

RESEARCH ARTICLE

Educational differences in the impact of maternal age on perinatal health in Spain: A population-based study

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ABSTRACT Advanced maternal age has been linked to unfavourable birth outcomes, yet uncertainties regarding the generalisability of these associations remain. Socioeconomic resources protect perinatal health, which raises the question of potential mitigation of age effects. Using register data from the Spanish Birth Statistics (2007–2021), this study explores how a wide range of adverse perinatal outcomes relate to mothers' age and education and their interaction. Statistically significant ($p < 0.05$) incremental effects of maternal age on most outcomes are observed. Maternal university-level education and, to a lesser extent, medium-level education play a protective role translating into a lower baseline probability of most events already at ages 25 to 29, and, generally, into lower figures across the age distribution. Nevertheless, effects are frequently small and sometimes restricted to specific combinations of education and age, which suggests that the perinatal health impact of maternal ageing should not be underplayed even among more advantaged population strata.

KEYWORDS Perinatal health • Late childbearing • Maternal education • Maternal age

Introduction

Over the past decades, the proportion of women who delay childbearing until later stages of their reproductive period has been rising, especially in high-income, low-fertility countries (Cooke et al., 2012; Beaujouan, 2020; Frick, 2021). Across several societies, women are having their first child, on average, in their early thirties (Beaujouan, 2020), with many making the transition to motherhood after age 35 (Eijkemans et al., 2014) and, increasingly, after age 40 (Beaujouan, 2020; Beaujouan and Sobotka, 2022). Furthermore, childbearing has become a possibility even in postmenopausal ages due to developments in medically assisted reproduction (MAR) (Ekberg, 2014).

While fertility delay started in affluent, post-industrial societies and among highly educated individuals – among whom it is still most prevalent (Beaujouan and Sobotka, 2022) – the phenomenon is rising globally (Fauser et al., 2024). Fertility delay is also reaching additional social strata as it becomes more manifestly linked to economic uncertainty and living conditions (see, e.g., Hellstrand et al., 2022; Savelieva et al., 2023; Van Wijk and Billari, 2024). Moreover, there is evidence of an increase in late fertility intentions, possibly reflecting reproductive constraints (Beaujouan, 2023), but also greater social acceptance of

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late childbearing (Lazzari et al., 2025) and confidence in the potential of MAR to overcome age-related fertility limitations (Maheshwari et al., 2008; Delbaere et al., 2020).

Fertility delay is, indeed, a complex and multifaceted phenomenon. It started as part of the broader sociodemographic transformation known as the second demographic transition, which entailed changes in family dynamics such as union formation and dissolution, and which has been explained with reference to ideational and value shifts towards the greater centrality of self-realisation and individual autonomy (Lesthaeghe and Van de Kaa, 1986; Lesthaeghe, 2010). Structural processes have also contributed to childbearing postponement, including the emergence and diffusion of effective contraception; women's educational expansion and large-scale incorporation into paid employment; and the extension of formative periods, which delay departure from the parental home and family formation (Mills et al., 2011, Ní Bhrolcháin and Beaujouan, 2012). Other relevant factors are difficulties with labour market entry and consolidation or in accessing affordable housing (Mills et al., 2011), changes in partnership dynamics (Sobotka, 2010; Kreyenfeld et al., 2012), work-family reconciliation barriers (Mills et al., 2011) and employment-related opportunity costs stemming from motherhood (Balbo et al., 2013). Recently, the growing importance of economic and labour market uncertainty, as well as of expectations about the future, for fertility delay has been underscored (Fahlén and Oláh, 2018; Vignoli et al., 2020; Lappegård et al. 2022; Savelieva et al., 2023), although evidence regarding these factors is mixed. Some findings indicate that perceived economic uncertainty is not as clearly linked to decisions about the transition to parenthood as income is (Van Wijk and Billari, 2024). Moreover, there is research showing changes in perceived optimal ages for childbearing (Lazzari et al., 2025) and weaker fertility aspirations among younger cohorts (Beaujouan, 2023), which could facilitate postponement decisions as well.

As a result of delayed childbearing, there has been a rise in the number of women who experience difficulties conceiving, carrying a pregnancy to term and achieving their desired family size. It has been estimated that women under 30 years old have an 85% probability of conceiving within one year, while this figure declines to 66% at age 35 and to 44% at age 40 (Delbaere et al., 2020). The development of medically assisted reproduction has made it possible to address age-related infertility challenges and to shift some biological limits to fertility through techniques such as oocyte vitrification or gamete or embryo donation (Daar et al., 2016; Van de Wiel, 2022). As a consequence, the proportion of treatments offered to women over 40 years old has increased substantially (Beaujouan, 2023). Nonetheless, late fertility continues to entail complications and potential risks, including that of childlessness. While medically assisted reproduction helps many individuals fulfil their reproductive aspirations, it has so far lacked the capacity to overcome all potential infertility challenges, not least those related to age (Präg et al., 2017). The risk of miscarriage increases rapidly after age 30, reaching almost 30% at age 40 (Delbaere et al., 2020) and surpassing 50% among women over age 45 (Magnus et al., 2019). The probability of maternal, foetal and perinatal complications also rises steadily with maternal age, especially after age 35 (Vandekerckhove et al., 2021; Saccone et al., 2022). Advanced paternal age has additionally been found to augment the risk of some adverse pregnancy and birth outcomes (Nybo Andersen and Kjaer Urhoj, 2017).

Consequently, part of the literature on late fertility, especially research from health-related fields, has been devoted to understanding the effects of maternal age on perinatal outcomes. Advanced maternal age (AMA, usually defined as an age equal to or over 35 years, see Geiger, et al., 2021) has been associated with poorer birth outcomes such as foetal growth restriction, prematurity, low birthweight, congenital anomalies and foetal and perinatal mortality (see for instance Lawlor et al., 2011; Walker and Thornton, 2016; Saccone et al., 2022). Several underlying biological mechanisms related to the health of the mother have been identified (Walker and Thornton, 2016). Such findings suggest that age-related perinatal risks could be contingent on maternal health status, since the incidence of adverse birth outcomes is low (Carolan and Frankowska, 2011; Mutz-Dehbalaiie et al., 2014; Frick, 2021). In addition, these results might not be generalisable to settings with high-quality antenatal monitoring and care (Geiger, et al., 2021) Furthermore, these findings raise questions about the potentially mitigating role of socioeconomic resources, which have been shown in many contexts to be protective of pregnant women's and newborns' health (De Graaf et al., 2013; Kim et al., 2018; Nicholls-Dempsey et al., 2023).

However, interactions of socioeconomic resources and the effects of age on birth outcomes are largely unexplored. Some earlier studies pointed to a reduction in the probability of low birthweight among women aged 35 years or older when adjusting for sociodemographic and lifestyle factors (Joseph et al., 2005; Cleary-Goldman et al., 2005). Other research, however, has found that a higher risk of adverse birth outcomes among women of advanced maternal age remains after adjustment for socioeconomic status (Kenny et al., 2013). As noted by Londero et al. (2019), the possibility that the social and economic advantages of older mothers could override the increased biological risks associated with age has yet to be tested. This study aims to fill this gap by analysing this question in a systematic manner, covering a broad range of perinatal health indicators and using long-term (2007–2021), large-scale birth register data that include women over age 45, who are often omitted from cohort studies due to small sample sizes (Claramonte Nieto et al., 2019). It focuses on Spain, a country that is characterised by late fertility and universal provision of high-quality prenatal care (García-Tizón Larroca, 2022), but also by difficulties in accessing care for socially vulnerable groups (Paz-Zulueta et al., 2015). The purpose of the analysis, which takes maternal education as the main independent variable due to its proven association with greater socioeconomic resources, healthier lifestyles and better access to reproductive knowledge and care (De Graaf et al., 2013; Mills and Lavender, 2014; Simoncic et al., 2022), is twofold. First, it will provide an overview of the prevalence and adjusted predicted probabilities of different birth outcomes across age and educational categories. This will allow us to assess how perinatal health is affected by maternal age within the Spanish pregnancy care context, and whether the protective role of education identified in earlier studies (see, e.g., Hvas Mortensen et al., 2011; Juárez et al., 2014; Seiz et al., 2024) holds across a wide range of birth outcomes and with advancing age. Second and most importantly, it will analyse whether maternal education mitigates the impact of age on birth outcomes. An additional contribution of the study is its attention to the impact of ageing on perinatal health indicators throughout the whole reproductive lifespan, as most previous work has been centred on advanced maternal age (i.e., 35 to 45 years old).

Earlier research and theoretical framework

Impact of maternal age on perinatal health: Underlying and potentially moderating mechanisms

The relationship between maternal age and perinatal health has received considerable attention within the medical, epidemiological and public health literature. The focus of most studies has been on the risks of adverse outcomes associated with advanced maternal age (AMA), long defined with reference to the age 35 threshold, although some authors have proposed a shift to age 40 or older (Sauer, 2015; Walker and Thornton, 2016; Claramonte Nieto et al., 2019). Studies from different countries have shown that AMA entails a higher probability of low birthweight (LBW), very low birthweight (VLBW), intrauterine growth restriction (IUGR), pre-term birth (PTB) (Lawlor et al., 2011; Laopaiboon et al., 2014; Saccone et al., 2022), pathologically high birthweight (HBW) (Walker and Thornton, 2016; Elçi et al. 2022), congenital anomalies (Correa-de-Araujo and Yoon, 2021) and stillbirth (Jacobsson et al. 2004; Laopaiboon et al., 2014; Mutz-Dehbalaie et al., 2014; Mills and Lavender, 2014; Walker and Thornton, 2016; Arya et al., 2018; Saccone et al., 2022).

The associations found between perinatal health risks and advanced maternal age have been explained by different biological factors. Among them are age-related utero-placental dysfunction (Lean et al., 2017) and declining oocyte quality leading to chromosomal abnormalities (Mikwar et al., 2020). Older women are also more likely to have pre-existing maternal conditions and pregnancy complications, such as diabetes mellitus or gestational diabetes, hypertensive disorders and other cardiovascular alterations, chronic diseases and placental pathologies (Walker and Thornton, 2016; Cooke and Davidge, 2019; Correa-de-Araujo and Yoon, 2021; Rademaker et al., 2021).

Nevertheless, other mechanisms that are not yet completely understood also seem to be at play (Carolan and Frankowska, 2011; Londero et al., 2019; Ye et al., 2024), some of which appear to be related to the ageing process alone (Correa-de-Araujo and Yoon, 2021). It has been noted that AMA is associated with a higher risk of perinatal complications among women both with and without pre-existing health conditions, when compared to younger women with the same health status (Berger et al., 2021). Advanced maternal age also appears to increase the risk of adverse outcomes in the presence of serious clinical maternal conditions such as preeclampsia (Tyas et al., 2019). Pregnancies through egg donation due to advanced age are also linked to a greater risk of preeclampsia and severe preeclampsia, potentially leading to deleterious birth outcomes (Moreno-Sepúlveda and Checa, 2019).

Despite this evidence, uncertainties remain regarding the strength of these associations and the extent to which they apply to healthy women, as the incidence of adverse birth outcomes continues to be generally low (Carolan and Frankowska, 2011; Mutz-Dehbalaie et al., 2014; Frick, 2021). As was noted, there are controversies regarding whether some specific risks remain unaltered after considering socioeconomic, demographic and lifestyle variables (Joseph et al., 2005; Cleary-Goldman et al., 2005). Accordingly, it has been acknowledged that the role of such factors, and especially of social and economic

advantages, in moderating the occurrence of certain birth outcomes among women of advanced maternal age needs further exploration (Carolan and Frankowska, 2011; Lean et al., 2017; Londero et al., 2019). Moreover, it has been observed that intense, high-quality prenatal monitoring and care may have significant positive effects on the survival and health of infants born to older mothers. It is unclear, however, whether the link between greater pregnancy surveillance and enhanced birth outcomes actually reflects differences in socioeconomic status (Geiger, et al., 2021; Ratiu et al., 2023).

The potentially mitigating role of education in AMA-related adverse perinatal outcomes

Older mothers are more likely than younger mothers to be highly educated, since childbearing postponement is still most prevalent among women who have completed university-level education (Beaujouan and Sobotka, 2022). In this context, it is relevant to analyse whether and to what extent education protects against the potential perinatal health impact of childbearing delay. Research has found that more educated women tend to have healthier pregnancies and better perinatal outcomes than women with lower education (Silva et al., 2010; Hvas Mortensen et al., 2011; Juárez et al., 2014; Funck Bilsteen et al., 2018). These differences, as well as broader socioeconomic differentials, have been observed even in settings with universal healthcare provision for pregnant women and/or good prenatal care (Joseph et al., 2007; Funck-Bilsteen et al., 2018; Kim et al., 2018; Luby et al., 2023; Seiz et al., 2024).

Several potential mechanisms through which maternal education could protect maternal and perinatal health have been highlighted. Education is generally associated with greater economic resources, which facilitate better nutrition and a healthier lifestyle (Larrañaga et al., 2013; Mills and Lavender, 2014; Simoncic et al., 2022). Women with higher educational levels, for instance, show higher levels of adherence to the Mediterranean diet, which is associated with more favourable pregnancy outcomes (Olmedo-Requena et al., 2014). More educated women may also have greater access to information, and thus more knowledge about how to take care of themselves during their pregnancy; greater awareness of potential complications and how to detect them; and a greater ability to access timely healthcare (De Graaf et al., 2013; Simoncic et al., 2022). Education has also been associated with more regular antenatal care attendance (Mills and Lavender, 2014), which, in combination with increased prenatal and antepartum surveillance for women over age 35, has been linked to improved outcomes regarding perinatal mortality (Geiger et al., 2021). Furthermore, in recent years, more attention has been given to the concept of “reproductive career”, which refers to the interconnectedness of an individual’s reproductive events throughout her/his life course, in the sense that past reproductive events have an impact on subsequent reproductive experiences, attitudes and behaviours. Within this framework, individuals with lower socioeconomic status tend to have more complex reproductive trajectories often entailing the accumulation of adverse exposures, and thus often have increased disadvantage (Johnson et al., 2018; 2023). From this perspective, more educated women might be more protected against deleterious birth outcomes because they have fewer past

unfavourable reproductive experiences that could impact later childbearing (e.g., unwanted pregnancies, abortions, miscarriages, medical disorders, stress, difficulties in accessing reproductive healthcare or contacting professionals).

For all these reasons, it is important to examine whether maternal education, in addition to protecting perinatal health, could also modify how perinatal health is impacted by maternal age. In light of earlier research, it appears that higher education – defined as completion of university-level education – is the most relevant factor. The literature on the protective role of education in maternal and perinatal health often finds dose-response educational effects indicating an especially strong association between university-level education and favourable outcomes. This relation is observed in low- and middle-income countries as well as in high-income societies (Bello Álvarez et al., 2025). These findings are consistent with recent research showing that women with university education are more likely to engage in healthier habits and maternal health promoting behaviours (MHPB) than women in lower educational strata (Lindqvist et al., 2017; Gete et al., 2022; Polanek et al., 2022, Simoncic et al., 2022). Nevertheless, there is also evidence that medium-level education could have some protective effects on maternal, foetal and perinatal health as well (Juárez et al., 2014; Baron et al., 2015; Seiz et al., 2024).

The Spanish context

Spain provides an interesting case to analyse the impact of maternal age on perinatal health, and the potential role of socioeconomic risk modulators. The Spanish healthcare system provides universal, high-quality coverage for women during pregnancy (García-Tizón Larroca, 2022) and regular monitoring of all pregnancies considered high risk. Nevertheless, certain access barriers for socially disadvantaged groups have been observed (Paz-Zulueta et al., 2015), which may result in resource-mediated differentials in health outcomes. Whether maternal education can mitigate the impact of age on perinatal results is also a relevant question in Spain's demographic context. The country exhibits lowest-low fertility rates (1.12 children per woman in 2023; see Instituto Nacional de Estadística, 2023a) and particularly pronounced fertility postponement, with a mean age at first birth of 31.5 years old among women (Instituto Nacional de Estadística, 2023b). Moreover, around 11% of all live births in Spain are to women over 40 years old (Eurostat, 2025). Individuals with university-level education, who have become increasingly represented among Spanish women of reproductive age due to educational expansion (Seiz et al., 2024), postpone their childbearing decisions longer than their less educated counterparts (Requena, 2022). Highly educated women also tend to face greater motherhood-related opportunity costs at early employment stages, which further delays childbearing (see Seiz et al. 2023), and they are more likely to have births through medically assisted reproduction (Goisis et al., 2024).

Against this backdrop, it is pertinent to examine whether education compensates to any extent for the impact of childbearing postponement on perinatal outcomes, or whether relatively late motherhood still entails a significant increase in risks that cannot be cushioned by this factor. As was noted, more educated women could have greater

informational, economic and social resources potentially leading to healthier lifestyles and better prenatal care. Pregnant women with low- and medium-level education in Spain are indeed more prone to develop conditions that potentially predispose them to adverse perinatal outcomes, such as obesity, overweight and preeclampsia, and they are also more likely to engage in harmful behaviours, such as smoking (Granés et al., 2023). Such findings are in line with evidence from other high-income countries (see, e.g., Baron et al., 2015; O'Brien et al., 2019). Moreover, the Spanish labour market has long been characterised by high unemployment rates, high prevalence of temporary contracts, protracted working hours and frequently precarious employment conditions, as well as by a marked insider-outsider divide (Schwander, 2023; Castro et al., 2025). In this context, higher skill levels are associated with more favourable working conditions and greater protection against job-related stress, both in physical terms and in relation to potential or actual employment loss, especially during economic crises (Távora and Rodríguez-Modroño, 2018). All these variables could result in better health during gestation and lower risk of adverse perinatal outcomes. Higher levels of maternal education have already been shown to be consistently protective of newborns' health in Spain, including in contexts of economic recession and high unemployment (Seiz et al. 2024). This study will contribute to earlier research by addressing whether this protective effect interacts with maternal age, moderating its impact on birth outcomes. It will also assess the importance of medium-level and university-level maternal education across age categories and a wider range of perinatal outcomes.

Data and methods

The analysis draws on data from the Spanish Birth Statistics, including register data from the Statistical Bulletin of Births collected by the Spanish National Statistics Institute (Instituto Nacional de Estadística). The specific dataset used in this study covers all births that took place in Spain place between 2007 and 2021. We consider a variety of perinatal health indicators – low birthweight (<2500 g), moderately low birthweight (MLBW) (1500–2499 g), very low birthweight (VLBW) (<1500 g), prematurity/pre-term birth (<37 weeks of gestation) (PTB), moderate prematurity/pre-term birth (MPTB) (28 to 36 weeks of gestation), extreme prematurity/pre-term birth (EPTB) (<28 weeks of gestation), post-term birth (42 and 43 weeks of gestation), high birthweight (HBW) (≥ 4000 g and <7000 g) and stillbirth (whether the child was born still or alive)¹ – as dependent variables. The maternal socioeconomic covariates incorporated into the analysis are education (university-level education, medium-level education and primary-level education

¹ Births at or after 22 completed weeks of gestation not resulting in a live-born infant have been classified as stillbirths. This definition, guided by the dataset structure, coincides with the one used in the World Health Organization's (2023) recent Progress report "Improving maternal and newborn health and survival and reducing stillbirth", as well as the one used by the European Medicines Agency. Nevertheless, for international comparisons the 28-week threshold is commonly used, as well as certain cut-offs regarding weight and size (see Tavares da Silva et al., 2016; World Health Organization 2023). The stillbirth figures obtained in this study may thus not be directly comparable with those reported from other countries.

or less, the latter being the reference category),² civil status (married versus non-married) and migrant background (born in Spain versus born in another country). Only children born between 22 and 43 gestational weeks and with a birthweight equal or superior to 500 g have been included. Additionally, the sample is restricted to children born to mothers aged between 25 and 50 years old – that is, those who have had enough time to complete university-level education – to assess the perinatal health impact of maternal age measured in different categories (30 to 34 years old, 35 to 39 years old, 40 to 44 years old and 45 to 50 years old, with the baseline being 25 to 29 years old) as well as potential independent and interactive effects of higher and medium-level education. The number of births initially reported in the dataset – that is, without subtracting missing values – adds up to 4,774,290 live births and 12,998 stillbirths (total $n = 4,787,288$). For all perinatal health indicators except stillbirths, only live births have been considered. The use of large-scale, population-based birth register data allows us to overcome some limitations presented by earlier analyses based on cohort studies, which draw on more reduced sample sizes and/or are restricted to very specific settings.

A descriptive analysis is first carried out to illustrate how births are distributed in the sample across maternal age categories for women with university-level, medium-level and primary-level education. Variations of this distribution over time are also examined to show changes in childbearing delay across educational groups in the analysed period. Additionally, we present the prevalence (percentages) of different adverse perinatal outcomes within each combination of age and educational level. Binary logistic regression models³ – estimating odds ratios and applying heteroskedasticity robust standard errors – are subsequently performed to examine relations between the different perinatal health indicators constituting the dependent variables, maternal age (measured as pertaining to one of the noted categories), maternal education (university-level and medium-level education, with primary-level education as the baseline category) and the interactions of maternal education with age. Statistical significance is assessed at the 95% confidence level ($p < 0.05$). The models are adjusted for the mother's marital status (married versus not married), migrant origin (born in Spain versus born in another country), sex of the newborn (female versus male) and pregnancy and birth-related characteristics conditioning perinatal health and potentially affected by maternal age (parity (first birth versus higher order birth), multiplicity and prematurity when relevant; both as binary variables).

2 University-level education comprises studies corresponding to categories 6 to 8 in ISCED 2011 (bachelor's or equivalent level, master's or equivalent level, doctoral or equivalent level). Medium-level education refers to studies equivalent to categories 2 to 5 in ISCED 2011 (lower and upper secondary education, post-secondary non-tertiary education and short-cycle tertiary education). Primary-level education or less is equivalent to categories 0 and 1 in ISCED 2011. In some years, the education variable shows relatively high proportions of missing values (between 5 and 10%; see Table S.1 in the Supplementary materials). To make sure that this does not alter or bias the results substantially, the regression models have been performed on a subsample with more than 5% of missing values in the education variable. Results have been compared to those obtained from the main sample and from a subsample with less than 5% of missing values in the education covariates. Some variations are observed regarding statistical significance (which sometimes oscillates below and above the 95% confidence level), but these mainly concern very specific interactions with minor coefficients (which are more sensitive to variations in sample size and composition) for relatively rare outcomes (very low birthweight, extreme prematurity, stillbirth). The main findings are essentially robust in terms of magnitude and direction of relations.

3 The models are presented in Figures 2, 5 and 8 in the results section, as well as in table form in the Supplementary materials (Tables S.2, S.3, S.4 and S.5).

Since healthcare provision in Spain is decentralised to the so-called autonomous communities, which entails variations in organisation and funding across regional healthcare systems (Antón et al., 2014), region-specific fixed effects (introduced as regional dummy variables for computational ease) have been incorporated into the models to control for unobserved time-invariant territorial heterogeneity. Paternal age has not been included in the main analysis due to uncertainties regarding the reliability of information on fathers and a lack of data for about 2% of our sample. Nevertheless, the regression models have also been performed on a subsample of observations for which paternal age was available ($n = 4,155,041$) as a robustness check. Results are presented in Tables S.4 and S.5 in the Supplementary materials (available online at <https://doi.org/10.1553/p-67f8-9f5p>).

To facilitate the interpretation of findings and to obtain a clearer picture of the interactive and main effects of maternal age and education, adjusted average predicted probabilities (predictive margins) of each birth outcome for all age groups by educational level are provided. This makes it easier to grasp the magnitude of each risk for each combination of age and education. Finally, to quantify more directly how risks are modified by education, the average marginal effects of having university-level education and medium-level education (as opposed to primary-level education) on the probability of the analysed outcomes for different age categories are also estimated. Post-estimation pairwise comparisons of marginal effects have been conducted to assess whether the marginal effects of education across age categories are uniform or differ significantly in magnitude from each other.

Results

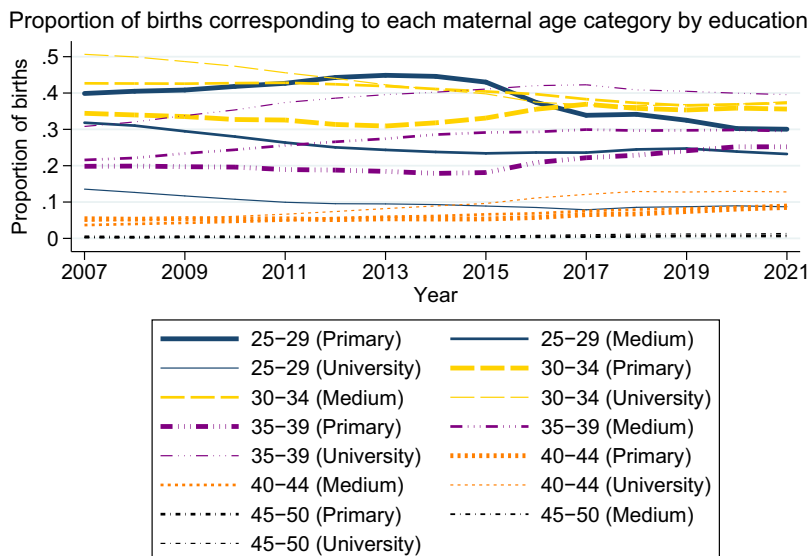
Descriptive analysis

Table 1 shows the age distribution of births by maternal education in the sample. Among women who completed university-level education, births are concentrated within the

Table 1 Percentage of total births within a given educational level corresponding to each age category

	University-level education (categories 6–8 in ISCED 2011)	Medium-level education (categories 2–5 in ISCED 2011)	Low-level education (categories 0–1 in ISCED 2011)
25–29 years old	9.81%	26.14%	39.39%
30–34 years old	42.17%	40.62%	33.83%
35–39 years old	38.26%	26.76%	20.42%
40–44 years old	9.05%	6.06%	5.90%
45–50 years old	0.70%	0.43%	0.46%
Total	100%	100%	100%

Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Women aged 25–50 years old, births at or beyond 22 weeks of gestation and with a birthweight equal to or above 500 g. Observations without missing values only.

Figure 1 Temporal evolution of the distribution of births across maternal age categories in Spain

Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Women aged 25–50 years old, births at or beyond 22 weeks of gestation and with a birthweight equal to or above 500 g.

30 to 39 age range, with the largest share of births (42.17%) occurring among women ages 30 to 34. Among women with medium-level education, births are also most frequent (39.66%) within this age category, followed by the 25–29 age category (28%, in contrast to 9.81% for highly educated women). Among women with primary-level education or less, the largest proportion of births (39.39%) falls within the 25–29 age range, followed by the 30–34 age category (33.83%). Births between ages 40 and 50 are more frequent among women with university education (9.75%) than among women with medium-level (6.49%) and primary-level education (6.36%). These figures illustrate that delayed childbearing in Spain has mainly been driven by women who have completed tertiary education, even though non-negligible proportions of women in lower educational strata have births in their mid- and late thirties as well (26.76% and 20.42%).

Figure 1 confirms that over the analysed period, childbearing at higher ages is consistently most frequent among women with university-level education, while also showing some noteworthy recent trends regarding the generalisation of motherhood postponement. The proportion of births to women over age 35 increases across all educational groups between 2007 and 2021, while the percentages concentrated in the 30–34 category have virtually converged by the end of the period. The proportion of births to women aged 25–29 decreases noticeably in all groups, and especially among women with primary-level education or less. Conversely, the proportion of births to women aged 40–44 increases in all educational categories, and especially among women with university-level education.

Table 2 Prevalence of weight-related perinatal outcomes (percentages) across age categories by level of education

Education	Age	LBW (<2500 g)	MLBW (1500–2499 g)	VLBW (<1500 g)	HBW (4000–6999 g)
University-level education	25–29	6.26	5.56	0.70	5.08
	30–34	6.91	6.17	0.75	4.90
	35–39	7.88	7.00	0.88	5.21
	40–44	9.96	8.73	1.23	5.08
	45–50	17.47	15.44	2.04	3.88
Medium-level education	25–29	7.37	6.52	0.85	5.81
	30–34	8.19	7.25	0.94	5.75
	35–39	9.31	8.21	1.11	5.81
	40–44	11.42	9.89	1.53	5.54
	45–50	19.67	16.74	2.93	4.07
Primary-level education or less	25–29	7.69	6.74	0.95	7.40
	30–34	8.38	7.24	1.14	8.38
	35–39	9.38	8.08	1.30	8.57
	40–44	10.50	8.95	1.55	8.59
	45–50	16.42	13.40	3.03	7.34
All levels	All ages	8.16	7.19	0.96	5.69

Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021.

As has been observed in earlier research (Requena, 2022), an educational gradient in child-bearing delay remains, although it seems to be diminishing over time.

As illustrated by Table 2 and Table 3, the adverse perinatal outcomes analysed are less prevalent, in all age categories, among women with university-level education. In general, the higher the mothers' level of education, the lower the rates of occurrence of unfavourable events. These rates become incrementally greater with age except in the case of high birthweight and post-term birth.

Logistic regression models

Outcomes related to birthweight

Figure 2 shows the results of binary logistic regression models (see Table S.2 in the Supplementary materials) analysing the impact of age, education and their interaction on weight-related perinatal outcomes. The probability of low birthweight increases steadily with age for women with the reference level of education (primary education or less).

Conversely, university-level education – and to a somewhat lesser degree medium-level education – are associated with a lower risk of low birthweight for women in the baseline age category (25 to 29 years old).

Table 3 Prevalence of pregnancy duration-related perinatal outcomes and stillbirth (percentages) across age categories by level of education

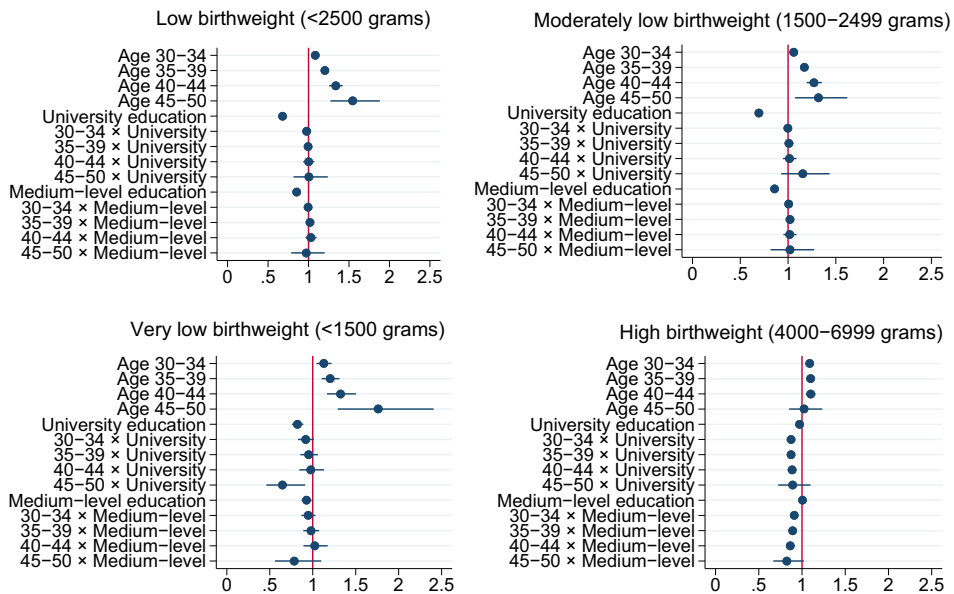
Education	Age	PTB (<37 weeks)	MPTB (28–36 weeks)	EPTB (<28 weeks)	Post-term birth (42–43 weeks)	Stillbirth
University-level education	25–29	5.89	5.70	0.19	1.91	0.14
	30–34	6.46	6.27	0.19	1.58	0.14
	35–39	7.28	7.04	0.24	1.37	0.18
	40–44	9.14	8.81	0.33	1.17	0.23
	45–50	15.87	15.27	0.60	0.84	0.34
Medium-level education	25–29	6.81	6.56	0.25	2.47	0.20
	30–34	7.46	7.20	0.26	2.10	0.21
	35–39	8.48	8.18	0.29	1.80	0.25
	40–44	10.33	9.92	0.41	1.67	0.32
	45–50	18.25	17.44	0.81	1.23	0.42
Primary-level education or less	25–29	7.58	7.31	0.27	2.82	0.29
	30–34	8.46	8.13	0.34	2.66	0.36
	35–39	9.55	9.18	0.37	2.53	0.46
	40–44	10.63	10.15	0.48	2.28	0.54
	45–50	15.84	14.97	0.87	2.62	0.81
All levels	All ages	7.57	7.30	0.27	1.90	0.27

Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021.

The statistically non-significant interactions of education with age suggest that similar, independent relations of these covariates with the outcome are likely to hold more generally, and not just with respect to the reference categories. A similar picture is observed for moderately low birthweight. In the case of very low birthweight, the results are essentially analogous, except for the significant negative interaction between higher education and age for the 45 to 50 age category, which reveals a greater protective effect of university-level education in this group. The probability of pathologically high birthweight increases significantly for women with primary-level education or less in the 30 to 34, 35 to 39 and 40 to 44 age categories (compared to those in the 25 to 29 age category). Significant negative interactions are also found between university- and medium-level education and the three noted age groups, which indicates that education mitigates the age-related risk of macrosomia between ages 30 and 44.

Figure 3 provides a more visual and intuitive depiction of the implications of these relations through the estimation of adjusted average predicted probabilities (predictive margins) of outcomes for each combination of education and age. It becomes evident, first, that the risk of low birthweight in general and moderately low birthweight more specifically increases with age. Furthermore, in all age categories, the higher the level of maternal education, the lower the probability of the outcome. For example, the likelihood of women in the 25 to 29 age range experiencing low birthweight is 6.95% for those with university-level

Figure 2 Binary logistic regression of weight-related perinatal outcomes (low birthweight, moderately low birthweight, very low birthweight, pathologically high birthweight) on maternal age and education and their interactions



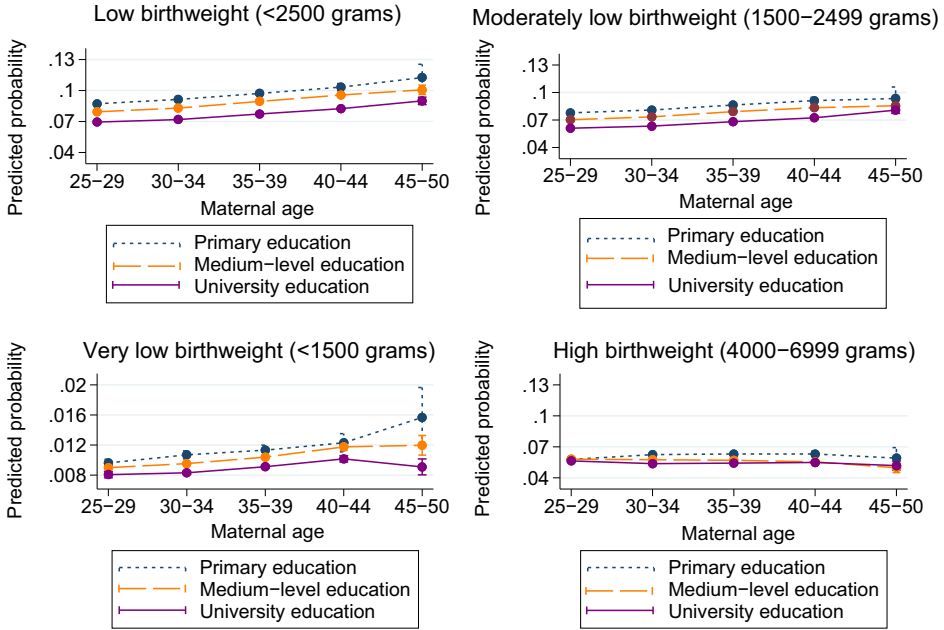
Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, prematurity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. Age reference category: 25–29 years. Education reference category: primary-level education or less. Odds ratios (OR) with 95% confidence intervals (CI).

education, 7.94% for those with medium-level education and 8.72% for those with primary-level studies or less.

As becomes apparent when comparing the respective slopes, this figure continues to rise with age in all educational groups, reaching 9% among mothers with university-level education and surpassing 11% among mothers with primary education or less in the 45 to 50 age category. Similar patterns with slightly lower probabilities are observed for moderately low birthweight. In the case of very low birthweight, the slopes – reflecting probabilities between 0.8% and 1.6% – also follow similar trajectories until ages 45 to 50, when the figure for highly educated women (0.9%) clearly diverges from those for mothers with medium-level (1.2%) and primary-level education (1.6%). These results reflect the statistically significant negative interaction between this age category and university-level education observed in Figure 2. Hence, they corroborate the assumption that higher education significantly reduces the impact of being at the latest reproductive stage on the risk of very low birthweight.

For women with a low level of education, the predicted probability of high birthweight increases only very slightly with age until age 44, surpassing 6% across several age categories. In contrast, for women with medium-level education, this risk decreases across ages 30 to 50. University-level education is also protective from age 30 onwards, with highly educated mothers showing lower probabilities of macrosomia, at around 5%, until age 40.

Figure 3 Average predicted probabilities (predictive margins) of weight-related perinatal outcomes (low birthweight, moderately low birthweight, very low birthweight, pathologically high birthweight). Adjusted binary logistic regression models



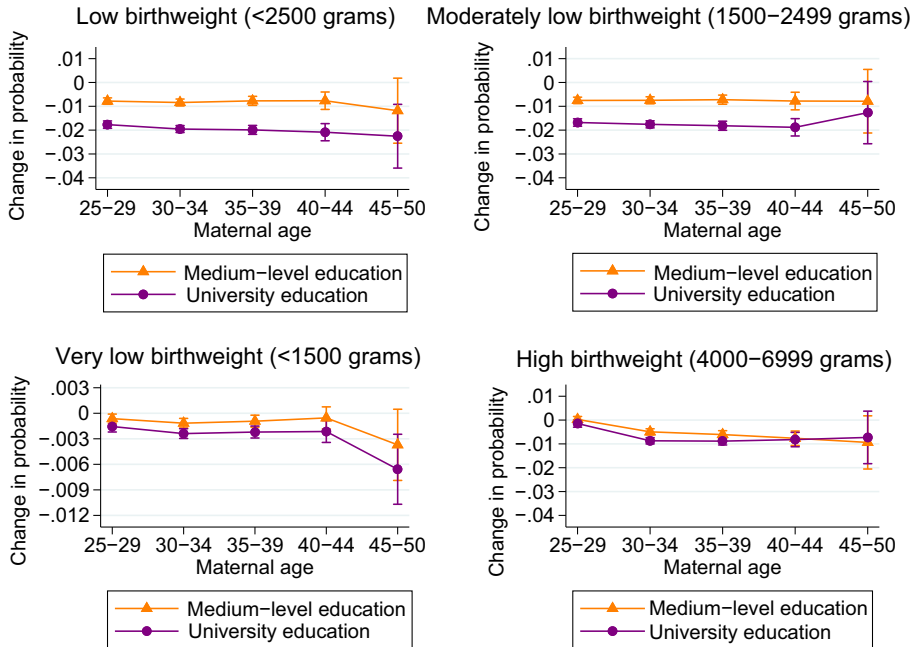
Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, prematurity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. 95% confidence intervals (CI).

However, the maximum shielding effect of higher education is observed at ages 30 to 34, while the difference between higher education and medium-level education is diluted in the 40–44 age category. It should also be noted that at ages 25 to 29, the predicted probabilities are roughly similar for women with primary-level and medium-level education (5.8%), while women with higher education exhibit only a very slight advantage (5.6%).

Figure 4, which presents the average marginal effects of university- and medium-level education on the likelihood of weight-related outcomes in different age ranges, shows that university-level education is associated with a statistically significant reduction of around two percentage points in the probability of low birthweight across all age categories. A similar yet more modest effect is found for medium-level education, which is linked to a reduction of around 0.8 percentage points, except in the 45 to 50 age category. Post-estimation pairwise comparisons of the marginal effects⁴ of each level of education confirm that no statistically significant differences in the magnitude of these educational effects are found between different age categories.

4 Results available upon request.

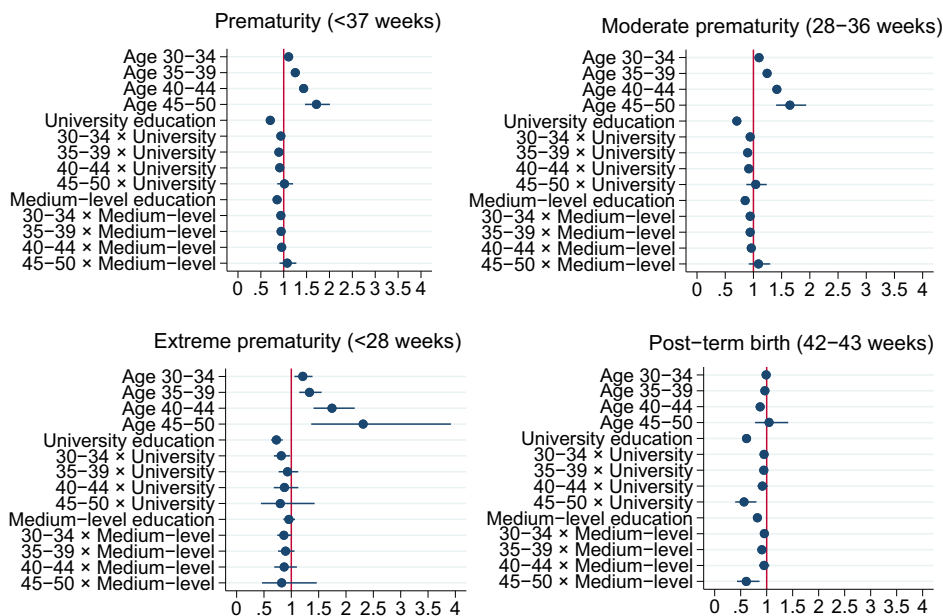
Figure 4 Average marginal effects of university- and medium-level maternal education on the probability of weight-related perinatal outcomes (low birthweight, moderately low birthweight, very low birthweight, pathologically high birthweight) within different age categories. Adjusted binary logistic regression models



Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, prematurity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. 95% confidence intervals (CI).

A largely similar pattern is found for moderately low birthweight (in this case, no significant effect of education can be found at ages 45 to 40) and very low birthweight (although the marginal effects are far smaller for this outcome, at between 0.1 and 0.6 percentage points, in line with its very low prevalence in the population (0.96%); it must be recalled that the predicted probability among low educated women lies at around 1% in most age groups). For very low birthweight, the marginal effect of having medium-level education as compared to primary-level education is not statistically significant in the 40 to 44 and 45 to 50 age categories. Moreover, post-estimation pairwise comparisons confirm that the reduction in the probability of very low birthweight associated with higher education is significantly greater between ages 45 and 50 than in the remaining age categories, as anticipated by the negative and significant interaction between age and education observed in Figure 2. Finally, these comparisons corroborate that higher education and medium-level education are associated with statistically significant decreases (between 0.8 and 0.9 percentage points and between 0.5 and 0.8 percentage points, respectively) in the probability of pathologically high birthweight at ages 30 to 44. The post-estimation pairwise comparisons substantiate that the reduction in the probability of macrosomia

Figure 5 Binary logistic regression of pregnancy duration-related perinatal outcomes (pre-term birth, moderately pre-term birth, extremely pre-term birth and post-term birth) on maternal age and education and their interactions



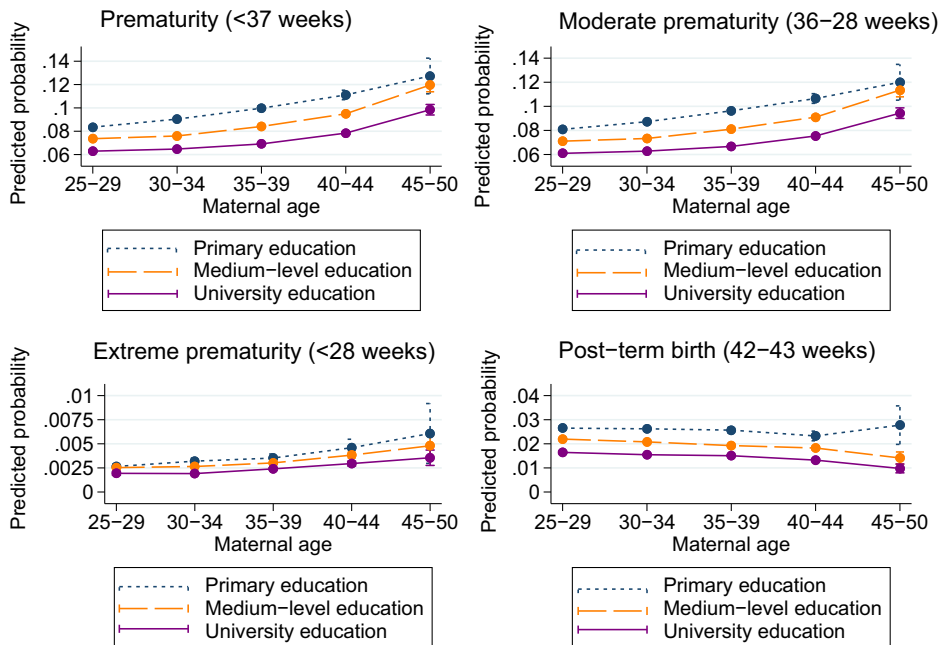
Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. Age reference category: 25–29 years. Education reference category: primary-level education or less. Odds ratios (OR) with 95% confidence intervals (CI).

driven by higher and medium-level education is significantly greater at ages 30 to 34, 35 to 39 and 40 to 44 than at ages 25 to 29, which confirms the protective effect of education in those age categories.

Outcomes related to the duration of pregnancy

The results of binary logistic regression models presented in Figure 5 (see also Table S.3 in the Supplementary materials) reveal that increasing age is significantly associated with a rising probability of prematurity for women with a low level of education. The positive odds ratio of maternal university-level and medium-level education indicates that they lower the risk of this outcome for women aged 25 to 29. In addition, the interactions of university education with age are negative and statistically significant at ages 30 to 34, 35 to 39 and 40 to 44. A similar pattern is observed for medium-level education, albeit to a lesser degree and only in the first two age categories. These findings, which also apply to moderate prematurity, indicate that women with university- and medium-level education in those age ranges are also more protected against prematurity than women with primary education or less.

Figure 6 Average predicted probabilities (predictive margins) of pregnancy duration-related perinatal outcomes (pre-term birth, moderately pre-term birth, extremely pre-term birth and post-term birth). Adjusted binary logistic regression models



Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. 95% confidence intervals (CI).

In the case of extreme prematurity, women with primary-level education show an incrementally increasing probability of experiencing the outcome as they age. University-level education reduces this risk for women aged 25 to 29. The absence of statistically significant interactions between education and most age categories suggests that the same relations could apply to the population in general, while the statistically significant negative interaction of university education with the 30 to 34 age category indicates that highly educated women in this age range are particularly protected. Medium-level education does not appear to confer any statistically significant protection against prematurity.

Finally, the probability of post-term birth, instead of increasing with age, decreases significantly with university- and medium-level education, especially for highly educated women aged 45 to 50 and for women with medium-level education in the same age range and in the 35 to 39 age category.

The average predicted probabilities presented in Figure 6 illustrate more clearly the relations between maternal age and outcomes related to pregnancy duration for women with primary-level, medium-level and university-level education. The probability of pre-term birth increases with age in all educational strata, yet it is systematically lower the higher

the level of education. At ages 25 to 29, women with university-level education show a predicted probability of pre-term birth of 6.3%, compared to 7.4% for women with medium-level education and 8.4% for women with primary-level studies or less. Put differently, education confers an initial advantage that is maintained over time, although the protective effect of medium-level education relative to lower education is no longer significant in the 40 to 45 age category, and that of university-level education is also diluted from age 45 onwards.

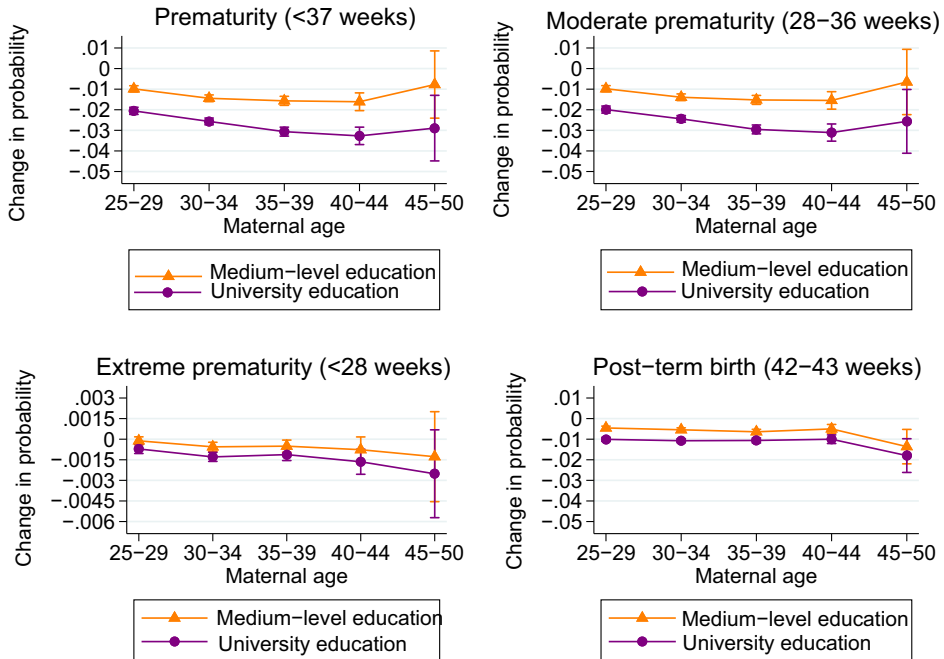
The trends are essentially the same for moderate prematurity. The probability of extreme prematurity also rises with increasing age – among university-educated women, from age 35 onwards – and, as was already noted, it is only university-level education that seems to consistently provide significant protection against moderate prematurity in comparison to primary education. The differences are nonetheless small, given the overall low probability of the phenomenon (which ranges between 0.2% and 0.6%).

In contrast to the above, the average predicted probabilities of post-term birth tend to decrease with maternal age, with more prominent reductions being observed in relation to the baseline category (25–29) within certain education and age combinations, as was previously explained when interpreting interactions. The exception to this decreasing pattern is that of women with low education after age 45. The predicted probabilities of post-term birth across different age categories are also modest in magnitude (at most 2.77% for women with primary-level education in the 45 to 50 age category), and are generally lower for women with medium-level education, and especially for those with university-level education.

Figure 7, which presents the average marginal effects of university- and medium-level education (as opposed to primary-level education) on birth outcomes related to pregnancy duration, conveys more clearly the magnitude of the protection conferred by maternal education across the analysed age distribution. When compared to primary-level education, university-level education is associated with a statistically significant reduction in the probability of prematurity of between 2.1 and 3.3 percentage points, while medium-level education is associated with a more modest reduction of between 1 and 1.6 percentage points. These effects are observed across all age categories (despite non-statistical significance for women with medium-level education in the 45–50 age category) and are attenuated from age 40 onwards, as reflected in the figure and confirmed by their post-estimation pairwise comparisons.

A very similar pattern with slightly higher values is observed for moderate prematurity specifically. The probability of extreme prematurity decreases with university-level education (with respect to primary-level education) in all age categories except 45 to 50, although the average marginal effects are low in this case (0.17 percentage points at most in the 40 to 45 age category, which is consistent with the low prevalence (0.27%) and baseline probability of the outcome, with the figure ranging between 0.25% and 0.6% among low educated women). Medium-level education shows negative significant marginal effects only in the 30 to 34 and 35 to 39 age categories, and they are very modest in magnitude (0.06 percentage points at most). Post-estimation pairwise comparisons reveal that education-driven protection is most evident at ages 30 to 34 when compared to ages 25 to 29. In terms of post-term births, both higher and medium-level education reduce the risk throughout the

Figure 7 Average marginal effects of university- and medium-level maternal education on the probability of perinatal outcomes related to pregnancy duration (pre-term birth, moderately pre-term birth, extremely pre-term birth and post-term birth). Adjusted binary logistic regression models



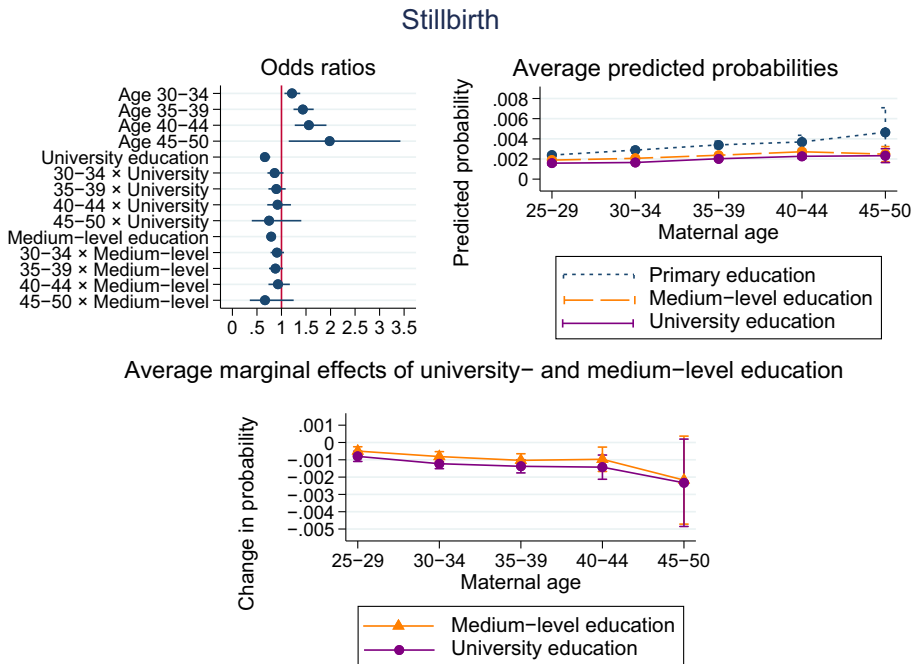
Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. 95% confidence intervals (CI).

age distribution (by between 1 and 1.8 percentage points in the case of the former and between 0.5 and 1.4 percentage points in the case of the latter). The impact of education on this outcome is generally quite uniform across age categories; it is only at ages 35 to 39 and 45 to 50 that the protection of medium-level education stands out significantly with respect to ages 25 to 29, according to post-estimation pairwise comparisons and in line with the interactions highlighted in Figure 5.

Stillbirth

Finally, Figure 8 shows the three types of estimations (adjusted odds ratios, average predicted probabilities and average marginal effects) for the last of the perinatal health indicators examined, namely stillbirth. The logistic regression model that these estimations draw on are also presented in Table S.3 in the Supplementary materials. As was observed for other adverse outcomes, the probability of stillbirth also rises with maternal age for women with primary-level education or less. In turn, university-level education and,

Figure 8 Estimation of odds ratios, average predicted probabilities (predictive margins) and average marginal effects based on binary logistic regression of stillbirth on maternal age and education and their interactions



Source: Spanish Birth Statistics (Statistical Bulletin of Births), Spanish National Statistics Institute, 2007–2021. Note: Models adjusted for foetal sex, parity, multiplicity, prematurity, maternal marital status, maternal migrant origin and autonomous community where the birth took place. 95% confidence intervals (CI).

to a lesser extent, medium-level education are associated with a reduced risk for women aged 25 to 29. The non-significant interactions between education and age suggest that these relations apply to the population in general.

The estimation of predictive margins confirms this finding and shows that the risk of stillbirth is overall very low, as the average predicted probability of this outcome for a woman with primary-level education or less during the analysed period ranges from 0.24% (ages 25 to 29) to 0.47% (ages 45 to 50). The equivalent figures for women with medium-level education are somewhat lower, and are again even lower for women with university-level education. Nonetheless, the average marginal effects show that the impact of higher and medium-level education is statistically significant within the sample up to age 45 despite being quantitatively small (university-level education reduces the probability of stillbirth by around 0.1 percentage points, and the effect of medium-level education is even smaller, which must be seen in light of the overall low prevalence of the phenomenon, at 0.27%, and the low baseline predicted probabilities among low educated women noted above). According to post-estimation pairwise comparisons, the effects of education are uniform over time; there is only a significant difference in the magnitude of the impact

of a move from lower education to medium-level and university-level education between the 25 to 29 and 35 to 39 age categories.

To close the section, it is worth mentioning the results obtained when performing the regression models on a subsample including paternal age. As shown in the Supplementary materials (Tables S.4 and S.5), most findings are not substantially altered in terms of magnitude or direction of effects, even if some lose or gain statistical significance at the 0.05 level. Interestingly, however, paternal age is itself associated with a higher risk of low birthweight (i.e., in its moderate version) after age 40, of very low birthweight after age 45, of high birthweight after age 35, of prematurity (moderate and extreme) between ages 40 and 44 and of stillbirth after age 30. In summary, paternal age has a deleterious influence of its own on the probability of adverse birth outcomes. In contrast, paternal age between 30 and 39 appears to be associated with a reduced risk of low birthweight (at ages 30–34), very low birthweight, prematurity (moderate) and post-term birth.

Conclusions and discussion

The analysis has revealed that even within the relatively privileged Spanish pregnancy healthcare context, maternal age significantly increases several perinatal health risks, as has been observed in other countries. This impact is incremental and can be clearly observed across all age categories and in the general population in the case of low birthweight, moderately low birthweight, very low birthweight, prematurity (in its moderate and extreme variants) and stillbirth. The risk of pathologically high birthweight also rises, albeit not incrementally, for low educated women between ages 30 to 44 in comparison to ages 25 to 29.

In line with earlier studies, maternal education is shown to be consistently protective of perinatal health in different ways. Across all age categories, university education clearly reduces the risk of low birthweight, very low birthweight (in this latter case, with a particularly pronounced effect at ages 45 to 50), post-term birth and stillbirth. Medium-level education, when compared to primary-level education or less, also plays a similarly protective role, yet the effects are smaller (around half of those for higher education), and are only found for ages 25 to 39 in the case of very low birthweight. The risk of macrosomia is also reduced among women with higher and medium-level education, but only between ages 30 to 44 (and most clearly at ages 30–34 in the case of university education). The probability of pre-term birth (especially in its moderate version) is significantly lowered among women with university-level education until age 44, and is more modestly reduced among those with medium-level education until age 39. University education confers protection against extreme prematurity at all ages, and particularly between ages 30 and 34.

Nevertheless, the relatively reduced magnitude of many of these educational effects, as well as the specificity of their interactions with age, indicate that education – despite the economic, informational and health advantages it confers – is not generally powerful enough to fully counteract the negative impact of reproductive ageing on birth outcomes. Given these findings, caution is advised before concluding that delaying pregnancy to

advanced ages carries negligible risks for the offspring provided adequate healthcare monitoring and sufficient maternal resources are in place. This study's findings must be seen in the context of Spain's comprehensive healthcare system, which has achieved comparatively low overall rates of pregnancy- and birth-related complications (García-Tizón Larroca et al., 2022). The fact that cumulative age effects are observable for a variety of perinatal health risks under such circumstances, and after discounting potentially protective effects of maternal resources, suggests that the consequences for child well-being of increasingly widespread and pronounced childbearing postponement should be considered. The additional importance for some outcomes of advanced paternal age identified in the robustness analysis reinforces the argument and merits further investigation. It is interesting to note that the incremental impact of age on several perinatal health outcomes found in this study very much aligns with the patterns that have been observed for fertility. The effects of rising age on fecundity occur along a continuum, with a more pronounced decline being observed after the mid-thirties (Correa-de-Araujo and Yong, 2021), which parallels the trajectory shown by this study's data on perinatal health. This suggests that there are biological, ageing-related and potentially also offspring-related factors that could be hard to address through lifestyle or better monitoring. It may also explain the relatively modest magnitude of some educational effects.

The above observations notwithstanding, it must be underscored that education does modify the impact of maternal age in an important way: namely by lowering the baseline probability of complications from early ages. The consistently lower likelihood of adverse outcomes observed across age groups among women with higher education and, to a lesser degree, medium-level education, when compared to women with primary-level education is indicative of a meaningful socioeconomic gradient in perinatal health. Although education does not strongly alter the effects of age, it nonetheless confers an initial advantage that tends to persist throughout the reproductive life course, especially for highly educated women. Women with university education have a lower risk of adverse perinatal outcomes in all age categories, including when they are under age 30, which raises the question of whether this is due to better maternal health status prior to conception, greater options to maintain a healthy pregnancy or a combination of the two. A limitation of this study is that it does not provide evidence of the mechanisms involved. Further research efforts should be made to generate large-scale, longitudinal data combining biological and socio-demographic variables that would enable us to explore in depth the linkages between maternal health, educational resources and the impact of age.

Another limitation of the analysis is that it was unable to consider the use of medically assisted reproduction (MAR) as a variable that may affect perinatal health and is likely associated with maternal education and age, since there are no suitable individual- or aggregate-level yearly data available that could be incorporated into the models. In the Spanish case, as in many societies, there are educational and age gradients in the use and success of MAR (Goisis et al., 2024). Since the direction of the effects of MAR on perinatal health is uncertain – some associations with adverse outcomes have been found (see Seiz et al., 2023), yet pre-implantation genetic testing and greater medical surveillance could also act as protective factors – the net impacts of education and age on perinatal health in this study could be over- or underestimated. Future studies should therefore also aim to disentangle

these mechanisms in order to shed light on the implications of MAR use at different ages and in different educational strata.

Supplementary materials

Supplementary file 1. Tables S.1–S.5.



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