Education, health indicators and fertility outcomes: A longitudinal analysis of couples in Britain

Nitzan Peri-Rotem[1]

[1]University of Exeter, United Kingdom

Abstract:

Previous studies have shown that highly educated women are more likely to realise their fertility aspirations, or experience a faster progression to a higher-order birth compared to lower educated women. This is often explained by improved economic or social resources among the higher educated. However, it is unclear whether educational differences in health behaviours may also contribute to these differential fertility outcomes. In this study, we use data from waves 1-7 of the UK Longitudinal Household Study, combined with data from the Nurse Health Assessment from wave 2 to estimate couples' likelihood of experiencing additional childbirth within six years. A discrete-time event history model is employed to analyse the transition to a higher order birth, while accounting for both partners' level of education as well as smoking patterns and body mass index. We find that couples in which the female partner is highly educated are more likely to experience childbirth within six years compared to others. In addition, female smoking is negatively associated with the likelihood of childbirth, while no significant effect has been found for male health factors. Female health indicators explain some of the variation in fertility outcomes for women with lower secondary education compared to degree-educated women. However, education remains a significant predictor of the transition to higher order births, also after accounting for male and female health indicators. It is therefore important to consider both socioeconomic and health factors in order to understand variations in fertility outcomes.

Key words:
Fertility; education; health indicators; smoking; BMI

Introduction

Women's education has been generally found to be inversely correlated with fertility; across post-industrial societies, women with higher educational attainment tend to have fewer children and are more likely to remain childless than those with lower levels of education (Smith and Ratcliffe, 2009; Kreyenfeld and Konietzka, 2017). However, it has been suggested that these differences are largely the result of births postponement among higher educated women (Berrington et al, 2015). Furthermore, when accounting for age at first birth, higher educated mothers are more likely to have another child and to do so more quickly than lower educated ones (Rendall and Smallwood, 2003). Other studies have also found that highly educated women are more "successful" in realising their fertility intentions at older reproductive ages, and, compared to less educated women, the decline in completed fertility with age at first birth is less pronounced for them (Berrington et al, 2015; Kravdal and Rindfuss, 2008; Sobotka, 2004).

Previous explanations for the higher parity progression rates among women (and men) with higher education have focussed on the link between education and improved economic resources, which make family expansion more affordable (Adsera, 2011; Kravdal and Rindfuss, 2008; Smith and Ratcliffe, 2009). In addition, it has been argued that highly educated individuals are generally more informed and knowledgeable and are therefore better equipped to make more realistic fertility plans (Sobotka, 2004; Spéder and Kapitány, 2009). Other studies have suggested that the increased transition rates to higher order births among more educated women is due to a selection effect. According to this assumption, those highly educated women who opt for motherhood may have a particularly high preference for children (Kreyenfeld, 2002; Berrington et al, 2015). Nevertheless, other unobserved characteristics may be responsible for educational differences in parity progression rates, including differences in fecundity (Kreyenfeld, 2002).

An increasing body of evidence suggests that health behaviours, including smoking, body weight maintenance and nutrition can have a substantial impact on biological childbearing capacity, as well as on outcomes of assisted reproduction treatments (Homan et al, 2007; Chavarro et al, 2007; Hart, 2016). Thus, while cigarette smoking and obesity can have a negative effect on male and female fecundity, maintaining a normal body weight and adhering to a healthy diet may improve the likelihood of conception (Chavarro et al, 2007; Sharma et al, 2013). These health indicators have also been found to be strongly associated with socioeconomic status in Western societies (Cutler and Glaeser, 2005; Pampel et al, 2010). Education in particular, is associated with a wide range of health promoting behaviours. For example, higher educated individuals are less likely to smoke or to be overweight and are more likely to exercise regularly and to engage in preventive healthcare (Cutler and Lleras-Muney, 2010; Park and Kang, 2008; Lawrence, 2017). These differential behaviours not only exacerbate health disparities, but may also contribute to educational disparities in reproductive outcomes.

So far, only few studies explored the combined role of socioeconomic and health factors in explaining fertility outcomes. One exception to that is a study by Beaujouan et al (2019), which explored the realisation of short-term fertility intentions among men and women in Australia. In this study, education was found to be a stronger predictor of realisation of fertility intentions than health characteristics, such as smoking and body mass index. Nevertheless, this analysis did not take into account the characteristics of respondents' partners. In the present study, we therefore use prospective data on heterosexual couples in reproductive ages. These couples are observed for a period of six years to estimate the likelihood of experiencing additional childbirth, while taking into account the educational attainment, fertility intentions and health indicators of both partners.

Health factors and fertility outcomes

Over the past decades, individuals in post-industrial countries are increasingly exposed to specific lifestyle factors and behaviours that could carry dramatic consequences for fertility. As a result of social and economic developments, including extended time spent in education, growing economic insecurity and shifts in family norms and personal aspirations, men and women are increasingly delaying childbearing to a later age (Kohler et al, 2002; Mills et al, 2011). Female and (to a lesser extent) male age are among the most important predictors of the likelihood of conceiving and maintaining a pregnancy to term; among women, fecundity starts decreasing from their late 20s, with a significant decline after the age of 35, due to a reduction in the number and quality of oocytes (Baird et al, 2005). Among men, testosterone levels are dropping with age, and semen volume and motility begin a steady decline as early as age 35 (Sharma et al, 2013). Overall, male and female ageing is associated with longer time to pregnancy and lower fertility outcomes, although the decline in fertility with age is more pronounced for women (Baird et al, 2005).

While age is a critical factor in determining the likelihood of giving birth, health behaviours may have further negative consequences on couples' fertility. For instance, cigarette smoking has been found to have a profound impact on fertility of both men and women (Hart, 2015; Homan et al, 2007; Li et al, 2011; Lotti et al, 2015; Sharma et al, 2013). Among women, smoking is associated with impaired fecundity through a range of pathways; previous studies have shown that smoking leads to a disruption in hormone levels, as well as alterations in ovarian, uterine tube and uterine functioning, which contribute to a higher risk of ectopic pregnancies, longer times to conception and miscarriage among women who smoke (Hart, 2015; Sharma et al, 2013). In addition, smoking is strongly linked with an earlier age at menopause, which may be due to disruptions in the production of estrogen and a reduction in ovarian reserve (Kinney et al, 2006; Gold et al, 2013). Moreover, the adverse consequences of smoking on fertility and reproductive ageing are particularly pronounced for heavy smokers, usually defined as smoking around 10-20 cigarettes or more per day (Kinney et al, 2006; Sharma et al, 2013).

In men, smoking is associated with reduced sperm parameters, including sperm volume, density, motility and morphology (Homan et al, 2007; Li et al, 2011). Interestingly, several studies have found that current smokers exhibit higher testosterone levels compared to non-smokers (Shiels et al, 2009; Wang et al, 2013), although the underlying mechanism for this association remains unclear. Furthermore, in a study of male subjects of infertile couples in Italy, Lotti and colleagues (2015) have found that despite showing elevated levels of testosterone, current smokers have had significantly lower semen volume than their non-smoking counterparts.

In addition to smoking, recent research suggests that body weight also plays an important role in relation to fertility outcomes. In women, being overweight or obese[1] is associated with irregular menstrual cycles, reduced spontaneous and assisted conception rate and increased risk of miscarriage (Hart, 2015; Pasquali et al, 2003; Sharma et al, 2013). In addition, obesity is frequently linked with polycystic ovary syndrome (PCOS); a collection of symptoms related to ovarian dysfunction and is often manifested by excessive androgen levels (Hart, 2015). PCOS is one of the most common causes of anovulatory infertility in young women and its prevalence in Western populations is estimated at around 5%-7% (Pasquali et al, 2003). Furthermore, obesity is assumed to exacerbate the symptoms of PCOS, and may be the underlying driver for its increasing prevalence in industrialised societies (Hart, 2015). Yet, the mechanism by which obesity interferes with the pathophysiology of PCOS is not completely understood (Pasquali et al, 2003).

Obesity may also have detrimental effects on male fertility, as it leads to reduced testosterone blood concentration levels in men (Pasquali, 2006). Several studies have shown that an increase in body mass index (BMI) for men is correlated with decreased sperm concentration and motility (Sharma et al, 2013). However, other studies have found little or no evidence for the relationship between body weight and semen parameters (See MacDonald et al, 2010 for a systematic review). Furthermore, Chavarro and colleagues (2010) have found that while there is a strong inverse correlation between BMI and testosterone levels, only severely obese men (BMI $\geq$ 35) have had reduced sperm parameters compared to men with normal weight.

Education, health indicators and fertility

The relationship between higher socioeconomic status and health-promoting behaviours, including avoidance of smoking, engagement in physical activity and improved nutrition, is well documented (Cutler and Lleras-Muney, 2010; Pampel et al, 2010; Lawrence, 2017). Of the components of socioeconomic status, education is particularly important, as it is generally established early in life and is a stronger predictor of health behaviours compared to other components, such as income and employment status (Cutler and Glaeser, 2005; Lawrence, 2017; Pampel et al, 2010). For example, using data from the USA National Center for Health Statistics, Pampel and others (2010) show that after controlling for occupation, employment status, income and home ownership, high school dropouts have odds of smoking, not exercising and being obese that are, respectively, 2.9, 2.8 and 1.5 times higher than the odds among college graduates. Furthermore, the educational gradient for obesity has been found to be particularly pronounced for women (ibid.). Cutler and Lleras-Muney (2010) have documented similar associations between education and health behaviours when comparing results from the United States and the United Kingdom, and showed that in both societies, health promoting behaviours increase linearly with education.

Another positive health behaviour associated with education is higher engagement in preventative care, including behaviours that directly promote reproductive health. For example, a positive association is found between education and getting a Pap smear among women in the United States (Cutler and Glaeser, 2005; Cutler and Lleras-Muney, 2010). In addition, a study from Sweden has found that highly educated women were more prone to comply with the recommendations of national health authorities regarding the use of folic acid supplements when planning a pregnancy (Murto et al, 2017). As previous studies show, folic acid supplementation is related to better embryo quality and improved chances of pregnancy and live birth (Boxmeer et al, 2009; Laanpere et al, 2010). Hence, educational differences in preventive healthcare may also account for educational variation in fertility outcomes.

An additional mechanism that could lead to differential fertility outcomes by education is the likelihood of seeking medical help when facing infertility; studies from the United Kingdom and other Western countries have shown that individuals with higher levels of education are more likely to seek medical help when experiencing infertility and to do so more quickly than lower educated people (Bunting and Boivin, 2007; Datta et al, 2016). The longer waiting times to seeking treatment for infertility among the lower educated could be attributed to reduced fertility awareness, including awareness to potential causes of infertility and knowledge about fertility treatment (Bunting and Boivin, 2007; Swift and Liu, 2014). In summary, individuals with higher levels of education are more likely to adopt health behaviours that are not only conducive to general health and well-being, but can also promote the chances of experiencing a live birth.

Structural mechanisms of health disparities by socioeconomic status

It has been recognized that disparities in health behaviours and outcomes are influenced by both individual and structural-level factors, as well as the interaction between them (Benzeval et al., 2014a; Short and Mollborn, 2015). According to Cohen et al. (2000), health differences by socioeconomic status are likely to be the result of differential social and environmental conditions, including adequate housing, employment opportunities and safe neighbourhoods. Thus, structural disadvantage can have a direct effect on health and health behaviours, through level of exposure to harmful products, such as tobacco and high-fat foods, or opportunities to engage in physical exercise (ibid). Furthermore, poorer material conditions can lead to increased levels of stress, which can have detrimental implications on health (Marmot, 2004), as well as increased risk of unhealthy coping behaviours, such as smoking, alcohol consumption and poor nutrition (Raphael et al., 2005).

Belonging to a lower social status can also affect health outcomes indirectly, by having fewer opportunities to form social relationships (Cohen et al., 2000). Previous research has shown that building strong social support networks can contribute to improved health outcomes through exchange of material, informational and emotional support between members (Cutler and Lleras-Muney, 2010; Egan et al., 2008). Furthermore, it has been argued that people who lack these resources will have reduced ability to cope with difficult or stressful situations in their lives, which may further exacerbate negative effects on health (Benzeval et al., 2014a).

In the context of educational disparities, Cutler and Lleras-Muney (2010) found that apart from differences in material resources and degree of social integration, health-specific knowledge, including knowledge about various health risks of smoking, has also played an important role in explaining educational differences in health behaviours. Similarly, the structural conditions associated with socioeconomic status may affect the process of reproductive decision making. For example, having a supportive social network can reduce uncertainty, and therefore, people with higher social capital may feel more positively about major life transitions, such as childbearing (Philipov et al., 2006). Therefore, it is important to understand the mechanism through which socioeconomic status, measured by level of education, may lead to differential reproductive outcomes and the role of health factors in explaining these differences.

Research hypotheses

As described above, women with higher qualifications have increased transition rates to second or higher order births compared to lower educated women, when fertility intentions and other demographic factors are taken into account. Therefore, the first hypothesis states that *highly educated women are more likely to experience the transition to higher order birth within six years compared to less educated women*.

Since higher educated individuals are more likely to have improved health indicators, including lower prevalence of smoking and obesity, and, given that these health indicators are associated with reproductive outcomes, particularly among women, these differences may contribute to the increased transition rate to additional childbirth among highly educated women. Thus, our second hypothesis postulates that *educational differences in health indicators - measured by smoking status and BMI levels - contribute to the increased transition rates to higher order births among highly educated women*. Furthermore, given that previous research has shown weaker or inconsistent support for the consequences of male health indicators, as opposed to female health indicators on fertility outcomes, our third hypothesis states that *the contribution of health indicators of the male partner to the transition to higher order birth will be less pronounced than that of the female partner*.

Data and methods

The data for this study is drawn from waves 1-7 of the UK Household Longitudinal Study, known as Understanding Society, covering the period from 2009 to 2016[2] (University of Essex/ISER, 2017). Understanding Society is a panel survey of around 30,000 households, where each member of the household aged 16 or over is interviewed annually. For the purposes of this study, we used the General Population Sample (GPS) component of the survey, which includes over 43,000 respondents from around 26,000 households from England, Scotland and Wales (Knies, 2017). The GPS is broadly representative of the population in Britain, although it suffers from a relatively high level of attrition, with only 52% of the original sample still participating in wave 7 (Lynn and Borkowska, 2018). The groups with the highest attrition include those aged 16 to 19 at wave 1, non-white ethnic minority groups, residents of Greater London and those with lower personal income. However, there is no evidence of disproportionate attrition of respondents based on health status or other key measures included in the present analysis (ibid).

The Understanding Society survey includes information on various demographic, socioeconomic and health indicators (e.g. smoking histories and BMI) as well as date of birth for respondents' children. In addition, a measure for male blood testosterone levels was obtained from the Nurse Health Assessment data (University of Essex/ISER, 2014). The nurse health assessments were conducted in 2010-2012 with a subset of the General Population Sample from wave 2 of the main Understanding Society survey. The eligibility criteria for the health assessments included a full face-to-face interview in English, and for those living in England, it was further restricted to 80% of the primary sampling unit (McFall et al, 2014)[3].

For the present analysis, the sample was restricted to heterosexual couples in reproductive ages who live in the same household. Within the General Population Sample, we identified 5,338 couples with the female partner aged 17 to 45 and their male partners aged 17 to 64 at the time of first wave. Of those couples, 4,337 were observed in at least two waves. Since the transition to first birth differs substantially from the transition to higher order births in terms of its association with education (Rendall and Smallwood, 2003), as well as with other health factors (Baird et al, 2005), only couples with at least one child were included in the analysis. Hence, 1,074 childless couples were removed from the sample. Further 468 couples were excluded due to missing or unknown fertility intentions, as well as 96 couples in which the woman was currently pregnant. There were only few cases in which either the male or the female partner were classified as underweight (BMI<18.5) and therefore removed from the analysis (a total of 44 couples). Finally, 455 couples had incomplete information on one or more relevant measures. This resulted in a sample of 2,200 couples (see Table 1 for a detailed description of the inclusion criteria).

- Table 1 here -

Measures

The dependent variable in our study is the probability of experiencing additional childbirth within the observed time period of six years. The explanatory variables consist a set of sociodemographic, biomedical and health measures; both partners' education is measured as the highest achieved level of education with the following categories: degree level, other higher education (e.g. diploma in higher education, nursing etc.), upper secondary education (A-level or equivalent) and lower secondary education (GCSE level or lower). Those with no formal qualifications are grouped together with GCSE level due to their small proportion in the sample. To distinguish between education and income effects, a measure of relative household income level, divided into quintiles, has been added.

Age of each partner is measured in calendar years, including a squared age term, to capture the decline in fertility with age. Our model also includes a time-varying measure for marital status, which indicates whether the couple is married or living in non-marital cohabitation, as well as the number of years elapsed since the start of partnership. In addition, the duration of time since the last birth is grouped into five categories (up to 12 months, 13-35, 36-71, 72-119 and 120 months or more).

Questions about smoking habits are recorded in the second, fifth, sixth and seventh waves of the survey, including the number of cigarettes smoked per day. Since the second and the fifth waves also include information on respondent's age when they started and/or stopped smoking, as well as the regular number of cigarettes smoked daily during that time, it was possible to reconstruct smoking histories for each respondent. Thus, in order to minimise the risk of reversed causality - i.e. changes in smoking behaviour around the time of childbirth - we used a one-year lagged measure for smoking, which includes three categories: non-smoker, smoking less than 10 cigarettes a day (light smoker) or smoking 10 or more cigarettes a day (heavy smoker).

Fixed time variables include parity, fertility intentions, ethnicity, BMI and male testosterone. The number of previous births each couple has is divided into three categories: 1, 2 and 3+ children. The measure for fertility intentions is based on a question asked in the first wave of the panel: "do you think you will have any more children?", where the optional answers are: "no", "yes", "self/partner currently pregnant" and "don't know". Since fertility intentions of both partners may affect the likelihood of giving birth (Berrington, 2004), we used a combined measure with four categories: both partners answered no, both answered yes, only the woman answered yes and only the man answered yes. The measure for ethnicity represents the main ethnic groups in Britain and includes the following categories: White, South Asian (including Indian, Pakistani and Bangladeshi origin), Black (including Black Caribbean and Black African origin) and other (including mixed ethnic background).

Information on BMI is included in the first wave and was grouped into four categories: 18.5 to less than 25 (normal), 25 to less than 30 (overweight), 30 to less than 35 (obese), 35 or more (severely obese). Finally, a measure for male testosterone levels is included in our model. This measure refers to total testosterone blood levels with a lower and upper detection limit of 1 to 52 nmol/L respectively. Testosterone levels between 9-25 nmol/L are considered normal for men (Benzeval et al, 2014b). Therefore, male testosterone is divided into three categories of low (<9 nmol/L), normal (9-25 nmol/L) and high (>25 nmol/L)[4]. Since blood samples were only obtained for a third of males in our sample, we included another category of "missing" for this measure.

It should be noted that region of residence was also considered as a potential predictor of progressing to a higher order birth. However, since this variable had no significant effect on the results, it was not included in the analysis.

Analytical approach

First, we explore how smoking behaviour and BMI levels vary by educational attainment among men and women in our sample, using a chi-squared test. Then, using information from the panel data on the year and month of biological childbirths in waves 2-7, we construct a discrete-time event history model to estimate the likelihood of experiencing a live birth. For this purpose, couples are followed from the date of interview until the event of childbirth or until the last available observation for censored cases, including couples who have separated before experiencing the event. This yielded a total sample of 109,428 couple-months.

The probability of a live birth is estimated using a logistic regression model, which is formulated as:

$$h_i(t) = \frac{exp(\sum_j X_{ijt}\beta_j)}{1 + exp(\sum_j X_{ijt}\beta_j)},$$

Where $h_i(t)$ denotes the probability that couple i experiences childbirth at a given month t; X_{ijt} represents couple's characteristics on a set of j potentially time-varying covariates at time t, and β_j are parameters that are estimated from the data using maximum likelihood.

Since there is a strong correlation between partners' characteristics in terms of education and ethnicity (Blossfeld, 2009), as well as in terms of health behaviours (Okechukwu et al, 2010), we first run separate regression models for the male and female partner's sociodemographic characteristics (education and ethnicity), alongside other demographic variables at the couple level. This is done to estimate the relationship between education and the transition to a higher order birth. Then, the male and female partner's health indicators are added, using different combinations of male and female characteristics, in order to test whether the inclusion of health indicators changes the results for education. Finally, we run a combined regression model that includes both partners' education and health indicators.

It should be noted that a comparison of odds ratios across models with a different set of independent variables is problematic due to variation in unobserved heterogeneity (Mood, 2010). Therefore, we address this issue by calculating the average marginal effects for the different models in our logistic regression analysis. Furthermore, we use seemingly unrelated estimation (SUEST), a method suggested by Mize et al (2019), to test for significant differences in average marginal effects across nested models. This is done to examine whether the coefficients for education change significantly after adding health indicators for each partner.

Since fertility intentions may interact with other covariates, including health behaviours, we also conducted a sensitivity analysis on a sub-sample of couples in which at least one partner expressed an intention to have more children.

Results

Table 2 shows the characteristics of couples in our sample at first observation. The average age of female partners is 36 years, while for male partners it is 39 years. The average partnership duration for all couples (including periods of pre-marital cohabitation) is 11 years. The majority of couples are married (77%) and the rest are cohabiting. The modal parity is two children (45% of couples), and just over a quarter of couples have one child. A similar proportion of couples have three children or more. Nearly three quarter of couples (73%) stated that they do not intend to have more children. In one fifth of the sample, both partners expressed positive fertility intentions and among other couples, either the woman or the man expressed positive fertility intentions (4% and 3% respectively).

A similar proportion of men and women have degree level education (26%), although a slightly higher proportion of women have other higher education compared to their male partners, which is in line with recent findings on gender differences in educational attainment in Britain and in other European countries (Van Bavel, 2012). In terms of household income distribution, a higher proportion of couples are concentrated in the upper quintiles, which could be explained by the fact that all households in the study include two partners in working ages.

In terms of smoking status, it is shown that women are less likely to smoke than men; about three quarters of female partners are non-smokers compared to just over two thirds of male partners. Men are also more likely to be heavy smokers (i.e. smoking 10 or more cigarettes a day) compared to women (22% and 17% respectively). The distribution of BMI status also differs for men and women, with a lower proportion of women who are overweight compared to males (31% and 47% respectively). Nevertheless, a higher proportion of women are severely obese (BMI of 35 and above) compared to men (9% and 5% respectively). These patterns are consistent with official statistics on obesity in the UK (Baker, 2019). Over 80% of male partners who provided a valid blood sample have testosterone levels within the normal range, while 14% have below normal levels and 5% have above normal levels.

- Table 2 here –

Distribution of smoking and BMI status by level of education

Figure 1 presents the distribution of cigarettes smoking status by level of education among women and men in our sample at the beginning of the observation period. For both men and women, the prevalence of smoking, and heavy smoking in particular, decreases significantly with education. Among women (Figure 1a), only 12% of those with a degree level education are smokers, compared to 38% of those with lower secondary education. The latter are also significantly more likely to be heavy smokers than their higher educated counterparts; 29% of women with lower secondary education are classified as heavy smokers compared to 15%, 11% and 5% of women with upper secondary, other higher and degree level education respectively. Similar patterns are found for men (Figure 1b); 44% of men with lower secondary education are smokers, with the majority of them classified as heavy smokers (a total of 33%), while only 14% of degree-educated men are smokers and 7% within that group are heavy smokers.

- Figure 1a-b here –

Figure 2 presents the distribution of BMI status by level of education. Similar to smoking, BMI levels vary significantly by education for both men and women, as the prevalence of obesity is lowest among those with degree-level education. Among women (Figure 2a), 13% of degree educated women are considered obese, compared to 29% among lower educated women. The parallel figures for men are 13% among the highest educated group compared to 24% among the least educated (Figure 2b). Nevertheless, no major differences in BMI levels by education are shown for men and women below degree-level education.

- Figure 2a-b here –

In the next section, we present the results from the multivariable logistic regression models, to further explore the role of health and biomedical factors in mediating the relationship between education and fertility outcomes.

Logistic regression analysis for the transition to higher order birth

Table 3 presents the results of the logistic regression model for couples' probability of experiencing another childbirth (see Table 5 in the appendix for full results with odds ratios). The first model, which includes education level of the female partner, alongside couple's fertility intentions and other demographic variables, shows that degree-educated women are significantly more likely to proceed to the next birth compared to women with lower levels of education. For each given month, the probability of experiencing a live birth is reduced by 0.10, 0.12 and 0.20 percentage points among lower secondary, upper secondary and those with other higher education (respectively), compared to degree-educated women (see Table 3, Model 1). This finding is in accordance with the first hypothesis about the positive relationship between women's education and the likelihood of proceeding to the next birth.

Female (lagged) smoking and BMI status are introduced in the second model, where it is shown that female smoking is linked with reduced likelihood of experiencing another childbirth, particularly among couples where the female partner is a heavy smoker (smoking 10 or more cigarettes a day). As shown in Table 3 (Model 2), female smoking reduces the monthly probability of live birth in the following year by 0.10 percentage points for those smoking up to nine cigarettes a day, and by 0.14 percentage points for those smoking 10 or more cigarettes a day. However, no significant association is found between Female BMI level and the probability of having a live birth.

- Table 3 here –

Once female smoking is introduced, there is no longer a significant difference in the probability of live birth between women with a degree level education and those with lower secondary education. However, women with upper secondary education and other higher qualifications are still significantly less likely to experience childbirth compared to those with a degree.

In contrast to the findings on female education, no significant association is found between male education and experiencing additional childbirth (see Table 3, Model 3). Furthermore, none of health indicators of the male partner are significantly correlated with the probabilities of experiencing live birth, including male smoking status, BMI and blood testosterone levels (see Table 3, Model 4). Finally, when including both male and female partners' health indicators (Table 3, Model 5), the results do not differ much from the second model, where only the female health indicators are taken into account. Thus, among the different health and biomedical factors examined at the couple level, only female smoking is found significantly correlated with the likelihood of experiencing a live birth.

The SUEST test presented in Table 4, confirms that the average discrete change (ADC) in the probability of live birth for lower educated women in relation to degree educated women is significantly different before and after introducing female health indicators (see ADC difference between model 1 and 2). This provides some support to the second hypothesis, regarding the contribution of health indicators to explaining differences by education in fertility outcomes, although no significant changes are shown for women with upper secondary or other higher education in relation to degree-educated women.

- Table 4 here –

It should also be noted that the difference in the ADC for lower educated compared to degree-educated women is not significant when comparing model 1 and model 5, which includes both male and female health indicators. This may be the result of the correlation between male and female health and education characteristics. However, the introduction of male health indicators does not lead to any significant change in the ADCs for male education (see Table 4, ADC difference between Model 3 and 4). In addition, a sensitivity analysis reveals that adding male health indicators to Model 1 does not result in a significant difference in the ADCs for female education. By contrast, the inclusion of female health indicators to Model 3 does result in a significant change to the ADC for men with lower secondary education compared to degree-educated men, though the coefficients for male education remain insignificant (see Tables 6 and 7 in the appendix). Overall, these finding lend support to the third hypothesis of the study, according to which female health indicators play a more important role in the transition to a higher order birth compared to health indicators of the male partner.

The findings for other covariates in the model are in line with previous research. For example, female age is positively associated with childbearing, while the squared term for female age is negatively significant, reflecting the decline in fertility among older women. Male age however, is not significant (see appendix, Table 5). In addition, the combined measure for couples' childbearing intentions is strongly correlated with fertility outcomes; when both partners intend to have more children, the odds of having another child are about 11 times higher than the odds of couples who do not intend to have more children. In addition, for couples in which only the woman or only the man intend to have more children, the odds of additional childbirth are around six and five times higher (respectively) than the odds for couples where none of the partners intend to have more children (see appendix, Table 5).

As described above, a sensitivity analysis with a sub-sample of couples with positive fertility intentions (i.e., at least one partner expressed intention to have more children) was conducted. This analysis yielded very similar results to those found for all couples (not shown).

Discussion and conclusions

In this study, we explored the interrelationships between education, health indicators and fertility outcomes. First, we demonstrated the close link between education and health factors, showing that degree-educated men and women are significantly less likely to smoke compared to their lower educated counterparts, with the largest differences found in the proportion of heavy smokers among those with lower secondary education and those with degree level education. Furthermore, it is found that degree-educated individuals are significantly less likely to be obese than those with lower qualifications. These health disparities may be the result of a combination of factors, including limited material and knowledge resources, as well as lack of social support networks among those with lower socioeconomic status (Benzeval et al, 2014a; Cutler and Lleras-Muney, 2010). In addition, these health indicators may also contribute to differential reproductive outcomes.

Using an event history analysis, we estimated couples' likelihood of experiencing additional childbirth within a period of six years, controlling for the female and male partner's level of education (separately), couples' fertility intentions and other demographic variables. In line with the first hypothesis, we find that degree-educated women are more likely to experience the transition to a higher order birth compared to lower educated women, when all other factors are held constant. In addition, we found that after introducing female health indicators (smoking and BMI), the difference in fertility outcomes between the highest and the least educated groups among women becomes insignificant. Furthermore, the average discrete change in birth probabilities for women with lower secondary education compared to degree-educated women is found to vary significantly after adding these health indicators. Nevertheless, birth probabilities for women with upper secondary and other higher education remained significantly lower compared to those of degree-educated women. Therefore, this study provides only partial support to the second hypothesis about the contribution of health indicators to explaining educational differences in fertility outcomes. It is possible though, that since the difference in smoking status is largest among the highest and the least educated women, controlling for this factor would have a greater effect on the differences in fertility outcomes between these two groups.

Among the health indicators that were examined for couples in our study, only female smoking was found significantly associated with reduced probability of experiencing a live birth, while none of the male health and biomedical factors - including smoking status, BMI, blood testosterone level, and even age – were found significant. These findings support the third hypothesis on the higher importance of the female partner's health indicators to couple's likelihood of having another child.

Previous studies have shown that female fertility is more susceptible to changes in biomedical factors, including age and metabolic and hormonal changes linked to smoking and obesity, compared to male fertility (Baird et al, 2005; Hart, 2015; MacDonald et al., 2010; Wang et al., 2013). While several studies have found that male smoking and obesity can lead to a deterioration in sperm parameters (Homan et al, 2007; Pasquali, 2006; Sharma et al., 2013), this effect is not uniform across different societies (Li et al, 2011) and the implications of these changes on fecundity are unclear (Sharma et al., 2013). Moreover, many of the studies that examined the relationship between health behaviours and fertility outcomes among men have been conducted on those who are undergoing fertility treatment (see: Homan et al., 2007), which form a highly selective group. Therefore, more research is needed in order to understand this relationship among the general population.

While our findings show that female health indicators, and smoking in particular, do contribute to explaining some of the differences by education in fertility outcomes, education remains a significant factor in predicting fertility outcomes. Similar results were presented by Beaujouan and others (2019), who found that female education remained a significant factor in achieving short-term fertility intentions, after accounting for various health factors, including BMI and smoking status. Moreover, they concluded that "epidemiological factors appear less important than sociodemographic factors" in explaining these differences (ibid, p. 1912).

Therefore, it is likely that structural factors, including improved social and cultural capital, play a more important role in explaining the educational gradient in the transition to higher order birth than health factors. As suggested by previous research, material and other structural conditions can account both for differential health behaviours (Cohen et al., 2000; Cutler and Lleras-Muney, 2010) as well as the process of reproductive decision making (Philipov et al., 2006). While degree-educated women tend to delay childbearing to later ages, they are more likely to start a family when they are financially established and within a stable partnership (Mclanahan, 2004; Smith and Ratcliffe, 2009). Hence, highly educated women often have favourable conditions for expanding their family, including greater job security, higher ability to outsource childcare, or flexible working conditions. In addition to improved economic conditions, higher education is also linked with increased cultural capital, which involves better access to information and contributes to effective fertility planning (Sobotka, 2004; Spéder and Kapitány, 2009). This could also include greater awareness of declining fertility with age, as well as increased likelihood among higher educated women to seek medical help when experiencing infertility (Bunting and Boivin, 2007; Swift and Liu, 2014; Datta et al, 2016). These combined characteristics could account for the higher parity progression rate among highly educated women.

Overall, the timing and occurrence of live birth is influenced by a complex set of factors. As this study shows, both women's level of education and health behaviours (i.e. smoking) contribute to explaining differences in fertility outcomes, though it is difficult to disentangle the contribution of each factor. In addition, the male partner's education and health indicators did not appear to have a significant effect on the likelihood of experiencing childbirth in this study.

The lack of association between men's educational attainment and progression to higher order birth can be explained by gender differences in the opportunity costs of children; as women carry the main burden of childbearing and rearing, they are more likely to be affected by the potential loss of income involved in having a larger family, as well as by the double burden of combining family and work responsibilities (Kravdal and Rindfuss, 2008). In this context, higher educated women who benefit from increased social capital are better supported financially and emotionally in making the transition to a higher order birth.

It should be noted that this study has several limitations. For example, the UKHLS includes information on whether respondents "think" they will have more children, rather than asking directly about fertility intentions or desires. While a more accurate measure is preferable, this question still provides a valuable distinction between individuals who consider expanding their family to those who are either not willing or unable to have more children. Another limitation in the measure for fertility intentions is that this variable is not included in the years following the first wave of the survey. This could lead to potential bias, as individuals may change their fertility preferences over time (Iacovou and Tavares, 2011) and might alter their health behaviours accordingly (e.g. stop smoking when planning to have a child). However, a sensitivity analysis with a more homogeneous sample of couples, where at least one partner expressed positive fertility intentions showed very similar results to that of the main analysis, which also included couples who do not intend to have more children. Another potential bias may be due to non-random attrition over the period of observation. We addressed this issue by limiting the observation period for six years, when the majority of the original sample is still present (Lynn and Borkowska, 2018). Furthermore, we controlled for the variables that were found linked with uneven attrition, such as ethnicity and income. Additional limitation is that due to the relatively small sample size, it was not possible to run separate analyses for each parity level, although we did control for parity in our models. Finally, the role of male testosterone levels could not be fully examined, due to the small proportion of respondents in the survey who provided a blood sample. Nonetheless, this study provides useful insights on the combined contribution of socioeconomic factors and health indicators to the likelihood of experiencing additional childbirth.

As our findings show, women at the highest level of education are more likely to experience the transition to higher order birth compared to women with lower qualifications, also after controlling for couples' health indicators. This is likely due to improved access to resources and greater social capital among the former. Therefore, policies aimed at helping individuals to fulfil their fertility aspirations should not focus merely on health behaviours, rather, a greater focus should be given to reducing the costs of childrearing and improving living conditions, which can contribute not only to achieving fertility aspirations, but also to improved health outcomes.

Future research should further explore the various mechanisms through which socioeconomic, health behaviours and biomedical factors influence fertility outcomes and the interaction between these factors among men and women.. In addition, it is important to understand how educational differences are associated with health and biomedical indicators during conception and pregnancy and their role in explaining pregnancy outcomes.

Notes

[1] Individuals are classified as overweight if their body mass index, calculated as weight in kilograms divided by height in meters squared (BMI=kg/m2), is 25 to less than 30 and obese if their BMI is 30 or above.

[2] While the Understanding Society study has more waves available, it was decided to limit the observation period to six years in order to focus on fertility outcomes in the short and medium term and to minimize the risk of bias due to attrition.

[3] The response rate for the Nurse Health Assessment is 59% out of a sample of 26,699 eligible respondents. The response rate of respondents who also provided a blood sample stands on 38%.

[4] Testosterone levels were also obtained for women. However, the majority of these measures are below the detection level of 1 nmol/L.

Funding

This project was carried out as part of an Understanding Society Biomarker Fellowship, funded by the Economic and Social Research Council (ESRC), grant reference ES/M008592/1.

Acknowledgments

I wish to thank Professor Michaela Benzeval, the Director of Understanding Society at the University of Essex for her helpful advice and support. In addition, I am grateful to Professor Jane Elliott from the University of Exeter for highly useful comments on previous versions of the manuscript. This study has also benefitted from valuable comments and suggestions made by the anonymous reviewers. I also wish to thank Emily Sewell, for assistance in collecting and managing the bibliographic materials for this study.

Data availability

This study uses data from the UK Household Longitudinal Study, which is managed by the Institute for Social and Economic Research at the University of Essex. The author takes responsibility for the integrity of the data (to the extent of using it as secondary data) and the accuracy of the analysis. Access to the data was facilitated by the UK Data Service, under special licence conditions.

Conflict of interest

The author declares that there is no conflict of interest.

References

Adsera, A. (2011) 'Where are the babies? Labor market conditions and fertility in Europe', *European Journal of Population*, 27(1): 1-32. doi:10.1007/s10680-010-9222-x.

Baird, D. T., Collins, J., Egozcue, J., Evers, L. H., Gianaroli, L., Leridon, H., Sunde, A., Templeton, A., Van Steirteghem, A., Cohen J., Crosignani, P. G., Devroey, P., Diedrich, K., Fauser, B. C., Fraser, L., Glasier, A., Liebaers, I., Mautone, G., Penney, G., Tarlatzis, B.; ESHRE Capri Workshop Group. (2005) 'Fertility and ageing', *Human Reproduction Update*, 11(3): 261–276. doi: 10.1093/humupd/dmi006.

Baker, C. (2019) *Obesity Statistics, Briefing Paper Number 3336* (6 August 2019), House of Commons Library.

Beaujouan, E., Reimondos, A., Gray, E., Evans, A., and Sobotka, T. (2019) 'Declining realisation of reproductive intentions with age', *Human Reproduction*, 34(10): 1906-1914. doi:10.1093/humrep/dez150.

Benzeval, M., Bond, L., Campbell, M., Egan, M., Lorenc, T., Petticrew, M., and Popham, F. (2014a) *How does money influence health?*, Joseph Rowntree Foundation. https://www.jrf.org.uk/report/how-does-money-influence-health.

Benzeval, M., Davillas, A., Kumari, M., and Lynn, P. (2014b). *Understanding Society: The UK Household Longitudinal Study, Biomarker user guide and glossary*, Institute for Social and Economic Research, University of Essex.

Berrington, A. (2004) ‘Perpetual postponers? Women's, men's and couple's fertility intentions and subsequent fertility behaviour’, *Population Trends*, 117: 9-19.

Berrington, A., Stone, J., and Beaujouan, É. (2015) ‘Educational differences in timing and quantum of childbearing in Britain: A study of cohorts born 1940−1969’, *Demographic Research*, 33(26): 733–764. doi:10.4054/DemRes.2015.33.26.

Blossfeld, H.-P. (2009) ‘Educational assortative marriage in comparative perspective’, *Annual Review of Sociology, 35*: 513–530. http://www.jstor.org/stable/27800089.

Boxmeer, J. C., Macklon, N. S., Lindemans, J., Beckers, N. G. M., Eijkemans, M. J. C., Laven, J. S. E., Steegers, E. A. P., and Steegers-Theunissen, R. P. M. (2009) ‘IVF outcomes are associated with biomarkers of the homocysteine pathway in monofollicular fluid’. *Human Reproduction*, 24(5): 1059–1066. https://doi.org/10.1093/humrep/dep009.

Bunting, L. and Boivin, J. (2007) ‘Decision-making about seeking medical advice in an internet sample of women trying to get pregnant’, *Human Reproduction,* 22(6): 1662-1668. https://doi.org/10.1093/humrep/dem057.

Chavarro, J. E., Rich Edwards, J. W., Rosner, B. A., and Willett, W. C. (2007) ‘Diet and lifestyle in the prevention of ovulatory disorder infertility’, *Obstetrics & Gynecololy,* 110(5): 1050-1058. doi: 10.1097/01.AOG.0000287293.25465.e1.

Chavarro, J. E., Toth, T. L., Wright, D. L., Meeker, J. D., and Hauser, R. (2010) ‘Body mass index in relation to semen quality, sperm DNA integrity, and serum reproductive hormone levels among men attending an infertility clinic’, *Fertility and Sterility*, 93(7): 2222–2231. doi: https://doi.org/10.1016/j.fertnstert.2009.01.100.

Cohen, D. A., Scribner, R. A., and Farley, T. A. (2000) 'A structural model of health behavior: A pragmatic approach to explain and influence health behaviors at the population level', *Preventive Medicine*, *30*(2): 146–154. https://doi.org/10.1006/pmed.1999.0609

Cutler, D. M. and Glaeser, E. (2005) 'What explains differences in smoking, drinking and other health-related behaviours?', *American Economic Review*, 95(2): 238-242. doi: 10.1257/000282805774670464.

Cutler, D. M. and Lleras-Muney, A. (2010) 'Understanding differences in health behaviors by education', *Journal of Health Economics*, 29(1): 1–28. https://doi.org/10.1016/j.jhealeco.2009.10.003.

Datta, J., Palmer, M. J., Tanton, C., Gibson, L. J., Jones, K. G., Macdowall, W., Glasier, A., Sonnenberg, P., Field, N., Mercer, C. H., Johnson, A. M., and Wellings, K. (2016) 'Prevalence of infertility and help seeking among 15000 women and men', *Human Reproduction*, 31(9): 2108-2118. doi: https://doi.org/10.1093/humrep/dew123.

Egan, M., Tannahill, C., Petticrew, M., Thomas, S. (2008) 'Psychosocial risk factors in home and community settings and their associations with population health and health inequalities: A systematic meta-review', *BMC Public Health*, 8, 239: 1-13. doi: 10.1186/1471-2458-8-239.

Gold, E. B., Crawford, S. L., Avis, N. E., Crandall, C. J., Matthews, K. A., Waetjen, L. E., Lee, J. S., Thurston, R., Vuga, M., and Harlow, S. D. (2013) 'Factors related to age at natural menopause: Longitudinal analyses from SWAN', *American Journal of Epidemiology*, 178(1): 70–83. doi: 10.1093/aje/kws421.

Hart, R. J. (2016) 'Physiological aspects of female fertility: Role of the environment, modern lifestyle, and genetics', *Physiological Reviews*, 96(3): 873–909. doi: 10.1152/physrev.00023.2015.

Homan, G. F., Davies, M., and Norman, R. (2007) 'The impact of lifestyle factors on reproductive performance in the general population and those undergoing infertility treatment: A review', *Human Reproduction Update*, 13(3): 209-223. doi: 10.1093/humupd/dml056.

Iacovou, M. and Tavares, L. P. (2011) 'Yearning, learning, and conceding: Reasons men and women change their childbearing intentions', *Population and Development Review*, 37(1): 89-123.

Kinney, A., Kline, J., and Levin, B. (2006) 'Alcohol, caffeine and smoking in relation to age at menopause', *Maturitas*, 54(1): 27–38. doi: 10.1016/j.maturitas.2005.10.001.

Knies, G. (2017) *Understanding Society: The UK Household Longitudinal Study, Waves 1-7 User Guide*, Colchester: University of Essex.

Kohler, H. P., Billari, F. C. and Ortega, J. A. (2002) 'The emergence of lowest-low fertility in Europe during the 1990s', *Population and Development Review*, 28(4): 641-680. http://www.jstor.org/stable/3092783.

Kravdal, Ø. and Rindfuss, R. R. (2008) 'Changing relationships between education and fertility: A study of women and men born 1940 to 1964', *American Sociological Review*, 73(5), 854–873. https://www.jstor.org/stable/25472561.

Kreyenfeld, M. (2002) ‘Time-squeeze, partner effect or self-selection?: An investigation into the positive effect of women’s education on second birth risks in West Germany’, *Demographic Research*, 7: 15-48.

Kreyenfeld, M. and Konietzka, D. (Eds.) (2017) *Childlessness in Europe: Contexts, causes, and consequences*, Rostock: Springer.

Laanpere, M., Altmäe, S., Stavreus-Evers, A., Nilsson, T. K., Yngve, A., and Salumets, A. (2010) ‘Folate-mediated one-carbon metabolism and its effect on female fertility and pregnancy viability’, *Nutrition Reviews*, 68(2): 99-113. doi: 10.1111/j.1753-4887.2009.00266.x.

Lawrence, E. M. (2017) ‘Why do college graduates behave more healthfully than those who are less educated?’, *Journal of Health and Social Behavior*, 58(3): 291-306. doi: 10.1177/0022146517715671.

Li, Y., Lin, H., Li, Y., and Cao, J. (2011) ‘Association between socio-psycho-behavioral factors and male semen quality: Systematic review and meta-analyses’, *Fertility and Sterility*, 95(1): 116–123. doi: 10.1016/j.fertnstert.2010.06.031.

Lotti, F., Corona, G., Vitale, P., Maseroli, E., Rossi, M., Fino, M. G., and Maggi, M. (2015) ‘Current smoking is associated with lower seminal vesicles and ejaculate volume, despite higher testosterone levels, in male subjects of infertile couples’, *Human Reproduction*, 30(3): 590–602. doi: 10.1530/endoabs.35.P704.

Lynn, P. and Borkowska, M. (2018) *Some Indicators of Sample Representativeness and Attrition Bias for BHPS and Understanding Society, Working Paper No. 2018-01*, Institute for Social and Economic Research, University of Essex.

MacDonald, A. A., Herbison, G. P., Showell, M., and Farquhar, C. M. (2010) ‘The impact of body mass index on semen parameters and reproductive hormones in human males: A systematic review with meta-analysis’, *Human Reproduction Update*, 16(3): 293–311. doi: 10.1093/humupd/dmp047.

Marmot, M. (2004) ‘Status syndrome’, *Significance*, 1: 150-154. https://doi.org/10.1111/j.1740-9713.2004.00058.x

McFall, S., Peterson, J., Kaminska, O., and Lynn, P. (2014) *Understanding Society: The UK Household Longitudinal Study, Waves 2 and 3 Nurse Health Assessment, 2010-2012, Guide to Nurse Health Assessment (Version 2.0),* Institute for Social and Economic Research, University of Essex.

Mclanahan, S. (2004) ‘Diverging destinies: How children are faring under the second demographic transition’, *Demography*, 41: 607–627.

Mills, M., Rindfuss, R. R., McDonald, P. and te Velde, E. (2011) ‘Why do people postpone parenthood? Reasons and social policy incentives’, *Human Reproduction Update*, 17(6): 848–860. doi: 10.1093/humupd/dmr026.

Mize, T. D., Doan, L., and Long, J. S. (2019) ‘A general framework for comparing predictions and marginal effects across models’, *Sociological Methodology*, 49(1): 152–189. https://doi.org/10.1177/0081175019852763

Mood, C. (2010) ‘Logistic Regression: Why we cannot do what we think we can do, and what we can do about it’, *European Sociological Review*, 26(1): 67–82. DOI: 10.1093/esr/jcp006.

Murto, T., Yngve, A., Svanberg, A. S., Altmäe, S., Salumets, A., Wånggren, K., and Stavreus-Evers, A. (2017) ‘Compliance to the recommended use of folic acid supplements for women in Sweden is higher among those under treatment for infertility than among fertile controls and is also related to socioeconomic status and lifestyle’, *Food & Nutrition Research*, 61(1): 1334483. https://doi.org/10.1080/16546628.2017.1334483.

Okechukwu, C. A., Nguyen, K., and Hickman, N. J. (2010) ‘Partner smoking characteristics: Associations with smoking and quitting among blue-collar apprentices’, *American Journal of Industrial Medicine*, *53*(11): 1102–1108. https://doi.org/10.1002/ajim.20890.

Pampel, F. C., Krueger, P. M., and Denney, J. T. (2010) ‘Socioeconomic disparities in health behaviors’, *Annual Review of Sociology*, 36: 349–370. doi: 10.1146/annurev.soc.012809.102529.

Park, C. and Kang, C. (2008) ‘Does education induce healthy lifestyle?’, *Journal of Health Economics*, 27(6): 1516–1531. https://doi.org/10.1016/j.jhealeco.2008.07.005.

Pasquali, R. (2006) ‘Obesity, fat distribution and infertility’, *Maturitas*, 54(4): 363–371. doi: 10.1016/j.maturitas.2006.04.018.

Pasquali, R., Pelusi, C., Genghini, S., Cacciari, M., and Gambineri, A. (2003) ‘Obesity and reproductive disorders in women’, *Human Reproduction Update*, 9(4): 359-372. doi: 10.1093/humupd/dmg024.

Philipov, D., Spéder, Z. and Billari, F. C. (2006) ‘Soon, later, or ever? The impact of anomie and social capital on fertility intentions in Bulgaria (2002) and Hungary (2001)’, *Population Studies*, 60(3): 289-308.

Raphael, D., Macdonald, J., Colman, R., Labonte, R., Hayward, K., Torgerson, R. (2005) ‘Researching income and income distribution as determinants of health in Canada: gaps between theoretical knowledge, research practice, and policy implementation’, *Health Policy,* 72(2): 217-232. https://doi.org/10.1016/j.healthpol.2004.08.001.

Rendall, M. S. and Smallwood, S. (2003) ‘Higher qualifications, first-birth timing, and further childbearing in England and Wales’, *Population Trends,* 111: 18–26.

Sharma, R., Biedenharn, K. R., Fedor, J. M., and Agarwal, A. (2013) ‘Lifestyle factors and reproductive health: Taking control of your fertility’, *Reproductive Biology and Endocrinology,* 11: 66. doi:10.1186/1477-7827-11-66.

Shiels, M. S., Rohrmann, S., Menke, A., Selvin, E., Crespo, C. J., Rifai, N., Dobs, A., Feinleib, M., Guallar, E., and Platz, E. A. (2009) ‘Association of cigarette smoking, alcohol consumption, and physical activity with sex steroid hormone levels in US men’, *Cancer Causes & Control,* 20(6): 877–886. doi: 10.1007/s10552-009-9318-y.

Short, S. E., and Mollborn, S. (2015) ‘Social determinants and health behaviors: Conceptual frames and empirical advances’, *Current Opinion in Psychology*, 5: 78–84. https://doi.org/10.1016/j.copsyc.2015.05.002

Smith, S. and Ratcliffe, A. (2009) ‘Women’s Education and Childbearing: A growing divide’, in J. Stillwell, E. Coast and D. Kneale (eds), *Fertility, Living Arrangements, Care and Mobility: Understanding population trends V. 1*, Dordrecht, Springer. pp. 41-58.

Sobotka, T. (2004) *Postponement of Childbearing and Low Fertility in Europe*, Amsterdam: Dutch University Press.

Spéder, Z. and Kapitány, B. (2009) 'How are time-dependent childbearing intentions realized? Realization, postponement, abandonment, bringing forward', *European Journal of Population*, 25(4): 503-523. https://doi.org/10.1007/s10680-009-9189-7.

Swift, B. E. and Liu, K. E. (2014) 'The effect of age, ethnicity, and level of education on fertility awareness and duration of infertility', *Journal of Obstetrics and Gynaecology Canada*, 36(11): 990-996. doi: 10.1016/S1701-2163(15)30412-6.

University of Essex. Institute for Social and Economic Research (2014) *Understanding Society: Waves 2-3 Nurse Health Assessment, 2010-2012 [computer file]. 3rd Edition*, Colchester, Essex: UK Data Archive [distributor], December 2014. SN: 7251, http://dx.doi.org/10.5255/UKDA-SN-7251-3.

University of Essex. Institute for Social and Economic Research, NatCen Social Research, Kantar Public. (2017) *Understanding Society: Waves 1-7, 2009-2016 and Harmonised BHPS: Waves 1-18, 1991-2009: Special Licence Access. [data collection]. 8th Edition*, UK Data Service. SN: 6931, http://doi.org/10.5255/UKDA-SN-6931-7.

Van Bavel, J. (2012) 'The reversal of gender inequality in education, union formation and fertility in Europe', *Vienna Yearbook of Population Research*, 10: 127-154. https://www.jstor.org/stable/41941000.

Wang, W., Yang, X., Liang, J., Liao, M., Zhang, H., Qin, X., Mo, L., Lv, W., and Mo Z. (2013) 'Cigarette smoking has a positive and independent effect on testosterone levels', *Hormones (Athens)*, 12(4): 567–577. doi: 10.14310/horm.2002.1445.

Table 1: Selection criteria for the analytical sample of couples

Selection criteria	**Couples (n)**
Heterosexual couples in reproductive ages	**5,338**
Of whom: observed in at least two waves	**4,337**
Exclusions:	
Childless couples	1,074
Fertility intentions are missing/unknown	468
Woman is currently pregnant	96
Underweight male or female partner	44
Missing data	455
Total sample selected	**2,200**

Table 2: Sample characteristics at first observation

		n	% / Mean (SD)
Age	Female age	2,200	36 (6.2)
	Male age	2,200	39 (7.2)
Union duration	Union duration	2,200	11 (6.6)
Marital status	Married	1,701	77
	Cohabiting	499	23
Parity	1 child	629	28
	2 children	982	45
	3+ children	589	27
Childbearing intentions	Both partners no	1,604	73
	Both partners yes	448	20
	Only female yes	81	4
	Only male yes	67	3
Time since last birth in months	≤12	300	14
	13-35	458	21
	36-71	458	21
	72-119	381	17
	120+	603	27
Female education	Degree	584	26
	Other higher	311	14
	Upper secondary	435	20
	Lower secondary	870	40
Male education	Degree	562	26
	Other higher	246	11
	Upper secondary	489	22
	Lower secondary	903	41
Female ethnicity	White	1,949	88
	South Asian	125	6
	Black	46	2
	Other	80	4
Male ethnicity	White	1,966	89
	South Asian	124	6
	Black	50	2
	Other	60	3
Household income	1st quintile	81	4
	2nd quintile	206	9
	3rd quintile	444	20
	4th quintile	719	33
	5th quintile	750	34

Table 2: Sample characteristics at first observation (continued)

Female smoking status	Non-smoker	1,627	74
	Smokes <10 cigs a day	194	9
	Smokes 10+ cigs a day	379	17
Male smoking status	Non-smoker	1,512	69
	Smokes <10 cigs a day	208	9
	Smokes 10+ cigs a day	480	22
Female BMI	Normal (18-25)	1,005	46
	Overweight (25-30)	676	31
	Obese (30-35)	311	14
	Severely obese (35+)	208	9
Male BMI	Normal (18-25)	699	32
	Overweight (25-30)	1,032	47
	Obese (30-35)	352	16
	Severely obese (35+)	117	5
Male testosterone	Low (<9)	96	4
	Normal (9-25)	550	25
	High (>25)	31	2
	Missing blood test	1,523	69

Table 3: Discrete-time hazard model for couples' likelihood of additional childbirth[a] (average discrete changes[b])

	1. Female education	2. Female education +health indicators	3. Male education	4. Male education + health indicators	5. Female + male health indicators
Childbearing intentions (ref=both no):					
Both yes	0.87***	0.88***	0.89***	0.90***	0.90***
Only female yes	0.47***	0.48***	0.50***	0.50***	0.49***
Only male yes	0.35***	0.36***	0.33***	0.33***	0.35***
Female education (ref=degree):					
Other higher	-0.20***	-0.20***			-0.19***
Upper secondary	-0.12**	-0.13**			-0.12*
Lower secondary	-0.10*	-0.08			-0.08
Male education (ref=degree):					
Other higher			-0.02	-0.02	0.01
Upper secondary			-0.09	-0.08	-0.05
Lower secondary			-0.05	-0.04	-0.01
Female smoking (ref=non-smoker):					
Smokes <10 cigs a day		-0.10*			-0.10*
Smokes 10+ cigs a day		-0.14***			-0.15***
Female BMI (ref=18-25):					
Overweight (25-30)		0.01			0.01
Obese (30-35)		0.03			0.03
Severely obese (35+)		-0.05			-0.05
Male smoking (ref=non-smoker):					
Smokes <10 cigs a day				-0.04	0.00
Smokes 10+ cigs a day				-0.05	0.02
Male BMI (ref=18-25):					
Overweight (25-30)				-0.04	-0.04
Obese (30-35)				0.01	0.02
Severely obese (35+)				-0.05	-0.04
Male testosterone (ref=9-25):					
Low (<9)				-0.09	-0.10
High (>25)				-0.12	-0.11
Missing blood sample				-0.03	-0.02
N	109,428	109,428	109,428	109,428	109,428
Log likelihood	-2188.5	-2184.4	-2193.6	-2191.8	-2182.1

*p<0.1, **p<0.05, ***p<0.01

[a]All models control for age and age squared of both partners, union duration, marital status, parity, number of months since last birth, ethnicity and household income level. See Appendix for the full models.

[b]The average discrete changes are multiplied by 100 to represent the percentage change in probability of live birth.

Table 4. SUEST test of differences in average discrete changes (ADCs) by level of education across models, based on results from Table 3 (P-value in parentheses)[a]

	ADC difference Model 1 & 2	ADC difference Model 3 & 4	ADC difference Model 1 & 5
Female education (ref=degree):			
Other higher	0.00 (0.921)		0.00 (0.832)
Upper secondary	0.00 (0.929)		0.01 (0.682)
Lower secondary	0.02 (0.049)		0.02 (0.360)
Male education (ref=degree):			
Other higher		0.00 (0.708)	
Upper secondary		0.00 (0.547)	
Lower secondary		0.01 (0.533)	

[a]The average discrete changes are multiplied by 100 (see Table 3).

Table 5. Discrete-time hazard model for couples' likelihood of additional childbirth (odds ratios)

	1. Female education	2. Female education +health indicators	3. Male education	4. Male education + health indicators	5. Female + male health indicators
Female age	1.697***	1.709***	1.713***	1.704***	1.711***
Female age squared	0.991***	0.991***	0.991***	0.991***	0.991***
Male age	1.069	1.069	1.053	1.061	1.071
Male age squared	0.999	0.999	0.999	0.999	0.999
Union duration	0.973	0.971*	0.973*	0.972*	0.970*
Marital status (ref=married):					
Cohabiting	0.934	0.957	0.938	0.947	0.959
Parity (ref=1 child):					
2 children	0.799*	0.791*	0.814	0.813	0.807
3+ children	0.869	0.908	0.870	0.879	0.919
Months since last birth (ref=36-71):					
<12	0.074***	0.072***	0.077***	0.075***	0.071***
13-35	0.634***	0.616***	0.650***	0.642***	0.610***
72-119	0.671***	0.690**	0.668***	0.672***	0.698**
120+	0.383***	0.400***	0.373***	0.384***	0.410***
Fertility intentions (ref=both no):					
Both yes	10.897***	11.097***	11.241***	11.392***	11.457***
Only female yes	6.243***	6.444***	6.643***	6.743***	6.592***
Only male yes	4.916***	5.108***	4.738***	4.753***	4.979***
Female education (ref=degree level):					
Other higher	0.579***	0.571***			0.580***
Upper secondary	0.731**	0.726**			0.744*
Lower secondary	0.786*	0.826			0.829
Male education (ref=degree level):					
Other higher			0.943	0.948	1.035
Upper secondary			0.789	0.796	0.870
Lower secondary			0.887	0.903	0.984
Female ethnicity (ref=White):					
South Asian	1.281	1.186			1.240
Black	1.725*	1.561			1.402
other	0.792	0.729			0.690
Male ethnicity (ref=White):					
South Asian			1.271	1.274	0.954
Black			1.485	1.470	1.108
other			0.938	0.962	1.102
Household income (ref=5th quintile):					
1st quintile	1.026	1.096	0.980	0.994	1.076
2nd quintile	1.024	1.101	0.966	0.975	1.104
3rd quintile	1.256	1.299*	1.188	1.202	1.319*
4th quintile	0.993	1.007	0.934	0.935	1.011
Female smoking (ref=non-smoker):					
Smokes <10 cigs		0.756			0.751
Smokes 10+ cigs		0.670**			0.646**
Female BMI (ref=18-25):					
Overweight (25-30)		1.017			1.020
Obese (30-35)		1.073			1.086
Severely obese (35+)		0.862			0.875
Male smoking (ref=non-smoker):					
Smokes <10 cigs				0.898	1.004
Smokes 10+ cigs				0.884	1.047
Male BMI (ref=18-25):					
Overweight (25-30)				0.906	0.904
Obese (30-35)				1.028	1.051
Severely obese (35+)				0.866	0.907
Male testosterone (ref=9-25):					
Low (<9)				0.785	0.762
High (>25)				0.725	0.741
Missing blood sample				0.931	0.938

*p<0.1, **p<0.05, ***p<0.01

Table 6: Discrete-time hazard model for couples' likelihood of additional childbirth[a] (average discrete changes[b])

	1. Female education	2. Female education + male health indicators	3. Male education	4. Male education + female health indicators
Childbearing intentions (ref=both no):				
Both yes	0.87***	0.88***	0.89***	0.90***
Only female yes	0.47***	0.47***	0.50***	0.51***
Only male yes	0.35***	0.35***	0.33***	0.34***
Female education (ref=degree):				
Other higher	-0.20***	-0.20***		
Upper secondary	-0.12**	-0.12**		
Lower secondary	-0.10*	-0.10*		
Male education (ref=degree):				
Other higher			-0.02	-0.03
Upper secondary			-0.09	-0.09
Lower secondary			-0.05	-0.03
Female smoking (ref=non-smoker):				
Smokes <10 cigs a day				-0.09*
Smokes 10+ cigs a day				-0.13***
Female BMI (ref=18-25):				
Overweight (25-30)				0.01
Obese (30-35)				0.01
Severely obese (35+)				-0.05
Male smoking (ref=non-smoker):				
Smokes <10 cigs a day		-0.04		
Smokes 10+ cigs a day		-0.04		
Male BMI (ref=18-25):				
Overweight (25-30)		-0.04		
Obese (30-35)		0.02		
Severely obese (35+)		-0.04		
Male testosterone (ref=9-25):				
Low (<9)				
High (>25)				
Missing blood sample				
N	109,428	109,428	109,428	109,428
Log likelihood	-2188.5	-2186.7	-2193.6	-2189.7

*p<0.1, **p<0.05, ***p<0.01

[a]All models control for age and age squared of both partners, union duration, marital status, parity, number of months since last birth, ethnicity and household income level. See Appendix for the full models.

[b]The average discrete changes are multiplied by 100 to represent the percentage change in probability of live birth.

Table 7. SUEST test of differences in average discrete changes (ADCs) by level of education across models, based on results in Table 6 (P-value in parentheses)[a]

	ADC difference Model 1 & 2	ADC difference Model 3 & 4
Female education (ref=degree):		
Other higher	0.00 (0.936)	
Upper secondary	-0.01 (0.541)	
Lower secondary	0.00 (0.899)	
Male education (ref=degree):		
Other higher		0.01 (0.283)
Upper secondary		0.00 (0.700)
Lower secondary		0.02 (0.020)

[a]The average discrete changes are multiplied by 100 (see Table 6).

Figure 1a. Distribution of smoking status by level of education among women aged 17-45 (Pearson chi2(6)=161.7, Pr<0.001)

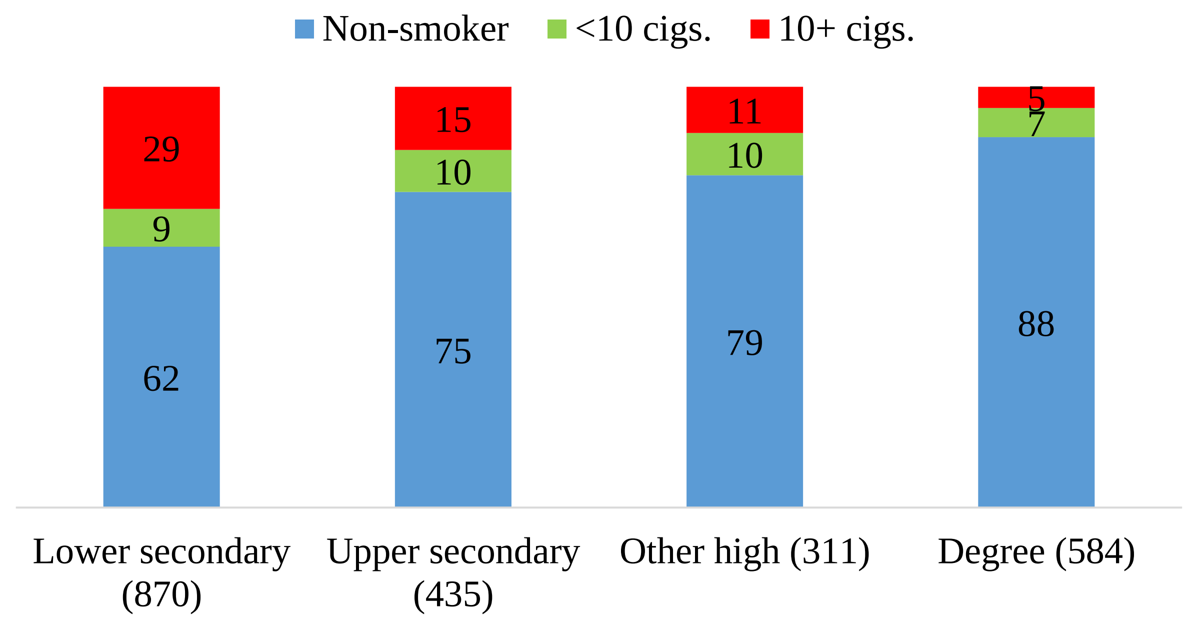

Figure 1b. Distribution of smoking status by level of education among men aged 17-64 (Pearson chi2(6)=169.1, Pr<0.001)

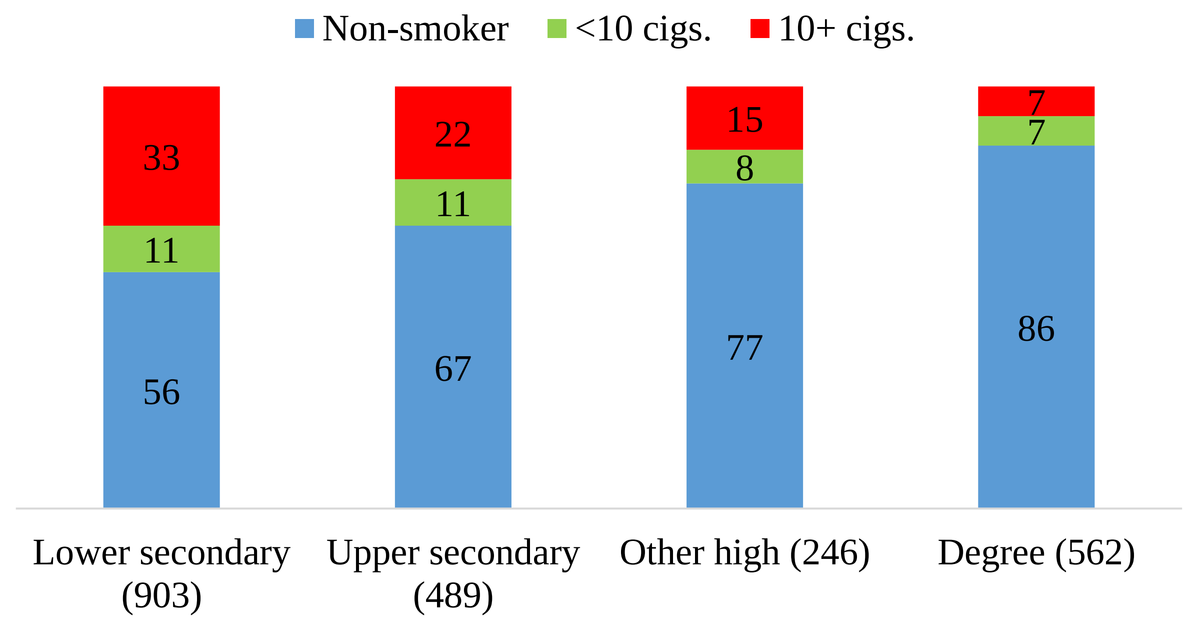

Figure 2a. Distribution of BMI status by level of education among women aged 17-45 (Pearson chi2(9)=66.6, Pr<0.001)

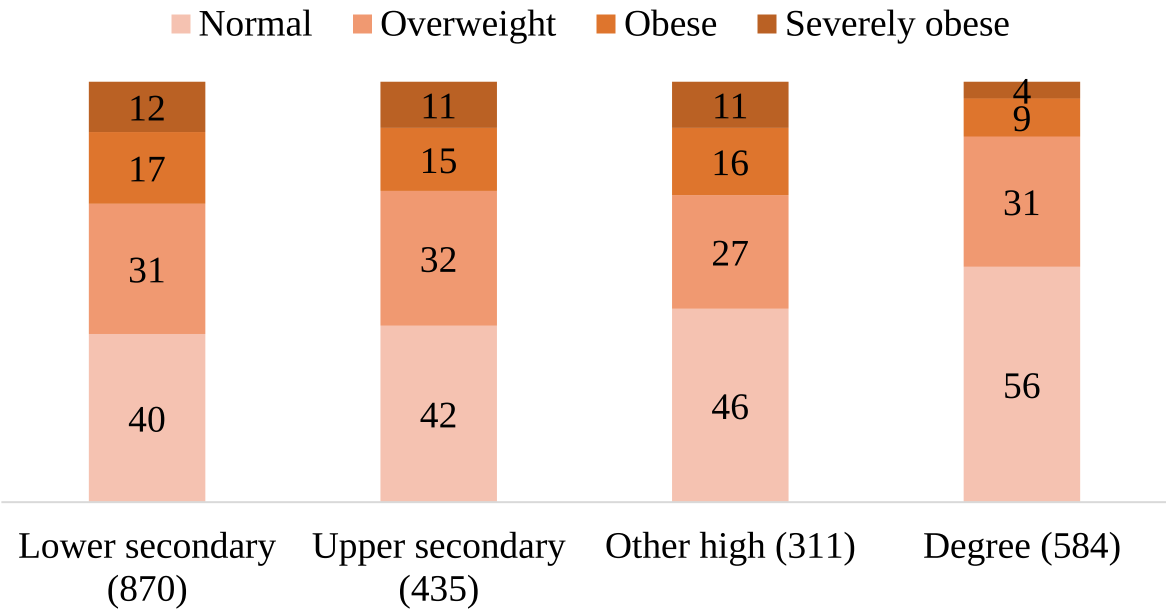

Figure 2b. Distribution of BMI status by level of education among men aged 17-64 (Pearson chi2(9)=55.3, Pr<0.001)