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Nature's Curriculum: Genes Linked to Educational Attainment and Adult Socioeconomic Status across Birth Cohorts in a Nordic Welfare State

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Abstract

Recent research has identified genes linked to educational attainment, but their effects on subsequent socioeconomic outcomes, particularly in egalitarian Nordic welfare states, remain largely unexplored.

We analyze two genetically informed Finnish datasets, encompassing longitudinal register information on earnings, employment, unemployment, occupational status, and social assistance receipt (n=31,622). We examine the role of a polygenic score for educational attainment (EA PGS), achieved level of education, and family socioeconomic background in predicting these outcomes in adulthood. We further study cohort differences around Finland's comprehensive school reform of the 1970s that aimed to promote equality of opportunity.

Our results show that in the post-reform generation, EA PGS did not significantly predict adulthood outcomes after controlling for the achieved level of education. A notable exception was occupational status. In contrast, in the pre-reform generation, EA PGS predicted later socioeconomic outcomes beyond education, indicating relationships not fully explained by schooling. Parental income did not moderate the effect of the EA PGS. Our findings shed additional light on the mechanisms connecting genetic factors and life chances, demonstrating that institutional setting and schooling can shape the influence of genetic endowment for high educational attainment in adult socioeconomic status.

Keywords

Education, polygenic score, socioeconomic status, equality of opportunity, cohort differences.

Introduction

It is widely recognized that life chances are not equally distributed across family backgrounds. The intergenerational transmission of socioeconomic status is evident even in the Nordic welfare states, including Finland, which place a high value on and actively promote equality (Erola et al., 2016; Thaning, 2021). Given that children benefit from their parents' material, cultural, and social resources for success and also inherit their genes, an individual's educational and economic attainment trajectory might start with a double (dis-)advantage (Belsky et al., 2018, 2016; Harden et al., 2020; Lin, 2020; Papageorge and Thom, 2020). Intergenerational inheritance of socioeconomic status is thus defined by the accumulation of environmental and genetic factors. Importantly, the institutional setting is likely to influence how these factors are linked to adult socioeconomic status in different countries, as well as within a country over time (Engzell and Tropf, 2019; Harden, 2021; Lahtinen et al., 2024).

Recent research exploiting information on genetics and classical sociological theories show that later life chances are indeed largely influenced by factors already defined at birth (Akimova et al., 2025; de Zeeuw et al., 2015; Okbay et al., 2022; Visscher, 2022). In this sense, both the socioeconomic status of a family and genes passed on from one generation to the next can be understood as circumstances beyond an individual's control that significantly influence later socioeconomic outcomes (Harden, 2021; Roemer, 2003). However, different societies have, to varying degrees, aimed to modify this link. Finland's comprehensive and free education system pursues two main goals: promoting equal opportunities and maximizing individuals' potential for thriving in adulthood. Equality of opportunity means ensuring that everyone has the same chance to succeed regardless of their background, while meritocratic principles suggest that social mobility and advancement in life should be based on merits, for example talent, effort and performance (Roemer, 2003). There is no consensus

in the scientific literature on the extent to which disparities in socioeconomic outcomes due to genetic endowment should be reduced through public policies and whether they are included in the sphere of "equality of opportunity" (Harden, 2022, 2021; Mills and Tropf, 2020; Morris et al., 2022; Plomin, 2018), but most people would agree that individuals should be able to benefit from their inherent talents regardless of their background and the different resources available to their family. Consequently, leveraging information on genetics enables a more comprehensive understanding of the mechanisms underlying social inequalities and provides a means to evaluate structures that promote equal opportunities.

Behavioral genetic studies have demonstrated that virtually all complex traits in humans have a genetic basis (Abdellaoui and Verweij, 2021; Polderman et al., 2015), and outcomes tied to education, such as earnings, occupational status, or unemployment are no exception (Akimova et al., 2025; Kweon et al., 2025). Over the past fifteen years, genome-wide association studies (GWASs) have identified for various complex traits genetic variants, single nucleotide polymorphisms (SNPs), that can be linked to them (Visscher et al., 2012). By summing up the SNPs associated with a trait, such as educational attainment, polygenic scores (PGSs) are created which indicate the genetic endowment towards this trait. The PGSs for educational attainment (EA PGS) explain up to 16 percent of the variance in years of education completed (Lee et al., 2018; Okbay et al., 2022, 2016), which is comparable to the influence of commonly studied indicators of the socioeconomic status of a family (Ghirardi et al., 2024; Harden, 2021). The genetic endowment for achieving high educational attainment correlates with a broad range of cognitive (IQ tests performance and pace of cognitive development) and non-cognitive skills (including a wide range of traits generally improving one's educational performance, such as grit, conscientiousness, motivation, or interpersonal skills) (see Demange et al., 2021), and decision-making throughout the school years (course choices and persistence) (Belsky et al., 2016; Harden et al., 2020). Family background does

not fully explain these associations as those with higher EA PGSs have been found to have better life chances regardless of their parental socioeconomic status and resources. This has been shown by controlling for family background and utilizing within-family analyses while the genetic prediction was substantially reduced (Belsky et al., 2018, 2016; Ghirardi et al., 2024; Tan et al., 2024). The EA PGS arguably plays an important role not only in educational attainment but also for social mobility.

Relatively little is known about how institutional settings alter the influence of genetic endowment in (re-)producing inequality in socioeconomic outcomes (Engzell and Tropf, 2019). Examining an egalitarian Nordic welfare state, such as Finland, over a longer period helps to unravel how genetic influences evolve within the societal fabric. Due to a Finnish educational reform of the early 1970s the minimum years of comprehensive schooling increased from 6 to 9 years, the costs of attaining education were reduced, and tracking into academic and vocational schools was postponed (Böckerman et al., 2021; Lahtinen et al., 2023; Pekkarinen et al., 2009). Sociological research on the consequences of educational expansion has demonstrated an increasing importance of formal educational qualifications in subsequent socioeconomic outcomes (Breen, 2010; Erola et al., 2016). Despite the higher levels of education observed among younger Finnish generations compared to older ones, the economic returns to additional schooling remain substantial in Finland. Individuals without formal qualifications encounter considerable difficulties in securing well-remunerated employment (Mäki-Fränti, 2019). At the same time, the lack of formal education might have been compensated by traits implied by the EA PGS in older birth cohorts, while this might be more difficult in today's Finland. A key consideration is therefore whether genes linked to educational attainment influence life chances beyond the realm of schooling (Belsky et al., 2018, 2016; Lin, 2020; Papageorge and Thom, 2020). The extent to which genetic endowment for education matters for socioeconomic status in adulthood, when achieved level

of education is accounted for, is largely unknown. Furthermore, the implications of detecting genetic influences beyond formal educational qualifications in terms of equality of opportunity are not fully comprehended yet.

In this study, we bridge existing research strands on intergenerational transmission of education and subsequent socioeconomic outcomes and on its interplay with the institutional setting. Using longitudinal register data, the present study contributes to the literature by providing unique evidence on two Finnish generations who attended school under different educational systems. Our analysis is based on reliable administrative records encompassing a large number of individuals and their parents, and it replicates the observed associations in an independent, genetically informed sample. Our research questions are: 1) Is genetic endowment for achieving high education associated with adult socioeconomic outcomes beyond schooling? 2) Do we find differences between birth cohorts going through the educational system before and after the Finnish comprehensive school reform designed to promote equality of opportunity? 3) Does family income moderate the influence education linked genes have on individuals' socioeconomic status in adulthood?

Previous literature

The influence of education-linked genes beyond schooling

Previous studies have shown that genetic endowment for higher education may predict adult economic outcomes even after controlling for the achieved level of education (Belsky et al., 2018, 2016; Lin, 2020; Papageorge and Thom, 2020). For instance, while the EA PGS was strongly associated with educational attainment, it also correlated with labor market earnings (Papageorge and Thom, 2020). This result suggests that there is genetic overlap across educational and economic attainment outcomes (Tambs et al., 1989). In the genetic literature,

vertical pleiotropy refers to a situation in which genetic variants, such as SNPs, first influences one trait (e.g., education), which in turn impacts another (e.g., labor market outcomes) as part of a single biological pathway (Abdellaoui and Verweij, 2021; Hemani et al., 2018). However, earlier findings suggest that this may not fully explain how genetic variants linked to education relate to subsequent socioeconomic outcomes, as genes associated with education seem to influence socioeconomic status beyond formal educational qualifications (Belsky et al., 2016). If so, then a genetic endowment for educational attainment may associate with adulthood outcomes, for example, via non-cognitive skills that facilitate progress throughout various stages of the socioeconomic attainment trajectory (Belsky et al., 2016; Demange et al., 2021). This more complex, *horizontal-pleiotropic* relationship where genetic variants affect multiple traits through independent biological pathways may partly explain why genes linked to education correlate with socioeconomic outcomes beyond schooling.

Most studies examining the role of genetic endowment on subsequent socioeconomic outcomes have utilized data from Anglo-Saxon countries (Belsky et al., 2018, 2016; Lin, 2020; Papageorge and Thom, 2020). Evidence from different institutional settings, such as the Nordic welfare states where promoting equality is a central societal objective, is accumulating only gradually (Ahlskog et al., 2024; Erola et al., 2023; Pettersson, 2023). Therefore, more evidence based on nationally representative data is needed for a more comprehensive understanding of the nature of genetic influences in individuals' life chances and how they evolve within the societal fabric over time.

The Finnish comprehensive school reform and equality of opportunity

High heritability does not necessarily indicate that a society is unequal. Researchers have recently argued that only in the presence of equal opportunity genetic associations become apparent and heritability estimates increase, because environmental (dis-)advantages, such as socioeconomic status and prejudice, have less impact on life chances (Plomin, 2018; Rimfeld et al., 2018). This has been demonstrated by increased genetic predictions of education and occupational status in post-Soviet era Estonia compared to Soviet era Estonia (Rimfeld et al., 2018). Furthermore, Herd et al. (2019) discovered a reduced gender gap in the association between genetics and educational outcomes after lifting the social and structural constraints to education in more recent birth cohorts in the United States. These findings suggest that heritability estimates and the magnitude of genetic predictions might be used as an index of equality of opportunity and meritocracy (Plomin, 2018; Rimfeld et al., 2018). However, Harden (2021) cautions against hastily equating high heritability with freedom and equal opportunities. While greater heritability in certain traits may reflect reduced environmental constraints, this does not necessarily imply a fair or meritocratic society. If interpreted uncritically, genetic differences could be framed as a natural and just determinant of an individual's life chances, even in the presence of systemic discrimination and favoritism.

A comprehensive school reform, implemented stepwise across the different regions of Finland between 1972 and 1977, sought to improve equal opportunities for higher education. Until the 1970s, Finland operated a selective two-track school system. This system was replaced by a comprehensive, uniform school system. This reform delayed the process of dividing students into different educational tracks from age 11 to age 16. Under the old system, students were grouped together in the same classes from age 7 to 11. After that, they were separated into either academic or vocational tracks for the next five years. In contrast, the new system implemented a largely uniform curriculum for all students across the nine-year span, up to age 16. The educational expansion in terms of longer comprehensive

schooling and better access to upper-secondary degrees and higher education institutions for later born generations reflects the core principles of an egalitarian welfare state in which a family's socioeconomic status affects children's life chances less (Böckerman et al., 2021; Pekkarinen et al., 2009). The Finnish comprehensive school reform mechanically increased the education levels in Finland, especially for those from less educated and affluent family backgrounds. According to Pekkarinen (2008) and Pekkarinen et al. (2009), the reform, while reinforcing gender differences in the probability of choosing an academic secondary education and completing tertiary education, favoring women in educational outcomes, decreased the gender wage gap in adulthood income and increased social mobility in terms of intergenerational income elasticity. Following Plomin's (2018) prediction that genetic associations become stronger as equality of opportunity increases, Erola et al. (2022) observed higher heritability of education in younger Finnish birth cohorts compared older ones. A recent set of studies by Lahtinen et al. (2023, 2024) further found that individuals from socially disadvantaged backgrounds benefitted the most from their inherent talents due to the educational expansion during the 20th century in Finland. In light of these findings, the Finnish comprehensive school reform offers an ideal context to investigate how institutional settings can influence the relationship between education linked genes and subsequent socioeconomic outcomes.

Comparing two generations exposed to different educational systems, we hypothesize that in the post-reform generation, who were exposed to a more open educational system, adult socioeconomic status reflects education-linked genes mainly through their association with the achieved level of education (i.e., vertical pleiotropy). In this case, genetic endowment for achieving high education will be no longer associated with adulthood outcomes after controlling for the achieved level of education. In contrast, in older birth cohorts, education-linked genes might have found alternative ways to express themselves in adult socioeconomic

outcomes in institutional settings not allowing equal access to formal education and qualifications (i.e., horizontal pleiotropy). In this case, controlling for the achieved level of education would not eliminate the association between education linked genes and life chances. Alternatively, the increase in educational opportunities may not have fundamentally changed the relationship between genetics, education, and other socioeconomic outcomes, but rather postponed the competition over attaining higher socioeconomic status in which case the EA PGS would continue to play a role beyond schooling. We can test these hypotheses by examining cohort differences between the pre-reform generation and the post-reform generation.

The moderating role of family background and the institutional setting

An important question in the equality of opportunity debate is whether genetic endowments express themselves differently depending on the parental socioeconomic status and resources (gene-environment interaction, GxE) (Cheesman et al., 2020; de Zeeuw et al., 2019; Erola et al., 2022; Ruks, 2022). There is no consensus on whether genes matter more versus less depending on an individual's family background. According to the Scarr-Rowe hypothesis (Scarr-Salapatek, 1971), genetic influences on cognitive abilities are stronger in financially better-off and more educated families, meaning that genetic endowments are more likely to be realized in supportive environments, while children born in more socially disadvantaged families fail to realize their inherent talent. A meta-analysis of the GxE interaction on intelligence found support for stronger genetic influence in high socioeconomic status families in the USA but not in Europe (Tucker-Drob and Bates, 2016). Yet, a recent study with Finnish register data utilizing a twin-study design found that genetic influences on education, occupation, and earnings were stronger among those with a more advantageous family background (Erola et al., 2022). Another good demonstration of the interplay between

genetic endowments and parental socioeconomic status and resources is the observation that individuals with a low EA PGS, who come from socially disadvantaged family backgrounds, are rarely found to achieve similar levels of educational and economic success as those without this double disadvantage (Belsky et al., 2016; Papageorge and Thom, 2020). At the same time, PGSs analyzed in a between-family setting capture not just direct genetic effects but also indirect genetic effects of the parent's genotype operating through the family environment (Kong et al., 2018; Okbay et al., 2022; Tan et al., 2024). This overlap between social and genetic factors makes it difficult to disentangle their effects without dyadic data (Trejo and Kanopka, 2024; Young et al., 2022) or the application of a causal identification strategy (Biroli et al., 2025).

One should acknowledge that heritability estimates, both derived from twin methods or polygenic prediction, are not stable over time and influenced by changes in the institutional setting. For instance, Lahtinen et al. (2024) found in their analysis of the Finnish comprehensive school reform of the 1970s that the variance explained by the EA PGS in the achieved level of education was one-third larger after the reform for individuals coming from low-educated families, with no change for women and those from high-educated families. The authors also found that the genetic prediction was stronger for individuals from more socially advantaged families before the reform, which they interpreted as supporting the Scarr–Rowe hypothesis (Scarr-Salapatek, 1971). A recent study on a similar comprehensive school reform in Sweden found, on the contrary, that among women coming from an advantageous family background, the reform had a larger effect on earnings for those with a lower EA PGS (Ahlskog et al., 2024). These studies, which use educational reforms as a natural experiment, provide powerful examples of how the institutional setting can meaningfully influence the relationship between genes, family socioeconomic background, and social mobility. However, none of the previous studies controlled for the achieved level

of education in their analyses because education was itself the experimentally manipulated outcome. The extant literature does not allow us to hypothesize whether the effect of genetic endowment for high educational attainment on outcomes beyond schooling is stronger for individuals with high versus low parental income within our more descriptive study design, but it does suggest that these associations might vary in response to changes in the educational system.

Methods

Data

We used two genetically informed multi-generational register data sets. INVEST data are described below and the Cardiovascular Risk in Young Finns Study (YFS)(Böckerman et al., 2019; Raitakari et al., 2008), used for replication purposes, in the Online Appendix.

INVEST full-population data, put together by INVEST (Inequalities, Interventions and New Welfare State) Research Flagship Centre, include genetic data which was collected by the Finnish Institute for Health and Welfare (THL) for its statutory duties related to monitoring health and well-being of the population. The genetic data from three population representative health surveys were used: The National FINRISK Study (1992–2012), the Health 2000/2011 Surveys, and the FinHealth 2017 Study. INVEST research data (https://invest.utu.fi/invest-data-infrastructures/) that combines register data with PGSs from the health surveys, has been approved by the THL Ethics Committee (decision number: THL/3121/6.02.01/2021 §883). As education is a key social determinant for health, we use the genetic data for the purpose for which they were originally collected. The total sample size of the genetically informed INVEST register data is 39,570. For the current study two broad generations, the 1941-1960 birth cohorts and the 1961-1980 birth cohorts (53.8 percent

female), were selected. A flow chart of the sample selection and exclusion criteria is shown in Figure 1. Since the educational reform was implemented gradually across different regions of Finland between 1972 and 1977, the sample (n = 29,690) was divided into two groups based on birth year and annual information on the place of residence. The post-reform generation (n = 9,645) consisted of individuals who were affected by the Finnish comprehensive school reform, while the pre-reform generation (n = 20,045) included those who went to school under the former education system (for details, see Böckerman et al., 2021; Lahtinen et al., 2023; Pekkarinen et al., 2009).

Add Figure 1 about here

Genetic data were linked to longitudinal register data of Statistics Finland, available from 1987 onwards, which includes comprehensive, annual information on educational and socioeconomic attainment. Information on participants' parents was further obtained from the 1970-1985 censuses.

We follow a predefined replication strategy in which we first run the analyses using the smaller YFS sample, and then re-estimated them in the several times larger and much better-powered INVEST sample.

Measures

The current study has five outcomes measured in 1991-2000 for the older and 2011-2019 for the younger birth cohort. The participants were of 31-59 years of age when outcomes were

measured.[1] We took the average over a ~10-year period of the outcome variables to provide a reliable picture of socioeconomic status during adulthood, minimizing the influence of short-term idiosyncratic fluctuations, reducing potential measurement error, and improving the statistical precision of the estimates. This way we obtained for each studied generation robust estimates of the socioeconomic status during adulthood.

Average annual earnings

Individual earnings were measured as the average annual pre-tax earnings from both employment in the public and private sectors and self-employment. The earnings measure was deflated using the consumer price index before calculating average annual earnings, which was then logarithmically transformed.

Unemployment months

Unemployment months at the individual level were measured as the average number of months of unemployment per year during the study period. An individual was classified as unemployed for a specific month if the number of days of unemployment exceeded 16.

Share of employment years

Employment was defined by the main type of activity during the last week of each year. The average share of employment years was used to measure the person's long-term attachment to the labor market.

Occupational status

The socioeconomic status of an occupation was measured by a national system that corresponds to the International Standard Classification of Occupations (ISCO) classification. This occupational information (ordinary scale) was transformed into the International

[1] The exact age of each birth cohort when a register started or a variable was measured can be calculated using a shiny app https://github.com/sohedo/Visualization-INVEST3/tree/main.

Socioeconomic Index of Occupational Status (ISEI) (Ganzeboom et al., 1992) using the Stata ISCOGEN package (Jann, 2020). The ISEI is a measure of the social and economic status of an occupation that ranks occupations based on their prestige and the educational and economic requirements needed to obtain them. The ISEI was treated as a continuous variable as it ranges from 16 to 90, with higher scores indicating higher status of an occupation.

Receipt of social assistance

In Finland, social assistance is the last resort means and needs tested income support indicating considerable financial difficulties. We used a count of the number of years during which the individual received social assistance as the fifth socioeconomic outcome of our study.

Our main independent variable: Genetic endowment for educational attainment.

In the INVEST data, the EA PGS was produced based on the PGI repository (https://www.thessgac.org/pgi-repository). We excluded Finnish samples and the 23&me data from the summary statistics used for the training of the PGS to avoid the risk of overfitting when comparing different birth cohorts. The EA PGS was produced with the PRS-CS method that infers posterior SNP effect sizes under continuous shrinkage priors using an external LD reference panel (Ge et al., 2019). This Bayesian regression method takes account of all identified SNPs and there is no p-value threshold.

Individuals with genetic relatedness based on Pi-HAT value > 0.2 were excluded during the calculation of the PGSs. Genetic population outliers were removed.

Achieved level of education

Years of education were calculated based on completed degrees taken from administrative records of the year 2000 for the INVEST 1941-1960 cohort and in 2019 for the INVEST 1961-1980 cohort. The achieved level of education was then converted to years of education

using Statistics Finland's official estimates for completing a specific degree. A powerful and broad PGS was used that explains 7.7 percent of the variance in years of education completed in the pre-reform generation and 6.2 percent in the post-reform generation.

Family socioeconomic background during childhood

Family socioeconomic background was measured with parental education and family income during childhood.[2] An indicator for high parental education equaled one if at least one parent had completed more than basic education. Information on parental education was drawn from the 1985 census data (missing values filled with information from the years 1970 to 1980). During that period, only a small proportion of parents had achieved more than a basic level of education (34.1 percent).

Family income during childhood was calculated by summing the parental income in 1985 and imputing the missing values with information from earlier census years. This income measure includes all sources of income that are subject to income taxation consisting of salary income, entrepreneurial earnings, and other income such as pensions, unemployment benefits, and other social security benefits. Based on this income measure, participants were divided into three equally-size groups, representing low (the lowest 33 percent), middle, and high (the highest 33 percent) income families.

Control variables

All models account for the basic covariates: age when the outcome was assessed, age squared (to account for non-linear effects of age and experience on the outcomes), gender, region of residence, and the top 10 genetic principal components (to account for differences in allele

[2] In INVEST pre- and post-reform generations, offsprings' EA PGS explained approximately 1.1/0.9 (education) and 0.6/1.9 (income) percent of the variance in family socioeconomic background measures. The intergenerational correlation was higher for education (R^2= 7.9/4.6 percent) than for income (R^2 = 1.7/1.8 percent) in both the older and younger birth cohorts.

frequencies within the population). The sample size of the analytical sample varied between analyses due to data availability. Individuals deceased before the outcomes were measured were excluded from the analysis. Descriptive statistics of the main study variables are presented in Table 1.

Insert Table 1 about here

Empirical strategy

To examine how the EA PGS was related to each of our social outcome measures (Y = earnings, employment, unemployment, occupational status or social assistance receipt, i refers to an individual), we estimated relationships using linear regression (Ordinary Least Squares, OLS) based on equations of the following form. First, we estimated the proportion of variance in these outcomes explained by the genetic endowment to achieve high education while accounting for basic covariates (Model 1):

$$(a)\ Y_i = \beta_0 + \beta_1\ EA\ PGS_i + \beta_2\ Basic\ covariates_i + \epsilon_i$$

This analysis shows whether the EA PGS is predictive for socioeconomic status in adulthood, which would suggest that genetic endowment for high educational attainment affects other outcomes either via achieved education (vertical pleiotropy) or, alternatively, directly or via other pathways (horizontal pleiotropy). Then, we controlled for individuals' achieved level of education to test whether genes linked to educational attainment influence the five outcomes beyond schooling (Model 2):

$$(b)\ Y_i = \beta_0 + \beta_1\ EA\ PGS_i + \beta_2\ Years\ of\ education_i + \beta_3\ Basic\ covariates_i + \epsilon_i$$

Providing insights into our first research question, these analyses show whether education-linked genes continue to be associated with later life chances after controlling for educational attainment.

The INVEST sample, further allows to compare birth cohorts completing their education before and after the Finnish comprehensive school reform of the 1970s. By comparing the results of these two broad generations, we aim to provide insights to our second research question on the role of the institutional context in the association between genes linked to educational attainment and adult socioeconomic outcomes. Thus, all our models are run separately for the pre-reform and post-reform generations.

In an intermediate model, we tested whether controlling for parental education and family income during childhood altered the association between the EA PGS and each adulthood outcome:

(c) $Y_i = \beta_0 + \beta_1\ EA\ PGS_i + \beta_2\ Years\ of\ education_i + \beta_3 Parental\ education_i + \beta_4\ Parental\ income_i + \beta_5\ Basic\ covariates_i + \epsilon_i$

This analysis sheds light on the potential double (dis-)advantage some individuals may experience due to the two lotteries—natural and social— at birth.

To address our third research question, we tested if parental resources moderated the influence of individual's genetic endowment for achieving high educational attainment on socioeconomic outcomes later in life. We tested moderation by family income but not by parental education because, in the birth cohorts under study, the number of highly educated parents is small, leading to insufficient variance in parental education to identify meaningful GxE interactions (Model 3):

(d) $Y_i = \beta_0 + \beta_1\ EA\ PGS_i + \beta_2\ Years\ of\ education_i + \beta_3\ Parental\ education_i + \beta_4\ Parental\ income + \beta_5\ EA\ PGS_i \times Parental\ income_i + \beta_6\ \ Basic\ covariates_i + \epsilon_i$

Results

In this section, we present the results based on INVEST data. The results based on YFS are found in the Online Appendix. The results of Models 1 and 2 are reported in Table 2. Model 1 reveals that the genetic endowment for achieving high education was associated with all five socioeconomic outcomes in adulthood, at $p < .001$ level, in both the pre- and post-reform generations.

In Model 2, we added information on the years of education completed. This analysis answers to our first and second research questions. The results of this model show that years of education are strongly and statistically significant associated with all five outcomes, $p < .001$. Importantly, in the post-reform generation, the estimated associations between EA PGS and adulthood outcome became statistically non-significant, apart from occupational status ($p < .001$), after accounting for differences in the achieved level of education. In the earlier born birth cohort, which was not yet affected by the school reform, however, genetic endowment for high educational attainment remained statistically significantly associated with all five socioeconomic outcomes, $p < .001$, even after controlling for educational attainment.

Insert Table 2 about here

Controlling for parental education and family income along with years of education completed did not alter the estimated associations between EA PGS and socioeconomic status. Nonetheless, family socioeconomic background was found to be associated with the five adulthood outcomes (see Table A1). Model 3 in Table 3 presents the results of the

moderation by parental income, which addresses our third research question. A trend in the data ($p < .01$) suggest that, in the pre-reform generation, the impact of the EA PGS on employment share and unemployment might have been weaker in higher income families. Further, the results suggested a weaker association between the EA PGS and social assistance receipt in less affluent families in the post-reform generation. Family income, however, did not moderate genetic endowment in either generation at statistical significance levels that would survive correction for multiple hypothesis testing.

Insert Table 3 about here

Comparison to YFS data

The results of the YFS data (basic demographics in Table A2), which are directly comparable to the post-reform generation of INVEST and presented in Appendix Tables A3-A5, were near perfectly replicated with few notable exceptions. Genetic endowment for achieving high education was predictive for the studied outcomes at generally lower levels of statistical significance in YFS data (Table A2, Model 1). There was also no association with unemployment in this much smaller sample, diverging from the INVEST data. Also, in the YFS data, genetic endowment remained to be associated only to occupational status after accounting for years of education completed (Table A3, Model 2).

Discussion

Access to genetic data in form of polygenic scores for educational attainment, combined with sociological theories allows us to investigate how genetic endowment interacts with educational success and influences adult socioeconomic outcomes beyond schooling. Such

evidence is crucial to better understand the consequences of equality of opportunity for an individual's educational and economic attainment trajectory in societies that are no longer "genome-blind" (Harden, 2021) and through which mechanisms social (dis-)advantage is accumulated over the life course. Finland's comprehensive school reform of the 1970s provides an excellent opportunity to contribute to the debate on the role of the institutional setting in moderating the complex interplay between social and genetic factors in shaping people's life chances.

In the present study, we described whether genetic endowment for high education is associated with subsequent socioeconomic outcomes after controlling for the achieved level of education, and how a major change in the educational system might modify genetic influences by comparing Finnish pre- and post-reform generations. Also, we analyzed whether family income moderates this relationship.

First, our results utilizing unique register-based data show that EA PGS was associated with five socioeconomic outcomes in both birth cohorts. Second, we found that, after accounting for educational attainment, genes linked to education were overall not predictive of adult socioeconomic status in the younger Finnish generation exposed to the school reform. This result is contrary to what has previously been found in other high-income countries (Belsky et al., 2018, 2016; Lin, 2020; Papageorge and Thom, 2020). Similarly to these earlier findings, we found an association for the pre-reform generation in Finland even after controlling for years of education completed. The effect of the EA-PGS beyond education should be interpreted with caution, however. By conditioning on education, the reported coefficients capture the association between the EA-PGS and socioeconomic outcomes among individuals with the same level of schooling. However, individuals with a high PGS and high education may differ in unobserved characteristics—such as health, effort, or academic aspirations—

from those with low EA PGS but the same level of education, so residual confounding cannot be ruled out.

The observed cohort difference in the EA PGS – socioeconomic status association could be an indication of change from horizontal to vertical pleiotropy implying that the EA PGS today influences socioeconomic status mostly via education and not through other pathways. We attribute this difference to be a consequence of the educational expansion in terms of longer comprehensive schooling and better access to upper-secondary degrees and higher education institutions as one of key policies that define Finland as a modern egalitarian welfare state. Nevertheless, EA PGS remained associated with occupational status in both generations, signaling a more complex horizontal-pleiotropic relationship not fully explained by schooling. That the college income premium in Finland is much smaller compared to that in the U.S. (Papageorge and Thom, 2020), for example, might explain why the prestige of an occupation but not earnings was found to be associated with EA PGS beyond schooling also in the post-reform generation. We did not correct in this analysis step for multiple hypothesis testing as our second research question was about the absence of an effect, which would have been confirmed even easier when using more stringent p-values.

In the pre-reform generation, genes linked to educational attainment might have paid off for achieving better adult socioeconomic outcomes even without a formal educational qualification, while in the post-reform generation, the presence of educational opportunities added both more competition over life chances but also highlighted the role of educational institutions (Breen, 2010; Erola et al., 2016). In other words, in today's labor market, securing well-paying employment without high educational attainment is significantly more challenging than in the past (Mäki-Fränti, 2019). From a meritocratic perspective, our findings for the younger birth cohort may therefore indicate that some

individuals cannot fully use their inherent talent for achieving their socioeconomic goals in life if they fail to succeed in school.

We show that if the importance of environmental factors, such as educational qualifications, increase, then the influence of education linked genes gets quantitatively smaller for subsequent socioeconomic attainment. This finding is not in conflict with Plomin and colleagues' claim that genes need freedom to be expressed (Plomin, 2018; Rimfeld et al., 2018). Education linked genes should not necessarily matter of socioeconomic outcomes beyond education. Accordingly, if higher heritability and increased genetic prediction of education are seen as indicators of equality of opportunity, the available evidence suggests that the Finnish comprehensive school reform may have contributed to its promotion (see, Erola et al., 2022; Lahtinen et al., 2024, 2023). In a society that places a strong emphasis on formal qualifications, genetic advantages in the realm of schooling alone may not be sufficient for achieving success without the necessary educational credentials. That the EA PGS was not associated with socioeconomic outcomes other than occupation after controlling for years of education completed in the post-reform generation could be then interpreted as evidence that longer comprehensive schooling and better access to upper-secondary degrees and higher education institutions addressed structural inequities by providing equal starting conditions into the working life (Harden, 2021).

While the educational expansion seem to have had positive effects especially for individuals with lower socioeconomic status in childhood (Lahtinen et al., 2024, 2023; Pekkarinen, 2008; Pekkarinen et al., 2009), controlling for family background and its interaction with the EA PGS did not affect our main results concerning the offspring's socioeconomic status in adulthood. That EA PGS was associated with socioeconomic outcomes in adulthood after accounting for parental education and income implies that genes contribute to social mobility

also in Finland (see Table A1; Belsky et al., 2018). Research has shown that even the non-transmitted genetic variants of the parents can indirectly influence the educational outcomes of their children by shaping the family environment (Kong et al., 2018). Parental genotype was not available and, therefore, we were unable to account for parental genetic background directly. Our estimates therefore also capture indirect genetic effects operating through the family environment (Kong et al., 2018; Okbay et al., 2022; Tan et al., 2024).

Even though we found evidence that some individuals experience double (dis-)advantages, as both the EA PGS and family socioeconomic background showed independent associations with the five studied outcomes, our results remain unsettled regarding the moderation of the effects by parental socioeconomic status. Notably, family income during childhood does not seem to modify genetic endowment in Finland. The three nominally significant GxE interactions ($p < .01$) we found, would not survive correction for multiple hypothesis testing. Given that high-status families are often successful in helping their offspring to reach a certain educational level and to keep their position in the society (e.g., Bernardi, 2014; Tanskanen et al., 2016), available resources might nonetheless compensate for lower EA PGS scores through different pathways (Abdellaoui et al., 2023; Lahtinen et al., 2024).

Also identified structural and institutional determinants, such as the educational system, can influence whether genetic endowment is realized (Engzell and Tropf, 2019; Rimfeld et al., 2018). Evidence on the contextual effects is starting to emerge: for example, studies from the U.S. have found that going to a better school can mitigate the genetic endowment for low academic achievement (Arold et al., 2022; Harden et al., 2020), while a Norwegian study found that genetic influences were stronger in disadvantaged schools (Cheesman et al., 2022). Our comparison of individuals subjected (or not) to the Finnish educational reform of the 1970s provides further evidence on the effects societal and political changes can have on the contribution of education-linked genes for subsequent socioeconomic outcomes. Before

definite conclusions are drawn, more empirical evidence is needed from other egalitarian welfare states.

A limitation of our study is the relatively small sample size of the YFS. Replication is of utmost importance in sociogenomic research (Border et al., 2019; Freese and Peterson, 2017), therefore we build the models first in this Finnish sample, and replicated and extended the results using the larger INVEST dataset. The comparison confirmed that the presented results are rather robust.

It should be further noted that our research design is primarily descriptive, and no causal claims can be made based on our data. The environmental factors vary in their degree of endogeneity, and genetic effects are likely overestimated, particularly when examining family socioeconomic background in combination with a PGS derived from between-family GWAS (Biroli et al., 2025). Further, the EA PGS explained a relatively small part of variance in educational attainment observed in Finnish administrative records (Lee et al., 2018; Okbay et al., 2022, 2016). This might partially be attributable to the genetic ancestry distance between Finns and the training data (Ding et al., 2023). It remains possible, however, that part of the observed inter-generational differences results from the fact that, even after excluding Finnish samples from the training data, the original GWAS may be more demographically similar to the older Finnish generation than to the younger. Further, our measure of income captures only earnings and therefore does not indicate whether an individual is living on family wealth and does not need to work. This is a rare but possible situation in the Finnish context.

Standards for responsible communication of sociogenomic research requires us to warn against the potential risk of overinterpreting and misinterpreting the results of our study (Meyer et al., 2023). The polygenic signals for educational attainment, like for no other complex trait, are socially stratified instead of measuring a biological entity (Abdellaoui et al., 2019; Howe et al., 2022). While some researchers might argue that this makes the use of

the EA PGS problematic, the current study highlights that education is one of the most interesting traits to study for social scientists interested in human genetics. Yet, it should be highlighted that PGSs measure genetic associations in a society "as is." The growing knowledge of genetic influences in people's life chances does not take away the responsibility of policy makers to define how the society "should be". Future policy decisions could alter which traits are valued and rewarded in a society, thereby influencing which SNPs become associated with educational attainment and subsequent socioeconomic outcomes. Moreover, well powered GWAS of other socioeconomic outcomes such as occupational status and income have been recently conducted which, as indicated by our findings, share many genetic variants with educational attainment (Akimova et al., 2025; Kweon et al., 2025).

Our study has important strengths. We base our conclusions on several objectively measured adult socioeconomic outcomes that originate from administrative registers. These high-quality registers were linked with genetically informed multi-generational data from national health surveys (INVEST) and an ongoing cohort study (YFS), which are largely representative for the Finnish population. The outcomes were assessed longitudinally over several years, while previous work often had to rely on cross-sectional data. Family linkages made it possible to reliably measure parental information during individuals' childhood, instead of relying on retrospective self-reports that are prone to recall error and other sources of measurement error that may significantly attenuate the estimated effects. Thus, the data used in this study is exceptionally rich compared to many biobank projects or other social science register-based projects, which often lack information on different measures of socioeconomic attainment or genetic data. This provided us with the unique opportunity to contribute to a more complete picture of the underlying mechanisms and show how genetic influences evolve within the societal fabric in the context of a Nordic welfare state.

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Table 1. Descriptive Statistics of the INVEST Data

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Obs.**	**Mean**	**Std. Dev.**
Years outcomes were measured		1991-2000			2011-2019	
Earnings (log)	19,928	6.6	1.7	9,450	6.8	2.1
Employment	19,928	0.8	0.3	9,450	0.9	0.3
Unemployment	19,928	1.2	2.3	9,450	0.8	1.8
Occupation	15,075	44.3	16.6	8,900	46.1	17.0
Social assistance	19,973	0.5	1.5	9,490	0.3	1.3
EA PGS	19,973	0.0	1.0	9,492	0.0	1.0
	Obs.	Percent		Obs.	Percent	
Gender						
Man	9,466	47.4		4,148	43.7	
Women	10,507	52.6		5,344	56.3	
Years of education in 2000/2019						
9	5,210	26.2		583	6.2	
12	8,024	40.4		3,770	40.1	
14	3,592	18.1		1,641	17.5	
16	1,345	6.8		1,485	15.8	
18	1,525	7.7		1,719	18.3	
21	188	1.0		205	2.2	
Parental education in 1985						
Only basic education	15,741	78.8		3,668	38.6	
Upper-secondary education	4,232	21.2		5,824	61.4	
Family income in 1985						
Low	6,665	33.4		3,121	32.9	
Medium	6,637	33.2		3,195	33.7	
High	6,671	33.4		3,176	33.5	

Table 2. Adult Socioeconomic Status Predicted by Polygenic Score for Educational Attainment (EA PGS) Before and After Controlling for Achieved Level of Education (Models 1 and 2), INVEST Sample

(Model 1)

	Effect of EA PGS									
Generation	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform
Outcome	Earnings		Employment		Unemployment		Occupation		Social assistance	
EA PGS	0.152***	0.102***	0.030***	0.014***	-0.231***	-0.074***	4.042***	3.599***	-0.134***	-0.066***
	[0.13,0.18]	[0.06,0.15]	[0.03,0.03]	[0.01,0.02]	[-0.26,-0.20]	[-0.11,-0.04]	[3.80,4.29]	[3.26,3.94]	[-0.16,-0.11]	[-0.09,-0.04]
Achieved years of education										
R^2	0.039	0.018	0.038	0.013	0.025	0.014	0.111	0.086	0.022	0.007
N	19,928	9,450	19,928	9,450	19,928	9,450	15,075	8,900	19,973	9,490

(Model 2)

	Controlled for achieved level of educational attainment									
Generation	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform
Outcome	Earnings		Employment		Unemployment		Occupation		Social assistance	
EA PGS	0.044***	-0.033	0.017***	0.000	-0.138***	-0.013	1.156***	0.847***	-0.084***	-0.016
	[0.02,0.07]	[-0.08,0.01]	[0.01,0.02]	[-0.01,0.01]	[-0.17,-0.10]	[-0.05,0.03]	[0.94,1.37]	[0.56,1.13]	[-0.11,-0.06]	[-0.04,0.01]
Achieved years of education	0.145***	0.202***	0.018***	0.020***	-0.122***	-0.091***	3.550***	4.021***	-0.066***	-0.075***
	[0.14,0.15]	[0.18,0.22]	[0.02,0.02]	[0.02,0.02]	[-0.13,-0.11]	[-0.11,-0.08]	[3.47,3.63]	[3.92,4.13]	[-0.07,-0.06]	[-0.09,-0.06]
R^2	0.086	0.081	0.061	0.050	0.043	0.032	0.424	0.458	0.034	0.031
N	19,884	9,403	19,884	9,403	19,884	9,403	15,059	8,865	19,884	9,403

Note. All models control for age when the outcome was assessed, age squared, gender, region of residence, and the top 10 genetic principal components. ***p<.001. **p<.01. *p<.05

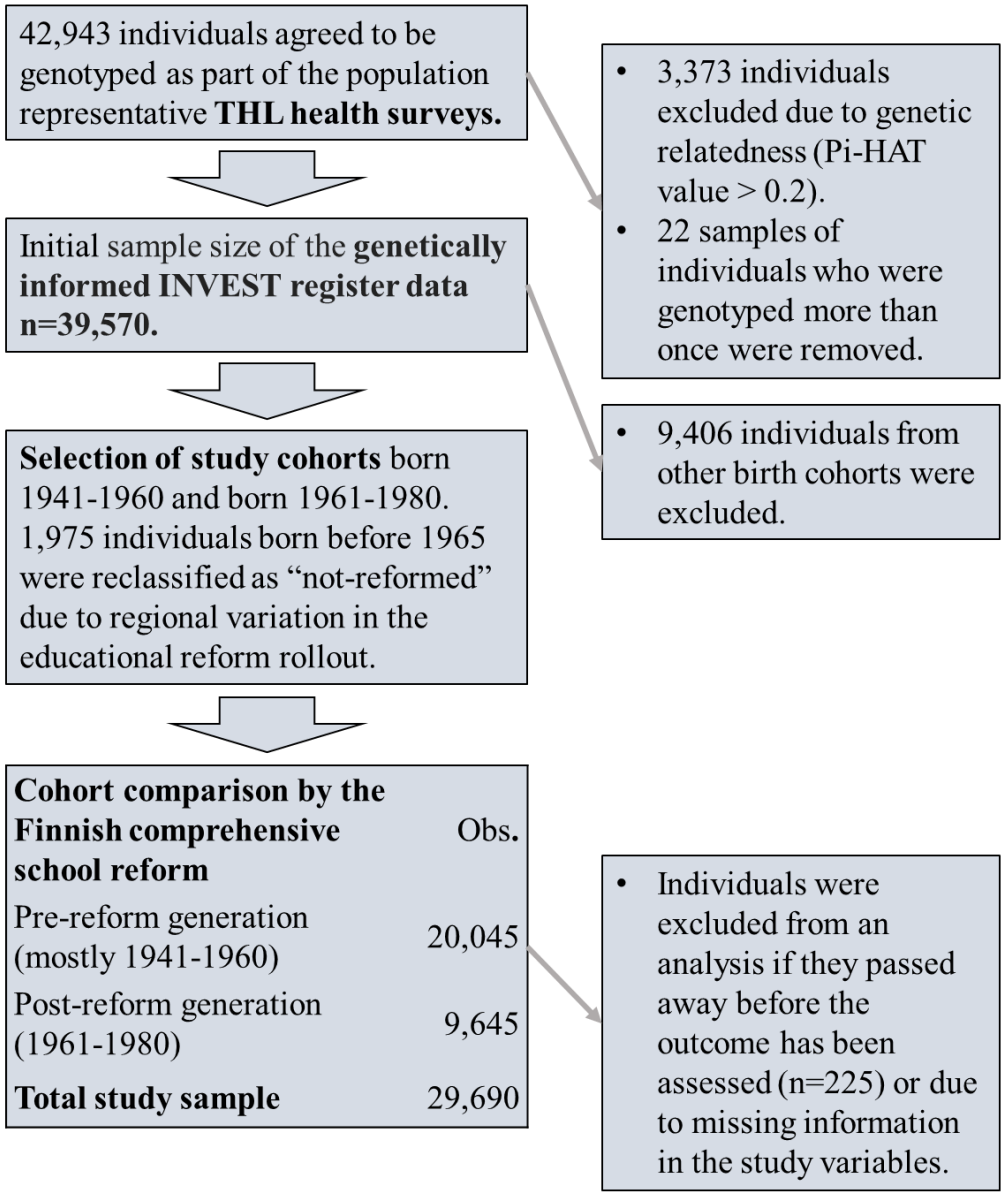
Table 3. The Interaction Effect of Polygenic Score for Educational Attainment (EA PGS) and Family Income (Model 3).

Generation	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform	Pre-reform	Post-reform
Outcome	Earnings		Employment		Unemployment		Occupation		Social assistance	
EA PGS (G)	0.039	-0.053	0.022***	0.000	-0.174***	0.015	1.081***	0.715**	-0.090***	0.020
	[-0.00,0.08]	[-0.12,0.01]	[0.01,0.03]	[-0.01,0.01]	[-0.23,-0.12]	[-0.05,0.08]	[0.73,1.43]	[0.24,1.19]	[-0.13,-0.05]	[-0.02,0.06]
Achieved years of education	0.141***	0.192***	0.017***	0.019***	-0.114***	-0.085***	3.443***	3.883***	-0.063***	-0.072***
	[0.13,0.15]	[0.17,0.21]	[0.02,0.02]	[0.02,0.02]	[-0.13,-0.10]	[-0.10,-0.07]	[3.36,3.52]	[3.77,3.99]	[-0.07,-0.06]	[-0.08,-0.06]
Low parental education	-0.011	-0.042	-0.006	0.002	0.109**	0.021	-1.260***	-1.214***	0.009	0.013
	[-0.06,0.04]	[-0.14,0.05]	[-0.02,0.01]	[-0.01,0.01]	[0.03,0.19]	[-0.06,0.10]	[-1.80,-0.72]	[-1.83,-0.60]	[-0.05,0.07]	[-0.05,0.07]
Family income (E)										
Low	0.125***	0.058	0.021***	0.005	-0.161***	-0.051	2.282***	1.674***	-0.044	-0.017
	[0.07,0.18]	[-0.04,0.15]	[0.01,0.03]	[-0.01,0.02]	[-0.24,-0.08]	[-0.14,0.03]	[1.77,2.80]	[1.00,2.35]	[-0.10,0.01]	[-0.08,0.04]
High	0.134***	0.079	0.027***	0.008	-0.202***	-0.067	2.505***	1.281***	-0.020	-0.007
	[0.08,0.19]	[-0.02,0.18]	[0.01,0.04]	[-0.01,0.02]	[-0.29,-0.11]	[-0.15,0.02]	[1.90,3.11]	[0.57,1.99]	[-0.08,0.04]	[-0.07,0.05]
Interaction (GxE)										
Low	0.043	0.052	-0.001	0.009	0.011	-0.099	0.179	-0.061	-0.010	-0.108**
	[-0.02,0.10]	[-0.06,0.17]	[-0.01,0.01]	[-0.01,0.02]	[-0.07,0.09]	[-0.20,0.00]	[-0.33,0.68]	[-0.74,0.62]	[-0.06,0.04]	[-0.18,-0.04]
High	-0.029	-0.002	-0.014**	-0.008	0.105**	0.020	0.038	0.184	0.028	0.000
	[-0.08,0.02]	[-0.09,0.09]	[-0.02,-0.00]	[-0.02,0.00]	[0.03,0.18]	[-0.07,0.11]	[-0.44,0.51]	[-0.46,0.83]	[-0.02,0.08]	[-0.05,0.05]
R^2	0.088	0.085	0.063	0.052	0.045	0.034	0.430	0.465	0.035	0.034
N	19884	9403	19884	9403	19884	9403	15059	8865	19884	9403

Note. All analyses control for age when the outcome was assessed, age squared, gender, region of residence, and the top 10 genetic principal components. ***p<.001. **p<.01. *p<.05

Figures and Captions

Figure 1. Flow chart illustrating the participants selection and exclusion criteria in the INVEST research data



Online appendix

Table A1. Controlling for Parents' Level of Education and Family Income During Childhood, INVEST Sample

Generation	**Pre-reform**	**Post-reform**	**Pre-reform**	**Post-reform**	**Pre-reform**	**Post-reform**	**Pre-reform**	**Post-reform**	**Pre-reform**	**Post-reform**
Outcome	**Earnings**		**Employment**		**Unemployment**		**Occupation**		**Social assistance**	
EA PGS	0.044***	-0.037	0.017***	0.000	-0.137***	-0.010	1.150***	0.759***	-0.084***	-0.015
	[0.02,0.07]	[-0.08,0.01]	[0.01,0.02]	[-0.01,0.01]	[-0.17,-0.10]	[-0.05,0.03]	[0.94,1.36]	[0.48,1.04]	[-0.11,-0.06]	[-0.04,0.01]
Years of education	0.141***	0.192***	0.017***	0.019***	-0.114***	-0.085***	3.443***	3.884***	-0.063***	-0.072***
	[0.13,0.15]	[0.17,0.21]	[0.02,0.02]	[0.02,0.02]	[-0.13,-0.10]	[-0.10,-0.07]	[3.36,3.52]	[3.77,3.99]	[-0.07,-0.06]	[-0.08,-0.06]
Low parental education	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]	[0.00,0.00]
Family income										
Low	-0.022	-0.251***	-0.010	-0.026***	0.033	0.130**	0.056	-1.598***	0.095**	0.100**
	[-0.09,0.04]	[-0.36,-0.14]	[-0.02,0.00]	[-0.04,-0.01]	[-0.06,0.12]	[0.03,0.23]	[-0.50,0.61]	[-2.27,-0.93]	[0.04,0.15]	[0.03,0.17]
High	0.125***	0.055	0.021***	0.004	-0.162***	-0.044	2.284***	1.686***	-0.044	-0.009
	[0.07,0.18]	[-0.04,0.15]	[0.01,0.03]	[-0.01,0.02]	[-0.24,-0.08]	[-0.13,0.04]	[1.77,2.80]	[1.01,2.36]	[-0.10,0.01]	[-0.07,0.05]
R^2	0.087	0.085	0.062	0.051	0.045	0.033	0.430	0.465	0.035	0.033
N	19,884	9,403	19,884	9,403	19,884	9,403	15,059	8,865	19,884	9,403

Note. All models control for age when the outcome was assessed, age squared, gender, region of residence, and the top 10 genetic principal components. ***p<.001. **p<.01. *p<.05

Description of the Young Finns Study

The Cardiovascular Risk in Young Finns Study (YFS) participants were from 3 to 18 years old in 1980 when the study started, and they have been followed since (Böckerman et al., 2019; Raitakari et al., 2008). The original sample, selected to be representative of the five Finnish university cities with medical schools and their rural surroundings from which it was drawn, consisted of 3,596 individuals of which 2,443 (53.4 percent female) agreed to be genotyped in 2007. YFS has both survey and register data available.

In the YFS data, genetic endowment for high education was measured with a different PGS than in the INVEST sample. The EA PGS was calculated as a weighted sum of the genotyped and imputed alleles that were associated with years of education (Smith et al., 2010; Viinikainen et al., 2022). The weights representing the effect sizes of each SNP to years of education were taken from the summary statistics of the GWAS by Okbay et al. (2016). Significance threshold of the PGS was set at $p < 0.01$.

In YFS data, the PGS explained 4.7 percent of the variance in educational attainment based on degree data.

Supplementary References

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Table A2. Descriptive Statistics in the YFS Sample

Post-reform generation			
Variable	**Obs.**	**Mean**	**Std. dev.**
Years outcomes were measured		2007-2019	
Earnings (log)	2310	7.0	1.8
Employment	2310	0.9	0.2
Unemployment	2310	0.6	1.5
Occupation	2310	45.9	17.2
Social assistance	2310	0.4	1.5
EA PGS	2310	-0.5	0.5
	Obs.	**Percent**	
Gender			
Men	1064	46.1	
Women	1246	53.9	
Years of education in 2000/2019			
9	162	7.0	
12	910	39.4	
14	425	18.4	
16	361	15.6	
18	399	17.3	
21	53	2.3	
Parental education in 1985			
Only basic education	771	38.9	
Upper-secondary education	1209	61.1	
Family income in 1985			
Low	644	27.9	
Medium	815	35.3	
High	851	36.8	

Table A3. Adult Socioeconomic Status Predicted by Polygenic Score for Educational Attainment (EA PGS) Before and After Accounting for Years of Education Completed, YFS sample

	Model 1: Effect of EA PGS					**Model 2: Controlled for achieved level of educational attainment**				
Generation	**Post-reform**					**Post-reform**				
Outcome	**Earnings**	**Employment**	**Unemployment**	**Occupation**	**Social assistance**	**Earnings**	**Employment**	**Unemployment**	**Occupation**	**Social assistance**
EA PGS	0.203**	0.020*	-0.041	6.964***	-0.149*	-0.080	-0.007	0.064	1.708**	-0.009
	[0.06,0.34]	[0.00,0.04]	[-0.16,0.08]	[5.70,8.23]	[-0.27,-0.02]	[-0.22,0.06]	[-0.03,0.01]	[-0.06,0.19]	[0.60,2.82]	[-0.14,0.12]
Achieved years of education						0.190***	0.019***	-0.071***	3.529***	-0.094***
						[0.16,0.22]	[0.01,0.02]	[-0.10,-0.05]	[3.30,3.76]	[-0.12,-0.07]
R^2	0.029	0.021	0.018	0.060	0.011	0.108	0.059	0.033	0.351	0.039
N	2,309	2,309	2,309	2,309	2,309	2,309	2,309	2,309	2,309	2,309

Note. All models control for age when the outcome was assessed, age squared, gender, region of residence, and the top 10 genetic principal components. ***p<.001, **p<.01, *p<.05.

Table A4. Controlling for Parents' Level of Education and Family Income During Childhood, YFS sample

	Post-reform generation				
Outcome	**Earnings**	**Employment**	**Unemployment**	**Occupation**	**Social assistance**
EA PGS	-0.116	-0.008	0.061	1.621**	0.005
	[-0.26,0.03]	[-0.03,0.01]	[-0.08,0.20]	[0.43,2.81]	[-0.13,0.14]
Years of education	0.178***	0.017***	-0.065***	3.305***	-0.082***
	[0.15,0.21]	[0.01,0.02]	[-0.09,-0.04]	[3.05,3.56]	[-0.11,-0.06]
Low parental education	-0.041	-0.007	0.042	-2.856***	-0.014
	[-0.21,0.13]	[-0.03,0.02]	[-0.12,0.21]	[-4.29,-1.42]	[-0.17,0.14]
Family income					
Low	-0.277*	-0.064***	0.291*	-0.615	0.189
	[-0.51,-0.04]	[-0.10,-0.03]	[0.04,0.55]	[-2.50,1.27]	[-0.04,0.41]
High	-0.038	-0.010	-0.090	2.657***	-0.107
	[-0.20,0.12]	[-0.03,0.01]	[-0.23,0.05]	[1.22,4.10]	[-0.24,0.02]
R^2	0.119	0.076	0.040	0.364	0.044
N	1,979	1,979	1,979	1,979	1,979

Note. All analyses control for age when the outcome was assessed, age squared, gender, region of residence, and the top 10 genetic principal components. ***p<.001, **p<.01, *p<.05.

Table A5. The Interaction Effect of Polygenic Score for Educational Attainment (EA PGS) and Family Income on Adult Socioeconomic Status (Model 4), YFS Sample

	Post-reform generation				
Outcome	**Earnings**	**Employment**	**Unemployment**	**Occupation**	**Social assistance**
EA PGS (G)	-0.101	-0.000	0.114	2.416**	-0.170
	[-0.34,0.14]	[-0.03,0.03]	[-0.08,0.31]	[0.60,4.23]	[-0.42,0.08]
Achieved years of education	0.178***	0.017***	-0.065***	3.305***	-0.082***
	[0.15,0.21]	[0.01,0.02]	[-0.09,-0.04]	[3.05,3.56]	[-0.11,-0.06]
Low parental education	-0.041	-0.007	0.042	-2.863***	-0.013
	[-0.21,0.13]	[-0.03,0.02]	[-0.12,0.21]	[-4.29,-1.43]	[-0.17,0.14]
Family income (E)					
Low	-0.387*	-0.068**	0.179	-2.061	0.502**
	[-0.74,-0.03]	[-0.12,-0.02]	[-0.12,0.48]	[-4.69,0.57]	[0.14,0.86]
High	-0.028	-0.017	-0.119	2.171*	-0.000
	[-0.24,0.19]	[-0.05,0.01]	[-0.32,0.09]	[0.26,4.09]	[-0.18,0.18]
Interaction (GxE)					
Low	-0.213	-0.008	-0.214	-2.765	0.599*
	[-0.66,0.24]	[-0.08,0.06]	[-0.61,0.18]	[-6.33,0.80]	[0.14,1.06]
High	0.028	-0.015	-0.052	-0.896	0.198
	[-0.28,0.33]	[-0.06,0.03]	[-0.32,0.21]	[-3.31,1.52]	[-0.08,0.48]
R^2	0.119	0.076	0.040	0.365	0.048
N	1,979	1,979	1,979	1,979	1,979

Note. All analyses control for age when the outcome was assessed, age squared, gender, region of residence, and the top 10 genetic principal components. ***p<.001, **p<.01, *p<.05