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Secular changes in the association between advanced maternal age and the risk of low birth weight: A cross-cohort comparison in the UK

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Existing studies provide contradictory evidence concerning the association between child health and advanced maternal age. A potential explanation for the lack of consensus on this issue is changes over time in the costs and benefits of giving birth at an advanced age. This is the first study to investigate secular changes in the characteristics of older mothers and in the association between advanced maternal age and child health. We use data from four UK cohort studies, covering births from 1958 to 2001, and use low birth weight (LBW) as a marker for child health. We find that across successive birth cohorts, the negative association between advanced maternal age and LBW becomes progressively weaker; and that this pattern is partially explained by secular changes in the characteristics of older mothers. Our results suggest that associations between maternal age and child outcomes are tied to a specific population and point in time.

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Keywords: maternal age; child health; postponement; cross-cohort; UK

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Introduction

Since the 1970s, there has been a marked increase in the postponement of childbearing in developed countries (Sobotka 2004). This trend has been marked by sharp increases in the mean age at first birth and in the numbers of births at advanced maternal ages (Billari et al. 2007). Although the postponement of childbearing has become common across the entire developed world, whether and, if so, to what extent women should be advised against giving birth at an advanced age because of the associated health risks are questions that are still being debated (Tough et al. 2002). One reason for the lack of general consensus on the question of 'how old is too old' (Heffner 2004) is the growing awareness that evidence from earlier periods might not accurately reflect the contemporary association between maternal age and child well-being. Whereas in earlier periods advanced maternal age at birth was associated with high parities and low socio-economic status, advantaged women today are more likely than disadvantaged women to give birth at an older age (Prioux 2005). It is therefore possible that older mothers and their children face lower risks of poor health outcomes today than they did two or more decades ago (Carolan 2003). Up to now, however, no study has analysed whether this is the case, despite the growing proportion of women giving birth at advanced maternal ages in the UK (Figure 1), as well as in other countries. Evidence on whether and why the association between maternal age and the risk of poor birth outcomes has changed over time is therefore relevant from both a demographic and a medical perspective.

We use data from four birth cohort studies covering births that occurred in the UK in 1958, 1970, 1992, and 2000–02. We find that, across successive birth cohorts, older mothers have become more advantaged on average; and that over time, advanced maternal age has become less likely to be associated

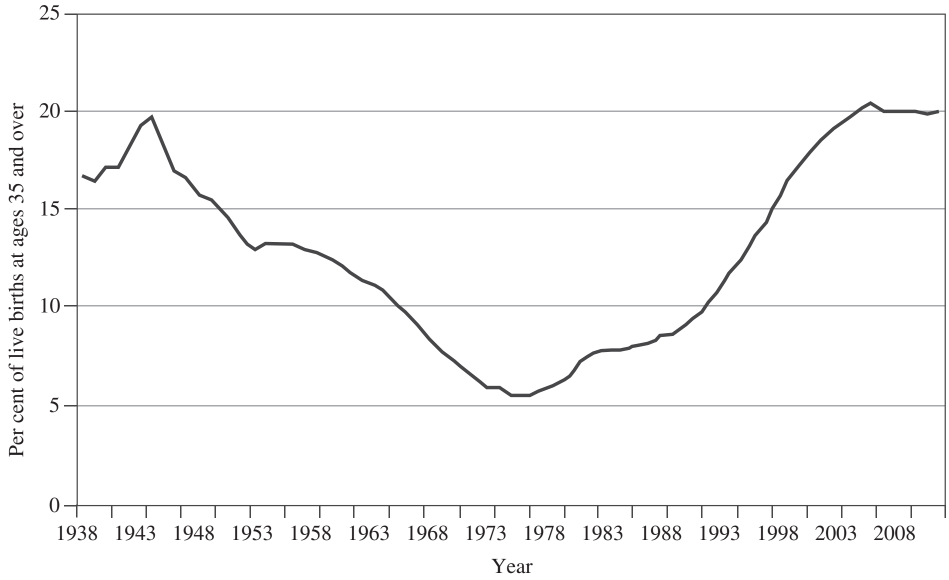

Figure 1 Percentage of live births at maternal ages 35 and over in England and Wales, 1938–2013
Source: Office for National Statistics (2014).

with having a low birth weight (LBW) child. Indeed, in the most recent birth cohort studied, the association is shown to be negligible, both statistically and substantively. The decline in the association can be partially explained by secular changes in the characteristics of older mothers. Moreover, overall improvements in the medical context of childbearing may have contributed to the decline.

Background

The question of whether there is an association between advanced maternal age and child health remains highly controversial. Concerns about late childbearing have been raised in the medical literature. A large number of studies have suggested that in terms of pregnancy outcomes, the optimal age range for childbearing is 20–35 (Bewley et al. 2005; Nwandison and Bewley 2006). This argument is based on evidence that women who give birth after age 35, and especially after age 40, face increased risks of antepartum, intrapartum, and post-partum complications. The potential complications include miscarriage, high blood pressure, pre-eclampsia, gestational diabetes, and chromosomal abnormalities, as well as problematic neonatal outcomes, such as preterm delivery and LBW (Hansen 1986; Aldous and Edmonson 1993; Fretts et al. 1995; Jolly et al. 2000; Kenny et al. 2013).

However, other studies have found no or only limited evidence of increased risks of adverse pregnancy outcomes among older mothers (Kirz et al. 1985; Barkan and Bracken 1987; Berkowitz et al. 1990; Cunningham and Leveno 1995; Carolan and Frankowska 2011). For example, while older mothers face higher risks of operative delivery (e.g., caesarean (C-section)) and morbidity (e.g., gestational hypertension), it appears that neonatal outcomes are not affected by maternal age (Bianco et al. 1996; Ziadeh and Yahaya 2001).

One potential reason for the lack of general consensus about the risks associated with giving birth at an advanced maternal age is that the nature and severity of these risks may be changing over time. It has been argued, though not tested empirically, that mothers who give birth at an advanced age today face lower risks of poor neonatal outcomes than their counterparts two or three decades ago (Carolan 2003).

There are several mechanisms through which the risks associated with giving birth at an advanced maternal age could have declined. First, the risks may be lower today than they were several decades ago because the socio-demographic characteristics of older mothers have changed. In a contemporary developed country like the UK, which is the geographical focus of this study, older mothers are, on average, a particularly advantaged subsection of the population, as they are more likely than younger mothers to be highly educated and employed in a professional occupation (Bray et al. 2006; Hawkes and Joshi 2012; Goisis 2015). Conversely, in the past, a child who was born to an older mother was, on average, more likely than a child born to a younger mother to have been a higher-order birth, and to have been born into a family that was large and relatively poor (Prioux 2005). Because there were fewer socio-economic incentives associated with giving birth at older ages, older mothers were a more heterogeneous group in the past than they are today. Moreover, knowledge about the link between health behaviours during pregnancy and birth outcomes has improved considerably over time. For example, in the UK, as in many other developed countries, knowledge about the detrimental effects of smoking during pregnancy on birth outcomes was not widespread until the 1970s. Thus, we expect smoking during pregnancy to have become more selective of disadvantaged and younger mothers over time (Fertig 2010).

Second, the risks associated with giving birth at an advanced maternal age may have declined as a result of changes in the medical and epidemiological contexts surrounding childbearing. The introduction of prenatal screenings has helped to reduce the number of negative birth outcomes associated with advanced maternal age (Myrskylä and Fenelon 2012), as these screenings have made it easier to detect genetic abnormalities and identify problematic pregnancies in the early stages. There have been significant advancements in postnatal care as well. For example, in the UK, special baby care units were introduced in the 1960s, neonatal intensive care was introduced in the 1970s, and further technological and pharmacological advancements were made during the 1970s and 1980s (Dunn 2006). Modern neonatal technology has contributed to the reduction in complications arising from poor health outcomes at birth (Hack et al. 1995). It therefore appears likely that these improvements in obstetric care have made the risks associated with giving birth at an advanced maternal age more manageable than they were in the past (Carolan 2003). Moreover, overall improvements in medical practice and services may have helped to slow down the natural health deterioration and reproductive ageing processes. Thus, today's older mothers may be healthier than their earlier counterparts.

In sum, the association between maternal age and child health reflects a complex set of interactions between health and social processes, which are broadly illustrated in Figure 2. Secular changes in the way advanced maternal age is associated with these socio-demographic and health processes, and in the contexts surrounding childbearing may have resulted in secular changes in the costs and benefits of giving birth at an advanced age. In this study, we aim to test empirically whether there have been secular changes in the socio-demographic characteristics and health (behaviours) of older mothers, and thus in the association between advanced maternal age and giving birth to an LBW child.

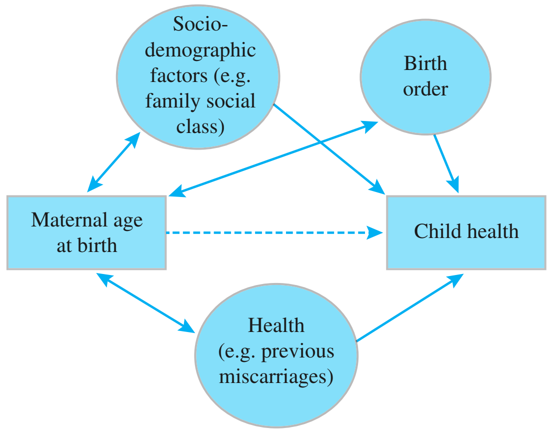

Figure 2 The association between maternal age and child health through social and health processes

Data

To examine the secular trends in the association between advanced maternal age and child health at the time of birth, we use data from four UK birth cohort studies that cover individuals born in the UK over four decades. These studies are longitudinal, but because this paper focuses on the association between maternal age and child health at the time of birth, we include only the data collected in the first sweep of each study. The focus of the analyses is on the cohort members' birth weights and their mothers' ages at birth.

1958 National Child Development Study (NCDS)

The 1958 NCDS is a nationally representative longitudinal cohort study of all children born (including stillbirths) in England, Scotland, and Wales during one particular week of March 1958. The study, which had its origins in the Perinatal Mortality Survey, later became known as the NCDS or the 1958 birth cohort study. The Perinatal Mortality Survey collected information on 17,416 babies. The birth survey was completed by a midwife who attended the delivery and interviewed the mother after the birth of the cohort child. In the case of a stillbirth or neonatal death, a clinical summary was also completed by the midwife and the medical attendants. The response rate for the birth survey was 98.8 per cent.

1970 British Cohort Study (BCS)

Like the NCDS, the 1970 BCS is a nationally representative longitudinal cohort study of all children born (including stillbirths) in England, Scotland, and Wales during a particular week, in this case in April 1970. The birth survey collected information on 16,571 babies. As in the NCDS, the birth survey was completed by the midwife who attended the birth, and was complemented with clinical information. The response rate for the birth survey was 95.9 per cent.

1992 Avon Longitudinal Study of Parents and Children (ALSPAC)

The ALSPAC is a longitudinal cohort study of children born in the county of Avon between April 1991 and 31 December 1992. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committee. The study targeted pregnant women who were living in the catchment area of the county of Avon (Boyd et al. 2013). The eligible sample consisted of 20,248 pregnant women, of whom 14,541 (71.8 per cent of the eligible sample) were recruited. A total of 14,062 live births were included in the baseline sample. Unlike the other cohort studies used in this study, the ALSPAC is not nationally representative. However, its inclusion in our analysis allows us to fill in a 30-year gap between the BCS and the Millennium Cohort Study during which no nationally representative data were collected. The birth weight of each child was taken from obstetric records collected at the time of birth. For ease of exposition, and because the majority of the births in the sample occurred in 1992, we refer to the ALSPAC as the 1992 cohort study.

2001 Millennium Cohort Study (MCS)

The MCS is a nationally representative longitudinal cohort study of 19,244 children born in England, Scotland, Wales, and Northern Ireland in 2000–02 (Hansen 2008). It is the most recent representative cohort study conducted in the UK. The first sweep was conducted when the cohort children were around nine months old, hence a response rate of 68 per cent, lower than in the two earliest studies where the data were collected by the midwife who attended the birth. In most cases, the main respondent for the MCS was the cohort child's biological mother. Mothers' reports of birth weight tend to be reliable and in line with registration data (Tate et al. 2005). Throughout our analyses, we exclude cases in which the main respondent was not the biological mother. Selected wards were disproportionately sampled in the MCS to over-represent areas of high child poverty, concentrations of ethnic minorities, and the three smaller countries of the UK (Scotland, Wales, and Northern Ireland). For this reason, we used weights in our analyses to rebalance the survey and to account for its complex structure. For ease of exposition, we refer to the MCS as the 2001 cohort study, as the majority of the births in the sample occurred in 2001.

Measures

Our outcome is a binary variable indicating whether the cohort child was LBW, defined as having a birth weight below 2.5 kg. We chose this outcome for three reasons. First, existing studies have shown that LBW is the most important determinant of neonatal and infant morbidity (Boardman et al. 2002) and that, on average, LBW is an indicator of individuals' chances later in life (Black et al. 2007; Figlio et al. 2014). Second, as many studies have shown that older women are more likely than younger women to give birth to an LBW baby (Aldous and Edmonson 1993), birth weight is a relevant outcome, given the scope of this study. Third, because birth weight data were collected in the four cohort studies, we can investigate secular changes in the association between advanced maternal age and child health. Since we rely on LBW as an indicator of chances later in life, we exclude stillbirths from the 1958 NCDS and the 1970 BCS samples. In ALSPAC, stillbirths were included in the original sample, but birth weight was not recorded and in the MCS, stillbirths were not part of the original sample. We also exclude children weighing more than 4.5 kg at birth from the reference category, as the later-life outcomes of these children tend to be worse than the outcomes for children of normal weight (Van Lieshout and Boyle 2011). Although the prevalence of macrosomia increases with maternal age at birth, the number of children weighing more than 4.5 kg was too small to allow us to analyse this outcome separately.

In order to investigate the association between maternal age and LBW across cohorts, we divide the mothers' ages at birth into six categories: under 20 (<20), 20–24, 25–29, 30–34, 35–39, and 40 or older (40+). Throughout the analyses, the age group 25–29 is used as the reference category, because in all four cohort studies the lowest prevalence of LBW babies was found among mothers in this age group. As it is likely that the social meaning of giving birth at ages 25–29 has changed over time (Rindfuss and Bumpass 1976), we replicated the analyses using the 20–24 age group as the reference category, which produced qualitatively similar results. We define advanced maternal age as ages 40+, as a large body of literature has shown that the association between advanced maternal age and adverse birth outcomes becomes clinically relevant after this age threshold (Mills and Lavender 2011).

Throughout the analyses, we consider an extensive set of covariates (discussed in the next section) that are used to describe the characteristics of the mothers by the ages at which they gave birth, and then to explore how their inclusion in regression models modifies the estimated association between maternal age and the risk of giving birth to an LBW child. Previous evidence has suggested that, on average, older mothers who gave birth recently had higher socio-economic status and better health behaviours in pregnancy than their younger counterparts (Carolan 2003; Martin 2004; McLanahan 2004). However, we do not know whether this pattern was similar in previous decades. We also expect to find that older mothers in all the cohorts experienced more complicated pregnancies than younger mothers. Again, it is unclear whether complications occurred to the same extent across the cohorts. Maternal age is a marker of both socio-demographic and health characteristics, and the interactions between these two sets of characteristics may determine whether mothers who give birth at advanced ages are at higher risk of having an LBW child (Goisis 2015). In other words, the social advantages of older mothers may compensate for or even outweigh the health risks associated with being older (Stein and Susser 2000). For this reason, we analyse both the socio-demographic and health characteristics of mothers based on the age when they gave birth. Some of the covariates were measured in an identical or highly similar way across the cohort studies (e.g., social class), while others were measured differently (e.g., mother's education), and still others were collected for some of the cohorts but not others (e.g., information on complications during pregnancy was collected in the MCS only). Health behaviours such as smoking and use of antenatal care, which are likely to be socially patterned, are considered as socio-demographic variables. For each cohort study, we use all the available and relevant variables. The variables are listed in Table 1.

We considered including additional covariates. For example, we adjusted for the region of residence, as doing so could have captured variation in the quality of the health services available in the place where the mother gave birth, but the results were largely unchanged. Our adjustment for mothers' ethnicity in the MCS (in the other cohorts, the samples were predominantly white) did not change the results either.

Statistical analyses

In the first step, we compare the socio-demographic characteristics, the health behaviours, and the health characteristics of mothers by the ages at which they gave birth. The aim of this step is to show whether and, if so, how the profiles of the women who gave birth at advanced ages have changed over time.

Next, in order to analyse the association between advanced maternal age and having an LBW child, we estimate a series of logistic regression models. Since some of the variables have missing values, we use multiple imputations to create 20 'filled-in' data sets for each birth cohort by applying multivariate imputation using the chained equation method in Stata 14. Table A1 in the supplementary material shows the sample size increase we obtain by imputing the data sets. The results from the non-imputed data set are qualitatively similar. We impute all the variables, except the dependent variable (LBW) and birth order. We are unable to impute birth order because some of the regression models are run on first births only. Using the imputed data sets, for each birth cohort separately we estimate a series of models that include varying sets of covariates. Analyses for the MCS are conducted using sample weighting and account for the complex survey design. All analyses are conducted in Stata 14.

We begin by exploring the association between maternal age and LBW using a sample including

Table 1 Description of covariates used in the analyses and collected at Sweep 1 for the four cohort studies

	NCDS 1958	BCS 1970	ALSPAC 1992	MCS 2001
Basic variables				
Maternal age at birth	√	√	√	√
Birth order	√	√	√	√
Multiple birth	√	√	√	√
Sex of cohort child	√	√	√	√
Socio-demographic variables				
Social class RGSC classification[1]	√	√	√	√
Mother's education	√	√	√	√
Mother employed at the start of pregnancy	√	–	–	–
Household income	–	–	–	√
Overcrowded household	√	–	–	√
Marital status[2]	√	√	√	√
Mother smoked during pregnancy	√	√	√	√
Mother's height	√	√	√	√
First antenatal care after twelve weeks of pregnancy	√	√	√	√
Mother drank during pregnancy	–	–	√	√
Pregnancy was planned	–	–	–	√
Health variables				
Mother had previous stillbirths	√	√	√	√
Mother had previous miscarriages	√	√	√	
C-section delivery	√	√	√	√
Foetal distress during pregnancy	√	–	–	–
Abnormality during pregnancy or delivery	√	–	–	–
Labour lasted more than 24 hours	√	–	–	–
Cohort child had abnormal heart rate during delivery	–	√	–	–
Number of hospital discharges during pregnancy	–	√	–	–
Mother in good health up to start of pregnancy	–	–	√	–
Gestational hypertension	–	–	√	–
Complications during pregnancy	–	–	–	√

[1]Registrar General's Social Class (RGSC): 1958, 1970 refers to social class of the father; 1992, 2001 refers to highest level in the household.
[2]1958 and 2001 refer to marital status at birth; 1970 and 1992 refer to marital status at eight weeks gestation and at conception, respectively.
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

births of all orders. We estimate four model specifications, illustrated in equations (1)–(4):

$$Logit(Y) = \alpha + \beta_1 MAB + \beta_2 CHILDDEM \quad (1)$$

$$Logit(Y) = \alpha + \beta_1 MAB + \beta_2 CHILDDEM + \beta_3 BIRTHORD + \beta_4 MATSOCIODEM \quad (2)$$

$$Logit(Y) = \alpha + \beta_1 MAB + \beta_2 CHILDDEM + \beta_3 BIRTHORD + \beta_5 MATHEALTH \quad (3)$$

$$Logit(Y) = \alpha + \beta_1 MAB + \beta_2 CHILDDEM + \beta_3 BIRTHORD + \beta_4 MATSOCIODEM + \beta_5 MATHEALTH \quad (4)$$

where Y is child health (LBW); *MAB* is maternal age at birth (in categories, with age group 25–29 as the reference category); *CHILDDEM* refers to the cohort members' basic demographic characteristics (sex, multiplicity); *BIRTHORD* is the cohort members' birth order in their family; *MATSOCIODEM* refers to the mothers' or families' socio-demographic characteristics (e.g., level of education, marital status at the time of birth); and *MATHEALTH* is maternal health before or during pregnancy/delivery (e.g., previous miscarriages, C-section delivery). Model 1 is the baseline model. Since a large family size could be an indicator of low socio-economic status and also a physiological/health predictor for LBW, Models 2–4 include an adjustment for the children's birth order that is not included in Model 1. In Model 2, we adjust for the mothers' or families' socio-demographic characteristics; and in Model 3, we adjust for mothers' health before or during pregnancy. Finally, Model 4 is a fully adjusted model. The models that include adjustments for covariates are only partially comparable across cohorts, as in each study we adjust for a different set of covariates, and the same variables do not necessarily capture the same family characteristics across cohorts.

As a second step, we estimate the models for first births only. We estimate the same four models, but this time we do not control for birth order. Although excluding higher-order births comes at the cost of sample size, first births represent an important subsample. Existing studies have shown that the negative association between advanced maternal age and child health is particularly pronounced for first births (Lisonkova et al. 2010). Moreover, among the more recent cohorts, it is likely that the mothers who gave birth to their first child at an advanced age were particularly selected and advantaged (Martin 2004), and that their characteristics more than compensated for the increased health risks associated with giving birth at an advanced age. Therefore, if a secular decline in the association between advanced maternal age and LBW exists, we would expect it to be more pronounced for first births than for all births.

Finally, in order to measure differences over time directly, we combine the data for the 1958 NCDS and the 2001 MCS studies (i.e., the least and most recent birth cohorts), and estimate a pooled model that includes the baseline variables (as in Model 1), as well as the interactions of the baseline variables with the MCS 2001 indicator variable. The pooled model enables us to estimate the coefficient and the statistical significance of the interaction of the 40+ age group with the 2001 indicator. As in the separate analyses of each birth cohort, we obtain estimates for a sample that includes births of all orders, and then for a second sample that includes first births only. Details of the pooling procedure are discussed in the supplementary material.

Results

Descriptive associations

Figure 3 shows the unadjusted U-shaped association between LBW and maternal age by birth cohort for births of all orders. The pattern we observe among young mothers is in line with our expectations, given the socio-economic disadvantages of members of this group (McLanahan 2004). The higher proportions of LBW we observe among older mothers are consistent with the findings of the medical literature on the adverse health outcomes of fertility postponement (Nwandison and Bewley 2006). The pattern we find for first births shows some inconsistencies in the shape of the association, which may be due to the small sample size (Figure A1 in the supplementary material). Table A2 in the supplementary material shows how sociodemographic characteristics and health behaviours varied across maternal age groups and cohorts, while Table A3 shows the same for health status. Figures 4–6 illustrate the results for selected indicators. Consistent with expectations, we find that older women who gave birth in 1992 and in 2001 were more advantaged than their younger counterparts.

With regards to socio-economic characteristics, Figure 4 shows that among women who gave birth in 1958 or 1970, smaller percentages of the older women were in a high social class than of the women who gave birth in their mid-20s. The reverse pattern can be observed among women

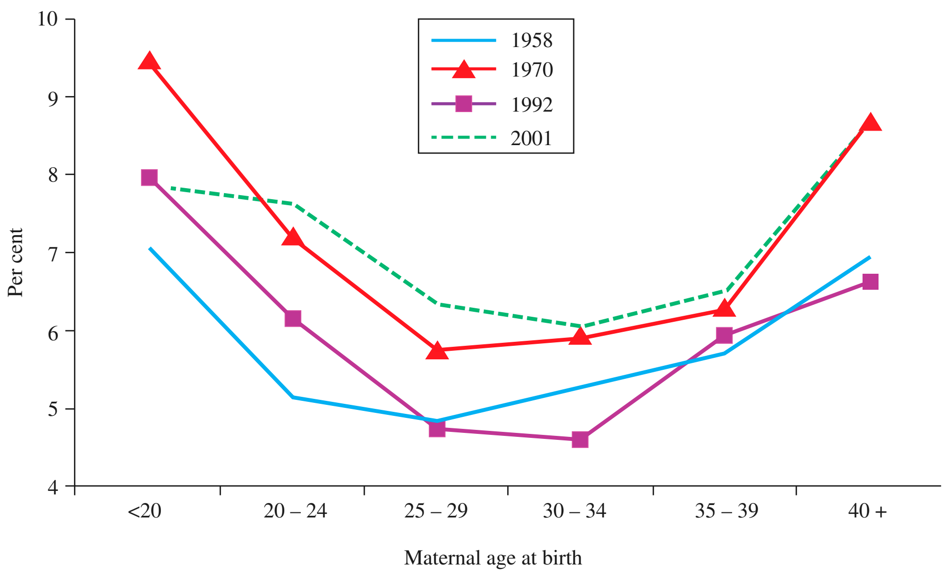

Figure 3 Percentage of births with low birth weight, by maternal age group and birth cohort, births of all orders
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

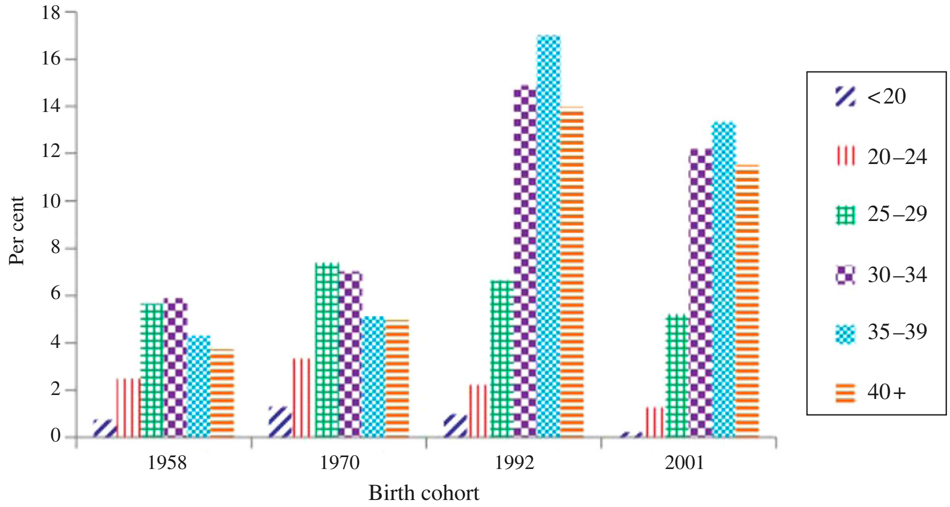

Figure 4 Percentage of mothers with high household social class, by maternal age at birth and birth cohort
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

who gave birth in 1992 or 2001, with older women being more likely to be in a high social class than younger women. The results for other socio-economic indicators are qualitatively similar. For example, whereas in all the cohort studies, older mothers were, on average, more likely than younger mothers to have been married when they conceived or gave birth, the differences in marital status between the older and younger mothers were much more pronounced in the more recent cohorts (see Table A2 in the supplementary material).

Looking at health behaviours, Figure 5 shows that there was no age gradient in smoking during pregnancy among the earlier cohorts, whereas the older mothers who gave birth in 1992 or in 2001 were far less likely to have smoked during pregnancy than the younger mothers. In the 1992 and 2001 cohorts, older mothers were more likely than the younger mothers to have been drinking heavily during pregnancy; although the differences between these groups were smaller in 2001 than they were in 1992 (Table A2 in the supplementary material).

The percentages of mothers who used antenatal care for the first time after twelve weeks of pregnancy declined steadily across the cohorts (Table A2 in the supplementary material); and, on average, the older mothers were less likely than the younger mothers to have first used antenatal care after twelve weeks of pregnancy in all the cohorts. This pattern is not, however, entirely linear, as the mothers in the oldest age group were marginally more likely than the mothers who gave birth in their mid- to late 20s or early 30s to have first used antenatal care after twelve weeks of pregnancy.

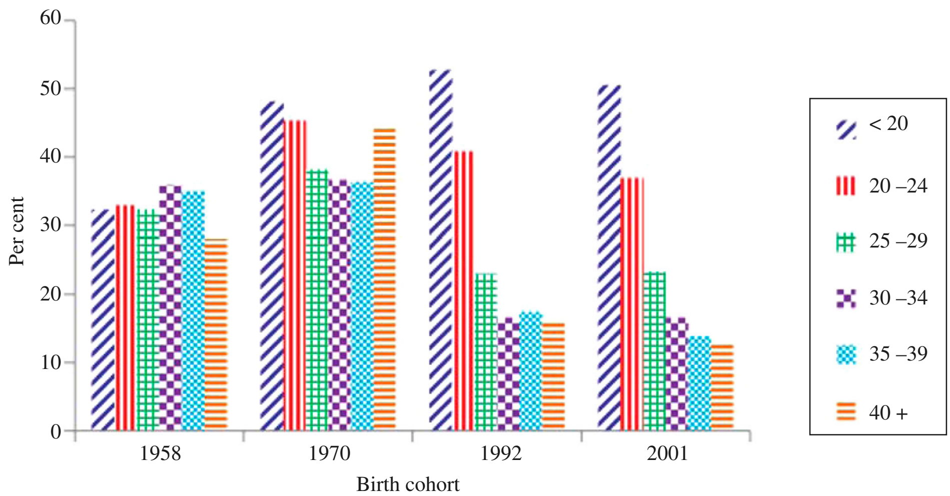

Figure 5 Percentage of mothers smoking during pregnancy, by maternal age at birth and birth cohort
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

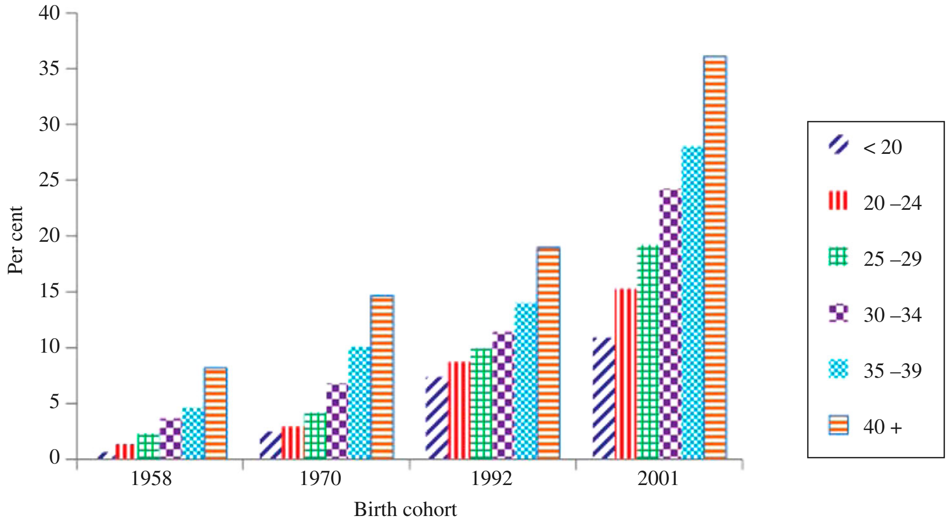

Figure 6 Percentage of mothers who delivered through C-section, by maternal age at birth and birth cohort
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

However, the age gradient is clearer when we look at first births only.

The results suggest that, across the cohorts, the differences in the profiles of mothers who gave birth at age 40+ and those who gave birth in their 20s grew, and advanced maternal age became increasingly associated with socio-economic advantages and positive health behaviours during pregnancy. In addition, the secular changes in the profiles of older mothers appear more pronounced when we look at the characteristics of first-time mothers (Table A2 in the supplementary material).

Moving on to health status, Figure 6 shows the results for C-section deliveries. In all the cohorts, older mothers were, on average, more likely than younger mothers to have experienced a C-section delivery. Additional results (Table A3 in the supplementary material) show that older mothers were more likely to have experienced stillbirths, miscarriages, and gestational hypertension. These results suggest that in all the cohorts, older mothers were at higher risk than younger mothers of experiencing complications during pregnancy and delivery.

Table 2 shows marked changes in the distributions of all births and first births by maternal age group. The percentage of births to mothers aged <20 remained fairly stable across the birth cohorts, while the percentage of births to mothers aged 20–24 halved, albeit not linearly, as the percentage of mothers giving birth at younger ages increased between 1958 and 1970. As expected, important changes occurred in the distribution of births at older maternal ages. The percentages of births (first births in particular) at ages 30–34 and 35–39 increased across birth cohorts (except in 1970). For example, 3 per cent of first births in 1958 were to mothers aged 35–39, compared with 9 per cent of first births in 2001. The percentage of births of all orders to mothers aged 40+ remained fairly stable across the birth cohorts, but the percentage of first births to women in this age group increased slightly. These changes across cohorts reflect the process of childbearing postponement that has been documented in the UK and other European countries since the 1970s (Sobotka 2004).

Table 2 also shows that the overall prevalence of LBW remained fairly stable across birth cohorts. This may be because survival rates for children with very low birth weights (VLBW) are higher today than they were in the past (Hack et al. 1995). This finding suggests that the more recent cohorts (1992 and 2001) include LBW children who were excluded from the earlier cohorts (1958 and 1970) as they would have been stillborn.

Regression results

Figure 7 shows the odds ratios of having an LBW child among mothers aged 40+ relative to mothers aged 25–29 from Model 1 (the baseline model). Table 3 shows the parameter estimates (with 95 per cent confidence intervals) from Models 1–4 for all births and first births among mothers aged 40+. Tables A4 and A5 in the supplementary material show the full model results for all age groups.

As we can see in Figure 7, Model 1 (the baseline model) shows a secular decline in the association between advanced maternal age and LBW for all

Table 2 Percentage of births by maternal age group, and percentage of births with low birth weight and other characteristics, in four birth cohorts

	1958	1970	1992	2001
All births				
Distribution of births				
<20	5.9	9.9	4.4	7.6
20–24	29.1	35.9	18.5	16.5
25–29	32.4	30.7	39.0	27.7
30–34	19.9	15.1	27.9	31.1
35–39	10.2	6.4	8.9	14.9
40+	2.5	2.0	1.2	2.1
% low birth weight				
<20	7.1	9.5	8.0	7.9
20–24	5.2	7.2	6.2	7.6
25–29	4.9	5.7	4.8	6.3
30–34	5.3	5.9	4.6	6.1
35–39	5.7	6.3	5.9	6.5
40+	6.9	8.7	6.6	8.6
All ages	5.3	6.8	5.2	6.7
% multiple birth	1.2	1.1	1.3	1.5
% girl	48.8	48.5	48.8	49.0
Number of observations	15,952	16,432	12,350	17,484
First births				
Distribution of births				
<20	13.2	21.6	8.4	15.5
20–24	44.0	47.5	23.7	20.3
25–29	29.1	22.5	41.0	28.9
30–34	9.9	5.7	20.9	25.2
35–39	3.2	2.0	5.4	9.1
40+	0.6	0.6	0.6	1.0
% low birth weight				
<20	7.5	9.6	8.4	7.7
20–24	5.4	8.3	7.0	9.2
25–29	6.4	7.3	5.5	7.8
30–34	8.5	10.3	7.9	7.5
35–39	4.6	10.5	8.3	8.1
40+	13.9	13.5	6.5	10.7
All ages	6.3	8.5	6.8	8.0
% multiple birth	0.9	0.8	1.0	1.6
% girl	49.0	49.3	49.2	48.6
Number of observations	6,075	6,284	5,622	7,400

Notes: Sample sizes for the 20 filled-in data sets. Survey weights have been used for the 2001 cohort study.
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

births and for first births. Figure A2 in the supplementary material shows very similar results when the maternal age group 20–24 is used as the reference category. It is worth highlighting that although the data allow us to cover a 43-year period, there is a large gap between the 1970 and 1992 cohort studies. This could explain why the transitions from one survey to another do not always appear to be smooth.

Starting with Model 1, Table 3 shows that for births of all orders, the mothers in the 1958 and 1970 cohort studies who were aged 40+ at the time of birth had significantly higher odds (at the 5 per cent level) of giving birth to a LBW child than the mothers in the reference category (aged 25–29). The secular decline is not monotonic, as the odds ratio for the 1992 cohort study is similar in size to the odds ratios for the 1958 cohort study. However, the parameter in the former study is not significant at conventional levels, while the parameter in the latter study is significant at the 5 per cent level. The odds ratio in the 2001 cohort study is not statistically significant and is smaller than those in the other cohort studies.

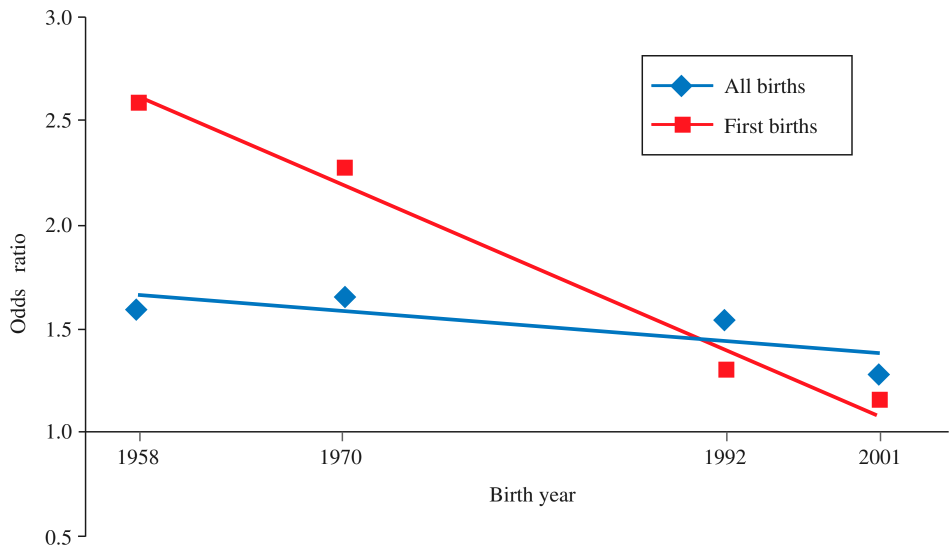

Figure 7 Odds ratios of having a baby with low birth weight for mothers aged 40+: all births and first births, by birth cohort (Model 1)
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

The results for first births from Model 1 reveal that in the 1958 and 1970 studies, the mothers who were aged 40+ when they gave birth to their first child experienced higher odds of having an LBW child than the mothers in the reference category (aged 25–29); these differences are large but only significant at the 10 per cent level, which could be because the small number of first births at ages 40+ results in an imprecise estimation of the parameters. In the 1992 and 2001 cohort studies, the mothers who were aged 40+ when they gave birth do not have significantly higher odds of having an LBW child than the mothers in the reference category and the corresponding odds ratios are smaller than in the earlier cohort studies. As expected, we find that the secular decline is more pronounced when we look at first births only. As we can see in the descriptive results, the mothers who gave birth to their first child at an advanced age in 1992 and 2001 were selected and advantaged, and their characteristics could more than compensate for the increased health risks associated with giving birth at an advanced age.

The upper part of Table 3 shows how the odds ratios of LBW for births of all orders among the mothers aged 40+ change when we adjust for socio-demographic and health characteristics. The results for

Table 3 Odds ratios of having a baby with low birth weight (Models 1–4) for mothers aged 40+: all births and first births in four birth cohorts

	Model 1: baseline		Model 2: baseline + socio-demographic characteristics		Model 3: baseline + health indicators		Model 4: baseline + socio-demographic characteristics + health indicators	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
All births								
NCDS 1958	1.59**	1.06–2.40	1.63**	1.07–2.49	1.51*	0.99–2.30	1.53**	1.00–2.34
BCS 1970	1.65**	1.09–2.50	1.45*	0.95–2.22	1.40	0.92–2.14	1.27	0.83–1.95
ALSPAC 1992	1.54	0.79–2.98	1.94*	0.99–3.82	1.41	0.72–2.78	1.55	0.78–3.08
MCS 2001	1.28	0.79–2.08	1.68**	1.01–2.79	1.11	0.67–1.82	1.43	0.85–2.39
First births								
NCDS 1958	2.58*	0.98–6.79	2.73**	1.02–7.30	2.41*	0.89–6.50	2.74**	1.00–7.47
BCS 1970	2.27*	0.86–5.95	1.62	0.60–4.36	1.93	0.72–5.14	1.48	0.55–4.00
ALSPAC 1992	1.30	0.31–5.51	1.40	0.33–5.99	0.97	0.22–4.25	1.02	0.23–4.55
MCS 2001	1.15	0.47–2.83	1.31	0.55–3.13	0.84	0.34–2.08	0.96	0.41–2.26

Notes: 95% CI refers to the 95 per cent confidence interval. Survey weights have been used for the 2001 cohort study. Significance at the *10, **5, and ***1 per cent levels. The reference category is mothers aged 25–29.
Source: 1958 NCDS cohort; 1970 BCS cohort; 1992 ALSPAC cohort; 2001 MCS cohort.

Model 2 show that the adjustment for socio-demographic characteristics (variables listed in Table 1) results in different changes for mothers in the 1958 and 1970 cohort studies than for mothers in the 1992 and 2001 cohort studies. The odds ratio decreases relative to Model 1 among mothers aged 40+ in the 1970 cohort study and remains almost unchanged in the 1958 cohort study; conversely, the odds ratio increases (more markedly) among mothers aged 40+ in the 1992 and 2001 cohort studies, and becomes statistically significant at the 10 and 5 per cent levels, respectively. The results for the 2001 cohort suggest that the secular decline in the association between advanced maternal age and LBW is at least partially explained by the more advantaged profile of the women who gave birth at advanced maternal ages in more recent years. The results for Model 3 show that adjusting for health characteristics reduces the odds ratios relative to Model 1 to a similar extent in all the birth cohorts, suggesting that (as revealed in the descriptive analyses) older mothers in all cohorts face more pregnancy complications than younger mothers, which potentially leads to an increased risk of LBW. The increased risk of LBW is more than compensated for by older mothers' advantaged profiles in the 2001 cohort study, but not in the earlier ones. The results for Model 4 (fully adjusted for both socio-demographic and health characteristics) show that only the odds ratio for mothers aged 40+ in the 1958 cohort is statistically significant (at the 5 per cent level). The secular decline is more attenuated in the fully adjusted model than in Model 1, but it is not entirely eliminated. However, caution should be used when comparing the results of the fully adjusted models across cohorts, as these models adjust for different sets of covariates. For example, using the data from the 2001 cohort study, we can adjust for pregnancy planning, which has been found to be a risk factor for LBW (Flower et al. 2013). This variable was not included in the earlier cohort studies. However, pregnancy planning could turn out to be integral to the advanced maternal age/LBW association, since some of the births at older ages may have been unplanned because of failure or non-use of contraception.

The lower part of Table 3 shows how the odds ratios of LBW for first births among mothers aged 40+ change after adjusting for mothers' socio-demographic and health characteristics. Compared with the baseline model, the adjustment for socio-demographic variables results in a decrease in the odds ratio among mothers aged 40+ in the 1970 cohort study and an increase in the odds ratio among mothers aged 40+ in the 1958, 1992, and 2001 cohort studies. However, among mothers aged 40+ in the 2001 study, the odds ratio for first births, unlike for births of all orders, does not reach statistical significance or the levels observed in the unadjusted model for the earlier cohorts. Adjustments for health variables (Model 3) produce changes similar to those observed for all births: that is, in all the cohort studies, the variables attenuate the association between giving birth at an advanced maternal age and the odds of having an LBW child. The odds ratios among mothers aged 40+ in the 1992 and 2001 cohort studies become smaller than one. Except for 1958, the odds ratios among mothers aged 40+ in Model 4 (fully adjusted) are lower than the baseline values, but the secular decline is not eliminated or reduced.

These results suggest that the increased odds of having a LBW child among mothers aged 40+ in the earlier cohorts can be at least partially or entirely explained (in the 1958 and 1970 cohorts, respectively) by their relatively high risks of health complications and by the fact that their socio-economic profiles did not differ from those of younger mothers (and therefore did not compensate for the health risks). The results also indicate that the women who gave birth at an advanced maternal age in recent years were at lower risk of giving birth to an LBW child than their counterparts in the past, despite having a higher risk of pregnancy complications. This finding reinforces the hypothesis that the secular decline could be attributable to changes in mothers' characteristics and obstetric practices, which may compensate for and contribute to the management of the health risks associated with giving birth at an advanced maternal age.

As a final step, we estimate the baseline model by pooling data from the earliest (1958) and most recent (2001) cohort studies to make direct comparisons of the differences across these cohorts and of the secular changes in the association between advanced maternal age and LBW. Table A6 in the supplementary material reports the main coefficients of interest. The pooled model includes interaction terms between the 2001 cohort variable and the categorical maternal age variable. Of central interest are the estimate and the statistical significance of the interaction of the 40+ age group with the 2001 indicator. The exponentiated interaction coefficient estimate is a ratio of odds ratios (ROR); in other words, the factor by which the odds ratio corresponding to the 40+ age group changes when comparing the MCS with the NCDS. Table A6 in the supplementary material displays both the 40+ odds ratio and the modifier for the 2001 cohort. The results are in line with those in Figure 7. For all births, using age 25–29 as the reference category, the interaction term is substantially below one (0.80), but is statistically insignificant at the 5 per cent level. When we look at first births only, we can see that the ROR is even smaller than the corresponding value for all births (0.44); but again, it fails to reach statistical significance. When we look at the results for first births with the reference category 20–24, this continues to be the case (p-value = 0.10).

Although the focus of this study is on women who gave birth at an advanced maternal age, we will briefly comment on the results for women who gave birth at the youngest ages. The unadjusted results show that in all cohorts, women who gave birth aged <20 had significantly higher odds (at least at the 5 per cent level) of having an LBW child than mothers who gave birth at age 25–29. However, the magnitude of this association weakened across cohorts. On the one hand, these findings are consistent with the descriptive results showing that the group of young mothers has remained a relatively disadvantaged subgroup of the population across the cohorts. On the other hand, the finding that the magnitude of this association has decreased over time could be attributed to changes in medical and obstetric practices, which mothers of all ages have benefited from.

Sensitivity analyses

Because comparing logit coefficients across model specifications and cohorts can be misleading (Mood 2010), we also estimated linear probability models. The results, displayed in Table A7 (in the supplementary material), show a consistent story. We also replicated the analyses using a continuous measure of birth weight and using continuous (rather than categorical) maternal age. The results, which are available on request, are qualitatively similar to the main results presented in this paper. Since the proportion of multiple births has increased across cohorts (Table 2)—a pattern that can be explained by medical developments that have resulted in higher survival rates in multiple pregnancies, as well as by increased use of assisted reproductive technologies (ART)—we also replicated the analyses excluding multiple births from all the cohorts. The results (available on request) are qualitatively similar to our main results; that is, they show a secular trend.

Conclusions

The association between maternal age and child well-being remains a highly controversial issue, as average maternal age at birth continues to increase across the developed world. The existing literature has not reached a consensus on the question of whether and, if so, to what extent giving birth at an advanced maternal age should be avoided. In this literature and in the current debates, a question that has not been addressed until now is whether the association between advanced maternal age and child health has been changing systematically over time. Secular changes in the association between advanced maternal age and child health may have occurred because of changes in the characteristics of older mothers, and due to improvements in medical and obstetric practices.

In this study, we investigated the questions of whether the characteristics of older mothers have changed over time and whether (possibly as a consequence of these characteristics) the association between advanced maternal age and LBW has also changed. We analysed data from four large UK birth cohort studies and found that giving birth at an advanced maternal age (i.e., at age 40+) became less likely to be associated with having an LBW child across successive cohorts, and particularly when we compared the 2001 cohort with the 1958 cohort. The secular decline in the association between advanced maternal age and birth weight was more pronounced for first births. While older mothers were, on average, more advantaged than their younger counterparts in all the cohort studies, this gap widened considerably over successive cohorts. Still, in all the cohort studies, older mothers were at higher risk than younger mothers of having complicated pregnancies and deliveries.

Adjusting the association between advanced maternal age and LBW for socio-economic characteristics and health of the mother separately, and then jointly, proved to be helpful for understanding the process through which this association declined over the birth cohorts studied. When we included adjustments for the mothers' socio-demographic characteristics in the models, we found that in the most recent cohorts the risk of LBW associated with advanced maternal age increased. This shows that an important mechanism through which the risk of having an LBW child has declined among older mothers is that the women in this group have become more socio-economically advantaged over time. Thus, it appears that the accumulation of social resources helps to offset the otherwise negative effects of an advanced maternal age on birth weight. When we included in the models an adjustment for the mothers' health, the increased risk of having an LBW child with advanced maternal age decreased in all the cohorts. But the health-adjusted results in particular contribute to our conclusion that the increased health risks faced by the mothers who gave birth at an advanced maternal age in the 1958 and 1970 cohort studies (and, to some extent, in the 1992 cohort study)—which were not compensated for by the increased socio-economic status of the older mothers, as was the case in the most recent cohort study—are an important mechanism for explaining the higher odds among this age group of having an LBW child.

We cannot directly compare the fully adjusted results across cohorts because different sets of covariates were used in each cohort study, and the same variables may have had different meanings across cohorts. For example, there was an adjustment in the 2001 MCS cohort study for whether the pregnancy was planned, but not in the previous studies. An adjustment for this variable in the previous cohorts could further attenuate the positive association between advanced maternal age and LBW; that is, having a child at an older age may have been the result of an unintended pregnancy due to failure or non-use of contraception. However, a possible explanation for the remaining secular trend is that there were changes in the medical context. Indeed, it is plausible to expect that having access to modern obstetric care could make the risks associated with giving birth at an advanced maternal age more manageable than they were in the past. Although the data do not allow us to test for such effects directly, we think it is reasonable to contend that the explanation for the secular decline lies at the intersection of changes in mothers' characteristics and in the surrounding medical context. In the UK, important advancements in antenatal care were introduced after the 1970s, and these improvements may have made it easier than it was in the past for women to manage the risks associated with giving birth at an advanced age. Changes in the epidemiological context have also made it more likely that VLBW children will be born alive, which may have led to an increase in the prevalence of LBW children born to mothers in their mid- to late 20s (i.e., the reference category). Excluding VLBW children from the 2001 cohort study marginally increases the association between advanced maternal age and LBW (results not shown). It is therefore possible that the increased survival of VLBW children has contributed to the flattening of the maternal age/LBW association in the more recent cohorts.

This research has limitations. First, because of sample size issues, especially in the analyses of first births, some parameters could not be precisely estimated. Nonetheless, the analyses of all births, which were less affected by sample size problems, showed a secular decline in the association between advanced maternal age and LBW. It was not possible to account for gestational age, as this information was missing or not reliable in 10 per cent of the 1958 cases and 18 per cent of the 1970 cases in our samples. Moreover, since ultrasound scans were generally not available when the less recent cohort studies were conducted, we expect the measurement of gestational age to have varied across cohorts in ways that would prevent us from meaningfully comparing this variable across cohorts. Nonetheless, LBW is considered an important indicator of neonatal outcomes, as many existing studies have found that for individuals born both preterm and at term, LBW is associated with important indicators measured at different stages of the life course (Hack et al. 1995; Richards et al. 2001; Black et al. 2007).

Second, the data from the ALSPAC 1992 cohort study are not nationally representative, in contrast to the data from the other cohort studies, as it was conducted in the Avon region and the majority of the participants were of white ethnicity. While validation studies have shown that the ALSPAC sample under-represented ethnic minorities, these studies also found that the sample only slightly under-represented disadvantaged families, and that the mean birth weights in the sample were in line with UK national estimates for 1990. Hence, we believe that the biases caused by the lack of national representativeness of the ALSPAC are limited. Moreover, this cohort study enabled us to fill in a 31-year gap between the 1970 and 2001 cohort studies.

Third, we were unable to determine to what extent secular changes in the association between advanced maternal age and LBW were driven by changes in the overall medical context. On the one hand, improvements in medical and obstetric practices may have helped to reduce the risks associated with giving birth at an advanced maternal age. On the other hand, there is evidence that the prevalence of gestational diabetes (Ferrara 2007), a condition associated with higher birth weights, has increased across cohorts. To reduce the possibility that our results reflect these secular changes, we excluded children weighing more than 4.5 kg at birth.

Fourth, this study focused on the UK only, so it is unclear to what extent the results are generalizable to other countries. We think it is likely that we would observe similar patterns in other developed countries in which trends in the postponement of childbearing and changes in the epidemiological context surrounding childbearing are similar to those in the UK. To overcome this limitation, it would be necessary to conduct similar analyses using different data, and, importantly, for countries that have not experienced medical improvements as well as for those that have.

Finally, while the most recent cohorts covered in this study were born in 2000–02, there is evidence that the percentage of mothers giving birth at an advanced maternal age has been increasing since then (Office for National Statistics 2014). It is likely that the patterns of social selection into giving birth at an advanced maternal age have remained similar or become even more pronounced in recent years; however, women who have postponed childbearing to older maternal ages are increasingly using ART, which have been shown to be associated with increased risks of poor birth outcomes (Sutcliffe and Ludwig 2007; Schmidt et al. 2012). Therefore, we cannot say whether the trends observed between 1958 and 2001 have continued, stabilized, or even reversed. However, additional analyses that excluded children born through ART from the 2001 MCS showed very similar results, which suggests that it is unlikely that these patterns will reverse because of the increased use of ART.

Despite these limitations, our findings have implications that are relevant for both theory and research. First, the intersection of the changing selection into older maternal ages and the improvements in the medical context over time may modify the association between maternal age and child well-being. As a consequence, both the direction and strength of any association between maternal age and child outcomes are tied to a specific population and point in time. Therefore, studies that investigate the association between maternal age and child well-being must reflect on and situate the meaning of maternal age within the context of the groups and the historical period under consideration, while paying particular attention to the selection processes underlying individual differences in the timing of childbearing (Geronimus 1996). Second, since the link between advanced maternal age and LBW has weakened over time, the children of older mothers are at lower risk of poor health outcomes today than they were 60 years ago. The results of our study are informative not only from a demographic perspective, but also from a public health/medical one, as they challenge the view that advanced maternal age is a risk factor for poor birth outcomes (Bewley et al. 2005; Nwandison and Bewley 2006). Our results suggest that the balance between the costs and benefits of childbearing at older ages varies over time, since it is tied to the characteristics of the affected groups. Therefore, although advanced maternal age should not be discarded as a risk factor for poor birth outcomes, its relevance should be weighted, as it is not static, but is instead shaped by the characteristics of older mothers and the surrounding medical context. This argument is further supported by evidence showing that the negative association between LBW and subsequent well-being has declined across cohorts (Goisis et al. 2017). It therefore appears that, compared with previous generations, children born to older mothers today are not only less likely to be LBW; when they are born with a LBW, the negative consequences are less severe.

In summary, this is the first study that has investigated how secular changes in the characteristics of older mothers are linked to the association between advanced maternal age and child health around the time of birth. This topic remains controversial, and our results suggest that the period under consideration may be an important source of variation between studies that needs to be taken into account, both before and after adjusting for covariates. Our results show that across successive birth cohorts, the association between advanced maternal age and LBW has become progressively weaker; and was negligible, both statistically and substantively, for the most recent birth cohort. The decline in the association is at least partially explained by the socio-economic advantages of the older mothers in the more recent cohort studies. Moreover, the results suggest that if selection into older maternal ages had not changed among the more recent cohorts, it is likely that advanced maternal age would still be associated with a higher risk of LBW. Future research should aim to improve our understanding of these time trends by replicating the analyses of this study through the investigation of other markers of child outcomes, and different geographical contexts and time periods.

Notes and acknowledgements

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