Low fertility increases descendant socioeconomic position but reduces long-term fitness in a modern post-industrial society

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Abstract

Adaptive accounts of modern low human fertility argue that small family size maximises the inheritance of socioeconomic resources across generations and may consequently increase long-term fitness. This paper explores the long-term impacts of fertility and socioeconomic position (SEP) on multiple dimensions of descendant success in a unique Swedish cohort of 14,000 individuals born 1915-1929. We show that low fertility and high SEP predict increased descendant socioeconomic success across four generations. Furthermore, these effects are multiplicative, with the greatest benefits of low fertility observed when SEP is high. Low fertility and high SEP do not, however, predict increased descendant reproductive success. Our results are therefore consistent with the idea that modern fertility limitation represents a strategic response to the local costs of rearing socioeconomically competitive offspring, but contradict adaptive models suggesting that it maximises long-term fitness. This indicates a conflict in modern societies between behaviours promoting socioeconomic versus biological success. This paper also makes a methodological contribution, demonstrating that number of offspring strongly predicts long-term fitness and thereby validating use of fertility data to estimate current selective pressures in modern populations. Finally our findings highlight that differences in fertility and SEP have important long-term effects on the persistence of social inequalities across generations.

Key Words: Demographic transition; multigenerational; fertility; socioeconomic position; reproductive success; quality-quantity trade-off.

Introduction

Evolutionary anthropologists argue that the physiological, cognitive and cultural mechanisms regulating human reproduction have evolved by natural selection to channel accumulated resources into the maximization of inclusive fitness (i.e. production of genetic descendants) [1, 2]. Supporting this proposition, male socioeconomic success has been reported to be positively associated with reproductive success across a range of 'traditional' pre-industrial societies [3]. There is also some evidence that fertility patterns in traditional societies approximate local optima for maximizing fitness in the presence of resource allocation trade-offs between offspring quantity and quality [4-6, but see 7]; that is, trade-offs between the number of descendants and their ability to reproduce in turn. By contrast, in 'modern' post-industrial societies that have undergone demographic transition (i.e. the sequential decline in mortality and fertility observed with population-level socioeconomic development [8]), the lowest recorded fertility rates in human history now coincide with unprecedented material prosperity. This immediately seems at odds with adaptive models, since such prosperity ought to enable individuals to rear more children should they desire to do so [9]. Furthermore, in modern societies the anticipated within-population positive associations between socioeconomic and reproductive success have been attenuated or even reversed [3, 10-12]. Why this shift occurs is poorly understood by both evolutionary and non-evolutionary social scientists [11, 13], but a persistent idea is that modernization favours reduced fertility by increasing the costs of rearing socioeconomically competitive offspring [1, 14-16]. Consistent with this view, many studies indicate that low fertility substantially advances offspring education and wealth in modern societies [17-19]. There is also evidence that such benefits emerge with or are magnified by socioeconomic development [2, 20], although direct tests of this hypothesis are rare [14].

Rising quantity-quality trade-offs with regard to the socioeconomic success of offspring have been incorporated into alternative evolutionary models of the demographic transition. Firstly, Kaplan has suggested that evolved psychological mechanisms may be maladaptive in the face of such novel costs of reproduction, favouring low fertility even if these do not enhance offspring quality in more direct ways (i.e. survival, mating or fertility) [1, 21]. This model argues that humans have undergone selection for psychological mechanisms that lead them to strive for the culturally-recognised goals of wealth and status, and to balance fertility against these goals, because until recently such advantages closely predicted offspring survival and reproduction. Modernisation, however, combines i) increased scope for socioeconomic competition between individuals due to engagement with modern labour-market economies; with ii) novel conditions where offspring survival is virtually guaranteed and where few individuals have insufficient resources to reproduce. This 'maladaptive' hypothesis is supported by studies showing that low fertility in modern populations advances offspring educational attainment and/or wealth, but does not increase offspring survival or fertility [22-25]. In contrast, other researchers have argued that immediate deficits in reproductive success may eventually yield adaptive increases in long-term fitness provided strong socioeconomic advantage is transmitted across generations, [26]. This second, 'adaptive' hypothesis is supported by a number of formal theoretical models [26-29], but a dearth of high-quality multigenerational data means that empirical data are lacking. This paper provides a powerful test of these competing hypotheses by considering associations between reproductive and socioeconomic success in a modern society, across both the short- and long-term. To do this we use data from the Uppsala Birth Cohort study (UBCoS), a unique Swedish dataset which tracks 14,000 individuals born in the early 1900s and all their descendants to the present day.

Understanding relationships between fertility, socioeconomic advantage and long-term descendant socioeconomic and reproductive success is also of wider importance for the biological and social sciences. Firstly, multigenerational analyses can provide crucial validation for research into long-term patterns of natural selection. In recent years, there has been much interest in using fertility data to estimate the direction and strength of natural selection currently acting in modern human populations [12, 30-32]. Among the most consistent findings is that, using lifetime number of offspring as a measure of reproductive success, both sexes are under selection for earlier age at first birth in both traditional and modern populations [31]. One study with unusually rich physiological data also reported selection in modern US women for shorter height, lower total cholesterol and lower systolic blood pressure, leading the authors to conclude that "natural selection is acting slowly and gradually on traits of medical importance and on life history traits" [30, p.1790]. Many of these studies, however, assume that lifetime number of offspring is an effective proxy for long-term genetic fitness, an assumption that would be invalidated if high fertility compromised descendant reproductive success. Our data enable us to examine this assumption explicitly by quantifying relationships between short- and long-term fitness. Secondly, multigenerational data is required to assess the long-term implications of modern inequalities in fertility and socioeconomic position (SEP). It is already well known that high parental fertility carries important costs for offspring health, education and socioeconomic success in modern societies [19]. Conversely, even within well-functioning welfare states, high parental SEP is a strong predictor of positive outcomes across a multiple domains of child and adult well-being [33]. Recent studies have also suggested that these effects interact, with the benefits of fertility limitation being particularly large in high SEP families [2]. Very little, however, is known about how fertility or SEP affect quantity and quality of grandchildren and later descendants. There is also very little research examining how far any long-term effects of fertility may be mediated by differences in the socioeconomic success of intervening generations, or vice versa.

Research aims and hypotheses

Our primary aim is to examine how and why parental fertility and SEP affect short- and long-term descendant socioeconomic and reproductive success. Specifically we test the following hypotheses: 1) that high parental SEP and low parental fertility increase descendant socioeconomic success across generations; 2) that high parental SEP and low parental fertility increase descendant reproductive success across generations; 3) that high parental SEP and low parental fertility interact such that the benefits of fertility limitation are greatest in high SEP families; and 4) that following hypotheses 1-2, long-term reproductive success is maximised at an intermediate fertility level. We also address the methodological aim of examining the validity of lifetime number of offspring as a measure of long-term reproductive success in modern low-fertility societies, and compare its performance with the alternative measures of number of grandchildren or great-grandchildren.

In testing these hypotheses using data from across four generations, we extend previous research in post-demographic transition populations which has focussed solely upon effects in the offspring generation [22-24] (but see [32] for an examination of longer-term outcomes in a pre-demographic transition population). The UBCoS dataset also provides a number of additional advantages. First, it is a large, population-based cohort that is known to be representative of the Swedish population at large in terms of infant mortality and fertility [25]. By contrast, previous studies of modern populations have used smaller and potentially biased samples, such as opportunistic sampling of men (only) at service stations [23] or drawing study populations from US military personnel and German physicians [24]. Secondly, UBCoS suffers from remarkably little loss to follow-up, allowing us to trace 96% of all cohort members (and all their registered descendants) up to 2009. Finally, high-quality data is available on an unusually wide range of measures for each individual, enabling us to examine effects upon descendant survival, marriage, reproduction, school achievement, educational continuation and family income.

Methods

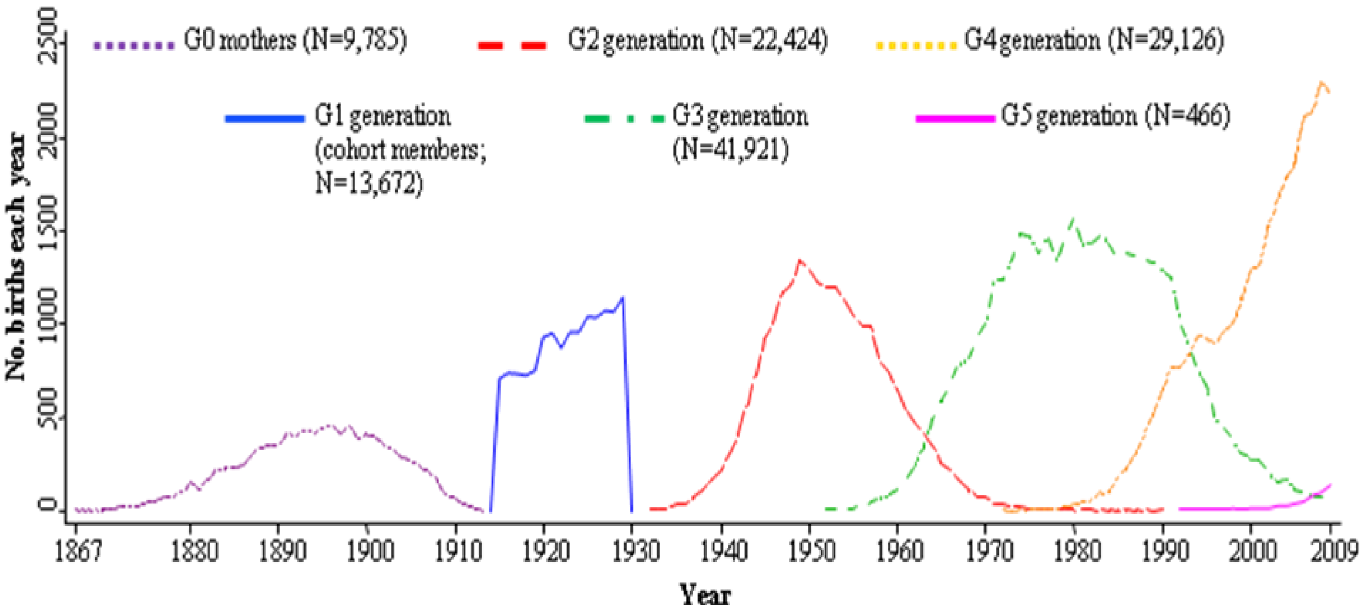
Sample selection and early-life characteristics

Our sample comprises all live births at the Uppsala University Hospital between 1915 and 1929. This hospital delivered an estimated 75% of births in Uppsala city and 50% of births in surrounding rural parishes. From a total of 14,192 births, 13,811 (98%) were successfully traced through parish archives until death, emigration or until being assigned a unique personal number in 1947. Of these we excluded 139 cohort members (henceforth 'G1s' from 'generation one') who emigrated permanently before reaching 60 years in age, leaving a study population of 13,672 (7178 male) G1s. This birth cohort is representative of Sweden nationally in terms of infant mortality and fertility [25], albeit with a somewhat higher proportion of infants from urban areas (46% vs. 31% nationally [34]).

Archived obstetric records provided data on G1 birthweight, gestational age, and twin/triplet status. These records also provided information on cohort members' parents ('G0s'), including mother's age, marital status and household head SEP (henceforth 'parental SEP': further details in Electronic supplementary material (ESM) 1). Finally, we assigned parental fertility as being equal to the total number of children (including deceased children) belonging to the parents' household in the 1930 census. Where this information was not available (47% of sample) we instead used the mother's maximum recorded parity in obstetric records (r=0.89 for correlation with the census data: details in ESM1).

We supplemented this data on parents (G0s) and offspring (G1s) by linking G1s to all biological descendants born up to 31st December 2009, using the Swedish Multigenerational Register (estimated completeness 97.7% for paternity, 99.6% for maternity: see [25]). As judged by the distribution of birth years, the grandchild ('G2s') and great-grandchild ('G3s') generations were essentially complete by 2009; the great-great-grandchild generation ('G4s') was in a relatively early phase; and the great-great-great-grandchild generation ('G5s') had just begun (Figure 1).

Figure 1: Distribution of year of birth for UBCoS cohort members, parents and biological descendants



Data presented on G0 mothers only, because we did not have data on the age of G0 fathers

Descendant socioeconomic and reproductive success

We operationalised descendant 'quality' in terms of both socioeconomic success (which is expected to have indirectly increased descendants' ability to reproduce in our evolutionary past) and also in terms of more direct measures of reproductive success (survival, mating and marriage). For all G1s, G2s and G3s we used Swedish Register data to assign three indicators of socioeconomic success: i) Schoolmarks: standardised average marks across all compulsory subjects in elementary school (collected age 10 in G1s, age 16 in descendants); ii) Entering university: ever entering university or equivalent, if aged 21 or over; and iii) Family income: disposable family income, standardised each calendar year by age and sex and then averaged across all available calendar years in which the descendant was aged 21-65. We also used three more direct measures of reproductive success: iv) Survival to age 16; v) Mating success: marriage before age 40, if survived to age 16; and vi) Fertility: number of offspring up to 2009. Further details of calculation are in ESM1, including details of instances where some measures were not available for all generations. From these individual-level outcomes we then generated averages across all available descendants in each generation (e.g. mean G1 schoolmarks, proportion of G1s surviving to age 16).

Estimated fitness of G1s

The increasing overlap between generations (see Figure 1) motivated us to create a measure of long-term fitness which combined descendants across generations. For each descendant, we calculated their reproductive value as their expected number of additional future offspring given their sex, age and parity in 2009. We used a lifetable approach which assumed the continuation of 2009 mortality and fertility rates in the total Swedish population (details in ESM1). We then multiplied this expected number of future offspring by the descendant's coefficient of relatedness to the G1 cohort member, i.e. 0.5 for G2s, 0.25 for G3s, 0.125 for G4s and 0.0625 for G5s. By summing this product across all a G1's descendants we obtained the estimated direct fitness of each G1. This can be interpreted as the expected number of future times in which each living descendant would pass on the G1's genes to the next generation.

Statistical analysis

We used multivariable regression to investigate the effect of G0 parental fertility and SEP upon the (average) socioeconomic and reproductive success of their G1, G2 and G3 descendants. To facilitate comparisons of effect sizes across generations and across outcomes, we standardised all outcomes for each generation and used these in linear regression analysis. The only exception was for our three binary outcomes (G1 survival, entering university and marriage), for which we used logistic regression and converted the log-odds to effect sizes [35]. We adjusted all analyses for G1 birthweight, gestational age, twin/triplet status, mother's age, mother's marital status and birth year (all correlation coefficients ≤0.49 between early-life characteristics: see ESM2). We calculated confidence intervals using robust standard errors clustered by G0 mother. We combined males and females unless there was evidence of a sex interaction ($p<0.05$), but present sex-stratified analyses in ESM3. We also tested for interactions between G0 parental fertility and SEP. All tests for interaction are reported in ESM3, and all significant interactions are reported in the text and/or figures.

To explore mediation across generations we fitted linear structural equation models for the G2 and G3 outcomes, using the same independent variables and including as mediators a) intervening SEP (e.g. G1's adult education) and b) intervening fertility (e.g. G1's number of offspring: see ESM3). We fitted these models with a robust maximum likelihood estimator using Gaussian integration with 24 quadrature points (see ESM3).

We addressed our aim of validating total number of children as a predictor of long-term fitness in two ways. First, we calculated the Pearson's correlation between G1 number of offspring (G2 generation) and total estimated fitness. We compared this to the correlations observed for G1 number of grandchildren (G3s) and great-grandchildren (G4s). Second, we used multivariable linear regression analyses to calculate and compare the early-life predictors of these four measures of G1 reproductive success, standardised to facilitate comparisons. Our purpose in running these analyses was the *methodological* aim of establishing whether these four alternative measures generated similar findings. See [25] for a detailed consideration of which early-life characteristics predict reproductive success, how this differs by sex, and which mortality/mating/fertility pathways mediate associations.

All analyses handled missing data on early-life characteristics (0-3.5% missing data) under an assumption of missing at random. We used maximum likelihood estimation in MPlus and used multiple imputation by chained equations in Stata (5 imputations, including all in our imputation model all variables and structure included in substantive models).

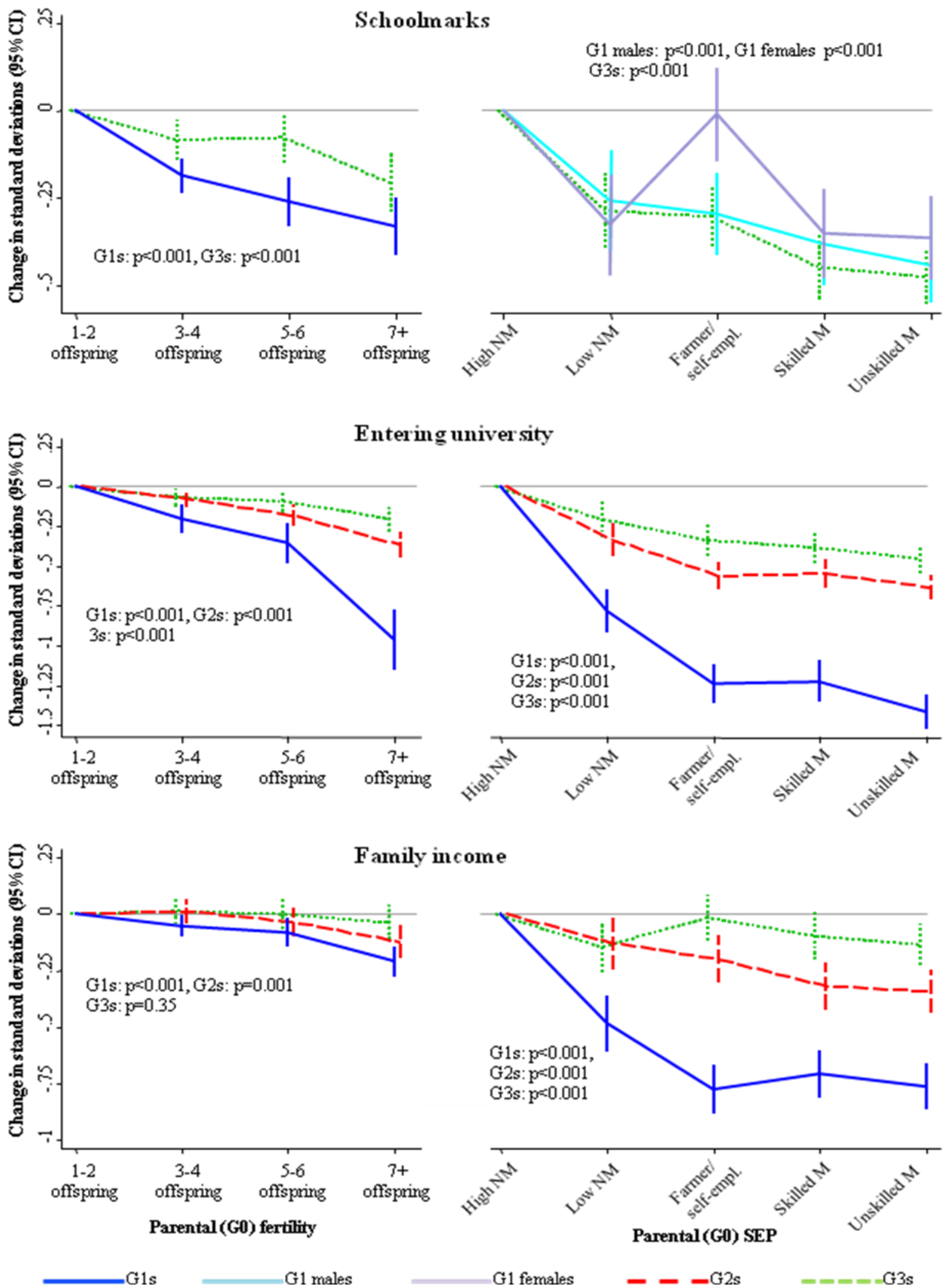
Results

Among the G0s, average fertility was 3.2 offspring. Their children, the G1s cohort members, had a mean of 1.7 offspring (2.3 for those with at least one offspring), and these grandchildren (G2s) had in turn a mean of 1.8 offspring (2.3 if at least one offspring). As of 2009, these great-grandchildren (G3s) had a mean of 0.7 offspring (1.9 if at least one offspring).

Fertility, SEP and descendant socioeconomic success

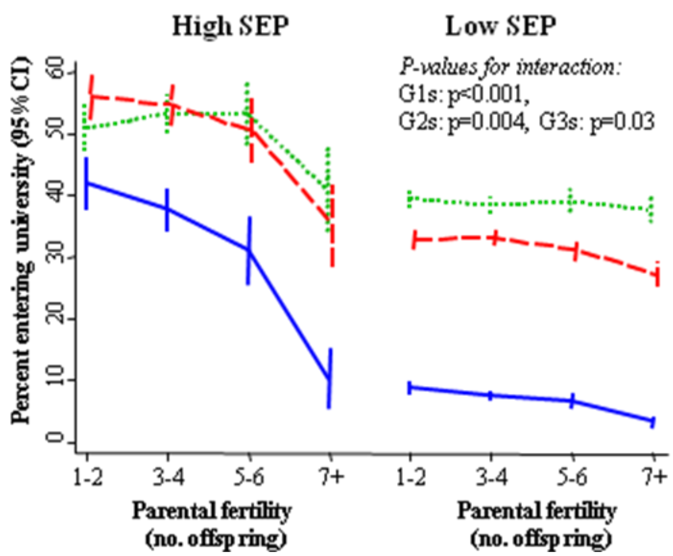
Figure 2 presents the adjusted effects of parental fertility and SEP upon our measures of descendant socioeconomic success. The underlying correlation coefficients are presented in ESM2, while ESM3 tabulates the data and also presents R^2 values, raw means and percentages, unadjusted analyses and sex-stratified analyses. Among both male and female G1 cohort members, both lower parental fertility and higher parental SEP were associated with substantially higher school marks, educational level and family income. The effects of parental SEP were particularly large. For example, high/mediate non-manual SEP vs. unskilled manual SEP was associated with an adjusted effect size of 0.41 standard deviations for schoolmarks; 1.41 for entrance to university; and 0.77 for family income (Figure 2). The corresponding effect sizes for parental fertility of $\geq$7 offspring vs. 1-2 offspring were 0.33, 0.96 and 0.21 (Figure 2, left-hand). There was also evidence that, as predicted, the benefits of low parental fertility were particularly large for G1s born into families of high SEP ($p \leq 0.03$ for interaction for all three measures of G1 socioeconomic success; see ESM3and see also Figure 3 for a graph of the interaction with respect to educational level). Moreover, most of these effects persisted to the G2s and G3s, including interactions with respect to educational level. There was strong evidence that all the multigenerational effects presented in Figure 2 were substantially mediated by intervening SEP, with the magnitude of this indirect path always being at least half that of the total effect (ESM3). By contrast, there was always little or no evidence of an indirect path via intervening fertility.

Figure 2: Effect of parental (G0) fertility and SEP upon descendant socioeconomic success



CI=confidence interval, SEP=socioeconomic position, High NM=high/mediate non-manual, Low NM=low non-manual, farmer/self-empl.=farmer or self-employed, Skilled M=skilled manual, Unskilled M=unskilled manual. P-values are from regression models adjusting for G1 early-life characteristics, and are for heterogeneity for SEP and for linear trend for parental fertility (substantive findings unchanged when using p-value for heterogeneity for both). See ESM3 for numbers of individuals, for raw data and unadjusted analyses.

Figure 3: Interactions between parental (G0) fertility and SEP in predicting descendant entrance to university



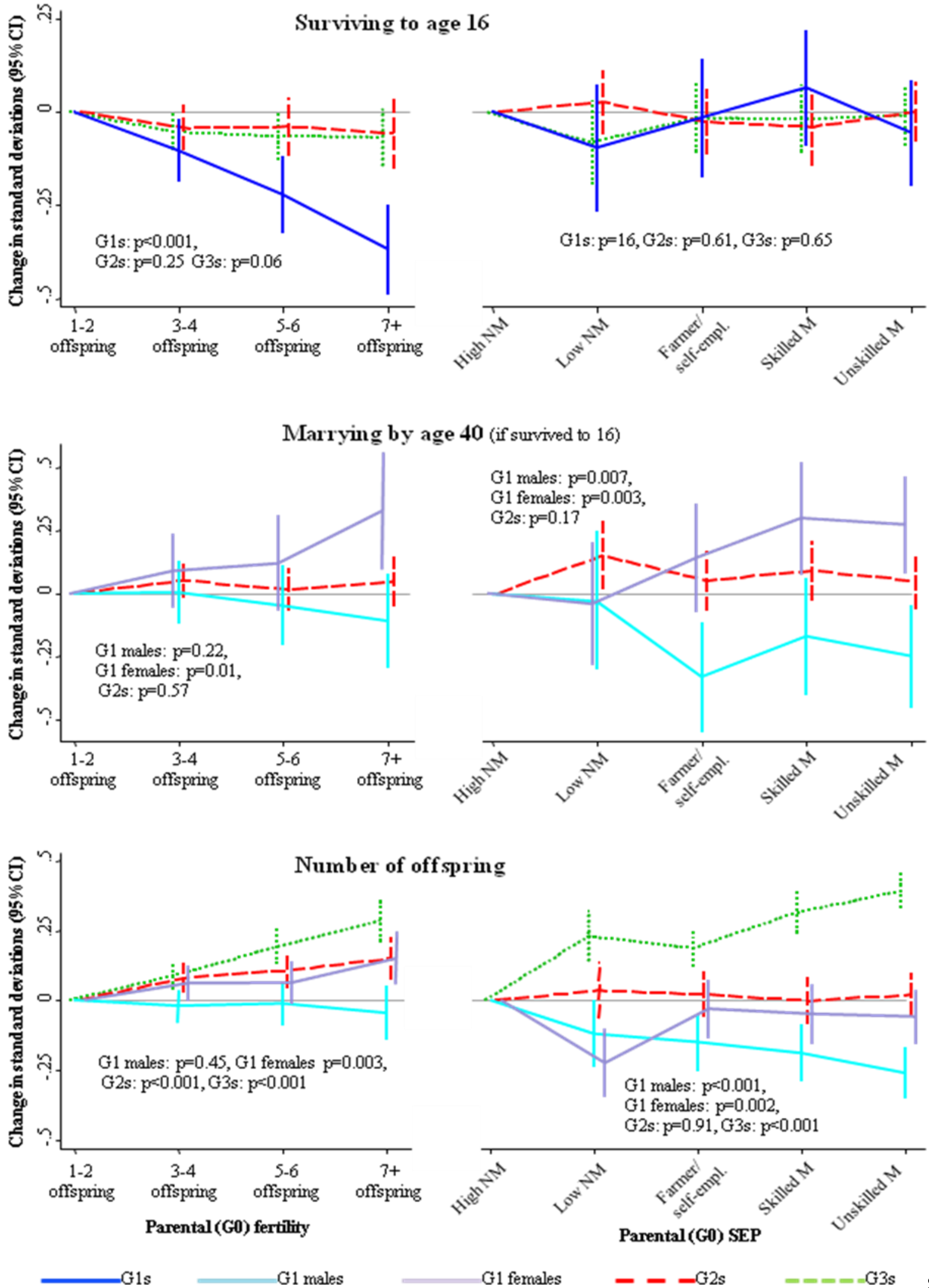
CI=confidence interval, SEP=socioeconomic position. 'High SEP' defined as high, mediate and low non-manual SEP; 'Low SEP' defined as skilled manual, unskilled manual, farmer or self-employed SEP. P-values for interactions are from regression models adjusting for G1 early-life characteristics; full results of all tests for interactions in ESM3.

These results therefore supported hypotheses 1 and 3: lower parental fertility and higher parental SEP increased offspring educational and socioeconomic quality, particularly when low fertility and high SEP coincided; and these advantages were in turn transmitted to subsequent generations. Nevertheless the size of these effects generally attenuated across generations as did the proportion of variation explained. For example, R^2 values indicated that an additional 11.2% of variation in G1 education was explained by parental SEP and 2.0% by parental fertility, as compared to 3.2% and 1.1% for G2 educational level and 1.6% and 0.3% for G3 educational level (ESM3).

Fertility, SEP and descendant reproductive success

Figure 4 demonstrates that, contrary to our second hypothesis, low parental fertility and high parental SEP either did not affect reproductive success beyond the G1 generation (survival to age 16, marriage by age 40, G2 fertility) or if anything showed a negative effect in subsequent generations (G3 fertility). For example, higher parental SEP predicted more offspring among G1s, particularly among G1 males (a sex interaction driven by high rates of childlessness among low SEP men: see ESM3) and also particularly among G1s from smaller families ($p<0.001$ for interaction: see ESM3). Higher parental SEP had no effect upon total number of offspring among G2s, however, and predicted fewer offspring among G3s.

Figure 4: Effect of parental (G0) fertility and SEP upon descendant reproductive success



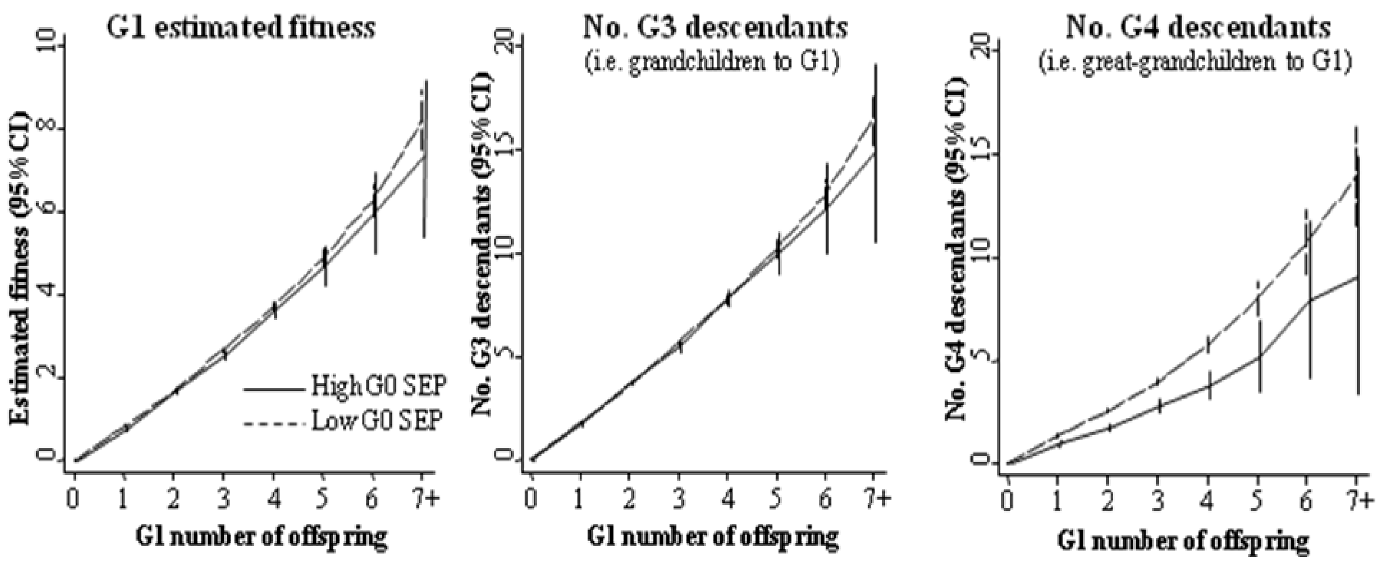
See notes to Figure 2.

These intergenerational effects on number of offspring persisted after excluding childless individuals (ESM3), and were once again mediated to a substantial degree by intervening SEP and hardly at all by intervening fertility (ESM3). Further exploratory analyses indicated that the crucial, socioeconomically-patterned factor was the longer generation time in the descendants of G0 parents of high SEP. Age at first childbearing was 27.2 vs. 25.8 years for G1s descended from G0s of high vs. low SEP; 27.6 vs. 26.0 years for G2s; and 27.4 vs. 26.8 years for G3s (all $p<0.001$). The result was that by 2009 the G3 descendants of high SEP lineages were on average younger and had also started child-bearing later. In path analyses, there was little or no evidence that any direct association remained between G0 SEP and G3 fertility once G1, G2 and G3 age at first childbearing were included as mediators (ESM3).

Optimal fertility levels for maximising long-term reproductive success

The shorter generation time of low SEP lineages meant that, at any given number of children, G1s from high SEP lineages had fewer G4 descendants (an incomplete generation) despite having a comparable number of G3 descendants (a complete generation). Figure 5 illustrates this, and also demonstrates that in neither SEP group did intermediate G1 fertility maximise number of G3 descendants, number of G4 descendants or the G1s total ‘estimated fitness’. Instead all associations were essentially linear across the full range of G1 fertility, with no suggestion of an inverted U-shaped relationship or even of any flattening of the line at the high end. This therefore provided evidence against our fourth hypothesis that intermediate fertility would maximise long-term reproductive success, and also indicated that the optimum number of offspring was far above the observed population mean (1.7 offspring for all G1s, 2.3 for those with at least one child).

Figure 5: Association between G1 fertility and subsequent reproductive success, stratified by parental (G0) SEP



Measuring long-term fitness

Finally, we turned to our methodological aim of examining the validity of total number of offspring as a measure of long-term fitness in modern societies. As illustrated in Figure 5, these variables were strongly correlated among G1 cohort members, with a Pearson's correlation coefficient (r) of 0.84 and an R^2 value of 0.71 (i.e. 71% of the variance explained). Number of grandchildren showed an even stronger correlation with total estimated fitness (r=0.97, R^2=0.94), but number of great-grandchildren showed a notably weaker correlation (r=0.73, R^2=0.53: results similar when stratified by sex, SEP or parental fertility, see ESM3). This weaker correlation results from the fact that the G4 generation is incomplete, and its size is therefore subject to additional 'noise' introduced by differences in the birth year of the G1s and in the age at which the G1s and their descendants reproduced.

The effects of this additional noise were also apparent when we examined which G1 early-life characteristics independently predicted our four alternative measures of G1 fitness (Table 1; sex-stratified results in ESM3; see also [25]). Once again, number of children performed well relative to our measure of total estimated fitness, generally showing similar effect sizes and significance levels. The only exception was an underestimation of the advantage of high parental fertility, an advantage that was comparatively smaller in the first generation because it was partly offset by higher mortality (see Figure 4; see also [25]). Number of grandchildren performed even better, showing identical substantive findings and near-identical effect sizes. By contrast, number of great-grandchildren showed several substantial differences including much stronger advantages associated with female sex and higher parental fertility; a novel positive association with unmarried mother status; and a reversal of the direction of the effect of SEP. These discrepancies were again driven by differences in generation length, which on average was shorter for female G1s (mean age first childbearing 24.6 years vs. 27.4 in G1 males), for G1s from larger families (25.6 years in families of size ≥5 vs. 26.2 years in families of size 1-4), for

G1s with unmarried mothers (25.3 years vs. 26.2 years in ever-married mothers) and for G1s, G2 and G3s alike from low SEP lineages (see above).

Table 1: Early-life predictors of four alternative measures of reproductive success among G1 cohort members, born 1915-1929 (N=13,672)

	Percent/ mean (SD) among G1s	**Regression coefficients from linear regression (95% confidence interval)**			
		Total estimated fitness (standardised)	**No. G2 descendants (standardised) – i.e. children to G1s**	**No. G3 descendants (standardised) – i.e. grandchildren to G1s**	**No. G4 descendants (standardised) – i.e. great-grandchildren to G1s**
		F(25, 13672)=9.76, R^2=0.017	F(25, 13672)=14.86, R^2=0.026	F(25, 13672)=9.40, R^2=0.017	F(25, 13672)=28.08, R^2=0.049
Female sex	47%	**0.08 (0.04, 0.11)**	**0.09 (0.05, 0.12)**	**0.09 (0.06, 0.13)**	**0.22 (0.18, 0.25)**
Birthweight, change per kg	3.4 (0.6)	**0.13 (0.10, 0.17)**	**0.16 (0.13, 0.20)**	**0.14 (0.10, 0.17)**	**0.08 (0.05, 0.12)**
Preterm birth (<37 weeks)	9%	**-0.07 (-0.14, 0.00)**	**-0.14 (-0.20, -0.07)**	**-0.07 (-0.14, 0.00)**	-0.05 (-0.11, 0.02)
Twin/triplet status	3%	0.01 (-0.09, 0.11)	-0.01 (-0.11, 0.09)	0.01 (-0.10, 0.11)	0.02 (-0.08, 0.12)
Mother's age, change per decade	28.4 (6.5)	**-0.09 (-0.12, -0.06)**	**-0.08 (-0.11, -0.04)**	**-0.09 (-0.12, -0.06)**	**-0.10 (-0.14, -0.07)**
Unmarried mother	20%	0.00 (-0.05, 0.05)	0.00 (-0.05, 0.05)	0.00 (-0.05, 0.04)	**0.06 (0.02, 0.11)**
Parental fertility 1-2 offspring	28%	0	0	0	0
Parental fertility 3-4 offspring	39%	**0.05 (0.01, 0.09)**	0.02 (-0.03, 0.06)	**0.05 (0.01, 0.09)**	**0.08 (0.04, 0.13)**
Parental fertility 5-6 offspring	19%	**0.07 (0.02, 0.12)**	0.02 (-0.03, 0.08)	**0.06 (0.01, 0.11)**	**0.14 (0.09, 0.20)**
Parental fertility 7+ offspring	14%	**0.12 (0.05, 0.18)**	0.05 (-0.02, 0.11)	**0.11 (0.04, 0.17)**	**0.24 (0.17, 0.30)**
High NM parental SEP	9%	0	0	0	0
Low NM parental SEP	7%	**-0.12 (-0.20, -0.03)**	**-0.16 (-0.25, -0.08)**	**-0.12 (-0.21, -0.03)**	**0.08 (0.00, 0.17)**
Farmer/self-empl. parental SEP	19%	-0.05 (-0.12, 0.02)	**-0.09 (-0.16, -0.02)**	-0.06 (-0.13, 0.01)	**0.12 (0.05, 0.19)**
Skilled M parental SEP	15%	**-0.09 (-0.16, -0.02)**	**-0.12 (-0.20, -0.05)**	**-0.10 (-0.17, -0.03)**	**0.17 (0.10, 0.24)**
Unskilled M parental SEP	50%	**-0.10 (-0.16, -0.04)**	**-0.16 (-0.22, -0.09)**	**-0.12 (-0.18, -0.05)**	**0.20 (0.14, 0.27)**

SD=standard deviation, CI=confidence interval, SEP=socioeconomic position, High NM=high/mediate non-manual, Low NM=low non-manual, Farmer/self-empl.=farmer or self-employed, Skilled M=skilled manual, Unskilled M=unskilled manual. Regression coefficients from linear regression, adjusting for all variables in column plus year of birth. Variables in bold are p≤0.05

Thus number of children and, even better, number of grandchildren were strongly correlated with long-term estimated fitness and yielded similar substantive findings with respect to the early-life predictors of long-term fitness. Moreover, these two completed generations performed better than a more recent but incomplete generation (great-grandchildren), which showed a weaker correlation and which generated biased effect sizes for several characteristics. These findings suggest that, at least with respect to modern societies, researchers seeking to estimate long-term fitness should use the youngest completed generation available. Furthermore if total number of offspring ('lifetime fertility') is the youngest generation available, then this will generally provide an adequate proxy for longer-term fitness.

Discussion

Our study contributes substantially to current understanding of the adaptive status of key phenotypic traits and the long-term dynamics of natural selection in modern human populations. Using high-quality multigenerational data from Sweden (1915-2009), we estimate for the first time the effects of fertility and SEP on multiple dimensions of descendant success and across four generations. Across two generations (i.e. from parents to offspring) we replicate previous findings in demonstrating that low family SEP predicts lower fertility, an effect which (in line with previous research [12, 36]) is particularly strong in males and is largely driven by higher rates of childlessness. Beyond two generations, however, we find no evidence for a predicted life history trade-off between the quantity and quality of descendants: relatively high fertility did not compromise the survival, mating success or reproductive success of grandchildren or great-grandchildren. This adds important support to previous studies reporting similar results in other post-demographic transition European and American populations, but with shorter follow-up (offspring generation only) and using smaller and less representative samples [23, 24]. Taken together, these findings suggest that fertility limitation in modern populations is unlikely to increase direct fitness even in the long term. This contradicts adaptive accounts of fertility limitation which have previously been supported through a series of theoretical models [26-29]. Our study therefore adds to the evidence that a satisfying evolutionary account of the demographic transition may require perspectives that explicitly model pathways to maladaptive decision-making, including adaptive lags in the face of environmental mismatch [11].

We do, however, find strong support for the prediction that fertility limitation in modern societies enhances descendant socioeconomic success. Thus, our results indicate that reproductive behaviours that promote biological success (i.e. long-term genetic fitness) are in conflict with those that promote descendant socioeconomic success in modern populations. Specifically, we find that both low parental fertility and high parental SEP independently predict higher schoolmarks, educational level and income, and this is generally true in male and female descendants alike (see [37] for a discussion of the one minor exception, concerning schoolmarks in the children of farmers). Moreover, these associations persist up to at least the great-grandchild generation, reflecting the advantage of starting one's own offspring on a favourable socioeconomic trajectory.

We also demonstrate for the first time a multigenerational interaction between SEP and fertility, such that the socioeconomic benefit of low fertility was especially large in groups that already had high SEP. This finding adds to a number of recent studies indicating that demographic modernization is associated with increased socioeconomic pay-offs to fertility limitation for the wealthiest families (reviewed in [2]). These differential consequences of low and high fertility across socioeconomic groups may stem from several related mechanisms. Kaplan suggests that direct wealth transfers and investments in skill-acquisition in modern economies dramatically increase a descendant's ability to generate new wealth and further invest in their own status, leading to magnified returns to strategies of low fertility and high parental investment [1]. Simultaneously, socioeconomic advantage may reduce the negative impact of extrinsic risks (e.g. environmental shocks) and so increase the relative importance of parental investment [7]. Finally, Downey distinguishes between 'base' and 'surplus' forms of specifically educational investment. In modern societies, he argues, base investments in schooling are covered by the welfare state and so available to low SEP families irrespective of family size [17]. High SEP families have, however, potentially also got access to expensive surplus investments (e.g. extra tuition or private schooling), which are consequently more subject to resource dilution effects as family size increases. Whichever mechanisms apply, our findings support both evolutionary [1, 2, 21] and non-evolutionary [14, 16] accounts of the demographic transition that view modern fertility limitation as motivated by the socioeconomic advantages it bestows on offspring.

We also make a broader methodological contribution to the study of natural selection in human populations. Our findings provide the best empirical evidence to date that total number of offspring is a valid proxy for long-term fitness in modern low-fertility societies, with the two measures being highly correlated and generally yielding similar substantive findings regarding the correlates of reproductive success. Most studies in this field have data on only one or two generations [31]. For studies with longer-term follow-up, we exemplify how generations increasingly overlap with time and show one method for combining information across all generations in a single measure of estimated fitness (the sum of each descendant's reproductive value multiplied their coefficient of relatedness to the index cohort member). If data are lacking for this single summary measure, we found that the size of completed generations provided a better proxy for long-term fitness than the size of a more recent but incomplete generation. This was because the latter was also affected by factors that predicted generation time, highlighting our somewhat counter-intuitive finding that, although earlier child-bearing has consistently been found to increase reproductive success at the individual level [31], earlier average child-bearing does not necessarily increase reproductive success at the lineage level. Getting a 'head start' by earlier childbearing is only expected to confer a selective advantage if 1) earlier child-bearing also predicts a greater total number of offspring and/or 2) if average fertility levels are above the replacement rate of 2.1 (i.e. if the population is expanding). By contrast if both early- and late-child-bearing lineages have similar total fertility (as was the case in our study for high SEP and low SEP lineages), and if the population as a whole has below-replacement fertility (which currently applies to more than half the world's population [8]) then shorter generation time may simply speed up a lineage's trajectory towards extinction. Yet despite not affecting reproductive success, earlier average childbearing may still increase the speed of selective responses in low versus high SEP lineages, and may therefore still be relevant for understanding the dynamics of current evolution in modern populations.

Our analyses highlight the value of using multigenerational datasets to examine evolutionary perspectives on human health and behaviour [31, 32]. They do, however, leave a number of questions unaddressed which warrant future investigation. First, we do not have access to information on the genetic basis of the traits we examine. These data are necessary to evaluate fully whether the fitness consequences of fertility and SEP are leading to new trajectories of genetic change over time [30]. Secondly, our focus here has been upon the long-term fitness implications of wealth and fertility for one particular generation (the G0s). Future analyses are required to model in more detail the underlying processes of social (im)mobility across generations, to explore how these interact with reproductive decisions such as age at first childbearing, and to examine how these effects may be changing over time. Similarly, because our hypotheses concern average effects of parental fertility and SEP upon descendant quality, we have not examined in detail potential differences in the dynamics of quality transmission across different types of descendants (e.g. males vs. females [22]). Finally, although broadly representative of early twentieth century Sweden, our birth cohort captures only one 'index' generation from a particular part of one Western country. Replication of these findings using multigenerational data in other settings is therefore required to draw firm conclusions about the generalisability of our results. Yet insofar as our findings across two generations are generally consistent with previous research in other high-income countries, there is some reason to believe that our novel multigenerational findings may also apply in other, similar populations. Indeed, one might expect the socioeconomic effects we observe to be stronger in settings which do not enjoy Sweden's unusually strong welfare state and unusually low levels of income inequality [33]. Thus from a broader social policy perspective, our findings highlight the continued need for policies which equalise opportunities across children in modern societies [33], including with respect to characteristics such as family size which typically receive far less attention than socioeconomic differences.

Conflict of interest

None

Acknowledgements

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Electronic Supplementary Material 1: Data sources and methods

1.1 Calculating exposure measures

Assignment of parental (G0) socioeconomic position from obstetric archives

We defined parental SEP using the Swedish socioeconomic classification scheme [SEI: 1] and for some purposes divided it into a binary variable of ‘high’ (non-manual) vs. ‘low’ (manual/farmer/self-employed). In the 1126 (8.2%) G1s whose parental SEP data at birth was missing or given as the socio-demographic category ‘house daughters’, we instead sought to use data from siblings (N=261), school records (N=379) or the 1930 census (N=163). When we had no information from these alternative data sources (N= 323) we used multiple imputation to impute early-life SEP in the same way as we imputed with other missing data on early-life characteristics.

Estimation of parental (G0) fertility from 1930 census data and obstetric archives

We estimated parental fertility by combining obstetric data on the mother’s maximum parity with census data on household composition. We defined the first measure as the highest recorded parity of each G0 mother recorded in obstetric records between 1915 and 1929 at the Uppsala Academic Hospital (i.e. the hospital from which our cohort was sampled). We obtained data on household composition by manually tracing as many cohort members (G1s) as possibly to 1930 census records from Uppsala. We successfully traced 8665 G1s, of whom 8208 were living with their biological mother and/or father. These census records listed individually all those living within the household and were also supposed to give the total count of children belonging to the household, including children who had died or left home (although this data was missing in 12% of records)

As shown in Supplementary Table 1.1, these three measures (one from the obstetric records, two from the census) were highly correlated, including a 0.89 correlation between ‘mother’s maximum parity’ (for which we had nearly complete data) and ‘all children belonging to the household’ (which was closest conceptually to what we were trying to measure).

Supplementary Table 1.1: Source, completeness and Pearson correlation coefficients for our three potential sources of data on

	Source	N available (%)	Mother’s maximum parity	Children living in household	All children belonging to household
Mother’s maximum parity	Obstetric records	13670 (>99.9%)	1		
Children living in household†	1930 census	8665 (63.4%)	0.78	1	
All children belonging to household† (including dead/living elsewhere)	1930 census	7206 (52.7%)	0.89	0.84	1

†We included the G1’s stepsiblings and half siblings in these two measures of 1930 sibling size: our substantive findings were unchanged when we restricted the analysis to full siblings.

We therefore estimated total parental (G0) fertility (as of 1930) as being equal to ‘All children belonging to household’ where available (N=7189), and as equal to ‘mother’s maximum parity’ where this was not available (N=6466). Our substantive findings were unchanged under a range of sensitivity analyses, including when we restricted our analyses to G1 individuals with parental fertility data from the 1930 census data or who were born 1915-1920, and for whom we were therefore most confident that we knew their true parental fertility (sensitivity analyses available on request).

1.2 Calculating proximate measures of quality

Mean schoolmarks for G1 cohort members

As previously described [2], we manually traced the spring term school records from each cohort member's third grade of elementary school, typically completed in the year they turn 10. Our first school performance measure was the child's mean school marks across up to ten standard subjects. Subjects were marked using the grades C (lowest), Bc, B, Ba, AB, a and A (highest), with additional qualification with pluses and minuses. We coded these from 0 (Grade C) to 18 (Grade A) in accordance with the scoring system suggested by the education department in 1942. As some children were missing information on some subjects (mean of 0.9 subjects missing per child, range 0–4), we calculated an overall third grade average after standardising marks in each subject individually.

Mean schoolmarks 1988-2008 for G3 cohort members

The Swedish National Board for Education provided information on grades achieved in year 9, the final year of Swedish compulsory school which students typically complete in the year they turn 16. From 1988 to 1997 the grades given ranged from 1 to 5 and reflected a relative grading system, such that teachers were instructed to assign marks relative to others in the class and with a view to achieving a roughly normal distribution. From 1998 onwards the scale of marks changed to a criterion-referenced system such that students were judged against fixed standards and not against their peers. The grades awarded also changed to: Fail (assigned 0 merit points by schools when calculating overall merit values), Pass (10 merit points), Pass with distinction (15 merit points) and Pass with special distinction (20 merit points). To take account of this change in grading system we standardised all means by year. We did this for all students receiving grades in any subject (mean 16.2 grades recorded, range 1-20); our findings were unchanged in sensitivity analyses restricted to the 99.7% of students receiving grades in at least 11 subjects.

Educational attainment

Our outcome was ever entering university or equivalent, if aged 21 or over. We obtained this from the 1960, 1970 and 1990 Swedish censuses plus the Longitudinal Database for Education, Income and Occupation (1985-2008).

Family income

We standardized family disposable income by age and sex, and then averaged this across all available years in which the descendant was aged 21-65. We obtained this from the Longitudinal Database for Education, Income and Occupation (yearly data 1990-2008) plus the 1970 and 1990 censuses.

Survival to age 16

We obtained year of death from the Death Register (1952-2009), supplemented by manual tracing of UBCoS G1 cohort members pre-1952.

Mating success

We recorded which descendants were married before age 40, among those who survived to age 16. We obtained this from the 1960, 1970, 1980 and 1990 censuses.

Descendant fertility

We obtained the total number of registered offspring for each descendants from 1932-2009, from the Swedish Multigenerational Register. Note that to be included in the Multigenerational registry, these descendants had to be born in 1932 or later (i.e. when the UBCoS cohort was aged 3-17 years) and to survive to at least 1961 [3].

Generations used

We did not calculate these values for the G4s because most members of this generation were still too young to be assigned most outcomes (82% under 16 years in 2009, 95% under 21). In addition we did not include schoolmarks as a G2 outcome or marriage as a G3 outcome because the relevant information was not available for the generations in question.

1.3 Calculating estimated fitness

Calculation of reproductive value

From Statistics Sweden [4] we obtained information on

1. **The risk of death** for the total Swedish population in 2009, by age and sex (obtained from death registry).
2. **The total population** in Sweden on 31 December 2008, by year of birth, sex and number of registered offspring (created bespoke using Multigenerational Registry).
3. **The total number of births** in Sweden in 2009, by the parents' year of birth, sex and parity (obtained from the Swedish Tax Agency).

From this we calculated the predicted number of future offspring [but not subsequent generations of descendants] born to an individual of any given age, sex and parity assuming the continuation of the 2009 mortality and fertility rates (i.e. using the same methodology as is used to calculate life expectancy and total fertility rates). This involved the following steps, schematically illustrated in Figure 1.1 using the example a woman who on 31 December 2009 was aged 39 and had a parity of zero. All modelling was done using MSOffice Excel 1997-2003.

a) Probability of survival "p(S)". We calculated the probability of surviving for another year, by age and sex. For example, in 2009 women aged 39 had a 0.0007 risk of death, or equivalently a 0.9993 probability of surviving to the next year.

b) Probability of birth "p(Off)". We calculated the probability of having one birth during any given year, by age, sex and parity. For this we assumed that births with unknown parent characteristics (0.05% for women, 6.8% for men) were missing at random with respect to age and parity. We then simplified the modelling process by assuming that all births were singletons and that each individual could have only one birth per year (note that this generates results which are unbiased at the population level, because the underestimation of individuals having multiple births is balanced by an underestimation of the number of individuals having zero births). This allowed us to estimate the probability having an offspring in the next year as being equal to the total number of births divided by the total population. For example, in Sweden on 31 December 2008 there were a total of 8701 women with a parity of zero and born in 1970 (i.e. of age 39 on 31 December 2009). During 2009, 624 births were registered to women born in 1970 with a previous parity of zero, which became 624.3 after multiplying by (1/(1-0.0005) to correct for the 0.05% of births to unknown mothers. The probability of having one offspring in the next year ("p(Off)") for women age 39 was therefore 624.3/8701 = 0.072, while the probability of having no offspring was 1- 624.3/8701 = 0.928.

c) Transition probabilities. We then created a grid where parity could be between 0 and 7 and where age could be from 0 to 75 years, with separate grids by sex (extract in Figure 1.1). To each grid we assigned the corresponding probabilities of survival and giving birth (i.e. p(S) and p(Off)). From these we calculated the transition probabilities between cells, illustrated in red in Figure 1.1. The diagonal arrows represent the probability of surviving a year and having one birth, i.e. [p(S) * p(Off)].The vertical arrows represent the probability of surviving a year and having no births, i.e. [p(S) * (1-p(Off)].

d) Probabilities of observation "p(Obs)". For each individual, we entered a probability of '1' into their observed combination of age, sex and parity in 2009 and a probability of '0' into other parities at the same age ("p(Obs)": Figure 1.1, values in green boxes). By applying the red transition probabilities to these starting values, we filled in the remainder of the grid with the probability that the individual would be in that cell in future years. Note that the sum of these probabilities at each year is slightly less than 1 as some individuals die each year, and so are not observed in any parity cell at older ages.

e) Expected number of offspring "Exp(Off)". Next at each age we calculated the expected number of offspring that year ("Exp(Off"), calculated as the probability an individual would be observed in each cell multiplied by the probability that they would have an offspring that year – i.e. p(Obs)*p(Off) summed across all cells in a row. This is shown in blue in the right-hand column in Figure 1.1.

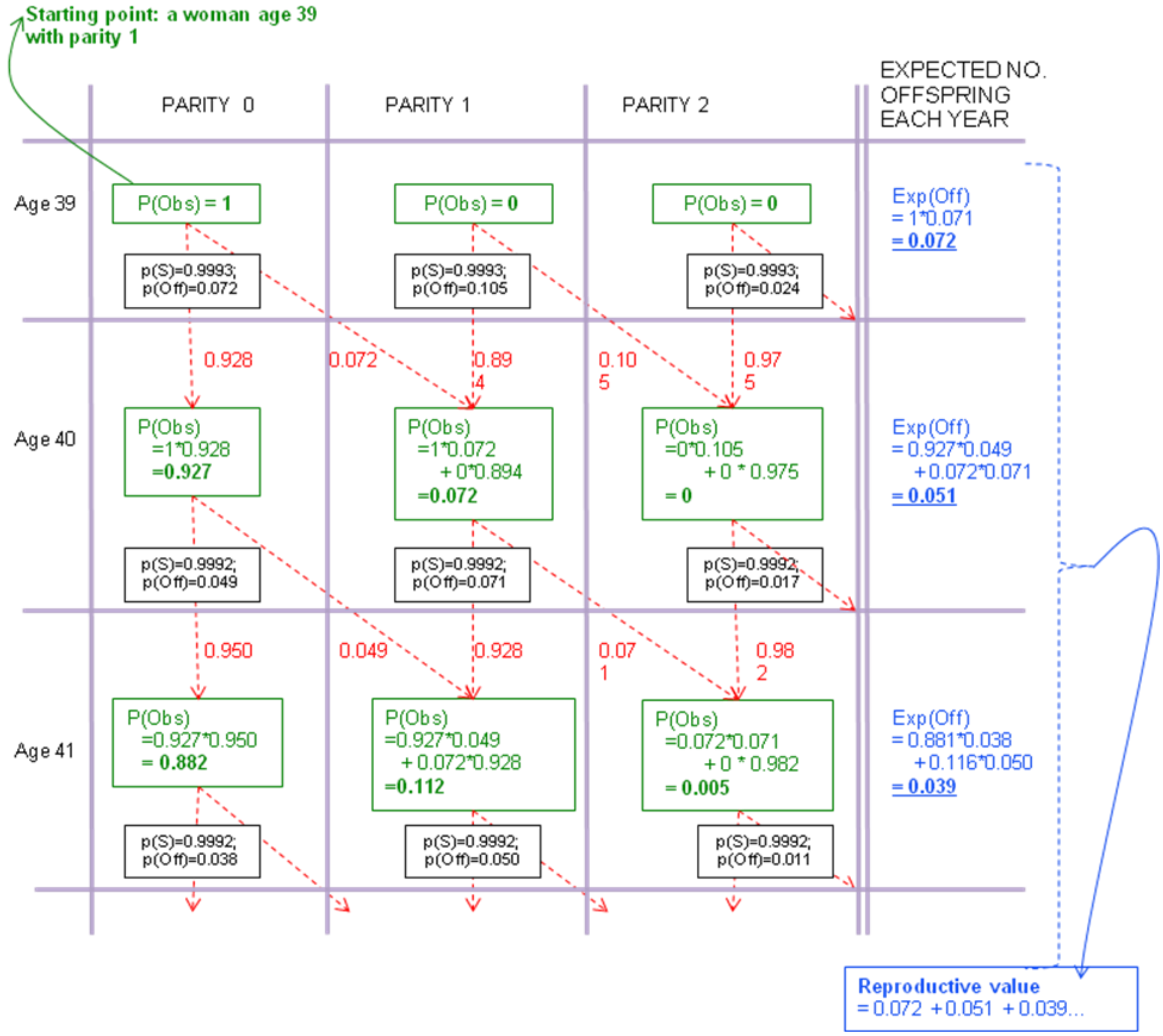
f) Reproductive value. Finally, we summed these yearly expected numbers of offspring across the whole life course, to give the reproductive value for each individual - that is their total expected number of future births.

Calculation of estimated fitness

We then calculated the total estimated fitness of each cohort member by multiplying the reproductive value of each descendant by their coefficient of genetic relatedness to the cohort member - i.e. 0.5 for children, 0.25 for grandchildren, 0.125 for great-grandchildren, 0.0625 for great-great-grandchildren. This product was then summed across all descendants to give the total estimated fitness of that cohort member:

$$\text{Estimated fitness} = \sum_{\text{All descendants}} [\text{reproductive value}_{(\text{age,sex,parity})} * \text{coefficient of relatedness}]$$

Supplementary Figure 1.1: schematic representation of method of calculating reproductive value



p(S)=probability of surviving to the next year, p(Off)=probability of giving birth to one offspring that year. Numbers in red are transition probabilities for surviving to the next year and having one offspring (diagonal: p(S)*p(Off)) or surviving and having no offspring (vertical: p(S)*(1-p(Off))). Numbers in black boxes (p(Obs)) are the probability of observation in each cell. Numbers in blue are the expected number of births that year (Exp(Off)), with the reproductive value calculated as the sum of these across all future years to age 75.

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Electronic Supplementary Material 2: Correlation coefficient matrix

Note:The table below is a subset of the correlation coefficient matrix included in the published version of this paper. The published version is a 31 x 31 variable matrix (which is too large to reproduce here), showing correlations between all early life characteristics, G1 outcomes, G2 outcomes, G3 outcomes and measures of reproductive success

	G0 socioeconomic position†	G0 fertility, no. offspring	G1 female (vs. male) sex	G1 birthweight, kg	G1 preterm (vs. term) birth	G1 twin (vs. singleton) status	G0 mother's age, years	G0 mother single (vs. ever married) at child's birth	G1 birth year
G0 socioeconomic position†	1								
G0 fertility, no. offspring	**-0.06**	1							
G1 female (vs. male) sex	0.01	0.00	1						
G1 birthweight, kg	**-0.06**	**0.14**	**-0.11**	1					
G1 preterm (vs. term) birth	**0.03**	-0.02	-0.01	**-0.43**	1				
G1 twin (vs. singleton) status	**-0.02**	**0.02**	0.01	**-0.28**	**0.19**	1			
G0 mother's age, years	**-0.24**	**0.49**	0.00	**0.12**	**-0.03**	**0.03**	1		
G0 mother single (vs. ever married) at child's birth	**0.32**	**-0.27**	0.01	**-0.11**	**0.06**	**-0.03**	**-0.41**	1	
G1 birth year	-0.02	**-0.09**	0.00	-0.01	0.01	0.01	-0.01	-0.01	1

†All correlations via Pearson's coefficients except those involving socioeconomic position, which use Spearman's
‡'Total number of G2 children to G1s' not presented as this is identical to 'G1 number of offspring' (row 16)
bold cells indicate p<0.01; Yellow fill indicates absolute correlation 0.2 - 0.4; Orange fill indicates absolute correlation 0.4 - 06

Electronic Supplementary Material 3: Additional analyses

- **PART 1:** Tabulation of data underlying Figures 2 and 4, plus additional descriptive / unadjusted / sex-stratified analysis
- **PART 2:** Structural equation models examining a) multigenerational mediation by intervening fertility and SEP and b) mediation by age at first birth
- **PART 3:** Comparison of the performance of alternative measures of reproductive success

PART 1: 3.1 Proportion of variance explained by different outcomes

Supplementary Table 3.1: Proportion of variation explained (adjusted R^2) in measures of descendant proximate quality

Outcome	Generation	Total variance explained by early-life characteristics	Variance explained by parental (G0) SEP†	Variance explained by parental (G0) fertility†
Schoolmarks	G1 males	3.7%	1.5%	0.7%
	G1 females	3.9%	2.4%	0.8%
	G3s	4.0%	1.9%	0.3%
Entering university	G1s‡	18.0%	11.2%	2.0%
	G2s	6.1%	3.2%	1.1%
	G3s	3.9%	1.6%	0.3%
Family income	G1s	6.5%	4.9%	0.3%
	G2s	2.2%	1.1%	0.2%
	G3s	0.8%	0.3%	<0.1%
Survival to age 16	G1s‡	8.5%	0.1%	0.5%
	G2s	0.6%	<0.1%	<0.1%
	G3s	0.3%	<0.1%	<0.1%
Marriage by age 40	G1 males‡	1.9%	0.4%	<0.1%
	G1 females‡	2.2%	0.6%	0.3%
	G2s	0.6%	0.1%	<0.1%
Number of offspring	G1 males	3.2%	0.6%	<0.1%
	G1 females	2.7%	0.2%	0.1%
	G2s	0.5%	<0.1%	0.1%
	G3s	14.3%	1.4%	0.6%

† Calculated as the difference between the adjusted R^2 value of a model including all early-life characteristics (i.e. captured in the left-hand column) and one which has all early-life characteristics except a) parental SEP or b) parental fertility.
‡For these binary outcomes, we present pseudo-R2 values calculated from logistic regression models.

3.2 Data underlying Figure 2 in main manuscript

A note on multicollinearity: As indicated in ESM 2, the correlation coefficients between early life characteristics were always ≤0.49, and were usually <0.3 (for 32/26 correlations). This suggested that multicollinearity was unlikely to be a major issue for these analyses. To check this we calculated variance inflation factors for the models presented in Figure 2 of the main manuscript and below. These always indicated low to moderate multicollinearity, with a maximum variance inflation factor of 4.48 for any early life characteristic in any model, and with a mean variance inflation factor of 2.05 across all variables across all models. These values were thus all below the cut-offs of 5 or 10 commonly used to identify high levels of multicollinearity.

Supplementary Table 3.1 Predictors of school marks (standardised)

	Exposure	**Level**	**Full G1 sample and their descendants**			**G1 males and their descendants**		**G1 females and their descendants**		**p-value for sex inter-action**	**p-value for fertility -SEP interaction**
			Mean	**Unadjusted effect sizes (95% CI)**	**Adjusted effect sizes (95% CI)**	**Mean**	**Adjusted effect sizes (95% CI)**	**Mean**	**Adjusted effect sizes (95% CI)**		
G1s (N= 10278)	Parental (G0) fertility	1-2 offspring	0.08	0	0	-0.04	0	0.21	0	0.65	<0.001 (males 0.02/ females 0.003)
		3-4 offspring	-0.01	-0.15 (-0.20, -0.10)	-0.19 (-0.24, -0.14)	-0.12	-0.17 (-0.24, -0.10)	0.11	-0.20 (-0.28, -0.13)		
		5-6 offspring	-0.05	-0.20 (-0.27, -0.13)	-0.26 (-0.33, -0.19)	-0.15	-0.23 (-0.32, -0.14)	0.06	-0.30 (-0.40, -0.20)		
		7+ offspring	-0.08	-0.24 (-0.32, -0.17)	-0.33 (-0.42, -0.25)	-0.19	-0.32 (-0.43, -0.20)	0.05	-0.35 (-0.46, -0.24)		
	Parental (G0) SEP	High NM	0.23	0	0	0.15	0	0.32	0	<0.001	
		Low NM	0.01	-0.18 (-0.27, -0.10)	-0.29 (-0.40, -0.19)	-0.05	-0.26 (-0.40, -0.11)	0.08	-0.33 (-0.47, -0.18)		
		Farmer/self-empl	0.09	-0.09 (-0.16, -0.01)	-0.16 (-0.26, -0.07)	-0.08	-0.30 (-0.41, -0.18)	0.28	-0.01 (-0.14, 0.12)		
		Skilled M	-0.03	-0.13 (-0.20, -0.05)	-0.37 (-0.46, -0.28)	-0.13	-0.38 (-0.50, -0.26)	0.07	-0.35 (-0.48, -0.22)		
		Unskilled M	-0.07	-0.16 (-0.22, -0.09)	-0.41 (-0.49, -0.32)	-0.18	-0.44 (-0.55, -0.33)	0.05	-0.37 (-0.49, -0.25)		
G3s (N= 7824)	Parental (G0) fertility	1-2 offspring	0.02	0	0	-0.02	0	0.06	0	0.82	0.16
		3-4 offspring	0.00	-0.02 (-0.08, 0.03)	-0.08 (-0.14, -0.03)	-0.03	-0.06 (-0.14, 0.02)	0.04	-0.11 (-0.19, -0.03)		
		5-6 offspring	0.03	0.01 (-0.06, 0.08)	-0.08 (-0.15, 0.00)	-0.01	-0.04 (-0.14, 0.06)	0.06	-0.12 (-0.22, -0.02)		
		7+ offspring	-0.06	-0.10 (-0.17, -0.03)	-0.21 (-0.29, -0.12)	-0.11	-0.19 (-0.32, -0.07)	0.00	-0.22 (-0.34, -0.10)		
	Parental (G0) SEP	High NM	0.33	0	0	0.29	0	0.39	0	0.09	
		Low NM	0.10	-0.30 (-0.40, -0.19)	-0.29 (-0.39, -0.18)	0.03	-0.32 (-0.47, -0.17)	0.19	-0.25 (-0.40, -0.10)		
		Farmer/self-empl	0.07	-0.33 (-0.42, -0.25)	-0.30 (-0.39, -0.22)	0.01	-0.32 (-0.43, -0.20)	0.13	-0.30 (-0.43, -0.18)		
		Skilled M	-0.04	-0.47 (-0.56, -0.38)	-0.45 (-0.54, -0.36)	-0.13	-0.50 (-0.63, -0.37)	0.05	-0.40 (-0.53, -0.27)		
		Unskilled M	-0.08	-0.52 (-0.60, -0.45)	-0.48 (-0.56, -0.40)	-0.10	-0.45 (-0.56, -0.34)	-0.06	-0.50 (-0.62, -0.39)		

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). Note schoolmarks data not available for G2s.

Supplementary Table 3.2: Predictors of entering university

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			%	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)		
G1s (N= 10461)	Parental (G0) fertility	1-2 offspring	14.8	0	0	17.8	0	12.0	0	0.39	<0.001
		3-4 offspring	12.9	-0.09 (-0.17, -0.01)	-0.20 (-0.29, -0.11)	16.0	-0.17 (-0.28, -0.05)	9.7	-0.26 (-0.40, -0.12)		
		5-6 offspring	9.9	-0.26 (-0.37, -0.15)	-0.36 (-0.48, -0.23)	12.1	-0.33 (-0.48, -0.17)	7.7	-0.40 (-0.58, -0.21)		
		7+ offspring	4.0	-0.79 (-0.96, -0.62)	-0.96 (-1.15, -0.77)	5.3	-0.89 (-1.13, -0.65)	2.6	-1.07 (-1.38, -0.76)		
	Parental (G0) SEP	High NM	49.3	0	0	55.1	0	43.3	0	0.08	
		Low NM	18.0	-0.82 (-0.95, -0.69)	-0.78 (-0.91, -0.65)	24.4	-0.68 (-0.85, -0.50)	11.6	-0.93 (-1.14, -0.71)		
		Farmer/self-empl	8.7	-1.28 (-1.40, -1.17)	-1.24 (-1.36, -1.11)	9.4	-1.29 (-1.45, -1.13)	7.8	-1.14 (-1.32, -0.96)		
		Skilled M	8.7	-1.28 (-1.41, -1.15)	-1.22 (-1.35, -1.09)	10.9	-1.19 (-1.36, -1.02)	6.7	-1.26 (-1.45, -1.06)		
		Unskilled M	5.9	-1.51 (-1.62, -1.41)	-1.41 (-1.52, -1.30)	8.1	-1.34 (-1.48, -1.19)	3.8	-1.53 (-1.69, -1.37)		
G2s (N= 9646)	Parental (G0) fertility	1-2 offspring	37.0	0	0	36.4	0	37.5	0	0.64	0.004
		3-4 offspring	36.9	0.00 (-0.05, 0.05)	-0.08 (-0.13, -0.02)	36.9	-0.05 (-0.12, 0.02)	36.9	-0.11 (-0.18, -0.03)		
		5-6 offspring	33.7	-0.08 (-0.14, -0.02)	-0.18 (-0.25, -0.12)	33.3	-0.15 (-0.24, -0.06)	34.0	-0.21 (-0.30, -0.12)		
		7+ offspring	27.9	-0.23 (-0.29, -0.16)	-0.37 (-0.44, -0.29)	26.5	-0.38 (-0.49, -0.27)	29.3	-0.35 (-0.46, -0.25)		
	Parental (G0) SEP	High NM	59.0	0	0	58.7	0	59.4	0	0.14	
		Low NM	44.3	-0.36 (-0.47, -0.26)	-0.33 (-0.44, -0.23)	41.9	-0.38 (-0.52, -0.24)	47.3	-0.27 (-0.42, -0.11)		
		Farmer/self-empl	34.0	-0.62 (-0.71, -0.53)	-0.56 (-0.65, -0.48)	33.5	-0.56 (-0.68, -0.44)	34.5	-0.56 (-0.69, -0.44)		
		Skilled M	35.0	-0.59 (-0.68, -0.50)	-0.55 (-0.64, -0.46)	32.1	-0.60 (-0.72, -0.47)	37.7	-0.49 (-0.62, -0.37)		
		Unskilled M	29.7	-0.72 (-0.80, -0.65)	-0.63 (-0.71, -0.56)	29.8	-0.63 (-0.74, -0.51)	29.6	-0.64 (-0.75, -0.53)		
G3s (N= 7964)	Parental (G0) fertility	1-2 offspring	41.4	0	0	39.7	0	43.0	0	0.82	0.03
		3-4 offspring	40.7	-0.02 (-0.07, 0.04)	-0.07 (-0.12, -0.01)	39.5	-0.04 (-0.12, 0.04)	42.0	-0.09 (-0.18, -0.01)		
		5-6 offspring	40.8	-0.02 (-0.08, 0.05)	-0.09 (-0.16, -0.02)	39.5	-0.06 (-0.16, 0.04)	41.9	-0.12 (-0.22, -0.02)		
		7+ offspring	37.8	-0.10 (-0.17, -0.03)	-0.20 (-0.29, -0.12)	35.8	-0.19 (-0.31, -0.07)	39.8	-0.21 (-0.32, -0.09)		
	Parental (G0) SEP	High NM	54.8	0	0	54.3	0	55.3	0	0.15	
		Low NM	47.1	-0.21 (-0.33, -0.09)	-0.21 (-0.32, -0.09)	43.9	-0.28 (-0.44, -0.12)	50.9	-0.12 (-0.30, 0.05)		
		Farmer/self-empl	41.3	-0.37 (-0.47, -0.28)	-0.34 (-0.44, -0.24)	38.5	-0.39 (-0.53, -0.26)	44.2	-0.28 (-0.42, -0.14)		
		Skilled M	40.2	-0.41 (-0.51, -0.30)	-0.38 (-0.48, -0.28)	37.2	-0.45 (-0.59, -0.30)	42.9	-0.32 (-0.47, -0.18)		
		Unskilled M	37.1	-0.49 (-0.58, -0.40)	-0.46 (-0.55, -0.36)	36.3	-0.46 (-0.59, -0.34)	37.7	-0.45 (-0.57, -0.32)		

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

Supplementary Table 3.3: Predictors of family income

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			Mean	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	Mean	Adjusted effect sizes (95% CI)	Mean	Adjusted effect sizes (95% CI)		
G1s (N= 10451)	Parental (G0) fertility	1-2 offspring	0.04	0	0	0.02	0	0.06	0	0.77	0.03
		3-4 offspring	0.03	-0.01 (-0.06, 0.04)	-0.05 (-0.10, 0.00)	0.04	-0.02 (-0.08, 0.05)	0.02	-0.09 (-0.16, -0.01)		
		5-6 offspring	-0.02	-0.06 (-0.12, 0.00)	-0.08 (-0.15, -0.02)	-0.02	-0.07 (-0.15, 0.02)	-0.01	-0.10 (-0.19, -0.01)		
		7+ offspring	-0.15	-0.20 (-0.26, -0.15)	-0.21 (-0.28, -0.14)	-0.17	-0.22 (-0.31, -0.13)	-0.12	-0.20 (-0.30, -0.10)		
	Parental (G0) SEP	High NM	0.66	0	0	0.67	0	0.65	0	0.52	
		Low NM	0.19	-0.50 (-0.62, -0.37)	-0.49 (-0.61, -0.36)	0.17	-0.51 (-0.68, -0.35)	0.21	-0.46 (-0.64, -0.27)		
		Farmer/self-empl	-0.10	-0.81 (-0.92, -0.71)	-0.78 (-0.89, -0.67)	-0.13	-0.82 (-0.96, -0.67)	-0.06	-0.73 (-0.89, -0.57)		
		Skilled M	-0.03	-0.74 (-0.84, -0.63)	-0.71 (-0.82, -0.60)	-0.03	-0.71 (-0.85, -0.56)	-0.03	-0.71 (-0.87, -0.55)		
		Unskilled M	-0.10	-0.81 (-0.91, -0.71)	-0.77 (-0.87, -0.67)	-0.10	-0.76 (-0.90, -0.62)	-0.10	-0.77 (-0.92, -0.63)		
G2s (N= 9643)	Parental (G0) fertility	1-2 offspring	-0.01	0	0	-0.01	0	0.00	0	0.81	0.33
		3-4 offspring	0.02	0.05 (0.00, 0.10)	0.01 (-0.04, 0.07)	0.02	0.03 (-0.05, 0.10)	0.03	-0.01 (-0.08, 0.07)		
		5-6 offspring	0.00	0.01 (-0.06, 0.07)	-0.04 (-0.10, 0.03)	0.00	0.00 (-0.09, 0.10)	-0.01	-0.07 (-0.16, 0.02)		
		7+ offspring	-0.05	-0.09 (-0.15, -0.03)	-0.12 (-0.20, -0.05)	-0.06	-0.12 (-0.22, -0.02)	-0.04	-0.13 (-0.23, -0.03)		
	Parental (G0) SEP	High NM	0.15	0	0	0.14	0	0.15	0	0.63	
		Low NM	0.08	-0.14 (-0.26, -0.02)	-0.13 (-0.25, -0.01)	0.05	-0.17 (-0.33, 0.00)	0.11	-0.08 (-0.25, 0.09)		
		Farmer/self-empl	0.03	-0.23 (-0.33, -0.13)	-0.20 (-0.30, -0.10)	0.03	-0.19 (-0.34, -0.04)	0.03	-0.21 (-0.35, -0.06)		
		Skilled M	-0.02	-0.34 (-0.44, -0.23)	-0.32 (-0.43, -0.22)	-0.05	-0.35 (-0.50, -0.20)	0.00	-0.29 (-0.43, -0.14)		
		Unskilled M	-0.04	-0.38 (-0.47, -0.28)	-0.34 (-0.44, -0.25)	-0.05	-0.35 (-0.49, -0.21)	-0.04	-0.33 (-0.47, -0.20)		
G3s (N= 7975)	Parental (G0) fertility	1-2 offspring	-0.01	0	0	0.00	0	-0.01	0	0.81	0.95
		3-4 offspring	0.01	0.04 (-0.02, 0.10)	0.01 (-0.05, 0.07)	0.00	-0.01 (-0.11, 0.08)	0.02	0.04 (-0.04, 0.11)		
		5-6 offspring	0.01	0.03 (-0.03, 0.10)	0.00 (-0.07, 0.07)	0.01	-0.02 (-0.13, 0.09)	0.01	0.01 (-0.07, 0.10)		
		7+ offspring	-0.01	-0.01 (-0.08, 0.06)	-0.04 (-0.12, 0.04)	-0.02	-0.09 (-0.21, 0.02)	0.00	0.00 (-0.10, 0.11)		
	Parental (G0) SEP	High NM	0.05	0	0	0.04	0	0.06	0	0.30	
		Low NM	-0.02	-0.15 (-0.26, -0.04)	-0.15 (-0.26, -0.04)	-0.05	-0.21 (-0.36, -0.05)	0.02	-0.08 (-0.24, 0.09)		
		Farmer/self-empl	0.04	-0.03 (-0.13, 0.07)	-0.02 (-0.12, 0.09)	0.03	0.00 (-0.15, 0.15)	0.04	-0.02 (-0.17, 0.12)		
		Skilled M	0.00	-0.10 (-0.21, 0.00)	-0.10 (-0.20, 0.01)	0.01	-0.06 (-0.22, 0.11)	0.00	-0.13 (-0.27, 0.01)		
		Unskilled M	-0.02	-0.15 (-0.24, -0.06)	-0.14 (-0.23, -0.05)	-0.02	-0.11 (-0.25, 0.02)	-0.01	-0.15 (-0.28, -0.03)		

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

3.3 Data underlying Figure 4 in main manuscript

Supplementary Table 3.4: Predictors of survival to age 16

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			%	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)		
G1s (N= 13672)	Parental (G0) fertility	1-2 offspring	90.4	0	0	89.5	0	91.3	0	0.16	0.17
		3-4 offspring	90.6	0.01 (-0.07, 0.09)	-0.10 (-0.19, -0.02)	89.5	-0.13 (-0.24, -0.01)	91.8	-0.07 (-0.20, 0.05)		
		5-6 offspring	89.2	-0.07 (-0.17, 0.02)	-0.22 (-0.33, -0.12)	88.8	-0.17 (-0.31, -0.03)	89.5	-0.29 (-0.44, -0.14)		
		7+ offspring	87.1	-0.18 (-0.28, -0.09)	-0.37 (-0.49, -0.25)	86.6	-0.32 (-0.49, -0.16)	87.6	-0.43 (-0.60, -0.26)		
	Parental (G0) SEP	High NM	91.6	0	0	91.2	0	92.2	0	0.42	
		Low NM	88.9	-0.18 (-0.35, 0.00)	-0.10 (-0.27, 0.07)	88.5	-0.11 (-0.34, 0.11)	89.2	-0.09 (-0.36, 0.18)		
		Farmer/self-empl	90.5	-0.08 (-0.23, 0.08)	-0.02 (-0.18, 0.14)	90.2	-0.03 (-0.23, 0.18)	90.8	-0.02 (-0.25, 0.21)		
		Skilled M	91.4	-0.02 (-0.17, 0.13)	0.06 (-0.09, 0.22)	91.3	0.10 (-0.11, 0.31)	91.5	0.02 (-0.20, 0.24)		
		Unskilled M	88.9	-0.17 (-0.31, -0.04)	-0.06 (-0.20, 0.08)	87.6	-0.10 (-0.29, 0.08)	90.4	0.00 (-0.20, 0.21)		
G2s (N= 6425)	Parental (G0) fertility	1-2 offspring	99.4	0	0	99.6	0	99.1	0	0.58	0.48
		3-4 offspring	99.2	-0.03 (-0.09, 0.03)	-0.04 (-0.10, 0.02)	99.4	-0.03 (-0.09, 0.03)	98.9	-0.07 (-0.18, 0.05)		
		5-6 offspring	99.3	-0.02 (-0.09, 0.05)	-0.04 (-0.12, 0.04)	99.7	0.02 (-0.04, 0.08)	98.8	-0.12 (-0.29, 0.05)		
		7+ offspring	99.4	-0.01 (-0.08, 0.07)	-0.06 (-0.16, 0.04)	99.4	-0.03 (-0.14, 0.09)	99.3	-0.09 (-0.26, 0.08)		
	Parental (G0) SEP	High NM	99.4	0	0	99.9	0	98.7	0	0.32	
		Low NM	99.6	0.03 (-0.06, 0.12)	0.03 (-0.06, 0.11)	99.8	-0.01 (-0.06, 0.04)	99.3	0.08 (-0.12, 0.28)		
		Farmer/self-empl	99.2	-0.02 (-0.11, 0.07)	-0.03 (-0.11, 0.06)	99.2	-0.10 (-0.19, -0.02)	99.3	0.08 (-0.10, 0.25)		
		Skilled M	99.0	-0.05 (-0.15, 0.05)	-0.04 (-0.14, 0.06)	99.5	-0.06 (-0.14, 0.03)	98.6	-0.01 (-0.23, 0.20)		
		Unskilled M	99.3	-0.01 (-0.09, 0.07)	0.00 (-0.08, 0.08)	99.5	-0.05 (-0.10, 0.00)	99.0	0.07 (-0.11, 0.24)		
G3s (N= 8724)	Parental (G0) fertility	1-2 offspring	99.4	0	0	99.2	0	99.5	0	0.27	0.04
		3-4 offspring	99.1	-0.06 (-0.11, -0.01)	-0.05 (-0.10, -0.01)	99.1	-0.02 (-0.10, 0.05)	99.0	-0.09 (-0.15, -0.03)		
		5-6 offspring	99.0	-0.07 (-0.13, -0.01)	-0.07 (-0.13, 0.00)	99.1	-0.02 (-0.11, 0.07)	99.0	-0.10 (-0.20, -0.01)		
		7+ offspring	99.1	-0.06 (-0.13, 0.00)	-0.07 (-0.14, 0.01)	99.1	-0.03 (-0.15, 0.09)	99.0	-0.10 (-0.21, 0.00)		
	Parental (G0) SEP	High NM	99.2	0	0	99.3	0	99.2	0	0.31	
		Low NM	98.8	-0.09 (-0.20, 0.03)	-0.08 (-0.20, 0.03)	98.7	-0.11 (-0.26, 0.05)	98.9	-0.06 (-0.23, 0.11)		
		Farmer/self-empl	99.1	-0.03 (-0.12, 0.06)	-0.02 (-0.11, 0.08)	99.3	0.01 (-0.10, 0.11)	98.9	-0.06 (-0.22, 0.10)		
		Skilled M	99.1	-0.03 (-0.12, 0.06)	-0.02 (-0.11, 0.07)	99.2	0.01 (-0.09, 0.12)	99.0	-0.05 (-0.20, 0.10)		
		Unskilled M	99.2	-0.01 (-0.09, 0.07)	-0.01 (-0.09, 0.07)	99.1	-0.03 (-0.13, 0.06)	99.3	0.00 (-0.14, 0.14)		

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

Supplementary Table 3.5: Predictors of ever marrying by age 40 (if survived to age 16)

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			%	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)		
G1s (N= 11884)	Parental (G0) fertility	1-2 offspring	91.1	0	0	90.0	0	92.2	0	0.05	0.39 (male 0.15 /females 0.74)
		3-4 offspring	91.7	0.04 (-0.05, 0.13)	0.03 (-0.06, 0.13)	90.8	0.00 (-0.12, 0.13)	92.6	0.09 (-0.06, 0.24)		
		5-6 offspring	91.0	-0.01 (-0.11, 0.10)	0.02 (-0.11, 0.14)	89.6	-0.05 (-0.21, 0.11)	92.4	0.12 (-0.07, 0.31)		
		7+ offspring	90.7	-0.03 (-0.15, 0.10)	0.06 (-0.09, 0.21)	87.8	-0.11 (-0.30, 0.08)	93.9	0.33 (0.09, 0.56)		
	Parental (G0) SEP	High NM	91.5	0	0	93.5	0	89.3	0	<0.001	
		Low NM	90.9	-0.04 (-0.22, 0.15)	-0.04 (-0.22, 0.15)	93.0	-0.03 (-0.31, 0.24)	88.6	-0.04 (-0.28, 0.20)		
		Farmer/self-empl	89.8	-0.11 (-0.26, 0.04)	-0.10 (-0.25, 0.05)	88.0	-0.33 (-0.55, -0.12)	91.8	0.14 (-0.08, 0.36)		
		Skilled M	92.3	0.06 (-0.10, 0.22)	0.06 (-0.11, 0.22)	90.9	-0.17 (-0.40, 0.06)	93.7	0.30 (0.07, 0.52)		
		Unskilled M	91.5	0.00 (-0.14, 0.14)	0.00 (-0.14, 0.15)	89.4	-0.25 (-0.46, -0.05)	93.8	0.27 (0.08, 0.46)		
G3s (N= 5914)	Parental (G0) fertility	1-2 offspring	81.2	0	0	82.0	0	80.6	0	0.86	0.10
		3-4 offspring	82.6	0.04 (-0.02, 0.11)	0.05 (-0.02, 0.12)	83.0	0.03 (-0.07, 0.13)	82.3	0.06 (-0.03, 0.16)		
		5-6 offspring	81.1	0.00 (-0.08, 0.07)	0.01 (-0.07, 0.10)	80.9	-0.03 (-0.16, 0.10)	81.3	0.05 (-0.06, 0.16)		
		7+ offspring	81.5	0.01 (-0.07, 0.09)	0.05 (-0.05, 0.14)	81.2	-0.01 (-0.16, 0.14)	81.7	0.09 (-0.04, 0.22)		
	Parental (G0) SEP	High NM	79.9	0	0	79.0	0	80.6	0	0.15	
		Low NM	85.0	0.15 (0.01, 0.28)	0.15 (0.01, 0.28)	84.0	0.15 (-0.05, 0.35)	85.9	0.15 (-0.03, 0.33)		
		Farmer/self-empl	81.0	0.03 (-0.09, 0.15)	0.05 (-0.07, 0.17)	80.1	0.06 (-0.12, 0.24)	81.7	0.04 (-0.12, 0.20)		
		Skilled M	82.9	0.09 (-0.03, 0.20)	0.09 (-0.03, 0.21)	81.3	0.08 (-0.10, 0.26)	84.2	0.10 (-0.06, 0.25)		
		Unskilled M	81.5	0.05 (-0.06, 0.15)	0.05 (-0.06, 0.16)	83.1	0.14 (-0.03, 0.30)	80.4	-0.03 (-0.18, 0.12)		

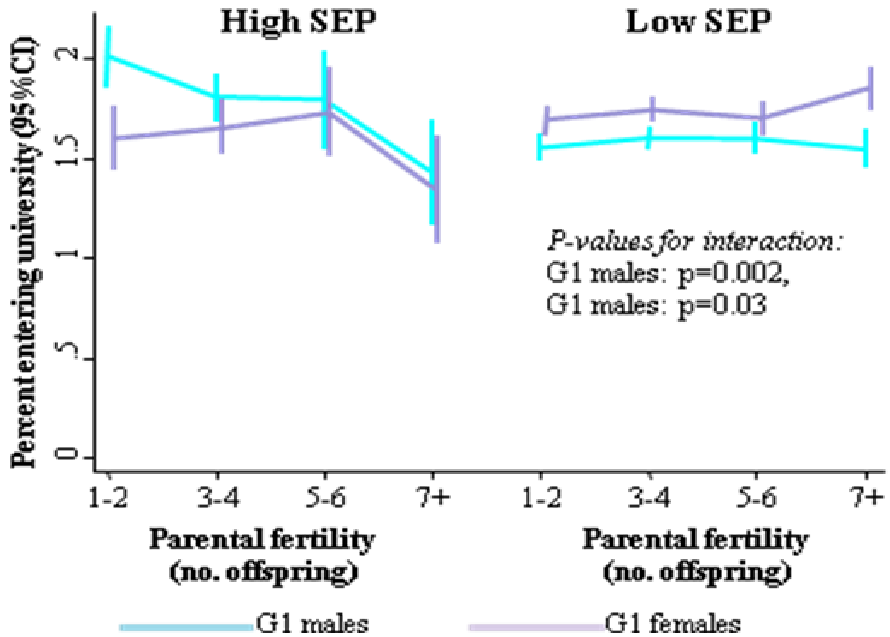
CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). Note marriage data not available for G3s.

Supplementary Table 3.6: Predictors of number of offspring

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			Mean	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	Mean	Adjusted effect sizes (95% CI)	Mean	Adjusted effect sizes (95% CI)		
G1s (N= 13457) †	Parental (G0) fertility	1-2 offspring	1.65	0	0	1.64	0	1.67	0	0.04	<0.001 (males 0.002/ females 0.03) see Figure on next page
		3-4 offspring	1.68	0.01 (-0.03, 0.06)	0.02 (-0.03, 0.06)	1.63	-0.02 (-0.08, 0.04)	1.72	0.06 (0.00, 0.13)		
		5-6 offspring	1.66	0.00 (-0.05, 0.06)	0.03 (-0.03, 0.08)	1.62	-0.01 (-0.09, 0.07)	1.70	0.06 (-0.01, 0.14)		
		7+ offspring	1.65	0.00 (-0.06, 0.06)	0.05 (-0.02, 0.12)	1.53	-0.04 (-0.14, 0.05)	1.79	0.15 (0.06, 0.25)		
	Parental (G0) SEP	High NM	1.85	0	0	1.92	0	1.78	0	<0.001	
		Low NM	1.58	-0.18 (-0.27, -0.10)	-0.17 (-0.25, -0.08)	1.72	-0.12 (-0.24, 0.00)	1.43	-0.22 (-0.35, -0.10)		
		Farmer/self-empl	1.73	-0.09 (-0.16, -0.01)	-0.09 (-0.17, -0.02)	1.70	-0.15 (-0.25, -0.05)	1.76	-0.03 (-0.14, 0.07)		
		Skilled M	1.67	-0.13 (-0.20, -0.05)	-0.12 (-0.20, -0.05)	1.62	-0.19 (-0.29, -0.09)	1.72	-0.05 (-0.16, 0.06)		
		Unskilled M	1.62	-0.16 (-0.22, -0.09)	-0.16 (-0.23, -0.10)	1.52	-0.26 (-0.35, -0.17)	1.73	-0.06 (-0.16, 0.04)		
G2s (N= 9719)	Parental (G0) fertility	1-2 offspring	1.78	0	0	1.76	0	1.79	0	0.95	0.54
		3-4 offspring	1.84	0.07 (0.02, 0.12)	0.08 (0.03, 0.13)	1.83	0.08 (0.00, 0.15)	1.86	0.09 (0.01, 0.16)		
		5-6 offspring	1.85	0.08 (0.02, 0.14)	0.11 (0.04, 0.17)	1.82	0.09 (0.00, 0.18)	1.88	0.12 (0.03, 0.22)		
		7+ offspring	1.86	0.09 (0.02, 0.16)	0.15 (0.07, 0.23)	1.84	0.14 (0.04, 0.25)	1.89	0.16 (0.05, 0.27)		
	Parental (G0) SEP	High NM	1.80	0	0	1.79	0	1.81	0	0.86	
		Low NM	1.84	0.05 (-0.05, 0.15)	0.04 (-0.06, 0.13)	1.79	-0.01 (-0.14, 0.12)	1.90	0.09 (-0.07, 0.25)		
		Farmer/self-empl	1.83	0.04 (-0.04, 0.12)	0.02 (-0.06, 0.10)	1.82	0.02 (-0.09, 0.12)	1.85	0.03 (-0.10, 0.16)		
		Skilled M	1.81	0.02 (-0.07, 0.10)	0.00 (-0.09, 0.08)	1.79	-0.02 (-0.14, 0.09)	1.84	0.02 (-0.11, 0.15)		
		Unskilled M	1.84	0.04 (-0.03, 0.12)	0.02 (-0.06, 0.10)	1.82	0.02 (-0.09, 0.12)	1.85	0.02 (-0.10, 0.14)		
G3s (N= 8996)	Parental (G0) fertility	1-2 offspring	0.60	0	0	0.52	0	0.69	0	0.97	0.20
		3-4 offspring	0.66	0.07 (0.02, 0.13)	0.09 (0.04, 0.14)	0.57	0.08 (0.01, 0.14)	0.75	0.10 (0.03, 0.17)		
		5-6 offspring	0.73	0.17 (0.10, 0.23)	0.19 (0.13, 0.26)	0.64	0.18 (0.10, 0.27)	0.81	0.20 (0.11, 0.30)		
		7+ offspring	0.78	0.24 (0.17, 0.32)	0.29 (0.21, 0.36)	0.72	0.29 (0.19, 0.39)	0.85	0.28 (0.17, 0.40)		
	Parental (G0) SEP	High NM	0.40	0	0	0.34	0	0.48	0	0.79	
		Low NM	0.62	0.30 (0.20, 0.39)	0.23 (0.14, 0.32)	0.54	0.20 (0.09, 0.32)	0.72	0.26 (0.12, 0.39)		
		Farmer/self-empl	0.57	0.23 (0.15, 0.30)	0.19 (0.12, 0.26)	0.49	0.18 (0.09, 0.27)	0.66	0.20 (0.10, 0.31)		
		Skilled M	0.69	0.39 (0.31, 0.47)	0.31 (0.24, 0.39)	0.64	0.33 (0.23, 0.43)	0.74	0.30 (0.19, 0.41)		
		Unskilled M	0.77	0.50 (0.43, 0.56)	0.39 (0.33, 0.45)	0.68	0.37 (0.29, 0.46)	0.85	0.41 (0.31, 0.50)		

†substantive findings unchanged if analysis repeated using Poisson rather than linear regression. CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

Supplementary figure 3. 6: Interactions between parental (G0) fertility and SEP in predicting number of offspring



'High SEP' defined as high, mediate and low non-manual SEP; 'Low SEP' defined as skilled manual, unskilled manual, farmer or self-employed SEP. P-values for interactions are from regression models adjusting for G1 early-life characteristics.

3.4 Additional analyses subdividing number of offspring into 'any offspring' and number of offspring if at least one

Supplementary Table 3.7: Predictors of having at least one child

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			%	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)	%	Adjusted effect sizes (95% CI)		
G1s (N= 13457)	Parental (G0) fertility	1-2 offspring	72.6	0	0	71.0	0	74.4	0	0.18	0.02
		3-4 offspring	73.1	0.01 (-0.04, 0.06)	-0.03 (-0.08, 0.03)	71.6	-0.05 (-0.13, 0.03)	74.7	0.00 (-0.08, 0.09)		
		5-6 offspring	71.5	-0.03 (-0.09, 0.03)	-0.06 (-0.13, 0.01)	69.3	-0.11 (-0.20, -0.01)	73.9	-0.01 (-0.11, 0.09)		
		7+ offspring	69.7	-0.08 (-0.15, -0.01)	-0.09 (-0.17, 0.00)	65.7	-0.18 (-0.29, -0.07)	74.1	0.03 (-0.09, 0.15)		
	Parental (G0) SEP	High NM	75.8	0	0	78.2	0	73.2	0	<0.001	
		Low NM	68.9	-0.19 (-0.30, -0.08)	-0.16 (-0.27, -0.05)	71.7	-0.16 (-0.31, -0.01)	65.6	-0.17 (-0.33, -0.01)		
		Farmer/self-empl	73.1	-0.08 (-0.17, 0.01)	-0.06 (-0.16, 0.04)	71.1	-0.19 (-0.32, -0.06)	75.4	0.07 (-0.06, 0.21)		
		Skilled M	74.8	-0.03 (-0.13, 0.06)	0.00 (-0.10, 0.09)	72.7	-0.12 (-0.26, 0.02)	76.9	0.12 (-0.02, 0.26)		
		Unskilled M	71.0	-0.14 (-0.22, -0.05)	-0.10 (-0.19, -0.01)	67.5	-0.24 (-0.37, -0.12)	74.8	0.06 (-0.07, 0.18)		
G2s (N= 9719)	Parental (G0) fertility	1-2 offspring	63.0	0	0	61.7	0	64.3	0	0.71	0.35
		3-4 offspring	65.3	0.05 (0.00, 0.10)	0.04 (-0.01, 0.09)	64.9	0.06 (-0.01, 0.13)	65.8	0.02 (-0.05, 0.10)		
		5-6 offspring	66.1	0.06 (0.01, 0.12)	0.06 (0.00, 0.12)	64.7	0.06 (-0.03, 0.15)	67.5	0.06 (-0.03, 0.16)		
		7+ offspring	66.6	0.08 (0.01, 0.14)	0.09 (0.01, 0.16)	65.5	0.10 (0.00, 0.21)	67.8	0.07 (-0.03, 0.18)		
	Parental (G0) SEP	High NM	57.6	0	0	57.6	0	57.6	0	0.89	
		Low NM	66.1	0.18 (0.08, 0.28)	0.16 (0.06, 0.27)	64.2	0.13 (-0.02, 0.27)	68.3	0.22 (0.06, 0.37)		
		Farmer/self-empl	65.3	0.16 (0.08, 0.25)	0.16 (0.07, 0.24)	63.9	0.13 (0.02, 0.25)	66.8	0.19 (0.06, 0.31)		
		Skilled M	65.3	0.16 (0.07, 0.25)	0.15 (0.06, 0.23)	63.9	0.12 (-0.01, 0.24)	66.6	0.18 (0.05, 0.30)		
		Unskilled M	66.1	0.18 (0.10, 0.25)	0.17 (0.09, 0.25)	65.5	0.17 (0.06, 0.27)	66.6	0.17 (0.06, 0.29)		
G3s (N= 8996)	Parental (G0) fertility	1-2 offspring	10.6	0	0	9.1	0	12.2	0	0.49	0.83
		3-4 offspring	10.2	-0.02 (-0.06, 0.03)	-0.01 (-0.06, 0.04)	9.0	0.01 (-0.06, 0.07)	11.4	-0.03 (-0.11, 0.05)		
		5-6 offspring	12.6	0.06 (0.00, 0.13)	0.07 (0.00, 0.14)	10.8	0.06 (-0.03, 0.16)	14.4	0.07 (-0.03, 0.17)		
		7+ offspring	13.8	0.10 (0.03, 0.17)	0.11 (0.02, 0.19)	11.8	0.09 (-0.01, 0.20)	15.8	0.12 (-0.01, 0.24)		
	Parental (G0) SEP	High NM	5.6	0	0	4.1	0	7.5	0	0.90	
		Low NM	10.0	0.14 (0.05, 0.23)	0.11 (0.02, 0.20)	8.0	0.08 (-0.03, 0.19)	12.5	0.13 (-0.02, 0.29)		
		Farmer/self-empl	8.8	0.10 (0.04, 0.17)	0.08 (0.02, 0.15)	7.1	0.09 (0.01, 0.16)	10.7	0.08 (-0.03, 0.19)		
		Skilled M	11.7	0.19 (0.12, 0.27)	0.16 (0.08, 0.23)	11.0	0.18 (0.09, 0.28)	12.4	0.13 (0.02, 0.25)		
		Unskilled M	13.2	0.24 (0.18, 0.30)	0.19 (0.13, 0.25)	11.8	0.19 (0.11, 0.27)	14.6	0.19 (0.08, 0.29)		

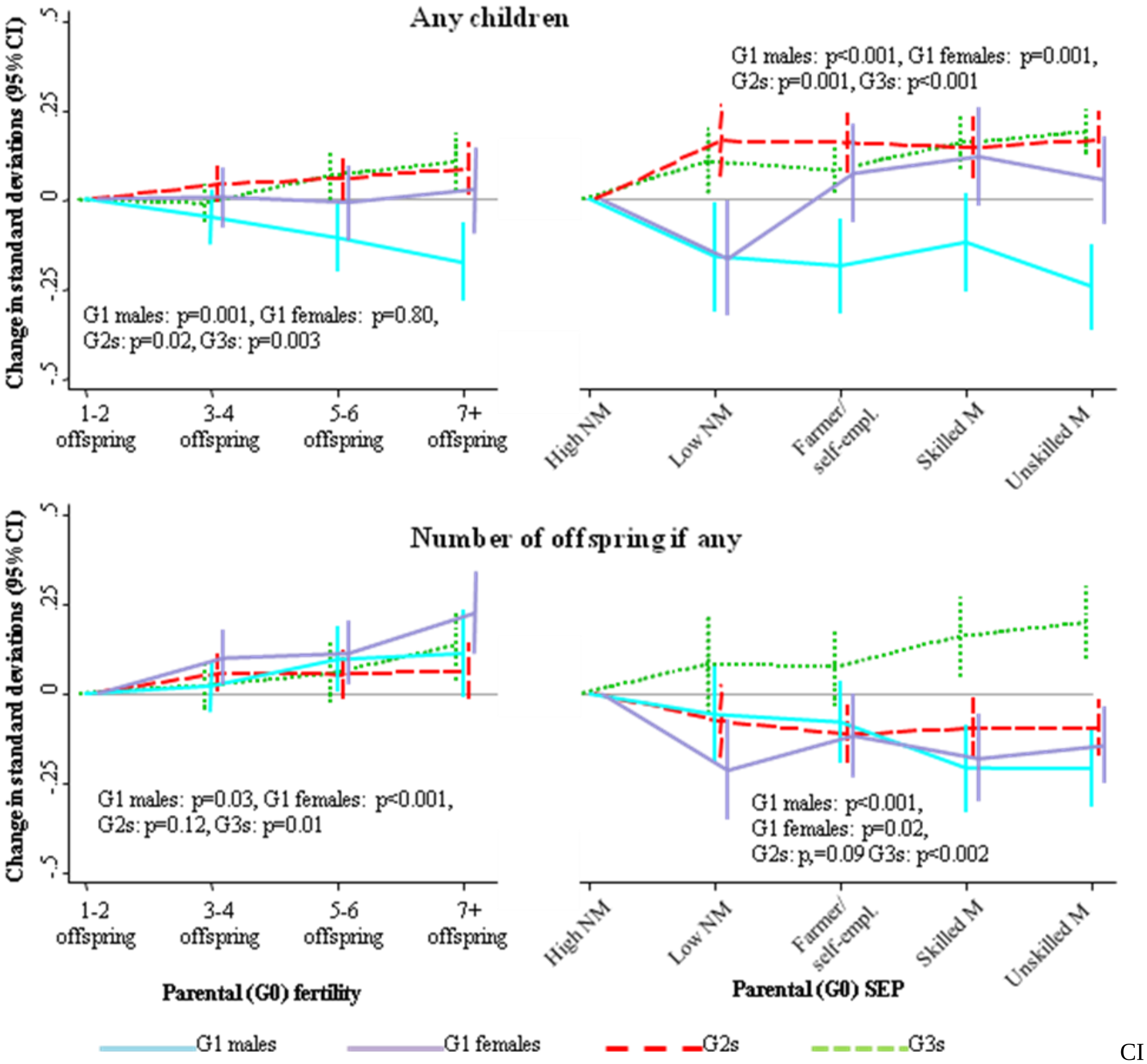
CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

Supplementary Table 3.8: Predictors of number of children, if have any children

	Exposure	Level	Full G1 sample and their descendants			G1 males and their descendants		G1 females and their descendants		p-value for sex inter-action	p-value for fertility -SEP interaction
			Mean	Unadjusted effect sizes (95% CI)	Adjusted effect sizes (95% CI)	Mean	Adjusted effect sizes (95% CI)	Mean	Adjusted effect sizes (95% CI)		
G1s (N= 9723)†	Parental (G0) fertility	1-2 offspring	2.28	0	0	2.30	0	2.25	0	0.26	0.002
		3-4 offspring	2.29	0.02 (-0.04, 0.08)	0.07 (0.01, 0.13)	2.28	0.03 (-0.06, 0.11)	2.31	0.12 (0.03, 0.21)		
		5-6 offspring	2.32	0.05 (-0.03, 0.12)	0.13 (0.05, 0.21)	2.34	0.11 (0.00, 0.23)	2.30	0.14 (0.03, 0.25)		
		7+ offspring	2.37	0.09 (0.00, 0.18)	0.21 (0.10, 0.31)	2.33	0.13 (-0.02, 0.29)	2.41	0.27 (0.14, 0.41)		
	Parental (G0) SEP	High NM	2.45	0	0	2.46	0	2.43	0	0.04	
		Low NM	2.30	-0.15 (-0.27, -0.03)	-0.16 (-0.28, -0.04)	2.40	-0.07 (-0.24, 0.09)	2.18	-0.26 (-0.43, -0.09)		
		Farmer/self-empl	2.36	-0.08 (-0.18, 0.02)	-0.12 (-0.22, -0.02)	2.39	-0.10 (-0.24, 0.04)	2.33	-0.14 (-0.29, 0.00)		
		Skilled M	2.23	-0.21 (-0.32, -0.11)	-0.24 (-0.35, -0.14)	2.23	-0.26 (-0.40, -0.11)	2.23	-0.22 (-0.37, -0.07)		
		Unskilled M	2.28	-0.16 (-0.25, -0.07)	-0.22 (-0.31, -0.13)	2.25	-0.26 (-0.39, -0.13)	2.31	-0.18 (-0.31, -0.05)		
G2s (N= 8996)	Parental (G0) fertility	1-2 offspring	2.23	0	0	2.23	0	2.24	0	0.97	0.69
		3-4 offspring	2.27	0.05 (0.00, 0.10)	0.06 (0.00, 0.11)	2.26	0.05 (-0.03, 0.12)	2.28	0.06 (-0.02, 0.14)		
		5-6 offspring	2.26	0.04 (-0.03, 0.10)	0.05 (-0.02, 0.12)	2.26	0.06 (-0.04, 0.15)	2.27	0.05 (-0.05, 0.15)		
		7+ offspring	2.26	0.04 (-0.03, 0.10)	0.06 (-0.02, 0.14)	2.26	0.06 (-0.04, 0.17)	2.27	0.06 (-0.06, 0.18)		
	Parental (G0) SEP	High NM	2.32	0	0	2.31	0	2.33	0	0.86	
		Low NM	2.26	-0.08 (-0.18, 0.02)	-0.08 (-0.18, 0.02)	2.24	-0.09 (-0.22, 0.03)	2.29	-0.06 (-0.23, 0.11)		
		Farmer/self-empl	2.24	-0.10 (-0.19, -0.02)	-0.12 (-0.20, -0.03)	2.23	-0.12 (-0.23, -0.01)	2.25	-0.12 (-0.25, 0.00)		
		Skilled M	2.25	-0.09 (-0.18, 0.00)	-0.10 (-0.19, -0.01)	2.24	-0.11 (-0.23, 0.01)	2.27	-0.10 (-0.23, 0.04)		
		Unskilled M	2.25	-0.09 (-0.17, -0.01)	-0.10 (-0.18, -0.02)	2.26	-0.09 (-0.19, 0.02)	2.25	-0.11 (-0.24, 0.01)		
G3s (N= 5831)	Parental (G0) fertility	1-2 offspring	1.85	0	0	1.81	0	1.88	0	.60	0.42
		3-4 offspring	1.85	0.00 (-0.06, 0.07)	0.02 (-0.05, 0.09)	1.81	0.02 (-0.08, 0.12)	1.88	0.02 (-0.07, 0.11)		
		5-6 offspring	1.86	0.02 (-0.06, 0.10)	0.05 (-0.03, 0.14)	1.86	0.10 (-0.02, 0.23)	1.86	0.01 (-0.10, 0.12)		
		7+ offspring	1.89	0.07 (-0.02, 0.15)	0.13 (0.04, 0.23)	1.86	0.16 (0.01, 0.30)	1.92	0.12 (-0.01, 0.25)		
	Parental (G0) SEP	High NM	1.76	0	0	1.72	0	1.80	0	.95	
		Low NM	1.81	0.08 (-0.06, 0.22)	0.08 (-0.06, 0.22)	1.79	0.10 (-0.09, 0.30)	1.84	0.04 (-0.15, 0.23)		
		Farmer/self-empl	1.80	0.05 (-0.06, 0.16)	0.07 (-0.04, 0.19)	1.78	0.10 (-0.06, 0.27)	1.81	0.03 (-0.12, 0.18)		
		Skilled M	1.86	0.16 (0.05, 0.28)	0.16 (0.05, 0.27)	1.83	0.17 (0.00, 0.33)	1.89	0.15 (0.00, 0.30)		
		Unskilled M	1.90	0.21 (0.11, 0.31)	0.20 (0.10, 0.30)	1.87	0.22 (0.07, 0.37)	1.92	0.17 (0.04, 0.31)		

†substantive findings unchanged if analysis repeated using Poisson rather than linear regression. CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Adjusted analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

Supplementary figure 3.7: Effect of parental (G0) fertility and SEP upon the reproductive success of G1 offspring and their descendants: additional outcomes (shown in preceding tables)

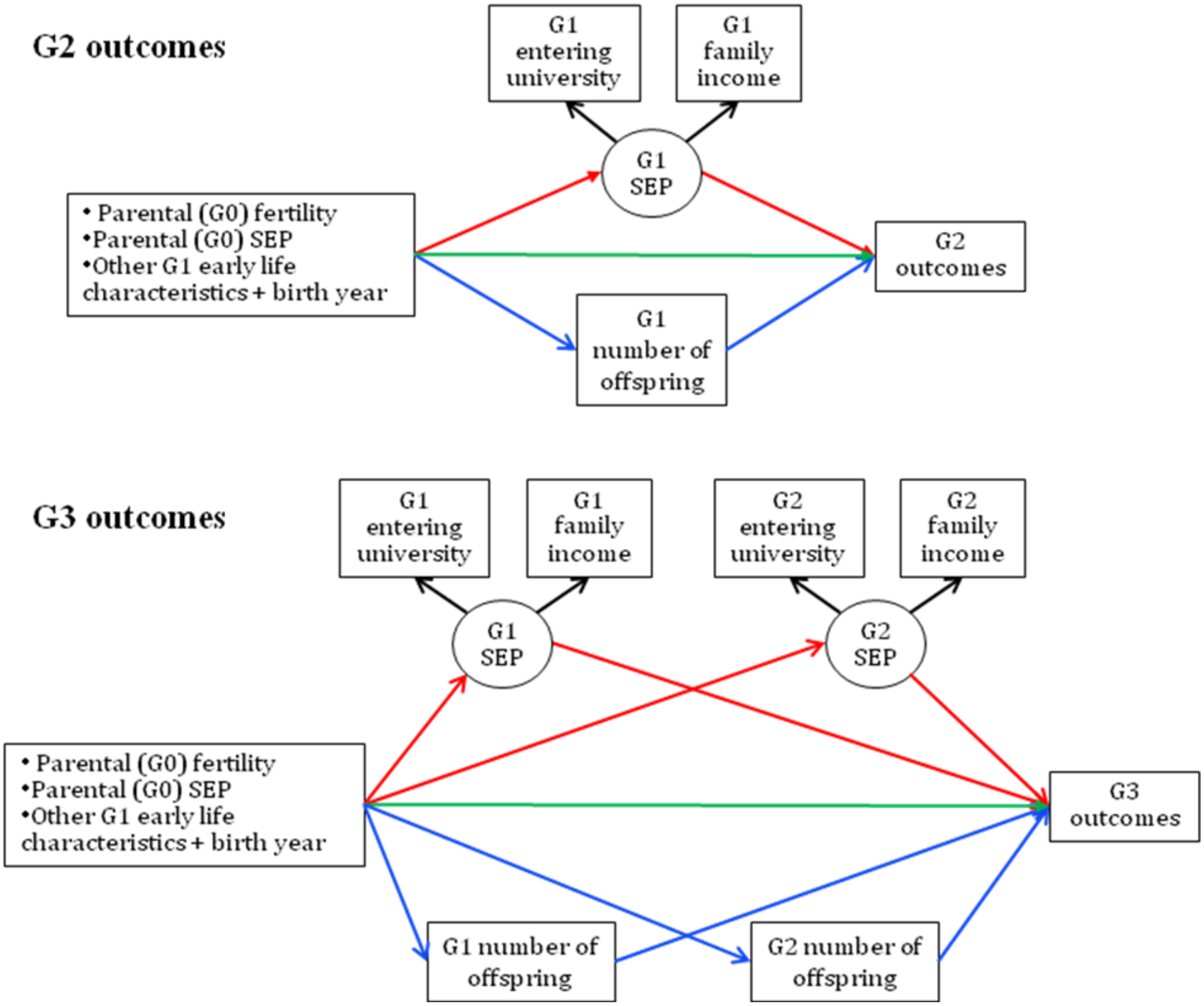


CI =confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. P-values are from regression models adjusting for G1 early-life characteristics, and are for heterogeneity for SEP and for linear trend for parental fertility.

PART 2: Structural equation models examining a) multigenerational mediation by intervening fertility and SEP and b) mediation by age at first birth

3.5 Multigenerational mediation by intervening fertility

Supplementary Figure 3.8: Structural equation model fitted when examining multigenerational mediation



Boxes indicate observed variables, circles indicate latent variables. Red lines indicate 'intervening SEP' pathway(s), blue lines indicate 'intervening fertility' pathway(s), and green lines indicate direct effects. For simplicity, error terms associated with observed and latent variables are not presented in the Figure.

Note on comparability between these analyses and those presented in the main text

The total effect sizes in the following six tables are equivalent to the ‘full sample, adjusted effect sizes’ presented in Part 1 of Electronic Supplementary Material 3. In some instances these estimates differ very slightly (in the second or third decimal) because of differences in the estimation approach used. Specifically, the analyses presented here use a robust maximum likelihood estimator using a Gaussian integration with 24 quadrature points. By contrast the analyses presented in Electronic supplementary material 3 and in the main text used the ordinary least squares (OLS) regression approach of minimising the sum of the squared vertical distance between the observed and expected values. These methods yield similar results when the assumptions of OLS regression are met, and the similarity of these two approaches therefore adds to our confidence in the OLS findings, which we choose to present in the main text because we believe they will be more familiar and transparent for many readers.

Supplementary Table 3.9 Mediation in relation to school marks (standardised)

	Exposure	Level	Adjusted, standardised effect sizes (95% CI)			
			Total effect	Mediated via SEP	Mediated via fertility	Direct effects
G3s (N=7824)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	-.08 (-.14,-.03)	-.01 (-.09,.07)	-.01 (-.01,.00)	-.06 (-.14,.02)
		5-6 offspring	-.09 (-.16,-.02)	-.11 (-.21,-.01)	-.01 (-.02,.00)	.03 (-.07,.13)
		7+ offspring	-.22 (-.30,-.13)	-.22 (-.34,-.10)	-.02 (-.03,-.01)	.02 (-.10,.14)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	-.28 (-.39,-.18)	.25 (-.02,.53)	.01 (-.01,.02)	-.54 (-.81,-.26)
		Farmer/self-empl	-.29 (-.38,-.21)	.21 (-.10,.53)	.00 (-.01,.01)	-.51 (-.82,-.20)
		Skilled M	-.45 (-.54,-.36)	.13 (-.16,.43)	.01 (.00,.02)	-.59 (-.88,-.30)
		Unskilled M	-.47 (-.55,-.40)	.07 (-.23,.36)	.01 (.00,.02)	-.55 (-.83,-.26)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother’s age, G0 mother ever married and G1 birthyear). ‘Percent of total’ values omitted if total effect ≤0.02, to avoid instability in percentages arising from a very small denominator. Note schoolmarks data not available for G2s.

Supplementary Table 3.10: Mediation in relation to entering university

	Exposure	Level	Adjusted, standardised effect sizes (95% CI)			
			Total effect	Mediated via SEP	Mediated via fertility	Direct effects
G2s (N=9646)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	-.08 (-.13,-.03)	-.08 (-.11,-.04)	.00 (.00,.00)	.00 (-.06,.05)
		5-6 offspring	-.18 (-.25,-.12)	-.13 (-.18,-.09)	.00 (-.01,.00)	-.05 (-.12,.02)
		7+ offspring	-.37 (-.44,-.29)	-.28 (-.33,-.22)	.00 (-.01,.00)	-.09 (-.17,.00)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	-.33 (-.44,-.23)	-.67 (-.79,-.55)	.01 (.00,.02)	.33 (.19,.46)
		Farmer/self-empl	-.56 (-.64,-.47)	-.91 (-1.04,-.77)	.01 (.00,.01)	.34 (.20,.48)
		Skilled M	-.54 (-.63,-.46)	-.89 (-1.02,-.76)	.01 (.00,.01)	.34 (.20,.48)
		Unskilled M	-.63 (-.71,-.55)	-.94 (-1.07,-.81)	.01 (.00,.02)	.30 (.16,.44)
G3s (N=7964)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	-.07 (-.13,-.01)	-.03 (-.09,.04)	-.01 (-.01,.00)	-.03 (-.10,.04)
		5-6 offspring	-.10 (-.17,-.03)	-.11 (-.19,-.04)	-.01 (-.02,.00)	.02 (-.06,.10)
		7+ offspring	-.21 (-.30,-.13)	-.23 (-.33,-.14)	-.02 (-.03,-.01)	.04 (-.07,.14)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	-.22 (-.33,-.10)	.08 (-.13,.29)	.00 (-.01,.01)	-.30 (-.52,-.08)
		Farmer/self-empl	-.35 (-.44,-.25)	.01 (-.24,.25)	.00 (-.01,.01)	-.35 (-.60,-.11)
		Skilled M	-.39 (-.49,-.29)	-.04 (-.27,.18)	.00 (-.01,.01)	-.35 (-.58,-.12)
		Unskilled M	-.46 (-.55,-.37)	-.11 (-.33,.12)	.00 (-.01,.01)	-.36 (-.59,-.13)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). 'Percent of total' values omitted if total effect ≤0.02, to avoid instability in percentages arising from a very small denominator

Supplementary Table 3.11: Mediation in relation to family income

	Exposure	Level	Adjusted, standardised effect sizes (95% CI)			
			Total effect	Mediated via SEP	Mediated via fertility	Direct effects
G2s (N=9643)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	.01 (-.04,.06)	-.05 (-.08,-.02)	.00 (.00,.00)	.06 (.00,.12)
		5-6 offspring	-.04 (-.10,.03)	-.09 (-.12,-.05)	.00 (.00,.00)	.05 (-.02,.12)
		7+ offspring	-.13 (-.20,-.05)	-.19 (-.24,-.13)	.00 (.00,.00)	.06 (-.02,.15)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	-.13 (-.25,-.01)	-.46 (-.58,-.33)	.00 (.00,.01)	.33 (.18,.47)
		Farmer/self-empl	-.20 (-.30,-.09)	-.63 (-.78,-.47)	.00 (.00,.00)	.43 (.26,.59)
		Skilled M	-.32 (-.42,-.21)	-.61 (-.76,-.46)	.00 (.00,.01)	.29 (.13,.45)
		Unskilled M	-.34 (-.44,-.24)	-.65 (-.81,-.49)	.00 (.00,.01)	.30 (.14,.47)
G3s (N=7975)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	.02 (-.04,.08)	.04 (-.03,.11)	.00 (-.01,.00)	-.02 (-.10,.06)
		5-6 offspring	.00 (-.07,.07)	-.01 (-.10,.07)	.00 (-.01,.00)	.02 (-.08,.11)
		7+ offspring	-.04 (-.12,.04)	-.05 (-.16,.05)	.00 (-.01,.00)	.02 (-.10,.14)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	-.15 (-.26,-.04)	.36 (.11,.60)	.00 (-.01,.00)	-.50 (-.75,-.25)
		Farmer/self-empl	-.01 (-.11,.09)	.41 (.13,.70)	.00 (-.01,.00)	-.42 (-.71,-.13)
		Skilled M	-.09 (-.20,.01)	.29 (.02,.55)	.00 (-.01,.00)	-.38 (-.65,-.11)
		Unskilled M	-.13 (-.22,-.04)	.27 (.00,.53)	.00 (-.01,.00)	-.39 (-.66,-.12)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). 'Percent of total' values omitted if total effect ≤0.02, to avoid instability in percentages arising from a very small denominator

Supplementary Table 3.12: Mediation in relation to survival to age 16

	Exposure	Level	Adjusted, standardised effect sizes (95% CI)			
			Total effect	Mediated via SEP	Mediated via fertility	Direct effects
G2s (N=6425)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	-.04 (-.10,.02)	.00 (-.01,.00)	.00 (.00,.00)	-.04 (-.10,.02)
		5-6 offspring	-.04 (-.12,.04)	.00 (-.01,.00)	.00 (.00,.00)	-.04 (-.11,.04)
		7+ offspring	-.05 (-.15,.04)	-.01 (-.02,.00)	.00 (.00,.00)	-.04 (-.14,.05)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	.03 (-.06,.12)	-.02 (-.06,.01)	.00 (.00,.01)	.05 (-.03,.14)
		Farmer/self-empl	-.02 (-.11,.06)	-.03 (-.08,.01)	.00 (.00,.00)	.01 (-.08,.10)
		Skilled M	-.04 (-.14,.07)	-.03 (-.08,.01)	.00 (.00,.01)	-.01 (-.11,.09)
		Unskilled M	.00 (-.07,.08)	-.03 (-.08,.01)	.00 (.00,.01)	.04 (-.04,.12)
G3s (N=8724)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	-.06 (-.11,-.01)	.00 (-.01,.00)	-.01 (-.01,.00)	-.05 (-.10,.00)
		5-6 offspring	-.07 (-.14,.00)	-.01 (-.02,.00)	-.01 (-.01,.00)	-.06 (-.12,.01)
		7+ offspring	-.07 (-.15,.00)	-.01 (-.03,.01)	-.01 (-.02,.00)	-.05 (-.12,.03)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	-.09 (-.20,.03)	-.02 (-.10,.06)	.00 (-.01,.01)	-.07 (-.21,.08)
		Farmer/self-empl	-.02 (-.11,.07)	-.03 (-.13,.07)	.00 (-.01,.01)	.01 (-.14,.15)
		Skilled M	-.02 (-.11,.07)	-.03 (-.12,.07)	.00 (.00,.01)	.00 (-.13,.14)
		Unskilled M	-.01 (-.09,.07)	-.03 (-.13,.07)	.00 (-.01,.01)	.02 (-.12,.15)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). 'Percent of total' values omitted if total effect ≤0.02, to avoid instability in percentages arising from a very small denominator

Supplementary Table 3.13: Mediation in relation to ever marrying by age 40 (if survived to age 16)

	Exposure	**Level**	**Adjusted, standardised effect sizes (95% CI)**			
			Total effect	**Mediated via SEP**	**Mediated via fertility**	**Direct effects**
G2s (N=5914)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	.05 (-.02,.12)	.00 (-.01,.00)	.00 (.00,.00)	.05 (-.01,.12)
		5-6 offspring	.01 (-.07,.10)	-.01 (-.02,.01)	.00 (.00,.00)	.02 (-.06,.11)
		7+ offspring	.04 (-.05,.14)	-.02 (-.05,.01)	.00 (.00,.00)	.06 (-.04,.16)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	.14 (.01,.28)	-.04 (-.12,.03)	.01 (.00,.01)	.18 (.03,.33)
		Farmer/self-empl	.04 (-.08,.16)	-.06 (-.16,.05)	.00 (.00,.01)	.10 (-.06,.25)
		Skilled M	.08 (-.04,.20)	-.06 (-.16,.04)	.00 (.00,.01)	.14 (-.02,.29)
		Unskilled M	.04 (-.07,.15)	-.06 (-.17,.05)	.01 (.00,.01)	.09 (-.06,.24)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). 'Percent of total' values omitted if total effect ≤0.02, to avoid instability in percentages arising from a very small denominator. Note marriage data not available for G3s.

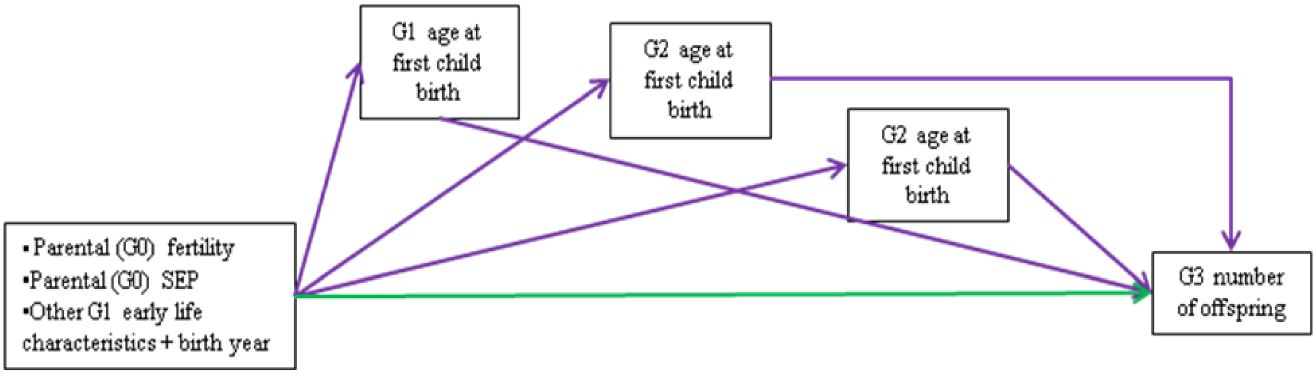
Supplementary Table 3.14: Mediation in relation to number of offspring

	Exposure	Level	Adjusted, standardised effect sizes (95% CI)			
			Total effect	Mediated via SEP	Mediated via fertility	Direct effects
G2s (N=9719)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	.08 (.02,.13)	.01 (.00,.01)	.00 (.00,.01)	.07 (.02,.12)
		5-6 offspring	.10 (.04,.17)	.01 (.00,.02)	.00 (.00,.01)	.09 (.02,.15)
		7+ offspring	.14 (.06,.22)	.03 (.01,.05)	.01 (.00,.01)	.11 (.03,.19)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	.03 (-.07,.13)	.07 (.02,.11)	-.02 (-.03,-.01)	-.02 (-.13,.09)
		Farmer/self-empl	.02 (-.06,.10)	.09 (.02,.15)	-.01 (-.02,.00)	-.06 (-.16,.05)
		Skilled M	.00 (-.08,.09)	.09 (.02,.15)	-.01 (-.02,-.01)	-.07 (-.17,.04)
		Unskilled M	.02 (-.06,.09)	.09 (.03,.16)	-.02 (-.03,-.01)	-.06 (-.15,.04)
G3s (N=8996)	Parental (G0) fertility	1-2 offspring	0	0	0	0
		3-4 offspring	.09 (.04,.14)	.02 (-.01,.06)	.01 (.00,.01)	.06 (.01,.11)
		5-6 offspring	.20 (.13,.26)	.07 (.03,.11)	.01 (.00,.01)	.12 (.05,.18)
		7+ offspring	.29 (.21,.37)	.15 (.10,.20)	.01 (.00,.02)	.13 (.05,.21)
	Parental (G0) SEP	High NM	0	0	0	0
		Low NM	.23 (.14,.32)	.04 (-.07,.15)	.00 (-.01,.01)	.19 (.06,.33)
		Farmer/self-empl	.19 (.12,.26)	.11 (-.02,.24)	.00 (-.01,.01)	.08 (-.06,.23)
		Skilled M	.31 (.24,.39)	.12 (.00,.24)	.00 (-.01,.01)	.19 (.05,.33)
		Unskilled M	.39 (.33,.45)	.16 (.04,.28)	.00 (-.01,.01)	.23 (.09,.36)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear). 'Percent of total' values omitted if total effect ≤0.02, to avoid instability in percentages arising from a very small denominator

3.6 Multigenerational mediation of effects on number of G3 offspring by age at first birth

Supplementary Figure 3.9: Path analysis fitted when examining mediation by age at first birth upon G3 number of offspring



Boxes indicate observed variables. Purple lines indicate 'intervening age first childbearing' pathways and green lines indicate direct effects. For simplicity, error terms associated with observed and latent variables are not presented in the Figure.

Supplementary Table 3.15 Mediation in relation to school G3 number of offspring

	Exposure	**Level**	**Adjusted, standardised effect sizes (95% CI)**		
			Total effect	**Mediated via age first childbearing**	**Direct effects**
G3s (N=7824)	Parental (G0) fertility	1-2 offspring	0	0	0
		3-4 offspring	.09 (.04,.13)	.07 (.04,.10)	.02 (-.02,.06)
		5-6 offspring	.19 (.13,.26)	.13 (.09,.17)	.06 (.01,.11)
		7+ offspring	.29 (.21,.37)	.22 (.18,.27)	.06 (.01,.12)
	Parental (G0) SEP	High NM	0	0	0
		Low NM	.22 (.13,.31)	.19 (.13,.26)	.03 (-.04,.10)
		Farmer/self-empl	.19 (.12,.26)	.18 (.13,.23)	.01 (-.05,.06)
		Skilled M	.31 (.24,.38)	.29 (.23,.34)	.02 (-.04,.08)
		Unskilled M	.39 (.32,.45)	.32 (.28,.37)	.06 (.01,.11)

CI=confidence interval, SEP=socioeconomic position; High NM=high/mediate non-manual; Low NM=low non-manual; farmer/self-empl.=farmer or self-employed; Skilled M=skilled manual; Unskilled M=unskilled manual. Mediation analyses adjust for G1 early life characteristics (G1 sex, G1 birthweight, G1 preterm birth, G0 mother's age, G0 mother ever married and G1 birthyear).

PART 3: Comparison of the performance of alternative measures of reproductive success

3.7 Correlation between measures of reproductive success

Supplementary Table 3.16: Correlation between alternative measures of G1 fitness, in different subpopulations

Sub-population		Total estimated fitness	No. G2 descendants	No. G3 descendants	No. G4 descendants
All G1s (N=13,672)	Total estimated fitness	1			
	No. G2 descendants	0.84	1		
	No. G3 descendants	0.97	0.86	1	
	No. G4 descendants	0.73	0.55	0.67	1
G1 males (N=7178)	Total estimated fitness	1			
	No. G2 descendants	0.84	1		
	No. G3 descendants	0.98	0.86	1	
	No. G4 descendants	0.68	0.51	0.62	1
G1 females (N=6494)	Total estimated fitness	1			
	No. G2 descendants	0.83	1		
	No. G3 descendants	0.97	0.86	1	
	No. G4 descendants	0.78	0.60	0.71	1
G1s with parents of manual SEP (N=11,214)	Total estimated fitness	1			
	No. G2 descendants	0.84	1		
	No. G3 descendants	0.97	0.86	1	
	No. G4 descendants	0.75	0.57	0.69	1
G1s with parents of non-manual SEP (N=2135)	Total estimated fitness	1			
	No. G2 descendants	0.83	1		
	No. G3 descendants	0.97	0.84	1	
	No. G4 descendants	0.62	0.47	0.57	1
G1 from families of 1-4 offspring (N=10657)	Total estimated fitness	1			
	No. G2 descendants	0.85	1		
	No. G3 descendants	0.97	0.88	1	
	No. G4 descendants	0.78	0.60	0.72	1
G1 from families of 5+ offspring (N=3015)	Total estimated fitness	1			
	No. G2 descendants	0.85	1		
	No. G3 descendants	0.97	0.88	1	
	No. G4 descendants	0.78	0.60	0.72	1

3.8 Sex-stratified results of Table 1

Supplementary Table 3.17: Early-life predictors of four alternative measures of reproductive success among G1 males in the UBCoS Cohort Study, born 1915-1929 (N=7178)

	Percent/ mean (SD) among G1s	Regression coefficients from linear regression (95% confidence interval)			
		Total estimated fitness (standardised)	No. G2 descendants (standardised) – i.e. children to G1s	No. G3 descendants (standardised) – i.e. grandchildren to G1s	No. G4 descendants (standardised) – i.e. great-grandchildren to G1s
		F(24, 7153)=6.18, R^2=0.020	F(24, 7153)=9.84, R^2=0.031	F(24, 7153)=5.89, R^2=0.019	F(24, 7153)=12.67, R^2=0.040
Birthweight, change per kg	3.5 (0.6)	**0.14 (0.10, 0.19)**	**0.19 (0.14, 0.23)**	**0.15 (0.10, 0.20)**	**0.07 (0.03, 0.11)**
Preterm birth (<37 weeks)	10%	-0.04 (-0.14, 0.05)	**-0.11 (-0.20, -0.02)**	-0.05 (-0.14, 0.05)	-0.04 (-0.12, 0.04)
Twin/triplet status	3%	-0.04 (-0.18, 0.10)	-0.06 (-0.21, 0.08)	-0.03 (-0.17, 0.11)	0.00 (-0.13, 0.12)
Mother's age, change per decade	28.4 (6.5)	**-0.10 (-0.14, -0.05)**	**-0.08 (-0.12, -0.04)**	**-0.09 (-0.14, -0.05)**	**-0.10 (-0.14, -0.06)**
Unmarried mother	19%	-0.04 (-0.11, 0.03)	-0.05 (-0.12, 0.01)	-0.05 (-0.12, 0.01)	0.01 (-0.05, 0.07)
Parental fertility 1-2 offspring	27%	0	0	0	0
Parental fertility 3-4 offspring	39%	0.02 (-0.04, 0.08)	-0.02 (-0.08, 0.04)	0.01 (-0.05, 0.07)	**0.06 (0.01, 0.11)**
Parental fertility 5-6 offspring	19%	0.04 (-0.03, 0.12)	-0.01 (-0.09, 0.06)	0.03 (-0.05, 0.10)	**0.14 (0.07, 0.20)**
Parental fertility 7+ offspring	15%	0.04 (-0.05, 0.12)	-0.05 (-0.13, 0.04)	0.02 (-0.06, 0.11)	**0.17 (0.10, 0.25)**
High NM parental SEP	9%	0	0	0	0
Low NM parental SEP	7%	-0.08 (-0.19, 0.04)	-0.11 (-0.22, 0.01)	-0.08 (-0.19, 0.03)	**0.13 (0.03, 0.24)**
Farmer/self-empl. parental SEP	19%	-0.08 (-0.18, 0.01)	**-0.13 (-0.23, -0.03)**	**-0.10 (-0.19, 0.00)**	**0.11 (0.02, 0.19)**
Skilled M parental SEP	15%	**-0.15 (-0.25, -0.05)**	**-0.18 (-0.28, -0.08)**	**-0.16 (-0.25, -0.06)**	**0.16 (0.08, 0.25)**
Unskilled M parental SEP	50%	**-0.16 (-0.25, -0.08)**	**-0.24 (-0.33, -0.15)**	**-0.18 (-0.27, -0.09)**	**0.16 (0.08, 0.24)**

SD=standard deviation, CI=confidence interval, SEP=socioeconomic position, High NM=high/mediate non-manual, Low NM=low non-manual, farmer/self-empl.=farmer or self-employed, Skilled M=skilled manual, Unskilled M=unskilled manual. Regression coefficients from linear regression, adjusting for all variables in column plus year of birth by one-year age band. Variables in bold are p<0.05

Supplementary Table 3.18: Early-life predictors of four alternative measures of reproductive success among G1 females in the UBCoS Cohort Study, born 1915-1929 (N=6494)

	Percent/ mean (SD) among G1s	Regression coefficients from linear regression (95% confidence interval)			
		Total estimated fitness (standardised)	**No. G2 descendants (standardised) – i.e. children to G1s**	**No. G3 descendants (standardised) – i.e. grandchildren to G1s**	**No. G4 descendants (standardised) – i.e. great-grandchildren to G1s**
		F(24, 6469)=, R^2=0.019	F(24, 6469)=, R^2=0.026	F(24, 6469)=4.80, R^2=0.017	F(24, 6469)=11.97, R^2=0.042
Birthweight, change per kg	3.3 (0.6)	**0.12 (0.07, 0.17)**	**0.14 (0.09, 0.19)**	**0.12 (0.07, 0.17)**	**0.10 (0.04, 0.15)**
Preterm birth (<37 weeks)	9%	-0.09 (-0.19, 0.01)	**-0.16 (-0.25, -0.06)**	-0.09 (-0.19, 0.00)	-0.05 (-0.16, 0.06)
Twin/triplet status	3%	0.06 (-0.09, 0.21)	0.05 (-0.09, 0.19)	0.05 (-0.10, 0.19)	0.05 (-0.11, 0.21)
Mother's age, change per decade	28.4 (6.5)	**-0.08 (-0.13, -0.04)**	**-0.07 (-0.11, -0.02)**	**-0.08 (-0.13, -0.03)**	**-0.10 (-0.15, -0.05)**
Unmarried mother	20%	0.05 (-0.02, 0.13)	0.06 (-0.01, 0.13)	0.05 (-0.03, 0.12)	**0.13 (0.05, 0.20)**
Parental fertility 1-2 offspring	28%	0	0	0	0
Parental fertility 3-4 offspring	38%	**0.09 (0.02, 0.15)**	0.06 (0.00, 0.12)	**0.09 (0.02, 0.15)**	**0.11 (0.04, 0.18)**
Parental fertility 5-6 offspring	20%	**0.10 (0.02, 0.18)**	0.06 (-0.02, 0.13)	**0.10 (0.02, 0.18)**	**0.14 (0.06, 0.23)**
Parental fertility 7+ offspring	14%	**0.20 (0.11, 0.30)**	**0.15 (0.06, 0.24)**	**0.20 (0.10, 0.29)**	**0.30 (0.20, 0.40)**
High NM parental SEP	9%	0	0	0	0
Low NM parental SEP	7%	**-0.17 (-0.29, -0.04)**	**-0.22 (-0.35, -0.10)**	**-0.16 (-0.29, -0.03)**	0.03 (-0.11, 0.16)
Farmer/self-empl. parental SEP	18%	-0.02 (-0.13, 0.09)	-0.03 (-0.14, 0.07)	-0.02 (-0.13, 0.09)	**0.15 (0.03, 0.26)**
Skilled M parental SEP	15%	-0.02 (-0.13, 0.08)	-0.05 (-0.16, 0.05)	-0.04 (-0.15, 0.07)	**0.18 (0.07, 0.30)**
Unskilled M parental SEP	51%	-0.03 (-0.12, 0.07)	-0.06 (-0.15, 0.03)	-0.04 (-0.14, 0.06)	**0.25 (0.15, 0.36)**

SD=standard deviation, CI=confidence interval, SEP=socioeconomic position, High NM=high/mediate non-manual, Low NM=low non-manual, farmer/self-empl.=farmer or self-employed, Skilled M=skilled manual, Unskilled M=unskilled manual. Regression coefficients from linear regression, adjusting for all variables in column plus year of birth by one-year age band. Variables in bold are p<0.05