Education Gradients in Mortality Trends by Gender and Race

Adam A. Leive
Frank Batten School of Leadership & Public Policy
University of Virginia

Christopher J. Ruhm
Frank Batten School of Leadership & Public Policy
University of Virginia
and
National Bureau of Economic Research

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Abstract

We examine gender and race differences in education-mortality trends in the United States from 2001-2018 among people aged 25-64. The data indicate that the relationships are heterogeneous with larger mortality reductions for less educated non-Hispanic blacks than other races and mixed results at higher levels of schooling. We also investigate the causes of death associated with changes in overall mortality rates and identify key differences across race groups and education quartiles. Drug overdoses represent the single most important contributor to increased death rates for all groups, but the sizes of these effects vary sharply. Cardiovascular disease, cancer, and HIV are the most significant sources of mortality rate reductions, with the patterns again heterogeneous across sex, race, and educational attainment. These results suggest the limitations of focusing on all-cause mortality rates when attempting to determine the sources of positive and negative health shocks affecting population subgroups. Examining specific causes of death can provide a more nuanced understanding of these trends.

JEL codes: I10; I12; I14; I24; J10

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* Corresponding author: Christopher Ruhm 235 McCormick Road, Charlottesville, VA 22903-4893. Phone: 434-243-3729. Email: ruhm@virginia.edu. We thank Bradley Katcher and Kelsey Pukelis for superb research assistance. Ruhm is grateful for financial support provided from the University of Virginia Bankard Fund.

1. Introduction

Race and education disparities in mortality rate trends have received increasing attention in recent years. Case and Deaton's (2015, 2017, 2020) findings of increased mortality rates for some groups of less educated non-Hispanic whites since the start of the 21st century add to an existing literature (Lleras-Muney, 2005; Cutler et al., 2011; Olshansky et al., 2012; Clark and Royer, 2013). Given that overall life expectancy in the United States fell on a year-to-year basis from 2014 to 2017 (National Center for Health Statistics, 2017), understanding the evolution of mortality trends is important to gauge the progress of economic and social indicators, and because of their implications for large areas of public spending, including Medicare and Social Security.

However, methodological challenges have frustrated efforts to compare changes in mortality rates over time by education and race. First, levels of schooling have generally increased which, under reasonable assumptions, results in increasing negative selection into the lowest education categories, and potentially into more educated groups as well (Dowd and Hamoudi, 2014; Bound et al., 2015).[1] Second, differences in the coding of education over time and across data sources complicates the construction of comparable levels of educational attainment.[2]

In this paper, we attempt to overcome these difficulties by constructing quartiles of educational attainment, based on single years of schooling, for population groups stratified by sex, race/ethnicity (hereafter referred to as race) and five-year age ranges, and then examining how mortality trends from 2001-2018 differed by race and education. The

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[1] Consider the simple case used by Case and Deaton (2020) where individuals are divided into those with and without a college degree. If education is trending upwards, persons who in previous cohorts would not have graduated from college might now do so. Assuming that these marginal changes occur among individuals who would have had among the lowest mortality rates for non-graduates (but higher rates than prior graduates) then, *ceteris paribus*, the negative selection might increase the death rates of both groups.
[2] Also, see Rostron, et al. (2010).

results indicate that this heterogeneity is important. There is little evidence of a consistent relationship between education and mortality rate changes, except for non-Hispanic whites (hereafter "whites) where the largest declines are experienced for the most educated. For non-Hispanic blacks (hereafter "blacks") and, to a lesser extent, Hispanics the biggest reductions are for those with intermediate levels of schooling, although the differences across education levels are generally not statistically significant. We do document that, for each race, the highest-educated quartile experienced the greatest percentage declines in mortality, although since these are often from low initial baseline levels, the absolute reductions are frequently small.[3]

Next, we examine specific causes of fatalities to determine which are associated with increases and decreases in overall mortality rates and identify key differences across race groups and education quartiles. Non-intentional drug deaths constitute the single largest cause of increased mortality across all demographic groups. There is also a marked education gradient in fatal overdoses, particularly for blacks and whites, with the greatest increases among the least educated. While suicides and liver disease have previously been suggested as important causes of the recent mortality increases among low-educated whites, we find that deaths from respiratory diseases and the variety of illnesses composing our residual category have generally increased at least as much, particularly for white females. The causes of death contributing substantially to declining mortality rates are cardiovascular diseases, cancer, and strokes. However, the sizes and patterns of these changes also vary dramatically across races. Low-educated blacks experience much larger

[3] We use similar methods in a recent paper (Leive and Ruhm, 2020) focusing on educational gradients in all-cause mortality within sex, age and race groups. An important result of that study is that the hypothesis that the worst mortality trends are concentrated at the bottom of the education distribution is overly simplified and, across important dimensions, substantially incorrect. The results of the current study are not inconsistent with these findings because we focus here on race differences across all age groups, rather than on heterogeneity between 5-year age ranges.

reductions in these causes than low-educated groups of whites, Hispanics, or other races, for example. These heterogeneous patterns suggest limitations in what can be learned about the nature of the favorable or unfavorable health shocks experienced by different population groups when focusing only on all-cause mortality rates. A more nuanced understanding can be attained by examining specific causes of death.

2. Data and Methods

Construction of Death Rates by Education Quartile

We provide a brief overview of the methods of calculating group-specific education percentiles and their use in calculating corresponding mortality rates. A more detailed description of the data and imputation methods is provided in Appendix A. Our analysis spans 2001-2018 and uses three data sources as inputs for calculating death rates at the level of sex, 5-year age groups, race, education quartile and year. First, we construct sex-age-race-education-specific death counts from the Centers for Disease Control and Prevention *Multiple Cause of Death* (*MCOD*) files, which provide data on the universe of deaths to U.S. residents in the specified year. Second, we utilize the National Cancer Institute's *Surveillance Epidemiology and End Results* (*SEER*) database to obtain population counts by sex, age and race. Third, we estimate educational attainment for each sex-age-race group using the Census Bureau's *American Community Survey* (*ACS*) since *SEER* does not provide information on education.

Combining these sources, we calculate educational quartiles separately by sex, 5-year age bins, gender, race and year. This approach allows the distribution of education to differ across both demographic characteristics and time periods. We construct death rates for age group a, race r and education quartile i, in year t as:

$$mort_{arit} = \frac{deaths_{arit}}{pop_{arit}} \quad (1)$$

where $deaths_{arit}$ and pop_{arit} refer, respectively, to the number of deaths and population of the relevant group. Throughout, we calculate and analyze mortality rates separately for males and females, with the sex subscript excluded from equation (1) and later equations to simplify notation. We restrict analysis to ages 25 to 64 since educational attainment may not be complete for person younger than 25 and prior mortality selection becomes increasingly important for senior citizens. For brevity, we often refer to the first through fourth education quartiles as Q1 through Q4, respectively, with Q4 indicating the highest education levels and Q1 the lowest.

For descriptive purposes, we sometimes calculate annual average mortality rates for education quartile-specific race and sex groups, but across the full set of ages analyzed. These are obtained as:

$$\widehat{mort}_{rit} = \sum_a (w_{ari}^{2018} \times mort_{arit}), \quad (2)$$

where $\widehat{mort}_{rit}$ denotes the death rate for race group r and education quartile i in year t and w_{ari}^{2018} are weights for each 5-year age group in education quartile i, based on 2018 population shares, as defined by:

$$w_{ari}^{2018} = \frac{pop_{ari}^{2018}}{\sum_a pop_{ari}^{2018}}$$

for pop_{ari}^{2018} the population of age group a, race r and education quartile i in 2018.

Our approach constructs education quartiles that are general across all races, within age and sex groups, rather than also being race-specific. This implies that persons of different races but with the same age, gender and education will be classified in the same quartile in a given year. We view this decision as reasonable since we are especially interested in comparing differences in education-related mortality trends across races, rather than quartile differences within races. However, it implies that the lower quartiles will be disproportionately populated by race groups with below average education levels (e.g. blacks and Hispanics) while the other whites and other races will be over-represented in the higher quartiles. We return to this issue below.

There are multiple complications involved in constructing the mortality rates described by equation (1). First, education is frequently measured in discrete rather than continuous units and the data are not fully comparable across time periods or data sources. If schooling were always a continuous variable, we could easily calculate the group- and year-specific distribution of education and then divide it into percentiles. Since this is not the case, we use or construct single-year measures of education ranging from 0 to 17 years.[4] The *MCOD* and *ACS* sometimes record education in single year increments but frequently instead code education into categories (e.g. high school, some college, college). Appendix A describes the imputation procedures employed to construct single years of education for death and population counts, as well as methods of dealing with other complicating factors, such as cases where education information is missing from the death certificate.

Another issue is that a single year of education may straddle quartiles. For instance, this often occurs for persons with exactly 12 years of schooling. In these cases, we proportionately assign deaths from the overlapping education cell to each quartile, based on population shares. Thus, if 12 years of education ranges from the 21st to the 40th percentile, we assign one quarter of these deaths to the bottom quartile and three-quarters to Q2. Bound et al. (2015) and Meara, Richards, and Cutler (2008) use a similar approach.

[4] In two cases we combine groups. Persons with one or more years of college, but no bachelor's degree, are assigned a value of 14 years of education. Those with at least a year of post-graduate education are categorized as having 17 years.

Regression Specifications

Our primary objective is to test whether the relationship between mortality trends and educational attainment differs by race. We do so using the regression specification:

$$mort_{arit} = \sum_{a \in A} \sum_{r \in R} \sum_{i=1}^{4} [\beta_{ari} age_a \times race_r \times Q_i] + \sum_{r \in R} [\pi_r trend \times race_r] + \sum_{r \in R} \sum_{i \neq 4} \pi_{ri} trend \times race_r \times Q_i + \epsilon_{arit}, \quad (3)$$

where $mort_{arit}$ is the death rate for age group a, race r and education quartile i in year t; Q_1, Q_2, and Q_3 denote indicator variables for education quartiles 1, 2, and 3, with the highest quartile, Q_4, serving as the reference group; $race_r$ is a vector of indicator variables for races: White, Black, Hispanic, and other non-Hispanics, age_a is a vector of indicators for 5-year ages from 25-64, and *trend* is a linear time trend. The regression models are estimated separately for men and women, so that each includes 160 age-race-education quartile groups. We cluster standard errors by age, race and education, and weight each cell by its population to obtain nationally-representative estimates.

Cause-Specific Death Rates

After examining trends in total mortality rates, we estimate models for specific causes of death. The specifications mirror equation (3), with the cause-specific mortality rates replacing the all-cause rate as dependent variables. We use detailed ICD-10 codes as reported on the death records and select causes of death to analyze using the following procedure. First, we identified the top 10 causes for each of the four ten-year age groups in the overall age range examined (25-34, 35-44, 45-54 and 55-64). We also separately categorize accidental deaths, excluding those involving drugs, and non-intentional drug fatalities (hereafter simply referred to as drug deaths). Suicides are the final cause of death analyzed and include intentional drug fatalities. We estimate race-ethnicity education quartile trends for each of these 13 causes, as well as for a residual category.[5] We divide the specific sources of death into "major" and "minor" causes, where the criterion for distinguishing between them is whether the magnitude of the trend coefficient exceeds 0.8 for any group.[6] Using this standard, the major causes of death are cardiovascular disease, malignant neoplasms (Cancer), cerebrovascular disease (Stroke), respiratory disease, HIV, drugs, and suicides. The minor causes are diseases of the liver, nervous system, and kidneys, diabetes, non-drug accidents (Accident) and homicides. ICD-10 codes corresponding to each of these causes of death are detailed in Appendix Table A1.

3. Trends in Total Death Rates

Descriptive Evidence

This section presents trends in annual death rates, from 2001-2018, for subgroups stratified by race and each of the four education quartiles, calculated using equation (2). Several patterns are consistent for both men (Figure 1a) and women (Figure 1b). Blacks have the highest average mortality rates for all education quartiles and in nearly all periods. The only exception is that Q1 white females have equal or marginally greater death rates in the last few years. Whites almost always have the second-highest mortality rates, with those of Hispanics and other races being much lower. For instance, quartile-specific death rates in 2018 for whites and blacks are often double those for Hispanics and other races. The magnitude of the race difference declines with rising educational attainment but remains apparent even in the top quartile.

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[5] There is one exception. Sepsis is among the leading causes of death for 35-64 year olds but is included in the residual category because the magnitude of its trend coefficient is below 0.2 in all but one case (where it os -0.27) and is 0.1 or less in 23 of 32 cases.

[6] This division represents a natural breakpoint in the data and also results in an equal number of major and minor causes, once the residual is included in the latter category.

The quartile-specific differences in death rates may understate the racial gap between blacks and whites. Evidence points to a variety of institutional and psychological factors that make it harder for blacks to attain the same level of education as whites (Bertrand, Chugh, and Mullainathan 2005; Milkman, Akinola, and Chugh 2012, 2015). Given these barriers, one might expect blacks to be healthier than whites at given levels of educational attainment. Specifically, conditioning on education may introduce a form positive health selection for blacks relative to whites. Consistent with this, 28-33 percent of blacks were in Q1 in 2001 and 2018, compared to just 20 percent of whites (Appendix Table B2). The positive selection is probably even more pronounced for Hispanics, who have the lowest overall amounts of education, providing a likely explanation for at least some of their lower mortality rates. However, the same is not true for other races, who are generally more educated than whites and with particularly high Q4 shares.[7]

We provide a detailed examination of mortality trends in the next section, but some key results are previewed in Figure 1. In particular, Q1 and Q2 whites experienced steady increases in mortality rates from 2001-2018, with more modest growth for Q3 and stable or slightly declining rates for Q4. By contrast, Q1 and Q2 blacks had some of the largest declines but starting from the highest levels. Since educational attainment rose more over time for blacks than whites, especially at the bottom of the distribution (Appendix Table B2), these changes are not due to increasing positive selection for blacks. Nonetheless, even by 2018, black mortality rates continued to equal or exceed those of whites. There are few obvious trends for Hispanics or other races. Given that schooling levels are also rising over

[7] These selection issues can be avoided by examining overall (not quartile-specific) mortality rates. This is done in Appendix Figure B1, which shows evidence consistent with the patterns of selection just described. For instance, mortality rates trended downwards for blacks, while remaining essentially constant for whites, but the black disadvantage remains sizable: black mortality rates per 100,000 declined from 882 to 709 from 2001-2018 for males and from 539 to 427 for females, while barely changing (from 539 to 541 and 334 to 330) for whites.

time for them, relative to whites, the changes in selection raise the possibility that the trends are marginally more favorable than they appear, but their overall rates of mortality are certainly low even without adjusting for this.

Regression Estimates of Trend Differences in All-Cause Mortality Rates

Figure 2 presents regression results from estimating equation (3) for death rates from all causes. The entry for Q4 is the trend "main effect" for race r, $\hat{\pi}_r$. Estimates for the remaining groups are calculated as the main effect plus the education quartile-specific trend coefficient. For instance, the estimated trend for Q1 and race r is calculated as $\hat{\pi}_{1r} + \hat{\pi}_r$. The 95 percent confidence intervals (CIs) are centered on the Q1 through Q3 total effects and indicate whether these are statistically significantly different from Q4.

The education gradient appears strongest for whites of both sexes, where Q1 and Q2 experienced either increased or unchanged mortality rates over time and statistically significantly worse trends than Q4. Q3 also did more poorly than Q4 but the differences are barely significant for men and insignificant for women. By contrast, there is no obvious education gradient for the other three races. None of the quartile differences are statistically significant for blacks or Hispanics and the point estimates for blacks suggest larger trend reductions in mortality for the two lowest quartiles. For other race males, Q4 does better than the other three education quartiles but the differences are modest.

Results from the models just estimated may be particularly strongly influenced by the experiences of groups with the highest baseline mortality rates, such as those in the lower education quartiles, since equal percentage changes in death rates will have larger absolute effects for them. As an alternative, Figure 3 summarizes regression estimates with logs rather than levels of death rates as the dependent variables. The results indicate that Q4 has the largest percentage reductions in mortality rates, with the differences between those of the of the other three quartiles generally being statistically significant. However, these often do not translate into large absolute reductions. For example, predicted death rates for Q4 Hispanic females decline by 1.39% more per year than those in the Q1, but this corresponds to just a 0.45 per 100,000 larger annual reduction in the overall rate. There are no clear education gradients for the lower three quartiles, except for white females, where larger percentage declines are again observed for the more educated. Blacks and Hispanics have the most favorable log mortality trends while less educated whites show the largest percentage increases.

4. Specific Causes of Death

We next examine trends in mortality rates from the specific causes described above. Figures 4 and 5 summarize the results for men and women. We display point estimates without confidence intervals or standard errors to aid interpretability, but report both the coefficients and standard errors in Appendix Tables B3 and B4.

Increases in (non-intentional) drug deaths are the single largest component contributing to rising mortality rates for all sex, race and education groups. The changes in fatal overdoses are monotonically declining in education for blacks and whites and, to a lesser extent, for Hispanics and other races. No other cause consistently contributes to trend increases in mortality. For whites, suicides play a role, particularly for men, as do respiratory diseases for the two lower quartiles of both sexes. Liver disease deaths contribute to higher mortality rates for whites in the bottom three quartiles, but the impact is modest. To illustrate, the estimated annual mortality rate increases per 100,000 for Q1 white males from drugs, suicides, respiratory and liver diseases are 4.34, 0.92, 0.74 and 0.72; for Q1 white females they are 2.74, 0.35, 0.97 and 0.64.

The causes of death contributing substantially to declining mortality rates are cardiovascular disease (CVD), cancer, sometimes HIV, and strokes. However, the sizes and patterns of these effects vary dramatically across races. Reductions in cancer and CVD death rates are of roughly equal magnitude for white males but there is no education gradient and they are the only two causes of any real importance. Decreases in cancer mortality are by far the most substantial for white females, especially for the highly educated, with CVD mortality also playing some role but only for Q3 and Q4.

The patterns for blacks differ markedly and these dissimilarities explain the much larger overall mortality reductions, particularly for the less educated. The three most important contributors to declining mortality among black males are CVD, cancer and HIV. These reductions are particularly large for Q1 (-4.21, -4.61 and -3.63 per 100,000) and Q2 (-5.52, -5.29 and -3.34 per 100,000). Stroke mortality also falls substantially, although by considerably less than the three causes just mentioned. For black males, reductions in death rates from these causes have been greater among the less educated than for Q4. Cardiovascular and cancer deaths also fall sharply over time for black females, although considerably less so for Q1 (-1.83 and -0.94 per 100,000) than the other three quartiles (ranging from -3.36 to -3.80 and -2.83 to 2.94 per 100,000). Conversely, the decrease in HIV mortality is largely restricted to Q1 and Q2 (-1.64 and -.1.39 per 100,000 for these two quartiles versus -0.59 and -0.36 per 100,000 for Q3 and Q4). The patterns for Hispanics and other races are generally similar to those just described for blacks, except that the magnitudes of the mortality changes are much smaller and declines in HIV are less important.

By construction, the minor causes of death play relatively small roles (Figures 4b and 5b). We display the mortality rate changes from these sources on the same scale as the major causes to illustrate the differences in relative magnitudes between them. Most important among these are deaths from liver disease for less educated whites, but the annual changes never exceed 0.72 per 100,000 and are dwarfed by the major source of death discussed previously. There is an education gradient in the residual "all other causes" category for whites – the estimated annual changes are 1.39 and 1.50 per 100,000 for Q1 males and females, but much smaller for their Q3 and Q4 counterparts – but no corresponding education relationship for other races. Further investigation into the residual causes revealed that their contribution reflects the cumulative influence of death from many diseases that each exhibited small increases over time.

5. Discussion

A principle conclusion of this analysis is that single factor explanations for mortality trends are likely to be inadequate and misleading, particularly given the heterogeneity of experiences across population groups. On the other hand, understanding can be gained by examining the differences in trends for specific types of deaths.

One reason that non-Hispanic whites have generally experienced less favorable mortality trends than other race groups over the first two decades of the 21st century is because they have been hardest hit by the fatal drug epidemic, a source of death that negatively affected the fatality rates of all groups. But other types of deaths are also important. For instance, limited progress in reducing cardiovascular and cancer mortality play a key role for less educated white females. These two sources are also important for white males, but across all education quartiles, not just for the less educated ones.

Conversely, less educated black males experienced the largest mortality rate reductions of any group because of exceptionally large decreases in deaths from HIV, cancer, cardiovascular and other diseases, which more than offset the increases in drug deaths. Increases in drug deaths for low educated blacks have been large but are well below the trends observed for whites. Mortality rates have also trended downwards for black females due to particularly large reductions in cardiovascular and cancer mortality; however, this progress has only been partially shared by the least educated quartile, resulting in a smaller overall mortality decline for them. The trends toward both towards higher drug mortality and lower cardiovascular, cancer and HIV death rates are generally smaller for Hispanics and other races than for blacks or whites, leading to modest overall death rate reductions that show no clear education gradient.

The findings inform some ongoing debates about the reasons for the patterns of rising and declining mortality that have been observed in the United States over the last two decades. Generally, the results are not supportive of a primary role for “deaths of despair” as a driver of the rising death rates of less educated whites (Case & Deaton 2015, 2017). As discussed, the fatal drug epidemic is the most important cause of higher death rates and changes in the drug environment are a key contributor (Ruhm, 2019). However, suicides and liver disease, the other two components frequently grouped with drug mortality, have much more modest impacts. Instead, other causes of death have often been more consequential. For instance, mortality to less educated whites from respiratory diseases and the variety of illnesses composing our residual category increased at least as much as those from suicides or liver disease.

Progress in reducing HIV deaths has been particularly important for less educated blacks and, to a smaller extent, Hispanic males. Decreases in cardiovascular and cancer deaths for black males and females have also been exceptional. Several factors may explain these improvements. Smoking declined more for blacks than whites from 1965 to 2008 (Garrett et al. 2011). Health insurance coverage expansions reduced inequalities in access to medical care, with recent research highlighting large effects of Medicaid insurance expansions (Sommers et al. 2012, Sommers 2017, Miller et al. 2019, Borgschulte and Vogler 2020), although gaps still persist (Buchmueller et al. 2016).

Several caveats should be kept in mind when interpreting our results. First, we reiterate that more favorable mortality trends (i.e. larger annual decreases in death rates) do not imply better overall status. In particular, while blacks experienced the largest mortality reductions over the first two decades of the 21st century, their 2018 death rates remained higher than those of other races in almost every case. Second, our estimates do not fully control for cross-sectional compositional differences or corresponding changes occurring over time. We have noted that these might lead us to understate the mortality disadvantage of blacks and overstate the corresponding advantage of Hispanics in any given year. However, they might also affect the estimated trends. For instance, the extent to which blacks and Hispanics are disproportionately represented in the lower education quartiles has fallen modestly over time (Appendix Table B2). This suggests a small decrease in the extent of favorable selection for them, possibly leading to slightly smaller mortality reductions (or larger increases) than if this selectivity had remained constant.

Finally, the COVID-19 pandemic may have modified or reversed some of the trends documented above. In particular, the large declines in mortality rates experienced by low educated blacks may have stalled or even reversed, given existing data indicating that blacks and Hispanics have experienced particularly high rates of COVID-related hospitalizations and deaths (Gross, et al., 2020; Price-Haywood, et al., 2020). The pandemic's health effects on different populations have become an active area of research and one that will continue to be important for both academics and policymakers. We hope our methods and findings will be useful to these and other researchers interested in estimating changes in mortality by educational attainment for different demographic groups.

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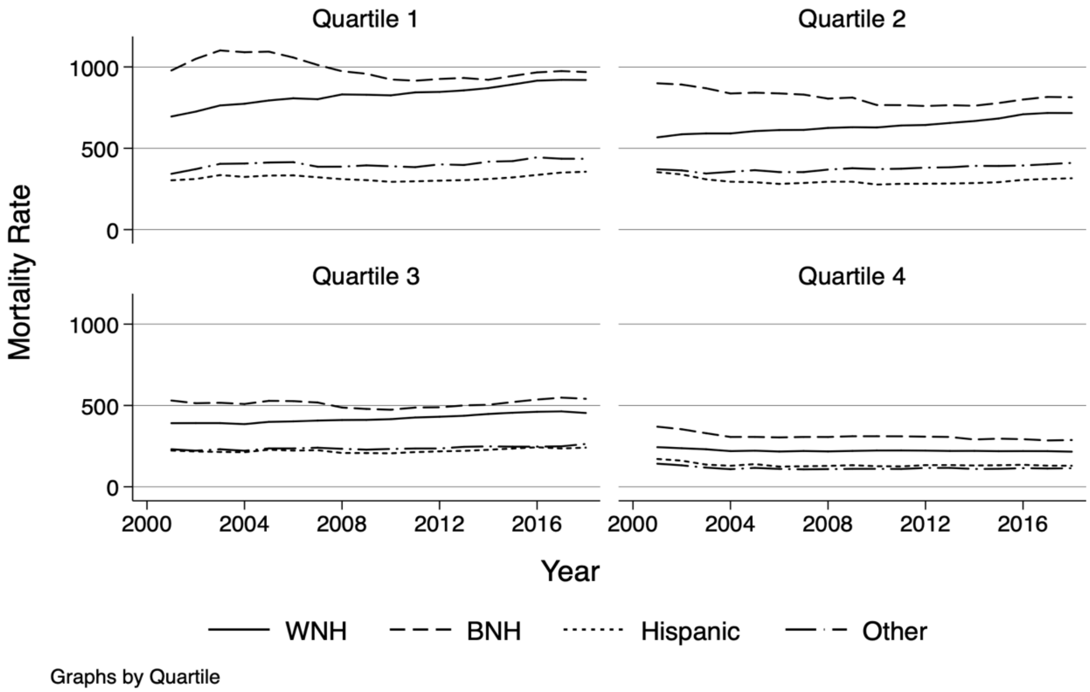
Figure 1 Trends in Death Rates for 25-64 Year Olds from 2001-2018, by Education Quartile

(a) Males



(b) Females

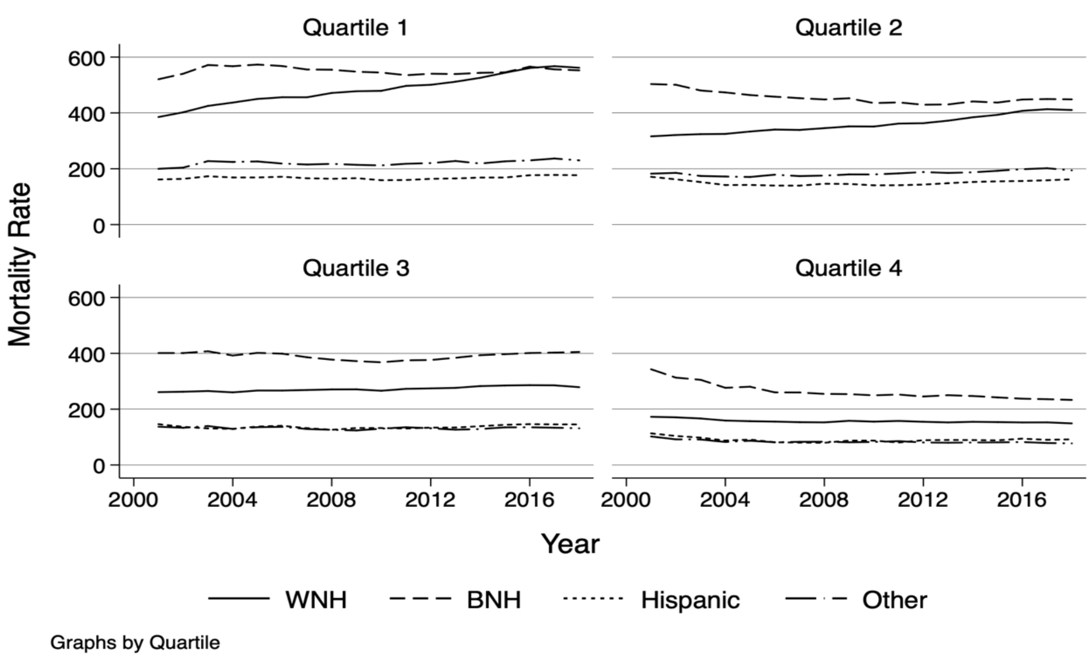
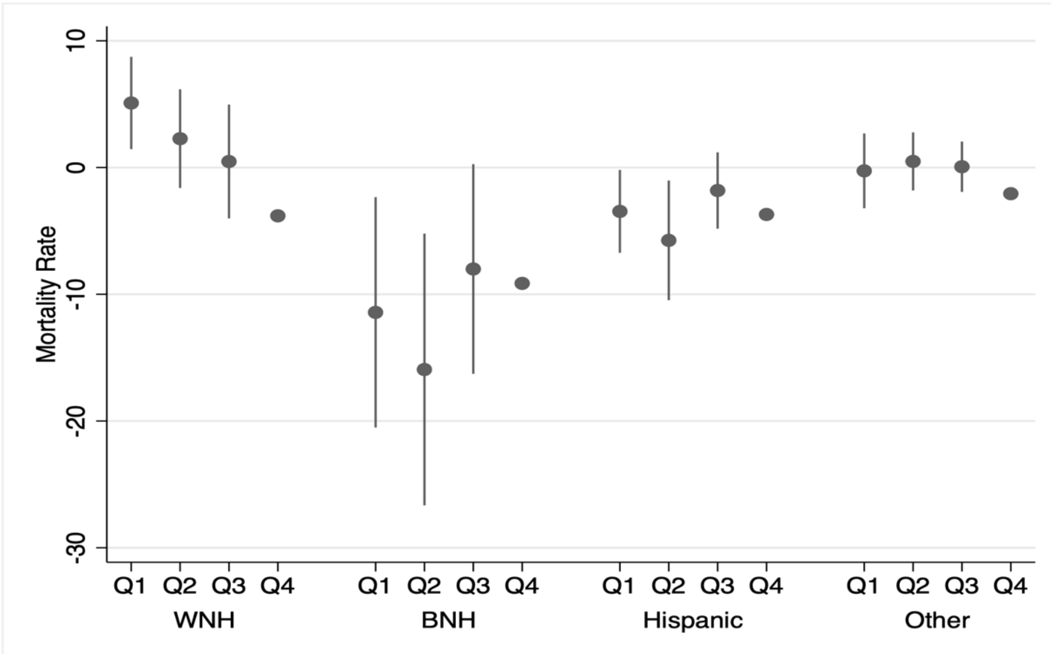


Figure 2: Regression Estimates for Death Rate Trends of 25-64 Year Olds, by Education Quartile

(a) Males



(b) Females

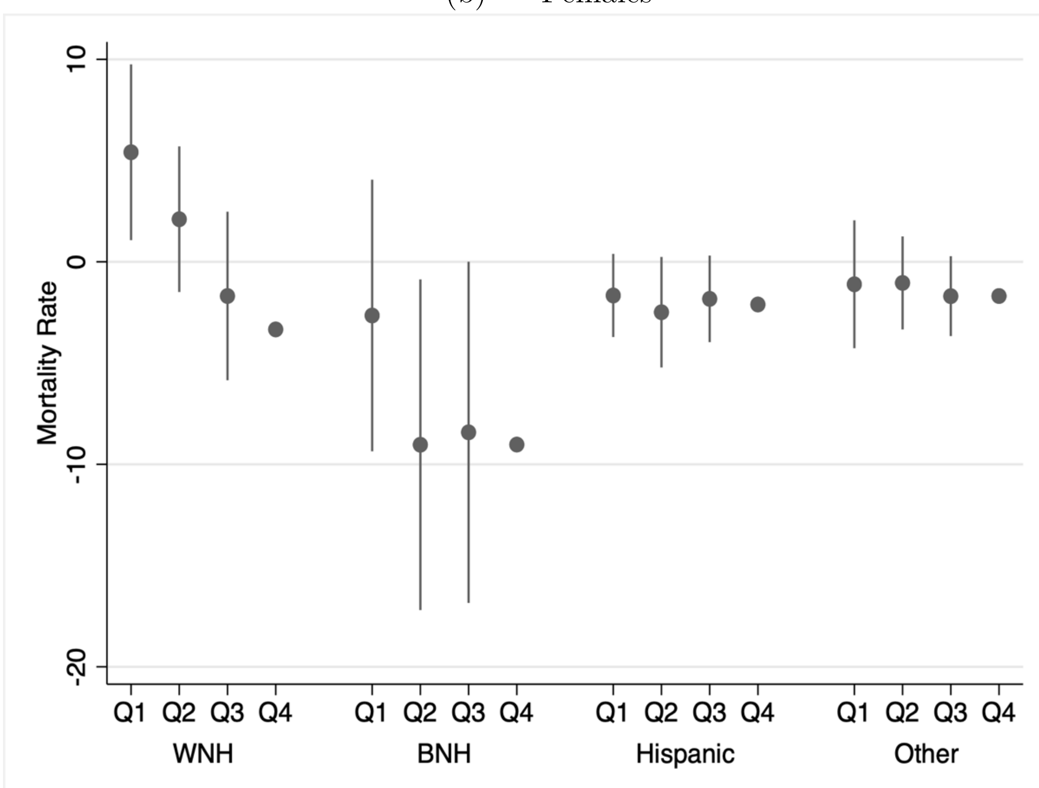
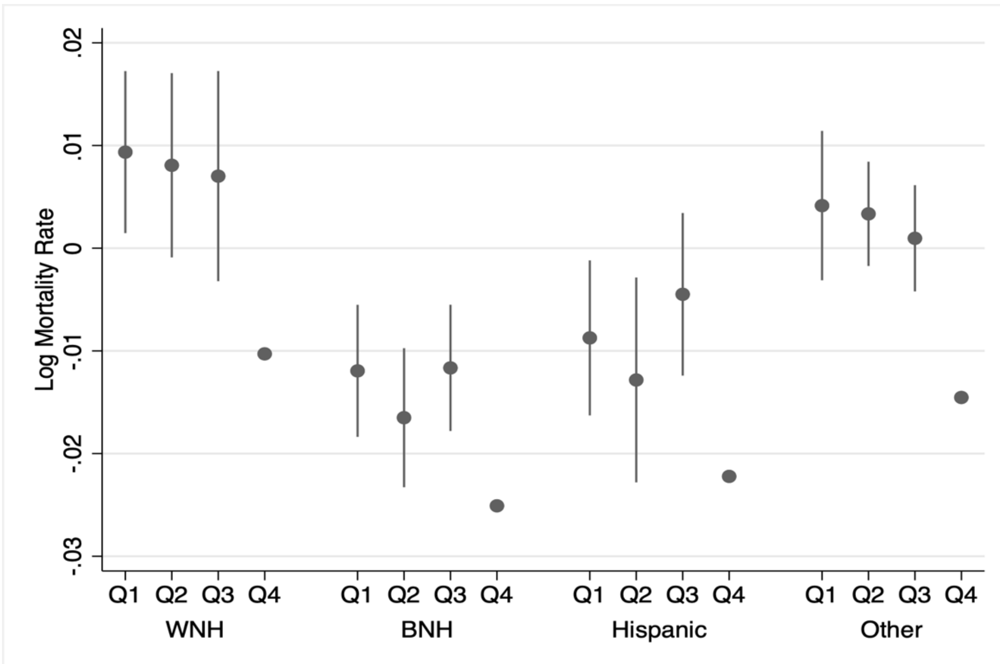


Figure 3: Regression Estimates for Log Death Rate Trends of 25-64 Year Olds, by Education Quartile

(a) Males



(b) Females

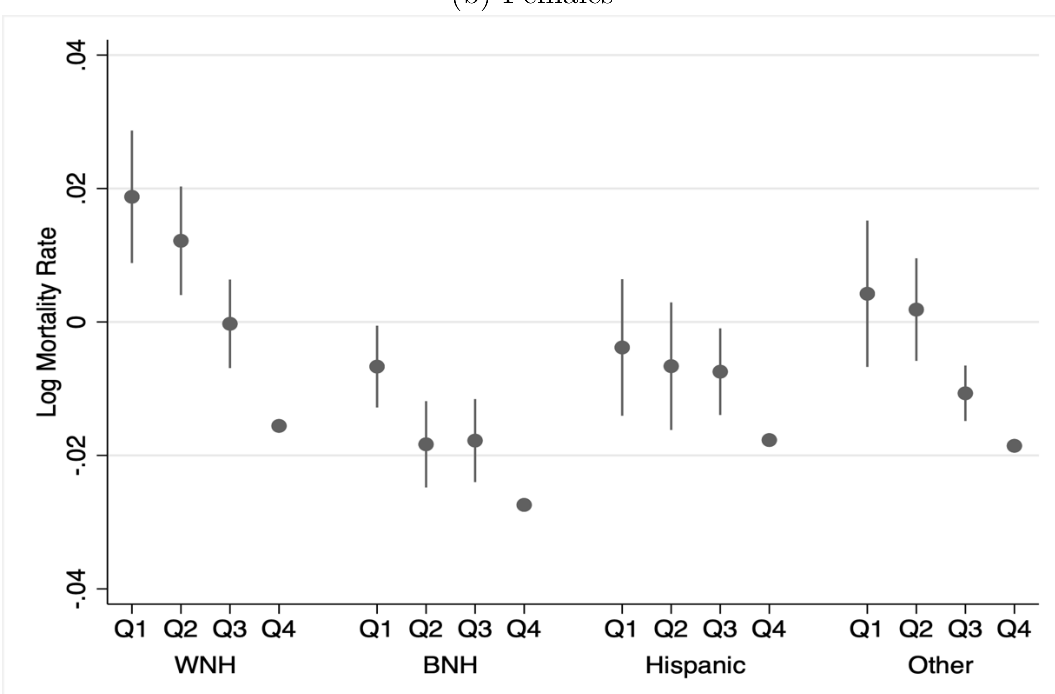
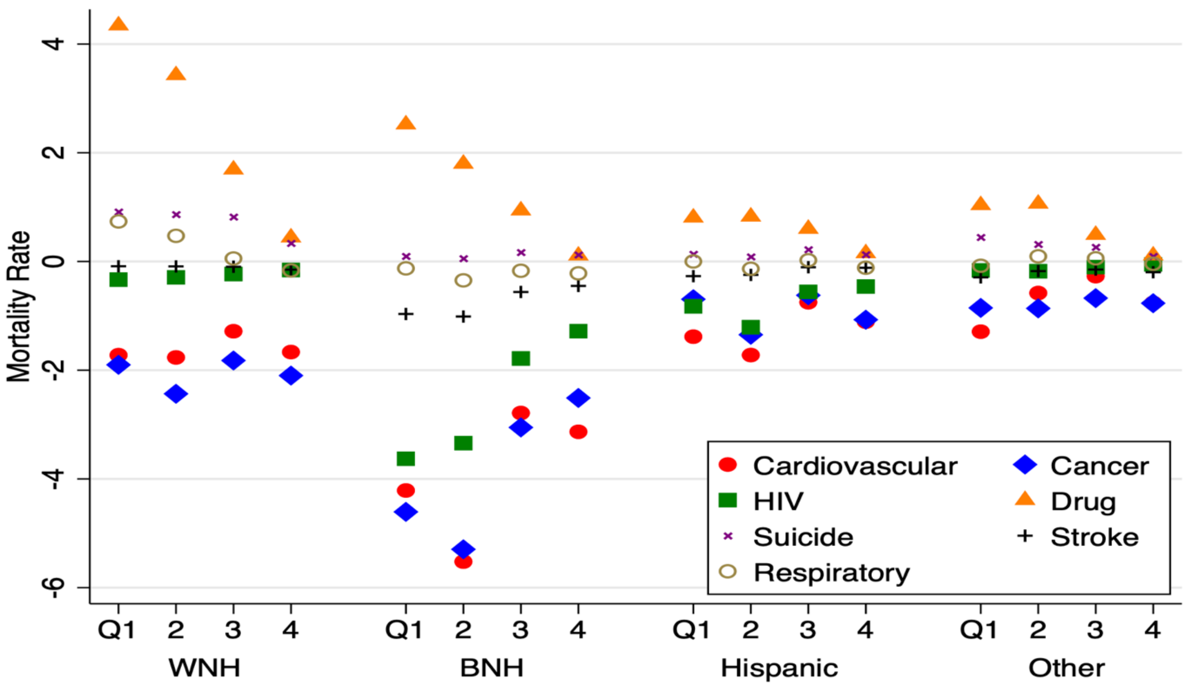


Figure 4: Regression Estimates by Causes of Death for 25-64 Year Old Males, By Education Quartile

(a) Major causes



(b) Minor causes

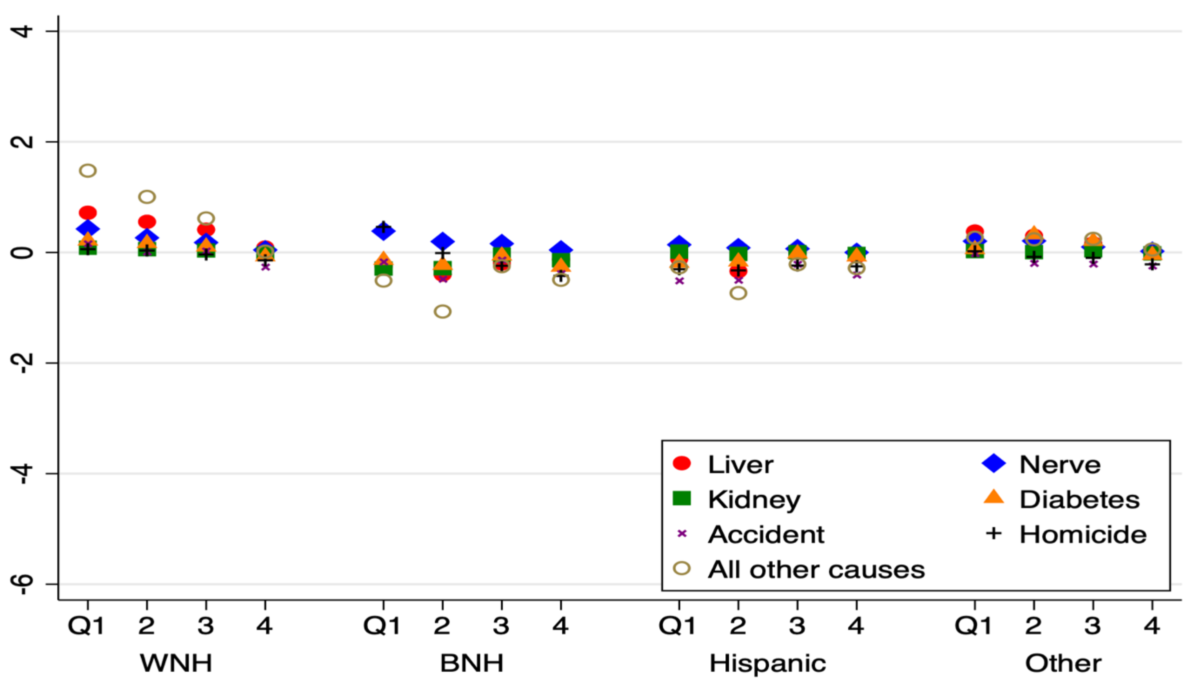
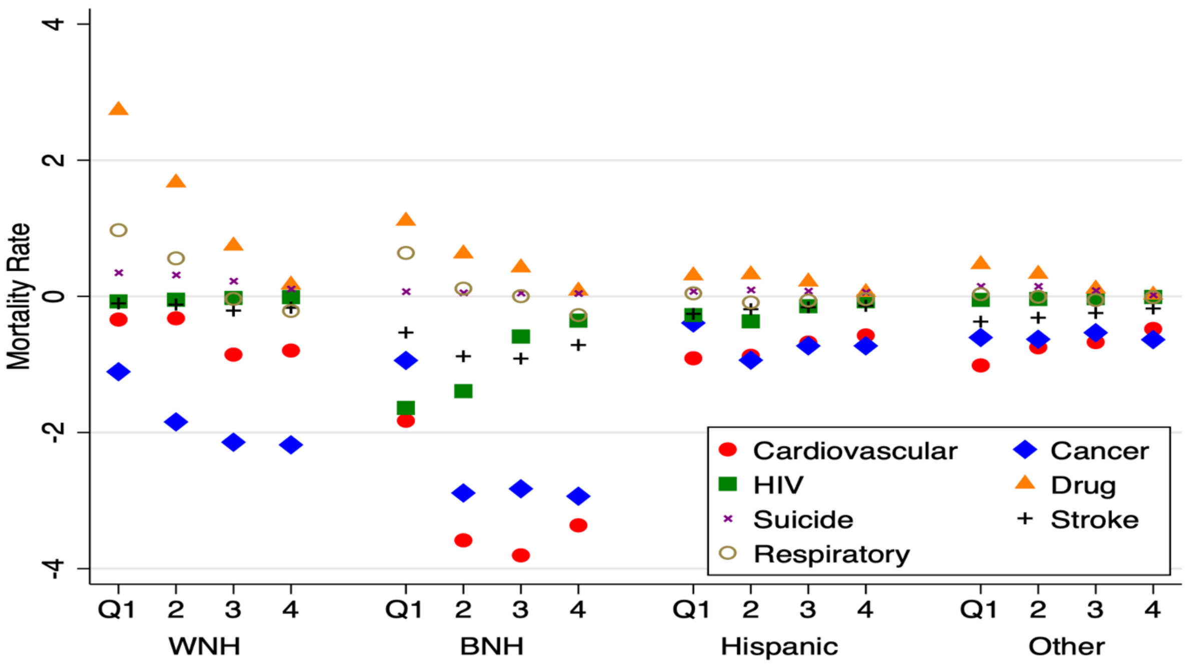
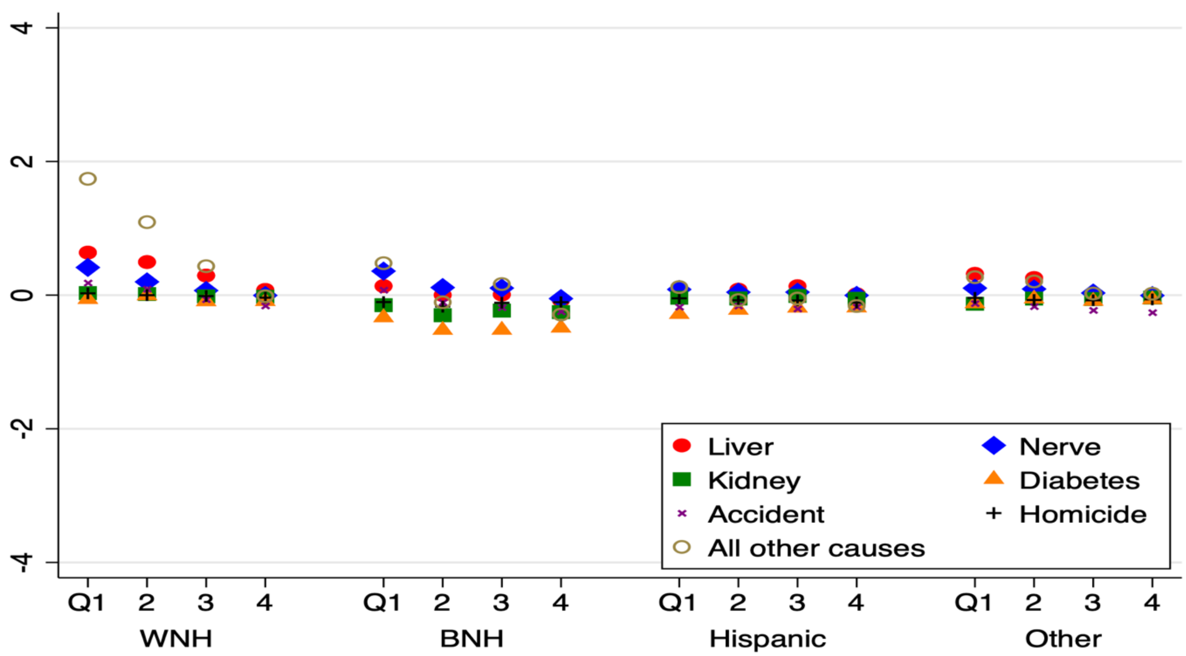


Figure 5: Regression Estimates by Causes of Death for 25-64 Year Old Females, By Education Quartile

(a) Major causes



(b) Minor causes



Appendix A. Construction of Death Rates by Education Quartiles

This Appendix describes our methods for constructing death rates by education quartile. We first detail the procedures used for calculating death and population counts by years of education and demographic characteristics. These counts are then used to construct death rates by group, and represent the data employed in the main regressions. Section A2 describes the specific causes of death analyzed.

A1. Procedure to Estimate Population and Deaths by Years of Education

To estimate death counts (the numerator in mortality rate calculations), we sum all yearly deaths for the specified gender-age-race-educational attainment cell using the *MCOD* data. We drop approximately 5,400 observations with missing age out of over 45.8 million recorded deaths during this period. Prior to 2003, information on single year of education is provided on the death certificates. Beginning in 2003, approximately 16 percent of deaths measure education in one of seven categories: 8^{th} grade or less, 9-12^{th} grades without a diploma, high school, some college (no degree), bachelor's degree, master's degree, or a doctorate/professional degree. By 2007, just over half of records classify education using these coarser groups, rather than single years, and in 2017, nearly all deaths are recorded using the seven education categories.

For some classifications, we can reasonably assign a single year of education. Specifically, we treat high school graduation as 12 years, some college or associate's degree as 14 years, a bachelor's degree as 16 years, and a master's or doctorate/professional degree as 17 years. However, for the other education categories (e.g. "<= 8th grade" and "9-12th grade, no diploma"), this assignment cannot be done, since they include people with substantially different years of schooling. Therefore, we developed an imputation procedure for these cases. To implement the procedure, we first calculate the fraction of single year educational attainment, when these are provided, comprising each of the broader categories.

For example, for grades 9 to 12 without a diploma, we calculate the percentages of deaths occurring among persons where the death certificate specifies 9, 10 and 11 years of education, respectively (and not just the broader education category). We then regress the percentages for each of these years of education on a quadratic trend in years and a full set of age, sex, and race interactions, with the sample restricted to those in the specified broader education categories (e.g. 9 to 12 years of education without a diploma). To ensure a large enough sample to make these extrapolations, we use wider than five-year age bins, specifically, combining those 25-39, 40-54 and 55-74 years of age. We restrict the time period for these regressions to be prior to 2011, since after 2010 fewer than 30 percent of death certificates record single years of education. Next we use these estimates to predict the probability of a particular number of years of schooling for persons with information only on the broad education category, conditional on the three aforementioned age categories as well as sex, race and year of death.

A potential threat to this strategy is that states adopting broad education categories might have different distributions of within-category educational attainment than those that do not. To examine whether this is a problem, we first classified states according to whether they predominantly reported continuous years of education in 2010 versus those that primarily used the broader education categories. We compared the distribution of deaths across these two classifications for those with 9, 10 and 11 years of education prior to 2003 (when all states used continuous education), conditional on having between 9 and 12 years of education without a high school degree. The distributions were nearly identical across the two types of states. We repeated this for those with 8th grade or less education, and again found very similar distributions of 0 through 8 years of education in the pre-2003 period for states using different classification methods in 2010. These results suggest that the educational distributions in earlier years provide a useful indication of the predicted distributions in later ones.

Educational attainment is missing for roughly 5 percent of death certificates. In these cases, we assume that the education distribution within a given year, race, sex, 5-year age bin is the same for these missing certificates as when schooling is reported and include such deaths in the analysis using this allocation.

To estimate population, the denominator of death rates, we first obtain counts by age, gender, year and race group from the *SEER*. Since, the *SEER* does not include education, we computed the distribution of education shares within these cells using the *ACS* to estimate population counts by single year of education and demographic sub-group. While information on education is also available from the 2000 Census, a preliminary analysis indicated that these data were not fully consistent with those reported in the ACS. Since we also use the ACS for other years, we choose to exclusively use the ACS to maintain comparability over time.

Our procedure for calculating years of education is straightforward for categories up to grade 12 starting in 2008, since education is measured in single year bins in the *ACS*. Prior to 2008, grades below 8^{th} grade were combined (nursery school to 4th grade, 5^{th} and 6^{th} grade, and 7^{th} and 8^{th} grade). We split these into each of the possible grades based on the distribution within a given race, sex and wide age bin for years 2008-2017. We record "no schooling completed", "nursery school, preschool", and "kindergarten" as 0 years of education. We assume a high school degree is equivalent to 12 years, classify 12^{th} grade without a diploma as 11 years of schooling, and less than one year of college as 12 years. We assign "1 or more years of college credit, no degree" or an associate's degree as 14 years and assume that a college degree without additional education is equivalent to 16 years. Education beyond a college degree is coded as 17 years. Using *ACS* sample weights, we then calculate the distribution of education for each of 0 to 17 years (excluding 13 or 15 years) by 5-year age categories, gender, survey year, and sometimes race.

It is important to acknowledge the assumptions implied by proportionately assigning deaths across quartiles for years of education that span thresholds. Novosad, Ravkin and Asher (2020) note that the proportional assignment, which is also used by Meara, Richards, and Cutler (2008) and Bound et al. (2015), treats mortality rates as being flat within education categories, and only allow for discrete changes across them. By contrast, their method assumes a continuous latent education rank distribution, with mortality rates weakly declining in this rank. Assuming a step-function of mortality with proportional assignment is undesirable when education bins are wide but is less problematic when education is measured in single years of schooling, as in our analysis. Where Novosad, Ravkin and Asher (2020) consider four education bins (less than high school, high school, some college, and bachelor's degree or higher), while we split education into 16 (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16 and 17 years). Given the finer granularity of our measure of educational attainment, we view the assumption of constant mortality rates within single year of education as reasonable and potentially advantageous compared to analyses that divide the sample into just four education categories.

A2. Classification of Causes of Death

Table A1 presents the ICD-10 codes used to classify the causes of death into the specific sources used in the regression analysis. We also have a residual "all other causes" category that includes any deaths other than for the 13 specific causes detailed below. Some drug deaths are intentional and so, in principle, could be included either in the drug fatality category or with other types of suicides. We have chosen to do the latter, so as not to understate the (relatively small) contribution of intentional deaths to mortality rate trends. Our accidental death category excludes accidental drug fatalities, which are separately analyzed given their particular importance.

Appendix Table A1: Causes of Death and ICD-10 Codes

Abbreviation	Description (ICD-10 Codes)
Cardiovascular	Major cardiovascular diseases (I00-I78)
Cancer	Malignant neoplasms (C00-C97)
Diabetes	Diabetes mellitus (E10-E14)
HIV	Human immunodeficiency virus (B20-B24)
Kidney	Nephritis, nephrotic syndrome, nephrosis (N00-N07,N17-N19,N25-N27)
Liver	Chronic liver disease and cirrhosis (K70, K73, K74)
Nerve	Nervous system diseases (G00-G99)
Respiratory	Respiratory diseases (J00-J98)
Stroke	Cerebrovascular diseases (I60-I69)
Drug (Non-Suicide)	Drug poisoning: accidental, undetermined intent, assault (X40-X44,X60-X64,X85,Y10-Y14)
Accident (Non-Drug)	Accidents, other than drugs (V01-X39, X45-X59, Y85-Y86)
Homicide	Homicide (*U01-*U02,X85-Y09,Y87.1)
Suicide	Intentional deaths, including drugs (*U03,X60-X84, Y87.0)

Appendix B. Supplemental Results

Appendix Table B1: Average Years of Schooling by Education Quartile and Sex, 2001 and 2018

Education Quartile	Males		Females	
	2001	2018	2001	2018
1	9.58	10.07	9.82	10.29
2	12.05	12.32	12.10	12.74
3	13.98	14.51	13.81	14.74
4	16.40	16.47	16.17	16.53

Note: Table shows average years of completed school by education threshold for 25-64 year olds, calculated as discussed in the text.

Appendix Table B2: Education Quartile Distributions Within Race Groups

Education Quartile	Non-Hispanic White		Non-Hispanic Black		Hispanic		Other	
	2001	2018	2001	2018	2001	2018	2001	2018
				Males				
1	19.84	19.66	32.95	29.81	51.82	44.71	20.89	18.90
2	25.63	24.96	28.57	30.10	21.01	24.80	17.38	17.14
3	26.41	26.70	24.94	25.02	16.86	18.78	23.48	24.16
4	28.13	28.68	13.53	15.07	10.31	11.72	38.25	39.80
				Females				
1	19.92	19.70	32.05	28.15	51.12	45.09	25.40	22.23
2	25.86	25.09	26.34	28.93	21.01	24.59	18.28	18.40
3	26.42	26.80	25.00	24.67	16.61	17.97	22.50	25.12
4	27.80	28.41	16.61	18.26	11.25	12.35	33.82	34.25

Note: Table shows the distribution across education quartiles (in percentages) for the 25-64 year olds in specified race group and year. These do not total 25 percent in each case because we utilize general rather than race-specific education quartile thresholds.

Appendix Table B3: Regression estimates by cause of death, Males

	WNH				Blacks				Hispanics				Other			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Total	5.09	-11.43	-3.46	-0.26	2.28	-15.93	-5.75	0.48	0.48	-8.00	-1.81	0.06	-3.81	-9.14	-3.70	-2.06
	(0.92)	(3.57)	(1.1)	(1.31)	(1.15)	(4.58)	(2.04)	(0.91)	(1.62)	(3.02)	(0.89)	(0.7)	(1.59)	(2.89)	(1.23)	(0.72)
Cardiovascular	-1.72	-4.21	-1.38	-1.29	-1.76	-5.52	-1.72	-0.58	-1.28	-2.79	-0.75	-0.27	-1.67	-3.13	-1.11	-0.76
	(0.75)	(1.65)	(0.64)	(0.8)	(0.78)	(2.22)	(0.82)	(0.55)	(0.78)	(1.45)	(0.38)	(0.23)	(0.68)	(1.36)	(0.5)	(0.31)
Cancer	-1.90	-4.61	-0.69	-0.85	-2.43	-5.29	-1.35	-0.86	-1.82	-3.05	-0.62	-0.67	-2.10	-2.51	-1.07	-0.77
	(0.63)	(1.66)	(0.28)	(0.26)	(0.97)	(1.99)	(0.62)	(0.44)	(0.94)	(1.43)	(0.3)	(0.39)	(0.95)	(1.14)	(0.5)	(0.32)
Drugs	4.34	2.52	0.81	1.04	3.43	1.80	0.83	1.06	1.69	0.94	0.60	0.49	0.44	0.11	0.15	0.11
	(0.42)	(0.39)	(0.12)	(0.1)	(0.4)	(0.36)	(0.11)	(0.07)	(0.25)	(0.23)	(0.08)	(0.06)	(0.05)	(0.08)	(0.03)	(0.02)
HIV	-0.33	-3.63	-0.82	-0.16	-0.29	-3.34	-1.21	-0.18	-0.23	-1.78	-0.56	-0.10	-0.16	-1.28	-0.46	-0.05
	(0.12)	(0.83)	(0.18)	(0.06)	(0.09)	(0.73)	(0.31)	(0.07)	(0.08)	(0.4)	(0.16)	(0.03)	(0.04)	(0.28)	(0.11)	(0.02)
Suicides	0.92	0.10	0.14	0.45	0.87	0.06	0.09	0.32	0.82	0.17	0.22	0.27	0.34	0.12	0.13	0.10
	(0.05)	(0.06)	(0.06)	(0.08)	(0.04)	(0.03)	(0.06)	(0.07)	(0.06)	(0.03)	(0.03)	(0.05)	(0.04)	(0.02)	(0.03)	(0.03)
Respiratory	0.74	-0.13	0.00	-0.08	0.47	-0.35	-0.13	0.10	0.05	-0.17	0.02	0.06	-0.16	-0.22	-0.11	-0.04
	(0.29)	(0.13)	(0.02)	(0.13)	(0.19)	(0.1)	(0.06)	(0.08)	(0.13)	(0.15)	(0.03)	(0.04)	(0.09)	(0.09)	(0.05)	(0.04)
Stroke	-0.09	-0.97	-0.27	-0.29	-0.09	-1.01	-0.25	-0.18	-0.10	-0.56	-0.11	-0.15	-0.15	-0.45	-0.12	-0.20
	(0.06)	(0.34)	(0.1)	(0.18)	(0.05)	(0.38)	(0.1)	(0.12)	(0.06)	(0.27)	(0.05)	(0.05)	(0.06)	(0.19)	(0.07)	(0.09)
Liver	0.72	-0.25	-0.12	0.38	0.55	-0.40	-0.34	0.30	0.41	-0.20	-0.01	0.16	0.09	-0.13	-0.07	0.00
	(0.37)	(0.27)	(0.16)	(0.1)	(0.26)	(0.22)	(0.2)	(0.05)	(0.13)	(0.13)	(0.08)	(0.07)	(0.02)	(0.05)	(0.04)	(0.02)
Kidney	0.09	-0.29	0.01	0.02	0.06	-0.28	-0.03	0.01	0.04	-0.04	0.00	0.04	-0.02	-0.14	-0.03	-0.02
	(0.03)	(0.11)	(0.01)	(0.02)	(0.02)	(0.1)	(0.02)	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.01)	(0.05)	(0.02)	(0.02)
Diabetes	0.21	-0.14	-0.19	0.06	0.17	-0.23	-0.17	0.32	0.10	-0.06	-0.02	0.20	-0.07	-0.26	-0.08	-0.05
	(0.06)	(0.17)	(0.14)	(0.11)	(0.04)	(0.16)	(0.1)	(0.09)	(0.06)	(0.13)	(0.08)	(0.06)	(0.03)	(0.13)	(0.05)	(0.05)
Nerve	0.43	0.39	0.14	0.20	0.26	0.20	0.09	0.21	0.18	0.16	0.07	0.10	0.04	0.04	0.00	0.02
	(0.12)	(0.13)	(0.05)	(0.03)	(0.07)	(0.07)	(0.03)	(0.07)	(0.08)	(0.07)	(0.04)	(0.03)	(0.04)	(0.07)	(0.02)	(0.02)
Accidents	0.16	-0.17	-0.51	-0.02	0.01	-0.48	-0.50	-0.19	0.03	-0.13	-0.21	-0.21	-0.26	-0.38	-0.40	-0.24
	(0.29)	(0.21)	(0.13)	(0.13)	(0.22)	(0.15)	(0.11)	(0.13)	(0.16)	(0.08)	(0.06)	(0.07)	(0.04)	(0.04)	(0.06)	(0.04)
Homicides	0.06	0.46	-0.30	0.02	0.03	-0.01	-0.32	-0.08	-0.04	-0.24	-0.24	-0.10	-0.14	-0.42	-0.25	-0.21
	(0.02)	(0.63)	(0.06)	(0.05)	(0.01)	(0.36)	(0.07)	(0.03)	(0.01)	(0.2)	(0.08)	(0.03)	(0.02)	(0.08)	(0.02)	(0.02)
All other causes	1.39	0.04	-0.17	0.33	1.00	-0.41	-0.55	0.33	0.64	0.04	-0.17	0.23	0.11	-0.14	-0.23	0.07
	(0.79)	(0.75)	(0.27)	(0.19)	(0.56)	(0.48)	(0.28)	(0.23)	(0.36)	(0.35)	(0.13)	(0.14)	(0.11)	(0.15)	(0.1)	(0.06)

Notes: Table presents regression estimates for cause of death. Standard errors are reported in parentheses.

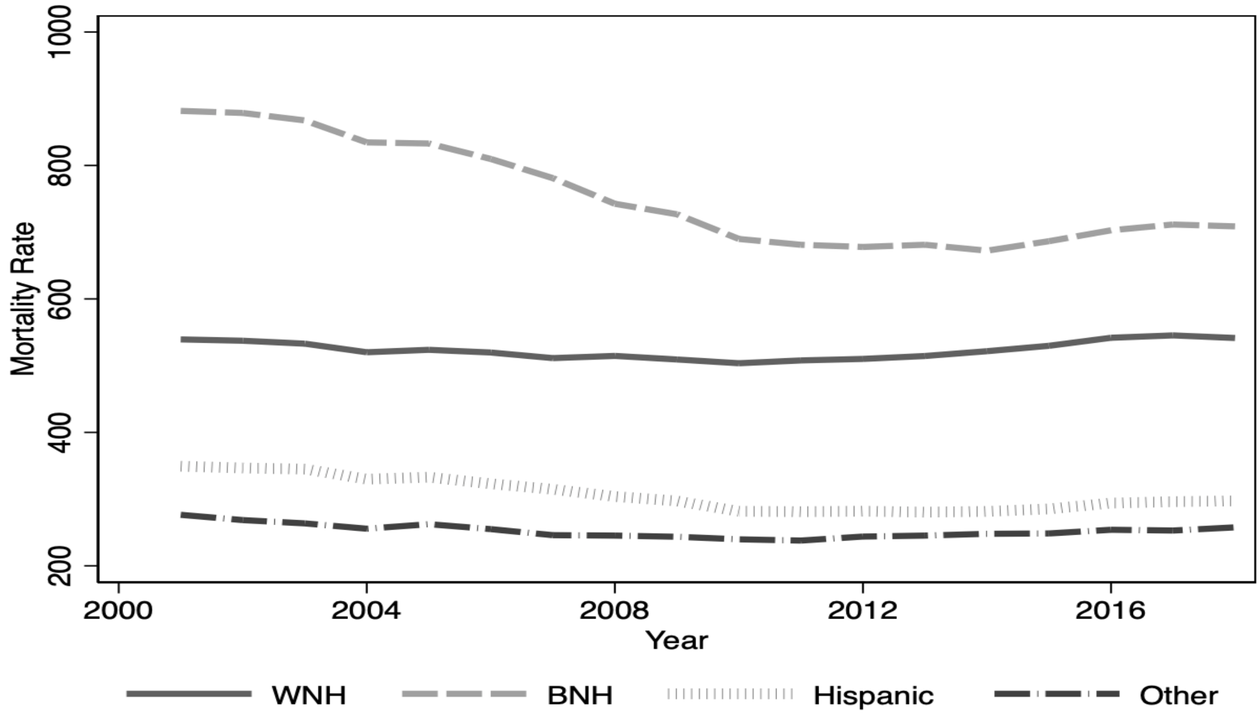
Appendix Table B4: Regression estimates by cause of death, Females

	WNH				Blacks				Hispanics				Other			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Total	5.41	-2.65	-1.66	-1.11	2.10	-9.03	-2.49	-1.04	-1.69	-8.42	-1.83	-1.69	-3.34	-9.02	-2.11	-1.69
	(1.57)	(0.72)	(0.74)	(1.48)	(0.99)	(2.46)	(1.17)	(1)	(1.45)	(2.68)	(0.8)	(0.8)	(1.53)	(3.31)	(0.73)	(0.6)
Cardiovascular	-0.34	-1.83	-0.91	-1.01	-0.32	-3.58	-0.87	-0.75	-0.85	-3.80	-0.68	-0.67	-0.80	-3.36	-0.57	-0.48
	(0.73)	(0.66)	(0.44)	(0.63)	(0.38)	(1.38)	(0.46)	(0.47)	(0.53)	(1.57)	(0.39)	(0.37)	(0.41)	(1.44)	(0.26)	(0.22)
Cancer	-1.11	-0.94	-0.39	-0.60	-1.84	-2.89	-0.94	-0.63	-2.14	-2.83	-0.73	-0.53	-2.18	-2.94	-0.73	-0.64
	(0.58)	(0.29)	(0.16)	(0.2)	(0.77)	(0.96)	(0.44)	(0.25)	(0.96)	(0.95)	(0.29)	(0.26)	(0.92)	(1.15)	(0.28)	(0.23)
Drugs	2.74	1.11	0.31	0.47	1.67	0.63	0.32	0.33	0.74	0.42	0.22	0.11	0.17	0.08	0.06	0.02
	(0.3)	(0.16)	(0.05)	(0.06)	(0.14)	(0.17)	(0.04)	(0.03)	(0.07)	(0.11)	(0.03)	(0.03)	(0.03)	(0.04)	(0.01)	(0.01)
HIV	-0.07	-1.64	-0.27	-0.05	-0.05	-1.39	-0.37	-0.04	-0.02	-0.59	-0.14	-0.02	-0.01	-0.36	-0.07	-0.01
	(0.03)	(0.41)	(0.05)	(0.02)	(0.02)	(0.3)	(0.08)	(0.01)	(0.01)	(0.13)	(0.03)	(0.01)	(0)	(0.05)	(0.02)	(0)
Suicides	0.35	0.07	0.08	0.15	0.32	0.06	0.10	0.15	0.23	0.05	0.08	0.09	0.11	0.05	0.06	0.02
	(0.03)	(0.01)	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
Respiratory	0.97	0.64	0.04	0.03	0.56	0.11	-0.09	0.00	-0.04	0.00	-0.06	-0.05	-0.21	-0.27	-0.04	-0.01
	(0.33)	(0.35)	(0.04)	(0.07)	(0.19)	(0.17)	(0.05)	(0.05)	(0.15)	(0.1)	(0.04)	(0.03)	(0.15)	(0.12)	(0.02)	(0.01)
Stroke	-0.10	-0.53	-0.26	-0.37	-0.12	-0.88	-0.19	-0.31	-0.21	-0.91	-0.16	-0.24	-0.17	-0.71	-0.14	-0.18
	(0.09)	(0.14)	(0.09)	(0.18)	(0.05)	(0.26)	(0.06)	(0.16)	(0.08)	(0.32)	(0.06)	(0.13)	(0.08)	(0.29)	(0.06)	(0.08)
Liver	0.64	0.14	0.08	0.32	0.50	0.00	0.08	0.26	0.29	0.01	0.13	0.02	0.08	-0.08	0.01	-0.02
	(0.16)	(0.09)	(0.05)	(0.08)	(0.12)	(0.06)	(0.02)	(0.06)	(0.09)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.02)	(0.01)
Kidney	0.03	-0.15	-0.04	-0.13	0.02	-0.30	-0.05	-0.05	-0.02	-0.23	-0.01	-0.06	-0.02	-0.25	-0.05	-0.04
	(0.02)	(0.08)	(0.02)	(0.08)	(0.01)	(0.12)	(0.03)	(0.04)	(0.02)	(0.11)	(0.01)	(0.02)	(0.01)	(0.1)	(0.02)	(0.02)
Diabetes	-0.06	-0.33	-0.29	-0.13	-0.01	-0.52	-0.22	-0.05	-0.10	-0.52	-0.19	-0.09	-0.09	-0.49	-0.19	-0.07
	(0.13)	(0.32)	(0.17)	(0.19)	(0.05)	(0.31)	(0.12)	(0.09)	(0.05)	(0.27)	(0.1)	(0.06)	(0.04)	(0.25)	(0.08)	(0.04)
Nerve	0.41	0.36	0.09	0.11	0.20	0.11	0.04	0.09	0.07	0.11	0.05	0.03	0.00	-0.05	0.00	-0.01
	(0.09)	(0.07)	(0.02)	(0.03)	(0.06)	(0.04)	(0.02)	(0.03)	(0.05)	(0.06)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.01)
Accidents	0.19	0.08	-0.17	-0.12	0.09	-0.11	-0.16	-0.17	-0.06	-0.18	-0.20	-0.22	-0.16	-0.24	-0.17	-0.26
	(0.06)	(0.03)	(0.04)	(0.07)	(0.05)	(0.04)	(0.05)	(0.07)	(0.04)	(0.03)	(0.04)	(0.05)	(0.01)	(0.04)	(0.04)	(0.03)
Homicides	0.03	-0.10	-0.05	-0.04	0.00	-0.17	-0.08	-0.07	-0.01	-0.11	-0.08	-0.08	-0.04	-0.11	-0.11	-0.06
	(0.01)	(0.06)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
All other causes	1.50	0.63	0.13	0.29	1.01	0.28	-0.02	0.26	0.49	0.45	-0.02	0.09	0.06	-0.05	-0.11	0.05
	(0.32)	(0.29)	(0.11)	(0.07)	(0.24)	(0.25)	(0.05)	(0.12)	(0.2)	(0.33)	(0.07)	(0.1)	(0.05)	(0.11)	(0.09)	(0.04)

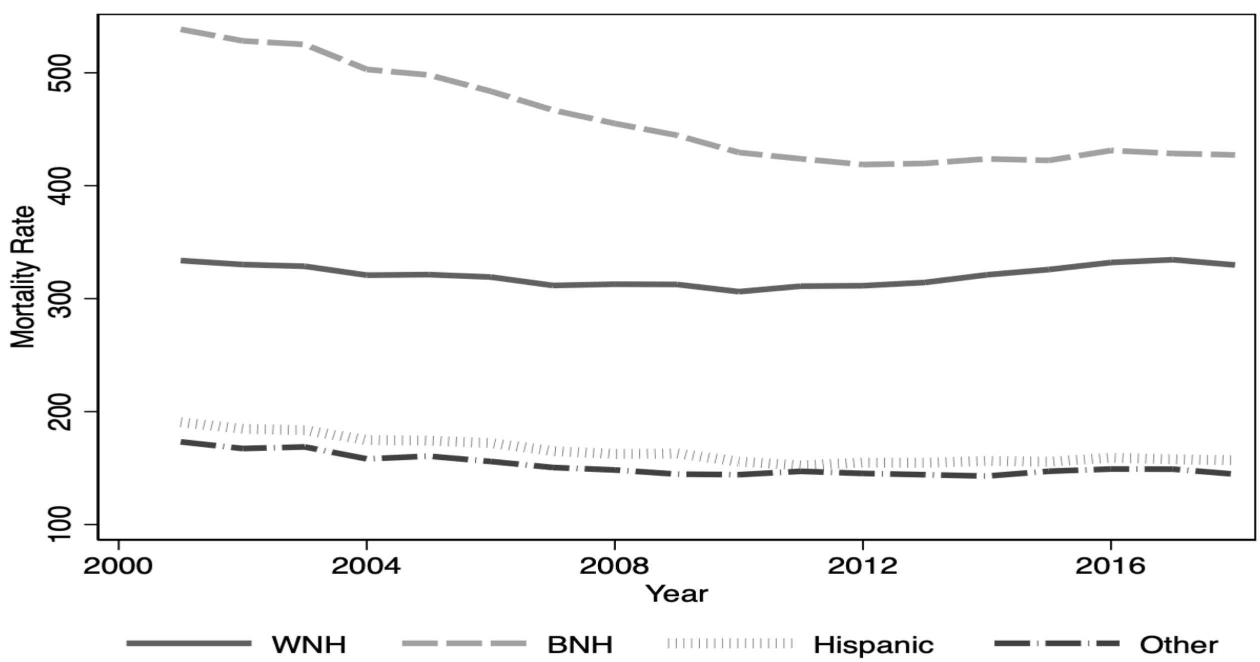
Notes: Table presents regression estimates for cause of death. Standard errors are reported in parentheses.

Appendix Figure B1: Trends in Total Mortality Rates: 25-64 Year Olds by Race

(a) Males



(b) Females



Note: Figure shows race specific annual age-adjusted mortality rates measured across all education quartiles.