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Does the Functional form of the Association between Education and Mortality Differ by U.S. Region?

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Abstract

To understand the education-mortality association among U.S. adults, recent studies have documented its national functional form. However, the functional form of education-mortality relationship may vary across geographic contexts. The four U.S. Census regions differ considerably in their social and economic policies, employment opportunities, income levels, and other factors that may affect how education lowers the risk of mortality. Thus, we documented regional differences in the functional form of the education-mortality association and examined the role of employment and income in accounting for regional differences. We used data on non-Hispanic white adults (2,981,672, person years) aged 45–84 in the 2000–2009 National Health Interview Survey, with Linked Mortality File through 2011 (37,598 deaths) and estimated discrete-time hazard models. The functional form of education and adult mortality was best characterized by credentialism in the Midwest, Northeast, and for Western men. For Western women, the association was linear, consistent with the human capital model. In the South we observed a combination of mechanisms, with mortality risk declining with each year of schooling and a step-change with high school graduation, followed by steeper decline thereafter. Our work adds to the increasing body of research that stresses the importance of contexts in shaping the education-mortality relationship.

Keywords

Education; Mortality; Region; Functional Form

Americans with more education live longer and proportionally healthier lives than their less-educated peers (Hayward, Hummer, and Sasson 2015; Hummer and Hernandez 2013; Hummer and Lariscy 2011; Rogers et al. 2010; Zajacova and Montez 2017; Montez and Hayward 2014; Sasson 2016a, 2016b). Recent research indicates that the relationship between educational attainment and U.S. adult mortality is strengthening over time

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(Hayward, Hummer, and Sasson 2015; Montez et al. 2011; Montez and Zajacova 2013) and among more recent birth cohorts (Masters, Hummer, and Powers 2012). Understanding why educational attainment remains such a strong predictor of mortality is a core sociological question, whose answers have critically important implications for population health and longevity.

To better understand the education-mortality association among U.S. adults, several recent studies have systematically investigated its functional form on a national level (Backlund, Sorlie, and Johnson 1999; Everett, Rehkopf, and Rogers 2013; Hayward, Hummer, and Sasson 2015; Montez, Hummer, and Hayward 2012). Identifying the functional form between education and mortality is a fundamental step in elucidating the myriad processes through which educational attainment may shape adult mortality (Hayward, Hummer, and Sasson 2015). For instance, if the association between education and adult mortality is best measured by a linear (or dose-response) functional form, where each additional year of education lowers mortality risk by a similar amount, this suggests that the incremental human capital gained during each year of schooling is largely responsible for lowering mortality risk. On the other hand, if the association is best described by a series of step-change reductions in mortality each time a credential is attained (e.g., Bachelor's degree), this suggests that education lowers mortality because educational credentials open doors to opportunities such as employment, higher incomes, medical care, or other factors.

Using U.S. data from 1979–1998, Montez and colleagues (2012) found that the best functional form was described by a shallow linear decline in mortality from 0 to 11 years of education, a step change reduction upon attainment of a high school credential, followed by a steeper linear decline afterwards. A subsequent study using U.S. data from 1986–2006 found that the form had evolved for white men in the early 21st century, adding a step change reduction upon attainment of a bachelor's degree (Hayward et al. 2015). The authors posited that major societal changes, particularly the technological advancements and the information economy helped fuel changes in the functional form. A main takeaway is that the functional form varies over temporal context. However, it remains unclear if the functional form of the relationship is the same for the entire U.S. or varies by geographic context.

Indeed, the functional form of the education-mortality association may also vary markedly by subnational areas, such as regions, states, or counties. While no study that we are aware of has examined whether the functional form differs across subnational areas, several have shown that the *strength* of the association (for a given functional form) does differ. The strength of educational attainment in relation to mortality differs across the four U.S. Census regions, with the weakest association for women in the Northeast (Montez and Berkman 2014). A study of U.S. men found that the association was stronger in urban than rural areas (Hayward, Pienta, and McLaughlin 1997). Similarly, a related study examining the association between income and mortality across commuting zones found the strength of the association differed markedly (Chetty et al. 2016). Taken together, these studies show that the *strength* of the association differs by geographic context, but does the *functional form* also differ? In this study, we address this question by focusing on the four U.S. Census regions.

If the functional form does vary across regions, it could provide important insight regarding why the education-mortality association exists and how contextual factors (e.g., regional economies, employment industries and opportunities, and tax structures) shape the association. Conversely, if the functional form is similar across the United States, it suggests that contextual factors do little to impinge on the association. Still, the extent to which the functional form varies between geographic contexts in general and regions in particular is unknown. This open question is also important, as extensive previous research has documented how geographic circumstances can shape health (Sheehan et al. 2017; Montez, Zajacova, and Hayward 2017) and mortality risks (Kaplan et al. 1996; Ezzati et al. 2008; Montez and Berkman 2014). Thus this study explicitly documents differences in the functional form of the education-mortality association across the four U.S. Census regions: the Northeast, Midwest, South, and West.

Four U.S. Census Regions

The Census Bureau defined the four regions (Northeast, South, Midwest, West) based on differences in historical development, economic structures, political systems, and other factors (U.S. Census Bureau 1994). These stark differences were documented by Newman and O'Brian (2011) in their detailed analysis of how the four Census regions differ in economic and tax policies. For instance, the Northeast has the most progressive tax structures and relatively high social expenditures per capita, while the South has the most regressive tax structures and comparably lower social expenditures (Newman and O'Brien 2011). One way this could affect the functional form is by buffering the mortality risk of lower-educated adults in the Northeast, compressing the lower tail of the education-mortality association (e.g., the mortality risk associated with 8 years of education may be similar to the risk associated with 12 years); and exacerbating the mortality risk of lower-educated adults in the South (e.g., the mortality risk associated with 8 years may be substantially worse than that associated with 12 years).

Related to the fact that regions differ in their policy contexts and educational quality, they also differ in terms of the opportunities they provide residents for employment and economic well-being. These differences may be important in explaining regional variation in the education-mortality functional form because employment and income are the major pathways through which education shapes health and mortality (Lynch 2006). For this reason, we focus on employment and income in our analyses as potential explanations for regional differences in the functional form. Indeed, regions differ in their industrial base, the occupational structure, employment opportunities, median income, and cost of living. For instance, the Northeast and West have undergone dramatic growth in "creative occupations" that often require a college degree, while many parts of the Midwest have seen manufacturing occupations shrivel up and be replaced with low-wage, precarious service jobs (Florida 2014). These factors could affect the functional form if, for example, access to the types of "good" employment available in a specific region is heavily dependent on certain educational credentials, thereby causing that region to exhibit a step-change functional form.

Regions also differ in their education systems. For instance, regions differ in terms of the pace of the educational expansion, the quality of primary and secondary schooling, and, consequently, the overall average level of education. The Northeast, and particularly the West regions, lead the educational expansion in the 20th century, with the South region continues to trail in the three dimensions just mentioned (Goldin 1998). These dimensions could shape the functional form in many ways. For example, if one region generally offered a higher quality primary and secondary education experience than did another region, we might expect the former region to exhibit a more prominent dose-response association between education and mortality because each year of additional exposure to education was particularly salubrious. Lastly, regions differ in other dimensions that could potentially affect the functional form. For instance, regions differ in climate, lifestyle behaviors, and physical infrastructure (Surgeon General 2014; Cobb 2007; Substance Abuse and Mental Health Services Administration 2013; Yocum 2007; Kachan et al. 2014; Le et al. 2014; Montez and Berkman 2014; Voeks et al. 2008). As mentioned above, in this study we focus on economic explanations given their well-documented importance for explaining the education-mortality association in the United States.

Aims

We use the 2000–2011 U.S. National Health Interview Survey Linked Mortality File to estimate the functional form of education-mortality association for non-Hispanic white adults aged 45–84 for the United States as a whole and then for the four U.S. Census regions. Our analyses are centered on three questions: (1) How does the functional form at the national level compare to the functional form reported in previous time periods? (2) Does the functional form differ across the four U.S. Census regions? (3) Can the regional patterns be explained by differences in employment and income across regions? Overall, a greater understanding of the regional differences in the functional form between education and mortality could help scholars better understand how contexts may alter the association, and could allow for subnational policies and strategies to be developed to minimize educational disparities in health and mortality.

Data and Methods

The data for this investigation came from ten years (2000–2009) of the publicly available Integrated Health Interview Series version of the National Health Interview Survey (hereafter NHIS). The NHIS is a large nationally representative annual survey of non-institutionalized American households, containing detailed information about educational attainment, region of residence, as well as sociodemographic and health factors. Critical for our research objectives, the NHIS is also is linked to the National Death Index (NDI) using a 14-point matching algorithm, which links survey respondents to national level death certificates using information such as social security number. This linkage is known as the Linked Mortality File (hereafter LMF) and allows researchers to connect surveyed respondents with longitudinal mortality information. We specifically used the Integrated Public Use Microdata Series (IPUMS) version, a version that the Minnesota Population Center harmonizes and prepares for public analysis (Minnesota Population Center and State Health Access Data Assistance Center 2016).

Our sample was comprised of non-Hispanic white respondents interviewed in 2000–2009, who were eligible for mortality follow up, who were not missing values regarding educational attainment (less than 2% of respondents in the NHIS are missing information on education), and who were aged 45–84 any time during the follow up period. We excluded Hispanic respondents and those who reported other racial/ethnic affiliation due to small cell sizes, especially given that we stratified by gender and region. We focused on ages 45–84 for three main reasons. Setting the lower limit at 45 allows education enough time to "play out" and shape mortality risk; setting the upper limit at 84 enhances the accuracy of the mortality matches; and this age range is used in two prior studies against which we compare our results (Hayward, Hummer, and Sasson 2015; Montez, Hummer, and Hayward 2012). The survey years included in our analysis began in 2000 because previous research (Hayward, Hummer, and Sasson 2015) has shown a different functional form in the relationship between education and mortality before that year. The last survey year included in the NHIS-LMF was 2009 while the mortality follow-up concluded at the end of 2011.

We used information regarding the age of birth, interview year, and date of death from the LMF to construct a person year file, where years where the respondent was alive the mortality status were coded "0" and, among decedents, the year the respondent died was coded "1." After death, the respondent was censored. All surviving respondents were coded to live until the end of 2011 (when the mortality follow up ended). We predicted all-cause mortality status provided in the public file, which previous research has shown provides extremely similar results compared to the restricted file (Lochner et al. 2008).

Educational Attainment

In coding our specification of educational attainment, we replicated the protocol of two previous studies (Hayward, Hummer, and Sasson 2015; Montez, Hummer, and Hayward 2012) that analyzed the functional form between education and mortality at the national level. We additionally followed their protocol by adjusting for age, coded continuously in each model. National While another study also investigated the functional form using smoothing splines, their approach is conceptually similar to ours, in that it does not presuppose a linear relationship between education and mortality (Everett, Rehkopf, and Rogers 2013).

Detailed information regarding the coding of the functional forms has been published elsewhere (Hayward et al. 2015; Montez et al. 2012) and is shown in Appendix Table 1, but to briefly review we implemented the following coding procedure. Specification 1 was coded as semi-parametric where each year of education was its own dummy variable with high school graduates as the reference. Specification 2 was linear based on years of attained education. However, given the educational response options possible in the NHIS, the linear specification can only be estimated, so we followed the assumptions of previous research regarding years of education (i.e. years until completion after high school; Hayward et al. 2015). Specifications 3–6 were various versions of "step-changes with zero slopes." For instance, mortality risk exhibits a step change reduction upon attainment of an educational credential, while the risk is the same across all years of education in between credentials. Specification 3 was coded in two groups: high school or less versus at least one year of college. Specification 4 was coded in three groups: less than high school, high school, at least one year of college. Specification 5 also had three groups: less than high school, high school and some college, bachelors and higher. Specification 6 had four groups: less than high school, high school, some college, bachelors and higher. Specifications 7–10 had step-changes with a constant, non-zero slopes. These specifications were coded identically to Specifications 3–6 but added the continuous years of education. Specifications 11–13 includes functional forms with step-changes with varying slopes.

Regions

We examined the four regions as classified by the U.S. Census Bureau. The entire distribution of the regional specification of States is presented in Appendix Table 2. Naturally, there is heterogeneity within regional units of analysis, just as there is heterogeneity in a national level of analyses (and likewise within smaller geographic units such as states). Nevertheless, there is a clear precedent for conducting analyses at the subnational level, and findings from these analyses have made important contributions to scientific understanding of the factors that drive health outcomes and health disparities (Montez and Berkman 2014; Newman and O'Brien 2011; Howard 1999; Voeks et al. 2008).

Other Measures

To address our third aim, we add measures of employment status and income to all functional forms. We used the employment status imputed variable from the IHIS, which classifies respondents as either “employed” or “not employed.” For income we used the continuously coded IPUMS imputed ratio of family income to poverty ratio where higher values correspond to a greater ratio and thus higher levels of income. We also specified the income to poverty ratio as a categorical variable, which provided the same top rankings.

Methods

We first descriptively documented regional differences in employment, occupational classification, and income by level of educational attainment for the sample adults of the NHIS. We next displayed basic descriptive statistics for our analytic sample. We then fit discrete-time hazard models (using logistic regression) predicting mortality from each of the 13 functional forms. We estimated the models for the nation as a whole and for the four regions, and all models are stratified by gender and control for single years of age. Following previous studies of the functional form, the model with the lowest Bayesian Information Criterion (BIC) was considered to provide the best fit to the data (Raftery 1995).

Results

Table 1 documents the descriptive statistics for the analytic sample of non-Hispanic whites aged 45–84 stratified by region and gender. The average age was relatively similar by gender and region, with an average age of our sample 59.5 years for men and 60.4 years for women. The distribution of educational attainment varied by regional context. The West had a smaller percentage of respondents without a high school education than did the Northeast and Midwest. However, the Northeast and West had higher levels of college education than the South or Midwest. The highest proportion of employed men was in the Midwest (74.5%)

with the lowest in the South (70.6%). Similarly, the highest proportion of employed women was in the Midwest (62.7%) and the lowest in the South (56.0%). In each of the regions, women had higher levels of poverty than men.

In Table 2 we show the rankings of the 13 functional forms by region and gender of non-Hispanic whites aged 45–84. Reassuringly, our national level results were largely consistent with previous analyses of the national functional form during 2000–2006 (Hayward et al. 2015). In fact, the best fitting functional form for women and for men in our results match the best fitting form of the previous analysis. In these national analyses, the best functional form was one that includes linear declines in mortality risk with increasing years of education in addition to step change reductions in mortality upon attainment of certain credentials. Specifically, the best form for women (and among the top 3 forms for men) included a shallow linear decline from 0 to 11 years of education, a step change at a high school credential, followed by a steeper linear decline from 13 years of education onward. The best form for men included a constant linear decline throughout plus step changes at high school and bachelor’s degree. The slight differences between our findings and those of Hayward and colleagues (2015) in the remainder of the functional form rankings likely reflect the five years of additional data included in our analyses.

The focus of our analysis was in regional differences in the functional form, which are also shown in Table 2. The results reveal intriguing similarities and differences across regions. Four findings stand out as particularly intriguing. First, similar to the national analyses, functional form #13—a step-change at high-school completion and varying slopes before and after high school—was among the top three functional forms in all regions except for the West. It was also the best form in the South for men and women. Second, unlike national analyses, functional form #5 (step changes at high school and college with zero slopes) generally ranked highest across all regions except for the South. Third, the Southern region stands out as unique. Specifically, functional form #13 dominated in the South for both men and women, harking back to the national-level analyses spanning the 1980s and 1990s reported by Montez and colleagues (2012). Fourth, there were few gender differences. In the Midwest, Northeast, and South, the best functional form was the same for women and men; in the West the best functional form for men was the second best form for women. The optimal functional form, without additional controls, and coefficients for each region are presented for men (Figure 1) and women (Figure 2).

We next added reported household income and employment status to assess whether adjusting for these measures of socioeconomic status attenuated the regional differences in functional form. The results of this analysis are presented in Table 3. We found that adjusting for those measures, at the national level, altered the best fitting specification for the unadjusted models for non-Hispanic white men (previously: step changes at high school and college, with constant, nonzero slopes) and women (previously: step change at high school, with varying, nonzero slopes) to Specification 5 which includes step-changes at high school and college, *with zero-slopes*. This suggested that the linear reductions in mortality risk associated with additional years of education (in between credential attainment) operated through greater employment opportunities and income that arise from each additional year of schooling. Likewise, it also suggested that after accounting for income and employment status, credentials are most important for mortality risk.

We now turn to the regional comparisons. Two findings were particularly noteworthy. First, adjusting for employment and income helped reconcile differences in the functional form between the South and all other regions. Recall that in the unadjusted models, Specification 13 was preferred for men in the South, while Specification 5 was preferred for men in all other regions. In the adjusted models, Specification 5 (step changes at high school and a college degree, with zero slopes) was the preferred form for men across all four regions. Also recall that in the unadjusted models for women, Specification 13 was preferred in the South, while Specification 5 was among the top three preferred forms in all other regions. In the adjusted models for women, Specification 5 was among the top three preferred models across all four regions. The second noteworthy finding was that there is more consistency in the functional form across regions among men than there is among women. To elaborate, as mentioned above, while Specification 5 in the adjusted models was the preferred form for men across all regions, it was the 1st, 2nd, or 3rd preferred model in all regions for women, falling short of models with only a linear term for education in some regions.

Discussion

While the association between education and mortality is well established, how the functional form of this relationship may vary based on geographic or regional context has not yet been documented. Of course, U.S. regions vary considerably in terms of access and quality of education, economic structure, job opportunity, policy climates, health behaviors, health care access, and other factors which could transform the functional form of the relationship between education and mortality. Thus, our analysis set out to document how the functional form of education and mortality differed by regional context while utilizing a large nationally representative sample of non-Hispanic whites whose mortality status was tracked longitudinally. We built on previous research by extending the mortality follow up period five additional years, documenting regional differences, and explicitly testing how the regional and national functional form rankings were altered when accounting for two key explanations for the education-mortality association; income and employment.

Specifically, we extended previous research (Hayward, Hummer, and Sasson 2015) which used the linked mortality file through the end of 2006, until the end of 2011 to document the functional form. We found that including three additional years of NHIS surveys and five additional years of mortality follow up did little to alter the top ranked functional forms between education and mortality at the national level for non-Hispanic white men and women. This suggests, that despite changes in the functional form between the 20th and 21st centuries (Hayward et al. 2015), the functional form in the 21st century has, so far, remained relatively stable, at least through the end of 2011. It also emphasizes that, at the national level, the best-fitting functional form for non-Hispanic white men and women is reflects a combination of credentialist and human capital explanations. That is, credentials (such as a high school degree) are important for lowering mortality risk, but so is each additional year of schooling.

To the best of our knowledge this is the first paper to document regional or geographic differences in the functional form between education and mortality. Looking across regions, we found that a credentialist model (step-changes at high-school and college completion, with no mortality reduction in between credential attainment) was the best fitting specification for non-Hispanic whites in the Northeast and Midwest and men in the West (but not women). In contrast, in the South, the best-fitting functional form was a step-change at high-school completion and a varying slope before and after for both non-Hispanic white men and women. Finally, for Non-Hispanic white women in the West, a simple linear relationship between education and mortality was the best fitting specification. We also formally tested how the functional form rankings were altered by adjusting for the primary explanations for the education-mortality association (e.g., Lynch 2006), employment status and household income. We found that accounting for employment and income altered the national rankings for men and women so that the credentials-only model became the best fitting specification. This suggests, that when income and employment are accounted for the relationship between education and morality is best expressed through one that specifically empathizes credentials and specifies no difference between high school and some college. Indeed, this finding comports with previous research which indicated that after adjusting for other measures of socioeconomic status, a credential based specification was most important (Backlund, Sorlie, and Johnson 1999).

An important finding is that the functional form in the South is different from all other regions. In fact, the preferred form in the South is the same as the preferred from in studies of the functional form for earlier time periods (Montez et al. 2012; Hayward et al. 2015). This implies one of two things. Either the South simply lags behind other regions in the ways that education has come to shape mortality, or else there is something so unique about the South that its preferred functional form is a permanent feature. More years of mortality follow up are necessary to fully tease out these two possibilities. Our models that adjusted for employment and income do provide some insights, however. Those models reveal that each additional year of schooling (in between credentials) lowered mortality risk in the South more than it did in other regions, in part because each additional year of schooling (in between credentials) in the South improved employment opportunities and household income to a greater degree than additional years of schooling did in the other three regions. Again, whether this simply reflects a time lag for the South or unique features of the region should be addressed in future studies when mortality follow-up for more recent years of data are available.

Another intriguing finding is that the functional form differs more across regions for women than men. For instance, recall that, in the adjusted models, the preferred form for men was characterized by “step changes at high school and college, with zero slopes” across all four regions. While this form was also among the top three for women across all regions, a linear form actually ranked first in the Northeast and West, and a form characterized by “step changes at high school and some college, with zero slopes” ranked first in the South. The fact that the preferred form differed more across regions for women than men is consistent with studies which report that contextual factors, such as economic policies and social cohesion, have a stronger influence on women’s than men’s health (Robert and Reither 2004; Stafford et al. 2005) and mortality (Montez, Zajacova, Hayward 2016). Contextual factors shape access to a range of resources such as health care, prenatal care, affordable housing, family leave policies, and financial safety nets which are disproportionately salient for women—particularly low-educated women—given that women are more likely than men to be economically disadvantaged, solely responsible for raising families and caring for aging parents, and employed in unstable and low-paying jobs.

Limitations

While our research contributes to a growing body of research investigating the functional form of the association between education and mortality, it has some limitations. Given the structure of the NHIS-LMF, it is impossible to determine the exposure time of respondents to their region of residence at the time of interview. Reassuringly, previous research has suggested that inter-regional migration is relatively rare, especially in the short term (Montez and Berkman 2014). Nevertheless, future research should consider analyzing how long-term exposure to specific geographic settings, contexts, and policy environments may influence the link between education and mortality. Additionally, using regions rather than more fine geographic measures likely obscures intra-regional heterogeneity. More studies are need to examine whether the best fitting form varies between states, counties, cities, or even census tracts. The most salient scale of the geographic context in shaping the relationship between education and mortality is ripe for future exploration. Notably, using finer measures of context such as states would also have important drawbacks and complications given available data sources, such as small numbers of deaths, particularly within higher levels of educational attainment. Nevertheless, our study makes an important first step in documenting geographic heterogeneity in the education-mortality association using a meaningful demarcation of context. Going forward, researchers with large data sources should consider systematically documenting the functional form by finer level of contextual analysis and determining which contextual level is most important in shaping the education mortality association.

Conclusions

Taken together these results comport with one of the overall conclusions of Hayward et al. (2015, p16) who argue: “there is no causal association between education and adult mortality; instead the causal association is dependent on time, place, and social environment under study.” Thus, our findings contribute to a building literature (Hayward and Sheehan 2016) which emphasizes that the relationship between education and mortality is context specific. However, despite the context, increased educational attainment provides resources which can be employed flexibly to avoid health risks or insults (Link and Phelan 1995). Researchers and policy makers alike should be explicitly aware of how context shapes educational disparities in population health.

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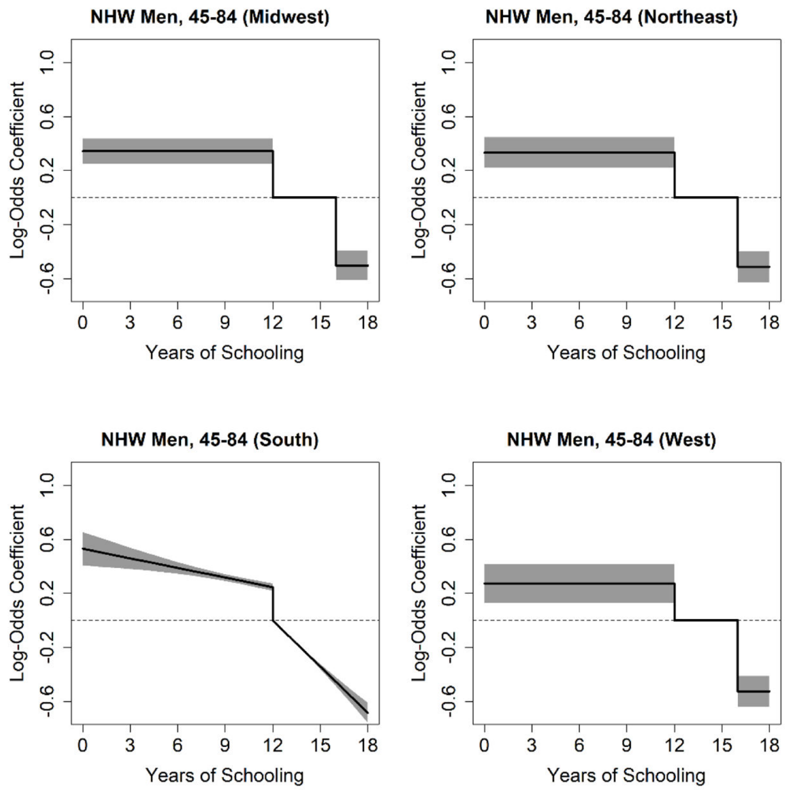

Figure 1.

Log-odds of the Coefficients of Risk (and 95% Confidence Bands) of Adult Mortality by Educational Attainment for the Optimal Functional Form for each U.S. Region, Non-Hispanic White Men, U.S., 2000–2011.

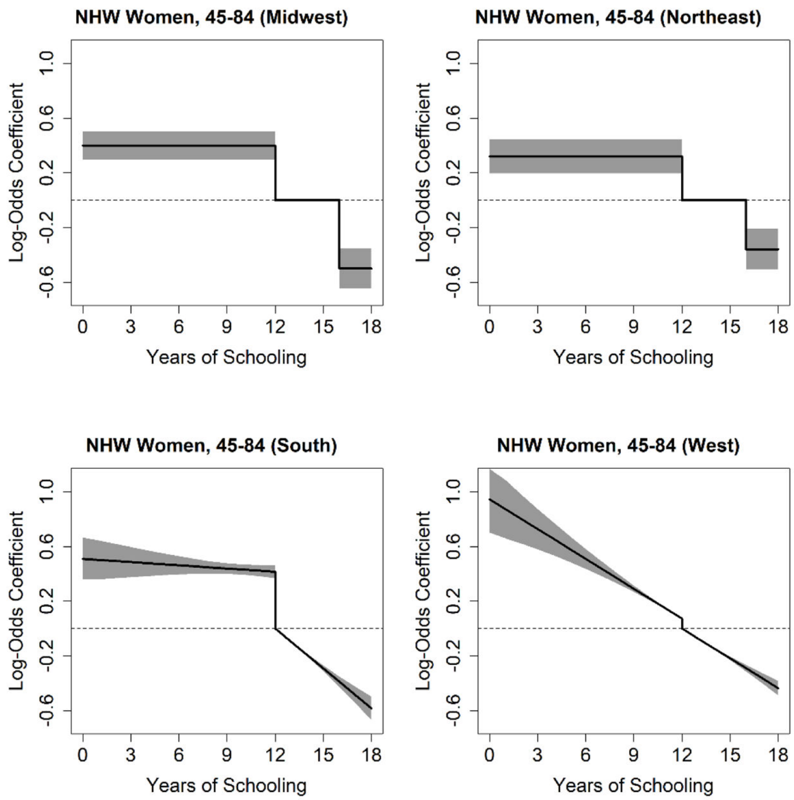

Figure 2.

Log-odds of the Coefficients of Risk (and 95% Confidence Bands) of Adult Mortality by Educational Attainment for the Optimal Functional Form for each U.S. Region, Non-Hispanic White Women, U.S., 2000–2011.

Table 1

Descriptive Statistics, Non-Hispanic White Americans aged 45–84, National Health Interview Survey, 2000–2009.

	Midwest		Northeast		South		West		National	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Age (mean)	59.2	60.2	59.7	60.5	59.7	60.6	59.5	60.2	59.5	60.4
Educational Attainment										
Less than High School (%)	36.1	39.7	35.0	39.8	30.9	35.7	25.2	30.0	32.0	32.0
High School (%)	10.1	9.9	9.7	9.3	13.3	13.0	6.2	6.4	10.4	10.4
Some College (%)	26.7	28.3	21.5	23.4	25.1	28.1	31.2	34.8	26.0	26.0
College+ (%)	27.2	22.2	33.8	27.6	30.7	23.3	37.3	28.9	31.6	31.6
Employed (%)	74.5	62.7	73.5	61.2	70.6	56.0	72.8	59.8	72.7	59.6
Below Poverty Threshold (%)	4.7	6.5	4.4	6.0	6.3	8.2	4.6	6.3	5.1	6.9
Deaths	2,756	2,219	1,982	1,638	3,991	3,091	1,726	1,396	10,455	8,344
Person-Years	192,032	211,532	141,501	158,670	240,351	268,240	134,092	144,418	707,976	782,860

Source: National Health Interview Survey, 2000–2009. Linked Mortality File through end of 2011.

Notes: Data are not weighted

Table 2

Ranking of the Functional Forms of the Association between Educational Attainment and U.S. Adult Mortality, Non-Hispanic Whites, aged 45–84.

	2000–2006 NHIS.[a]		*2000–2011 NHIS.*									
	National		**National**		**Midwest**		**Northeast**		**South**		**West**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
1. Semi-Parametric	11	12	11	13	13	13	13	13	13	13	13	13
2. Continuous (ed)	9	10	9	10	2	7	4	2	5	6	4	1
Step changes with zero slopes												
3. lths +hs, sc +co	13	13	12	12	12	12	12	9	12	12	11	5
4. lths, hs, sc +co	12	9	13	9	11	8	9	6	11	2	12	7
5. lths, hs + sc, co	8	7	6	3	1	1	1	1	3	5	1	2
6. lths, hs, sc, co	7	2	2	2	3	3	3	4	4	3	2	3
Step changes with constant, nonzero slopes												
7. ed, lths +hs, sc +co	4	4	4	4	7	5	7	7	7	8	7	10
8. ed, lths, hs, sc +co	10	8	10	8	9	10	10	10	10	4	10	9
9. ed, lths, hs + sc, co	1	3	1	6	4	4	5	5	2	7	3	6
10. ed, lths, hs, sc, co	5	5	5	5	8	6	8	8	8	9	8	11
Step changes with varying slopes												
11. ed, lths +hs, sc +co, ed x (lths +hs), ed x (sc +co)	6	11	8	11	6	11	6	11	6	11	5	8
12. ed, lths, hs +co, ed x lths, ed x (hs +sc), ed x co	3	6	7	7	10	9	11	12	9	10	9	12
13. ed, lths, ed x lths	2	1	3	1	5	2	2	3	1	1	6	4

Source: National Health Interview Survey, 2000–2009. Linked Mortality File through end of 2011.

[a]Estimates from Hayward et al. 2015, Table 2.

Notes: Data are not weighted. All models account for age. Top Three Specifications are highlighted.

Notes: ed = continuous educational attainment. lths = less than high school. hs = high school. sc = some college. co = college. X denotes an interaction.

Table 3

Ranking of the Functional Forms of the Association between Educational Attainment and U.S. Adult Mortality, Non-Hispanic Whites ages 45–84, Including Controls for Income and Employment Status.

	2000–2011 NHIS. NH White Americans 45–84.									
	National		**Midwest**		**Northeast**		**South**		**West**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
1. Semi-Parametric	13	13	13	13	13	13	13	13	13	13
2. Continuous (ed)	9	9	2	2	2	1	2	2	2	1
Step changes with zero slopes										
3. lths +hs, sc +co	12	12	7	7	3	3	12	7	6	2
4. lths, hs, sc +co	11	5	10	6	6	4	11	1	10	4
5. lths, hs + sc, co	1	1	1	1	1	2	1	3	1	3
6. lths, hs, sc, co	2	3	3	5	5	6	5	5	4	6
Step changes with constant, nonzero slopes										
7. ed, lths +hs, sc +co	5	6	8	8	9	10	7	9	8	10
8. ed, lths, hs, sc +co	10	10	11	10	11	9	9	6	11	9
9. ed, lths, hs + sc, co	3	4	4	4	7	5	4	8	3	7
10. ed, lths, hs, sc, co	6	7	9	9	10	11	8	10	9	11
Step changes with varying slopes										
11. ed, lths +hs, sc +co, ed x (lths +hs), ed x (sc +co)	8	11	6	11	8	8	6	11	5	8
12. ed, lths, hs +co, ed x lths, ed x (hs +sc), ed x co	7	8	12	12	12	12	10	12	12	12
13. ed, lths, ed x lths	4	2	5	3	4	7	3	4	7	5

Source: National Health Interview Survey, 2000–2009. Linked Mortality File through end of 2011.

Notes: Data are not weighted. All models account for age, employment status, and income. Top Three Specifications are highlighted.

Notes: ed = continuous educational attainment. lths = less than high school. hs = high school. sc = some college. co = college. X denotes an interaction.

Appendix Table 1

Coding of Educational Attainment for each Specification

Specification 1	Semi-Parametric
Specification 2	Continuous (ed)
Step changes with zero slopes	
Specification 3	lths +hs, sc +co
Specification 4	lths, hs, sc +co
Specification 5	lths, hs + sc, co
Specification 6	lths, hs, sc, co
Step changes with constant, nonzero slopes	
Specification 7	ed, lths +hs, sc +co
Specification 8	ed, lths, hs, sc +co
Specification 9	ed, lths, hs + sc, co
Specification 10	ed, lths, hs, sc, co
Step changes with varying slopes	
Specification 11	ed, lths +hs, sc +co, ed x (lths +hs), ed x (sc +co)
Specification 12	ed, lths, hs +co, ed x lths, ed x (hs +sc), ed x co
Specification 13	ed, lths, ed x lths

Notes: ed = continuous educational attainment. lths = less than high school. hs = high school.

sc = some college. co = College. X denotes an interaction.

Appendix Table 2

United States State Census Regional Designations

Midwest	Northeast	West	South
ND	PA	WA	TX
SD	NJ	OR	OK
NE	NY	ID	LA
KS	RI	MT	AR
MO	CT	WY	MS
IA	MA	CO	AL
WI	VT	NM	GA
MI	NH	AZ	SC
OH	ME	UT	NC
IN		NV	VA
IL		CA	WV
		HI	DC
		AK	MD
			DE
			FL
			KY
			TN

Source: United States Census Bureau.

Appendix Table 3

Bayesian Information Criterion (BIC) Values from Models Predicting Mortality Based on Different Specifications of Educational Attainment, Non-Hispanic Whites, Age 45–84.

	Midwest		Northeast		South		West		National	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Table 3 BIC values										
Specification 1	26093	22466	18799	16505	37157	30825	16855	14459	98403	83753
Specification 2	25951	22365	18664	16378	37027	30700	16724	14315	98330	83685
Specification 3	26011	22395	18690	16396	37127	30760	16764	14329	98580	83817
Specification 4	25988	22367	18680	16387	37078	30687	16768	14331	98455	83666
Specification 5	25948	22346	18657	16373	37026	30699	16713	14320	98281	83629
Specification 6	25955	22353	18663	16384	37027	30689	16724	14328	98272	83618
Specification 7	25967	22363	18675	16396	37032	30701	16735	14340	98277	83631
Specification 8	25974	22376	18681	16396	37046	30693	16747	14336	98348	83661
Specification 9	25956	22358	18667	16384	37022	30701	16724	14331	98269	83636
Specification 10	25967	22363	18675	16396	37032	30701	16735	14340	98277	83631
Specification 11	25966	22379	18673	16396	37028	30718	16730	14335	98300	83695
Specification 12	25978	22372	18684	16405	37039	30711	16745	14351	98282	83637
Specification 13	25959	22351	18663	16384	37018	30687	16731	14329	98274	83612
Table 4 BIC values										
Specification 1	25873	22283	18668	16422	36834	30563	16651	14293	97444	82987
Specification 2	25727	22165	18527	16287	36691	30420	16513	14145	97340	82868
Specification 3	25747	22172	18530	16292	36720	30431	16525	14145	97414	82896
Specification 4	25748	22170	18534	16296	36717	30414	16536	14156	97389	82856
Specification 5	25723	22158	18522	16289	36686	30421	16507	14155	97290	82841
Specification 6	25735	22169	18532	16301	36697	30424	16518	14166	97300	82849
Specification 7	25747	22177	18542	16311	36708	30437	16530	14177	97314	82859
Specification 8	25751	22182	18544	16308	36714	30426	16536	14168	97364	82869
Specification 9	25735	22168	18534	16300	36696	30432	16518	14167	97302	82855
Specification 10	25747	22177	18542	16311	36708	30437	16530	14177	97314	82859
Specification 11	25742	22183	18540	16307	36698	30441	16523	14167	97323	82888

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Table 3 BIC values

	Midwest		**Northeast**		**South**		**West**		**National**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Specification 12	25758	22188	18553	16322	36716	30448	16541	14188	97322	82868
Specification 13	25740	22166	18531	16301	36696	30424	16527	14165	97313	82843

Source: National Health Interview Survey, 2000–2009. Linked Mortality File through end of 2011.