INEQUALITY IN PROCESS:
income and heterogeneous educational health gradients among blacks and whites in the U.S.

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Abstract

Though considerable research demonstrates that Non-Hispanic Blacks and Non-Hispanic Whites in the United States vary in *how much* their health improves from educational attainment, empirical work that explains *why* these populations arrive at unequal returns to education is sparse. In this study, to flesh out our understanding of how heterogeneous educational gradients arise among racial populations in the U.S., I examine how *income*—a crucial mediator of the education-health association—contributes to racially-disparate health returns to college. In particular, I compare how the association among college completion and health status would manifest across Blacks and White subpopulations if income were factored out of the underlying education-health generative process. I use data from the National Longitudinal Study of Adolescent to Adult Health ($n = 7,222$) and sequential g-estimation for this investigation. Results demonstrate that income plays a larger role in mediating the association among college completion and health status for Blacks and, as such, that sizable racial differences in the health benefits of college persist after controlling for income.

Introduction

In the contemporary United States (U.S.), as well as various other temporal and geographic contexts, education is a fundamental input to social well-being (Goldin and Katz 2008; Montez and Friedman 2015). *Educational gradients*—or patterns such that more-highly educated individuals fare better than their less-highly educated peers exist among a mixture of economic resources (e.g., income; occupational status), human-capital skills (e.g., cognitive ability; meta-cognitive functioning) and social and psychosocial outcomes (e.g., access to marriage; exposure to chronic stress). Educational disparities are particularly pronounced among individuals with and without college degrees and only appear to be widening with time. The social and economic consequences of not holding a college degree are more severe now, than “ever before in the modern era” (Pew Research Center 2014).

By broadly shaping social welfare, education functions as a powerful determinant of population health. The many economic, human-capital and (psycho-)social resources derived from education function as health protective inputs; in attaining additional educational attainment then, individuals are returned a diverse, comprehensive “health-toolkit” that can be used to maintain physical and emotional welfare across a variety of scenarios (Mirowsky and Ross 2003; Phelan et. al. 2010). Due (ostensibly) to this bundle of salubrious resources that educational attainment confers, college-degree holders typically experience lower mortality risk and better general health status (Hummer and Hernandez 2013; Rogers et. al. 2000); decreased risk of developing various chronic and progressive conditions (e.g., hypertension; dementia) (Sharp and Gatz 2012; Vargas et. al. 2000); and increased psychological functioning (Bauldry 2015; Erickson et. al. 2016) than their non-college educated peers. Like educational gradients in well-being more generally, the health advantage experienced by more highly educated individuals has existed in the U.S. for decades and become more acute overtime (Masters et. al. 2012). Education’s persistent, powerful and multifaceted relationship with wellness indeed positions it as a fundamental determinant of health in the U.S. (Phelan et. al. 2010).

Despite education’s remarkable role in shaping population health, one must be careful to dis-

tinguish *fundamental* from *universal* or *uniform*. Like many other social processes in the U.S., the association among education and health is characterized by stark racial disparities. Research has most consistently shown that Non-Hispanic Blacks (Blacks) receive weaker improvements to general health-status indicators (e.g., mortality risk; self-rated health) upon college completion than Non-Hispanic Whites (Whites) (Hummer and Hernandez 2013; Hayward et. al. 2000; Kimbro et. al. 2008). While the exact size of this disparity varies among studies—from findings which suggest that Blacks receive little to no health-status returns to education (e.g., Farmer and Ferraro 2005), to findings which point to smaller, but still measurable, Black-White inequality in gains (e.g., Shuey and Wilson 2008)—research consistently shows that the gap in health status between college-educated Blacks and non-college educated Blacks is narrower than the health-status gap among college educated Whites and their same race, non-college educated peers.

Though literature that documents Black-White variation in the association among education and health-status is extensive, there is still room for expansion around this idea. Most work on the topic focuses on quantifying racial differences in average effect sizes, rather than in explicating racial differences in underlying processes. Put differently, though prior work has provided substantial evidence to suggest that Blacks and Whites differ in *how much* their general health improves from attaining a college degree, empirical attempts to explain *how and why* these populations arrive at disparate effects are sparse (Hayward et. al. 2015; Walsemann et. al. 2013). Because education is a central input to wellness in the U.S., racial inequality experienced in this social process likely contributes to racial inequality in health more broadly (Williams et. al. 2016). Explicating how and why racial differences emerge in the strength of the association among education and health is thus an important task for population health scientists to address (Montez et. al. 2012).

In the current study, to flesh out our understanding of how and why heterogeneous educational gradients manifest among racial populations in the U.S., I examine how *income*—a crucial mediator of the education-health association that is experienced differently by race—contributes to racially-distinct health status returns to college. In particular, I compare how the association among college completion and health status would manifest across Blacks and White subpopulations if income were factored out of the underlying education-health generative process. Ob-

serving the education-health association net of income's influence allows us to describe income's role in generating this relationship; to assess if and how income contributes to racial disparities in this association; and to potentially combat racial inequity in an essential driver of U.S. population health.

I use data from the National Longitudinal Study of Adolescent to Adult Health (Harris et. al. 2009) and *sequential g-estimation*—a method for identifying controlled direct effects in the presence of intermediate confounders (Acharya et. al. 2016; Vansteelandt 2009)—in this investigation.. In the end, I find that controlling for income's influence as a mechanism serves to, if anything, *widen* racial disparities in health returns to college, as earnings play a proportionally larger role in mediating the relationship among college completion and health status for Blacks relative to Whites.

The remainder of the paper proceeded as follows. In the next section, I discuss income as a mediator of the relationship among a college degree and health, as well as how it diverges across Blacks and Whites. In the following section, I describe the data, methods and analytical strategy. In the final sections, I present the results of the analysis and offer a discussion that contextualizes them in the broader population health literature.

Background

Income as a mediator of the education-health association

Increased income is a direct, immediate by-product of educational attainment. Across a range of education levels, attaining additional educational credentials typically results in higher annual earnings. The boost in income that accompanies the attainment of a Bachelor's degree is particularly stark. In 2017 for instance, individuals with high-school degrees earned an average of \$712 per week, while college-degree holders earned \$1,173 per week (Torpey 2018). Over the course of a full year, this accumulates to an approximately \$24,000 difference in earnings. Remarkably, income differences among differently educated individuals manifest early into adulthood: in 2013, among population aged 25-32, college-degree holders earned a median income of \$45,000 per year, while high-school graduates earned only \$28,000 per year (Pew Research Center 2014).

The substantial and prompt increase in income experienced upon college completion positions it as a crucial mechanism of the association among education and health. Income is itself a flexible, multifaceted determinant of wellness (WoOLF et. al. 2015). Access to greater amounts of money allows access to higher quality physical goods (e.g., higher quality diets; residence in more health-protective neighborhoods; higher quality health care) and symbolic resources (e.g., rank in a community; control over one's environment)—both of which significantly and positively affect an assortment of health outcomes (Kawachi et. al. 2011). That educational attainment leads to a considerable increase in this influential health-input suggests that income explains a sizable portion of why education is tied to health. Indeed, under (very) strong assumptions, income alone has been shown to comprise upwards of 33% of education's total effect on health among the general population (Cutler and Lleras-Muney 2006; Lynch 2006).

Race(-sim), earnings and education in the U.S.

Income provides a compelling explanation for why Black and White populations experience differential health returns to college completion (Walsemann et. al. 2013). Indeed, educational credentials are not experienced in a vacuum, but rather in a social system that is highly cognizant of race (Bonilla-Silva 1997). An array of social, economic and ideological structures—including permeative racist-ideology that characterizes workers in ways that (de-)legitimize their claims to education-appropriate wages (Avent-Holt and Tomaskovic-Devey 2013) or labor market segregation in high-education jobs (Hamilton et. al. 2011)—serve to create stark Black-White differences in income among college graduates. College educated Blacks have, and have historically, experienced earnings that are approximately 20% less than college educated Whites (Bureau of Labor Statistics 2015; Wilson and Rodgers 2016). As income is estimated to explain a sizable portion of education's effect on health, this inequality in access to earnings likely contributes to inequality in educational effects. Blacks may indeed experience shallower educational gradients because access to an essential pathway that generates much of education's health effect is restricted among this group (Walsemann et. al. 2013).

Beyond differences in *how much* income Blacks and Whites are returned from college completion, significant racial variation exists in what individuals might acquire with the same amount of education-earned income. Structural processes act to constrain *purchasing power* among Blacks, and thus the amount and quality of health-protective goods that their income affords them (Williams et. al. 2016). Systems that underlie racial residential segregation, for instance, restrict Black individuals' ability to translate their education earned-income into housing in health-advantageous neighborhoods (Pais et. al. 2012; Pattillo 2005). Variation in purchasing power extends beyond just physical goods too, with increased income affording Blacks differential, often curbed, access to salubrious social goods—such as well-populated marriage markets or extended and accessible friendship and kin networks (Cole and Omari 2003; Crowder and Tolnay 2000; Thomas 2015). These non-equivalences, in what salubrious resources the same amount of income yields, have been hypothesized to contribute to racially distinct educational gradients in health (Pearson 2008). Indeed, structurally propagated constraints on what health-resources education-earned income “buys” Blacks may diminish the effectiveness of education as a health-protective resource overall.

Racial heterogeneity in what increased income “purchases” individuals applies to psychosocial experiences and exposures as well. Psychological stressors unique to populations of color—such as interpersonal discrimination or racial vigilance—generally share a positive association with socioeconomic status. Indeed, because mid- to high incomes are often earned and translated into goods in White-dominated sites, such as middle-class workplaces or resource-rich neighborhoods, higher income Blacks typically experience more instances of day-to-day interpersonal discrimination than their lower-SES peers (Cole and Omari 2003; Hudson et. al. 2016; Lee and Hicken 2016). These chronic psychological stressors have direct, negative impacts on well-being (e.g., Hicken et. al. 2014) and serve to undermine the symbolic and psychological salubrious goods typically returned from income¹—and, by extension, perhaps the positive health effects of acquiring additional education.

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¹Experiencing day-to-day interpersonal racism, for instance, can diminish the feelings of control over one's environment and perceived societal rank that often accompany elevated incomes (Hudson et. al. 2012).

Current Study

As demonstrated above, stark heterogeneity exists in how racial subpopulations experience earnings in the U.S. Blacks experience systematic restrictions both in terms of how much income is returned from college completion and in what health-related goods and exposures said earnings might purchase. Because income is considered a crucial mediator of the relationship among college completion and well-being, these multiple points of blockage may help account for why Blacks receive shallower health returns to advanced education than Whites. Indeed, if not for these stark differences in income, educational gradients might manifest more similarly across Black and White populations.

The primary goal of the current paper is to examine this idea empirically. To accomplish this, I estimate and compare *how the association among college completion and health status would manifest across Black and White subpopulations if income were factored out of the underlying education-health generative process*. Given income's proposed importance in linking college completion to health, as well as the multiple barriers face by Blacks in accessing and leveraging earnings, I predict that controlling for post-education income will help explain away racially disparate health returns to college. More specifically, I hypothesize that:

H1: Black-White differences in health status returns to college completion will narrow after controlling away income's influence as a mediator of said relationship.

Data

Dataset: The National Longitudinal Study of Adolescent to Adult Health

Data for this project come from the National Longitudinal Study of Adolescent to Adult Health (Add Health). Add Health is an ongoing, nationally representative, school-based study of adolescents in grades 7 to 12 that began in 1994 (Harris et. al. 2009). Add Health currently includes four waves of data: Waves 1 (W1: 1994-95); 2 (W2: 1996); 3 (W3: 2001-02); 4 (W4: 2007-08). In W4, respondents ranged in age from 24-32 years old.

For this paper, the utility of Add Health data come from their richness. The wealth, diversity, and accuracy of measures that Add Health collects on each respondent allows for me to flesh out the conceptual model in Figure 1 (below). The relatively large sample of Black, White and college educated individuals—observed pre- and post- educational attainment—contained in these data also make them ideal for this analysis. Add Health, and similar variable-rich surveys of young adults, has been invaluable in addressing recent, particularly nuanced questions about education’s relationship with health (e.g., Bauldry 2014; Lynch and von Hippel 2016).

Measurement

College degree status (A) is operationalized with a respondent’s W4 educational attainment. To keep definitions of treatment ($A = 1$) and control ($A = 0$)—and thus treatment effects—tightly defined, I take a relatively conservative approach in specifying educational groups. Individuals who completed a 4-year college degree, and no further degree, by W4 were coded as $A = 1$. Individuals who completed a high school degree, and no further degree, by W4 were coded as $A = 0$. Respondents who completed an advanced educational degree, beyond a BA (e.g., a PhD), or who did not finish high school were set aside from this analysis. Individuals still enrolled in school were similarly withheld from the analysis as well. Effect estimates in this paper thus quantify the health advantage that 4-year college graduates experience over high school graduates. Note that more liberal/conservative groupings (e.g., completed a 4-year college degree or more vs. completed anything less than a 4-year college degree) produced similar results to what is presented below.

Health (Y) is measured as W4 self-rated health status. At W4, respondents were asked to describe their health as either *excellent*, *very good*, *good*, *fair*, or *poor*. Like many other researchers who use this measure (e.g., Braveman and Gottlieb 2014), I group adjacent categories to represent broad regions of health: *excellent/very good health vs other* and *fair/poor vs. other*. I choose this outcome: (1) given that the vast majority of studies that describe racial disparities in educational gradients rely on this and other general health-status measures (e.g., Farmer and Ferraro 2005; Shuey and Wilson 2008); (2) given its strong and consistent correlation with a spectrum of health measures

that vary with education (e.g., mortality; recurring health problems; physical tiredness; stress; underlying biomarkers) (Bauldry 2014; Idler and Benyamini 1997; Foose and Haas 2009; Jylha et. al. 2006; Jylha 2009); and (3) because it has been shown to share a (modest) causal relationship with college completion among the age group represented in Add Health (Lynch and von Hippel 2016). Note that, because analysis for excellent/very good health vs. other and fair/poor vs. other lead to the same substantive conclusions, I only present models for excellent/very good health vs. other in this paper. Note also that *excellent/very good health* and *superlative health* will be used interchangeably from here on.

The focal mechanism, income (M), is defined using a respondent's annual income at W4. Individuals were asked, *over the past year, how much income did you receive from personal earnings before taxes, that is, wages or salaries, including tips, bonuses, overtime pay, and income from self-employment?*. Responses were taken as a measure of annual earnings (in log dollars). Income is winsorized, like other Add Health earnings measures, at \$5,000 and \$100,000 to lessen the influence of extreme values on our parameters (Gelman and Hill 2007). Results are robust to varying these cutoffs.

Pretreatment confounders (C) are features that influence college degree attainment and W4 self-rated health. I define this vector of traits using: (1) basic demographic controls that are associated with education and health status [*self-reported sex category* (male or female); *W4 age* (in years); *W1 from South* (1 if resides in South; 0 if otherwise)]; (2) household and economic factors, experienced during adolescence, that may influence later health and the likelihood of college completion; [*parent's college degree status* (1 if has a parent with at least a college degree; 0 if otherwise); *W1 household structure* (1 if two residential parents; 0 if otherwise)]; (3) measures of adolescent health and well-being that capture selection into schooling and later health [*W1 health status* (1 if excellent/very good health; 0 if otherwise); *W1 depression* (measured by the 9-item Center for Epidemiological Studies Depression scale) (e.g., Boardman and Alexander 2011)]; (4) W1 measures of cognitive ability and non-cognitive factors that affect school performance, well-being, and the likelihood of college completion [*W1 Add Health Picture-Vocabulary Test Score* (age-standardized score on a revised version of the Peabody Picture Vocabulary Test) (Harris 2009); *W1 college expectation* (from -2, low expectation that will attend college; to +2, highly expect to attend college)];

and (5) contextual controls that describe respondents' adolescent schooling and socioeconomic environments [*W1 school with masters degree* (proportion of teachers at W1 school that have a Master's degree); *W1 block poverty* (proportion of Census block-group households that are below the poverty line)]. Race is self-reported, coded as "black" if Non-Hispanic Black and "white" if Non-Hispanic White, and used to stratify the sample.

Post-treatment confounders (**L**) are features that occur during W4, and simultaneously: (1) are influenced by college completion status; (2) influence an individual's level of income; (3) and influence an individual's health status. This vector of traits is defined with *W4 occupational status* (1 if in a managerial or professional level occupation; 0 if otherwise); *W4 employment status* (1 if employed; 0 if not); *W4 marital status* (1 if married; 0 if not); and *W4 Number-Recall Test*, to represent cognitive skills at W4, developed post-college completion (in respondent score on an Add Health administered, 7-point number recall test). See below for more discussion of post-treatment variables' role in this analysis.

Methods

Analytical Framework

To help fix ideas, Figure 1 displays the relationship between education, income, and health status.

Figure 1: Conceptual model of the relationship among education, income, and health. Orange lines represent the *controlled direct effect of education* not due to income.

To quantify the strength of the association among a college degree and general health, *I estimate the average treatment effect* (i.e., the ATE) for each racial group:

$$ATE(a, a') = E[Y_i(a) - Y_i(a')]. \quad (1)$$

The $ATE(a, a')$ gives a difference in counterfactual states (Rubin 2005): $Y_i(a)$ gives the health (Y) of an individual who completed a college degree ($A = a$), while $Y_i(a')$ gives the health of the *same* individual—with the same background characteristics (C_i)—had only they not received a college degree ($A = a'$). This difference, averaged across all individuals in the data, summarizes the health benefits of a college degree.

I also estimate the *average controlled direct effect of a college degree on health* (i.e., the ACDE) for each racial group:

$$ACDE(a, a', m) = E[Y_i(a, m) - Y_i(a', m)]. \quad (2)$$

Like the ATE, the ACDE gives the gap in health status among individuals had they and had they not completed a college degree. The difference here is that the ACDE fixes the mechanism of interest (M) to be equal across counterfactuals. The ACDE thus summarizes the “effect” of attaining a college degree, if attaining a college degree did not come with an increase in income (Acharya et. al. 2018). This quantity can be thought of as the total effect of a college degree on health status that is not due to income (VanderWeele 2016).

Comparing ACDE estimates across racial populations allows us to evaluate how educational gradients—and thus racial disparities in gradients—would manifest net of the influence of post-education income. Additionally, the quantity $ATE - ACDE$ provides a useful summary of the health effect of college attainment that would remain under an intervention that fixes income to a specific value for each racial group (VanderWeele 2016).² Generally speaking, a larger difference between the

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²In more detail, $ATE - ACDE$ represents two quantities: (1) an indirect effect (i.e., how a college degree affects income and subsequently how much income affects health); and (2) a causal interaction effect (i.e., how income modifies the direct effect of college on health or the portion of education’s effect not explained by income) (VanderWeele 2014). Without making additional assumptions, that are often far beyond any social science question (Imai et. al. 2011),

ATE and ACDE indicates that income is participating more in generating a relationship among a college degree and health-status.

In this analysis, I compare: (1) ACDEs across racial groups with income fixed (M) to each group’s respective mean—to evaluate the consequences of controlling for income’s influence as a mediator for the typical individual in the sample; and (2) ACDEs across groups with income (M) fixed to values other than sample averages—to evaluate the consequences of controlling for income’s influence as a mediator among Black and White individuals at non-average levels of annual income.³

Sequential g-estimation

The presence of intermediate confounders (L)—i.e., features that simultaneously: (1) are a consequence of education, (2) affect earnings, and (3) shape health status—complicates the estimation of the ACDE. Either ignoring intermediate confounders all together or adjusting for them via conventional regression could lead to biased results (Gelman and Hill 2007; Rosenbaum 1984). For example, take L as a respondent’s occupation. As occupation predicts earnings and predicts health status, conditioning on income while ignoring occupation would risk inducing spurious associations among education, intermediate confounders, and health (Rosenbaum 1984). Controlling for occupation in a traditional regression model to account for this confounding however, would block part of the controlled direct effect ($A \rightarrow L \rightarrow Y$), which is problematic as we only wish to adjust for M (Acharya et. al. 2017; Imai et. al. 2011).

Given the above concerns, I estimate the ACDE with sequential g-estimation (Acharya et. al. 2016; Vansteelandt 2009). This method proceeds in two steps. In Step 1, a regression model, $Y \sim f(A_i, M_i, C_i, L_i)$, is fit to estimate the effect of income (M) on health status (Y), conditional

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further separating out these two quantities is infeasible. While the difference in the ATE and the ACDE offers a broad summary of how a resource participates as a mechanism, the fact that is identifiable under reasonable assumptions makes it useful for this paper.

³ACDEs may vary across values of $M = m$ because of causal interaction processes (Acharya et. al. 2018). An individual with a very high level of income might be more reliant on earnings as a mediator of the education-health association than an individual who makes zero income, for instance. See Acharya et. al. (2016) or Acharya et. al. (2018) for further details.

on all other variables. (In the model $Y_i = \beta_0 + \beta_1 A_i + \beta_2 M_i + \beta_3 C_i + \beta_4 L_i$, for instance, $\beta_2 M_i$ is this effect). In Step 2, each individual’s health outcome is “de-mediated”, to produce $\hat{Y}_i$, by subtracting the effect of the mediator obtained in Step 1 from Y_i . (Returning to the previous example, this means $\tilde{Y}_i = Y_i - \beta_2 M_i$). The de-mediated outcome is then regressed on college degree status and pretreatment confounders to estimate $E[\tilde{Y}_i | A_i, C_i]$. This final quantity is an estimate of the ACDE that avoids bias from conditioning on post-treatment variables (Acharya et. al. 2017). A nonparametric bootstrap, that repeats both steps of the method, is used to obtain uncertainty estimates.

Identifying the ACDE through sequential g-estimation assumes sequential unconfoundedness—or that the variable sets **C** and **L** contain enough confounders of the association among A and Y and M and Y , respectively—and no intermediate interactions (Acharya et. al. 2016). (Violating the sequential unconfoundedness is akin to omitting a confounder in a traditional analysis; violating the no intermediate interaction assumption is akin to precision loss that comes from omitting an interaction in standard analyses.) Again, the assumptions needed to identify direct effects here are far weaker than the assumptions needed to identify related quantities through other methods—which, for instance, often require that no intermediate variables **L** exists whatsoever (Acharya et. al. 2016; Imai et. al. 2011). Please see the supplemental materials for more information on the identifying assumptions underlying this approach and various sensitivity analyses of these assumptions.

Missing data

Most variables in the analysis are missing a trivial amount of responses. W4 income had the largest proportion of missing, at about 6%. To retain individuals with missing responses, and avoid bias that might arise from list-wise deletion, I employ the *Amelia* algorithm for multiple imputation (Honaker et. al. 2001). I adjust this method to fit within a bootstrap framework following Schomaker and Heumann’s (2018) guidelines, particularly their *MI Boot* recommendation. This strategy entails: (1) creating J imputed datasets using *Amelia*; (2) drawing B bootstrap samples from each imputed data set; (3) calculating bootstrapped quantities of interest within each imputed set; and (4) combining quantities from each set using Rubin’s Rules (Schomaker and

Heumann 2018). I use $J = 20$ imputations and $B = 200$ bootstrap samples in this process. All analysis were run in the R statistical programming language (R Core Development Team 2018).

Results

To contextualize the sample, Table 1 and Table 2 provide descriptive statistics for Black ($n = 1,881$) and White ($n = 5,341$) sample populations, respectively. Among both sample populations, respondents who completed a college degree had better starting mental and physical health; were from higher socioeconomic status families and neighborhoods; and performed better on early cognitive-functioning tests. College-educated respondents similarly fared better on post-education outcomes: individuals with only a high-school degree at W4 had worse self-rated health, lower annual incomes and performed worse on tests of cognitive capacity. Note that pronounced Black-White differences exist among college-educated individuals: Whites with a college degree experienced elevated health status, were more likely to be married, and, most relevantly, had higher incomes than their Black, college educated peers.

measure	w/o college ($n = 1,402$)	w/ college ($n = 479$)
	mean (sd)	mean (sd)
Age (in years)	29.1 (1.79)	28.8 (1.70)
Female	0.46 (-)	0.60 (-)
Has a parent with a college degree	0.27 (-)	0.54 (-)
W1 lives in a two-parent household	0.42 (-)	0.59 (-)
W1 is in excellent/very good self-rated health	0.66 (-)	0.76 (-)
W1 CES-D (depression) score	6.49 (4.21)	5.05 (4.04)
W1 college-expectation scale score	1.04 (1.16)	1.69 (0.65)
W1 picture-vocabulary test score	91.7 (13.1)	101.0 (12.5)
W1 % of teachers in Rs school with a masters degree	42 (23)	47 (26)
W1 % of households in Rs Census block in poverty	26 (18)	22 (17)
W1 lives in the South	0.63 (-)	0.57 (-)
W4 is in excellent/very good self-rated health	0.50 (-)	0.61 (-)
W4 annual income	\$22,000 (18,000)	\$35,000 (21,000)
W4 number-recall test score	3.67 (1.48)	4.33 (1.51)
W4 is currently married	0.23 (-)	0.29 (-)
W4 in professional/managerial occupation	0.17 (-)	0.64 (-)
W4 is unemployed	0.25 (-)	0.12 (-)

Table 1: Blacks: analytical-sample descriptive statistics. Note: W1 and W4 refer to Wave 1 and Wave 4 of Add Health, respectively. R refers to respondent. Means of binary variables encode proportions (e.g., Female gives the proportion of respondents that identify as female, as opposed to as male).

	w/o college ($n = 3,572$)	w/ college ($n = 1,769$)
measure	mean (sd)	mean (sd)
Age (in years)	29.1 (1.77)	28.9 (1.74)
Female	0.48 (-)	0.56 (-)
Has a parent with a college degree	0.26 (-)	0.59 (-)
W1 lives in a two-parent household	0.71 (-)	0.82 (-)
W1 is in excellent/very good self-rated health	0.63 (-)	0.81 (-)
W1 CES-D (depression) score	5.89 (4.25)	4.58 (3.70)
W1 college-expectation scale score	0.89 (1.26)	1.72 (0.63)
W1 picture-vocabulary test score	103.7 (11.7)	110.0 (10.7)
W1 % of teachers in Rs school with a masters degree	49 (25)	50 (0.24)
W1 % of households in Rs Census block in poverty	13 (10)	9 (8)
W1 lives in the South	0.36 (-)	0.30 (-)
W4 is in excellent/very good self-rated health	0.52 (-)	0.75 (-)
W4 annual income	\$26,000 (21,000)	\$40,000 (24,000)
W4 number-recall test score	4.15 (1.47)	4.66 (1.42)
W4 is currently married	0.50 (-)	0.50 (-)
W4 in professional/managerial occupation	0.22 (-)	0.65 (-)
W4 is unemployed	0.21 (-)	0.11 (-)

Table 2: *Whites*: analytical-sample descriptive statistics. Note: W1 and W4 refer to Wave 1 and Wave 4 of Add Health, respectively. R refers to respondent. Means of binary variables encode proportions (e.g., Female gives the proportion of respondents that identify as female, as opposed to as male).

Additional descriptive analysis, displayed in Figure 2, shows that Black and White sample populations differed in how income protects health. At the same level of income, Black respondents were generally less likely to be in superlative health than their same-income, White peers. Indeed, the same amount of income appeared to afford Blacks and Whites different levels of health in these data.

Figure 2: Black-White differences in the observed probability of excellent/very good health across binned values of income. Note: income is binned at tenths of a log-dollar. Point size represents the number of Black respondents in each income bin, with larger points indicating more Black respondents in each bin.

The first set of empirical results—displayed in Figure 3 and Figure 4—give the average association among a college degree and health (i.e., the ATE), that same association with post-college income factored out (i.e., the ACDE), and an estimate of the difference between these two quantities (i.e. $ATE - ACDE$) for Blacks and Whites, respectively. The ACDEs in these plots are estimated with income at their group-specific means, which demonstrates how income participates as a mediator of education’s health effect for the average individual in the sample.

Figure 3: Blacks: (1) Estimated effect of college completion on excellent/very good self-rated health (i.e., ATE); (2) estimated effect of college completion on excellent/very good self-rated health after controlling for income (i.e., ACDE); and (3) the difference between these two quantities (i.e., ATE-ACDE). Note: the ACDE is calculated here with income fixed to its sample average among Blacks (approximately \$25k). Distributions reflect quantity estimates from each imputed dataset used in the analysis.

Figure 4: Whites: (1) Estimated effect of college completion on excellent/very good self-rated health (i.e., ATE); (2) estimated effect of college completion on excellent/very good self-rated health after controlling for income (i.e., ACDE); and (3) the difference between these two quantities (i.e., ATE-ACDE). Note: the ACDE is calculated here with income fixed to its sample average among Blacks (approximately \$25k). Distributions reflect quantity estimates from each imputed dataset used in the analysis.

For the average Black individual in the sample, income plays a sizable and significant role in generating the association among a college degree and health status. The ATE, represented in the first panel of Figure 3, shows that completing college increases ones probability of possessing superlative self-rated health by approximately 7.8 percentage points. The ACDE, represented in the second panel, gives the ATE if we were to hold income constant among all individuals, *regardless of college status*. Here, we see that factoring out the income boost that typically accompanies attainment of a college degree reduces education's effect on health by about 2.9 points, to 4.9 points. This difference between the ATE and ACDE, represented in the final panel, is statistically significant (95% CI: 1.3, 4.4) and sizable: approximately 36% of a college degrees effect on health status appears to be due to income among Blacks, on average.

Figure 4 shows that, among the average White individual in the sample, income plays a proportionally less essential role in generating the positive health effects of a college degree. For this group, attaining a college degree was associated with a 14.4-point increase in the probability of reporting excellent/very-good health. When factoring out post-education income from that estimate, college-completion yields a 13.4-point increase in superlative health-status. While this 1.1-point decrease is significant (95% CI = 0.46, 1.64), it represents only 8% of education's total effect on health among Whites.⁴

Because income plays a larger role in generating effects among Blacks, controlling for it serves to, if anything, widen disparities in educational gradients. Initial health returns to college among Blacks are approximately 54% the size of returns among Whites ($ATE_{Black}/ATE_{White} = 7.8/14.4$). This 6.6 percentage point difference is statistically significant at a 0.05 level in a Clogg-Z score test (Clogg et. al. 1995). Controlling for income exacerbates this inequality, reducing returns for

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⁴For comparison, I also analyze these populations using the Baron-Kenny process that is often used to investigate mechanisms in the social sciences and has been problematized for its ambiguous handling of intermediate confounders (VanderWeele 2016; Gelman and Hill 2007). Results for Whites are consistent with results presented above, largely because income plays little role in college effects on average. Results for Blacks vary depending on whether one includes intermediate confounders. In an analysis where one does not control for confounders of the income-health relationship, income is estimated to explain around 40% of education's health status effect. In an analysis that does control for intermediate confounders, that, as stated above, constitute part of education's total effect on health, this estimate drops to 29%. Sequential g-estimation allows us to adjudicate between these results by allowing us a principled way of adjusting for intermediate features.

Blacks to approximately 37% the size of returns among Whites ($ATE_{\text{Black}}/ATE_{\text{White}} = 4.9/13.4$). Indeed, for individuals with average earnings, factoring out income from the education-health generative process does not appear to narrow racial gaps in the health status returns to education.

To evaluate the consequences of controlling for income among Black and White individuals with non-average annual earnings, I next estimate ACDEs while fixing income to various values of post-education earnings. Figure 5 displays the increase in probability of possessing superlative self-rated health that accompanies college completion, net of income, across individuals with varying levels of annual earnings:

Figure 5: Estimated effect of college completion on excellent/very good self-rated health after controlling for income (i.e., ACDE) for Blacks and Whites at various levels of annual earnings. Note: bootstrapped 50%, 75% and 90% uncertainty intervals marked by shaded regions.

Figure 5 suggests that, among Whites, income varies across earners in how it mediates a college degrees relationship with health status. While factoring out income among low-earning Whites does little to nothing to alter total effects (e.g., $ATE - ACDE$ equals approximately 0 at \$15,000 per year), controlling for income among high-earning Whites leads to an appreciable decrease in health returns to college completion (e.g., $ATE = 14.4$ and $ACDE = 10.6$ for individuals making \$80,000 per year). For Blacks, evidence of a similar causal interaction process is absent: income

appears to play a similar role in generating the health effects of college completion across all earners examined.

Despite varying ACDEs among Whites, controlling for income does little to diminish racial disparities in health returns to college across earners. Indeed, across the range of annual earnings examined, controlled direct effects for Blacks remain below controlled educational effects for Whites. Even among high-level earners where income played the largest role as a mediator among Whites, estimates of educational effects net of income remain double for Whites compared to Blacks [e.g., $ACDE(m = \$80,000 \text{ per year}) = 10.6$ for Whites and 4.9 for Blacks]. Under no scenario examined did factoring out income from the education-health process serve to close gaps in educational gradients.

Discussion

This project adds to extensive literature on racial disparities in educational health gradients by examining whether income helps account for Black-White disparities in the health-status returns to college. Indeed, using sequential g-estimation and data from Add Health, I compared how the association among college completion and health status would manifest across Black and White subpopulations if income were factored out of the education-health generative process.

Contrary to initial predictions, I found that Black-White disparities in health-status returns to college persisted, and even widened, after controlling away income's influence as a mediator. Income accounted for a larger proportion of the association among college completion and health status for Blacks than it did for Whites. Removing this important mediator from the education-health relationship failed to narrow racially disparate health returns to college as such.

Controlling for earnings did not narrow racial disparities in educational gradients because of stark departures in how educational effects emerged across groups. That is, results hint that the underlying causal infrastructure that links college completion to health deviated across racial groups in a more dynamic way than is often assumed (Pearson 2008). Indeed, the prediction that

Black-White disparities would narrow after controlling for income implicitly assumes that the underlying education-health generative process is structurally identical across populations and that disparities arise because of blockage along an important pathway (Pearson 2008). Results here hint that this may not be the case, but instead that the precise role of any particular mediator, the entire arrangement of mechanisms, or even what pathways are present might vary across racial groups in ways that contribute to producing heterogeneous overall effects.

Indeed, among Whites, education appeared to function as a stylized fundamental determinant of health (Phelan et. al. 2010). At no point did income dominate college completions total effect on health status. At any level of earnings, a substantial proportion of education's total effect on health appeared to be constituted by a bundle of non-earning related resources. This classic pattern of how we conceptualize that education—or similar fundamental causes—functions as a health determinant did not hold as cleanly for Blacks: income was a fairly greedy participant of education's total health effect among this population, explaining near a majority of college completions health benefits across all earners.

Taken together, these results suggest that racial disparities in educational gradients are not necessarily due to Black's restricted access to and use of income, but instead stem from relatively limited use of other mechanisms that education develops. Nonequivalent returns to education may indeed be a product of nonequivalent underlying processes. Additional work that: (1) unpacks which non-income resources comprise such a large proportion of educational effects among Whites; (2) why Black individuals rely less on these alternative pathways to generate health effects; and (3) what non-earnings pathways might be active in one population but not another would further develop our understanding of how disparate returns to education arise.

Several features of this study motivate additional consideration. First, and most importantly, I note that results should be contextualized within a life-course perspective. The association among education and health is highly dependent on the broader setting in which it is evaluated (Montez and Friedman 2015). While we must learn about features of the education-health relationship by focusing in on particular samples, researchers should note that any description we produce of this

relationship is reflective of the particularities of the population(s) through which we examine it (Montez and Friedman 2015).

In this case, we are evaluating educational gradients among young adults in the U.S. The health benefits of attaining a college degree during this critical, far-reaching period of health-development appear to be related in no small part to income, particularly among Blacks. Income may be an especially important mechanism of the education-health association at this stage of the life-course, where family formation and the establishment of independent households are prime activities (Eliason et. al. 2015). Black-White variation in how income functions as a mechanism of the education-health process may be especially pronounced at this stage in the life-course as well. Black-White differences in the timing of first birth/family formation may, for instance, shift the importance of acquiring economic resources upwards among Black individuals at this age range (Matthews and Hamilton 2016). Moreover, the early development of independent economic resources, through college completion, may be especially important for young adult Black populations that systematically experience lower SES childhoods and thus have fewer alternative sources of economic resources to draw upon in tackling the activities of young adulthood (Thomas 2015). Among older adults, who are more economically established, annual income may be a less pronounced generator of educational effects among either racial group.⁵

With this in mind, cataloging how income contributes to disparate educational effects for individuals at different stages of the life course is essential work to be pursued. The narrow, relatively young age-range of Add Health respondents is a limitation of the data. Indeed, individuals in the Add Health sample are not far removed from college. Among this population, the multiple resource advantages conferred by education are only beginning to solidify. The patterns observed in this paper will likely shift and evolve as respondents move further away from completion of their degrees and the resources conferred by education have additional time to develop. A particularly promising venue for future research would be to examine how income participates in divergent educational gradients among this same cohort of young adults as they continue to age.

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⁵As an extreme example, annual earnings likely play little to no role in propagating educational gradients or differences in educational gradients among post-retirement older adults.

Second, how income participates in educational gradients should be examined for outcomes other than general health-status as well. Indeed, while health-status is an informative dimension of well-being, that has been shown to share a causal relationship with college completion for the age group examined here, it is representative of a broad, inseparable, mixture of psychological and physical conditions (Fosse and Haas 2009; Jylha 2009; Lynch and von Hippel 2016). Examining other health measures—that are more specific, but not as immediately affected by college completion⁶—should be pursued as the Add Health sample continues to age. Identifying for which specific health measures, or types of health measures, the above patterns hold—and for which they do not—would add specificity to our understanding of how income participates in educational gradients. Similarly, examining how income participates at other levels of education and for other racial groups would be helpful to document as well.

Third, future researchers should take advantage of in-progress data collection efforts that better capture early-life factors. Indeed, Add Health contains limited indicators of early childhood traits that may differentially influence blacks' and whites' later health and socioeconomic status. Without explicitly controlling for these features, it is possible that some portion of the variation across groups, displayed in the results, is due to omitted confounding. In a preliminary investigation that flexibly controls for a much expanded set of pretreatment traits—including several covariates that are likely strongly correlated with/capture the effect of unobserved childhood measures (e.g., a measure of W1 BMI; indicators of if a respondent experienced a set of adverse childhood experiences; W1 drinking and smoking behavior; contact with the criminal justice system as a child; etc.)—I find similar average effect sizes to what is presented above. This supplementary analysis makes it plausible that omitted confounders are not greatly disrupting results, but does not entirely rule out the possibility of such bias (Bauldry 2014; Hill 2011). In-development data collection efforts that contain explicit measures of early life features—such the *High School and Beyond: Midlife Follow Up* (Warren et. al. 2017)—should be used to recreate this study and further

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⁶In analyses of more objective indicators (e.g., hypertension; systolic blood pressure; diabetes), observed associations among college completion and health evaporated when controlling for pretreatment confounders. Education's causal effect on other indicators of health may indeed need more time to fully develop.

bolster confidence that results are not driven by bias due to omitted features.

Third, by using a parametric modeling procedure, the study is subject to the same model misspecification risks inherent to other parametric modeling strategies (e.g., Hill 2011). Additional work that takes advantage of in-development, nonparametric sequential g-estimation strategies—such as Ratkovic and Tingley (2017)’s *direct estimation* technique or Blackwell and Strezhnev (2018)’s *telescope matching* method—would likely enhance inference.

Despite these limitations, this study offers insight into potential interventions for narrowing racial disparities in health returns to education. Results align with prior speculation that intervention on the non-material resources that accompany educational attainment may be key to closing racially unequal gradients (Montez et. al. 2012; Hayward et. al. 2015). Indeed, because income is a dominant mediator of the education-health association for Blacks, hypothetical interventions that increase average incomes among Blacks to match average incomes among Whites—while keeping the underlying education-health process unchanged for both populations—could potentially accelerate health returns to education for Blacks. However, because Whites appear more readily able to benefit from the non-income aspects of college completion, even such a substantial intervention would likely fall short of eliminating disparities. Instead, interventions on the human-capital, social and psychological goods returned from education may be necessary to flatten racial disparities in effect sizes. Additional work on how these non-material goods participate in providing Black and White individuals with improved health upon educational attainment is needed to better understand how to proceed in designing effective, targeted interventions that eliminate disparities.

This study has broader implications, too, for understanding social inequity in health more generally. Indeed, heterogeneity exists in many of the patterns that we observe in population health. How much any social-input matters for well-being typically varies by one’s precise social-location (e.g., Bauldry 2015; Hudson et. al. 2012; Umberson and Montez 2011). Often, we make assumptions about how these outcomes are constituted and forgo empirical examinations of why they diverge across groups (Bowleg 2012; Pearson 2008). This study demonstrates that making such assumptions, even when average differences between groups are only modest, can conceal valu-

able information about how socially distinct individuals experience the same health processes. Indeed, differences in how effects emerged across populations in this study arguably outweighed differences in overall effect sizes. Results suggest that empirical research that seeks to describe inter-group variation in population health processes go beyond only documenting differences in average effects sizes. Empirical work that unpacks how individuals from different social-groups vary in how they utilize social-inputs to protect health is encouraged, as it may flesh out our understanding of how health outcomes—and health inequalities—come to be.

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