical models applied attempt to come as close as possible to a causal interpretation of results with the data available, given the bandwidth between a purely descriptive correlation and the true magnitude of the causal effect.

Still, it is important to consider other issues empirical analyses could suffer from. These could involve the external validity of results and the researcher's degrees of freedom while conducting the analysis and choosing specifications. Even if there already is causal evidence for a particular country available, it is always fruitful to analyze comparable datasets or the same data but from another time period and check whether the results are data-specific and infer on robustness. One example of this approach is presented in Chapter 3. Even though any empirical study should try to be an objective description of patterns in the data, researchers still have comparably large degrees of freedom in the model specification they present. Hence, researchers might tend to report results that support their hypothesis, which in turn might increase the chances of publication. Specification curves could reduce these degrees of freedom, while they graphically show the robustness of the results with respect to multiple models and datasets (see Chapter 3). The results should be similar given different specifications, and substantial differences across specifications need to be explained. Since specification curves could be estimated independently of the exact research question and applied using various statistical models, their use should be promoted for application in future research.

This dissertation studies adverse birth outcomes, their causes and consequences, and their socioeconomic implications using data from two developed countries: the United Kingdom and Germany. For various reasons I emphasized earlier, the results cannot be generalized but are rather country-specific (Chapter 2). My findings indicate that poor maternal mental health is a risk factor for adverse birth outcomes (Chapter 3), and better preschool skills might mitigate the long-term consequences preterm birth has on educational attainment in adolescence (Chapter 4). Children with adverse birth outcomes are born into families with lower incomes before birth, but this income gradient does not widen after birth (Chapter 5). To summarize, the analyzed data shows the socioeconomic implications of adverse birth outcomes in the United Kingdom and Germany, even though they are not magnificent.

As already mentioned previously, the analyses conducted could not rely on exogenous variation in the variable of interest. Since pandemics are one of the most frequently used sources of this variation (see Chapter 2), future research could focus on the Corona crisis as such an event. Arguably, the general environment during the pandemic was not favorable for affected mothers and their fetuses in the womb. In contrast to previously studied flu pandemics, the quality and quantity of data available to researchers have drastically improved. Combined with exceptional improvements in the analysis of large datasets (big data), the future of research on adverse birth outcomes and their socioeconomic consequences looks promising.

Unfortunately, the pandemic has also shown that not all countries were able to study the consequences of the pandemic sufficiently or even describe the pandemic course itself, given the existing data infrastructure. From the perspective of a policymaker in those countries, it should be evident that efforts to increase the availability, quantity, and quality of data available to researchers are required in order to profit from evidence based on comparably new estimation techniques based on Machine Learning (ML) and Artificial Intelligence (AI) to evaluate and design efficient policy measures.