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Inequalities at birth: stable socioeconomic differences in birth outcomes in three British cohorts

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Abstract

In this article, I investigate the association between maternal socioeconomic status (SES) and children's birth outcomes (birth weight) across three different birth cohorts. I also perform mediation analysis to assess the degree to which maternal smoking habits during pregnancy account for this relationship. I draw from three UK cohort studies: the 1958 National Child Developmental Study (NCDS); the 1970 British Cohort (B70); and the 2001 Millennium Cohort study (MCS). There are two main results. First, low-SES mothers are more likely to have children with poor birth outcomes and this association has remained persistent throughout the last 50 years. Second, smoking explains a large part of this association, but only in the two most recent cohorts.

Keywords: Birth outcomes, Inequalities, British cohorts, Cohort study, Low birth weight

Introduction

There is a vast literature focusing on trends in demographic phenomena. Much attention has being given to long term fluctuations in fertility, age at first child, as well as mortality and infant mortality (Christensen et al., 2009; Frejka & Sardon, 2006; Goldstein et al., 2009) and the variation of these trends by different socio-economic groups (Arntzen et al., 2004; Jalovaara et al., 2019; Masters et al., 2015). However, trends in other important population outcomes such as birth outcomes have received surprisingly less attention. Birth outcomes as birth weight (BW) and low birth weight (LBW) have been shown to be important predictor of future socio-economic success (Almond & Mazumder, 2013; Härkönen et al., 2012; Heckman, 2007; Torche & Conley, 2016). They have been also shown to be socially stratified (Currie, 2011; Kramer et al., 2000), making them a first pathway of transmitting socio-economic status from one generation to the next.

A few studies have showed a persistent longitudinal association between maternal socio-economic status and birth outcomes (Aizer & Currie, 2014; Fairley & Leyland, 2006; Moser et al., 2003; Ward, 2015). However, studies addressing socioeconomic inequality in birth outcomes usually examine a short time span (Aizer & Currie, 2014; Fairley & Leyland, 2006; Moser et al., 2003). Furthermore, little is known on the underlying determinants of the observed trends in SES inequality in birth outcomes. A particularly important factor accounting for inequalities in birth outcomes may be maternal smoking behaviors. Smoking is the most important cause of poor birth outcomes in developed countries (Kramer et al., 2000; Rogers, 2009), and it has a strong social gradient, which changed notably over time (Fertig, 2010; Pampel, 2005; Thun et al., 2012).

In this article, I provide novel evidence on the association between SES and BW across three British cohorts over a time span of almost 50 years and examine what may account for the association over time. More specifically, I posit four research questions. First, is there an association between SES and BW? Second, how has this association changed over time? Third, does maternal smoking in pregnancy account for the SES gradient in BW? Fourth, how has its relevance changed over time? To answer these research questions, I draw on three large-scale representative cohort studies from the United Kingdom: the 1958 National Child Development Study (NCDS), the 1970 British Cohort (B70), and the 2001 Millennium Cohort Study (MCS).

Background

Birth weight and its stratification

The social environment a mother lives in plays a crucial role in triggering the biological processes shaping birth weight. Research has shown how, consistently across countries with different levels of development, maternal socio-economic conditions are linked to their children's fetal development and ultimately to their birth outcomes, with children born from low socio-economic mothers showing lower birth weight, shorter gestational length, higher incidence of low birth weight and pre-term births (Currie, 2011; Kramer et al., 2000). There may be many causes linking maternal socioeconomic conditions to birth outcomes (de Graaf et al., 2013). Material conditions specific to disadvantaged mothers such as low financial resources, poor housing conditions, restricted access to healthcare, and unstable working conditions may have a detrimental effect on maternal health and consequently on birth weight (Aizer et al., 2016; Persson & Rossin-Slater, 2018; Tattarini et al., 2018). Environmental and community factors may also play a role, as poor mothers are more often exposed to residential segregation in poor neighborhoods and to high level of toxic pollutants, chemicals, violence, and stress, and worse climatic conditions (Conte Keivabu & Cozzani, 2022; Cozzani et al., 2021a, 2021b; Currie, 2011; Slama et al., 2008). Psychosocial conditions such as resilience to stress and access to social support may also play in harming or sheltering birth outcomes (Turner & Avison, 2003). Non-material resources such as health literacy, and education, may also shape maternal health and thus affect fetal development (de Graaf et al., 2013).

Among the social determinants of birth weight, stratified health behaviors may play a pivotal role in shaping SES inequalities in birth outcomes, especially in developed countries, where access to nutrition is not a major concern (Kramer et al., 2000). Research has shown that there is a strong SES gradient in a large set of unhealthy behaviors such has having a poor diet, scarce physical activity, tobacco, and alcohol consumption (Pampel et al., 2010).[1] The SES gradient in health behaviors holds also for pregnant women, as low-SES mothers are more likely to smoke during pregnancy than their higher SES counterparts (Härkönen et al., 2018). Moreover, maternal smoking is likely to be one of the strongest determinant of SES inequalities in birth outcomes across developed countries, as it is both highly prevalent in the population and strongly socially stratified (Kramer et al., 2000).

Trends in birth outcomes: previous research

There is plenty of research investigating how and why demographic phenomena such as fertility and mortality vary across decades and even centuries (Christensen et al., 2009; Goldstein et al., 2009). Other phenomena such birth outcomes, on the other hand, have received surprisingly less attention, but they also evolve over time. Birth outcomes follow secular trends in epidemiological conditions, population compositional changes, maternal behaviors, and technological innovations. A recent longitudinal analysis examined birth weight distributions across the nineteenth and twentieth century and found a substantial stagnation in average birth weight in the US (Schneider, 2017). Other studies have investigated recent trends in birth weight in the UK, and they generally found that newborns were getting bigger (Bonellie & Raab, 1997; Ghosh et al., 2018; Power, 1994). Yet, investigations from other countries (i.e., France, Germany, and the US) showed a small decrease in average birth weight within the last two decades (Diouf et al., 2011; Donahue et al., 2010; Schiessl et al., 2009). These discordant findings may be due to various reasons. First, compositional changes in the population of live births may alter the population averages. The increasing amount of multiple births due the sharp increase in medical assisted reproduction (MAR) in the last decades (Pison et al., 2015), for example, may have reduced average birth weight at the population level, as twins are usually smaller than singleton newborns. Second, improvement in maternal nutrition, the introduction of supplements, and overall more attention towards maternal health during pregnancy may have boosted birth outcomes over time. Third, medical technological advancements aimed at improving perinatal health may have reduced stillbirths, which, in turn, may increase the share of low-birth-weight deliveries, slowing improvement in average birth weight. Fourth, and likely with a large importance in advanced societies, changes in health behaviors, such as smoking, which peaked and then started to reduce in the twentieth centuries, following the stages of the tobacco epidemic (Lopez et al., 1994), may have improved birth outcomes over time. Moreover, these mechanisms may work simultaneously and may be true for some population groups but not for others.

Regarding socio-economic differences in birth weight, Aizer and Currie (2014) found substantial differences in birth weight between advantaged and disadvantaged mothers in the US, which has slightly decreased across the 1990s and the early 2000s. In the UK, Moser et al. (2003) found that class differences in birth weight remained constant across the 1990s. Similarly, also Maher and Macfarlane (2004) found stable class differences in birth weight between the 1980s and the 1990s. To sum up, despite some improvements

[1] The reasons why low-SES individuals engage more in unhealthy behaviors remain somehow debated (Pampel et al., 2010), but there is some evidence that exposure to harsh life conditions, stress, peer-influence, and lack of medical knowledge may play a role in generating SES disparities in health behaviors (Cutler & Lleras-Muney, 2010).

in birth weight at the population level, research investigating socioeconomic differences in birth weight has reported stable or only small reductions in socioeconomic inequality in birth outcomes over time. There may be many forces at work in different groups in generating trends in inequalities in birth outcomes. On one hand, it may be possible that the selective growth of MAR births among high SES groups (Cozzani et al., 2021a; Goisis et al., 2020, 2023) may have slowed the advancement in birth outcomes among them. On the other hand, the capability of having higher returns of medical advancements may instead have boosted high SES children's birth outcomes (Link & Phelan, 1995). In addition, the capability of rescuing frail fetuses may be more relevant among low SES groups, which may have higher stillbirths and miscarriages rates, slowing more their birth outcomes advancements. Finally, and again more importantly, tobacco consumption changes happened heterogeneously in the twentieth century, with high SES being the firstcomer in abandoning this behavior and low SES the last ones (Thun et al., 2012). Overall, many forces may together influence birth outcomes for different socioeconomic groups. Tobacco consumption is the one studied here as it is the most important determinants of poor birth outcomes in Western Societies (Kramer et al., 2000).

Data and variables

Data

To investigate the association between social background and BW, I draw on three large-scale longitudinal UK cohort studies: the 1958 National Child Development Study (NCDS), the 1970 British Cohort (B70), and the 2001 Millennium Cohort Study (MCS), which all have the newborn as unit of analysis. From each of these cohort studies, I use the first wave. In the analyses, there are three sample restriction criteria. First, I restrict the sample to those who have a UK or in European ethnic origin to maintain homogeneity of the sample, as the ethnic composition across the three cohorts varies considerably[2] making comparison across time difficult. Furthermore, ethnic origin overlaps with social background and maternal behaviors (Fertig, 2010),[3] and another study has already investigated class differences in birth weight between ethnically European and various non-European groups with the MCS data (Kelly et al., 2008). Second, I also examine only singleton births, as fetal development varies significantly between singleton and multiple deliveries. Furthermore, the share of multiple births has changed over time, increasing the share of small deliveries (Moser et al., 2003). Third, I exclude births without complete information.[4] The final analytical sample consists of 45,671 births.

The NCDS is a large-scale longitudinal study that consists of a representative sample of children born in the United Kingdom in the week commencing March 3, 1958. The first wave was completed by midwives who attended the delivery. The final analytical

[2] Among observation with valid information for all the variable used in the analyses, non-European-origin individuals are: 1.2% in the NCDS (N = 188); 4.72% in the B70 (N = 771); 12.47% in the MCS (2,883).

[3] I also computed the analysis for non-EU individuals in the MCS cohort (given the larger sample size), and the results are different. Maternal smoking during pregnancy does not play any role in explaining these differences. Results are available in the Appendix, Table 4.

[4] Table 5 in the appendix report the distributions of the variables used for the cases having missing information in BW. The share of missing cases for birth weight is higher in the NCDS, where they are about 9,75% of the sample (N = 1776). In the B70 and MCS the cases are a few, being the 0.18% (N = 31) and the 0.36% (N = 65) respectively. Moreover, when Table 5 in the appendix and Table 1 are compared, no major systematic differences are found.

Table 1 Descriptive statistics of variables by cohort. Source: NCDS, B70, MCS

Cohort:	**NCDS (1958)**		**B70 (1970)**		**MCS (2001)**	
	Mean/%	**SE**	**Mean/%**	**SE**	**Mean/%**	**SE**
Outcome variables						
Birth Weight (g)	3300.91	4.59	3299.78	4.51	3404.51	6.16
LBW	7.23		6.64		5.46	
Independent variables						
Maternal education						
High	24.99		33.19		33.64	
Low	75.01		66.81		66.36	
Smoking in pregnancy (SIP)	34.06		43.10		23.15	
Controls						
Child is female	48.61		48.10		48.50	
Maternal height (cm)	161.01	0.051	161.02	0.051	164.34	0.082
Maternal age						
< 19	5.61		9.88		4.97	
20–29	61.01		66.87		40.49	
30–39	30.86		21.29		51.13	
40+	2.52		1.97		3.41	
Marital status						
Married	96.43		93.13		54.96	
Non-Married	3.57		6.87		45.04	
Birth order						
First born	36.51		37.67		42.66	
Second born	31.26		32.71		36.85	
Third + born	32.23		29.62		20.48	
Timing of prenatal care access						
Before 12th week	20.93		31.39		43.8	
12th to 23rd week	62.50		43.05		52.36	
After 23rd week	16.04		24.94		1.41	
No visits	0.53		0.63		2.43	
N	15,500		15,552		14,619	

sample consists of 15,500 births. The B70 design resembles the one of the NCDS, and it includes children born in the week commencing April 5th, 1970. The final analytical sample includes 15,552 births. Differently from the previous two cohorts, the MCS is a sample of children born in the 12 months following September 2000. The respondent of the MCS was mainly the biological mother. Since MCS has a complex sampling design, analyses adopt sampling weights. The final analytical sample consists of 14,619 births.

Dependent variable

The main outcome variable in this article is birth weight. I operationalize it both as a metric variable in grams, and as a binary variable for low birth weight (birth smaller than < 2500 g; LBW). Birth weight and LBW are good predictors of fetal environment, fetal health impairments, and developmental potential (Hernández-Alava & Popli, 2017; Torche & Conley, 2016).

As outlined in the data section, birth information, including birth weight, is reported by midwives attending the delivery in the NCDS and B70 cohorts, whereas the respondent was the mother in the last cohort. Despite this difference, data on birth weight in the MCS is mostly consistent with the hospital records (Goisis et al., 2018; Tate et al., 2005).

Socio-economic background

I use a binary measure of low and high maternal education as a proxy for social background. In the NCDS and B70, maternal education is considered low if the mother has attained less than compulsory education. In the MCS, low maternal education is considered if she has less than a university degree. These categorizations allow to consistently identify as high educated about the top 30% of the education distribution across the three cohorts and to compare it to the rest of the distribution, which is identified as low. Since between 1958 and 2001, the UK has experienced a large educational expansion that has led to changes in the educational distribution over time (Breen, 2010; Goldthorpe, 2016), operationalizing maternal education by identifying about the top 30% of the educational distributions allows to address structural changes in the educational distribution across the cohorts, and thus should ensure comparability across the three cohorts. Moreover, in this way I am able to always identify a similar share of individuals at the top of the educational distribution, comparing across the cohorts those at the top against those at the bottom. This approach is similar to that of considering educational as a positional good (Triventi et al., 2016). Moreover, beyond the advantage in comparability, among the possible measures of social background (i.e., social class, income, prestige scores), I use maternal education because it is considered as one of the most important predictors of maternal smoking (Härkönen et al., 2018). Finally, in Fig. 2 in the appendix I also report a sensitivity analysis using the highest parental social class among the parents (managers vs. manual workers) and results are consistent. Similarly, by controlling for maternal occupational status results do not change (results available upon request).

Prenatal maternal smoking in pregnancy

Smoking during pregnancy is a binary variable having value one when a mother did not stop smoking during pregnancy. In the NCSD and MCS cohorts, mothers are considered to have smoked during pregnancy if they continued smoking after the fourth month of pregnancy. For the B70, it is possible to distinguish only whether a mother continued smoking after the fifth month of pregnancy. The distribution of smoking during pregnancy across the three cohorts is consistent with previous studies (Fertig, 2010; Goisis et al., 2018).

Control variables

In the analyses, in order to account for possible confounders and changes in population characteristics across cohorts, I include a set of control variables. (1) Maternal age is included as it is associated with birth outcomes across the three cohorts (Goisis et al., 2018), and the average age at birth varies considerably over time (Maher & Macfarlane, 2004); it is discrete and operationalized in five age categories: < 19; 20–29; 30–39; 40 +. (2) I include maternal height in cm (standardized within each cohort in the analyses), as a proxy for maternal health.[5] (3) The sex of the newborn. (4) Maternal marital status at birth. (5) Birth order as a categorical variable: first born, second born, third + born. (6) Timing of the first visit to antenatal care: before the 12th week of gestation; 12th–23rd; 23rd +; no visit.

Analytical strategy

Cohort comparison

To investigate how the association between SES and birth outcomes changed over time, I use a combination of linear and logistic regression models, depending on whether the outcome is binary or metric. I define and describe here the basic structure of the logistic and linear regression models, which are computed separately for each one of the three cohorts:

$$Y_i(\text{BW}; \text{LBW}) = \alpha_i + \beta 1(\text{SES}_i) + (\text{Controls}_I)\boldsymbol{\delta} \tag{1}$$

where Y_i indicates the outcome variables: birth weight measured in grams or the probability of delivering a LBW child *i*. $\beta 1(\text{SES}_i)$ is the binary variable for high- versus low-educated mothers; and $(\text{Controls}_I)\boldsymbol{\delta}$ is the array of control variables specified in the section above.

SES differences in birth outcomes: the mediating effect of maternal smoking

To estimate the mediation effects, I adopt the strategy outlined by causal mediation analyses literature (VanderWeele, 2015), and its applied empirical strategy (see Hicks & Tingley, 2011 for a description of the estimation strategy and the estimation algorithm). Using this framework has several advantages. First it allows to estimate mediation effects for any kind of outcomes and functional forms. Second, it provides a clear estimate of the mediation effect as the average effect of the mediator at fixed level of the independent variable of interest, in this case maternal education. In other words, how much of the effect of maternal education on birth outcomes is due to smoking. Third, it provides tools for sensitivity analyses of the mediation effect. Fourth, it provides uncertainty estimates of the mediation effect. In the results below, I will thus report the mediation effect both as the quantity of the effect of maternal education mediated by smoking and as the share of the effect in maternal education which is mediated by maternal smoking.

Results

Descriptive results

Table 1 describes the variables used in the analyses for each of the three cohorts. Birth outcomes generally improved across the three cohorts. The average birth weight in grams remained similar in the first two cohorts, being of about 3300 g, whereas it increased to about 3400 g in the MCS. The share of LBW children decreased from 7.23% of all births in the 1958 cohort to 5.46% in the youngest cohort in the 2001. The independent variable SES refers to the level of education of the mother, as described in the variable section above. The share of high-educated mothers slightly increases across

[5] This is unfortunately not the best proxy for maternal health status, but a better proxy as body mass index was not computable in all the three cohorts, as the B70 did not report maternal weight.

the three cohorts, from about a quarter of cases in the 1958 cohort, to about 33% in the 1970 and in the 2001 cohort. The share of mothers that smoked during pregnancy, on the other hand, changed notably across the three cohorts. One out of three mothers smoked after their fourth month of pregnancy in the 1958; more than 40% of mothers smoked after the fifth month in the 1970; but in the 2001, the share of smoking mothers decreased and only 1 out of 5 smoked after the fourth month of pregnancy.

For the other variables, it can be noticed an increase in the average age of the mothers: the share of women giving birth between 20 to 29 years decreased 20 percentage points from 1958 to 2001, whereas the share of mothers giving birth between 30 and 39 years increased from about 31% in the NCDS to 51% in the 2001 cohort; a 20 percentage points increase. An even more pronounced change happened for marital status. In the 1958 cohort almost every woman was married at the time of birth, whereas only half were married in the 2001 cohort. The share of cohort members being first child (compared to other birth orders) slightly increased across the three cohorts: the share was about 37% in the 1958 and 1970, increasing to 40% in the 2001. A greater change happened among those who were the third or subsequent child of a mother: they decreased from 31% in the 1958 cohort to only about 20% in the 2001 cohort. Finally, mothers have become more attentive to prenatal care, and accessed this service at earlier stages of the gestation across the three cohorts: if only 20% of women were doing their first visit before the 12^{th} week in the 1968 cohort, more than 40% accessed the care early in the 2001 cohort.

Figure 1 displays the percentage of mothers that smoked during pregnancy across the three cohorts by their educational level. The bars report the share of smokers across the educational categories and the three cohorts. Across the three cohorts, it is possible to notice that there is a relationship between smoking during pregnancy and maternal education, as low-educated mothers were consistently more likely to smoke in respect to their high educated counterpart. However, this relationship changed over time. In the 1958 and 1970 cohort, a sizeable proportion of both high- and low-educated mothers smoked, although a difference of 13 percentage points in 1958 and 19 percentage points in 1970 existed between high- and low-educated mothers. The largest change in smoking habits happened among the 2001 cohort. Both educational groups reduced smoking during pregnancy, but the decrease was more pronounced among highly educated mothers: only less than 1 in every 10 women smoked during pregnancy. To sum up, educational differences persisted across the three cohorts, but in the most recent cohort highly educated mothers almost completely quit smoking during pregnancy.

Maternal education & birth outcomes across three cohorts

Table 2 shows the results of six regression models estimating the effect of maternal SES on birth weight (measured in grams) and LBW across the three cohorts. In Panel A, coefficients in the table report the average difference between high- and low-educated in birth weight. Coefficients in Panel B show the difference in odds ratios between high- and low-educated mothers in the chance of delivering a LBW child. Standard errors are in brackets.

Overall, Table 2 shows an association between maternal education and birth outcomes across the three cohorts analyzed ($P < 0.05$), with low SES children having worst birth

Table 2 Linear and logistic regression models predicting the association between SES and birth outcomes

	NCDS (1958) Model 1 Beta/OR (SE)	B70 (1970) Model 2 Beta/OR (SE)	MCS (2001) Model 3 Beta/OR (SE)
Panel A $Y =$ Birth Weight (g)			
Ref. High Education			
Low Education	− 54.14***	− 45.60***	− 58.80***
	(10.44)	(9.54)	(12.88)
Panel B $Y =$ LBW			
Ref. High Education			
Low Education	1.47***	1.26**	1.45**
	(0.12)	(0.09)	(0.16)
N	15,500	15,552	14,619

Panel A shows the estimates of three linear regression models having as outcome variable birth weight measured in grams. Panel B shows the estimate of three logistic regression models having as outcome variable low birth weight (deliveries < 2500 g. Coefficients reported in Panel B are odds ratios. Each coefficient is estimated in a separate regression. All the models reported include the following control variables: child's sex; maternal age; maternal marital status at birth; birth order; timing of prenatal care access; maternal height (standardized by cohort). The control variables are defined, as shown in Table 1

Significance levels: ** < 0.01; *** < 0.001 (two-tailed test)

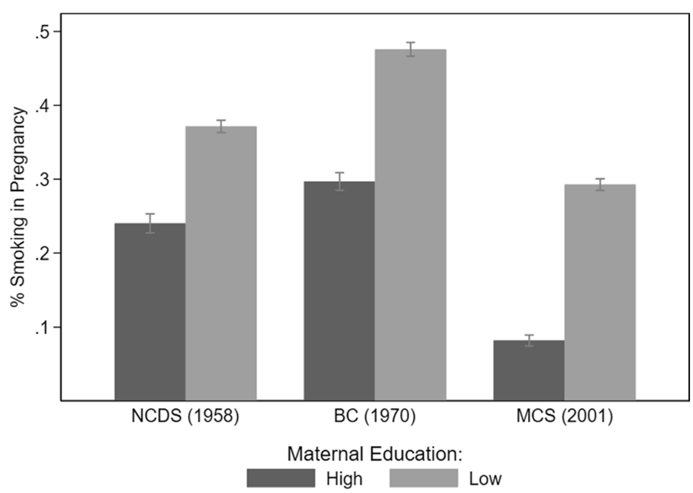

Fig. 1 Smoking during pregnancy by maternal education across the three cohorts (Source: NCDS; B70; MCS. First waves. Own elaboration)

outcomes than children born from high SES mothers. Model 1 in Panel A shows a difference of about 54 g between high- and low-educated mothers in the 1958s cohort. Model 2 in Panel A reports the same coefficient for the 1970 cohort, predicting a difference of about 46 g between high- and low-educated mothers. In addition, in Model 3, the result for the most recent cohort displays a difference in birth weight between high- and low-educated mothers of about 59 g. In Panel B, where the outcome is whether a child is born with LBW, we find a similar pattern. Model 1, for the 1958 cohort, shows an

Table 3 Mediation effect of maternal smoking on birth outcomes by cohort

	NCDS (1958) Mediation effect (CI)	B70 (1970) Mediation effect (CI)	MCS (2001) Mediation effect (CI)
Panel A			
Y = Birth Weight (g)			
Maternal behavior (M)			
Smoking in pregnancy	− 19.657 (− 23.322, − 16.4)	− 30.605 (− 35.02, − 26.556)	− 39.886 (− 45.68, − 33.822)
% Mediation	35.9%	65.6%	60.5%
Panel B			
Y = LBW			
Maternal behavior (M)			
Smoking in pregnancy	0.004 (0.002, 0.005)	0.007 (0.007, 0.005)	0.009 (0.007, 0.011)
% Mediation	16.4%	46%	46.2%
N	15,500	15,552	14,619

Panel A shows the mediation effect of maternal smoking in pregnancy on birth weight measured in grams. Panel B shows the mediation effect of maternal smoking in pregnancy on low birth weight. All the models reported include the following control variables: child's sex; maternal age; maternal marital status at birth; birth order; timing of prenatal care access; maternal height (standardized by cohort). The control variables are defined, as shown in Table 1

All the reported mediation effects are statistically significant

increase of about 47% in the chances of low-educated mothers in delivering an LBW child with respect to their high-educated counterparts (2.4 percentage points). In the 1970 this difference is about 26% (1.4 percentage points). In the youngest 2001 cohort, the relative difference is about a 45% increase (1.77 percentage points).

I also compare these effects with results found in previous research on birth outcomes (Bernardi et al., 2016). Difference of about 50 g in birth weight are generally similar to the effect found in programs aimed to enhance birth weight (Bitler & Currie, 2005; Torche, 2011) or in relation to the exposure to heavy pollutants (Currie & Schwandt, 2015). An increase of about 2 percentage points in LBW is generally higher than the effects found in the case of an exposure to a violent earthquake (about 1.5 percentage points) (Torche, 2011), an upset victory in the Super Bowl (0.4 percentage points), or pollutants (0.76 percentage points) (Currie & Schwandt, 2015; Duncan et al., 2017).

Mediation analyses: the role of maternal smoking

Table 3 reports the mediating effect of maternal smoking during pregnancy across the three birth cohorts. The estimates reflect the quantity and the share of the effect of maternal education accounted by smoking in pregnancy. Panel A shows the mediating effects on birth weight measured in grams. Panel B reports the mediating effects on LBW. Confidence intervals of the estimates are reported in brackets. All the mediation effects reported in the table are statistically significant.

In both Panel A and Panel B, it is possible to notice that the relevance of the effect of maternal smoking behaviors changed across the three cohorts for both outcomes. Maternal smoking accounted for about 35% of birth weight reduction and 16% LBW increase among the 1958 cohort. Among the following cohorts, the influence of maternal smoking became substantially larger. It accounted for 65% and 60% of the effect on birth weight in the 1970 and 2001 cohort, respectively. Similarly, the share of the effect mediated by smoking increased also for LBW, from 16% in the 1958 cohort, to about 46% in the 1970 and 2001 cohorts. These results highlight the fact that maternal behaviors such as smoking have become important in explaining educational differences in birth outcomes only among the more recent cohorts, whereas other factors may have been at play in before.

Sensitivity and secondary analyses

In this section, I provide a sensitivity analysis for the mediation effects I estimated and two secondary analyses. The mediation effects estimated in these analyses are valid under the assumption that no other confounders affect the mediator outcome relationship. However, even when controlling for a large set of covariates, the sequential ignorability assumption is seldomly respected. This risks to be especially true when comparing three different cohorts with only a limited set of comparable control and maternal behaviors variables.

Here, I provide sensitivity analyses for the mediating effect of maternal smoking in pregnancy on birth weight in grams (Keele et al., 2015). This sensitivity analysis simulates a confounder factor correlated with error terms in both the mediator and outcome equations and re-estimates the mediation effect for various level of correlation (ρ) among the error terms. Here, to consider reliable the estimated mediation effect we would expect that small variations in ρ would not be associated with large changes in the mediation effect.[6] Figure 2 in the appendix reports the results of a sensitivity analysis. The x-axis reports the simulated correlation (ρ) between the error terms in mediator and outcome equations, and the y-axis displays the value the mediation effect would take at different levels of (ρ). Across the three cohorts, the results of the sensitivity analyses point towards the conclusion that the estimated mediation effect is less sensitive to unobserved confounders in the 2001 cohort with respect to previous cohorts ($\rho = -0.3$ in 2001; $\rho = -0.2$ in 1958 and 1970), as it requires the highest correlations between the error terms to both reduce the effect to zero or double it in size. Across the three cohorts, maternal smoking in pregnancy seems to be a more robust mediator in the relationship between maternal socio-economic status and birth outcomes in the 2001 cohort.

I further performed two secondary analyses to better understand the role of improvement in antenatal care and of MAR for inequalities in birth outcomes. First, perinatal medical technologies have improved drastically in the last 50 years, boosting birth outcomes and increasing fetal survival (Goisis et al., 2017a, 2017b). This increase in survival may have led to an increase share of rescued "frail" births (Fertig, 2010). In other words, medical technological advancements "rescue" frail fetuses that would have ended up in miscarriages. I investigated this scenario using the share of very low birth weight children (VLBW—born smaller than 1500 g) as a proxy for weak fetuses surviving gestation.

[6] The mediation effect in Figure A2 is called natural indirect effect (NIE), drawing from terminology from causal mediation effects (VanderWeele, 2015).

I find that VLBW deliveries remained almost constant among the high-SES: about 0.5% across the three cohorts; and VLBW deliveries decreased for low-SES from about 1.1% in the 1958 to about 0.7% in 2001. If medical advancements impacted birth outcomes inequalities, they may have contributed in reducing them, as the number of very frail births slightly decreased for the low SES.

Second, another possible explanation to the persistence of inequalities across cohorts may be that the composition of live-births among highly educated has changed due to the increased number of MAR-conceived children. Since MAR children are both more likely to be born from high SES parents and are more likely to have poor birth outcomes, their conceptions may have stagnated birth outcomes among the high SES: I re-estimated Eq. (1) for the MCS (the cohort where MAR may play a role), including a control for whether the child is MAR born. Results are identical and reported in Table A3. This suggests that MAR did not contribute in mantaining inequalities constant.

Conclusions and discussion

In this article, I investigated the association between socioeconomic status measured as maternal education and birth outcomes across three British cohorts. I further investigated how maternal smoking behaviors during pregnancy accounted for this association. There are two main findings in this article. First, the difference in birth weight and in the probability of LBW between high- and low-educated mothers is non-trivial, and it persists across the three cohorts with values similar to those found by causal literature on the effect of exogenous shocks on birth outcomes. This result holds also when SES is measured as the highest social class among the parents. I further investigated the role of MAR and medical advancement in accounting for these trends and they did not seem to play a large role in explaining the persistence of these differentials.

The second main finding of this article is that the amount maternal smoking accounts for the SES gradient in LBW varies notably across the three cohorts, highlighting the fact that underlying causes of these disparities may have changed across time. An explanation for the change in the relevance of maternal smoking across the three cohorts may be that also among mothers smoking followed the stages of tobacco epidemic. Prenatal maternal smoking was more evenly distributed among socioeconomic strata in 1958, and it became a behavior mainly concentrated among low-SES among the 1970 and 2001 cohorts, following the stage of the tobacco epidemic (Khlat et al., 2016; Lopez et al., 1994), as also Fig. 1 seems to suggest. What may have contributed to SES disparities in the 1958 cohort remains an open question. In this regard, I investigated (analyses not shown) whether quality and quantity to access prenatal care played a role in explaining educational differences in 1958, but I did not find any evidence. It may be thus possible that material conditions such as maternal nutrition and working conditions may have played a predominant role in shaping SES differences in birth outcomes.

Taken together, the two main results of this study suggest that the constant levels in inequalities in birth outcomes may reflect many processes that evolved across these four decades, many of which may be at play together and in opposite directions, as I argued in the background section. In fact, despite smoking in pregnancy become more stratified and consequently a more important determinant of inequalities, it did not imply a change in levels of the trends of inequalities overall. Further research should examine how the evolution of different—often contradictory—phenomena contributed to shape levels of inequalities in birth outcomes.

This work is not free of caveats. I have only a limited number of comparable covariates to use across the three cohorts, reducing the number of possible confounders I can control for. Second, following from the previous limitation, I can only account for one maternal behavior during pregnancy, and consequently the estimates of the mediation effect are likely to be biased upwards. However, maternal smoking during pregnancy is likely to be positively correlated with other health behaviors (Pampel et al., 2010), and consequently it could be considered as a proxy for unhealthy behaviors. Third, I decided to approach the comparability of the SES measure using a relative measure of education. This is only one of the possible approaches to make this measure comparable across cohort, also accounting for large changes in the composition of highly educated women over time.

This study corroborates the idea that together with better-known inequality in health, morbidity and mortality in the adult population (Mackenbach, 2012; Mackenbach et al., 2008), also disparities in birth outcomes exist. These inequalities, and their persistence across these three cohorts, also imply that children from lower SES consistently started with a disadvantage at the very beginning of life for over 40 years, and this may have contributed to the reproduction of observed disparities in health and socioeconomic success across childhood and adulthood (Skopek & Passaretta, 2020). Moreover, in the 1970 and 2001 cohorts, disparities in birth outcomes are most likely determined by preventable factors, such as maternal smoking and behaviors.

Appendix

See Tables 4, 5, 6 and Figs. 2, 3

Table 4 Mediation effect of maternal smoking on birth outcomes for non-UK children in the MCS

	Non-UK MCS (2001)	
	M1 $Y = \mathrm{BW(g)}$	**M2** $Y = \mathrm{LBW}$
	NIE	**NIE**
Ref. High Education		
Low Education	− 5.81	0.001
%Mediation	8%	3%
N	2887	

Control variables: Maternal height; maternal age; maternal marital status at birth; parity; timing of access to first antenatal care; sex of the newborn

The NIE are not statistically significant

Table 5 Descriptive statistics of cases having missing values on LBW (Source: NCDS, B70, MCS waves 1. Own elaboration)

	Cohort:		
	NCDS (1958)	**B70 (1970)**	**MCS (2001)**
	Mean/%	**Mean/%**	**Mean/%**
Independent variables			
Social background			
High	25.60	40.00	14.54
Low	74.40	60.00	85.46
Smoking in pregnancy (SIP)	31.80	45.16	26.73
Controls			
Female	46.02	46.15	40.54
Maternal Height (cm)	160.98	161.42	161.48
Maternal age			
< 19	5.23	3.23	0.78
20–29	59.87	67.74	43.39
30–39	32.39	29.03	38.35
40 +	2.53	–	10.46
Marital status			
Married	95.42	70.97	39.88
Non-Married	4.58	69.03	60.12
Birth order			
First born	43.29	29.03	52.57
Second born	29.07	22.58	24.41
Third + born	27.65	49.39	23.02
Timing of prenatal care			
Before 12th week	22.90	22.58	41.41
12th to 23rd week	61.78	38.71	45.54
After 23rd week	14.33	38.71	–
No visits	0.99	–	18.05
N	1776	31	65

Table 6 Regression results including MAR indicator

	(1)	**(2)**	**(3)**	**(4)**
	LBW	LBW	BW	BW
	Table 2	MAR	Table 2	MAR
	OR (SE)	OR (SE)	Beta (SE)	Beta (SE)
University educated	1.437***	1.446***	− 57.086***	− 57.207***
	(0.161)	(0.161)	(12.896)	(12.926)
MAR		1.700**		− 94.152**
		(0.379)		(39.080)
N	14,598	14,598	14,598	14,598

Note: Estimates in column (1) and (3) are obtained as in Table 2 from the MCS. Estimates in column (2) and (4) are obtained including a dummy for whether the child was conceived after MAR. Controls included are the same of estimates from Table 2

***p < 0.01, **p < 0.05, *p < 0.10

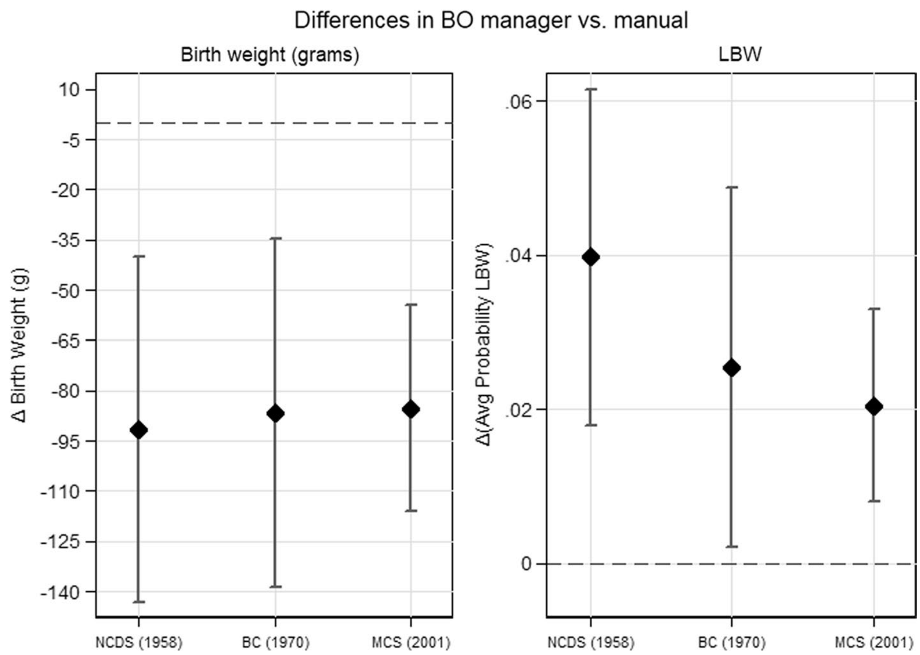

Fig. 2 Class differences in birth outcomes. This graph is computed by estimating Eq. 1 using a measure of parental class (the highest social class among the father and the mother). The point estimates report the difference in birth outcomes for manual occupations compared to manager (the reference line). *BO* birth outcomes

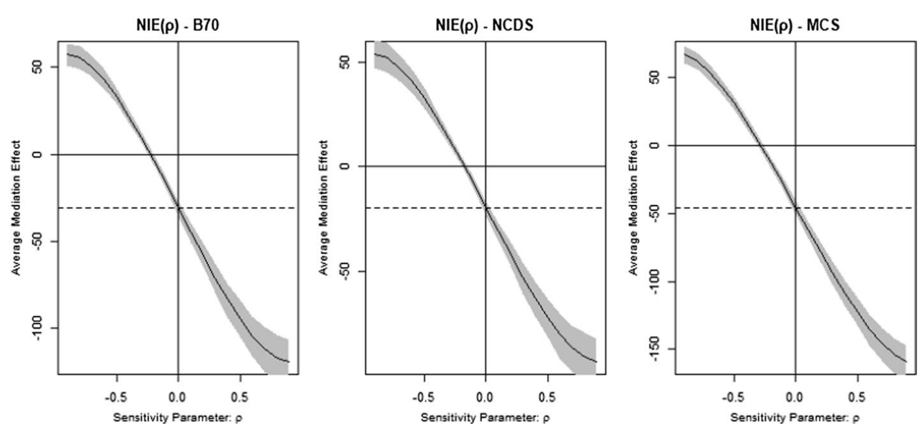

Fig. 3 Sensitivity analyses for the mediation effect of maternal smoking in pregnancy for each cohort. The graph reports the correlation between the error terms in the mediator (Eq. 4) and outcome models (Eq. 5) and the NIE. Dashed line is the estimated NIE. Estimates obtained with 500 simulations

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Author contributions

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Availability of data and materials
Data are available under reasonable request to the corresponding author.

Declarations

Competing interests
The author declare no competing interests.

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