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ABSTRACT

We document the correlations between early childhood health (as proxied by height) and educational attainment and investigate the labor market and wealth returns to height for United States cohorts born between 1820 and 1990. The 19th century was characterized by low investments in height and education, a small correlation between height and education, and positive but small returns for both height and education. The relationship between height and education was stronger in the 20th century and stronger in the first part of the 20th century than later on (when both investments in education and height stalled), but never as strong as in developing countries. The labor market and wealth returns to height and education also were higher in the 20th compared to the 19th century. We relate our findings to the theory of human capital formation and speculate that the greater importance of physical labor in the 19th century economy, which raised the opportunity cost of schooling, may have depressed the height-education relationship relative to the 20th century. Our findings are consistent with an increasing importance of cognitive abilities acquired in early childhood.

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I. Introduction

The United States experienced large increases in educational attainment starting in the late 19th century and well into the 20th century. Years of schooling among those in the labor force rose by about 6 years, from about 7.5 years in 1915 to 13.5 years in 2005 (Goldin and Katz 2008). Incomes also rose quite substantially, with real GDP per capita growing an average of 2.23% per year in the same period. A large amount of research has been devoted to understanding the factors that led to the rise in education, whether these increases in education led to the higher incomes we observe, or whether other factors led to the rapid increases in both (Card 2001).

A somewhat less explored question is the extent to which improvements in health throughout the same period contributed to the observed changes in educational attainment and incomes. Improvements in health have also been quite dramatic: life expectancy at birth increased by about 30 years in the 20th century—an unprecedented increase. Mortality decreases were mostly concentrated among children before 1950. These declines were mostly due to the eradication of infectious and parasitic diseases, which reduced morbidity in the population (Bleakley 2010a). However there were also substantial improvements in the health and mortality of the elderly, particularly after 1950 (Cutler, Deaton and Lleras-Muney 2006).

The main difficulty in establishing the effects of health improvements on education and productivity is to find variation in health that is not driven by the same factors that determine education and income. Additionally to explore the long-term relationships between these factors we require comparable measures of health, income and education. Indeed, obtaining consistent series of aggregate education and income measures over time is difficult, and this is also the case for health measures.

In this chapter we propose to make use of many individual datasets spanning 1850 to 1980 to explore how health relates to education and income or wealth. To obtain a picture of trends over the very long run in the United States, we make use of three datasets coming from Army recruits prior to 1950 (the Union Army data, The Gould sample and the World War II data) and combine them with data from the National Health and Nutrition Examination Surveys (1971 and later), the National Longitudinal Surveys (1966 and later), and the Health and Retirement Surveys

(1992 and later). Together these data cover cohorts born between 1810 and 1990 and contain information on health, education, occupation and income (or wealth).

We use height as a proxy for early childhood health, which has many advantages. First, height is a good proxy for general health conditions in childhood. Height is a measure of *net* nutritional status during the growing years, including the fetal period. Although genes are important in the determination of height, numerous studies have shown that differences in height reflect mostly differences in environmental factors (Steckel 1995), such as the availability of food and the presence of disease.

Second, adult height is mostly determined by early childhood, prior to obtaining schooling and entering the labor market. Most of the relative differences in height appear to be determined by age 3: for example the correlation between height at age 3 and height in adulthood as large as 0.7 or larger (Case and Paxson 2008). Stunting starts in utero or in early childhood (before age 3) and usually persists to give rise to a small adult. Based on extensive studies in Guatemala, Martorell, Rivera and Kaplowitz (1990) concluded that stunting is "a condition resulting from events in early childhood and which, once present, remains for life." [1]

Although height is a very rough measure of health, previous work suggests that short stature is indeed associated with worse health later in life. Waaler (1984), using a sample of Norwegian males age 40-49 in 1963-79, was the first to show that mortality first declines with height to reach a minimum height close to 187 cm and then starts to rise. Costa (1993) and Floud et al (2011) report a similar functional relation between height and subsequent mortality among Union Army recruits, white American males in the 1986-1992 and among Union Army veterans.[2]

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[111] The extent to which catch-up is possible is not known, but it appears that full catch up is not possible after age 3. Rat pups and piglets that were malnourished for a period shortly after birth never caught up, suggesting that stunting in humans may be permanent (Widdowson and McCance 1960). Although there is usually definite catch-up growth in studies of adoptees, emigrants, or children treated for diseases it is often not to the NCHS standards (Proos, Hofvander and Tuvemo 1991). There may be a limitation imposed on an individual's maximum height by genetic imprinting in very early development. Full catch-up appears to take place at young ages (Barhman et al 2013) but is followed by an advanced puberty and early cessation of growth (Proos, Hofvander and Tuvemo 1991).

[2] A caveat is that the relationship between height and subsequent mortality only shows up in large samples and is sensitive to the choice of follow-up period. When we tried to reproduce Costa's (1993) results using a larger sample of Union Army recruits, we obtained suggestive evidence of a J-shaped relationship between height and mortality but the height that minimized mortality was about 10 cm shorter than in Waaler's (1984) Norwegian sample and the odds of death was greater at taller than at shorter heights.

Height appears to be inversely related to heart and respiratory diseases and positively related to the hormonal cancers (Barker 1992).

Lastly height has also been shown to be strongly associated with wages and productivity in a variety of settings. Surveying the evidence from developing countries, Schultz (2002) concludes that an additional centimeter of adult male height is significantly associated with a higher wage of 1.5% in Ghana and 1.4% in Brazil. Historical data also shows that height was associated with lower productivity in now-developed countries. Data from the antebellum American South shows that height and weight were positively associated with slave value, suggesting that better fed, healthier slaves were more productive (Margo and Steckel 1982). In the contemporary US, taller individuals also earn higher wages (Case and Paxson 2008), although the "height premium" is higher in developing countries than in the US (where one more centimeter raises wages by 0.45%). However, this evidence does not purely reflect the better physical health of taller individuals—improved conditions in childhood will often result in better health and cognitive abilities both (Case and Paxson 2008, Schick and Steckel 2012, Barham et al 2013).[3]

A second challenge for this study is to construct measures of education that are comparable over time. Years of schooling (the standard measure used for education) are generally unavailable prior to the 1940 census in the US. The World War II data allows us to look at years of schooling because it was collected from all enlisted men. The older Union Army samples do not contain comparable measures of education—we develop a measure to transform the information in these older data sets into units comparable to modern measures.

The last data challenge is obtaining comparable productivity or income measures. Wages and income data are not available in the US prior to the 1940 census. However, all the data we have contain measures of occupation, though the codes vary over time. We therefore convert occupation into a ranking reflecting the wages associated with each occupation in 1950.[4] We

[3] An alternative explanation for the returns to height is that height is correlated with personal traits conducive to worker productivity, such as emotional skills and extraversion. For example, if the tall receive more investments and praise they become more optimistic and also have better communication skills (e.g. Persico et al. 2004; Mobius and Rosenblatt 2006).

[4] We use the occupational score created by IPUMS. Occupational score has been used by Sacerdote (2005) and Bleakley (2010b), and a modified version has been used by Angrist (2002).

compare the occupation results to those we obtain using earnings in modern data sets. Finally we also make use of the wealth measures available in various samples.

Together the data provide a comprehensive picture of how health, education and incomes evolved over the past two centuries. We document substantial changes in these relationships and provide suggestive explanations for the patterns we observe.

II. Data

a. Union Army Sample

Our analysis will use two subsets of the roughly 39,000 white Union Army (UA) soldiers collected under the *Early Indicators* project (NIA AG10120, Robert Fogel, PI) and available for download at www.cpe.uchicago.edu. At enlistment the white Union Army sample was representative not just of the Union Army but also of the northern population of military age in height, wealth and literacy rates (Fogel 1993). Although men could purchase a substitute once the draft was imposed, more than 90% of soldiers were volunteers with the remainder evenly divided between substitutes and draftees. At older ages, these men experienced the same mortality rates seen in samples based on genealogies (Fogel 1993) and thus remain representative of their birth and nativity cohort.

The military service records provide information on height at enlistment. The full sample is linked to the 1850 and 1860 censuses (among others), which provides information on the school attendance of children and on the literacy of those age 21+, and a subset is linked to the 1870 census, which provides information on real-estate and personal-property wealth. The censuses also provide geographic, demographic and socioeconomic information. In addition, we use occupational information in the 1870 census to construct an occupational income score based on the median income in that occupation in 1950.[5] The final sample covers the cohorts born between 1819 and 1850.

We construct several proxies for education using observations in the linked census manuscripts of the UA soldiers when they were of school age. Typically, the concept used for education is a

[5] The variable is constructed first by re-coding the 1870 occupations into the 1950 coding scheme and then using the "occscore" classifications of income from ipums.org.

stock variable: years of schooling. This presents a measurement difficulty in that the 19th-century censuses contain information on the flow of school attendance and not the stock of schooling.[6] This is to some extent informative of time spent in school: if we observe a thirteen-year old child in school in 1850, it should raise our expectation about the total years of schooling that he attains. Nevertheless, the variable only has information content during school ages; at other ages the attendance indicator is negligible and probably dominated by measurement error.

The definition of "school age" is complicated by the school-starting age having a large variance. We examined the fraction at school by age for the Northern states in the 1850 and 1860 IPUMS data.[7] Rather than a spike at 5 or 6 years, the attendance rate slopes up gently and only peaks around 10 years. We opted for a conservative approach and use the raw school-attendance variable only if that variable is observed sometime after the latest likely age at which someone would have started school (say 10 or 11 years) and before the age at which very few still attend school (say 21 years). So, we only include in the sample those who were linked to an antebellum census for which their ages were on the range [11,21] at the time of the census.

To impute years of schooling based both on attendance and on the age at which the boy was observed we proceed as follows. Consider two examples. Observing a 10-year-old boy in school in these data imparts relatively little information about his eventual attainment in that he may have just started school and may drop out at the end of the year. In contrast, a 20-year-old boy observed in school probably had above-average years of schooling. Following this logic, we construct the first measure of education, E_1, as follows,

$$E_1 = S_a * (a-a_0),$$

where a is age, a_0 is 10, E_1 is measure 1 for years of schooling, and S is the dummy variable for school attendance. This measure is an imputation of "years of school after turning 11" rather than simply total years in school. This measure is highly correlated with the dummy variable: the R^2 in a regression of measure 1 on the attendance dummy is 0.57 and the slope is 5.61.

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[6] Using linked census samples, Long (2006) shows that childhood school attendance is predictive of higher occupational standing in the 19th-century UK. Bleakley and Ferrie (2012) show that this variable predicts both higher occupational score as well as higher wealth in 19th-century Georgia.

[7] The IPUMS sample that we used was restricted to boys and excludes the three Southern census regions.)

We construct one additional imputation of years of schooling ("measure 2") using three factors: school attendance, age when attendance status was observed, and contextual information on the rates of school attendance by age. One difficulty with the previous two measures is that they ignore the information in the overall distribution of attendance by age. To account for this information, we first treat flows of school attendance across the observed school ages as if they come from a single cohort. This is similar to work done by Margo (1986), who cumulates the flows of school attendance across ages within a particular to compute years of schooling by cohort.[8]

We use the observed flows of schooling to adjust the imputed years of schooling for those observed out of school. Note that we assumed for measure 1 that the $S_a=0$ boys got zero time in school, which is obviously extreme. If those in school at age a have been in school continuously since age a_0, it must be that

$$\underline{E}_a = q_a\,(a-a_0) + (1-q_a)\,X_a,$$

where $\underline{E}_a$ is the (cumulated) stock of years in school at age a, q_a = the fraction in school at age a and X_a is the average years in school of those that dropped out before age a. We estimate q_a using aggregate data on school attendance by age in the antebellum IPUMS data.[9] Again maintaining the assumption of continuous schooling since a_0 if a boy is observed in school at age a, we set measure 2 equal to measure 1 if $S_a=1$. If $S_a=0$, however, we set measure 2 equal to X_a. For example, for 11-year-old boys, we impute an $E_2=1$ if they are in school and $E_2=0$ if not. For 21-year-olds, however, we set $E_2=11$ if they are in school and $E_2=5.1$ if not, which keeps the average years of schooling consistent with what is implied by cumulating the flows of attendance over those ages.

b. The Gould Sample of Union Army Soldiers

[8] This method has been also used more recently by Hazan (2009) to construct school attendance by cohort over 150 years of cohorts in the US and by Bleakley and Hong (2013) to examine changes in school quality by US region in the 19th-century.

[9] These flows of school attendance (the *q* measures) are computed by age, but not decomposed by area, except that the Southern regions are excluded. The correlation between measure 2 and a version constructed instead with region-specific schooling flows is 0.9719. We also constructed state-specific approximations, but concluded that the flow measures were too noisy. When the full-count files for the 1850 census becomes available, it may be possible to do state-specific imputations, but the existing IPUMS samples were too thin at the state x age level.

In the early part of 1863 the United States Sanitary Commission began its inquiry into the physical and social condition of soldiers by sending sixteen examiners to specific locations, including Washington, where the armies of the Potomac and the West were concentrated. Examiners were instructed to measure as many men as possible. When necessary, additional examiners were sent to a location and then sometimes accompanied an army corps to obtain further measurements. Trained examiners armed with andrometers, spirometers, dynamometers, facial angle instruments, platform balances, calipers, and measuring tape measured men's body dimensions, weight, lifting strength, and vital capacity, and obtained basic demographic and socio-economic information. The data were first analyzed by Gould (1869) and the original forms were collected by Costa (2004) and include 15,866 white Union Army soldiers and sailors. Of these men, 11,710 are native-born.

Compared to the Union Army as a whole, the location of the examiners increases the proportion of recruits who were born in the Middle Atlantic (especially New York City) relative to the Union Army. Therefore, the average recruit was shorter and the proportion of recruits who were farmers was smaller than in the Union Army. The average recruit in the Gould sample was also more likely to be native-born.

We will restrict ourselves to the native-born and use the height and educational information in the Gould sample. After limiting the sample to men for whom education is available, we are left with 7,624 men. Education is described as none, limited common school, common school, college, or professional. We attribute 0.5 years to education to none, 4 years of education to limited common school, 8 years of education to common school, 10 years of education to high school, and 14 years of education to college or professional. These cohorts were born between 1793 and 1851.

c. World War II Enlisted Men

The World War II (WWII hereafter) data contain 9.2 million observations of individuals enlisted in the Army between 1938 and 1946. The records contain the information reported at the time of enlistment, including measured height, educational attainment and occupation prior to enlistment. A total of about 16 million men served in all branches of the military, and a total of

11 million served in the Army. About 60% were drafted and 40% volunteered. The records in the WWII data contain about 85% of those who served in the Army (15% of the original records are unreadable). Thus the data is likely to be representative of the men who served in the Army.

However, because of drafting criteria, these men are not necessarily representative of the US population of men of drafting ages. To serve in WWII, a man had to be between five and six and a half feet tall, weigh at least 105 pounds, and have good vision and good teeth. Additionally men had to be able to read and write. Those convicted of a crime were not eligible to serve. Finally there were exemptions based on occupation (men in a few agriculture and war-related production occupations were exempt), and initially married men and fathers were exempt. Because of segregation relatively few blacks were drafted. Acemoglu, Autor and Lyle (2004) and Goldin and Olivetti (2013) provide evidence that these exemptions generated substantial differences in the likelihood of serving in the war: blacks, farmers and individuals of German descent were much less likely to have served.

To obtain a sample that is likely to be representative by cohort, we keep all white men born in the United States between 1898 and 1923 (other cohorts have very few observations), ages 20-45, with valid heights (between 60 and 78 inches), valid weight (over 105 pounds), and valid enlistment year (1938-1946). The final data we use contain about four million observations.

We construct years of schooling based on the reported educational attainment. No individual is listed as having less than primary school—we impute those with exactly 8 as having 4.5 years of schooling. Alternatively we code them as illiterate, and all others as literate, under the assumption that the literacy requirement resulted in the education always being coded as at least 8 years of schooling/primary grade.

We matched occupation to occupational scores using the 1950 occupation categories. To each occupation in the WWII records we assign the occupational score associated with that occupation in the 1950 census. When multiple 1950 occupational categories were assigned to WWII civilian occupations we used the average occupational score for 25- to 49-year-old white males in those occupations. We then compute the log of the occupation score, which is a positive value for everyone except for those that declared “no occupation” or “student” as their occupation prior to enlistment.

d. Commonly used contemporary samples

To cover as many cohorts and time periods as possible we use several well-known recent data sets, that contain standard measures of years of schooling, height, occupation and earnings. The National Health and Nutrition Examination Surveys I, II, II and IV combine survey information from the years 1971-4, 1976-80, 1988-94 and 1999-2010 on education and labor market outcomes with physical examination measurements, including height and death certificates. We also use the 1961 wave of the National Longitudinal Survey of Old Men, the 1981 wave of the National Longitudinal Survey of Young Men, and the 1996 wave of the National Longitudinal Survey of Youth. Heights are self-reported but the surveys have good information on incomes and wealth for individuals in their prime labor market years. We also use the Health and Retirement data—it contains excellent measures of wealth but individuals are only sampled after age 55 and their heights are also self-reported. We also include a few results from the National Health Interview surveys to look at the most recent cohort of men. These data do not contain wealth, heights are self-reported and income is reported in categories only.

III. Trends in height and education

a. Height and other health measures

Figure 1 illustrates the well-known long-term trend in heights in the United States, compiled from heights of native-born soldiers from the 18th through the 20th centuries and of native-born men in the last decades of this century.[10] The data, which are arranged by birth cohort, show that troops who fought in the French and Indian War of the 1750s and the 1760s or who fought in the American Revolution of the 1770s nearly attained 1930s heights of 175 cm. Cohorts born from the early 1700s to those born in 1830 achieved a gradual increase in average stature of

[10] Since the sample sizes are substantial, particularly for those periods before the large wars, the major movements in the series are unlikely to represent sampling variation. In fact, the difference in average height between rejectees and those who served in the Union Army was 0.25 inches. The averages have been corrected for minimum height standards.

approximately one centimeter. Average heights fell by approximately 4 cm in the ensuing half-century, reaching a trough among births in the 1880s.[11]

Corroborating evidence for the decline in stature among whites is found in mortality data from genealogies. Life expectancy at age 20 declined from approximately 47 years at the beginning of the century to slightly less than 41 years in the 1850s and recovery to levels of the early 1800s was not attained until the end of the century (Pope 1992). The decline in black stature is consistent with Steckel's (1979) finding of a decline of two and a half to seven and half centimeters in the heights of slave children born in the two decades after 1830. Other work has documented that industrialization (and perhaps the accompanying urbanization) was associated with a mortality "penalty"—but the height decline is observed in both rural and urban areas and few Americans lived in urban areas.

After the 1880s, American men experienced the familiar secular increase in stature of recent times, gaining approximately six centimeters by the mid-20th century. This large increase in heights occurs at the same time that life expectancy and health are rising substantially.

The secular increase in heights continues in recent decades, although at a much slower pace. As others have documented (Komlos and Lauderdale 2007), there is a stagnation in height growth, the causes of which are not understood.

We now plot the height series we obtain from our datasets and compare it to these series. The results are in Figure 2. As seen in the data for the population, we observe a steady increase in heights in the early period, and then stagnation for the post-WWII birth cohorts.

The increase in heights coincides with a decline in the variance of heights.   The estimates in Table 1 reveal that the correlation in adult heights between brothers has increased since the US Civil War.   The most likely cause for the low correlation in the past is families' inability to protect themselves against disease and nutritional shocks.   Among brothers in the Union Army heights were lower in more populous counties and the variability in height was greater, suggesting that the environmental contribution to variability in height is of greater relative

[11] No national height series is available for the end of the 19th century. Interpolation was based upon the assumption that the time pattern for the country followed that for Ohio.

importance in populations reared in worse environments (Lauderdale and Rathouz, 1999). The US decline in brother-brother correlations is consistent with the increase in height heritability observed among Finnish twins born in the first half of the 20th century and those born later (Silventoinen et al. 2000).

Finally the trend in height appears to follow the declines in infectious disease mortality: Panel b of Figure 2 shows that infectious disease mortality fell dramatically until about mid-century and then remained at a very low and stable level—cardiovascular mortality by comparison starts falling much later. This coincidence in the trend for height and for mortality is consistent with the notion that adult heights are most affected by conditions early in life, at least proxied by infectious disease mortality, which mostly kills children.

b. Trends in education

Figure 3 plots the average years of education by year of birth for various samples. The trends show a steady increase in educational attainment starting in the 19th century and continuing up to about 1950, at which point education plateaus. The increase in years of schooling from 1900 to 1960 is about 5.5 years. These trends are consistent with the patterns that have been documented for the nation, although the stagnation for the very last few cohorts is atypical compared with other data for the population, though our data for these later cohorts are noisy. It is remarkable that the stagnation in years of schooling coincides with the stagnation in heights and in infant mortality.

Together this evidence suggests that conditions in early life improved substantially in the early 20th century both in terms of health and education in childhood. We next look at the consequences of these improvements on long-term measures of labor market success. We start by assessing the extent to which education was determined by early childhood health, proxied by heights. Then we move on to examine how height and/or education affected our measures of labor market success and wealth.

IV. The effects of height on education

We start by reporting the correlations between height and education in the 19th century. Table 2 presents the results from estimating a regression of the education on height. Heights had little effect on educational attainment in either the Union Army or the Gould sample. The most that an extra centimeter of height contributed to years of education was 0.009, a 0.3% increase relative to the mean. Heights had no effect on illiteracy rates. Recall that the main difficulty with these data is that we have to impute education based on enrollment and age. It is possible that our measures of education are too noisy. Nevertheless the results suggest a small effect of height.

When we restricted height to men above 5 feet and below 6 feet, 5 inches (the restriction for WWII enlisted men) in the Gould sample, the coefficient rose only to 0.003 ($\widehat{\sigma} = 0.005$) from 0.002. When we restrict to men who were younger than 25 at enlistment the coefficient on the second measure of education in the Union Army sample rises from 0.005 to 0.008 ($\widehat{\sigma}$=0.036). When we restrict the sample to men who were older than age 35 at enlistment the coefficient falls to -0.031 ($\widehat{\sigma}$= 0.322). So these results suggest that the effect of heights is larger among the more recent cohorts in the 19th century sample.

Table 3 presents the results from the identical models estimated with 20th and 21st century data. The effect of height on education is now much larger in magnitude and statistically significant in all cases.[12] For cohorts born between 1897 and 1959 (Panels A-C) we find that a one centimeter increase in height is associated with 0.08 more years of schooling. But interestingly, the coefficient of height on education is smaller in more recent cohorts: for the birth cohorts 1943 to 1974 the effect falls to 0.05 and then to 0.04 for the most recent cohorts.

A caveat to our results is that unobserved family or environmental effects may lead us to overstate the cross-sectional height-education relationship. Case and Paxson (2008) find that controlling for mother fixed effects in the NLSY attenuates but still leaves statistically significant the relationship between test scores and children's height. By linking the WWII

[12] An important caveat is that our results would change substantially in magnitude if we did not drop individuals with heights within enlistment parameters. If all height observations are included then the coefficients on education would be substantially smaller.

enlistment data to earlier censuses, Parman (2010) was able to identify brothers and also finds an attenuated but still statistically significant relationship between height and education among brothers.[13]

To assess the magnitude of our effects in Table 3 we compute the fraction of the changes in education that can be "explained" by changes in heights. Height increased by about 1.2 centimeters across cohorts in Panels A-C, thus the increase in education it is associated with is about 0.1 years of school, a small fraction of the increases in education across these cohorts (years of schooling increases by about 2.9 years). The decline in education in panels D through H is -0.02. Heights fell by 1.56 centimeters, and given the coefficient of -0.05, height accounts for about 0.0078 of the 0.02 decline, or about 40%.

The overall patterns suggest there are three periods: In the 19th century, during which a large fraction of the sample is in farming occupations, education and height are low in levels, and their correlation is low. In a period from the late 19th century up to the 1940s, when height and education are increasing rapidly, and the correlation between them is higher. Finally from about 1940 onward, there is a period where both education and heights are falling, and their correlation falls.

These results raise questions. What drove the tremendous improvements in education and health observed in the first part of the 20th century and were both driven by the same factors? A large number of policies were directed at improving maternal and child health as well as increasing education during the progressive era. This era also saw large increases in incomes and nutrition, as well as increases in the returns to school. The next question is: What explains the stagnation of education and health measures and whether the period of possibly declining in childhood investments has consequences for the labor market?

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[13] Parman (2010) concluded that a one inch difference in the height of brothers leads to 0.03 years of education compared to 0.07 years of education in a naïve regression that does not control for family effects. (An extra centimeter would lead to 0.01 years of education compared to 0.03 years in a naïve regression. Parman restricted his sample to privates but we do not find that this explains the difference between our results and his. His sample over-represents men from large families.)

V. Height, Wealth and Income

a. The 19th Century

We start by analyzing the relationship between height and productivity measures in the 19th century data. The two datasets are the Union Army enlistment records linked to the 1870 Census and the Gould sample of Union Army soldiers. We have two variables that proxy for income and wealth, respectively. The income variable is the "occupational income score," which combines the occupation reported in the 19th century data with a tabulation of median income by occupation in 1950. The wealth variable is the sum of real estate and personal property wealth reported on the 1870 census. We transform both variables into natural logarithms. Figures 4A, 4B and 4C show the basic results for the 1870 data. We disaggregate the results by farming and non-farming occupations in 4A and 4B, respectively, and then present the pooled estimates in Figure 4C. Panel C of each of these figures displays the estimated distribution of heights. Panels A and B depict the estimated non-parametric regression of the relationship between height and outcomes. (In these figures, the estimated relationship is not adjusted for controls. We present regression-adjusted results below.)

In both subsamples the (logarithm of the) value of wealth increases almost linearly with height for most of the distribution, although apparently peaking a bit below six feet. The wealth/height gradient appears to be steeper among farmers. Height is also associated with a higher occupational score among farming occupations. (The main two occupations in this category are farmers, who might own their farm, and farm laborers, who presumably do not.) In contrast, among non-farmers height is negatively correlated with occupation. Overall, in the pooled sample (Figure 4C), wealth and height are positively associated, but occupational score and height are negatively related. Indeed, this negative relationship is stronger in the pooled sample because farmers have low occupational scores and were on average taller.

We replicate these findings in a regression framework for the 1870 and Gould Union Army samples. These results for occupational score are found in the upper panels of Tables 4. One additional centimeter in height among non-farmers in the Gould sample was associated with a 0.2% increase in the occupation score, and this coefficient remains unchanged when we control for education. For the 1870 UA sample, the increase in occupation score with height was 0.1% and not significantly different from zero. The table also shows that even among non-farmers, returns to education, although positive, were low. An additional year of education increased the occupation score by only 1.2% circa 1860 and by 1.3% circa 1870.

In Table 5 we report the results for wealth. We see that a centimeter of height is associated with an additional 1% of wealth. This result is unchanged by controlling for education.[14] A similar pattern emerges from regressions that control for place of birth using alternative levels of geographic detail, use various sampling weights to make the sample more representative of the 1860 US population, drop outliers in height, or compute wealth in alternative ways.[15]

The height-wealth relationship was stronger among the farm population (see Table 5). When we split the sample between farmers and non-farmers, we obtained coefficients on height of 0.009 and of 0.022 for the non-farm and farm samples, respectively, with controls for education. The returns to height may have been greater for farmers because the physical demands of farming put a premium on health.

We suggest two explanations for the puzzling negative relationship between height and occupational income scores in the 19th century. On the one hand, perhaps the higher price on physical strength in this period caused sorting into manual occupations. But, because of mechanization, these occupations probably pay lower wages in 1950 (the year that is used to compute the occupational score measure) than in 1860-70. On the other hand, it is possible that farmers and farm workers earned relatively little, but may have been less exposed to disease and thus taller. Indeed there are well known examples of poor but tall populations, such the Plains Indians (Steckel 2001), the Irish (Nicholas and Steckel 1997) in pre-famine times and the Scots

[14] However, the coefficient on education might be biased downward by measurement error; we note that the coefficient on height drops to 0.7% if we fix the coefficient on education to be 0.4, roughly in line with what is estimated in the 20th century data.
[15] Results available upon request

relative to the English in the second half of the 1700s and the first half of the 1800s (Floud et al.1990: 202-204).

b. The 20th Century

The results for the 20th century (Table 4) paint a different picture. In the first two columns we report the coefficient from a regression of the logarithm of the 1950 occupational score on height with and without controls for education, and with basic geographic and age controls. Several patterns emerge. The returns to height increased substantially throughout the century. Without education controls the returns to height increased from about 0.2% to 0.9%, and controlling for education they rose from 0.2% to 0.4% (panel A v. panel F). The returns to education also rose dramatically from 1.2% to 12.9%. In the 20th century samples (Panels B-F) controlling for education substantially lowers the returns to height, unlike in the 19th century samples. This suggests that part of the returns to height in the 20th century are driven by cognitive improvements associated with both height and education. Interestingly in the WWII enlistment data, we also observe positive and statistically significant effects of height and education for women and for black males.[16]

Results without farmers are very similar; for example, in the WWII data, the coefficient on height controlling for education is 0.0010 for the full sample (panel B of Table 2), 0.0013 for non-farmers, and 0.0002 for farmers. Farmers constituted at this point less than 20% of the labor force (Wyatt and Hecker 2006). The last two columns show that despite the coarseness of our occupation score measure, the same basic patterns are observed with wages. In fact the returns to height are larger when we use wages—suggesting that within occupations there are substantial returns to height that are not accounted for when we use variation in income only across occupations.

Table 6 presents the results for wealth in the 20th century samples. Unfortunately the WWII enlistment data contain no information on wealth. It also is substantially more difficult to

[16] Results available upon request. Women who enlisted to serve in the Army in WWII are unlikely to be representative of women at the time, and in previous research Blacks were under-represented (Acemoglu et al 2004).

construct comparable wealth measures over time. For instance the NLS samples collected different information about wealth over time. Therefore it is more difficult to compare these coefficients and their evolution. However, in all of the samples we observe a very large and robust association between early investments and wealth. Both education and height are positively associated with wealth. The coefficients on height in these late 20th century samples range from 0.024 to about 0.04. In all of these samples height and education have larger coefficients than in the 19th century samples. The wealth results are consistent with the occupation and wage results.

Overall a picture emerges with the 19th century having lower health and human capital (height and education), and positive but small wealth returns for both education and height. In the first part of the 20th century, there are large increases in education and height, yet at the same time returns appear to have increased substantially.

c. Comparisons with US Slaves

The only other study examining the relationship between height and wealth in the 19th United States is Margo and Steckel's (1982) examination of the relationship between height and slave prices. Their Table 6 reports a coefficient of log slave price on height of 2.1% per cm. Although this coefficient is similar to the height-wealth relationship we observe for farmers in Table 6, slave prices exhibit a steeper gradient for height than those for all free men. Throughout this chapter we interpret the returns to height being returns to both broader health and cognition. But this cognition interpretation does not seem consistent with the returns to height being higher for slaves than free men. Slaves were not being purchased for their cognitive skills, by and large. The labor services provided by slaves *circa* 1860 were likely more physical than cognitive, especially relative to *circa* 1870 free whites in the North. We argue that there is no inconsistency, however, for both theoretical and econometric reasons.

Why would the measured return to some endowment be higher in the slave price than in the wealth accumulation of a free person? One possibility is a failure of the law of one price to hold in the economy of that period.[17] Let us set aside this possibility for the moment. Instead, we suggest two relevant distinguishing characteristics:

(i) is the variable forward or backward looking?

(ii) what is the endowment effect if the labor endowment belongs to someone else?

The first point (point i) is that the slave price is an asset value, and thus forward looking, while a free man's wealth is the result of an accumulation process, and thus backward looking. This indicates that we should compare the gradient among young (adult) slaves with that of older free men. Indeed, if we re-estimate the height/wealth model with an interaction term between age and height, it is strongly positive and statistically significant. Evaluating the coefficient at age 25, we find a return to height of .01 per cm.[18] Evaluating instead at age 55, we obtain .04, which is double the Margo/Steckel number for slaves.

Now consider the endowment effect (point ii). If the taller free man has in effect a more valuable labor endowment, he might work less (and thus accumulate less wealth) because of the endowment effect (some might call this a wealth effect instead). Whether this effect is strong enough to generate backward-bending labor supply is not the point. The point is that the endowment effect is weaker for slaves, *who did not own their own labor endowment*. Thus, we would expect that the marginal value of height to be higher for slaves. (Note that this difference would disappear if we could control for labor effort, but the price or wealth data is not adjusted for hours worked.) Furthermore, combining points (i) and (ii), we note that the slave price also incorporates the productive value of their progeny, which might be higher for taller men.

Further, the gradient in slave prices with height becomes considerably smaller than the estimated wealth/height gradient in 1870 if we account for two important differences between our specification and the one used by Margo and Steckel. First, their specification included weight as well as height, while ours above does not. Those authors sought to relate observed anthropometric measures to slave prices, and thus it was appropriate to control for height and weight simultaneously. For the purposes of the present study, however, we are interested in height as a proxy of early-life endowments. We are therefore cautious about over-controlling for

[17] Various authors have discussed the weak sectional integration of the 19th-century US economy (Rosenbloom 1990 and Margo 2009).

[18] We also found evidence of increasing age profiles for occupation in the WWII data and for wealth in the NLS data. Results available upon request.

too many physical attributes. Fortunately, the data employed in their study was conserved as ICPSR study #9427 (Margo, 1979), and therefore we can estimate comparable specifications using their original data.[19] When we re-estimate their model dropping both weight and the interaction of weight and height from the specification, we obtain a coefficient on height of .005 per cm. This is considerably smaller than our results above using 1870 wealth. At first glance, this was perplexing because our intuition was that the coefficient on height would rise after dropping the weight controls, because height and weight are positively correlated. But this brings us to a second issue in their specification: namely, the construction of the interaction term. Their interaction between height and weight appears to be the simple product of the two variables. Constructing the interaction term this way forces the main effect of height to be evaluated at a weight equal to zero. For the present purposes, this is not an interesting point in the distribution at which to evaluate productivity/height gradient. With an interaction term constructed by first removing the means from height and weight, the coefficient on height is now evaluated at the mean of the weight distribution. When estimating their equation with this alternative construction of the interaction term, we obtain a coefficient on height of .004 per cm. This is 2 to 4 times lower than what we estimate in Section IV.a above for height and 1870 wealth, which suggests that the cognitive channel plays a role in interpreting these results, even in the 19th century. Indeed, this comparison supports the idea that a good part of the return to height was via cognitive human capital rather than physical strength, even in the 19th century.

d. Comparisons with Developing Countries

Findings from developing countries on the relationship between education and health include work by Glewwe and Jacoby (1995) on Ghana finding that the shorter sibling receives less schooling, and work by Paxson and Schady (2007) showing that taller children in Ecuador have better cognitive outcomes.

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[19] In our attempt to replicate their results in Table 6, we drop females, those with age less than 18, and those with height or weight coded to zero. Light skin complexion is coded as stated in the data documentation. Nevertheless, the sample that we obtain is substantially larger (871 versus 523 observations) and the coefficient of log slave price on height in inches is 0.043 rather than their reported estimate of 0.053. The pattern of statistical significance across variables is similar to their results. Most of the other coefficients are smaller in magnitude in our estimates than those reported by Margo and Steckel. Note that our focus here is on how much the price/height gradient attenuates when adjusting the specification to match ours, and we suppose that the comparative values of coefficients would be similar if we were able to match their sample exactly.

One of the difficulties, however, in comparing our results with those from developing countries is that specifications and sample restrictions differ, and more importantly large representative samples of adult males with height measures are uncommon. We therefore use the 2005-2006 Indian Demographic and Health Survey (hereafter DHS) to examine the relationship between height, education, and wealth among Indian men age 20-45. The DHS is a unique dataset for our purposes: it sampled all men age 15-54 (regardless of marital status), and the sample is very large. The survey covered 99% of the population and was designed to be representative of the nation and of rural and urban areas both. It contains years of schooling, occupation and a measure of wealth. Height and weight were measured by interviewers.[20] Although wealth is difficult to measure is agrarian societies, the wealth index provided by the DHS survey is an excellent measure of resources.[21] We restrict attention to men ages 20 to 45, with non-missing values for height and education and use survey weights. The final sample has about 48,000 observations. On average these men have about 8 years of school and measure 164 cms.

Panel A of Table 7 shows that the relationship between height and education in India was 0.15 for all men with slightly smaller effects for farmers. The effects were larger than for the 20th century United States. Interestingly, the Mincerian wage returns to education are also higher in developing than in developed countries (Psacharopoulos 1994).

Panel B of Table 7 shows that the wealth returns to height in India are 0.018 without controls for education and 0.008 controlling for education. The returns are thus similar to those observed in the 19th century United States and lower than those observed in the 20th century United States.

The pattern of coefficients in India is similar to several recent studies using data from Latin America.[22] Using data from Colombia (the ENH), Ribero and Nuñez (2000, Table 5, Column 6) report a coefficient of log wages on height of 0.008 when controlling for education, which is identical to the estimate from India just reported. Vogl (2011, Table 2, Column 4, and Table 4,

[20] http://www.measuredhs.com/pubs/pdf/FRIND3/00FrontMatter00.pdf
[21] http://www.measuredhs.com/pubs/pdf/CR6/CR6.pdf
[22] Our review of the developing-country literature is selective, however, because the heterogeneity in specifications makes it difficult to compare results from all of the studies we found. As we saw above in the comparison with slave prices, seemingly small differences in the specification can make major differences in comparability of the coefficients. We restrict ourselves here to a few cases where it seemed clear that we are making an apples-to-apples comparison.

Column 1) finds in Mexican data (the MxFLS) that an additional centimeter of height is associated with 0.023 higher log wages and 0.16 extra years of schooling.

e. Discussion: Brain or Brawn?

We interpret height as a proxy for early-life health endowments that manifest themselves both in increased physical capability ("brawn") as well as in improved cognitive ability ("brain"). Brawn, when considered relative to brain, must have been of greater relative value in the 19th century than the 20th century. Prior to widespread mechanization, physical labor was used to do a variety of things that today would be done by machines. Yet we find higher returns to height in the 20th century.

It is useful to think about this issue through a simple decomposition.[23] Let *y(e)* be the lifetime income (in present discounted value) that accrues to a worker who has *e* years of schooling. Suppose the optimal choice of education is e^* and define $y^*=y(e^*)$. We are interested in the question of how a worker's productivity increases as his health endowment *h* changes: *i.e.*, the derivative dy^*/dh. This full derivative of y^* w.r.t. *h* can be decomposed as

$$\frac{dy^*}{dh} = \left.\frac{\partial y}{\partial h}\right|_{e^*} + \frac{de^*}{dh}\left.\frac{\partial y}{\partial e}\right|_{e^*}.$$

The first term gives us the direct effect of health on income even holding fixed education. The second term values the re-optimized schooling choice at the marginal return to schooling. It is helpful to further decompose the direct effect of health on income into two components, which yields this expression for the full derivative:

$$\frac{dy^*}{dh} = \left.\frac{\partial y}{\partial h}\right|_{e=0} + \int_0^{e^*} \frac{\partial^2 y}{\partial h \partial e} de + \frac{de^*}{dh}\left.\frac{\partial y}{\partial e}\right|_{e^*}.$$

The first term is the effect of the health endowment on the productivity of an unskilled (unschooled, possibly illiterate if $e=0$) worker. The complementarity between school and health is seen in both the second and third terms, which measure the infra-marginal and marginal

[23] The theoretical presentation in this subsection borrows heavily from Bleakley (2010a, pp. 292-4), who presents a simple version of the Ben Porath model.

effects, respectively, of health on income by way of schooling. In words, we can think of the effect of health on income as coming through three distinct channels:

1. An unskilled worker is more productive if he is healthier.
2. Better health helps a student learn, thus he obtains more value from his infra-marginal (i.e., 'would have attended anyway') time in school.
3. Better health might motivate a student to spend more time in school.

Presumably the first, "unskilled" channel arises disproportionately because of physical strength and stamina. And this effect diminishes over time as machines replace humans for brute force and repetitive assembly. Yet the increasing magnitude of the height coefficients over time suggests a rising importance of the second and third cognitive channels. Furthermore, in the 19^{th} century results, only the first channel should have been present for slaves, while the gradient for free men would have the sum of all three channels listed above.

One remaining loose end is the rise in the education/height gradient. If the return to height had a strong cognition component even in the 19^{th} century, then why was the relationship between height and education so weak? The answer starts with two plausible intuitions: (i) schooling is of less value when much of the labor is physical and (ii) a healthier child might be a better student, but is also a better unskilled worker, especially in an economy dominated by physical labor. But these intuitions are a bit too imprecise as it turns out, so we return to the model. We augment the *y* function of lifetime income above to include both education and health (h) as arguments, and recall that it is a discounted sum of period-specific incomes, $\tilde{y}(e,h,t)$:

$$y(e,h) = \int_{e}^{\infty} \beta(t)\, \tilde{y}(e,h,t)\, dt \; - \hat{c}(e),$$

in which t is time, the *(t)* term reflects both discounting and wage growth that comes with age and/or economy-wide growth, and $\hat{c}$ are out-of-pocket costs of schooling.

To compute the optimal choice of education, we take the derivative of *y* with respect to *e*, which yields two groups of terms:

$$\frac{\partial y}{\partial e} = \underbrace{\int_e^{\infty} \beta(t) \frac{\partial \tilde{y}}{\partial e} \, dt}_{\substack{marginal \\ benefits}} - \underbrace{\left(\beta(e)\tilde{y} + \frac{d\hat{c}}{de}\right)}_{\substack{marginal \\ costs}}$$

The marginal benefits (call them MB) are the appropriately discounted sum of gains in future earnings. The marginal costs (MC) are both direct and opportunity costs of schooling. The usual assumptions are that the marginal benefit of schooling declines with more time in school but that the marginal cost rises: $MC_e > 0$ and $MB_e < 0$, where subscripts denote partial derivatives. These assumptions turn the optimization problem into an "optimal stopping rule": stay in school as long as marginal benefits exceed marginal costs; when MB=MC, leave school and work. This is shown graphically in Figure 6 (as the "Baseline model") and a dashed, vertical line denotes the optimal choice of time in school.

In this standard model, the effect of childhood health on years of schooling could be positive or negative. Taking full differentials of the condition for optimization (*MB=MC*), we derive the optimal response of schooling to health as

$$\frac{de^*}{dh} = -\left(\frac{MB_h - MC_h}{MB_e - MC_e}\right)$$

By assumption, the denominator is negative. If childhood health raises the marginal benefit of schooling, then $MB_h>0$. Nevertheless, it might also be the case that $MC_h>0$, if a healthier child is more productive (for reasons that we discuss below). Thus, the sign of the expression is ambiguous. Yamauchi (2008), Bleakley (2010b), and Pitt, Rosenzweig, and Hassan (2012) present some empirical examples of this ambiguity.

We consider four cases here in our analysis of the health/education relationship. The associated MB and MC curves for each case are shown in Figure 5. In each case, the baseline equilibrium is also shown in gray. The three cases are as follows:

Case 1: *Healthier children get (relatively) stronger as they mature.* Height is associated with physical strength and stamina, which would have commanded a relatively higher wage premium in the era prior to mechanization. This raises the opportunity cost of school for healthy children, and especially when they are in adolescence and thus closer to physical maturity. This raises and rotates up the MC curve, depressing the optimal time in school.

Case 2: *Healthier children learn more in school (parallel shift).* Learning more from the same time in school shifts up the MB curve. (In this and the remaining cases, $MB_h>0$.) But yesterday's marginal benefits raise today's marginal costs.[24] Put another way, more education raises the worker's productivity and therefore raises the opportunity cost of getting even more education. If health raises the MB of schooling equally at all (inframarginal) levels of schooling, then the MC curve shifts up in parallel, with little effect on the choice of time in school. Note that this is true even in an economy with no emphasis on physical labor, as long as health induces a parallel shift of the MB curve. In terms of the equations above, this neutral effect of health on the education choice obtains if $MB_{eh}=0$. (This second derivative of *MB* is in reality a third derivative of the production function $\tilde{y}$. This is one more derivative beyond than the usual criterion for complements or substitutes because education is purchased with time rather than money, and education raises the value of time.)

Case 3: *Health and school are strongly complementary.* Informed by the previous case, we see that the MB curve needs to shift up *more* at higher levels of schooling if optimal time in school is to increase: $MB_{eh}>0$. This is to say that healthier children are not much better at learning basic school skills like literacy and numeracy, but do have an advantage at more advanced concepts.

Case 4: *Health and school are less than strongly complementary.* For completeness, we consider this case as a counterpoint to cases 2 and 3. In this case, learning better basically equates to learning faster, allowing the child to get to the labor market earlier with the same amount of schooling human capital. This case is best understood with the example of child prodigies, where the cognitive endowment is sufficient to allow children to 'blast through' school. Norbert Weiner (noted early-

[24] One additional assumption, verified by Mincer and commonly used for this model, is that more education shifts up the $\tilde{y}$ function in a manner that is essentially independent of *t*. In words, more education raises period-specific productivity in roughly equal proportion across the working life. This imposes a good deal of structure on the model in that each point on the marginal-cost curve includes the (amortized) sum of earlier marginal benefits. The curves that we draw in Figure 6 reflect this relationship. An excel spreadsheet with supporting calculations is available from the authors upon request.

20th-century child prodigy and PhD in math at age 17) and Doogie Howser (noted 1980s-TV-fictional-character child prodigy and MD at age 14) could have obtained three doctoral degrees at an age before any of the co-authors of this chapter had obtained even one. But the opportunity cost of their time was apparently too high at the conclusion of their first doctorate. Bill Gates and Mark Zuckerberg, both Harvard College dropouts who founded lucrative companies, might also be examples. For Case 4, $MB_{eh}<0$. (We do not graph this case to save space.)

Whether Case 4 is mostly an intellectual curiosity (only holding in extreme cases) is debatable. But Cases 1-3 all seem pertinent to some aspects of the results from the 19^{th} and 20^{th} centuries.

How do our empirical results relate to these comparative statics from the model? In the 20^{th} century, the height/education gradient is stronger than in earlier periods. This suggests that the health endowment is strongly complementary with education (Case 3) in this period. The Mincerian returns to education were highest before WWII and in the last two decades of the 20^{th} century (Goldin and Margo 1992; Goldin and Katz 2000; Autor et al. 2004). Consistent with this, the height/education gradient is lower for those cohorts in school in the several decades following WWII.

We know little about Mincerian returns in the 19^{th} century, however, so we cannot compare our results with this benchmark. We know that the wage returns to clerks relative both to common laborers and to artisans were increasing (Katz and Margo 2013) in the 19th century but do not know the relationship between white collar skills and formal education. Table 5 shows that the returns to formal schooling to climbing the occupational ladder among non-farmers were small in the 19th century, only 1.2%, and much greater in the 20th century. In the 19^{th} century samples, the height/education gradient is also much weaker. This would indicate some combination of Case 1 and Case 2. The greater weight on physical labor in the 19^{th}-century economy would had reduced or even flipped the relationship between height and education (Case 1). It may also be that the nature of the technology frontier was sufficiently different back then, such that one could acquire a high level of relative skill without having to delve into subjects that might be more cognitively taxing. This puts us closer to the realm of Case 2 if the complementarity between health and education was not so strong.

Why, then, are the coefficients of education on height so much stronger in developing countries? One tempting hypothesis is that the returns to education are generally higher in contemporary developing economies. But if this is the explanation, then the coefficients of productivity measures on height should be markedly higher as well, which they are not. Why? Because, if health is a complement with education, the endowment becomes more valuable still if the return to education rises. (This is the second term in the decomposition above.) Further, the continued presence of brawn-intensive jobs in the developing world should attenuate the height/education relationship. For the moment, we leave this inconsistency for future research.

V. Education and mortality

We have focused thus far on the effect of early life investments on economic success. We finish this chapter by considering how education affects adult mortality—another welfare measure. We examine the effects of education on mortality among native-born Union Army veterans alive and on the pension rolls in 1900 and age 55-74 and men of the same age in the second and third NHANES surveys. To ensure comparability across the surveys we examine 12-year mortality rates. We run Gompertz hazard models of the form,

$$h(t) = h_0(t)e^{x\beta}, h_0(t) = e^{\gamma t} .$$

We control for age at time of observation, population (size of city of enlistment for Union Army veterans and whether in a metro area for NHANES), state of enlistment or residence fixed effects, and, for Union Army veterans, a dummy for census year used and age in 1850 or 1860 fixed effects.

Table 8 shows the results. Education was not a statistically significant predictor of 12-year middle and older age mortality rates among native-born Union Army veterans. When we use our first measure we obtain a coefficient of 0.994 ($\hat{\sigma}$ =0.030). When we instrument using our first measure of education we obtain a coefficient of 0.991 ($\hat{\sigma}$ =0.050). We also performed additional robustness tests. The results were similar even controlling for occupation in 1900 (or past occupation if retired). We also obtained similar results using a Cox proportional hazards model. When we looked at cause of death, we found that the more educated were less likely to die of stroke but were more likely to die of ischemic heart disease.

However, education was a statistically significant predictor of mortality rates in all three late 20th century samples, and its effect appears to be increasing.   However the hazard ratios suggest that the relative risk of death for a year of education fell from 0.989 in the Union Army to 0.969 in NHANES I to 0.956 in NHANES II and then to 0.948 in NHANES III, only the differences between the Union Army sample and NHANES II and III were statistically significant in a pooled sample.

These results are consistent with the labor market and wealth results—the returns to early investments appear to have increased substantially in the 20th century, and this is also true for mortality.

Conclusion

We document trends in early childhood investments measured by height and educational attainment for cohorts born in the United States between 1820 and 1990 and the extent to which height and education were correlated over time. We then relate the heights and education to various measures of labor market success and wealth. To investigate these relationships we make use of a large number of data sets containing the highest-quality comparable measures of height and economic success.

Overall a picture emerges with the 19th century having low investments in height and education, and positive but small returns for both education and height in non-farm occupations. Height was a significant predictor of wealth in the population; however, height was negatively associated with occupational scores among farmers.

In the first part of the 20th century, there are large increases in education and height but these investments stall in the second part of the 20th century. At the same time returns appear to have increased substantially all throughout the 20th century and appear to be at their highest today. Interestingly investments in college education also seem to have stalled despite persistently high returns the second half of the 20th century (Oreopolous and Petronijevic 2013). Understanding the determinants of investments in early human capital investments and why these investments have stopped growing is an important topic for future research.[25]

We speculate that the greater importance of physical labor in the 19th century economy, which raised the opportunity cost of schooling, may have depressed the height-education relationship relative to the 20th century. Technological change, leading to a move from a brawn- to a brain-based economy, and the rise in publicly funded education (Goldin and Katz 2008) lowered the opportunity cost of schooling and increased the marginal benefit of time spent in schooling.

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[25] Unfortunately our data sets are not well-suited to investigate the determinants of education and height over time since the WWII records and the UA data contain very little information on parental of family background.-

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Table 1: Brother-Brother Adult Height Correlations Among Whites

Union Army, 1861-65	World War II, 1939-45	PSID
(1812-1844 Cohort)	(1909-1924 Cohort)	(1959-1968 Cohort)
0.394	0.462	0.492
(0.024)	(0.024)	(0.017)

All correlations are estimated using Restricted Maximum Likelihood (REML). Standard errors are in parentheses. We thank John Parman for estimating the WWII correlation for us. The PSID estimates are from Mazumder (2004).

Table 2: The effect of height on schooling in the 19th Century (birth cohorts)

	Union Army, Dummy=1 if in school, 1850 or 1860 $\partial P/\partial x$	Union Army, Years Education, Measure 1	Union Army, Years Education, Measure 2	Gould Sample, Years Education	Union Army, Dummy=1 if illiterate (age 21+) $\partial P/\partial x$
Mean dependent Variable	0.652	3.322	4.072	5.766	0.026
Height (cm)	0.001	0.009*	0.005*	0.002	-0.000
	(0.001)	(0.004)	(0.003)	(0.003)	(0.000)
State FE	Y	Y	Y	Y	Y
Age census FE	Y	Y	Y		
Age enlistment FE	Y	Y	Y	Y	Y
Log population in town of enlistment	Y	Y	Y		Y
Population in town of enlistment >= 50,000				Y	
Year census dummy	Y	Y	Y		
Adjusted R-squared or Pseudo R-Squared	0.151	0.281	0.567	0.056	0.086
Observations	10,606	10,615	10,615	6,695	8,518

Standard errors clustered on state. The Gould sample is restricted to the native-born. Because the first three columns of the Union Army sample (except for the last column) are restricted to children in 1850 or 1860, it consists predominately of the native-born. The two education measures for the Union Army sample are constructed from the school attendance from linked antebellum censuses. See Section II.a for further information.

Table 3: Effect of Height on schooling in 20th century
White native-born males (OLS)

	Effect of height on years of schooling	Education mean (sd)	Height mean (sd)	N	Year data collect ed	Birth cohorts
Panel A: WW2 Sample.						
height (cms)	0.080 ***	9.8	175.4	3,862,22 8	1939-45	1897-23
	[0.000]	(3.6)	(16.2)			
Panel B: NLS Old men						
height (cms)	0.076***	10.16	177.20	1,266	1961	1904-21
	[0.015]	(3.72)	(6.95)			
Panel C: NHANES I & II						
height	0.074***	12.7	176.6	4,155	1971-76	1930-59
	[0.006]	(3.03)	(6.79)			
Panel D: NLS young men						
height (cms)	0.044***	13.64	179.86	1,597	1981	1941-52
	[0.010]	(2.66)	(6.69)			
Panel E: NLSY79						
height (cms)	0.047***	13.44	178.53	2,615	1996	1957-64
	[0.007]	(2.56)	(7.31)			
Panel F: NHANES III						
Height (cms)	0.054***	12.8	175.9	1,566	1988-94	1943-74
	[0.009]	(2.66	(6.99)			
Panel G: NHANES 1999-10						
Height (cms)	0.037 ***	13.5	178.5	2,556	1999-10	1954-90
	[0.005]	[1.9]	(6.88)			
Panel H: NHIS samples						
height (cms)	0.039 ***	13.4	178.3	43,190	2000-11	1955-91
	[0.002]	[2.71]	(7.14)			

All samples are restricted to white native males between the ages of 20 and 45. NHANES 1 and 2 controls include state/place of birth dummies, year of survey dummies, age dummies, and 10 year cohort dummies.   NHANES III only includes AGE dummies (neither survey year nor year of birth are given), region of residence dummies, and metro area.   NHANES 1999-2010 includes age dummies and survey dummies. Sample weights were used. NHIS samples include age dummies, year of survey dummies, and region of residence dummies. NHIS uses sample weights.

Table 4: Effect of Height and education on labor market outcomes 1870-1996

Dependent variable:	log (occupational score)		log(annual wages)	
Panel A: UA Gould Sample (non-farmers)				
height	0.002*	0.002*		
	[0.001]	[0.001]		
years of school		0.012***		
		[0.003]		
Panel B: UA 1870 (non-farmers)				
height	0.001	0.001		
	[0.001]	[0.002]		
years of school		0.013*		
		[0.006]		
Panel C: WW2 Sample.				
height	0.003***	0.001***		
	[0.000]	[0.000]		
years of school		0.031***		
		[0.000]		
Panel D: NHANES I & II (1971-76)				
Height	0.008***	0.004***		
	[0.001]	[0.001]		
years of school		0.044***		
		[0.002]		
Panel E: NLS 1961				
height (cms)	0.008***	-0.000	0.012***	0.004*
	[0.002]	[0.002]	[0.002]	[0.002]
years of school		0.097***		0.084***
		[0.004]		[0.005]
Panel F: NLS 1981				
height (cms)	0.009***	0.004**	0.011***	0.008***
	[0.002]	[0.002]	[0.002]	[0.002]
years of school		0.129***		0.079***
		[0.005]		[0.006]
Panel G: NLS 1996				
height (cms)			0.013***	0.008***
			[0.002]	[0.002]
years of school				0.108***
				[0.006]

Occupational score is based on 1950 incomes. We imputed 1950 occupation codes and matched to occupational score in the 1950 census. When multiple 1950 occupation codes were imputed to an occupation, we took a population weighted mean of income.

The WWII sample is restricted to white males ages 25-45 with no missing values for education, height and year of birth and within enlistment parameters. Those without occupation codes, or reporting their occupation as “Student” or “None” are excluded in the occupation regressions. Regressions include state/place of birth dummies and year of birth dummies.

Gould sample controls include age, whether the soldier was US-born and whether he enlisted in city with a population of 50,000+.

Controls for the 1870 Union Army sample include age and region of birth dummies.

Controls for NHANES 1 and 2 include age and whether the man was US-born.

NLS notes: Sample includes all white males with no missing values for education, height and year of birth from the 1961 wave of the of National Longitudinal Survey of Old Men, the 1981 wave of the National Longitudinal Survey of Young Men, and the 1996 wave of the National Longitudinal Survey of Youth. Regressions include age dummies, year dummies and a dummy for foreign-born. We did not impute occupation scores for the NLSY79 because it uses 1960 occupation codes which are not detailed enough. Individuals with zero or missing values for annual earnings are not included in the earnings regressions.

Table 5: Height, Education, and Wealth Among Union Army Veterans in 1870

Dependent Variable: Logarithm of Wealth		
All		
Height	0.010***	0.017**
	(.003)	(0.005)
Years of Education		0.064***
		(0.014)
Non-farmers		
Height	.001	0.009
	(.003)	(0.006)
Year of Education		0.053**
		(0.018)
Farmers		
Height	0.012*	0.022*
	(.005)	(0.009)
Years of Education		0.056**
		(0.021)

All regressions include state fixed effects. Standard errors are in parentheses. *** $p < 0.001$, ** $p < 0.010$, * $p < 0.100$. Total wealth is the sum of real estate and personal property wealth, as transcribed from the 1870 Census manuscripts. The years of school are "measure 2" of education, imputed using the data on school attendance in 1850 or 1860 (depending on the census year in which the veteran was observed when of age (11,21]). The regression includes controls for age in 1870, age at enlistment, and region of birth (all entering as dummy variables).

Table 6: The relationship between height, education and wealth measures, 1961-2004
White Males

Dependent variable:	log (all observed wealth)		log(real estate and business wealth)	
Panel A: NLS 1961				
height (cms)	0.053***	0.025**	0.061***	0.038**
	[0.012]	[0.012]	[0.017]	[0.017]
years of school		0.318***		0.269***
		[0.024]		[0.034]
Panel B: NLS 1981				
height (cms)	0.040***	0.024*	0.037*	0.022
	[0.013]	[0.013]	[0.020]	[0.020]
years of school		0.368***		0.326***
		[0.034]		[0.051]
Panel C: NLS 1996				
height (cms)	0.099***	0.075***	0.105***	0.081***
	[0.012]	[0.012]	[0.019]	[0.019]
years of school		0.517***		0.505***
		[0.034]		[0.054]
Panel D: HRS Samples 1992, 1998 and 2004				
height (cms)	0.053***	0.032***	0.070***	0.045***
	[0.005]	[0.004]	[0.01]	[0.01]
years of school		0.238***		0.276***
		[0.015]		[0.034]
X (1998 dummy)		0.095***		0.038
		[0.026]		[0.057]
X (2004 dummy)		0.084***		0.172***
		[0.026]		[0.057]

NLS notes: real estate wealth is the sum of the reported value of house owned, farm owned, business or other real estate owned. All wealth is the sum of real estate wealth, savings, bonds, and stocks. Value of automobiles is never included as it was not collected prior to 1996. The data collection is, however, not identical over the years so the wealth measures are not exactly identical. Missing and non-reports are treated as zeros, and set to 0.01 before taking logs.

Table 7: Height, Education, and Wealth Among Indian Males, Age 20-45, in 2005-6

Panel A: Dependent Variable=Years of Education

	All	Farmers	Non-Farmers
Height	0.151***	0.114***	0.161***
	[0.003]	[0.006]	[0.004]
State and Age FE	Y	Y	Y
Observations	48,670	11,978	36,692
R-squared	0.115	0.131	0.102

Panel B: Dependent Variable=Logarithm of Wealth Index

	All		Farmers		Non-Farmers	
Height	0.018***	0.008***	0.015***	0.009***	0.018***	0.008***
	[0.000]	[0.000]	[0.001]	[0.001]	[0.000]	[0.000]
Years of Education		0.063***		0.049***		0.060***
		[0.000]		[0.001]		[0.000]
State and Age FE	Y	Y	Y	Y	Y	Y
Observations	48,670	48,670	11,978	11,978	36,692	36,692
R-squared	0.193	0.447	0.210	0.370	0.184	0.440

Estimated from the Indian DHS 2005-6. The mean of years of education is 7.97 and mean height is 164.73 cms.

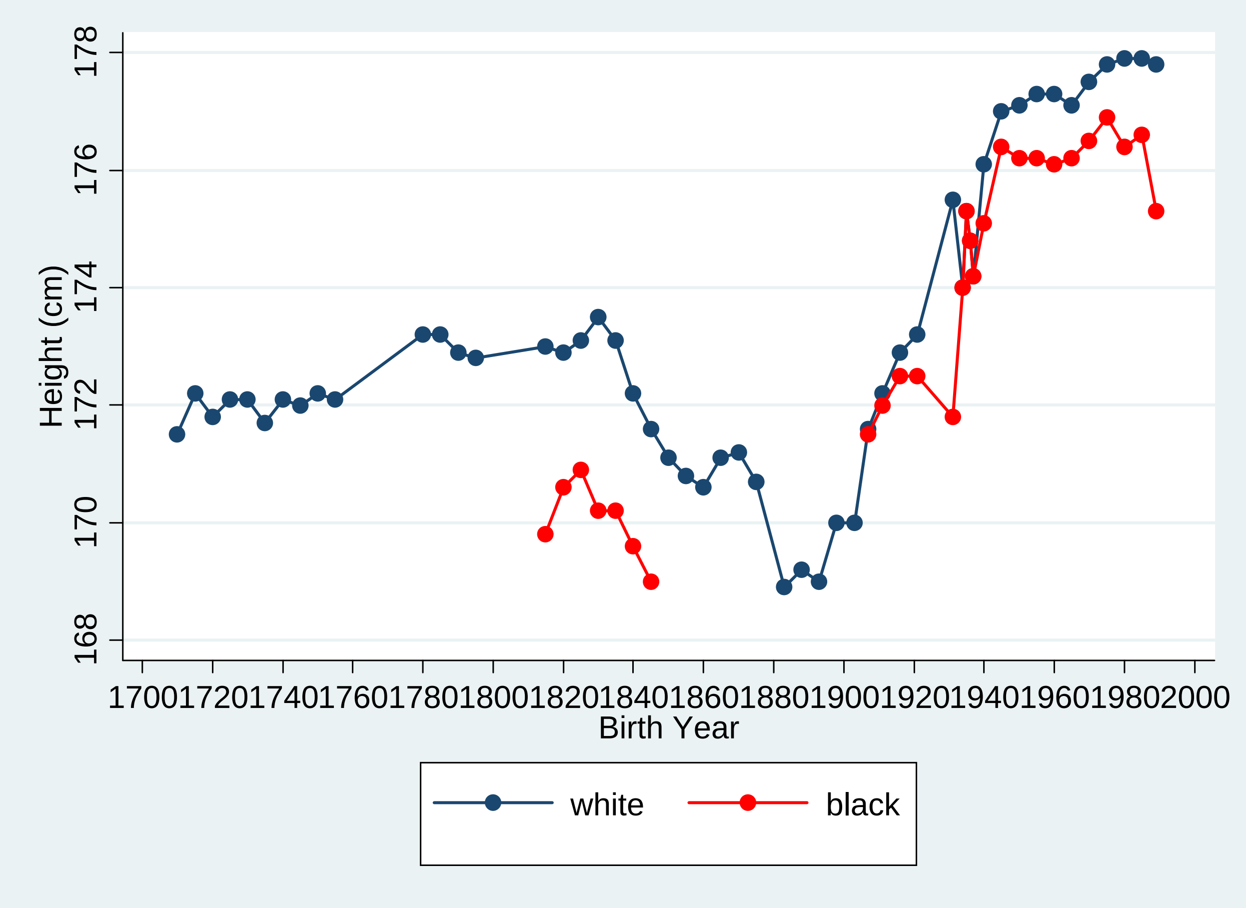
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Effect of education on mortality over time

	Union Army	NHANES I (1971-1975)	NHANES II (1976-80)	NHANES III (1988-94)
	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio
Years Education, Measure 2	0.989			
	(0.025)			
Years Education		0.969***	0.956***	0.948***
		(0.007)	(0.010)	(0.008)
Age in 1900 or at survey (NHANES)	Y	Y	Y	Y
Log(population in city of enlistment) or metro dummy (NHANES)	Y	Y	Y	Y
1860 census dummy	Y			
State of enlistment FE or residence (NHANES III)	Y	N	N	Y
Region of residence		Y	Y	
Age in 1850/60 census FE	Y			
γ	0.047***	0.060***	0.089***	0.094***
	(0.015)	(0.005)	(0.011)	(0.017)
Number of observations	4,143	1,797	1,902	1,430

The samples exclude deaths due to violence. Both NHANES II and NHANES III use the survey sample weights.

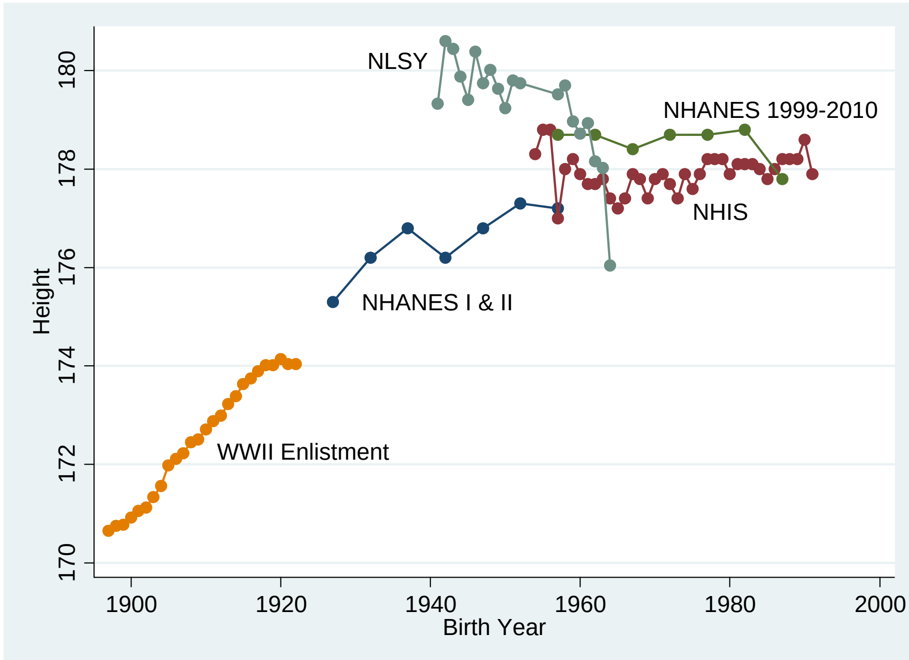
Figure 1: Long-Term Trends in US Heights



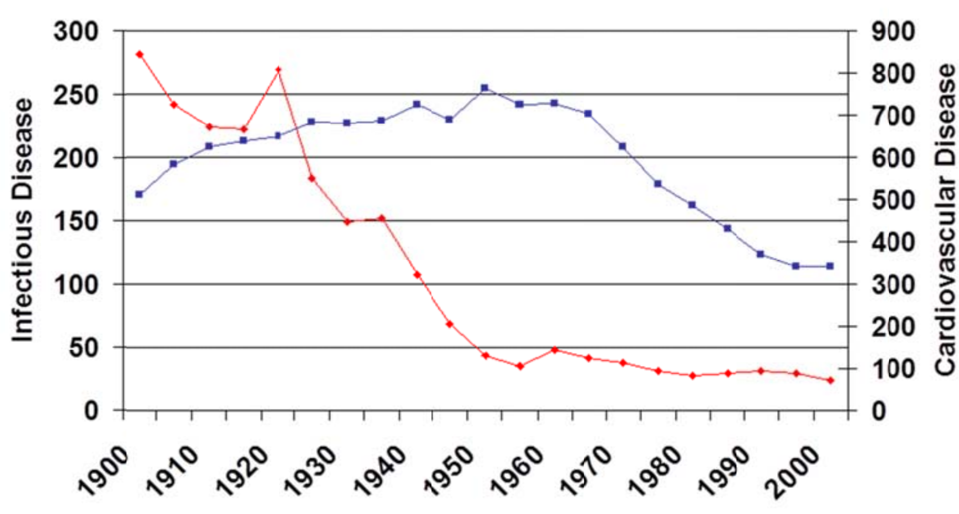
This figure updates the white height series in Figure 2.1 in Costa and Steckel (1997) using the 1963-2010 NHIS and adds a height series for blacks using Union Army records, published WWII heights, and the NHIS. Year of birth is centered at the marks. Estimates using the NHIS were adjusted to account for biases resulting from self-reporting in the NHIS.

Figure 2: Evolution of heights and mortality in the 20th century United States

Panel A: Trends in Heights



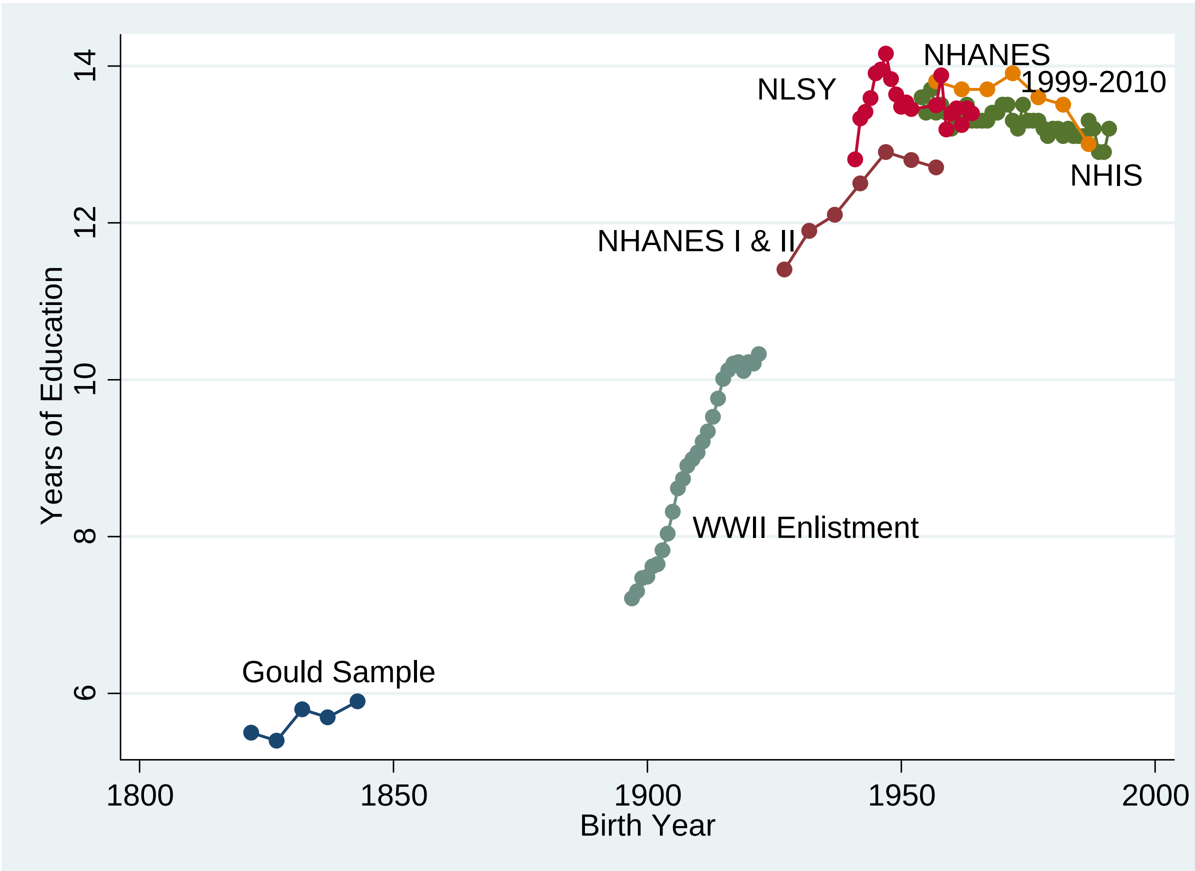
Panel B: Mortality rates over time



Panel A: The means are centered at the mark. We do not have exact year of birth for NHANES 1999-2010. The surveys were done over a two-year period but the year of the survey was not recorded. Year of birth is not available for NHANES III.

Panel B: Figure 3 from Cutler et al. 2006.

Figure 3: Trends in educational attainment in some of our samples



The means are centered at the mark. We do not have exact year of birth for NHANES 1999-2010. The surveys were done over a two-year period but the year of the survey was not recorded. Year of birth is not available for NHANES III.

Figure 4A: Height, Occupation and Wealth in the 19th century among Farmers. Union Army sample linked to 1870

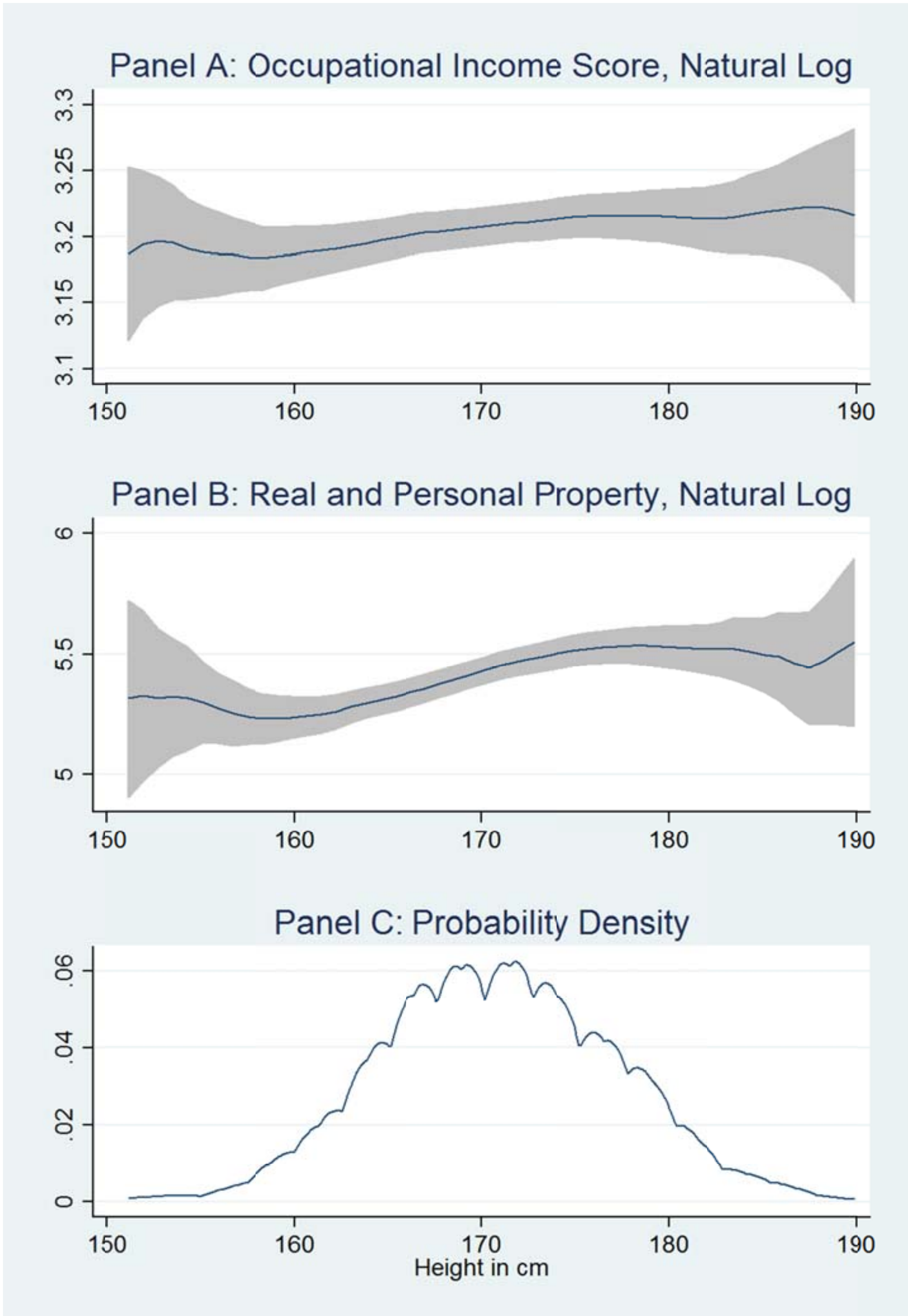


Figure 4B: Height, Occupation and Wealth in the 19th century among Non-Farmers, Union Army Sample Linked to 1870

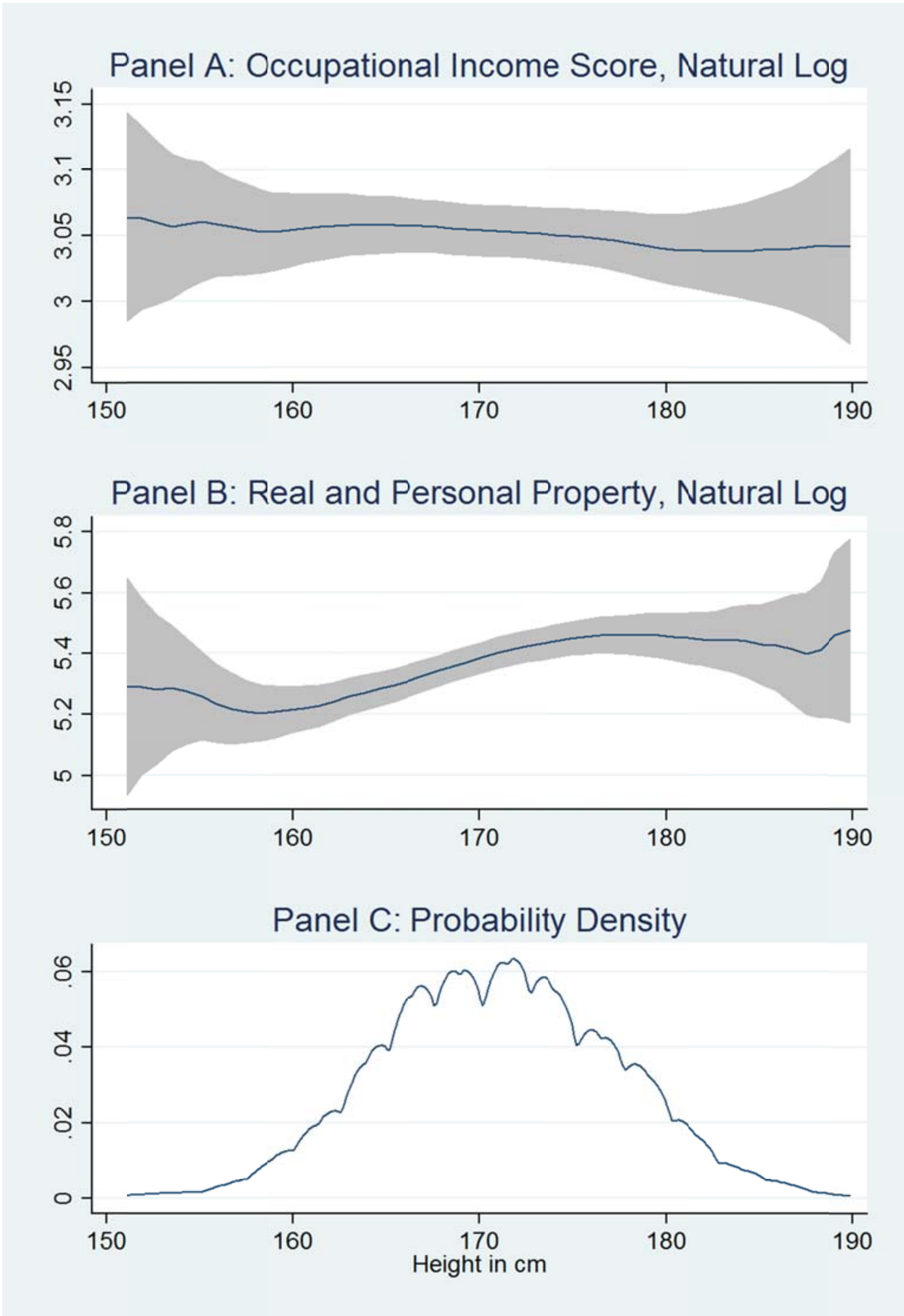


Figure 4C: Height, Occupation and Wealth in the 19th century. Full sample, Union Army Sample Linked to 1870

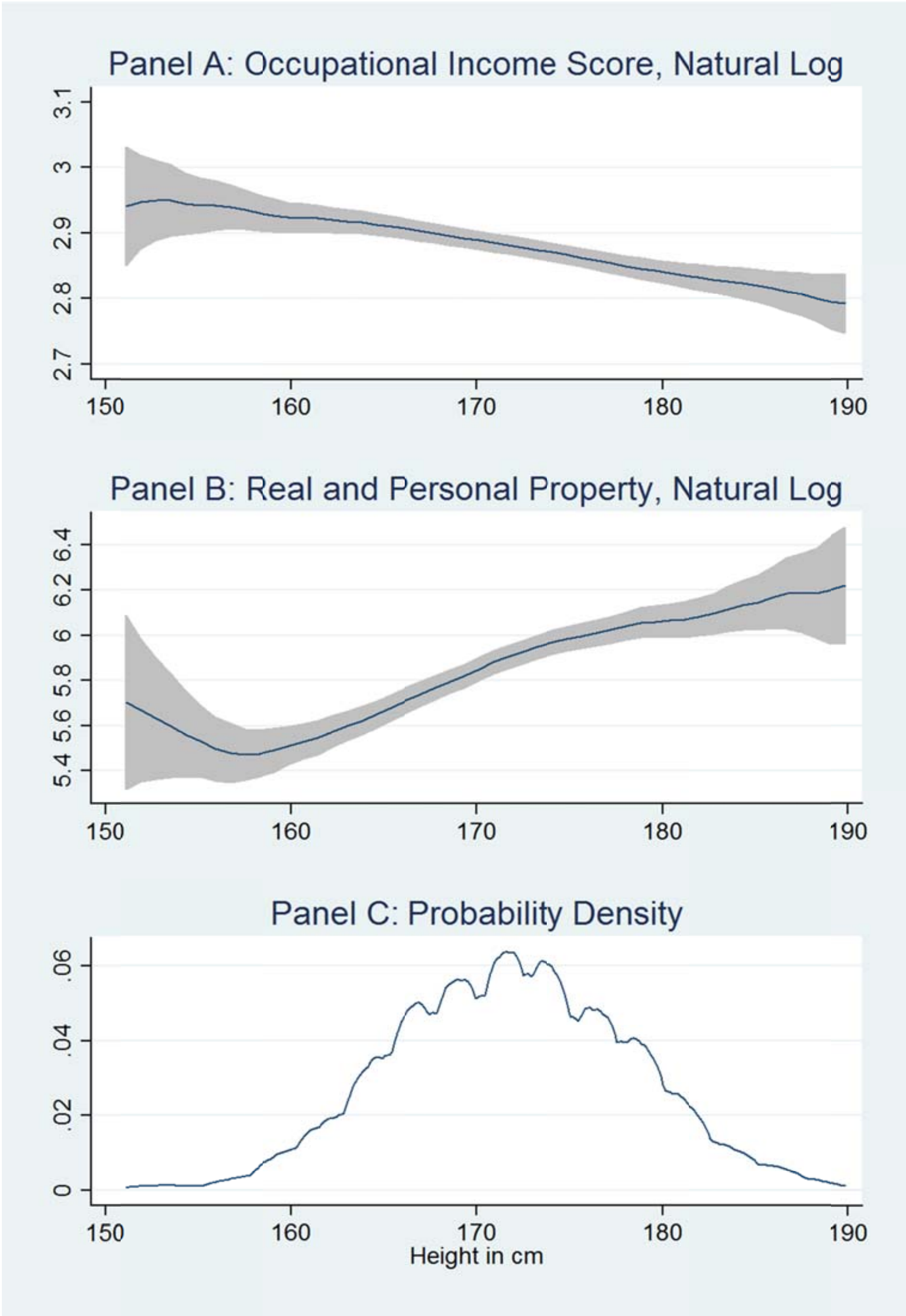
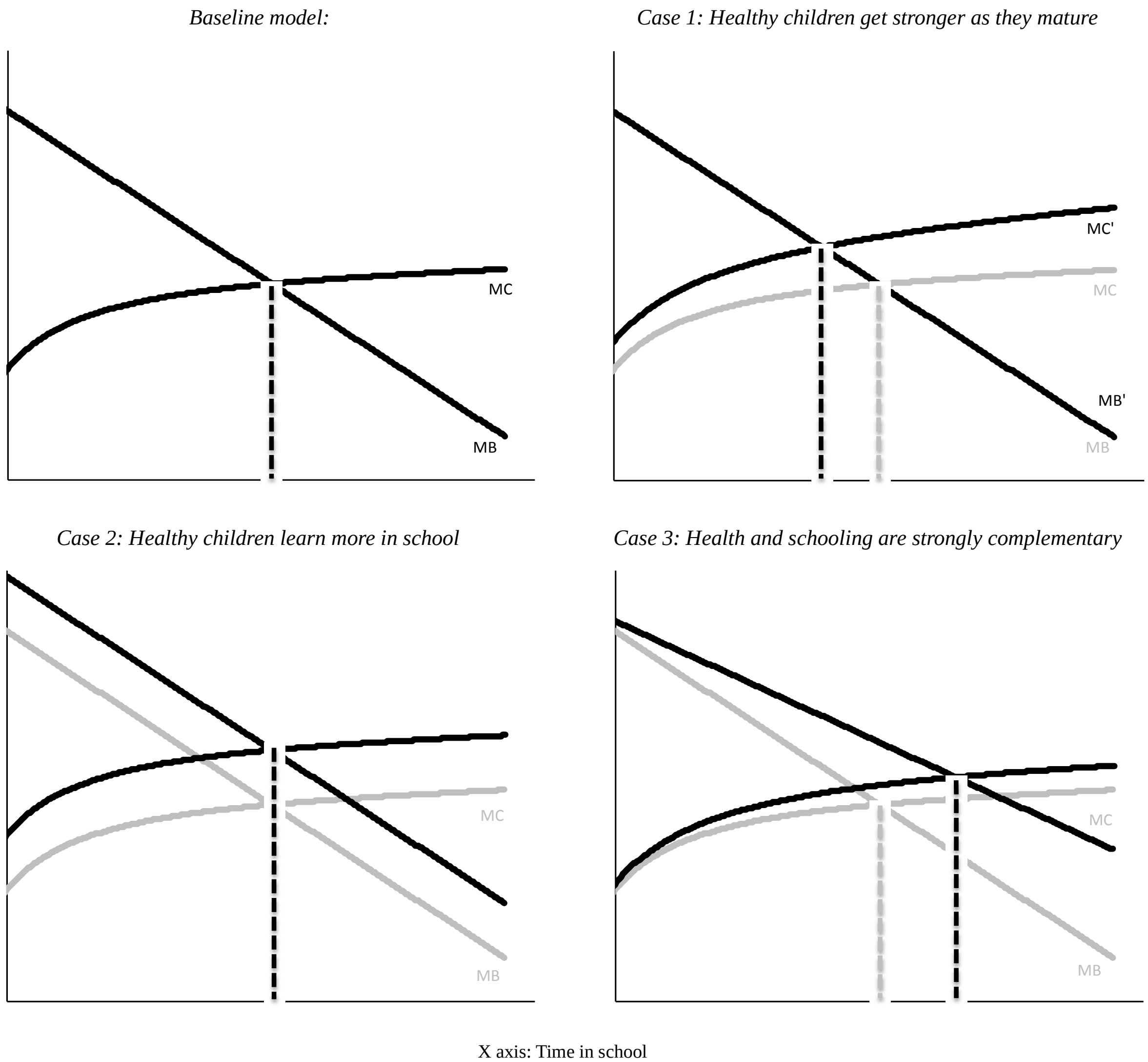


Figure 5: Health and the standard model of schooling



Notes: this figure displays simulations of the Ben Porath model of schooling choice under alternative assumptions about how childhood health affects the marginal benefits (MB) and marginal costs (MC) of time in school. The *x* axis is time in school (modeled as a time at which a child leaves school and starts working). The *y* axis measures present discounted value on a logarithmic scale. For further description of the model and cases, see Section IV.c of the chapter. An excel spreadsheet containing these simulations is available from the authors upon request.