Cognitive ability and fertility among Swedish men born 1951–1967: evidence from military conscription registers

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Abstract: We examine the relationship between cognitive ability and childbearing patterns in contemporary Sweden using administrative register data. The topic has a long history in the social sciences and has been the topic of a large number of studies, many reporting a negative gradient between intelligence and fertility. We link fertility histories to military conscription tests with intelligence scores for all Swedish men born 1951 to 1967. We find a positive relationship between intelligence scores and fertility, and this pattern is consistent across the cohorts we study. The relationship is most pronounced for the transition to a first child, and men with the lowest categories of IQ-scores have the fewest children. Using fixed effects models we additionally control for all factors that are shared by siblings, and after such adjustments we find a stronger positive relationship between IQ and fertility. Furthermore, we find a positive gradient within groups at different levels of education. Compositional differences of this kind are therefore not responsible for the positive gradient we observe - instead the relationship is even stronger after controlling for both educational careers and parental background factors. In our models where we compare brothers to one another we find that, relative to men with IQ 100, the group with the lowest category of cognitive ability have 0.56 fewer children, and men with the highest category have 0.09 more children.

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Introduction

A paradox of human behaviour in industrialized societies is that high socioeconomic status is usually negatively associated with reproductive success. This is puzzling from an evolutionary perspective in which high status is assumed to give greater access to partners as well as enhanced ability to support offspring [1-3], which was also the case in pre-industrial societies, and has likely been true throughout *Homo Sapiens* pre-historic past [4]. It is also puzzling from an economic perspective because children are a major expenditure that should be more affordable for those with more resources [5]. The typically-observed negative relationship has been described as a central problem in the evolutionary study of human behaviour [2]. The relationship between cognitive ability and fertility is an important dimension of this puzzle. For more than a century most studies have found that higher cognitive ability is associated with lower reproductive success [e.g. 2, 6, 7], despite the fact that individuals with high cognitive ability achieve substantially higher socioeconomic success than individuals with lower cognitive ability [8], and both men and women rate intelligence as a desirable feature in a potential mate [9]. Furthermore, it has been suggested that the evolution of high cognitive ability in *Homo Sapiens* is attributable to positive selection on intelligence, as higher intelligence facilitated greater social interaction capabilities, which in turn led to greater reproductive success [10, 11]. Empirical evidence suggests that the link between socioeconomic success, likely associated with high cognitive ability, and reproductive success was positive in a wide variety of pre-industrial societies [4, 12]. In contrast, the empirical evidence for the relationship between socioeconomic status and fertility over the past two centuries is ambiguous, with most studies reporting a negative association. In this study we revisit this research question, applying a rigorous statistical treatment to high quality population data to study the relationship between cognitive ability and fertility in contemporary Sweden.

Previous Research on Intelligence and Fertility

The relationship between cognitive ability and fertility was a prominent research question in the social and biological sciences in the first half of the 20th century, and was of central concern to the pioneers of contemporary statistics. Francis Galton, Karl Pearson, and Ronald Fisher all examined differential fertility between individuals with high and low achievement and intelligence in order to investigate whether these intergenerational processes[2] would influence the future distribution of cognitive ability in the population [14, 15]. Kevles [16] provides an overview and history of this topic. Most researchers examining the relationship between intelligence and fertility have been concerned about the potential 'dysgenic' population effects of lower intelligence individuals having higher fertility, and this debate has also found interest and enthusiasm amongst the general public (e.g. see the 2006 Hollywood film *Idiocracy* for a popular culture example).

Research on the IQ-fertility relationship has largely focused on the United States, with some studies using nationally representative samples and others focusing upon data from the Midwest, though a smaller number of studies have examined other high-income countries [6, 17-21]. These studies suggest that there has been a transition in the relationship between intelligence and fertility over time, from no clear gradient amongst cohorts born in the first half of the 20th century, to a small to moderate negative gradient (i.e. higher intelligence, lower fertility) for cohorts born in the second half of the 20th century [6, 18, 20, 21], though a minority of studies have reported positive gradients [17, 22, 23]. In general, studies have reported a steeper negative gradient for women than for men [e.g. 19, 20]. Those studies that have gone beyond examining the overall gradient between completed fertility and IQ find that lower intelligence is most commonly associated with either childlessness, or large family sizes [20, 24]. This previous research has, with very few exceptions, been based on either surveys or samples of school classes. To accurately assess the relationship between cognitive ability and fertility it is essential to capture the complete population, and groups with low cognitive ability would often be missing or underrepresented in the data sources previously used to address this research question. These problems are most severe when samples are drawn from older children in secondary education, where individuals of low cognitive ability would often not be present. Most relevant to the Nordic context that we examine are previous studies of Swedish and Norwegian samples. A Swedish study found high fertility amongst high IQ males, and for women an unclear pattern [22], but the low quality of the data used means that the findings cannot be considered conclusive. More recently, a study using Norwegian data reported a positive fertility-intelligence gradient using conscription data on intelligence, but this analysis was limited to a minor supplementary treatment [23].

[2] Intergenerational (Pearson) correlations for cognitive ability are around 0.3 to 0.4 with some outliers in both directions, and recent genomic studies can attribute some of that correlation to specific genes [13].

Recent research on polygenic scores and educational attainment is also relevant for the relationship between cognitive ability and fertility. An Icelandic study found lower reproductive success amongst individuals whose polygenic scores predicted greater educational attainment [25]. A US study found negative selection for polygenic scores associated with higher educational attainment for men and women [26], though another study on this topic found no such pattern [27]. A study using UK data found that polygenic scores associated with number of children was negatively associated with observed educational attainment [28]. However, it was not possible to isolate the effect of cognitive ability net of education in these recent genomic studies (with the partial exception of [25]), and all of these studies were conducted in contexts where the overall association between socioeconomic success and fertility may differ from contemporary Sweden.

Potential Pathways for the Association between Cognitive Ability and Fertility

Many explanations have been proposed to account for the relationship between cognitive ability and fertility [e.g. 7]. Variation in access to resources by cognitive ability is likely to be important. The link between cognitive ability and childbearing is plausibly primarily mediated through the positive influence of cognitive ability on adult socioeconomic status attainment. In many high-income societies there is evidence for a negative association between socioeconomic status and fertility [12]. However, in contemporary Sweden the patterns are more complex, and some evidence indicates that socioeconomic status is positively correlated with male fertility [29, 30]. Health differences may be another alternative explanation, since low scores on cognitive ability tests are strongly correlated with health in both childhood and adulthood [31]. This might be of particular importance in the lower ranges of the IQ distribution, where men with poor health and disabilities are likely to be overrepresented. Finally, it is plausible that partner search and family formation processes are particularly important for understanding male fertility. Failure to find and/or keep a partner for childbearing may be an important determinant of low fertility for men in contemporary Sweden. Low fertility may therefore be attributable to unmet fertility and family formation preferences.

Material and Methods

Data and Measurement

Our study is based on Swedish administrative registers. This data source allows us to capture the complete population of Sweden, including institutionalized individuals, in contrast to previous research that has used more narrow sampling criteria and relied upon survey responses. This is a very significant advantage when we are interested in the population composition, because men with below average cognitive ability may be particularly underrepresented in the survey data typically used to examine the relationship between intelligence and fertility, and self-reported male fertility may not be reliable. To our knowledge, we provide the first estimates for the relationship between intelligence and fertility based upon population-level data rather than survey data.

Register data with monthly event histories of vital events are available from 1968 to 2012. By means of the universal Swedish identification number we combine data from military conscription registers, fertility registers, and educational registers. Linkage quality is virtually perfect for fertility and education. As the vital events are based on birth records, we can only link fathers to children that are known by the authorities, though these represent over 99% of all births [32], partly because of rigorous paternity investigations by the social services. As such our data is superior to self-reported information which can be problematic, and particularly so for assessing male fertility.

We define our population as all men born in Sweden from 1951-1967 (N=779,146), alive until the end of their reproductive ages, which we define as at least age 45. Nearly all of our data is based on fertility measured at or after age 50, which assures that we have a virtually complete count of fertility, missing less than 1% of births. We also calculate fertility at earlier ages in order to examine whether relying on fertility measured at younger ages, a common practice in previous research, influences the gradient between cognitive ability and fertility.

Cognitive Ability Tests

The measure of cognitive ability that we use is drawn from the Swedish Enlistment Battery, a series of tests that military conscripts were subject to in Sweden in the second half of the 20th century. All Swedish men were required by law to attend these tests. Sweden had universal military conscription for most of the 20th century, in which all men were obliged to spend 1 year with the military, typically at ages 18-20. To assess eligibility, and more importantly to assign people to suitable branches and jobs within the military, all men in Sweden had to participate in a one to two day examination before the beginning of their conscription. As part of these examinations, men were subjected to a battery of tests to assess their suitability for the armed forces, and to determine their assignment. One of these assessments was of general cognitive ability [33].

This cognitive ability test consisted of subtests that measured logical, spatial, verbal, and technical abilities. Each of these sub-tests was first evaluated on a normalized 9-point (stanine) scale. The subtest scores were summed to obtain an overall score and transformed onto a stanine scale with a mean of 5 and a standard deviation of 2. Throughout our study we are using the 9-level categorical stanine measure for our analysis, and present results translated into IQ scores based on a standard Wechsler scale. Although the nature of the cognitive ability test changed somewhat over the years, the test was stable for the years during which the sample included in this analysis were conscripted [33]. The tests were normalized by the military for each year, so our IQ measure is always relative within a given cohort. As such, there can be no increase or decline in IQ scores over time.

The cognitive ability scores we use in this study are designed to capture and reflect an underlying generalized intelligence. General intelligence is correlated with performance on mental tasks such as visuo-spatial, quantitative, and verbal reasoning, cognitive attributes such as working memory, a wide variety of life course outcomes, including educational attainment and labour market success, and health behaviours, amongst many other things [e.g. 34]. Different aspects of cognitive ability are also strongly correlated with each other, with each aspect predicting other aspects [35]. Cognitive ability will likely be both affected by, and a determinant of, childhood educational trajectories. Throughout childhood, children are gradually able to solve increasingly complex problems due to physiological developments as well as exposure to social learning, greatly enhanced by formal education in contemporary settings. The most important environmental factor is likely cognitive stimulation during upbringing, strongly mediated by education and training [36]. Childhood environmental influences such as early life exposures and childhood nutrition are also likely to be important [37], in addition to genetic traits associated with IQ [38].

The military conscription tests, despite being mandatory, were not taken by everyone, and 3% of the men born in the cohorts that we study did not take the IQ test. However we have information on educational and fertility histories even for those who did not take the examination, which allows insights into the reasons why they were selected out. Of the 3% who did not take the test, approximately 2% showed up for the examination, but were not administered the test. Our data show that this group achieved both lower educational attainment and lower fertility, and most likely predominantly consists of individuals with various traits or (often non-cognitive) disabilities that rendered them unfit for military service. The other 1% for whom we do not have data on the cognitive ability test did not show up for the examination. We assume that this missing category is a heterogeneous group, including, for example, people who were abroad at the time. This group has an educational distribution close to, but slightly lower than, the population as a whole, and fewer children.

Educational Attainment

Information on educational attainment is derived from administrative registers. We use three categories: primary education, secondary education, and any tertiary education. The information is based on highest educational attainment in 2012. Primary and secondary attainment will mostly take place before measurement of IQ, while tertiary education is attained after measurement.

Statistical Analyses

Descriptive Statistics

We first present descriptive statistics for the level of fertility at different points in the IQ distribution. We decompose completed fertility into the contribution of men based on their eventual parity at their end of the reproductive careers, for different levels of IQ. This is done by multiplying the proportion of men with a given parity, with the given parity (e.g. if 40% of all men with IQ 96-104 have 2 children, they contribute 0.8 to the completed fertility of men with IQ 96-104). This equals the average fertility of that group when summed up for all parities. We make a similar decomposition for fertility by first, second, and third or higher childbearing partners. We also report how the patterns of fertility by cognitive ability vary by age at measurement, starting at age 25 and going up to age 45 in 5-year increments.

Regression Analyses

In addition to a presentation of descriptive statistics, we conduct a number of regression analyses[3] on completed fertility as well as parity transitions. The populations of our models for parity transition n are the population with at least a final parity of n-1, and these models have a similar interpretation as the parity progression ratio. The parity progression ratio is the proportion of women with a certain number of children who go on to have at least one more child. To study parity transitions we apply linear probability models. We present linear regressions where we use all men in the population, as well as fixed effects models in which we only analyse variance between full biological siblings. The latter class of models requires at least two brothers in each family, that they were both born in the 1951-1967 cohort window that we study, and that they differ on either IQ or completed fertility. In practice these sibling fixed effects models are estimated as within-sibling group deviations-from-means, averaged across all sibling groups. That is to say, the estimates are based upon the relationship between variation in cognitive ability scores around the within-group mean cognitive ability score in each sibling group and variation in fertility around the within-group mean level of fertility.

Using these sibling comparison models, we can hold constant all factors that are shared by siblings. Most importantly this includes parental background variables such as parental education and parental income, but also include factors harder to measure, such as parental intelligence, behaviour, and personality traits. These models will also adjust for shared ethnic, regional, school (as long as shared between brothers), and other socialized differences within sibling groups, and will adjust for genetic similarity to the extent that this is shared amongst brothers (on average 50% of genes). As such we can examine the importance of cognitive ability for fertility net of important shared genetic and environmental factors that influence both cognitive ability scores as well as fertility preferences.

In our regression analyses we also present models with and without adjustments for birth order and family size, as there is evidence that these factors are related to both cognitive ability and fertility in contemporary Sweden [39-42]. We also present regression models with and without controls for educational achievement. Previous studies have shown a very strong relationship between education and IQ scores [43]. To examine if the fertility-IQ gradient is mediated by the effect of IQ scores on education, we examine the gradient by final achieved education.

[3] These models were estimated using Stata 15.

Results

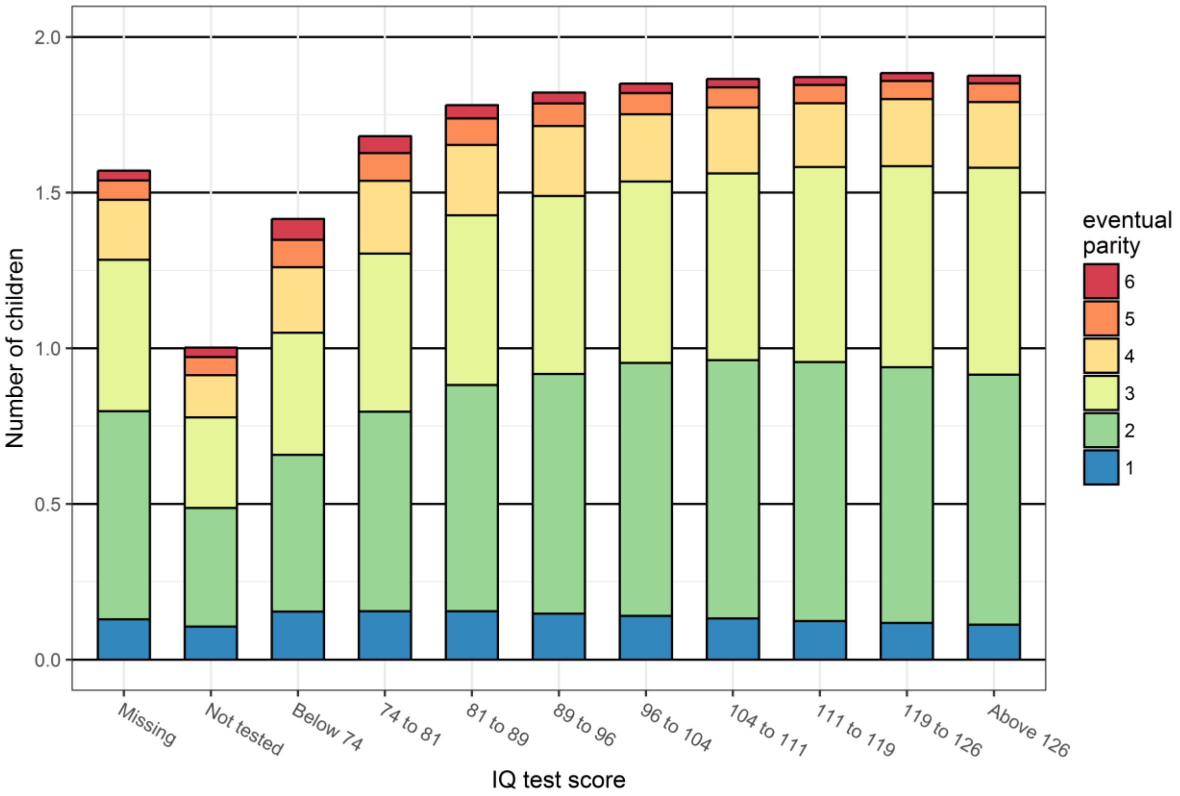
Descriptive Statistics: Cognitive Ability and Completed Fertility

Figure 1 shows mean completed fertility calculated separately for each category of our IQ measure. The overall mean number of children in the population was 1.80, where the lowest IQ category had 1.41 and the categories above the median had 1.87-1.89 children. Figure 1 shows a clear pattern where fertility is much lower for men with lower IQ scores, but that this difference largely disappears at IQ scores higher than the median. Above the median IQ score we find no large differences in average fertility. While 98% of the men in the cohorts we study attended the conscription testing, 2% did not take the IQ test, likely because they were considered unqualified for military service due to medically verifiable disabilities. We find that this group had much lower fertility, with a mean of 1.0 child versus a mean of 1.8 amongst all those who took the IQ test.

Figure 1 also shows a decomposition of completed fertility by different final parity (for parities 0 to 6+) for each IQ category. Over 40% of the Swedish men in these cohorts had 2 children, and they contribute almost half of all children to completed fertility. The lower fertility amongst men with low IQ scores is mainly the result of a large share of childless individuals combined with a small proportion of men with 2 or 3 children (see Figure S1 for the parity distribution by IQ-scores, and Figure S2 for mean IQ by parity). To understand the overall gradient between fertility and IQ scores it is mainly the IQ scores of the common parities 0 to 3 (and a lesser extent 4) that have an impact on the gradient (see Figure S3 for the distribution of fertility).

We show changes across cohorts for the fertility-IQ gradient in Tables S3 and S4 in the Supplementary Information. We find that the overall patterns in our IQ-fertility relationship were consistent over time, though we find a slightly stronger positive gradient for the earliest cohorts that we study. We also examine the IQ-fertility relationship within educational categories, and find a similar IQ-fertility gradient within each category (see Appendix A). We present tables with the source of figures as well as further descriptive tabulations in Tables S1-S7 in the Supplementary Information section for all our descriptive results.

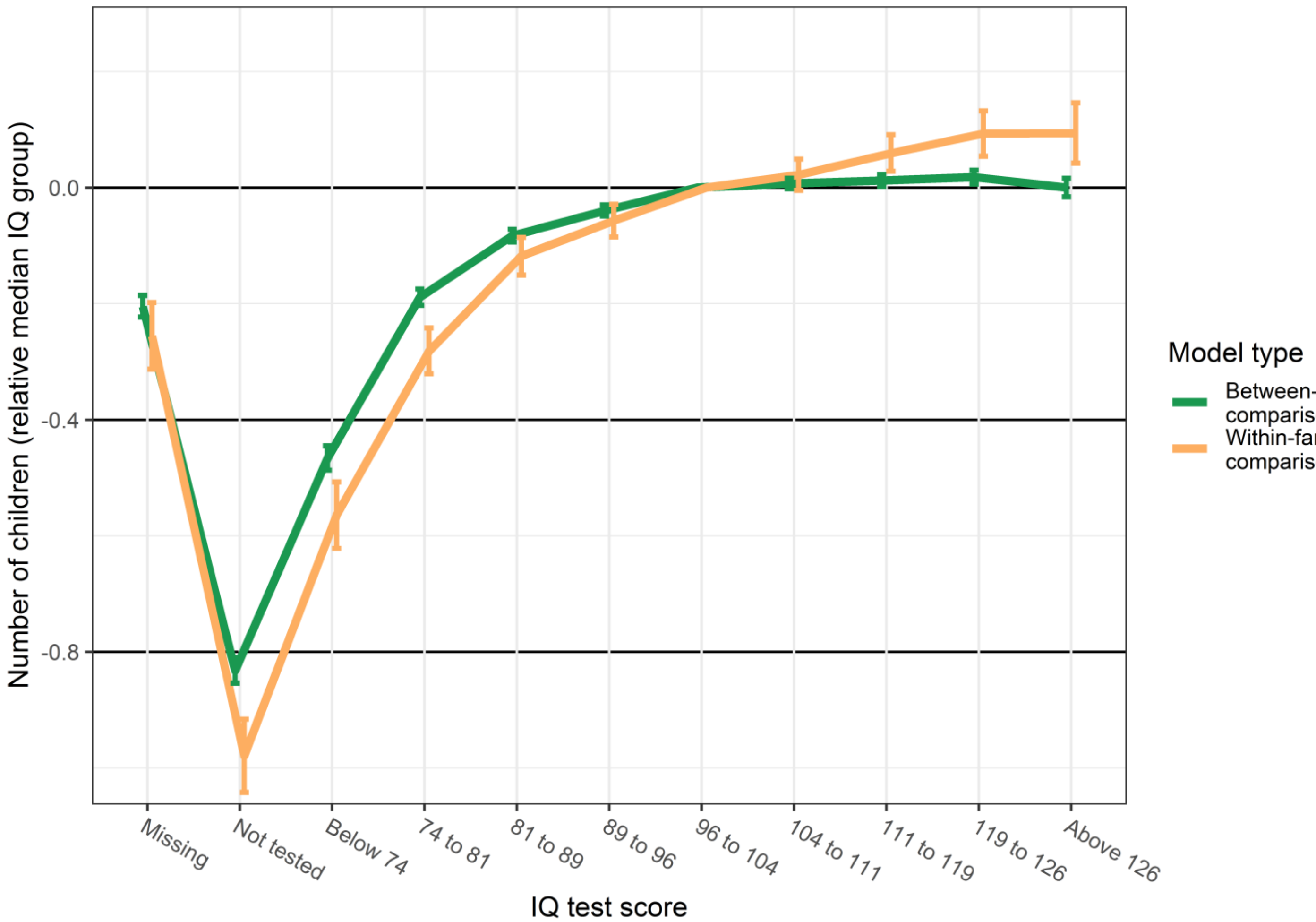
Figure 1: Completed fertility by IQ category for Swedish men born 1951-1967. Contribution to completed fertility by eventual parity of the men.



Regression Models: Cognitive Ability and Completed Fertility

Figure 2 shows results from regression models examining the effect of IQ category on completed fertility with adjustment for birth year, educational attainment, birth order, and family size. These results are from analyses based upon the full population of men as well as from analyses based upon sibling comparison models where we compare brothers born to the same mother and father. As can be seen, we find a clear positive effect of an increase in our IQ stanine measure on completed fertility, consistent with our previous descriptive results. Most of the positive relationship between IQ and fertility is attributable to very low fertility among the group with low IQ scores, and the results from our between family regression models are very similar to the descriptive pattern shown in Figure 1. In our sibling comparison models we find even stronger differences between our lowest IQ groups and the highest IQ groups. Relative to the median, the lowest group have 0.56 fewer children, and the highest 0.09 more children. Men with scores of 81 to 89 have 0.12 fewer children than the median, and men with scores 111 to 119 have 0.06 more children than the median. We find that increasing IQ is monotonically associated with higher fertility, including for men with higher IQ scores. See Model 2 in Supplementary Tables S10 and S11 for further detailed output related to Figure 2, including models without sociodemographic adjustments (e.g. educational attainment).

Figure 2: Regression of IQ on number of children for Swedish Men Born 1951-1967.



We also present models where we treat IQ as a continuous instead of as a categorical measure in our regression models to assess the linear gradient between IQ and fertility. In these models an increase in our stanine score by 1 (or 0.5 SD) is associated with an increase in number of children by 0.036 in the full population, and 0.074 in the sibling comparison models (see Tables S8-S9). Overall, when controlling for parental intelligence and educational background, socioeconomic status in the family of origin, neighbourhood and primary/secondary school environment, and to some extent genes, the relationship between cognitive ability and fertility is markedly stronger (see Tables S8-S11). While the sibling comparison analyses are necessarily restricted to a subsample of families, this change in sample does not in itself have any substantial effect on the estimates we would obtain from standard OLS models (see Tables S19-S23).

Parity Progression by Cognitive Ability

We also examine parity progressions in order to understand how cognitive ability is associated with differences across the fertility distribution, i.e. the probability of having $n+1$ children having already had n children. We find that the main difference across IQ groups is the probability of having at least one child. The results based upon the full population are shown in Figure 3, and the results based upon the sibling comparisons are shown in Figure 4. Each line illustrates the results from a model for that parity transition with the median IQ group as our reference category. We find that men with lower IQ scores are much less likely to make the transition from being childless to having a first child than other categories of men. In the cohorts that we study, 20% of men were childless at the latest age of measurement, i.e. the baseline probability of childlessness is 0.20. In our regression models we find that the relative predicted probability of being childless amongst the lowest IQ scoring group compared to the median IQ scoring group was 0.20 in the full population, and 0.23 in the fixed effects analyses, which corresponds to an approximately twice as high relative probability of being childless in our data for the most disadvantaged IQ group. Men with IQ scores below the median are also less likely to make the transition to having a second child. We find that propensities for common parity transitions to the 1st, 2nd and 3rd child are more common among men with high IQ scores, but that for very high parity transitions, men with lower IQ scores are overrepresented. Detailed output from the regression models can be found in Tables S13 to S16.

Figure 3: Probability of parity transition by IQ group (relative median IQ group) for Swedish men born 1951-1967. Between-family comparison (no fixed effects).

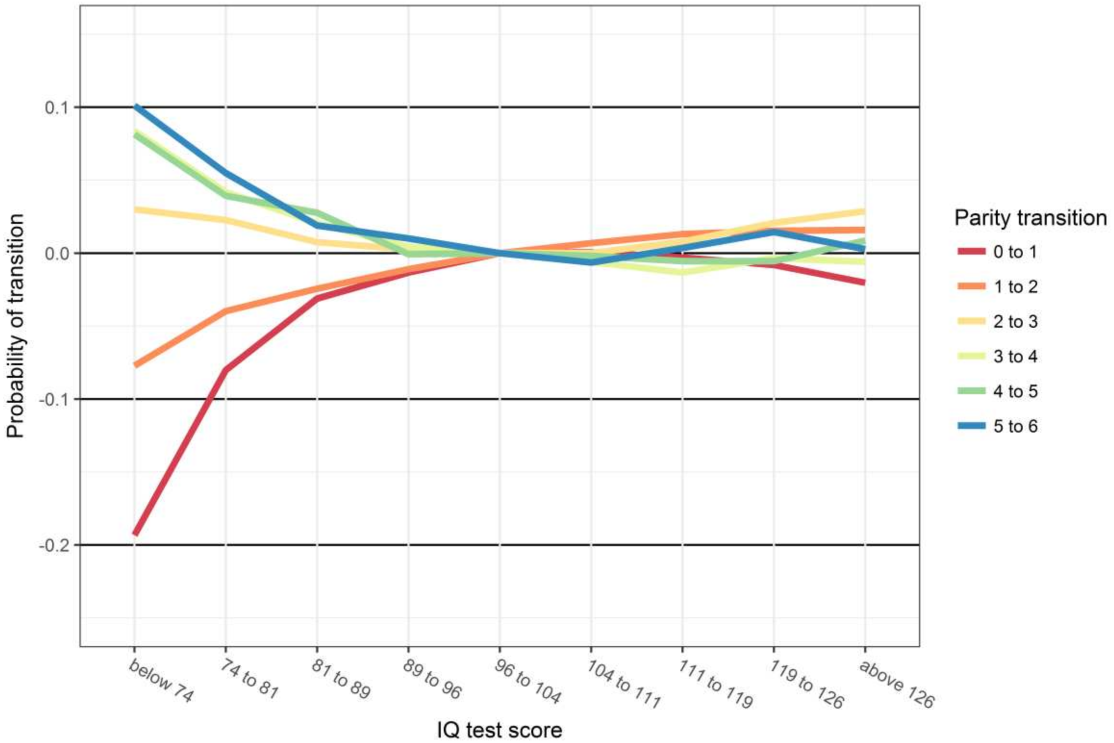
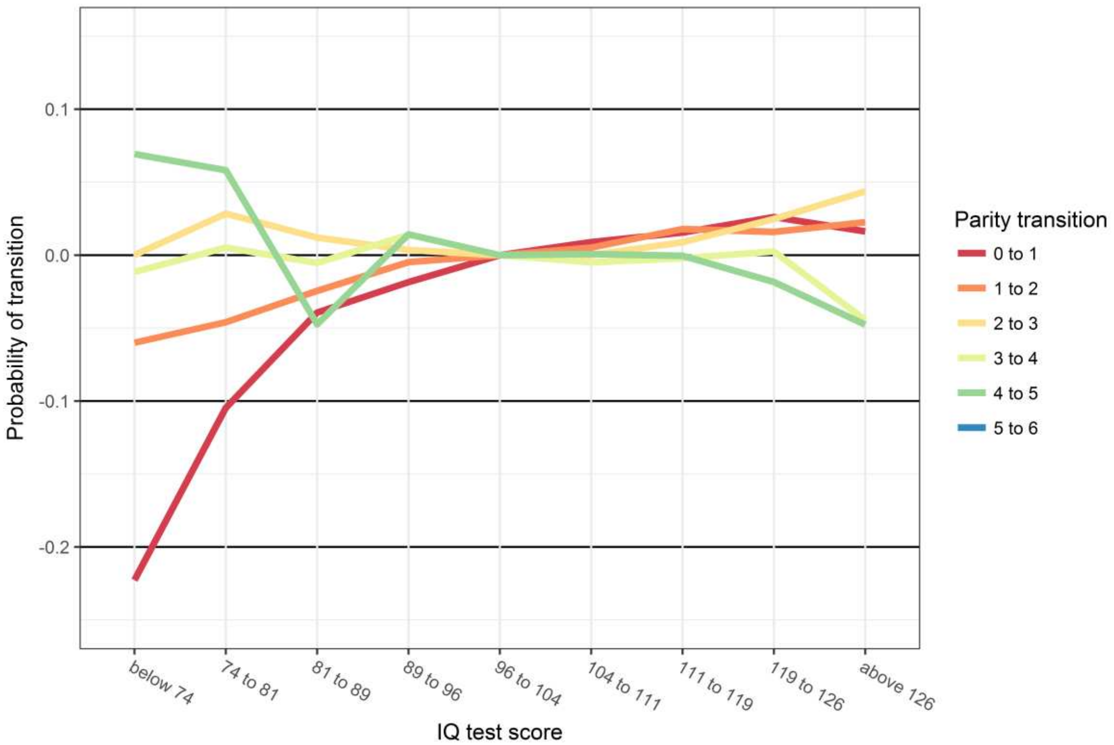


Figure 4: Probability of parity transition by IQ group (relative median IQ group) for Swedish men born 1951-1967. Within-family comparison (fixed effects).



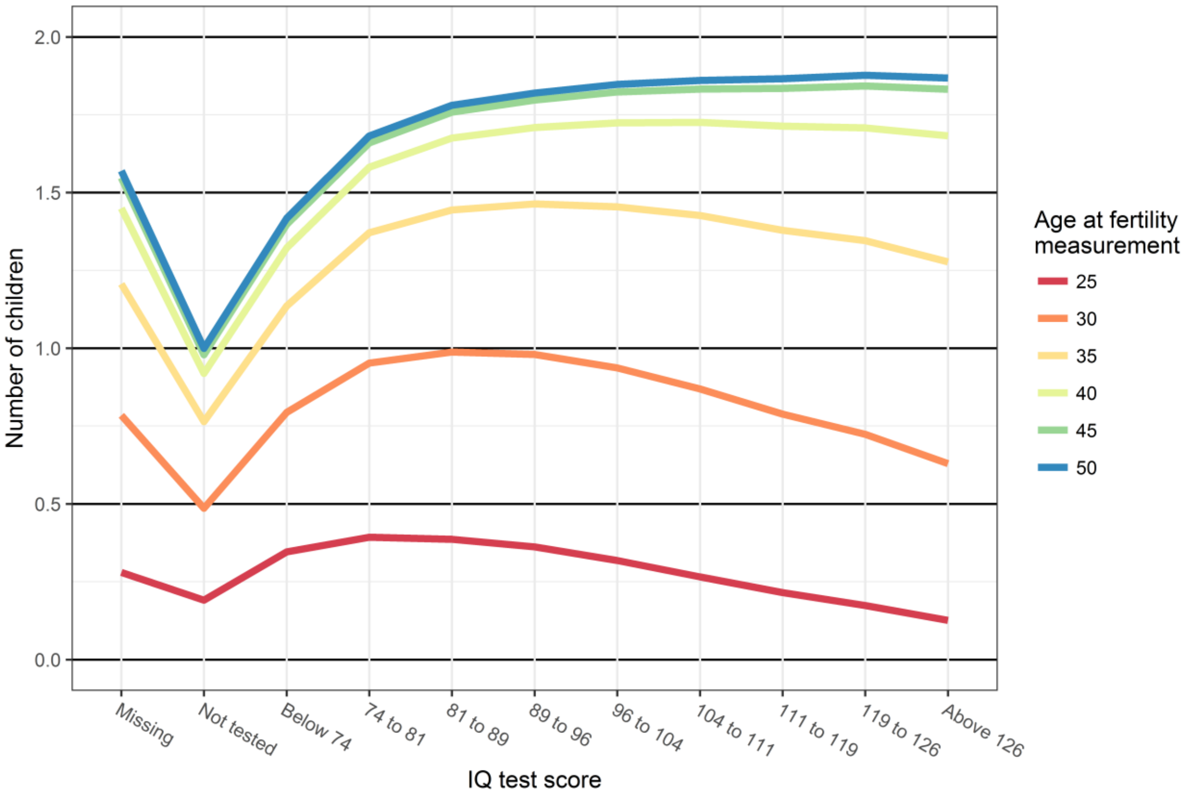
Cognitive Ability and Fertility Age Patterns

In the above analyses, we have assessed the IQ-fertility gradient at ages where fertility can be considered completed. This is important, as IQ is strongly related to the timing of births. In Supplemental Figure S4 we show the distribution of age at first birth for men who had at least one child by IQ score category. We find a very strong pattern of increasing age at first birth, where the lowest IQ score category had their first child at age 27.6 while the highest IQ score category has a mean age of 31, with a monotonic increase in-between. The share of children above age 35 is substantially greater at higher IQ scores. Such differences have strong implications for the gradient between IQ scores and fertility as measured at different ages, as we show in Figure 5. The lower ages at birth among men with lower IQ scores means that the gradient between IQ scores and fertility is completely reversed when fertility is measured before age 30. Earlier in the reproductive life course, men with low IQ scores have twice as many children as men in the highest IQ categories. Our results illustrate that we need data until at least age 45 to accurately assess the overall gradient between IQ scores and fertility. This has implications for previous research that has often been based on fertility histories collected at much earlier ages. Any study examining the relationship for men and women in their early 30s or earlier risks severe biases by discounting such childbearing, and studies based upon samples at any age below age 40 would also be problematic for studying the intelligence-fertility gradient of males [e.g. 6, 19].

Multi-partner fertility and cognitive ability

Finally, we also analysed the degree of sequential multi-partner fertility by IQ scores. In Figure S5 we show that having children with more than one woman is more common among men with lower IQ scores and that men with higher IQ scores have a larger proportion of their births with their first childbearing partner. These results therefore indicate that the higher fertility among men with higher IQ scores are due to higher fertility with a single partner, and not due to a larger number of partners over the life course. We also estimated regressions on the progression to a new childbearing partner (Tables S17 and S18).

Figure 5: Fertility by IQ category by the age of measurement of fertility for Swedish men born 1951-1967 for Swedish men born 1951-1967.



Conclusions

Overall we find a clear positive relationship between intelligence, as measured by Swedish military conscription tests at age 17 to 20, and later fertility. Contrary to most previous research we find an unambiguously positive relationship between cognitive ability and fertility. These results are consistent both in descriptive tabulations and in our regression models. We also find a positive relationship between intelligence and fertility when using sibling comparison models, and when examining the relationship between intelligence and fertility within each level of attained education. That is to say, the relationship between cognitive ability and fertility is clear even after accounting for socioeconomic status in the family of origin, other shared environmental factors during childhood, as well as attained educational level. A common criticism of intelligence tests is that they are socioculturally biased. However, given the homogenous nature of our study population, Swedish-born men, and siblings sharing the same parents, such issues are less of a concern.

When we adjust for parental background characteristics we find that the group with the lowest IQ scores (below 76) have 0.58 fewer children than men with median IQ, and men with the highest IQ scores (above 126) have 0.14 more children. We find that men with very low IQ scores are more likely to be childless or have only 1 child, and that men with high IQ scores frequently have 2 or 3 children, resulting in a clear positive gradient between intelligence and fertility. At higher parities the pattern is more ambiguous, with lower IQ scoring men overrepresented amongst those who had 5 or more children, but such births are not common enough to influence the overall fertility gradient.

We argue that this study marks a significant improvement over virtually all previous research on this topic. First, we use a larger and more representative dataset than all previous research on fertility and cognitive ability. Critically, our study includes information on the complete population of Sweden, including men that for various reasons would not be included in standard surveys. While a share of our population did not take the conscription IQ test, we can identify these individuals and their subsequent childbearing and educational trajectories. As much previous research on intelligence and childbearing has been interested in population-level outcomes, this is a clear improvement over previous research on this topic. Second, we provide a rich and detailed description of the fertility outcomes, including parity transitions, measurement of fertility at various ages, age at first birth, and childbearing with sequential partners. By examining differences in the intelligence-fertility relationship by age at measurement we demonstrate the importance of allowing individuals to complete their fertility in order to accurately assess the relationship between IQ scores and fertility, as using early age cut-off points risks severely biasing the results for the overall gradient.

We note that our findings are inconsistent with a large literature on this topic predicting "dysgenic deterioration" of the population [e.g. 2, 18, 19], through an increasing prevalence of genes associated with high fertility and low IQ in subsequent generations. We find an unambiguously positive association for all of the birth cohorts that we study, though we cannot say anything certain about the population level effect since we lack data on cognitive ability and fertility for women. We also note that the very strong positive association between lower IQ scores and early age at first birth will, given genetically heritable fertility, mean that the relative share of high IQ traits will increase in subsequent generations. In a population with above replacement fertility earlier childbearing would result in the increase of a quicker reproducing trait, but in a society with below replacement level fertility, such as the contemporary West, the effect is reversed and the population proportion of a slower reproducing trait will increase as a share of the total population over time.

The positive gradient between cognitive ability and fertility that we observe in Sweden is consistent with emerging evidence that an increasingly wide variety of status indicators are positively associated with fertility in contemporary high-income societies. A positive macro-level association between income and fertility has also been observed across most OECD countries over recent decades [e.g. 44]. In Sweden and the other Nordic countries, income and labour force participation are positively associated with fertility decisions at the individual-level for both men and women [30]. In Sweden a positive association between education and fertility has been observed for men for several decades, while the negative gradient has disappeared for women over time [29]. Interestingly, we find that the IQ-fertility gradient within educational levels is similar to the IQ-fertility gradient at the population-level. In other words, despite the very strong relationship between cognitive ability and education, we find that the association between cognitive ability and fertility is not mediated by education.

The observation of strikingly low fertility among individuals with the lowest IQ scores and the non-tested group also demonstrates that socially disadvantaged groups have lower fertility than other groups in society. The differences shown in our within-family models are very substantial, with the most disadvantaged groups having less than half the children of the rest of the population in sibling comparison models. Our results suggest that socially disadvantaged groups of Swedish males either have low fertility preferences, or are constricted in their opportunities to act upon their fertility preferences. This might be explained by physiological or socioeconomic limitations, or difficulties in finding a partner for childrearing. This is relevant from a policy viewpoint as childlessness is associated with a number of negative health outcomes [45]. This issue is of rising importance given increasing rates of childlessness in high-income countries, which is particularly concentrated amongst lower educated men [29].

Much research shows that the relationship between socioeconomic success and fertility was positive in pre-industrial societies but reversed during the industrial revolution and subsequent period of modernization [4, 12]. A tentative explanation for the transformation from a positive gradient in high fertility societies to a negative gradient during the fertility transition, and then the observed re-emergence of a positive gradient (as shown in this study), is related to ideational change across different social groups. During the 20th century high status groups adopted values and behaviours associated with restraint, and ideational values that are sometimes described as post-materialist, earlier, and to a greater extent, than other social groups [46, 47]. As a consequence, fertility decreased first amongst these high status groups. These changes have been described as the Second Demographic Transition in the context of fertility and family formation behaviours. This led to a negative relationship between socioeconomic success and fertility across much of the 20th century. While preferences for low fertility may have been more common amongst individuals with higher levels of intelligence and education in the 20th century, these values have now diffused across society and are now less associated with income, intelligence, or wealth in Sweden. The positive relationship between intelligence and fertility is probably explained by men with higher cognitive ability having higher status and more resources, and the fact that high cognitive ability is an attractive trait in the partner market [11]. In affluent societies today, individuals' expressed fertility desires are higher than the fertility levels observed in the population. Socioeconomically successful individuals are therefore better able to afford and achieve modal and preferred family sizes (2 or 3 children), which are above the population fertility mean. We think that a plausible future scenario is that many societies will see the re-emergence of a positive association between high intelligence – as well as other dimensions and correlates of status – and fertility. Such a scenario would also likely imply an increasingly strong correlation between low fertility and other dimensions of disadvantage.

Due to the nature of our data, our analyses are restricted to men. A major task of future research on this topic is to find comparably large and representative datasets that also include women. Such datasets do exist – for example, both men and women are conscripted by the military in Israel – but institutional barriers may prevent the widespread use of these data by researchers. A lack of data on women means that it is also difficult for us to project how the relationship between cognitive ability and fertility will translate into the distribution of cognitive ability in future generations.

We have analysed men born in Sweden in the 1950s and 1960s. Sweden is a relatively homogenous and wealthy nation with a developed welfare system, and therefore our findings might not be generalizable everywhere. Some social trends have emerged in Scandinavia before becoming a norm elsewhere. The evolution of a positive intelligence and status gradient for fertility may be one such phenomenon. It is also worth noting that the Swedish welfare state protects the living standards of the more vulnerable in society, and structural constraints on the ability of men with low cognitive scores to realize their fertility preferences may be stronger elsewhere. We expect that more researchers will find a positive relationship between intelligence and fertility. We also expect that such effects will be larger when researchers examine gradients within various social strata and adjust for parental background factors, as we have found in Sweden.

Appendix A

Within each educational category we find an IQ-fertility gradient that is very similar to that in the full population, with the highest IQ scores among parity 2 and 3, and a consistent positive gradient. The overall gradient between IQ scores and fertility is slightly stronger within educational groups than for the complete population, which also show in Figure S6 with mean completed fertility by IQ score. This implies, consistent with the lack of mediation by education in our regression models (when we compare models with and without adjustments for educational attainment of our males), that the relationship between IQ scores and fertility is not mediated by education. The similar gradient within different educational groups is consistent with our regression results (see Tables S8-S11).

In Figure S7 we show the number of men by education and IQ score. There is a very strong correspondence between IQ scores and educational achievement with virtually no tertiary educated men with low IQ scores, and virtually no one with only primary education amongst men with the highest IQ scores. We note that the distribution of educational attainment for men who missed the cognitive ability tests largely represents the population as a whole, while that of the non-tested group is more representative of the lower IQ score groups. This suggests that the non-tested group with low fertility and low educational achievement largely consisted of individuals that would have scored below average on IQ measurements if they had taken the test, and that the gradient we show between fertility and IQ scores in Figure 1 is underestimated.

Supplemental figures and tables

Supplemental data and figures are available at the following link:
https://doi.org/10.6084/m9.figshare.c.4481804.v1

All aggregated data and detailed analysis code related to this paper is available in Data available from the Dryad Digital Repository:
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