Early Childhood and Adult Health Disparities *

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Abstract

A large body of population health research focuses on the causes of health and mortality disparities by education and a growing part of it emphasizes the importance of experiences and exposures early in life. We contribute to this research by modeling selected pathways connecting childhood and adolescent experiences and trait formation to adult health status using data from the National Child Development Study (NCDS), a uniquely rich longitudinal survey of a 1958 birth cohort in Great Britain followed through age fifty. While NCDS has been used many times to answer questions related to the ones we pose here, our contribution is distinct. First, we investigate the origin of the observed education-adult health gradient and estimate the part attributable to characteristics individuals acquire before they complete their education. Second, we propose a dynamic structural equation model with latent constructs that simultaneously considers family background, early capabilities and behaviors, parental investments, health risk behaviors, and adult self-reported health status stretching over a span of 50 years of the life of the cohort. Third, we examine in some detail parental investments as inputs in the production of early capabilities and behaviors that contribute to adult health and educational attainment. Finally, we assess the role of key health behaviors both as promoters of adult health and as complex outcomes of preferences, outlooks, mindsets and choices sculpted early in life. In addition to estimating the gross contribution of early attributes to the adult education health disparity, we also identify the part of that contribution that is mediated by health behaviors. Our results show that parental investments and early cognitive skills and behaviors account for upwards of 70 percent of the association between adult education and health status at age 50. Early cognitive skills and behavioral traits have powerful indirect effects that operate mostly through socioeconomic status (SES) attainment, smoking, and obesity. Research in labor economics has amply demonstrated that leveling the field for the acquisition of early capabilities and behaviors is paramount to attenuate inequalities in labor market success. The most important implication of our investigation is that this also applies for reducing disparities in adult health.

1 INTRODUCTION

The positive relationship between education and other indicators of socioeconomic status (SES) attainment and health – the education and SES-health gradient – is a stubborn finding across countries, institutional contexts, and time (Mackenbach 2012; Meara et al. 2008; Cutler et al. 2011; Lleras-Muney 2005). Recent evidence suggests that adult education and SES-health gradients may have become steeper in the last ten years of so (Meara et al. 2008; Mackenbach 2012; Montez et al. 2011). Explanations of these gradients emphasize the role of adult economic status and access to resources on health (Mackenbach 2012), reverse effects of health conditions on individual occupations, labor market success, labor productivity and wealth (Smith 1999), and selection mechanisms of diverse nature (Chandola et al. 2003; West 1991; Mulatu and Schooler 2002). More recently, empirical evidence for a correlation between early life factors and adult outcomes has rekindled interest in some selection-like mechanisms linking adult health,education and SES attainment to early life experiences. The existence of pathways stemming from adverse childhood conditions and health, running through early cognitive development, personality traits and behaviors, and ultimately influencing individual health trajectories in adulthood, is plausible and raises the possibility that the origins of adult education gradients in health and mortality may be rooted in early life (Case et al. 2005; Conti and Heckman 2010; Palloni et al. 2010). While this conjecture provides a compelling explanation for the persistence of education and other SES gradients in health and mortality, the idea remains controversial and robust empirical confirmation elusive.

This paper aims to extend recent research on the role of early conditions in the genesis of adult health inequalities. We contribute to this literature by assessing the impact of early cognitive skills and behaviors on the adult education-health gradient and by estimating how much of the impact is mediated by selected health behaviors. We investigate the role of selected processes in childhood and adolescence that may simultaneously influence individuals' educational attainment and health outcomes. Of importance is the acquisition during formative years of cognitive skills and behaviors relevant for both educational attainment and decision-making about risk behaviors known to compromise health.

Our work rests on other researchers' insights and findings, but offers new contributions. First, we extend recent efforts to formally represent educational attainment, occupational skills and health status in adulthood as a product of direct and indirect pathways originating in the early stages of the life course (Palloni et al. 2010; Conti and Heckman 2010; Warren 2009; Jackson 2015; Lee and Jackson 2015). As Conti and Heckman (2010) does, we follow a single birth cohort and simultaneously account for health status and education but, unlike that study, we do so up to age 50 thus including a stage in the life course when the incidence of morbidity and health events responsive to early exposures begins to increase rapidly. Like previous research (2010; 2010) we estimate the size of the contribution to the education-health gradient of a pre- and post-educational attainment set of pathways but, unlike these authors, we also investigate the degree to which each pathway is driven by selected health risk behaviors with early origins. Second, unlike other studies (Palloni et al. 2010), and following recent research (Cunha and Heckman 2008; Conti and Heckman 2010), we use a structural equation model (SEM) with latent constructs and associated measurement models to capture the dynamic nature of skill development and the relations among early latent traits. This strategy helps us handle measurement errors and their potential correlation across constructs and over time and leads to more conservative interpretations. Third, as others before us have done, (Jackson 2015; Lee and Jackson 2015; Case et al. 2005; Conti and Heckman 2010) we minimize endogeneity problems associated with family characteristics by using several measures of childhood background conditions. In addition, we test alternative model specifications to assess sensitivity of estimates to controlling for multiple confounding factors. Fourth, unlike most previous studies with the same data and like others have done with different data sets (Todd and Wolpin 2003, 2007; Cunha and Heckman 2008), we address endogeneity in the early capabilities' production process and account for parental investments both as inputs to the formation of cognitive skills and behavioral problems and as responses to earlier assessments of these traits. Lastly, we take very seriously the threat posed by missing data and attrition and employ a suite of approaches to assess the sensitivity of our results to item missingness, panel attrition, alternative variable definitions, and model specification.

The organization of the paper is as follows: in Section 2 we briefly discuss findings about the relation between early conditions, on one hand, and adult health and SES and education, on the other, and propose three hypotheses for testing. Section 3 introduces models of the relationship between health and education, and identifies selected pathways emerging from early conditions. Section 4 describes the data, variables, and indicators used in our analyses. In Section 5 we discuss results from the structural equation models and the final section summarizes, identifies limitations, and draws implications.

2 SOCIOECONOMIC-HEALTH GRADIENTS AMONG ADULTS

2.1 Magnitude and trends of adult health disparities

Pronounced adult health and mortality gradients by education in most high income countries date back to at least 1950, have persisted and endured over time and, more recently, increased (Mackenbach 2012; Meara et al. 2008; Cutler et al. 2011; Banks et al. 2006; Montez et al. 2011). Since the landmark study by Kitagawa and Hauser (1973), studies using different data sources from the United States show that mortality rates among the better educated are several times lower than among the less educated (Preston and Taubman 1994; Elo and Preston 1996; Lauderdale 2001). These disparities are similar in the US, England and Wales, Finland, Hungary, Norway, and Denmark (Valkonen 1989; Mackenbach 2012; Baker et al. 2011; Eikemo et al. 2008). Education-mortality gradients are only a particular example of a more generalized phenomenon. Comparable gradients also exist for self-reported health status, self-reported conditions and disability (Smith and Kington 1997; Lynch 2006) as well as for chronic diseases, such as hypertension, diabetes, coronary heart disease and cancer (Mackenbach et al. 2008). Finally, education gradients extend beyond health outcomes and include health behaviors such as smoking, diet, and exercise (Pampel et al. 2010).

2.2 Explaining the health education gradient

There is no conclusive empirical evidence to support the idea that the relation between education and adult health and mortality is direct and causal (Cutler and Lleras-Muney 2010; Lleras-Muney 2005; Grossman 2008). In a recent review of traditional explanations, the author identifies a number of pathways that could explain the making of gradients and their evolution over time (2012). First, more years of education and education accreditation translate into income, knowledge, information, and access to health services (*Mechanism 1*) (Cutler and Lleras-Muney 2010; Lochner 2011; Brunello et al. 2016). Second, education facilitates the acquisition of personal traits and capabilities (future outlooks, self-efficacy, perseverance) that promote adherence to healthy behaviors (*Mechanims 2*) (Pampel et al. 2010; Ross and Wu 1995; Mirowsky and Ross 2003). Third, causality may also run from health to education. In particular, there are early health conditions that heighten risks of adult illness and also impair acquisition of education-related skills (Auld and Sidhu 2005).

A more recent and novel body of research conjectures that education is an individual attribute operating as a "fundamental cause". This perspective emphasizes the link between education and resources (e.g. knowledge, wealth, power, prestige, social capital) that to reduce the risk of diseases via multiple mechanisms that may vary across places and over time (Link and Phelan 1995; Phelan et al. 2004; Miech et al. 2011). While highly suggestive, this framework is less helpful if our goal is to formulate an explanation that fully integrates the role played by early upbringing and very early experiences.

Here we focus on pathways of recent interest in economics and social psychological literature. They implicate processes with early onset that simultaneously influence education and adult health. Of special importance is the adoption of health protective behaviors, such as avoidance of smoking, healthy diets, and physical activity that seem to be more frequent among individuals with strong future outlooks, low discount rates of the future, discipline, and high levels of self-control (Fuchs 1982; Leigh 1990; Daly et al. 2016). These traits, however, also influence decisions about school continuation and education accreditation goals as well as the acquisition of complementary skills on which labor market success depends. It is thus possible that part of the association between education and adult health and mortality has roots on the early formation of these preferences and traits (Farrell and Fuchs 1982; Grossman 2000).

In a nutshell, the conjecture is that early conditions (health, skills, behaviors) influence later traits, attributes, and behaviors on which both the stock of individuals' human capital and adult health status depend. These processes may require critical and sensitive periods (Knudsen et al. 2006), could involve complicated synergies (Heckman 2007), and proceed via accumulation dynamics pepcitepDiPrete whereby impaired early health and poor skills limits acquisition of subsequent skills, impoverishes the quality of human capital, constraint access to resources, and promote unhealthy behaviors. The sequence of events can take a long time to unfold before it generates the education-health gradient and cannot be identified empirically in cross-sectional or limited panel studies.

This conjecture is not original and has a distinguished history. What is new here is the proposed integrated empirical test that connects all, or the most important, dots.

2.3 Evidence of the influence of early childhood conditions on adult outcomes

A strong case for the foregoing conjecture requires that two conditions be satisfied: (a) empirical evidence that weakens the case for the *Mechanisms 1 & 2*, identified above, while removing the threat of reverse causality (*Mechanism 3*); and (b) confirmation of pathways that connect traits acquired early in life to conditions that regulate the risk of adult ill-health, on one hand, and promote/impair investments in education and accreditation, on the other. A growing body of empirical evidence suggests that these two conditions are satisfied. First, siblings and twin studies, as well as research based on natural experiments, support the idea that the education gradient is not primarily the result of a direct causal effects and can be partially attributed to shared early life conditions (Amin et al. 2015; Lundborg 2013; Madsen et al. 2014; Oreopoulos et al. 2008; Lleras-Muney 2005; Albouy and Lequien 2009; Clark and Royer 2013). Second, there is large body of work that documents the effects of early ill-health and exposure to adverse early conditions on cognitive development (Knudsen et al. 2006; Shonkoff and Phillips 2000; Gluckman et al. 2016), non-cognitive and personality traits and behaviors (Boardman et al. 2002; Knudsen et al. 2006; Shonkoff and Phillips 2000), educational attainment (Currie and Moretti 2007; Oreopoulos et al. 2008; Black et al. 2007) and, lastly, labor market success (Smith 2009; Currie 2009). Of particular salience is empirical evidence that disadvantageous early environments increase the risk of maladjustment, disruptive behaviors, and risky life styles, all factors that reduce chances of scholastic and labor market success and are deleterious to health (Shonkoff and Phillips 2000). Finally, a growing body of evidence documents that some of these cognitive and non-cognitive skills forged early in life influence later educational achievement and labor market success (Todd and Wolpin 2007; Cunha and Heckman 2007; Heckman 2007).

2.4 Early conditions and the education-health gradient: an integrated empirical test

The empirical evidence referred to above supports two inferences. The first is that there are plausible pathways linking early health and conditions, early cognitive and non-cognitive capabilities, educational attainment, and adult health status over long swaths of time. The second is that these pathways are strong enough to generate the education-health gradient even in the absence of a causal effect of education.

However, this evidence has a flaw and is not sufficient to close the case. Because it has been retrieved piecemeal from multiple studies, each focusing on a limited subset of processes of interest (variables and stages of life course), it cannot be used to confirm the gestation and development of the education-health gradients. This could be achieved with an integrated empirical test that includes most, not just a selected few, states and events relevant for the education and health gradient. We know of only a handful of attempts to achieve this (Palloni et al. 2010; Conti and Heckman 2010; Jackson 2015), but each one of these has limitations we seek to overcome here. First, we assess relations over a very long swath of the life course, from birth up to age 50, old enough to capture part of the initial exponential increase in morbidity at adult ages. Second, we use as a guide an integrated model of relations that chains together early environments, early parental interventions and individual traits and attributes, and connects them to key mediators and, importantly, to two health behaviors responsible for an large part of adult ill-health and mortality toll in modern societies, smoking and obesity

2.4.1 Conceptual clarifications

Before stating hypotheses we clarify terminology used throughout rather loosely. First, the terms "early traits", "early capabilities", and "early behaviors" evoke multiple dimensions, not all of which are equally relevant nor play the same role in our accounting. The literature on human capital formation and, more generally, the psychological literature on personality development, assigns importance to (a) early cognitive skills, acquired or innate verbal abilities, logical and numerical reasoning; (b) emotional growth and behavior development referred to as externalizing and internalizing behaviors, and (c) personality traits such as perseverance, goal orientation, industriousness, self-control. All three may be implicated in the process of interest to us, but our models can only include latent constructs for (a) and (b) and must ignore (c), as the data set we use has no information about them (a) and (b) will be referred to as "cognitive skills" and "behaviors", respectively.

Second, parental/teacher investments–a latent construct in our models– refers to inputs produced by parents and teachers (and schools) that could alter the accumulation of cognitive skills and modify behaviors. In our study we refer to these as "parental investments" as we lack precise information on teacher inputs or school quality, resources, and environments.

Finally, to abbreviate we refer to smoking and obesity as health behaviors, even though obesity is the result of multiple behaviors and smoking is a highly heterogeneous behavior (initiation, quantity, intensity)

2.5 Testable hypotheses

We pose the following hypotheses for testing:

1. ***Hypothesis 1:*** *The education-health gradient in adulthood will be significantly attenuated when conditioning on mediators (income, social class, health behaviors), and both the socioeconomic and behavioral dimensions will make unique contributions.*

2. ***Hypothesis 2:*** *Early cognitive skills and behaviors modify the effects of education on adult health status via strong influences on mediating factors associated with both socioeconomic resources and health behaviors.*

3. ***Hypothesis 3:*** *Early cognitive skills and behaviors are strongly responsive to parental investments partially induced by very early assessments of these capabilities and behaviors. These investments will have a long reach by exerting influences on subsequent cognitive skills and behaviors, health behaviors and SES and, through these, modify the education-health gradient.*

3 STRUCTURAL EQUATION MODELS WITH LATENT TRAITS

Our hypotheses are formally represented in two structural models with latent traits linking early cognitive skills and behaviors, health behaviors, education, and adult health. The first model is a simplified version that ignores complexities of early skill formation and behavior development. In particular, it assumes that the relevant cognitive skills and behaviors are those observed at age 16 – before completion of educational attainment – and that these are determined by background characteristics (gender and family of origin) only, not earlier skills, behaviors, or parental interventions. The second model includes a submodel that considers cognitive skills and behaviors at one point in time as a function of both earlier cognitive skills and parental investments in response to assessments made at an earlier point in time. A comparison of results obtained from these models reveals the extent to which accounting for the endogeneity of parental investment modifies inferences regarding the importance of early conditions for the education-health gradient.

3.0.1 The baseline model: M1

We begin with a model of latent traits, M1, that address Hypotheses 1 and 2, and is represented in Figure 1.The complete model, including the measurement model, is represented in Figure B.1 in Appendix B. This model features four intervening variables (mediators)– social class (SC), log family income (INC), smoking (SMK), and obesity (OB) at age 32 – that mediate the effect of education (E) on adult health (H) assessed at ages 23 and 50, respectively. As discussed above, we hypothesize that these mediators are also influenced by early cognitive skills (C) and behaviors (B) measured at age 16. The algebraic rendition of the structural version of M1 – identifying relations between latent traits only– is in Equation A.1 in Appendix A.

Estimates of the parameters in M1 are used to partition the total effect of education on health into the contributions made by the direct effect and the indirect effects operating through social class, log family income, smoking, and obesity, net of family background and early conditions. To illustrate the extent to which the education-health gradient depends on cognitive skills and behavior, we begin by estimating a constrained version of M1 that omits early conditions, C and B. These results are then compared with estimates from the unconstrained model that includes C and B.

3.0.2 The full model: M2

The second structural model, M2, addresses Hypotheses 2 and 3 and is represented in Figure 2 . The complete model, including the measurement model is represented in Figure B.2, Appendix B. It explicitly accounts for inputs into the production of educational attainment and health. We again acknowledge the role of family background while simultaneously capturing the endogenous nature of cognitive and behavioral development (Todd and Wolpin 2003; Cunha and Heckman 2007). More specifically, investments that parents make in a child may depend on that child's previously demonstrated abilities or behaviors. The role of family background is limited to having direct effects on early traits assessed at age 7, parental investment measured at age 11, and mother's and father's education have direct effects on the individual's educational attainment (dashed line in Figure 2). In theory, parental investment should exert all of its influence indirectly, through cognitive and behavioral factors. However, we include a direct effect to capture any associations involving behavioral factors that we cannot measure (e.g., time preferences, risk aversion, self-control) but are related to both parental investments and educational attainment. These dynamics are captured by the algebraic rendition of M2 in Equation A.2 in Appendix A.

4 DATA AND MEASUREMENT

4.1 The National Child Development Study (NCDS)

The NCDS is a prospective longitudinal study of nearly all (98.8%) children born in the week of March 3-9, 1958 in Great Britain (England, Scotland, and Wales). Medical, social, demographic and economic data have been collected on cohort members at birth and ages 7, 11, 16, 23, 32, 42, 46, and 50. In the earlier waves of the study, information is also provided from parents, teachers, and doctorsFerri (1993); Power and Elliott (2006) .The size of the initial birth cohort has decreased approximately 46% from the first to the last wave, dropping from 17,416 in 1958 to 14,010 in 1981 (when the cohort members became the primary respondents), and, finally, to 9,337 in 2008. The final number of cases with full information on all relevant variables at all waves is 1,763 (case complete sample). Rather that following standard practice and limiting analyses to the complete case sample, we make use of many more observations which have non-missing values for at least two endogenous variables or one exogenous and one endogenous variable that appear in our models. The number of individuals that contribute observations for each variable are presented in Table 1 (see Appendix E)

4.2 Variables & Measurement Models

Our measurement models include a suite of indicators that, due to space constraints, we fully describe in Appendix C. They include measures of educational attainment and health status (self-reported) as well as indicators of SES attainment, social class and income in early adulthood. The two health behaviors are assessed at age 30 in the form of BMI and current smoking (regardless of quantity, intensity and age of initiation). In addition, we choose to employ measures of early cognitive skills at ages 7 and 16, multiple indicators of the individuals' behavior profile (behavior internalization/externalization), and parental and teacher interventions and assessments. Finally, we include multiple measures of early family conditions (parental education, social class)

5 Results

Our analyses lead to three inferences. The first is that the original education-health gradient is reduced by over 70% once mediators (income, social class and health behaviors) are accounted for and that, as expected (Hypothesis 1; Figures 1 and 2), both socioeconomic and behavioral factors make significant contributions. Smoking plays the largest role, accounting for nearly 30% of the total effect of education on health. The second finding is that cognitive skills and behavior problems attenuate the gradient further, beyond the reduction associated with mediators (described in Hypothesis 1). More specifically, early traits account for the remainder of the direct effect of education on health, as well as a considerable fraction of each of pathway running through both socioeconomic and behavioral mediator. This offers strong support for Hypothesis 2. The third finding is that the foundation of the education-health gradient begins to take shape as early as age 7, when early traits begin to influence subsequent parental investments and cognitive and behavioral development, as expected by Hypothesis 3. Below we present the evidence that support these three inferences.

These three findings confirm other recent research showing that the health-education gradient is not primarily the result of a causal effect but is heavily dependent on early conditions with broad influence on determinants of education and health status.

5.1 Anatomy of the Education-Health Gradient

The first step in the assessment of the education-health gradient is based on a structural equation model that omits cognitive skills and behaviors assessed early in adolescence but includes the role of mediators (income, social class, and health behaviors). The main results are in Table 2. Estimates of the measurement model are presented in Table C.1 in Appendix C. The first column in Table 2 contains the standardized effects of gender, father's social class, parental education, and an indicator for the family experiencing financial difficulties during childhood on educational attainment (at age 23). The next four columns show the effects on mediators (measured at age 32) for gender, family background, and the respondent's educational attainment. Of particular interest are the positive and significant effects of education on individual's social class, family income, as well as negative effects on obesity and smoking. The education-health gradient that exists net of these mediating factors is shown in the final column of Table 2. After conditioning on socioeconomic and behavioral factors, education still has a positive and significant direct effect on self-reported health at age 50 but, as expected by Hypothesis 1, these effects are only a fraction of the original raw ones. More specifically, when gender and education are the only predictors of health, the standardized coefficient for the effect of education on health is 0.335, which declines to 0.325 when family background measures are included, and is attenuated to 0.101 when the mediators are included (in M1). Thus, social class, family income and health behaviors reduce the education-health gradient by over 70%.

The decomposition analysis offers further confirmation of Hypothesis 1. The lower panel of the table displays selected results. About 42% of the total education-health gradient is due to a direct effect of education on adult health, net of gender and family background (bottom row , first column). With regard to mediators we verify that individuals' social class and income account for about 7% and 11%, respectively, of the original education-health gradient. Roughly 11% of the gradient is attributable to obesity, whereas lion's share, nearly 30%, of the total effect of education on health is contributed by the pathway through smoking. These findings are consistent with Hypothesis 1. The next step is to test Hypothesis 2 by assessing whether or not the inclusion of indicators of early conditions erodes even further the education-health gradient.

5.2 The power of early cognition and behavioral development

To test Hypothesis 2 we estimate a model that includes two additional latent factors representing cognitive skills and behavioral problems assessed at age 16. Table 3 displays standardized coefficients in the pertinent structural equation model. Estimates for the corresponding measurement model are presented in Table C.1 in Appendix C. We highlight three findings. First, estimated effects of parental socioeconomic attainment (father's social class and indicator of family's financial difficulties) and indicators of parental education on early cognition and behavioral problems are sizable, properly signed, and statistically significant. This confirms well-known facts regarding the impact of family background on the genesis of individuals' cognitive and behavioral traits.

Next, the impact of behavioral problems is pervasive and persistent as it influences both education and mediators, particularly smoking (but not obesity) as well as self-reported health. These effects are large, signed as expected, and statistically significant. The effects of early cognition are equally persistent and pervasive but, unlike the effects of behaviors, early cognitive skills is neither a predictor of obesity nor of self-reported health (net of other covariates in the model).

Third and finally, after including the two indicators of early cognition and behaviors, the direct effect of education on health vanishes (last column), due to the strong direct effects of behavioral problems on both education and self-reported health. The education-health gradient still persists, however, as it is propped up by the indirect effects of education working through social class, family income, and smoking which account for 9%, 27%, and 64%, respectively, of the gradient (see decomposition at the bottom of Table 3). The persistent effect of education on smoking, net of early cognition and behavior problems, is an interesting finding in itself. It may work through a greater likelihood of smoking desistance among the more educated that occurs as a reaction to increasing information and awareness of the risks of smoking and the public health campaigns in the 1970s when members of this cohort are completing secondary education. We did not attempt to test this conjecture. The indirect pathway from education, through obesity, and then self-reported health is now accounted for by early traits. Moreover, the pathways associated social class, family income, and smoking have have been reduced 79%, 55%, and 65%, respectively. In total, the education-health gradient is reduced by 68% when early cognitive skills and behavior problems are introduced into the model.

5.3 Magnitude of effects

The results discussed above provide support for Hypotheses 1 and 2, but do not shed light on the actual magnitude of the effects involved. In this section we use the parameter estimates in Tables 2 and 3 to calculate predicted probabilities of self-reporting in each health category for each education group in different scenarios.Predicted probabilities are calculated using equations for women and setting the values of control variables to their respective means Results from the model that omits (includes) early capabilities and traits are presented in panel A (panel B) of Figure 3. When early traits are not accounted for (panel A), health disparities are much larger across education groups compared to the differentials that exist after adjusting for cognitive and behavioral problems (panel B). For example, when early conditions are ignored, there is a 21.8 percentage point difference in the probability of reporting very good or excellent health between those with the highest and lowest level of education (63.6% versus 41.8%, respectively) – we refer to this as the *high-low gap*. When early conditions are included in the model, the high-low gap shrinks to 2.2 percentage points, as 46.0% of the highest education group report being in the healthiest category compared to 43.8% of the group with the lowest level of educational attainment. Note that the probabilities of reporting the healthiest category are lower for each education group because the effects of cognitive skills and behavioral problems measured at age 16 are fixed at the mean values. In other words, these factors are not reinforcing the education-health gradient by improving the outcomes of the highly educated, while penalizing those with less education. Similar processes (working in the opposite direction) operate at the lower end of the health spectrum.

Conversely, the *low-high gap* in the probability of reporting *fair or poor health*, is 13.4 percentage points (23.4% versus 10.0%, respectively) when early conditions are ignored. This gap shrinks to 1.6 percentage points (21.7% versus 20.1%, respectively), when estimating the effects of education net of early cognitive skills and behavioral problems.

Next, we decompose the education-health gradient into the contributions of direct and indirect pathways. Results from the model that omits (includes) early developmental outcomes are presented in the left (right) bar of Figure 4. When early traits are ignored, the high-low gap in reporting the healthiest category consists of a 21.8 percentage point difference. The direct effect of education on health accounts for 9.16 percentage points (or 42% of the total effect), while 6.32 percentage points (29%) are attributable to education differentials in smoking. Family income, obesity, and social class contribute 2.33, 2.33, and 1.55 percentage points (or 10.7%, 10.7%, and 7.1% of the total effect) to the education-health gradient, respectively. Each of these contributions shrinks considerably when cognitive skills and behavioral problems measured at age 16 are incorporated into the model (right panel of Figure 4). After accounting for differences in early traits, the *low-high* gap in reporting *fair or poor health* declines from 13.4 percentage points to 2.2 percentage points. The direct effects vanish and the bulk of the remaining gradient (1.41 or 64%) is due to smoking, whereas 0.59 percentage points (or 27%) are attributable to family income, and the remainder is accounted for by social class.

5.4 Early origins of the gradient: parental investments and the production of early cognitive skills and behaviors

The previous sections demonstrate the extent to which the education-health gradient is diminished when accounting for cognitive skills and behaviors measured at age 16. Our aim in this section is to investigate further the development of these early traits that help lay the foundation for adult health disparities by education (Figure 2, Hypothesis 3). We estimate a structural equation model that captures these early dynamics and their relation to both educational attainment and self-rated health. To simplify, we ignore the intervening variables that mediate the total effect of education on health (examined in Tables 2 and 3). Standardized estimates of the structural parameters in our model are presented in Table 4 (see Appendix C for estimates of measurement model)

We highlight a handful of findings. First and as expected, family background directly affects the earliest measures of development, represented with two latent constructs that reflect cognitive skills and behavior problems observed at age 7. Thus, children whose family experience financial difficulties are expected to be 0.68 standard deviations lower than those who do not face such financial hardship. With respect to behavior problems at age 7, higher levels of parental socioeconomic status are associated with fewer problems, but only financial difficulties and the father's social class have statistically significant effects.

Second, a crucial feature of early developmental processes is that parents respond to the demonstrated abilities of children. This is captured in our model through the inclusion of a latent variable measuring parental investment in the child at age 11, which we allow to depend on gender, family background, and both cognitive skills and behavior problem observed at early ages. Our measure of parental investment reflects the amount of time that each parent spends with the child, the extent to which the parents engage the child's teacher to discuss how well the child is doing at school, and a measure of the school quality based on the proportion of students determined to be capable of passing qualifying exams (as assessed by a teacher or school official). We find statistically significant effects for each measure of parental SES such that higher status is associated with more investment. Of primary interest are the findings linking early development to parental investment. An increase of one standard deviation in cognitive ability at age 7 is associated with a 0.27 standard deviation increase in parental investment at age 11, net of parental SES. Conversely, a one standard deviation increase in behavior problems at age 7 is associated with a decrease of 0.11 standard deviations in parental investment at age 11. With respect to cognitive development at age 16, we see that parental investment at age 11 works to reinforce early disparities in cognitive and behavioral traits. While cognitive skills and behavioral problems measured at age 7 have, respectively, positive and negative (direct) effects on cognitive ability at age 16, higher levels of parental investment at age 11 are also associated with greater cognitive ability at age 16.

Our results for behavioral problems at age 16 are slightly different. Parental investment at age 11 is still significantly associated with fewer behavior problems observed several years later at age 16. We also find that early behavior problems at age 7 predict subsequent behavior problems at age 16. However, cognitive ability at age 7 has a statistically significant and positive direct effect on behavioral problems at age 16, net of the other factors in our model. This counter intuitive finding arises because of the (negative) correlation between the residuals for the developmental outcomes observed at age 7. The total effect of cognitive skills at age 7 on behavioral problems at age 16 is negative, as expected, and thus the positive direct effect is simply working to reduce the total negative association between these two variables. Constraining the correlation between the errors for cognitive skills and behavioral problems measured at age 7 results in a negative, direct effect of cognitive skills at age 7 on behavioral problems at age 16. This model, however, has a relatively poor fit to the data, which is improved substantially by allowing for the errors of the age 7 measures to be correlated.

Finally, the remaining results in Table 4 simply replicate the findings discussed in the previous section, but in the context of a model that includes early developmental processes. Thus, cognitive ability at age 16 has a positive and statistically significant effect on educational attainment, while behavioral problems at age 16 are significantly associated with lower levels of educational attainment. By the same token, the direct effect of behavioral problems on self-rated health at age 50 is negative and statistically significant, net of education. The same is not true for cognitive skills, which operate indirectly to influence the education-health gradient.

This brief exploration of the dynamic of early skill acquisition and behaviors confirms Hypothesis 3: very early assessment of skills and behaviors prompts parental interventions that either reinforce or weaken capabilities acquired earlier. Conditions at ages 11 and 16 that we found to be highly consequential for the adult education-health gradient are in part the outcome of early interventions that follow assessments made at even earlier ages. Thus, early disparities in a handful of key characteristics may become fixed, mark an individual permanently, strengthened over time and translated into adult health disparities. In more than one way this is the human health accumulation equivalent of a human capital accumulation process (Heckman 2007).

A final caveat is in order. All empirical results reported above rest on decisions regarding choices of preferential estimators, handling of missing data and cohort attrition, choices of alternative models, and coding of the variable education. Appendix D addresses each of these and shows that, within fairly conservative bounds, alternative strategies to deal with each of these problems are not consequential for our inferences.

6 Discussion

6.1 Summary of results

The analyses in the paper address three general hypotheses describing the influence of early cognitive and behavioral factors on the education-health gradient. We replicated previous work by confirming the hypothesis that both socioeconomic and behavioral variables mediate the vast majority of the total effect of education on health. We also hypothesized that early traits would similarly influence both the direct and indirect effects of education on health. As a consequence, we expected that the gradient could be considerably reduced when accounting for early conditions. Our results generally support this hypothesis as cognitive ability and behavioral problems measured at age 16 account for over 60% of the direct effect of education on self-rated health. Furthermore, these early traits are completely responsible for the indirect effect running through obesity. While we also find that early traits attenuate each of the other pathways, there still exists an effect of education on health (net of early traits) that is primarily buttressed by smoking. These results support Hypothesis 2 and suggest that the influence of cognitive skills and behavioral problems works through both socioeconomic status and health behaviors. But there is curious specialization of roles as cognitive skills exert direct influence on both family income and the risk of obesity, while behavioral problems do not. Conversely, behavioral problems exert strong effects on smoking and self-rated health, which is not the case for early cognitive skills.

Our third hypothesis is also supported by the results in that cognitive ability and behavioral problems, observed as early as age 7, play a role in generating the education-health gradient observed in adulthood. More specifically, these early traits help predict the level of parental investment in a child's development, and are highly correlated with subsequent measures of cognitive skills and behavior problems observed at age 16, both influential factors in the generation of education health gradients. Investment tends to be greater in children who demonstrate higher levels of cognitive ability and fewer behavior problems at age 7, and these inputs are significantly associated with higher levels of cognitive ability and fewer behavior problems at age 16. We also find evidence of cross-fertilization (Heckman 2007; Cunha and Heckman 2007, 2008; Knudsen et al. 2006), such that early cognitive skills are negatively correlated with latter measures of behavioral problems, and vice versa. Interestingly, our results suggest that the correlation between behavioral problems at age 7 and cognitive skills at age 16 is larger (i.e., closer to -1) than the correlation between cognitive skill at age 7 and behavioral problems at age 16.

Altogether, these results support the key conjecture that early cognitive and behavioral development is a process primed to perpetuate disparities encountered earlier in life by promoting inequality in educational attainment, differential health behaviors and, as a consequence, disparities in adult health status.

6.2 Afterword: why could gradients be increasing?

The key idea explored in this paper are not new and has a long history (Grossman 1972, 2000; Black et al. 1988). Our contribution of this paper consists of a simplified framework that captures those ideas and, importantly, an integrated empirical test that, to our knowledge, has not yet been carried out.

How could our findings help explain variation of the gradient across in time and space? If the seeds of the adult education-health gradient are indeed planted early in life, *why should the strength of this gradient be on an increasing path in the developed world?* The answer may be that the set of skills and capabilities acquired early in life that contribute to both education and health grow and diversify over time. Prior to the discovery of germ theory, educational levels were not decisive for health and mortality. Group health and mortality differentials were more strongly associated with residential conditions, parental occupation and household income. Once communicable diseases are displaced by chronic illnesses, the contraction and treatment of which has much to do with individual mindsets and decision making that play out over a lifetime, the grounds for influence of early conditions that determine both education and health status becomes more fertile and the room for increases in the education-health gradients amplified. The example of smoking is telling. Smoking is a behavior acquired early, difficult to abandon, and its effects are felt only after long latency periods. For the most part, tobacco addiction is acquired during early adolescence, is influenced by parental, sibling and peer smoking and initiation and persistence are tightly related to time preferences, future outlooks, risk aversion and self-control and discipline. Early exposures to family environments and upbringing powerfully selects who smokes and who does not, and it also contributes to sort out those who graduate from high school and those who drop out.

The inescapable policy implication of all this is that, as is the case with human capital formation (Heckman 2007; Cunha and Heckman 2007), early investments encouraging selected behaviors and mindsets, while discouraging others, may have larger adult health-related payoffs than late interventions aimed at altering behaviors that took a lifetime to acquire or directed at diminishing the burden of illness created by these behaviors. One would hope that future empirical research will help to identify a much broader set of early capabilities that influence adult SES and health.

6.3 Limitations of the present study and future research

Despite our argument for broadening the view of the education-health gradient, our approach has some limitations. First, we ignored dynamics that unfold later in life when health deterioration may exert powerful influences on wealth, income and labor force, and could alter the education-health gradients at very old ages (Smith 1999; Case et al. 2005; Palloni et al. 2010; Palloni 2006). It could well be the case that other mediators, such as preventative behaviors or access to timely diagnosis and treatment, begin to weight heavily as individuals age. It remains to be demonstrated that these mediators are modulated by early cognitive and behavior traits.

Second, as stated before, a dimension of capability development that is absent from our model involves positive traits and social skills which, though related, are very different from the behavioral and emotional problems included here (Shonkoff and Phillips 2000). To the extent that these omitted factors are related to the early traits included in our analysis, we may be overstating their impact on the education-health gradient.

Third, our model of the early dynamics oversimplifies the developmental processes at play and under represents more complicated forms of the endogeneity of parental investment. For example, families with greater economic resources may respond differently to the behavior problems of children, relative to families that face more financial constraints. The relationships between parental investment (as an outcome and a predictor) and child development may depend on the level of family SES, a potential non-linearity that we do not explore further. Another issue relates to the fact that parental investments can occur throughout childhood, adolescence, and early adulthood, and that some stages of development may be more sensitive to or critically depend on investments (Knudsen et al. 2006; Heckman 2007; Shonkoff and Phillips 2000; Ben-Shlomo and Kuh 2002). These high order interactions were totally ignored in our models.

Finally, we use a crude approximation to the dynamics at the other end of the life course and ignore the complex interplay between health, SES, and related behaviors. Thus, we ignore decisions about smoking continuation or changes in diet and physical activity in response to past health status. Furthermore, smoking and obesity are just two among other health behaviors that matter for adult health and mortality. As a consequence, our results may be underplaying the role of early conditions and traits.

While acknowledging these shortcomings, the results and models presented here serve as useful steps in painting a more complete picture of the education-health gradient that emerges over the life course. The omissions described above limit the reach of our inferences but open up, we believe, useful directions for future research.

References

Albouy, Valerie and Laurent Lequien. 2009. "Does compulsory education lower mortality?" Journal of Health Economics 28:155–168.

Amin, Vikesh, Jere R. Behrman, Hans-Peter Kohler, Yanyan Xiong, and Junsen Zhang. 2015. "Schooling has smaller or insignificant effects on adult health in the US than suggested by cross-sectional associations: New estimates using relatively large samples of identical twins." Social Science & Medicine 127:181–189.

Auld, Christopher M. and Nirmal Sidhu. 2005. "Schooling, cognitive ability and health." Health Economics 14:1019–1034.

Baker, David P., Juan Leon, Emily G. S. Greenaway, John Collins, and Marcela Movit. 2011. "The Education Effect on Population Health: A Reassessment." Population and Development Review 37:307–332.

Banks, James, Michael Marmot, Zoe Oldfield, and James P Smith. 2006. "Disease and disadvantage in the United States and in England." Journal of the American Medical Association 295:2037–45.

Ben-Shlomo, Yoav and Diana Kuh. 2002. "A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives." International Journal of Epidemiology 31:285–293.

Black, D., J.N. Morris, C. Smith, P. Townsend, and M. Whitehead. 1988. Inequalities in Health: The Black Report: The Health Divide. London: Penguin.

Black, Sandra E., Paul J. Devereux, and Kjell G. Salvanes. 2007. "From the Cradle to the Labor Market? The Effect of Birth Weight on Adult Outcomes." The Quarterly Journal of Economics 122:pp. 409–439.

Boardman, Jason D., Daniel A. Powers, Yolanda C. Padilla, and Robert A. Hummer. 2002. "Low Birth Weight, Social Factors, and Developmental Outcomes among Children in the United States." Demography 39:353–368.

Brewer, Richard I. 1986. "A Note on the Changing Status of the Registrar General's Classification of Occupations." The British Journal of Sociology 37:pp. 131–140.

Brunello, Giorgio, Margherita Fort, Nicole Schneeweis, and Rudolf Winter-Ebmer. 2016. "The Causal Effect of Education on Health: What is the Role of Health Behaviors?" Health Economics 25:314–336.

Case, Anne, Angela Fertig, and Christina Paxson. 2005. "The lasting impact of childhood health and circumstance." Journal of Health Economics 24:365–89.

Chandola, Tarani, Mel Bartley, Amanda Sacker, Crispin Jenkinson, and Michael Marmot. 2003. "Health selection in the Whitehall II study, UK." Social Science and Medicine 56:2059–72.

Chase-Lansdale, P. Lindsay, Andrew J. Cherlin, and Kathleen E. Kiernan. 1995. "The long-term effects of parental divorce on the mental health of young adults: a developmental perspective." Child Development 66:1614–34.

Clark, Damon and Heather Royer. 2013. "The Effect of Education on Adult Mortality and Health: Evidence from Britain." The American Economic Review 103:2087–2120.

Conti, Gabriella and Christopher Hansman. 2013. "Personality and the education-health gradient: A note on 'Understanding differences in health behaviors by education'." Journal of Health Economics 32:480–485.

Conti, Gabriella and James J. Heckman. 2010. "Understanding the Early Origins of the Education-Health Gradient: A Framework That Can Also be Applied to Analyze Gene-Environment Interaction." Perspectives on Pyschological Science 5:585–605.

Cunha, Flavio and James Heckman. 2007. "The Technology of Skill Formation." The American Economic Review 97:31–47.

Cunha, Flavio and James J. Heckman. 2008. "Formulating, Identifying and Estimating the Technology of Cognitive and Noncognitive Skill Formation." Journal of Human Resources 43:738 – 782.

Currie, Janet. 2009. "Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development." Journal of Economic Literature 47:87 – 122.

Currie, Janet and Enrico Moretti. 2007. "Biology as Destiny? Short- and Long-Run Determinants of Intergenerational Transmission of Birth Weight." Journal of Labor Economics 25:pp. 231–264.

Cutler, David M, Fabian Lange, Ellen Meara, Seth Richards-Shubik, and Christopher J Ruhm. 2011. "Rising educational gradients in mortality: the role of behavioral risk factors." Journal of Health Economics 30:1174–87.

Cutler, David M. and Adriana Lleras-Muney. 2010. "Understanding differences in health behaviors by education." Journal of Health Economics 29:1–28.

Daly, Michael, Mark Egan, Jody Quigley, Liam Delaney, and Roy F Baumeister. 2016. "Childhood Self-Control Predicts Smoking Throughout Life: Evidence From 21,000 Cohort Study Participants." Health Psychology 35:1254–1263.

Duke, Naomi and Ross Macmillan. 2016. "Schooling, Skills, and Self-rated Health: A Test of Conventional Wisdom on the Relationship between Educational Attainment and Health." Sociology of Education 89:171–206.

Eikemo, T A, C Bambra, K Joyce, and Espen Dahl. 2008. "Welfare state regimes and income-related health inequalities: a comparison of 23 European countries." European Journal of Public Health 18:593–9.

Elo, I T and S H Preston. 1996. "Educational differentials in mortality: United States, 1979-85." Social Science and Medicine 42:47–57.

Enders, Craig K. and Deborah L. Bandalos. 2001. "The Relative Performance of Full Information Maximum Likelihood Estimation for Missing Data in Structural Equation Models." Structural Equation Modeling: A Multidisciplinary Journal 8:430–457.

Farrell, P. and V. R. Fuchs. 1982. "Schooling and health: the cigarette connection." Journal of health economics 1:217–230.

Ferri, E. 1993. Life at 33: The Fifth Follow-Up of the National Child Development Study. National Children's Bureau, London.

Fuchs, Victor R. 1982. "Time Preference and Health." In Economic Aspects of Health, edited by Victor R. Fuchs, pp. 93–120. Chicago, IL: University of Chicago Press.

Ghodsian, M. 1977. "Children's behaviour and the BSAG: Some theoretical and statistical considerations." British Journal of Social and Clinical Psychology 16:23–28.

Gluckman, Peter, Tatjana Buklijas, and Mark Hanson. 2016. "The developmental origins of health and disease (DOHaD) concetp: past, present and future." In The Epigenome and Developmental Origins of Health and Disease, edited by Cheryl Rosenfeld, pp. 1–15. London: Elsevier.

Goodman, Alissa, Robert Joyce, and James P Smith. 2011. "The long shadow cast by childhood physical and mental problems on adult life." Proceedings of the National Academy of Sciences 108:6032–7.

Grossman, Michael. 1972. "On the Concept of Health Capital and the Demand for Health." Journal of Political Economy 80:pp. 223–255.

Grossman, Michael. 2000. "The Human Capital Model." In Handbook of Economics, edited by Anthony J. Culyer and Joseph P. Newhouse, pp. 347–408. Amsterdam: Elsevier.

Grossman, Michael. 2008. "The Relationship between Health and Schooling." Eastern Economic Journal 34:281–292.

Hawkes, Denise and Ian Plewis. 2006. "Modelling Non-Response in the National Child Development Study." Journal of the Royal Statistical Society. Series A (Statistics in Society) 169:pp. 479–491.

Heckman, James J. 2007. "The economics, technology, and neuroscience of human capability formation." Proceedings of the National Academy of Sciences 104:13250–5.

Jackson, Margot I. 2015. "Cumulative Inequality in Child Health and Academic Achievement." Journal of Health and Social Behavior 56:262–280.

Joshi, Heather. 2014. 'Non-cognitive' skills: What are they and how can they be measured in the British cohort studies? Working Paper 2014/6, Center for Longitudinal Studies, Institute of Education, University of London.

Kitagawa, Evelyn Mae and Philip Morris Hauser. 1973. Differential mortality in the United States: a study in socioeconomic epidemiology. Cambridge, Mass.: Harvard University Press.

Knudsen, Eric I., James J. Heckman, Judy L. Cameron, and Jack P. Shonkoff. 2006. "Economic, Neurobiological, and Behavioral Perspectives on Building America's Future Workforce." Proceedings of the National Academy of Sciences of the United States of America 103:10155–10162.

Lauderdale, D S. 2001. "Education and survival: birth cohort, period, and age effects." Demography 38:551–61.

Lee, Dohoon and Margot Jackson. 2015. "The relationship between lifetime health trajectories and socioeconomic attainment in middle age." Social Science Research 54:96 – 112.

Leigh, J. Paul. 1990. "Schooling and Seat Belt Use." Southern Economic Journal 57:195–207.

Link, Bruce G. and Jo Phelan. 1995. "Social Conditions as Fundamental Causes of Disease." Journal of Health and Social Behavior 35:80–94.

Liu, Hui and Robert A. Hummer. 2008. "Are Educational Differences in U.S. Self-Rated Health Increasing?: An Examination by Gender and Race." Social Science and Medicine 67:1898–1906.

Lleras-Muney, Adriana. 2005. "The Relationship between Education and Adult Mortality in the United States." The Review of Economic Studies 72:pp. 189–221.

Lochner, Lance. 2011. "Non-Production Benefits of Education: Crime, Health, and Good Citizenship." NBER Working Paper w16722 .

Lundborg, Petter. 2013. "The health returns to schooling – what can we learn from twins?" Journal of Population Economics 26:673–701.

Lynch, Scott M. 2006. "Explaining life course and cohort variation in the relationship between education and health: the role of income." Journal of Health and Social Behavior 47:324–38.

Mackenbach, Johan P. 2012. "The persistence of health inequalities in modern welfare states: the explanation of a paradox." Social Scince and Medicine 75:761–9.

Mackenbach, Johan P, Irina Stirbu, Albert-Jan R Roskam, Maartje M Schaap, Gwenn Menvielle, Mall Leinsalu, Anton E Kunst, and European Union Working Group on Socioeconomic Inequalities in Health. 2008. "Socioeconomic inequalities in health in 22 European countries." New England Journal of Medicine 358:2468–81.

Madsen, Mia, Per K. Andersen, Mette Gerster, Anne-Marie N. Andersen, Kaare Christensen, and Merete Osler. 2014. "Are the educational differences in incidence of cardiovascular disease explained by underlying familial factors? A twin study." Social Science and Medicine 118:182–190.

Meara, Ellen R, Seth Richards, and David M Cutler. 2008. "The gap gets bigger: changes in mortality and life expectancy, by education, 1981-2000." Health Affairs 27:350–60.

Miech, Richard A., Fred Pampel, Jinyoung Kim, and Richard G. Rogers. 2011. "The Enduring Association between Education and Mortality: The Role of Widening and Narrowing Disparities." American Sociological Review 76:913–934.

Mirowsky, John and Catherine E. Ross. 2003. Education, social status, and health. New York: A. de Gruyter.

Montez, Jennifer Karas, Robert A Hummer, Mark D Hayward, Hyeyoung Woo, and Richard G Rogers. 2011. "Trends in the Educational Gradient of U.S. Adult Mortality from 1986 to 2006 by Race, Gender, and Age Group." Research on Aging 33:145–171.

Mulatu, Mesfin Samuel and Carmi Schooler. 2002. "Causal connections between socioeconomic status and health: reciprocal effects and mediating mechanisms." Journal of Health and Social Behavior 43:22.

Muthén, L.K. and B.O. Muthén. 1998-2012. Mplus User's Guide. Los Angeles, CA: Muthén & Muthén.

Oreopoulos, Philip, Mark Stabile, Randy Walld, and Leslie L. Roos. 2008. "Short-, Medium-, and Long-Term Consequences of Poor Infant Health." Journal of Human Resources 43:88 – 138.

Palloni, Alberto. 2006. "Reproducing Inequalities: Luck, Wallets, and the Enduring Effects of Childhood Health." Demography 43:pp. 587–615.

Palloni, Alberto, Carolina Milesi, Robert G. White, and Alyn Turner. 2010. "Early Childhood Health, Reproduction of Economic Inequalities and the Persistence of Health and Mortality Differentials." Social Science and Medicine 68:1574–1582.

Pampel, Fred C., Patrick M. Krueger, and Justin T. Denney. 2010. "Socioeconomic Disparities in Health Behaviors." Annual Review of Sociology 36:349–370.

Phelan, Jo C., Bruce G. Link, Ana Diez-Roux, Ichiro Kawachi, and Bruce Levin. 2004. ""Fundamental Causes" of Social Inequalities in Mortality: A Test of the Theory." Journal of Health and Social Behavior 45:265–285.

Power, Chris and Jane Elliott. 2006. "Cohort profile: 1958 British birth cohort (National Child Development Study)." International Journal of Epidemiology 35:34–41.

Preston, Samuel H. and Paul Taubman. 1994. "Socioeconomic Differences in Adult Mortality and Health Status." In Demography of aging, edited by Linda G. Martin and Samuel H. Preston, pp. 279–318. Washington, D.C.: National Academy Press: Washington D.C.

Ross, Catherine E. and Chia-ling Wu. 1995. "The Links Between Education and Health." American Sociological Review 60:719–745.

Rubin, Donald B. 1987. Multiple imputation for nonresponse in surveys. New York: Wiley.

Shepherd, Peter. 2013. Bristol Social Adjustment Guides at 7 and 11 years: 19. 1958 National Child Development Study user guide, Center for Longitudinal Studies, Institute of Education, University of London.

Shonkoff, Jack P. and Deborah A. Phillips. 2000. From Neurons to Neighborhoods: The Science of Early Childhood Development. Board on Children, Youth, and Families, Commission on Behavioral and Social Sciences Education. Washington, D.C.: National Academy Press.

Smith, J P. 1999. “Healthy bodies and thick wallets: the dual relation between health and economic status.” Journal of Economic Perspectives 13:144–66.

Smith, James P. 2009. “The Impact of Childhood Health on Adult Labor Market Outcomes.” The Review of Economics and Statistics 91:478–489.

Smith, J P and R Kington. 1997. “Demographic and economic correlates of health in old age.” Demography 34:159–70.

Todd, Petra E and Kenneth I Wolpin. 2003. “On the specification and estimation of the production function for cognitive achievement.” The Economic Journal 113:F3–F33.

Todd, Petra E. and Kenneth I. Wolpin. 2007. “The Production of Cognitive Achievement in Children: Home, School, and Racial Test Score Gaps.” Journal of Human Capital 1:pp. 91–136.

Valkonen, T. 1989. “Adult Mortality and Level of Education: A Comparison of Six Countries.” In Health inequalities in European countries, edited by John Fox, pp. 142–160. Aldershot, Hants,: Gower Pub. Co.

Warren, John R. 2009. “Socioeconomic Status and Health across the Life Course: A Test of the Social Causation and Health Selection Hypotheses.” Social Forces 87:2125–2153.

Warren, John R. and Elaine M. Hernandez. 2007. “Did Socioeconomic Inequalities in Morbidity and Mortality Change in the United States over the Course of the Twentieth Century?” Journal of Health and Social Behavior 48:335–351.

West, P. 1991. “Rethinking the health selection explanation for health inequalities.” Social Science and Medicine 32:373–84.

Wooldridge, Jeffrey M. 2007. "Inverse probability weighted estimation for general missing data problems." Journal of Econometrics 141:1281 – 1301.

FIGURES

Figure 1: Path diagram for structural model (M1) of pathways connecting education to adult health, adjusting for early traits.

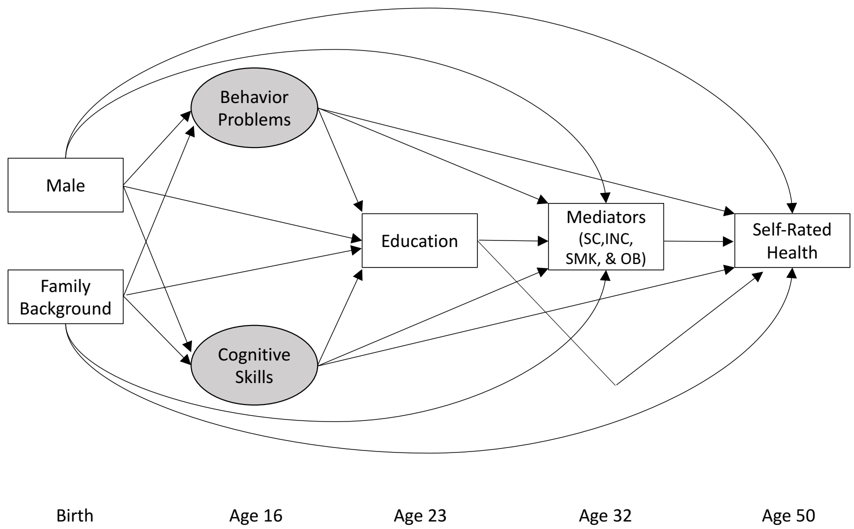


Figure 2: Path diagram for structural model (M2) of early development, investment, education, and health.

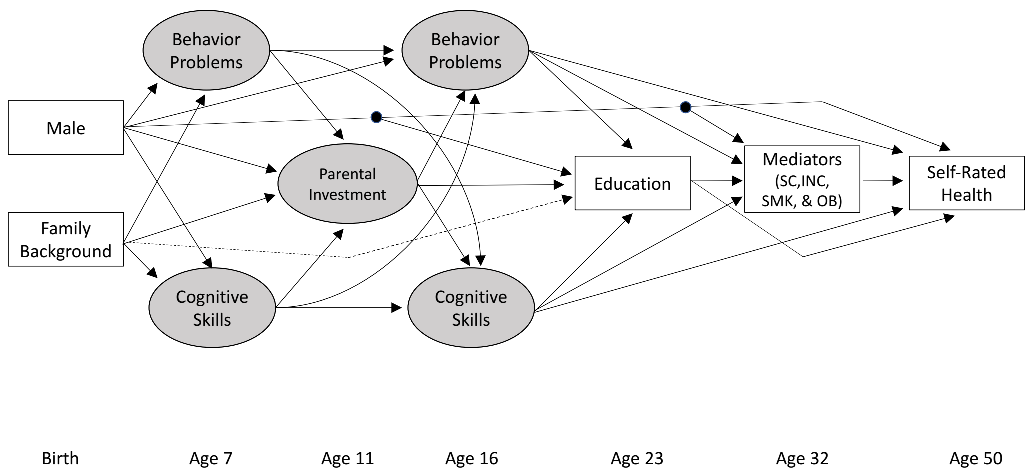


Figure 3: Predicted probabilities of self-rated health at age 50 by education groups from models with (right panel) and without (left panel) cognitive ability and behavior problems at age 16.

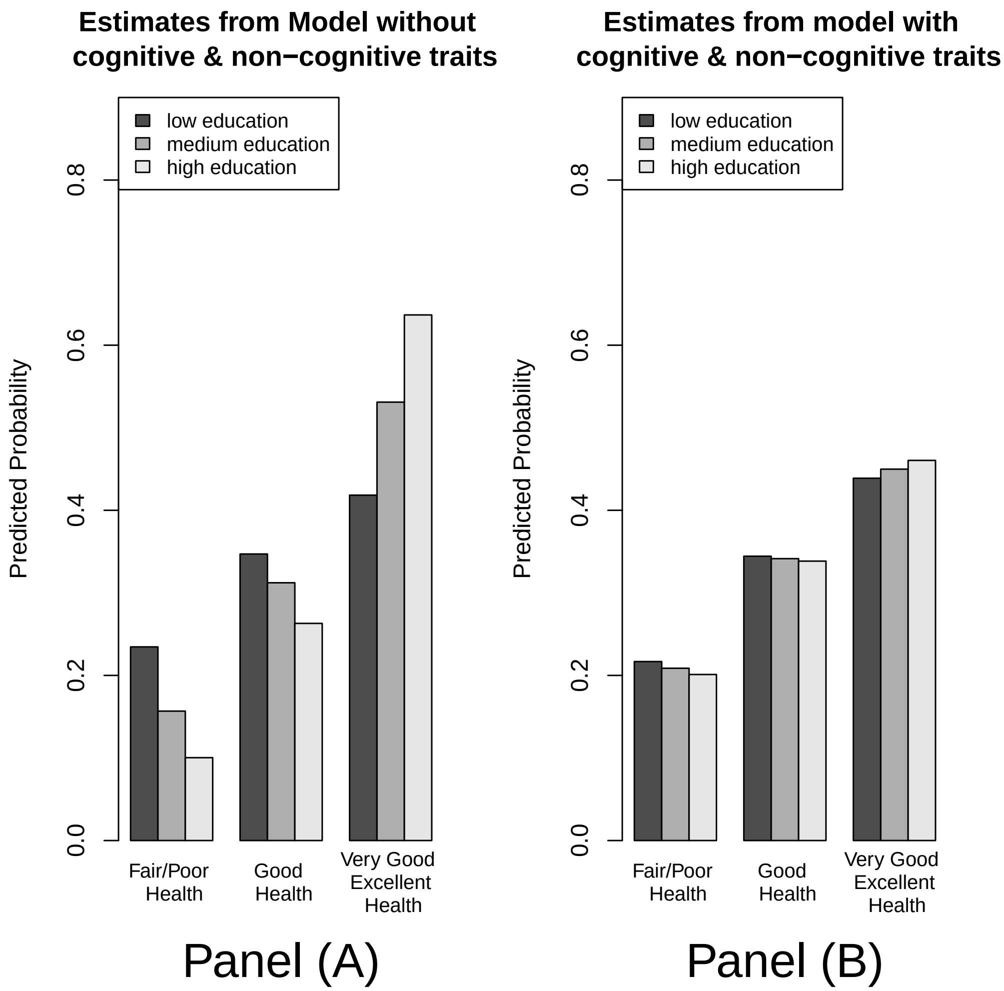
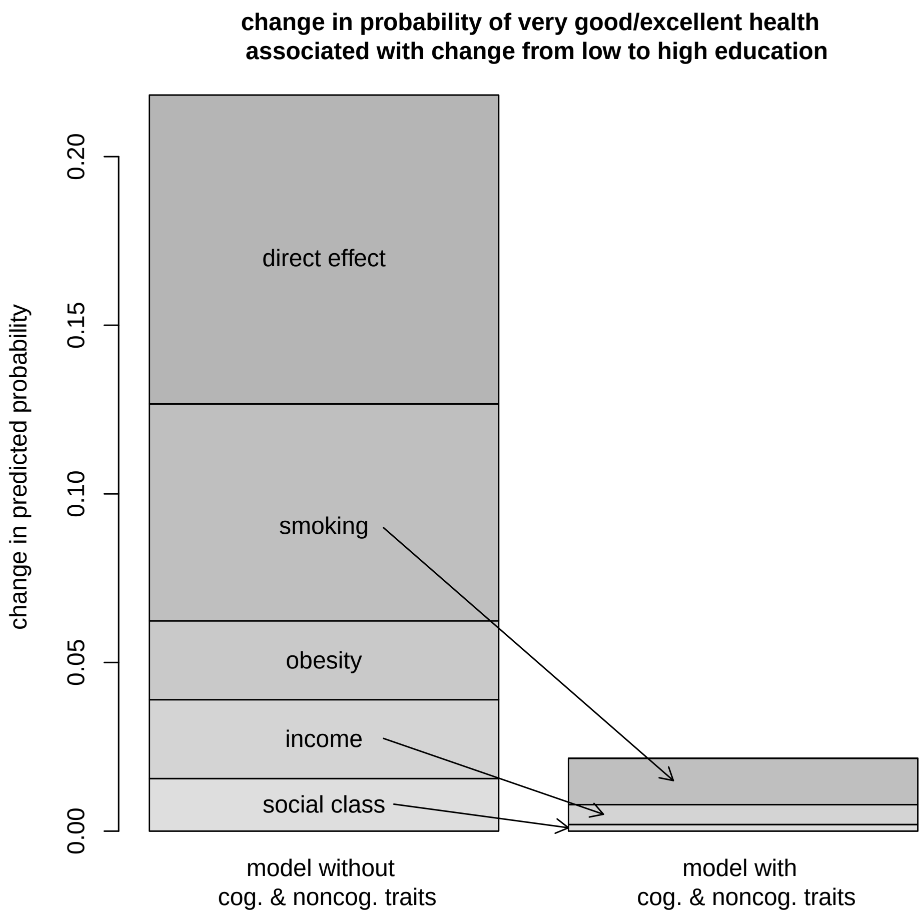


Figure 4: Decomposition of total effect of education on self-rated health at age 50 from models with (right panel) and without (left panel) cognitive ability and behavior problems at age 16.



TABLES

Table 1: Descriptive statistics for model 1 (M1), model 2 (M2), and all available information.

	Model 1 (M1)		Model 2 (M2)		All Available Information	
Demographic Characteristics and Family Background	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Male	0.500	0.500	0.507	0.500	0.517	0.500
Father's Social Class at Child's Birth	1.898	0.727	1.889	0.728	1.848	0.754
Mother's Years of Education at Child's Birth	15.002	1.609	14.991	1.595	14.974	1.566
Father's Years of Education at Child's Birth	15.006	14.988	1.975	1.974	14.983	1.974
Family Had Financial Difficulties	0.072	0.258	0.076	0.265	0.084	0.277
Child Age 7 Characteristics						
Standardized Score on the Reading Exam	--	--	0.54	6.77	0.036	7.077
Standardized Score on the Math Exam	--	--	0.063	2.437	-0.010	2.464
Teacher Rating of Child's Reading Ability	--	--	0.056	0.902	0.006	0.919
Teacher Rating of Child's Math Ability	--	--	0.036	0.860	-0.003	0.863
Bristol Social Maladjustment Externalizing Problems	--	--	3.782	5.056	3.963	5.265
Bristol Social Maladjustment Internalizing Problems	--	--	3.932	4.767	4.073	4.847
Rutter Home Behaviour Scale Externalizing Problems	--	--	2.024	1.510	2.050	1.529
Emotional Maladjustment	--	--	0.041	0.198	0.046	0.209
Child Age 11 Characteristics						
% of Students Capable of Passing a Qualification Exam	--	--	26.351	16.729	26.428	17.463
Frequency Parent Takes Child on Outings	--	--	2.950	1.163	2.916	1.180
Measure of Parent Initiating Discussion with Child's Teacher						
neither parent initiates discussion	--	--	0.405	0.491	0.414	0.493
mother or father initiates discussion	--	--	0.361	0.480	0.362	0.481
both mother and father initiate discussions	--	--	0.234	0.423	0.223	0.416
Child Age 16 Characteristics						
Standardized Score on the Reading Exam	0.761	6.585	0.601	6.686	0.099	6.955
Standardized Score on the Math Exam	0.584	6.945	0.448	6.945	-0.034	6.967
Teacher Rating of Child's Reading Ability	3.337	1.150	3.309	1.162	3.224	1.190
Teacher Rating of Child's Math Ability	3.022	1.204	2.991	1.211	2.898	1.231
Rutter School Behaviour Scale Externalizing Problems	0.540	1.230	0.566	1.268	0.668	1.420
Rutter School Behaviour Scale Internalizing Problems	0.624	0.867	0.633	0.873	0.673	0.912
Rutter Home Behaviour Scale Externalizing Problems	0.860	1.197	0.875	1.206	0.902	1.247
Rutter Home Behaviour Scale Internalizing Problems	0.718	0.946	0.719	0.945	0.730	0.955
Child Education						
Not Passing O-Level or A-Level Exams (~ less than a high school degree)	0.364	0.481	0.364	0.481	0.391	0.488
Passing 1 or more O-Level Exams, but No A-Level Exams (~ high school degree)	0.412	0.492	0.412	0.492	0.395	0.489
Passing O-Level and A Level Exams (~ at least some college)	0.223	0.416	0.223	0.416	0.213	0.409
Child Characteristics Age 32						
Social Class	1.475	0.995	--	--	1.461	0.999
Log of Family Income	5.691	0.560	--	--	5.683	0.569
Obesity	0.124	0.330	--	--	0.130	0.336
Ever Smoked	0.315	0.465	--	--	0.331	0.471
Age 50 Health						
Fair or Poor	0.172	0.377	0.172	0.377	0.184	0.387
Good	0.292	0.455	0.292	0.455	0.290	0.454
Very Good or Excellent	0.536	0.499	0.536	0.499	0.525	0.499
N	7,833		8,476		17,633	

Notes: Standardized scores are centered and adjusted for the month and year when the exam or assessment was given.

Table 2: Standardized weighted least squares estimates for structural model of pathways connecting education to adult health at age 50 (N = 7,833).

	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.075***	0.345***	-0.096***	-0.04	-0.028	-0.016
Father's social class at birth	0.164***	0.047***	-0.012	-0.022	-0.024	0.044**
Father's age when left school	0.231***	0.014	0.028	-0.054	0.063***	-0.008
Mother's age when left school	0.218***	-0.017	-0.008	-0.081**	0.081***	0.011
Family experienced financial difficulties	-0.563***	-0.110*	-0.082	0.009	0.209***	-0.147**
Education (age 23)	--	0.281***	0.337***	-0.123***	-0.386***	0.101***
Social Class (age 32)	--	--	--	--	--	0.063***
Log Family Income (age 32)	--	--	--	--	--	0.076***
Obesity (age 32)	--	--	--	--	--	-0.205***
Current Smoker (age 32)	--	--	--	--	--	-0.184***
	direct effect		indirect effects			
% Contribution to Total Effect of Education on Health	41.96%	7.14%	10.71%	10.71%	29.46%	--

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.987/0.905; root mean square error of approximation = 0.026. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes.

Table 3: Standardized weighted least squares estimates for structural equation model of pathways connecting education to health at age 50, adjusting for early traits (N = 7,833).

	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	0.031	-0.072**	-0.104***	0.318***	-0.114***	-0.03	0.014	-0.026
Father's social class At birth	0.276***	-0.234***	-0.001	0.032**	-0.022	-0.013	-0.001	0.034*
Father's age when Left school	0.083***	-0.029**	0.101***	0.029*	0.036*	-0.053	0.032	0.002
Mother's age when left school	0.099***	-0.029*	0.094***	-0.003	-0.001	-0.080**	0.049**	0.019
Family experienced financial difficulties	-0.709***	0.766***	0.033	-0.031	-0.048	-0.017	0.067	-0.093
Cognitive skills (age16)	--	--	1.575***	0.136***	0.211***	-0.167**	0.013	0.018
Behavioral Problems (age 16)	--	--	-0.185***	-0.117***	0.017	-0.044	0.399***	-0.154***
Education (age 23)	--	--	--	0.089**	0.157***	-0.020	-0.178***	0.027
Social Class (age 32)	--	--	--	--	--	--	--	0.042**
Log Family Income (age 32)	--	--	--	--	--	--	--	0.073***
Obesity (age 32)	--	--	--	--	--	--	--	-0.204***
Current Smoker (age 32)	--	--	--	--	--	--	--	-0.148***
			direct effect omitted		indirect effects (nonsignificant effects ommited)			
% Contribution to Total Effect of Education on Health[a]	--	--	--	9.09%	27.27%	--	63.63%	--

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.943/0.900; root mean square error of approximation = 0.043. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes. [a]The decomposition of the total effect is calculating using a different model with directs effect of education on obesity and self-rated health are omitted to yield a positive total effect on self-rated health.

Table 4: Standardized weighted least squares estimates for structural equation model of early development, education, and adult health (N = 8,476).

	Cognitive Skills age 7	Behavioral Problems age 7	Parental Investment age 11	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Self-Reported Health age 50
Male	-0.154***	0.642***	0.072	0.246***	-0.740***	-0.094***	-0.008***
Father's social class At birth	0.132***	-0.123***	0.227***	--	--	--	--
Father's age When left school	0.277***	-0.009	0.277***	--	--	0.091***	--
Mother's age when Left school	0.208***	-0.017	0.208***	--	--	0.095***	--
Family experienced financial difficulties	-0.680***	0.802***	-0.430***	--	--	--	--
Cognitive skills (age 7)	--	--	0.272***	0.389***	0.622***	--	--
Behavioral Problems (age 7)	--	--	-0.110**	-0.238***	1.137***	--	--
Parental Investment (age 11)	--	--	--	0.420***	-0.482***	--	--
Cognitive skills (age 16)	--	--	--	--	--	0.731***	0.048
Behavioral Problems (age 16)	--	--	--	--	--	-0.093***	-0.184***
Education (age 23)	--	--	--	--	--	--	0.110**

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.904/0.885; root mean square error of approximation =0.044. Larger values of cognitive skills, education and self-rated health correspond to better outcomes.

Appendix A Equations for Model 1 and Model 2

Our hypotheses are formally represented in two structural models linking early experiences, education, and adult health. For ease of exposition, we ignore gender in the formulation of our structural models. In practice, we include a dummy variable for males as a predictor of each endogenous outcome. Indeed, these two pieces could naturally link together, but given the complexity of the more general model (particularly with respect to parameter estimation) we prefer to consider each part separately. We begin with a model, M1 (depicted in Figure 1), that features four intervening variables – social class (SC), log family income (INC), smoking (SMK), and obesity (OB) at age 32 – that help mediate the effect of education (E) on adult health (H) assessed at ages 23 and 50, respectively. As discussed above, we hypothesize that these mediators are also influenced by early cognitive skills (C) and non-cognitive traits that are measured at age 16 and treated as determinants of educational attainment. Due to data availability, we use measures of behavioral problems (BP) to represent non-cognitive traits (see the next section for more details). M1 can be written as

$$\begin{pmatrix} C_{16} \\ BP_{16} \\ E_{23} \\ SC_{32} \\ INC_{32} \\ SMK_{32} \\ OB_{32} \\ H_{50} \end{pmatrix} = \begin{pmatrix} \gamma_{10}FB & & & & & & & \\ \gamma_{20}FB & & & & & & & \\ \gamma_{30}FB + & \beta_{31}C + & \beta_{32}BP & & & & & \\ \gamma_{40}FB + & \beta_{41}C + & \beta_{42}BP + & \beta_{43}E & & & & \\ \gamma_{50}FB + & \beta_{51}C + & \beta_{52}BP + & \beta_{53}E & & & & \\ \gamma_{60}FB + & \beta_{61}C + & \beta_{62}BP + & \beta_{63}E & & & & \\ \gamma_{70}FB + & \beta_{71}C + & \beta_{72}BP + & \beta_{73}E & & & & \\ \gamma_{80}FB + & \beta_{81}C + & \beta_{82}BP + & \beta_{83}E + & \beta_{84}SC + & \beta_{85}INC + & \beta_{86}SMK + & \beta_{87}OB \end{pmatrix} + \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \\ \psi_6 \\ \psi_7 \\ \psi_8 \end{pmatrix} \tag{A.1}$$

where FB represents measures of family background, γ_{ij} and β_{ij} are estimated coefficients for exogenous and endogenous variables (respectively), and the ψ_i are error terms. (Subscripts for the variables on the right side of the equation are omitted to save space.) Given that our exogenous family background variables will not include all of the common causes of cognitive skills and behavioral factors, we allow their errors (ψ_1 and ψ_2) to be correlated (all other errors are assumed to be independent of each other). Estimates from M1 are used to partition the total effect of education on health into the contributions made by the direct effect, $\beta_{83,}$, and the indirect effects operating through social class, log family income, smoking, and obesity, net of family background and early conditions. To illustrate the extent to which the education-health gradient depends on cognitive and behavioral traits, we begin by estimating a constrained version of M1 that omits C and BP. These results are then compared with estimates from the unconstrained model that includes C and BP.

Our second structural model, M2 (depicted in Figure 2), shifts the focus to the development processes that act as inputs into the production of educational attainment and health. Here, we again acknowledge the role of family background while also capturing the endogenous nature of cognitive and behavioral development (Todd and Wolpin 2003; Cunha and Heckman 2007). More specifically, the investments that parents and teachers make in a child may depend on that child's previously demonstrated abilities or problems. These early dynamics appear in M2 as follows

$$\begin{pmatrix} C_7 \\ BP_7 \\ INV_{11} \\ C_{16} \\ BP_{16} \\ E_{23} \\ H_{50} \end{pmatrix} = \begin{pmatrix} \gamma_{10}FB & & & & & & \\ \gamma_{20}FB & & & & & & \\ \gamma_{30}FB + & \beta_{31}C_7 + & \beta_{32}BP_7 & & & & \\ & \beta_{41}C_7 + & \beta_{42}BP_7 + & \beta_{43}INV_{11} & & & \\ & \beta_{51}C_7 + & \beta_{52}BP_7 + & \beta_{53}INV_{11} & & & \\ \gamma_{60}FB + & & & \beta_{63}INV_{11} + & \beta_{64}C_{16} + & \beta_{65}BP_{16} & \\ & & & & \beta_{74}C_{16} + & \beta_{75}BP_{16} + & \beta_{76}E \end{pmatrix} + \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \\ \psi_6 \\ \psi_7 \end{pmatrix}. \tag{A.2}$$

As with the first model, our exogenous family background variables will not include all of the common causes of cognitive skills and behavioral factors measured at age 7, and thus we allow their errors (ψ_1 and ψ_2) to be correlated (all other errors are assumed to be independent of each other). Preliminary analyses (not reported here) suggest that the omitted paths in M2 do very little to improve the model fit and, thus, we prefer the more parsimonious specification presented above. Finally, direct effects of family background variables on education are included only for measures of parental education.

Appendix B Supplemental Figures for Model 1 and Model 2

Figure B.1: Path diagram and measurement component of the structural model (M1) of pathways connecting education to adult health, adjusting for early traits.

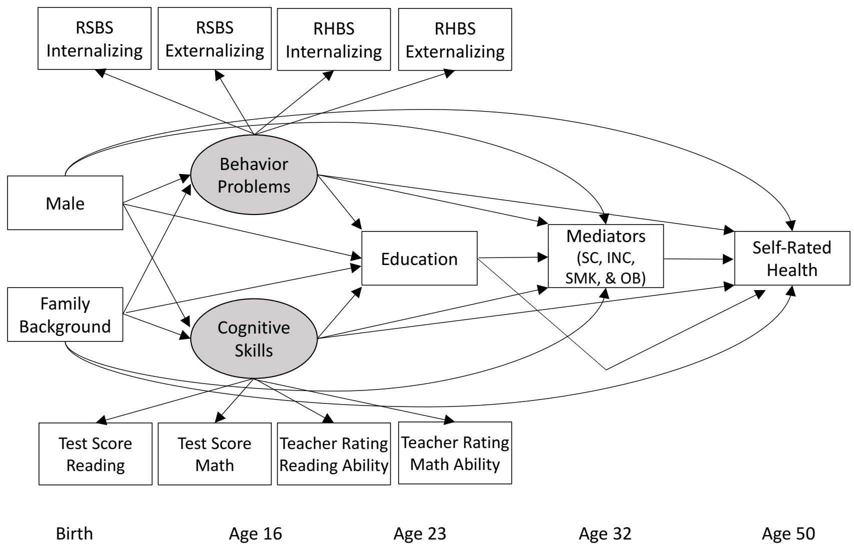
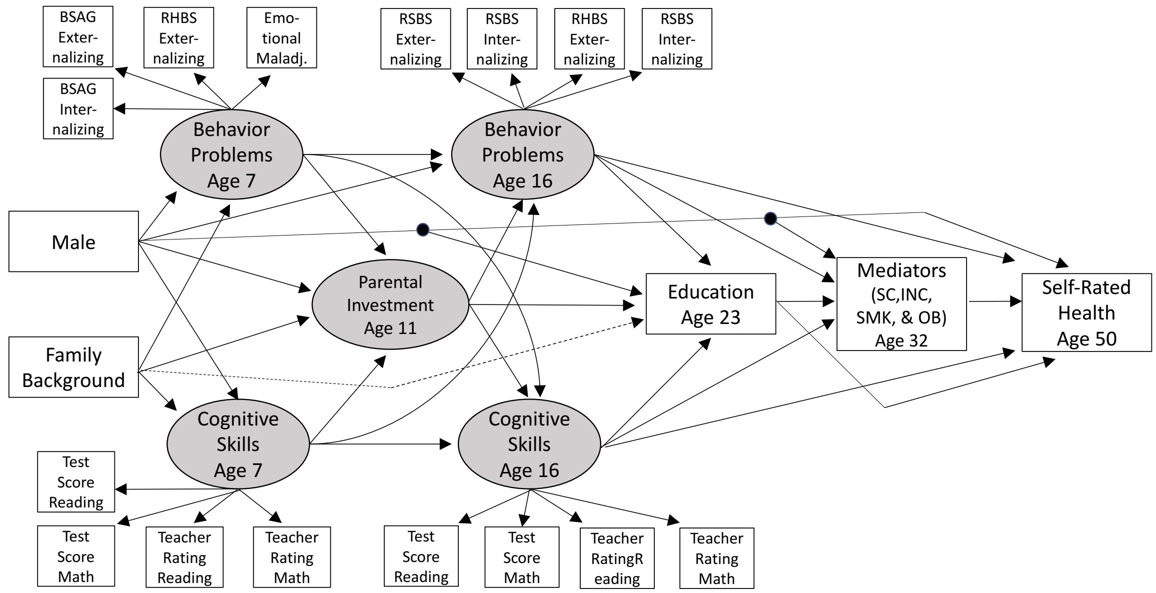


Figure B.2: Path diagram and measurement component of the structural model (M2) of early development, investment, education, and adult health.



Appendix C Supplemental Tables

Table C.1: Estimates from the measurement model corresponding to the structural model (Table 3) pathways connecting education to health at age 50, adjusting for early traits (N = 7,833).

	Cognitive Ability	Behavioral Problems
Score on reading exam	1.00[b]	
Score on math exam	1.022***	
teacher's rating of child's english ability	1.267***	
teacerh's rating of child's ability in math	1.307***	
Rutter's School Behavior Scale		
composite for externalizing behaviors		1.00[b]
composite for internalizing behaviors		0.445***
Rutter's Home Behavior Scale		
composite for externalizing behaviors		0.777***
composite for internalizing behaviors		0.194***

Note: (a) All variables measured when the child was age 16. (b) Parameter constrained to 1 for model identification. * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.943/0.902; root mean square error of approximation = 0.043.

Table C.2: Estimates from the measurement model corresponding to the structural model (Table 4) of early development, education, and adult health (N = 8,476).

	Cognitive Ability (Age 7)	Behavioral Problems (Age 7)	Parental Investment (Age 11)	Cognitive Ability (Age 16)	Behavioral Problems (Age 16)
Score on reading exam	1.00[a]			1.00[a]	
Score on math exam	0.829***			0.973***	
teacher's rating of child's reading (age 7) or english (age 16) ability	0.903***			1.206***	
teacerh's rating of child's ability in math	0.810***			1.228***	
Bristol Social Maladjustment Guide					
composite for externalizing behaviors		1.00[a]			
composite for internalizing behaviors		1.077***			
Rutter's Home Behavior Scale					
composite for externalizing behaviors		0.629***			0.870***
composite for internalizing behaviors					0.331***
Doctor indicates child experiences a handicap due to emotional maladjustment		0.774***			
School official's assessment of the % of students capable of passing a qualification exam			1.00[a]		
Extent to which parents initiate discussions with child's teacher about the child's performance			1.353***		
Frequency with which parents take child on outings			0.923***		
Rutter's School Behavior Scale					
composite for externalizing behaviors					1.00[a]
composite for internalizing behaviors					0.743***

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. (a) Parameter constrained to 1 for model identification. Model fit statistics: CFI/TLI = 0.904/0.885; root mean square error of approximation = 0.044.

Appendix D Variables & Measurement Models

The following is a detailed description of latent traits and their indicators used in our measurement model.

Education, Mediators, and Health. Educational attainment is measured using a classification recommended by previous research with British data that ensures comparability with conventional education categories used elsewhere in the world . In particular, we follow a practice adopted for the comparative study of elderly (HRS and ELSA) suggested by Banks, Marmot and Smith (2006) and employ a three category variable: 1) not passing any O-level or A-level exams; 2) passing one or more O-level exams, but no A-level exams; and 3) passing both O-level and A-level exams by age 23. This coding scheme is meant to mimic the categories of less than a high school degree, a high school degree, and more than a high school degree in the United States.
We use two indicators of for the latent trait SES. First we include social class using the classification originally devised by the British Registrar General for use in the national census and remains a standard measure of SES in studies of health and mortality disparities in the United Kingdom (Brewer 1986). Second, we include the (log of) family income, as well as dummy variables for obesity (i.e., binary indicator for Body Mass Index, BMI$>$30) and current smoking status. All four mediating variables are measured at age 32. Finally, the ultimate outcome of interest is the cohort member's self-rated health at age 50, which takes on the following values: 1 – poor or fair; 2 – good; 3 – very good or excellent. This classification is a compromise between previous work that singles out substandard health – i.e., poor or fair (Goodman et al. 2011; Liu and Hummer 2008; Warren and Hernandez 2007) – and those that exploit the full range of the scale (Case et al. 2005).
Early cognitive Skills. Four different indicators of cognitive ability are included at age 7. The first two indicators are the cohort member's test scores on an arithmetic exam

(with scores ranging form 0 to 10) and a reading exam (with scores ranging from 1 to 30). The remaining two measures of cognitive ability at age 7 are taken from the teacher's ratings of the child's reading ability and their number work (with scores ranging from 1 to 5). We adjust each variable for the age (in months) at which the child ability was assessed. A similar approach is used to measure cognitive ability at age 16. Scores from a reading exam (ranging from 0 to 35) and a math exam (ranging from 0 to 31) are employed in conjunction with the teacher's rating of the cohort member's ability in both mathematics and English (with scores ranging from 1 to 5). Again, the exam scores are adjusted for age (in months) at which the cohort member took the exam.

Early behaviors. The latent construct early behaviors we use here is meant to capture emotional and behavioral problems. These are empirically assessed using multiple NCDS protocols: (a) Rutter Home Behaviour Scale (RHBS) administered at ages 7 and 16 and based on reports from parents; (b) the Rutter School Behaviour Scale (RSBS) administered at age 16 and based on reports from teachers; and (c) the Bristol Social Adjustment Guide (BSAG) administered at ages 7 and based on reports from teachers (see Chase-Lansdale et al. (1995) for a discussion of these different measures). We follow the lead of previous research and use two composites from each source that represent internalizing and externalizing behavior problems (Ghodsian 1977; Joshi 2014; Shepherd 2013). The only exception involves the RHBS composite for internalizing behavior problems observed at age 7. In preliminary analyses, we found that this measure has a very low factor loading, and thus we only use the composite for externalizing behavior problems. We supplement the age 7 behavioral measures with a dummy variable that indicates if a doctor identified the child is handicapped by emotional maladjustment.

We hasten to add that a complete test of the hypotheses formulated earlier requires not just measures of emotional and behavioral problems (internalizing or externalizing behaviors) as we do here, but also indicators of non-cognitive skills, such as individual discipline, initiative, self-control, industriousness. These are not available in the NCDS and we are limited to a highly constrained set of traits that exclude potentially important determinants of educational attainment and adult health status. Unlike some of the non-cognitive traits conventionally referred to in the literature, those we are able to include here are markers of behaviors that should contribute negatively, rather than positively, to both educational attainment and health status. It must be said, however, that inclusion of measures of early maladjustment, emotional and behavioral problems is a strength in our data since these have proven to be powerful predictors of health behaviors (Daly et al. 2016; Duke and Macmillan 2016; Conti and Hansman 2013). In any case, we remain mindful that excluding from consideration the non-cognitive traits for which we have no indicators will underplay the degree to which early capabilities contribute to the education-health gradient.

Parental Investment. Measures of investment on children are taken from the NCDS wave conducted at age 11, and reflect either parental involvement in the child's life or the quality of the school the child attends. Indicators for the former dimension of investment include the cohort member's teacher reporting if the mother, father, or both parents take the initiative to discuss the child with the teacher (with values ranging from 0, neither parent taking the initiative, to 2 if both parents engage the teacher in discussion). Parental involvement is also measured using categorical variables for the frequency with which each parent takes the child with them on outings: 1 – hardly ever; 2 – occasionally; and 3 – most weeks. We sum the variables for mother and father involvement to create a composite ranging from 2 to 6. School quality is measured using the fraction of students in the child's school who have the ability to pass an academic qualification exam roughly equivalent to a graduating from high school (Banks et al. 2006). This final indicator is reported by an official from the cohort member's school. In what follows we will refer to these indicators as measures of parental investments even though they also include features of teachers and schools.

Family Background. Four different indicators are used to capture the effect of family background on the subsequent outcomes. The first indicator is the father's social class observed at the birth of the child. We use a modified version which includes a (reference) category for families in which the father is unemployed, out of the labor force, or absent. To ensure sufficient observations we also collapse the following classes: (1) unskilled and partly skilled; (2) skilled manual and skilled non-manual; and (4) managerial, technical, and professional. Family background is also captured by measures of parental education, namely, the age at which each parent left full-time education. Finally, when the cohort member was age 7, the family respondent (typically one of the parental figures) was asked if the family experiences financial difficulties, which we treat as a 0/1 indicator.

Appendix E Parameter Estimation & Sensitivity Analyses

The results discussed in the main body of the paper depend on a number of decisions regarding class of estimators chosen, treatment of missingness and sample attrition, and coding of the key variable in the analyses, namely, education. With the aim of providing sensitivity bounds, we pursued in each case alternative strategies. These are described below.

Choice of estimators. Results in Tables 2-4 are obtained via a robust weighted least squares estimator, as implemented in the Mplus statistical software (Muthén and Muthén 1998-2012). This particular estimator is best suited for decomposing the total effect of education when categorical variables appear on the model as mediators. However, if we assume that the NCDS data are missing at random (Hawkes and Plewis 2006), full information maximum likelihood (FIML) estimates are more efficient, unbiased (Enders and Bandalos 2001), and adjustments can be made {to} correct the standard errors for any biases induced by lack of normality (Muthén and Muthén 1998-2012). To test the sensitivity of our estimates to the estimation procedure we replicate our analyses using FIML and find that our conclusions remain virtually unchanged.These results are included in Tables E1-E3. The one notable exception is that we find that cognitive skills observed at age 16 has a statistically significant and positive direct effect on adult health, net of educational attainment (see Table E2). This coefficient is positive, but not statistically significant in the analysis presented in Table 4 in the body of paper. This FIML result suggests that early cognitive skills may play an even more important role in producing the education-health compared to the previous analysis using the weights least squares estimator.

Missingness and attrition. To help assess the sensitivity of our results to treatment of missing data we replicated the analyses above (with the weighted least squares estimator), but employing multiple imputation techniques (Rubin 1987) as well as inverse probability weighting (Wooldridge 2007) methods to handle attrition. Results after using multiple imputation are displayed in Tables E4-E6. Estimates obtained with inverse weighing are in Tables E7-E9. Not surprisingly, the numerical values in these tables are not identical to those shown in the main body of the paper. However, they lead to the same inferences.

Model specification. M1 and M2 are the most parsimonious models we can propose. They were arrived after an extensive evaluation of alternative specifications. Despite the additional complexities introduced by these alternative models, their fit was worse (net of number of parameters) than that of the models we settled on. We cannot show results corresponding to all the alternative specifications we worked with. Here we only address two of these.

Our choice of models could be questioned for at least two reasons. First, it may be argued that the processes we model here are different by gender and that the models should have been estimated separately for males and females. We did so and estimated models M1 and M2 separately by gender but found that there is no strong evidence to support the idea that the genesis of the education-health gradients differs by sex. Second, the body of the paper does not discuss results of models that include lagged values of key latent traits, a strategy that in some cases at least, reduces endogeneity biases. To tackle this and in an attempt to investigate a vastly more conservative approach, we proceeded to estimate value added versions of M1 and M2 that include lagged values of all the dependent variables. The problem is that these models are very difficult to estimate in an SEM framework without making assumptions that are difficult to justify, perhaps more so than the ones that the value added models are supposed to circumvent. As a result we were not able to identify parameters in all models of interest to us and cannot compare results with those we discuss in the paper. This may not be a big loss since like other specifications that remove the influence of potential confounders, value added models, also remove relations of interest.

Coding of education. In our analyses of the NCDS data, we follow the lead of Banks et al. (2006) by employing a three category variable for educational attainment that facilitates comparisons with results of the education-health gradient in the US. To explore the possibility that more heterogeneity in educational attainment may uncover different results concerning the health gradient, we replicated our analyses using a variable that includes six categories of educational attainment that identifies finer detail at the higher end of the spectrum. The results, shown in E10-E12, are generally similar to those presented earlier, with one exception. In our model that captures early development, M2, the direct effect of education on adult health is no longer statistically significant when using the more expansive coding of education (see Table E10). This suggest a possible nonlinear relationship between education and health, such that the health disparity is primarily concentrated between those at the very bottom of the education distribution and those with at least some accreditation.

Table E.1: Full information maximum likelihood estimates (with robust standard errors) for structural model of pathways connecting education to adult health at age 50 (N = 17,622).

	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.193***	0.337***	-0.088***	0.000	-0.026	-0.001
Father's social class at birth	0.447***	0.068***	0.023	-0.084*	-0.153***	0.096***
Father's age when left school	0.447***	0.032**	0.051***	-0.083*	0.039	0.019
Mother's age when left school	0.414***	-0.008	0.021	-0.162***	0.110***	0.048
Family experienced financial difficulties	-1.147***	-0.129***	-0.206***	0.031	0.442***	-0.347***
Education (age 23)	--	0.347***	0.357***	-0.301***	-0.732***	0.244***
Social Class (age 32)	--	--	--	--	--	0.138***
Log Family Income (age 32)	--	--	--	--	--	0.159***
Obesity (age 32)	--	--	--	--	--	-0.751***
Current Smoker (age 32)	--	--	--	--	--	-0.549***

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes.

Table E.2: Full information maximum likelihood estimates (with robust standard errors) for structural equation model of pathways connecting education to health at age 50, adjusting for early traits (N = 17,630).

	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.015	-0.015	-0.377***	0.316***	-0.105***	0.014	0.034	-0.017
Father's social class At birth	0.216***	-0.180***	0.002	0.033**	-0.009	-0.054	-0.059	0.053*
Father's age when Left school	0.067***	-0.035***	0.127***	0.015**	0.022**	-0.039	0.022	0.008
Mother's age when left school	0.077***	-0.030***	0.149***	-0.009	0.007	-0.096***	0.067***	0.032
Family experienced financial difficulties	-0.573***	0.606***	-0.048	0.005	-0.114**	-0.056	0.059	-0.196**
Cognitive skills (age16)	--	--	3.561***	0.216***	0.378***	-0.345***	-0.046	0.155**
Behavioral Problems (age 16)	--	--	-0.234**	-0.168***	0.011	-0.034	0.991***	-0.407***
Education (age 23)	--	--	--	0.108***	0.078***	-0.045	-0.283***	-0.003
Social Class (age 32)	--	--	--	--	--	--	--	0.098***
Log Family Income (age 32)	--	--	--	--	--	--	--	0.141***
Obesity (age 32)	--	--	--	--	--	--	--	-0.738***
Current Smoker (age 32)	--	--	--	--	--	--	--	-0.404***

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes.

Table E.3: Full information maximum likelihood estimates (with robust standard errors) for structural equation model of early development, education, and adult health (N = 12,198).

	Cognitive Skills age 7	Behavioral Problems age 7	Parental Investment age 11	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Self-Reported Health age 50
Male	-0.154***	0.260***	0.072	0.246***	-0.740***	-0.094***	-0.008***
Father's social class At birth	0.132***	-0.090***	0.227***	--	--	--	--
Father's age When left school	0.277***	-0.021***	0.277***	--	--	0.091***	--
Mother's age when Left school	0.208***	-0.034***	0.208***	--	--	0.095***	--
Family experienced financial difficulties	-0.680***	0.802***	-0.430***	--	--	--	--
Cognitive skills (age 7)	--	--	0.200***	0.477***	0.507***	--	--
Behavioral Problems (age 7)	--	--	-0.036	-0.385***	1.184***	--	--
Parental Investment (age 11)	--	--	--	0.984***	-0.723***	--	--
Cognitive skills (age 16)	--	--	--	--	--	0.731***	0.048
Behavioral Problems (age 16)	--	--	--	--	--	-0.093***	-0.184***
Education (age 23)	--	--	--	--	--	--	0.110**

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Larger values of cognitive skills, education and self-rated health correspond to better outcomes.

Table E.4: Standardized weighted least squares estimates for structural model of pathways connecting education to adult health at age 50 using multiply imputed data (N = 17,633).

	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.099***	0.288***	-0.123***	0.002	-0.084***	0.018
Father's social class at birth	0.166***	0.047***	0.003	-0.023	-0.032**	0.027**
Father's age when left school	0.203***	0.016	0.021	-0.025	0.004	-0.001
Mother's age when left school	0.191***	-0.024*	0.006	-0.052**	0.046***	0.007
Family experienced financial difficulties	-0.594***	-0.084**	-0.203***	-0.061	-0.033	-0.154***
Education (age 23)	--	0.329***	0.303***	-0.130***	-0.168***	0.138***
Social Class (age 32)	--	--	--	--	--	0.103***
Log Family Income (age 32)	--	--	--	--	--	0.105***
Obesity (age 32)	--	--	--	--	--	-0.186***
Current Smoker (age 32)	--	--	--	--	--	-0.123***

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Model fit statistics: CFI/TLI = 0.959/0.690; root mean square error of approximation = 0.052. Fit statistics averaged over multiply imputed data sets. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes.

Table E.5: Standardized weighted least squares estimates for structural equation model of pathways connecting education to health at age 50, adjusting for early traits and using multiply imputed data (N = 17,633).

	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.008	-0.042	-0.096***	0.248***	-0.159***	0.003	-0.117***	0.005
Father's social class At birth	0.250***	-0.214***	0.007	0.029***	-0.012	-0.020	0.029**	0.017
Father's age when Left school	0.080***	-0.028***	0.078***	0.036**	0.035**	-0.024	0.026	0.010
Mother's age when left school	0.105***	-0.030***	0.060***	-0.011	0.012	-0.051**	0.060***	0.016
Family experienced financial difficulties	-0.683***	0.787***	-0.008	0.008	-0.149***	-0.074	-0.057	-0.090*
Cognitive skills (age16)	--	--	1.666***	0.331***	0.436***	-0.006	0.431**	0.055
Behavioral Problems (age 16)	--	--	-0.131**	-0.122***	0.005	0.014	0.085*	-0.149***
Education (age 23)	--	--	--	-0.049	-0.101	-0.127	-0.556***	0.022
Social Class (age 32)	--	--	--	--	--	--	--	0.085***
Log Family Income (age 32)	--	--	--	--	--	--	--	0.099***
Obesity (age 32)	--	--	--	--	--	--	--	-0.184***
Current Smoker (age 32)	--	--	--	--	--	--	--	-0.118***

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.937/0.891; root mean square error of approximation = 0.049. Fit statistics averaged over multiply imputed data sets. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes. Direct effects of education on obesity and self-rated health are omitted to yield a positive total effect on self-rated health.

Table E.6: Standardized weighted least squares estimates for structural equation model of early development, education, and adult health using multiply imputed data (N = 17,633).

	Cognitive Skills age 7	Behavioral Problems age 7	Parental Investment age 11	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Self-Reported Health age 50
Male	-0.153***	0.619***	0.033	0.222***	-0.786***	-0.094***	-0.008***
Father's social class At birth	0.179***	-0.158***	0.294***	--	--	--	--
Father's age When left school	0.048***	-0.002	0.137***	--	--	0.081***	--
Mother's age when Left school	0.084***	-0.016	0.136***	--	--	0.068***	--
Family experienced financial difficulties	-0.632***	0.727***	-0.515***	--	--	--	--
Cognitive skills (age 7)	--	--	0.306***	0.412***	0.696*	--	--
Behavioral Problems (age 7)	--	--	-0.021	-0.245***	1.299***	--	--
Parental Investment (age 11)	--	--	--	0.399***	-0.424***	--	--
Cognitive skills (age 16)	--	--	--	--	--	1.448***	0.061
Behavioral Problems (age 16)	--	--	--	--	--	-0.161***	-0.165***
Education (age 23)	--	--	--	--	--	--	0.128***

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.894/0.872; root mean square error of approximation =0.049. Fit Statistics averaged over multiply imputed data sets. Larger values of cognitive skills, education and self-rated health correspond to better outcomes.

Table E.7: Standardized weighted least squares estimates for structural model of pathways connecting education to adult health at age 50 using inverse probability weights (N = 7,833).

	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.074***	0.278***	-0.100***	-0.046	-0.025	-0.016
Father's social class at birth	0.162***	0.048***	-0.013	-0.019	-0.027	0.040**
Father's age when left school	0.229***	0.014	0.030	-0.052	0.057***	-0.009
Mother's age when left school	0.221***	-0.019	-0.009	-0.081**	0.086***	0.006
Family experienced financial difficulties	-0.573***	-0.114**	-0.083	-0.012	0.216***	-0.127**
Education (age 23)	--	0.278***	0.330***	-0.128***	-0.383***	0.097***
Social Class (age 32)	--	--	--	--	--	0.059***
Log Family Income (age 32)	--	--	--	--	--	0.073***
Obesity (age 32)	--	--	--	--	--	-0.211***
Current Smoker (age 32)	--	--	--	--	--	-0.205***
	direct effect		indirect effects			
% Contribution to Total Effect of Education on Health	39.92%	6.58%	9.88%	11.11%	32.10%	--

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Model fit statistics: CFI/TLI = 0.987/0.904; root mean square error of approximation = 0.026. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes.

Table E.8: Standardized weighted least squares estimates for structural equation model of pathways connecting education to health at age 50, adjusting for early traits and using inverse probability weights (N = 7,833).

Table F2 — IPW

	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	0.028	-0.082**	-0.102***	0.311***	-0.118***	-0.040	0.018	-0.018
Father's social class At birth	0.272***	-0.231***	0.000	0.033**	-0.022	-0.012	-0.005	0.037**
Father's age when Left school	0.083***	-0.030**	0.099***	0.027*	0.037*	-0.050	0.028	-0.006
Mother's age when left school	0.099***	-0.026*	0.098***	-0.004	-0.002	-0.078**	0.053**	0.010
Family experienced financial difficulties	-0.709***	0.754***	0.021	-0.041	-0.051	-0.03	0.081	-0.109*
Cognitive skills (age16)	--	--	1.577***	0.130***	0.205***	-0.145*	0.010	-0.017
Behavioral Problems (age 16)	--	--	-0.175***	-0.111***	0.016	-0.051	0.387***	-0.070
Education (age 23)	--	--	--	0.095**	0.154***	-0.048	-0.174***	0.084
Social Class (age 32)	--	--	--	--	--	--	--	0.047***
Log Family Income (age 32)	--	--	--	--	--	--	--	0.073***
Obesity (age 32)	--	--	--	--	--	--	--	-0.212***
Current Smoker (age 32)	--	--	--	--	--	--	--	-0.190***
			direct effect omitted		indirect effects			
% Contribution to Total Effect of Education on Health	--	--	--	8.77%	21.05%	--	70.18%	--

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.943/0.901; root mean square error of approximation = 0.042. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes. Direct effects of education on obesity and self-rated health are omitted to yield a positive total effect on self-rated health.

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Table E.9: Standardized weighted least squares estimates for structural equation model of early development, education, and adult health using inverse probability weights (N = 8,476).

	Cognitive Skills age 7	Behavioral Problems age 7	Parental Investment age 11	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Self-Reported Health age 50
Male	-0.162***	0.637***	0.079*	0.253***	-0.735***	-0.049***	-0.004
Father's social class At birth	0.177***	-0.172***	0.308***	--	--	--	--
Father's age When left school	0.059***	-0.006	0.141***	--	--	0.089***	--
Mother's age when Left school	0.083***	-0.01	0.130***	--	--	0.101***	--
Family experienced financial difficulties	-0.687***	0.774***	-0.477***	--	--	--	--
Cognitive skills (age 7)	--	--	0.282***	0.383***	0.604***	--	--
Behavioral Problems (age 7)	--	--	-0.091*	-0.253***	1.128***	--	--
Parental Investment (age 11)	--	--	--	0.411***	-0.457***	--	--
Cognitive skills (age 16)	--	--	--	--	--	1.462***	0.015
Behavioral Problems (age 16)	--	--	--	--	--	-0.170***	-0.140***
Education (age 23)	--	--	--	--	--	--	0.164***

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.903/0.883; root mean square error of approximation =0.044. Larger values of cognitive skills, education and self-rated health correspond to better outcomes.

Table E.10: Standardized weighted least squares estimates for structural model of pathways connecting education to adult health at age 50. Alternate coding of education: 6 categories instead of 3 (N = 7,833).

	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	-0.056**	0.339***	-0.109***	-0.037	-0.02	-0.019
Father's social class at birth	0.179***	0.046***	-0.016	-0.022	-0.021	0.044**
Father's age when left school	0.184***	0.029**	0.044**	-0.061*	0.063***	0.042*
Mother's age when left school	0.185***	-0.006	0.009	-0.087**	0.066***	0.016
Family experienced financial difficulties	-0.574***	-0.115**	-0.110*	0.013	0.214***	-0.150**
Education (age 23)	--	0.267***	0.318***	-0.115***	-0.370***	0.087***
Social Class (age 32)	--	--	--	--	--	0.066***
Log Family Income (age 32)	--	--	--	--	--	0.076***
Obesity (age 32)	--	--	--	--	--	-0.207***
Current Smoker (age 32)	--	--	--	--	--	-0.188***
	direct effect		indirect effects			
% Contribution to Total Effect of Education on Health	39.19%	8.11%	10.81%	10.81%	31.53%	--

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.988/0.907; root mean square error of approximation = 0.026. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes.

Table E.11: Standardized weighted least squares estimates for structural equation model of pathways connecting education to health at age 50, adjusting for early traits. Alternate coding of education: 6 categories instead of 3 (N = 7,833).

	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Social Class age 32	Log Family Income age 32	Obesity age 32	Current Smoker age 32	Self-Reported Health age 50
Male	0.031	-0.072**	-0.087***	0.314***	-0.125***	-0.028	0.019	-0.030
Father's social class At birth	0.276***	-0.235***	0.006	0.031**	-0.025	-0.014	0.000	0.034*
Father's age when Left school	0.083***	-0.029**	0.048***	0.035**	0.042**	-0.055*	0.022	0.005
Mother's age when left school	0.099***	-0.029*	0.055***	0.002	0.009	-0.082**	0.041*	0.022
Family experienced financial difficulties	-0.709***	0.766***	0.054	-0.031	-0.071	-0.017	0.068	-0.089
Cognitive skills (age16)	--	--	1.659***	0.153***	0.220***	-0.187**	0.002	0.047
Behavioral Problems (age 16)	--	--	-0.197***	-0.120***	0.012	-0.041	0.401***	-0.157***
Education (age 23)	--	--	--	0.062	0.132***	0.005	-0.149**	-0.007
Social Class (age 32)	--	--	--	--	--	--	--	0.043**
Log Family Income (age 32)	--	--	--	--	--	--	--	0.069***
Obesity (age 32)	--	--	--	--	--	--	--	-0.205***
Current Smoker (age 32)	--	--	--	--	--	--	--	-0.149***
			direct effect omitted		indirect effects			
% Contribution to Total Effect of Education on Health	--	--	--	8.82%	26.47%	--	64.71%	--

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.946/0.907; root mean square error of approximation = 0.043. Larger values of education, social class, log family income, and self-rated health correspond to better outcomes. Direct effects of education on obesity and self-rated health are omitted to yield a positive total effect on self-rated health.

Table E.12: Standardized weighted least squares estimates for structural equation model of early development, education, and adult health. Alternate coding of education: 6 categories instead of 3 (N = 8,476).

	Cognitive Skills age 7	Behavioral Problems age 7	Parental Investment age 11	Cognitive Skills age 16	Behavioral Problems age 16	Education age 23	Self-Reported Health age 50
Male	-0.154***	0.643***	0.069	0.248***	-0.748***	-0.076***	-0.020
Father's social class At birth	0.182***	-0.168***	0.314***	--	--	--	--
Father's age When left school	0.058***	-0.004	0.140***	--	--	0.039***	--
Mother's age when Left school	0.084***	-0.011	0.130***	--	--	0.057***	--
Family experienced financial difficulties	-0.675***	0.798***	-0.431***	--	--	--	--
Cognitive skills (age 7)	--	--	0.278***	0.381***	0.644***	--	--
Behavioral Problems (age 7)	--	--	-0.104*	-0.244***	1.152***	--	--
Parental Investment (age 11)	--	--	--	0.421***	-0.492***	--	--
Cognitive skills (age 16)	--	--	--	--	--	1.524***	0.082
Behavioral Problems (age 16)	--	--	--	--	--	-0.186***	-0.195***
Education (age 23)	--	--	--	--	--	--	0.067

Note: * p < 0.10; ** p < 0.05; *** p < 0.01. Model fit statistics: CFI/TLI = 0.907/0.887; root mean square error of approximation =0.045. Larger values of cognitive skills, education and self-rated health correspond to better outcomes.