

# Natural selection in the Health and Retirement Study

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I investigate natural selection on polygenic scores in the contemporary US, using the Health and Retirement Study. Results partially support the economic theory of fertility as an explanation for natural selection: among both white and black respondents, scores which correlate negatively (positively) with education are selected for (against). However, unlike in the UK, there is little evidence that selection effects are larger among low-income or less educated people.

Hugh-Jones and Abdellaoui (2022) explain patterns of natural selection on polygenic scores in the UK, using an economic theory of fertility derived from Becker and Tomes (1976). The theory has two components.

1. There is a trade-off between time spent working and raising children. This leads people with more human capital and higher expected wages to have fewer children.
2. The trade-off is sharper for low-income people, people with low human capital, and single parents. As a result, natural selection is stronger among these groups.

The evidence for point 1 is that polygenic scores which correlate positively with human capital correlate negatively with number of children, i.e. they are being selected against. And vice versa, scores which correlate positively with human capital are being selected for. The evidence for point 2 is that correlations with number of children are larger and more significant among people with lower income, less education and single parents.

Here, I test the same theory in the US population, using the Health and Retirement Survey (HRS 2023a, 2023b). This gives an independent test of the theory. The HRS is more representative of the population than UK Biobank, which addresses one potential weakness of the previous paper. Also, the HRS provides precalculated polygenic scores (Ware et al. 2020) for both black and (non-hispanic) white participants, so I can check whether the human capital theory of natural selection works in both these ethnicities.

Economic theory treats all humans as the same. Once you have controlled appropriately for people’s preferences, resources and beliefs, there should be no difference between ethnicities. So, the economic theory of fertility predicts that patterns of natural selection should be the same in both white and black ethnic groups. Of course, ethnic groups may have different economic characteristics. Also, most of the polygenic scores were created using people of European ancestry. This means they are less predictive for people with African ancestry. If natural selection works via scores’ correlation with phenotypes, then we would expect these correlations to be smaller among black people.

## Data

The HRS sample focuses on cohorts born between 1920 and 1960, but contains some younger and older participants. I include only male participants born before 1965 and female participants born before 1970, which guarantees that most will have completed their fertility by 2010.

The resulting sample contains 10619 genotyped white participants and 2803 genotyped black participants. Genotyping took place in 2006, 2008 and subsequent years. I discard obsolete PGS for which there is a newer, more accurate score targeting the same phenotype. I also discard PGS for number of children ever born (but keep scores for age at first birth). This leaves a total of 58 scores.

PGS are rescaled to zero mean and unit variance within each ethnic group, so effect sizes are not directly comparable between ethnic groups, but are measured in standard deviations of the within-ethnic-group score. In all regressions using PGS, I control for ten principal components of the DNA array data.

I use realised fertility (number of children ever born) as the key dependent variable. I use this rather than relative lifetime reproductive success for ease of interpretation and because I don’t have data for dates when children were born. My focus is on examining patterns of natural selection across PGS, rather than estimating their effects on PGS over time; raw fertility is good enough for this.

The HRS contains weights which match survey respondents to the US population. I use weights for the biomarker subsample (\*BIOWGTR in the HRS tracker file). Since half the sample enters the extended interview including biomarker data in each biannual survey, I weight individuals by either their 2010 weight or their 2012 weight. This maximizes the available sample of both black and white respondents, and should approximately match the US population of the sample cohorts between 2010 and 2012. Statistical tests are adjusted for clustering and stratification using the R “survey” package (Lumley 2023).

## Results

I estimated effect sizes of PGS correlations with realised fertility among black and white respondents separately.<sup>1</sup> Appendix Figure 3 shows effect sizes for white respondents only; power is too low for individual PGS estimates to be informative in the black sample. Standard errors are large because of the relatively low sample sizes, and no scores are significant at Bonferroni-corrected  $p < 0.05/116$ . But I am most concerned with looking at patterns across scores rather than judging the significance of individual scores.

Figure 1 plots each PGS’s partial correlation with fertility against its partial correlation with educational attainment. The relationship is negative among whites (correlation -0.786, bootstrapped 95% C.I. -0.989 to -0.583) and negative but insignificant among blacks (correlation -0.384, bootstrapped 95% C.I. -0.832 to 0.063). Bootstraps are used so as to make inferences from the sample of respondents (the different PGS are not a “sample” of anything).

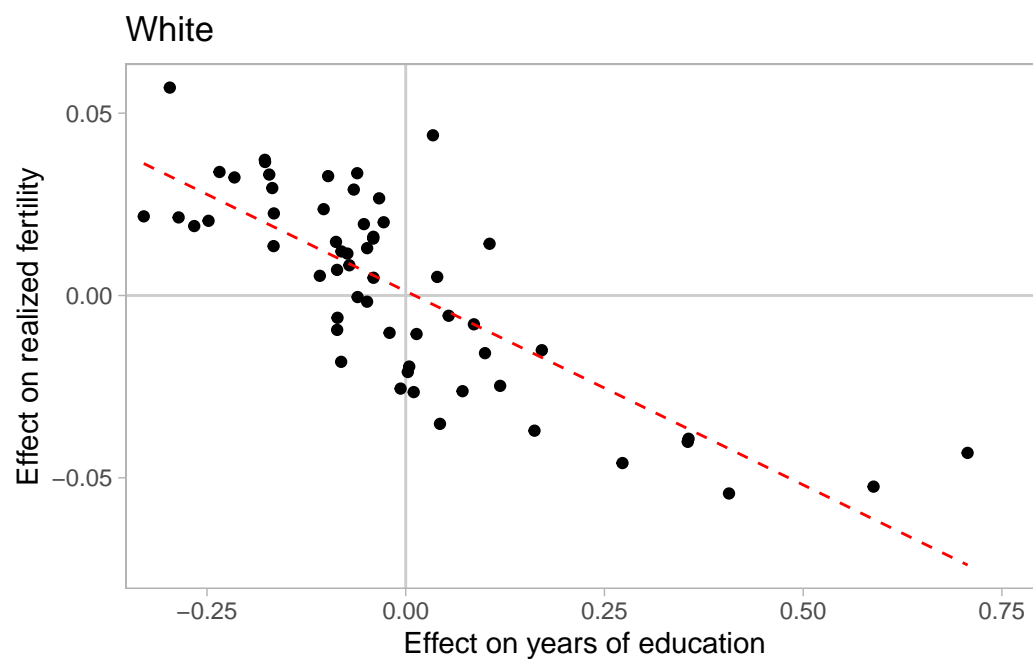
I can also examine natural selection in the previous generation, by regressing PGS on respondents’ number of siblings (including dead siblings) in 2010. I reweight respondents by the reciprocal of their number of siblings, to account for parents of many siblings being more likely to be a parent of a respondent. Parents of no siblings cannot be included, so effect sizes are not comparable across the generations. Appendix Figure 4 plots effects on number of siblings versus effects on years of education. Correlations are insignificant for both ethnic groups, although note that standard errors are large (whites: correlation -0.161, bootstrapped 95% C.I. -0.581 to 0.26; blacks: correlation 0.2, bootstrapped 95% C.I. -0.425 to 0.824).

I next test part 2 of the theory more directly by interacting PGS with measures of education, income, marital status, and age at first birth. Education is years of education, split at 12 years. Income is respondent’s mean wage income over all surveys, residualized on a full set of birth year dummies, and median-split. From here on I only use the white subsample: there are too few black respondents to be informative.

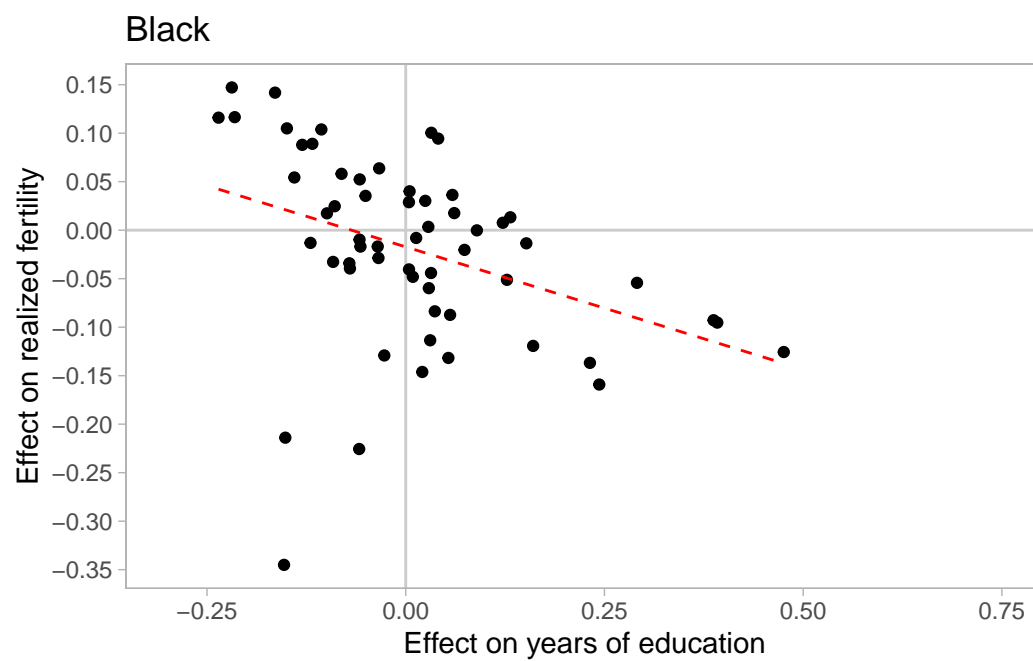
Appendix Figure 5 shows essentially no difference in the distribution of absolute effect sizes between respondents with more and less education. Appendix Figure 6, on the other hand, shows that absolute effect sizes appear larger among lower-income respondents. Appendix Figure 7 shows absolute effect sizes for respondents who were married in 2010 against all other statuses. Effect sizes appear larger for unmarried respondents. Appendix Figure 8 splits respondents by age at first birth (median within each ethnicity). There are no large differences between early and late parents. Note that the N is lower here due to missing

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<sup>1</sup>Throughout, I use “effect” as shorthand for “regression coefficient”. No claim about causality is implied. Recall that natural selection involves correlation, not necessarily causation, between selected characteristics and fertility.



(a)



(b)

Figure 1: Scatterplot of PGS effect sizes on fertility and years of education. Controls include 10 principal components of genetic array data. Dashed lines show linear regressions.

values. Table 1 shows means and 95% confidence intervals for mean absolute effect sizes in the two groups, and the difference between them, using bootstraps. Differences for income and marriage are significant.

Table 1: Bootstrap estimates and 95% confidence intervals for mean absolute effect sizes of PGS on fertility in “low” and “high” groups among white respondents. Groups are: 0-12 years education vs. 13-17 years; below vs. above median income; all others vs. married; below vs. above median age at first birth. 99 bootstraps.

	Low group	High group	Difference
Education	0.027 (0.017 to 0.036)	0.023 (0.015 to 0.032)	0.003 (-0.009 to 0.015)
Income	0.038 (0.029 to 0.046)	0.025 (0.016 to 0.034)	0.013 (0.003 to 0.022)
Marriage	0.040 (0.031 to 0.050)	0.024 (0.016 to 0.031)	0.017 (0.007 to 0.027)
Age 1st birth	0.025 (0.015 to 0.036)	0.029 (0.019 to 0.039)	-0.003 (-0.016 to 0.009)

The economic theory of fertility in Hugh-Jones and Abdellaoui (2022) implies that correlations between education and fertility should be more negative for lower-income/education people, single parents and people who have children earlier.<sup>2</sup> This in turn implies that correlations between PGS effects on education and on fertility should be more negative among these groups. I tested this with bootstraps, but confidence intervals were always too wide to be informative.

## Discussion

The results here provide qualified support for the economic theory of fertility as an explanation for contemporary natural selection in humans. PGS which predict less education are being selected for, and PGS which predict more education are being selected against. PGS effects on fertility also appear larger for low-income groups and unmarried respondents. However, there is little evidence for larger effects among people with lower education or younger parents. This may be due to the low sample size. But in the UK, the between-group differences were large (Hugh-Jones and Abdellaoui 2022); differences that big would surely have been visible here. Lastly, the smaller black sample makes most tests inconclusive for this population: I can only say that the data do not reject a negative association between PGS correlations with fertility and on education.

<sup>2</sup>See Hugh-Jones and Abdellaoui (2022) equation (6) and following.

## Appendix

### Acknowledgements

The HRS (Health and Retirement Study) is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan.

### Figures

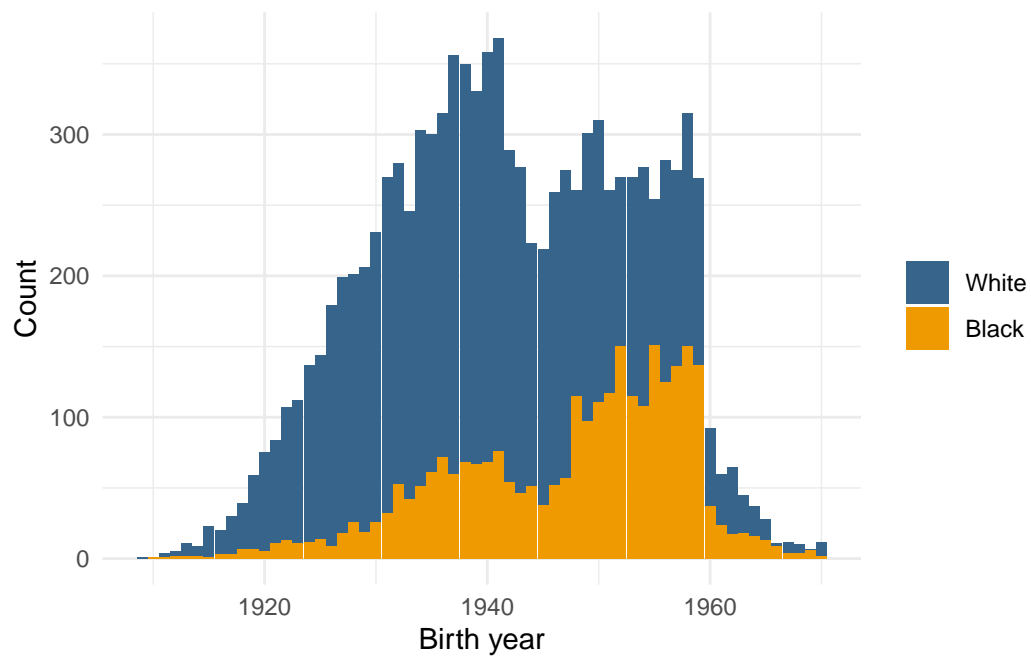


Figure 2: Distribution of birth years for the sample

### Effects of polygenic scores on fertility

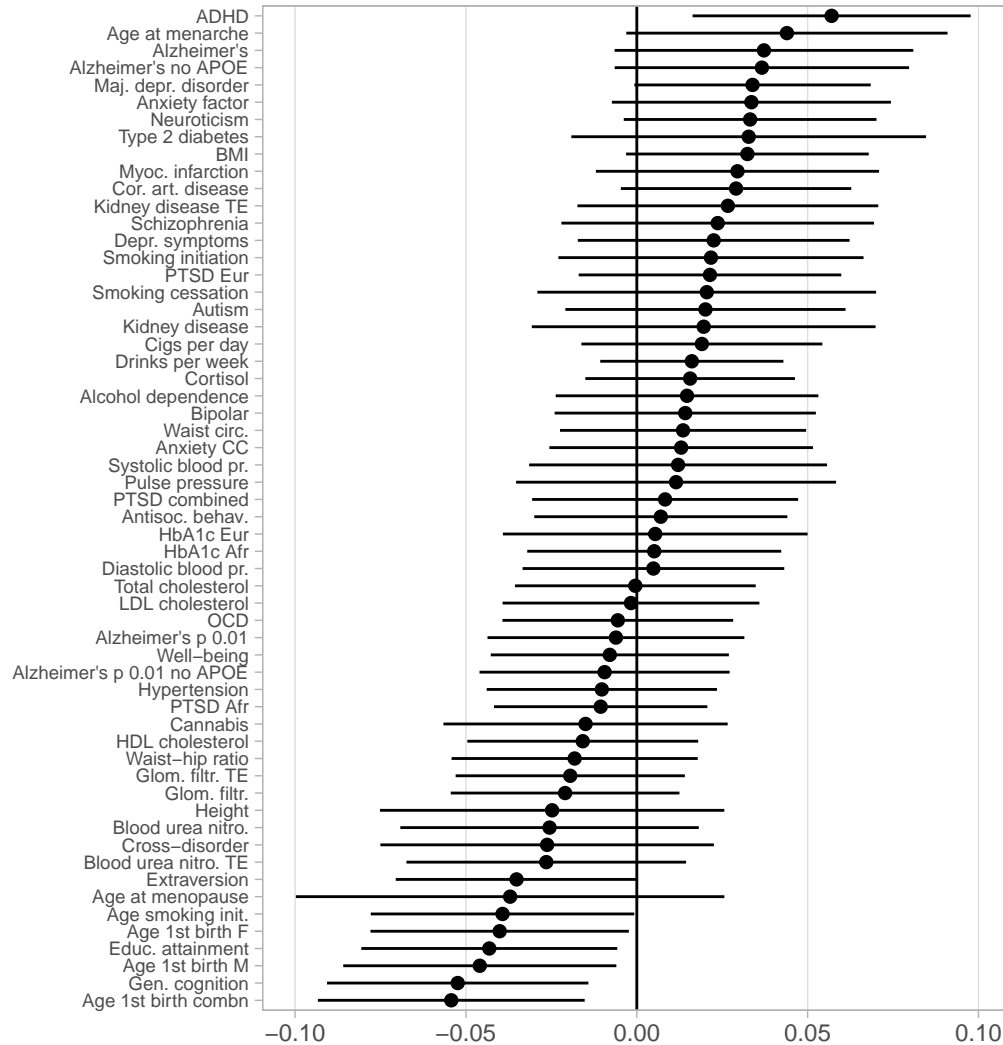
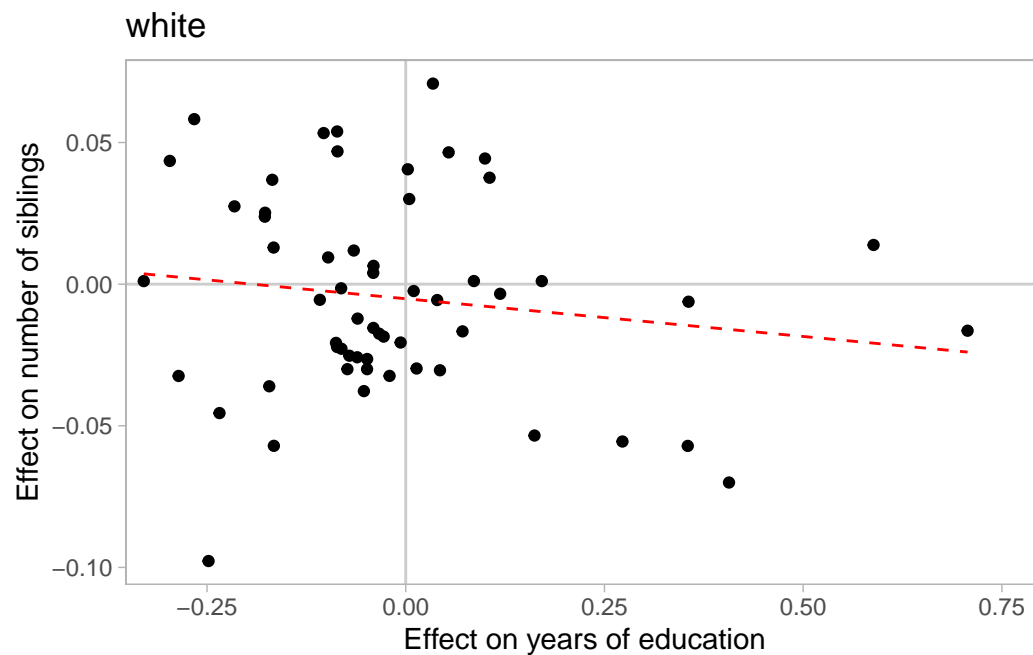
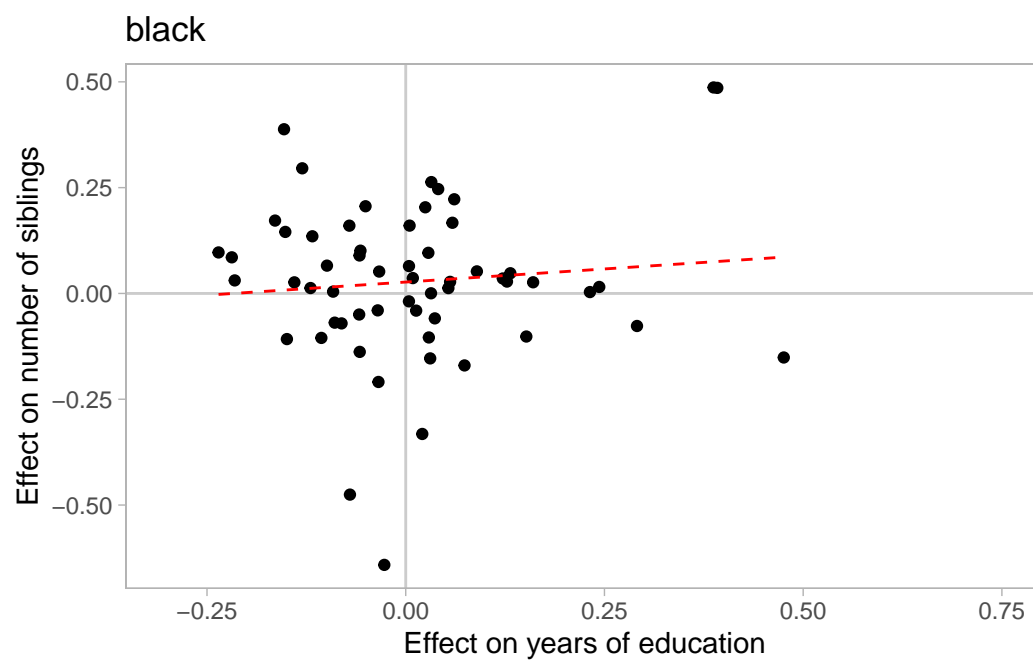


Figure 3: Effects of PGS on realized fertility among white respondents. Values are partial correlations of a one standard deviation (within ethnicity) change of the PGS with fertility, controlling for 10 principal components of genomic array data.



(a)



(b)

Figure 4: Scatterplot of PGS effect sizes on number of live siblings and years of education. Controls include 10 principal components of genetic array data. Dashed lines show linear regressions.



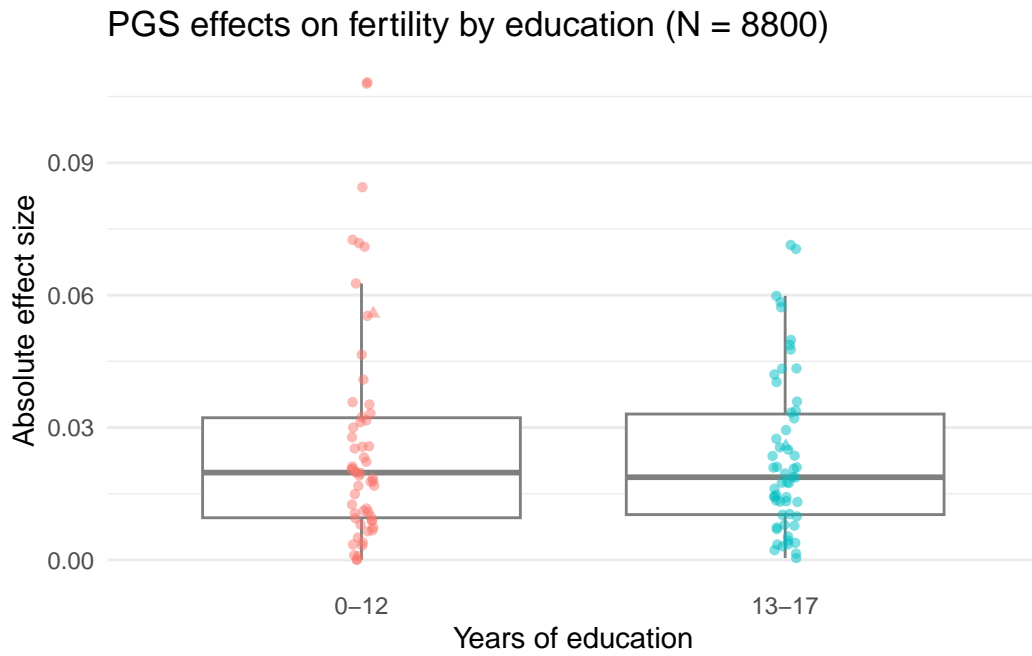


Figure 5: Boxplots of polygenic score effects on fertility by education among white respondents. Effect sizes are absolute sizes of effects of a one standard deviation (within-ethnicity) change of the PGS on fertility, controlling for 10 principal components of genetic array data, estimated within the low/high education group. Boxes show quartiles.

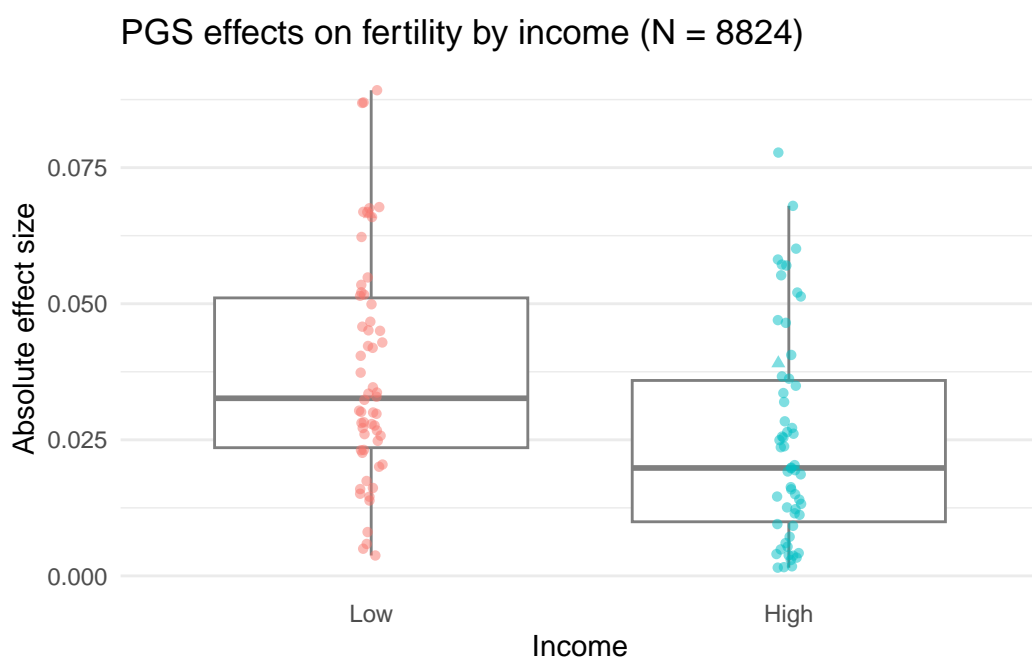


Figure 6: Boxplots of polygenic score effects on fertility by income among white respondents. Effect sizes are absolute sizes of effects of a one standard deviation (within-ethnicity) change of the PGS on fertility, controlling for 10 principal components of genetic array data, estimated within the low/high income group. Boxes show quartiles.

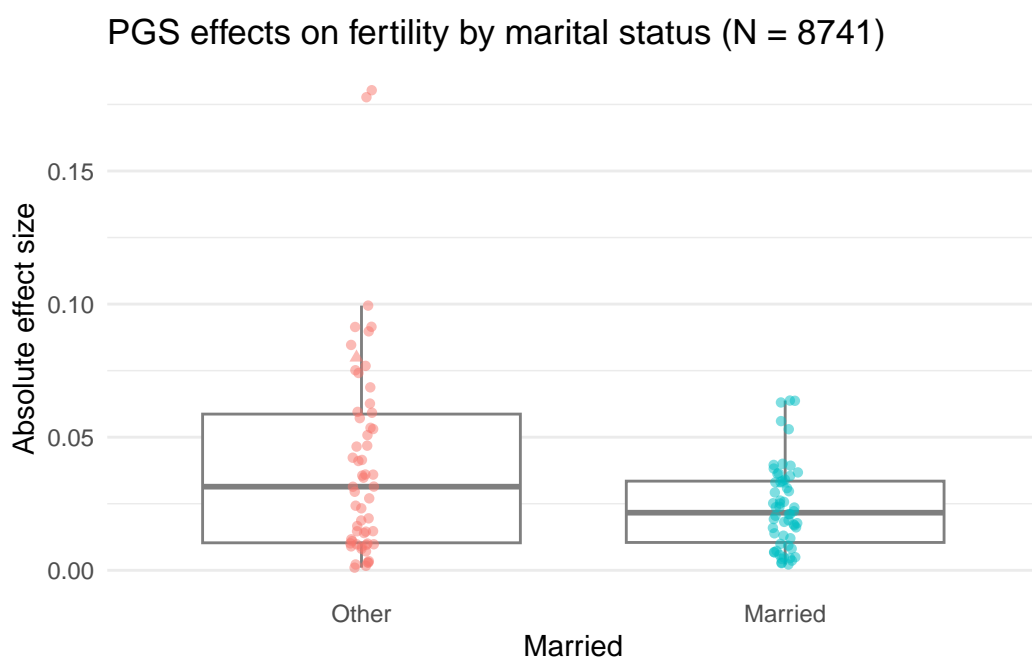


Figure 7: Boxplots of polygenic score effects on fertility by marital status among white respondents. Effect sizes are absolute sizes of effects of a one standard deviation (within-ethnicity) change of the PGS on fertility, controlling for 10 principal components of genetic array data, estimated within the low/high income group. Boxes show quartiles.

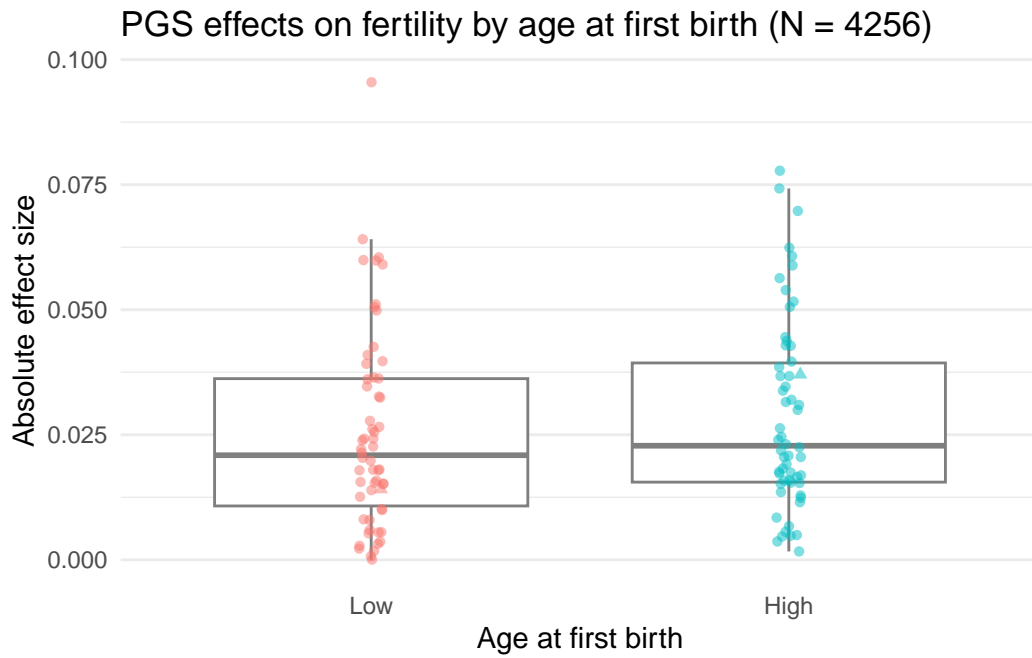


Figure 8: Boxplots of polygenic score effects on fertility by age at first birth (median split) among white respondents. Effect sizes are absolute sizes of effects of a one standard deviation (within-ethnicity) change of the PGS on fertility, controlling for 10 principal components of genetic array data, estimated within the low/high income group. Boxes show quartiles.

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