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ABSTRACT

Mortality Inequality: The Good News from a County-Level Approach*

Analysts who have concluded that inequality in life expectancy is increasing have generally focused on life expectancy at age 40 to 50. However, we show that among infants, children, and young adults, mortality has been falling more quickly in poorer areas with the result that inequality in mortality has fallen substantially over time. This is an important result given the growing literature showing that good health in childhood predicts better health in adulthood and suggests that today's children are likely to face considerably less inequality in mortality as they age than current adults. We also show that there have been stunning declines in mortality rates for African-Americans between 1990 and 2010, especially for black men. The fact that inequality in mortality has been moving in opposite directions for the young and the old, as well as for some segments of the African-American and non-African-American populations argues against a single driver of trends in mortality inequality, such as rising income inequality. Rather, there are likely to be multiple specific causes affecting different segments of the population. We show that the differential timing of smoking reductions among the rich and the poor can explain a significant fraction of the current increase in mortality inequality in older cohorts.

JEL Classification: I14, I32, J11, J13

Keywords: mortality, inequality, racial differences, smoking

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Life expectancy for the U.S. population has shown a strong increase since 1990. The rise in life expectancy at birth holds for both men and women, as shown in Figure 1. This development has not been driven solely by improvements in life expectancy at older ages. Mortality rates for those under one year of age, for the age group 1-4, and for every 5-year age group above that level, declined for both males and females between 1990 and 2010 (Figure A1). Particularly pronounced improvements in mortality occurred at younger ages, which tend to be age groups in which deaths occur predominantly among the poor.

However, this overall decline in mortality rates has been accompanied by prominent recent studies highlighting that the gains have not been distributed equally (e.g. Cutler et al. 2011; Chetty et al. 2015; NRC 2015; Case and Deaton 2015). Indeed, several studies argue that when measured across educational groups and/or geographic areas, mortality gaps are not only widening, but that for some U.S. groups, overall life expectancy is even falling (Olshansky et al. 2012; Wang, Schumacher, Levitz, Mokdad, and Murray 2013; Murray et al. 2006). In fact, it seems to have become widely accepted that inequality in life expectancy is increasing. Given that the number of years that one can expect to live is such an important indicator of welfare, this finding has been heralded as yet another dimension in which overall societal inequality is increasing.

In this essay, we ask whether the distributions of life expectancy and mortality have in fact become generally more unequal. Focusing on groups of counties ranked by their poverty rates, we show that in fact, gains in life expectancy *at birth* have been relatively equally distributed between rich and poor areas. Analysts who have concluded that inequality in life expectancy is increasing have generally focused on life expectancy at age 40 to 50. This observation suggests that it is important to examine trends in mortality for younger and older ages separately.

Turning to an analysis of age-specific mortality rates, we show that among adults age 50 and over, mortality has declined more quickly in richer areas than in poorer ones, resulting in increased inequality in mortality. This finding is consistent with previous research on the subject. However, among children, mortality has been falling more quickly in poorer areas with the result that inequality in mortality has fallen substantially over time. This is an important result given the growing literature showing that good health in childhood predicts better health in adulthood (Currie and Rossin-Slater, 2015). Hence, today's children are likely to face considerably less inequality in mortality as they age than current adults.

We also show that there have been stunning declines in mortality rates for African-Americans between 1990 and 2010, especially for black men. The fact that inequality in mortality has been moving in opposite directions for the young and the old, as well as for some segments of the African-American and non-African-American populations argues against a single driver of trends in mortality inequality, such as rising income inequality. Rather, there are likely to be multiple specific causes affecting different segments of the population.

In what follows, we first provide a brief overview of the literature on inequality in mortality. This is followed by a discussion of our methods, data, and main results. The end of this paper offers some hypotheses about the causes of our results, including a discussion of differential smoking patterns by age and socioeconomic status. These patterns may explain a significant fraction of the increase in mortality inequality in older cohorts. Finally, we offer a summary and suggestions for future research.

Background

Is There a Causal Relationship Between Inequality in Income and in Mortality?

It is no accident that the resurgence of interest in mortality inequality has followed growing public interest in income inequality. The two are linked in the minds of the public and many academics (Marmot et al. 1991; Wilkinson 1996). There is no doubt that lower socioeconomic status tends to be associated with higher mortality; Kitigawa and Hauser (1973) showed this relationship more than 40 years ago. However, this insight does not mean that increases in income inequality must inevitably widen differentials in mortality regardless of actual income levels or other relevant policies. Indeed, given that much of the recent increase in economic inequality is at the very top of the income distribution, it is not immediately obvious why it should result in increases in deaths for other groups.

In the academic literature, the idea that rising income inequality must necessarily lead to rising inequality in mortality has been vigorously disputed. Deaton and Paxson (2001) show that there is no necessary relationship between trends in income inequality per se and mortality trends, and that in fact, the two moved in opposite directions for much of the twentieth century. Gravelle (1998) argues that empirically, places that have a lot of income inequality also tend to have a lot of poverty, and that it is poverty and not income inequality that is causally related to higher mortality.

In this journal, Smith (1999) argues that health may be driving income differences rather than the reverse, at least among adults. Similarly, Case and Paxson (2011), in their reanalysis of data from the Whitehall studies of British civil servants, show that poor health in childhood causes lower socioeconomic status in adulthood, rather than lower socioeconomic status causing poor health in adulthood. An important possible explanation may be that health trajectories are established early in childhood (Almond and Currie 2011; Smith 2007). From this perspective, mortality differentials that are seen today among middle-aged and older adults likely had their roots decades ago. Aizer and Currie (2014) show that the health of infants in the lowest socioeconomic status groups is catching up to those of higher status groups and argue that this convergence likely reflects a range of recent policies that have improved the prospects of these children.

An overall reading of this evidence suggests that it is not at all obvious how one should expect trends in mortality inequality to have evolved over the past 20 years. While income inequality has increased greatly over this period, there have been dramatic changes in access to health insurance among pregnant women and children, as well as a sea change in societal attitudes towards smoking. Fenelon and Preston (2012) place particular emphasis on smoking, estimating that about 20 percent of U.S. mortality may be attributed to smoking, and that there are deleterious effects even on those "ever smokers" who have not smoked for many years. There have also been tremendous increases in obesity rates and addiction to prescription painkillers, as well as the rise (followed by the subsequent imperfect control of) HIV/AIDS.[1]

Complicating matters further, many of the health-related behaviors that are associated with lower socioeconomic status contemporaneously—like smoking, drinking, or overeating—do not explain differences in health at the population level. For example, Banks et al. (2006) show that British citizens have lower morbidity than Americans even though they tend to smoke and drink more and are almost equally likely to be overweight. The question of how inequality in mortality has evolved cannot be readily inferred from the mixture of other social trends about income inequality or behavior and instead must be estimated directly.

[1] Crime is not likely to be large factor over the timeframe considered here since over this period crime was low by historical standards. See http://www.pewsocialtrends.org/2013/05/07/gun-crime.

Approaches to Measurement of Inequality of Mortality

An important point to keep in mind is that although life expectancy sounds like it measures the number of years that a particular cohort can expect to live, it is unlikely to do so. It is easiest to understand the problem with a concrete example. Suppose we are interested in the life expectancy of the cohort that is currently 20 years old. Life expectancy is computed using the assumption that when this cohort reaches age 40, it can expect to live the same number of years as the cohort that is currently 40 years old. It is easy to see that if age-specific mortality rates are changing over time, then this assumption will be false. Only in a world where mortality rates are static does life expectancy mean what most people think that it does. For this reason, we focus most of our attention in what follows on age-specific mortality rates.

A recent National Academy report lays out three common approaches to measuring inequality in mortality: "One looks at differences in the mortality of populations of U.S. counties in relation to county-level economic measures. Another looks at mortality by educational attainment. A third approach looks at mortality by career earnings" (NRC, 2015). One reason for the multiplicity of approaches is that each has weaknesses.

The most popular method involves splitting the population either by education or by income level. Examples of studies looking at inequality in mortality by education level include Pappas et al. (1993), Elo and Preston (1996), Preston and Elo (1995), Olshansky et al. (2012), Meara et al. (2008), Cutler et al. (2011), Montez and Berman (2014), and Montez and Zajacova (2013). The main difficulty with this approach is that the share of the population in different educational categories has changed dramatically over time (Dowd and Hamoudi, 2014; Hendi, 2015; Bound et al., 2014; Godring et al. ,2015). For example, the share of white, non-Hispanic women aged 25-84 who had less than a high school degree fell by remarkable 66 percent between 1990 and 2010 (Table A1). Moreover, it is likely that those women who would have been high school dropouts in 1990, but who now have higher levels of education, are of higher socioeconomic status and/or ability than those who remain in the high school dropout category. They might therefore have been expected to have better health in any case.

Thus, the observed decline in life expectancy among white, non-Hispanic, high school dropout women highlighted in Olshansky et al. (2012) could be mostly or entirely accounted for by changes in the composition of this group. Bound et al. (2014) address the issue by categorizing education in terms of relative rank in the overall distribution and focusing on the bottom quartile of the education distribution. They find no evidence that survival probabilities declined in the bottom quartile of the education distribution.

A second strategy is to examine mortality inequality by relative income levels (NRC, 2015; Pappas et al., 1993; Waldron, 2007; Waldron 2013; Bosworth and Burke, 2014; Pijoan-Mas and Rios-Rull, 2014). These studies are subject to the concerns mentioned earlier about possible reverse causality—that is, the idea that economic hardship could be caused by ill health rather than vice-versa, (Smith 1999, 2005, 2007). Moreover, these analyses have been limited by the fact that many potential data sources for mortality rates do not include information on income or earnings.

The Health and Retirement Study, which follows a representative sample of the U.S. elderly population who can be linked to Social Security earnings histories, does include information on both income and mortality. Studies based on the HRS find increasing divergence in life expectancy at age 50 by income over time (for example, NRC 2015; Bosworth and Burke, 2014; Pijoan-Mas and Rios-Rull, 2014). However, these analyses are constrained by the limited age ranges that are observed in different years due to the cohort structure of the data, as well as by small sample sizes; for example, the sample used in the NRC (2015) study includes 5,740 deaths, compared to the 21 million deaths analyzed in our study). These data limitations mean that strong assumptions are required to estimate and project life expectancy trends in socioeconomic subgroups, given that some subgroups have very few deaths.

A third strategy, and the one we pursue here, is to examine inequality by geographical areas, such as counties. Analyses based on geographic areas are potentially subject to bias due to selective migration. If for example, the most healthy and able-bodied people tend to leave lower-income counties over time and migrate to higher-income counties, we might expect to see mortality increase in the poor counties and decrease in the rich counties even if in fact each individual's health remained exactly the same.

Some previous studies have taken this geographical approach (for example, Wilmoth et al. 2011; Sing and Siahpush 2006; Kulkarni et al. 2011; Wang et al. 2013; Murray et al. 2006), but concerns over migration and other changes in geographic areas can make the results tricky to interpret. For example, Wang et al. (2013) find that female life expectancy decreased by 2.68 years in the counties with the sharpest declines in life expectancy between 1985 and 2010, while it increased by 6.16 years in the counties with the largest gains in life expectancy. However, our calculations show that during this time period, the population fell 6 percent in the counties with the largest mortality declines, while the population of the top counties grew on average by 101 percent, making it extremely difficult to interpret these trends (these calculations are presented in Appendix Table A1).

Sing and Siahpush (2006) divide counties based on a socioeconomic index for the population in 1980 and follow these same county groups up to 2000. We follow a similar strategy here, although we reorder the counties in each Census year to insure that we are always comparing poor counties to rich ones. In practice, this refinement does not have a lot of impact on our estimates. Our approach differs from theirs in that we examine age-specific mortality in addition to life expectancy.

In an exceptional recent paper, Chetty et al. (2015) categorize individuals by both income and location. Using tax data, they first examine mortality by percentiles of the income distribution for each age from 40 to 76. Their preferred specification uses income from two years ago in order to reduce the chance that their results are driven by reverse causality from health to inequality of income, but they show that they would obtain similar results using income from five and ten years ago. Using this information, they calculate survival curves and extrapolate them to age 90. These data are then used to calculate life expectancy at age 40 for each quartile of the income distribution, in different locations using either counties or clusters of counties that make up commuting zones.

They conclude that “low-income individuals live longest in affluent cities with more educated people and higher local government expenditures…[and] low-income individuals on both coasts experienced annual gains in life expectancy of approximately .3 years, comparable to the mean gain in the U.S. for the highest income individuals.” This work does show significant declines in life expectancy at age 40 among low income individuals in some places, including

Nevada, Appalachia, and southern Ohio. However, the results also suggest that some features of location boost health at least as much among the poor as among the rich.[2,3]

Hence, the Chetty et al. study suggests an additional reason that we should be interested in the analysis of inequalities in mortality across geographical areas: There may be features of particular areas (e.g. air pollution) that affect everyone living in a particular location. There may also be spillovers from rich to poor (or vice versa) within areas. For instance, if the rich insist on excellent parks and hospitals, then to the extent that the poor are able to live in the same locations, they may also benefit from these resources.[4]

Mortality Rates: Measurement Issues

An intrinsic problem in empirical work with U.S. mortality rates is that the numerator and denominator come from different data sets, with somewhat different and changing measures of key concepts. Death statistics come from the Vital Statistics mortality data, which are collected by each local county registrar-recorder and eventually forwarded to the national government. However, population estimates come from the decennial Census and the American Community Survey. Debate continues as to the quality of the reporting in these sources (Arias et al., 2008). Information on education, Hispanic ethnicity, race, and occupation of the decedent is supposed to

[2] Costa and Kahn (2015) provide a historical example of how improvements in a location's health environment reduce mortality among the poor more than among the rich by studying city-wide clean water interventions and drug availability in New York City and Philadelphia in the early twentieth century.

[3] Some limitations of the Chetty et al. approach include the fact that income is not observed for non-earners and race is not observed while (as we will show) there having been dramatic improvements in mortality among African-Americans.

[4] A somewhat obvious point about any analysis of inequality between counties is that such an analysis neglects inequality within county, which may nevertheless be important. Thus, between-county inequality in mortality is only part of the story, albeit an important part.

be completed by the funeral director on the basis of information provided by an informant (or in the absence of an informant, based on observation). These variables do not appear on the certified death certificate.[5] In 1990, about 8 percent of certificates were missing education--a proportion that fell to 1 percent by 2010. If the missing data are concentrated in lower-education subgroups, then excluding observations with missing values will bias estimated trends in mortality by education.

Changes in the measures over time present a vexing question for the analysis of trends. For example, the Census now allows each respondent to report more than one race. Similarly, since 2003, an increasing number of states changed from reporting education by years completed to reporting educational degrees as stated on death certificates, while the Census and American Community Survey data continue to report education in years completed.

An important change regarding Hispanic origin occurred recently in the American Community Survey: In 2008, the wording in the questionnaire changed from "Hispanic" to "Hispanic origin." According to the Census Bureau (undated), this wording change "likely identified Hispanics--mostly native-born--who would not have been captured before."[6] If there is an increasing tendency for people to identify themselves as Hispanic in the American Community Survey, while no changes in race reporting occur in the Vital Statistics data, the mortality rate of Hispanics will mechanically decrease and the rate for non-Hispanics will increase, with the impact being larger for Hispanics than for non-Hispanics because the latter group is much larger.

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[5] More than one race can be entered on the death certificates, but only the first-mentioned race is recorded in the Vital Statistics files. While there is evidence of a slight general underreporting of Hispanic origin in death certificates (Murphy et al. 2013), no systematic changes have occurred over time.

[6] Figure A8 shows that among US born adults the fraction identifying as Hispanic sharply increased after 2008.

A related issue that could also have a large impact on the size of the denominator is undercounting of undocumented immigrants in the U.S. Census. To the extent that the size of the population is undercounted while the deaths are all counted, mortality rates will tend to be too high. However, Hispanics are estimated to have the highest life expectancy at birth in the U.S. despite large numbers of both documented and undocumented immigrants, though it is unknown to what extent this result may be due to the sorts of measurement problems we highlight here (Arias et al., 2010).

Methods and Data

In our main analysis of mortality and inequality, we follow Currie and Schwandt (2016), and rank counties by their poverty rates and then divide the counties into groups that each represent equal one percent shares (or equal five percent shares) of the overall U.S. population. We do this separately for each Census year. In this way, we compare the one (five) percent of the population who lived in counties with the highest poverty levels in 1990 to the one (five) percent of the population who lived in counties with the highest poverty levels in each Census year. This approach accounts for the fact that counties may change poverty rank over time and avoids problems due to shrinking or growing counties by always looking at county bins of similar size.[7]

Our focus on mortality at the level of county groups has advantages beyond the possibility of adjusting for changes in population shares. County of residence is consistently reported both in the Vital Statistics and the Census data, unlike other proxies for socioeconomic status such as education or race. Moreover, grouping counties into equal shares of the population

[7] If people systematically left the poorest counties, then over time the population in a fixed group of counties would represent a smaller share of the total population. Moreover, if out-migrants were relatively healthy while the relatively unhealthy remained, then it could appear that health was declining in the poorest counties even if in fact all that was happening was selective out-migration of the healthy.

helps to address the problem of measurement error in mortality rates for small counties, in particular when analyzing age ranges with low mortality or racial minorities. We also look at mortality rates over a 3-year period in each county, which further helps to minimize noise due to measurement error and to avoid counties reporting zero deaths. A further advantage of our approach is that several socio-economic indicators are available at the county level. Our baseline specification ranks counties by their poverty rates, but we also show results for rankings in terms of the fraction of the population that are high school dropouts, median income, and life expectancy.

Various issues arise when dividing up counties in this way. For example, dividing counties into groups that represent equal fractions of the population is not an exact procedure because counties at the margin will overlap the bins, making one group too large and the next group too small.[8] In practice, however, this variation in county group size is relatively small, and it is not systematically related to county-level poverty.[9]

[8] In order to smooth the size of the county groups we divide the five largest counties in our sample—Cook County, Illinois (which includes the city of Chicago), Los Angeles County, California, Riverside County, California, Harris County, Texas (including Houston), and Maricopa County (including Phoenix), Arizona into three smaller groups, each of identical size and with the identical mortality rates. See Appendix Figure A2 for evidence that the variation in county group size is relatively small. Figure A2 also shows how median income and per capita income vary with the county group poverty ranking.

[9] Most of the poorest counties that together make up 10 percent of the U.S. population in both 1990 and 2010 were located in the South and Southwest, together with some counties in the Midwest (in particular, in South Dakota), and in Alaska. Conversely, the counties with the lowest poverty rates that make up 10 percent of the population in both 1990 and 2010 are predominantly located in the North, with clusters in the Northeast. Thus, the geographic distribution of the counties with the highest and lowest poverty rates remained fairly stable between 1990 and 2010, and in fact, whether we readjust county groups to account for population changes or instead follow fixed sets of poor and rich counties over time provide similar results.

Our analysis requires three broad categories of data: on life expectancy, on mortality rates, and about county characteristics including the poverty rate, median income, and the fraction of high school dropouts.

For *mortality rates,* we construct age group, gender, and race-specific 3-year mortality rates at the level of county groups for the years 1990, 2000, and 2010 based on Vital Statistics mortality data and population counts from the decennial Census. In order to account for changes in the age structure within age groups (e.g. the fact that within a group like "over 50" the age distribution can change over time), we age-adjust mortality rates in 2000 and 2010 using the 1990 population. This means we apply the age-specific mortality rates in 2000 and 2010 to the 1990 population, which effectively keeps the age composition within broader age groups constant over time.

The mortality data gives the month of death, which allows us to construct mortality rates based on deaths that occurred after Census Day (April 1). To be specific, the 3-year mortality rate in 1990 is the ratio of all deaths that occurred in a cohort between April 1, 1990, and March 31, 1993, divided by the 1990 Census population count. We use the decedent's county of residence, which is what the Census reports, rather than the county where the death occurred.

Following Dorn (2009) we account for changes in county definitions that occurred between 1990 and 2010. Mortality rates by race are constructed using single-race definitions in the 2000 and 2010 Census. We focus on mortality rates in levels and consider there to have been a decline in inequality if the mortality rate in poor counties decreased more strongly in absolute terms than the mortality rate in rich counties. In what follows, we also discuss percentage changes in mortality. Because death rates tend to be higher among the poor than among the rich, the same absolute decline in mortality represents a larger percent decline among the rich and vice versa.

We calculate gender-specific life expectancy at the level of county groups based on 1-year mortality rates in 19 age groups (following standard life table techniques, e.g. described in Chiang, 1984).

Finally, county characteristics are taken from the Census (in 1990 and 2000) and from the American Community Survey (ACS) in 2010 (the ACS replaced the long form of the Census). These include: the poverty rate, median income, and the percent of respondents who are high school dropouts. Further details about definitions of race, education level, and other variables are discussed below.

The Evolution of Inequality in Life Expectancy and Mortality

Inequality is never fully captured by any single all-inclusive measure. Thus, we slice up the data in several ways to present our findings, first looking at life expectancy at birth, then at mortality by age group, and finally at mortality by race and age. Throughout, we show separate estimates for males and females given that there are profound gender differences in both levels and trends of mortality.

Life Expectancy at Birth

The points in Figure 2 represent measures of life expectancy at the level of county groups. On the horizontal axis, county groups are ranked from those with the lowest percentage of the population in poverty to those with the highest percentage in poverty. The size of each group represents about one percent of the population in the relevant year. The vertical axis shows life expectancy at birth, with the left-hand panel showing data for males and the right-hand panel for females. The triangles show the average life expectancy in each county bin in 1990, with a light best-fit regression line drawn through the points. The dashed line shows a fitted regression line for life expectancy at birth in 2000. The circles refer to the 2010 life expectancy at birth (again with a light best-fit regression line drawn through them). The negative slope of each line shows that life expectancy is lower for people in counties with higher poverty rates in each Census year. The fact that the 2010 line is consistently above the 1990 line shows that life expectancy increased in every type of county group, from those with the lowest to the highest poverty rates.

If the slope of the line becomes flatter over time, then this indicates that life expectancy is increasing more in poorer areas than in richer ones, and vice versa. For men, the shift in life expectancy over time is shown by essentially parallel lines, implying that life expectancy increased roughly equally in rich and poor counties and that inequality in life expectancy at birth neither decreased nor increased. For women, increases in life expectancy at birth have been somewhat stronger in the low-poverty county groups resulting in a steepening of the gradient between 1990 and 2010, which illustrates a slight increase in inequality.[10] For women between 1990 and 2010, life expectancy at birth in the county group with the lowest poverty increased by 3 years, about 1 year more than in the county group with the highest poverty rate. However,

[10] Table A2 provides numerical values. Figure A3 plots changes in life expectancy at birth between 1990 and 2010 across county groups. For men the slope of the fitted line is 0.0043 with a standard error of 0.0041—which means that the change in the slope is not significantly different from zero. For women, the slope of the corresponding line is -0.009 with a standard error of 0.0041, indicating a small but statistically significant increase in inequality. Figure A3 also shows these changes in percent of the 1990 level. Since males in poor counties have low levels of life expectancy in 1990, the positive change in the poorest groups becomes more pronounced relative to the richer counties, implying a statistically significant decrease in inequality for males according to this measure.

changes in life expectancy at birth are positive for each county group, with an average improvement in life expectancy of about two years for the county groups with the highest poverty rates. Overall, improvements in life expectancy have been greater for men than for women, implying a strong reduction of the gender gap (a change also visible in Figure 1).

How do these results relate to the findings of an increase in inequality in life expectancy from previous prominent studies such as Chetty et al. (2015) and NRC (2015)? One salient difference in methodology is that those studies focus on life expectancy at older ages. For example, Chetty et al. (2015) use mortality at age 40 to 63 to estimate income-specific trends in life expectancy, while NRC (2015) uses mortality at age 50 to 78, an approach that by construction does not consider developments at younger ages. Figure A4 shows that when we use our data and method to look at life expectancy at age 50, we also find increases in inequality in life expectancy for both men and women. The next subsection investigates the potential for differences between old and young in trends in age-specific mortality.

Age-specific Mortality

Our data allow us to construct death rates at different ages. Figure 3 shows 3-year mortality rates at the level of county groups, with counties ranked by the share of their population below the poverty line, for males and females in four different age groups.[11] In these figures, each marker shows the mortality rate for a bin representing five percent of the U.S. population in the relevant year. As in the life expectancy figures, a slope that becomes steeper over time implies increasing inequality and vice versa.

[11] For an analysis by finer age groups, see Currie and Schwandt (2016). Table A3 shows numerical values for the mortality estimates and includes tests for whether the slopes of a line drawn through the 1990 points is different from the slope of a line drawn through the 2010 points for each age group.

Figure 3 shows dramatic reductions in mortality among children aged zero to four between 1990 and 2000, with smaller reductions between 2000 and 2010. From 1990 to 2000, the reductions in under-five mortality were much greater in poorer counties than in richer ones, and slightly larger for males than for females. For example, the under-five mortality rate for males fell from 4.5 per 1000 in 1990 to 2.3 per 1000 in the poorest counties, compared to a decline from 2.4 to 1.3 per 1000 in the richest counties over the same period. Among children aged 5 to 19, there were large reductions in mortality for males, with more modest reductions for females (from already low levels). Once again, reductions were larger in poorer counties, implying significant reductions in mortality inequality.

Moving into young adulthood and middle age, Figure 3 shows that the different trends for males and females intensified. Males aged 20-49 experienced declines in mortality in poorer counties (though not so much in richer ones) leading to a significant decline in mortality inequality, whereas for women there was little improvement in mortality in either rich or poor county groups. This a truly remarkable stagnation in light of the significant progress in mortality reduction made in other age categories.

After age 50, mortality again showed large decreases over the whole 20-year period. For females, virtually all of this improvement occurred between 2000 and 2010. For men, there were larger and steadier declines in mortality. For women in this age group, gains were bigger in the richest county groups, leading to a significant increase in inequality in mortality. For men, the increase in mortality inequality is not statistically significant in the 50-plus group, though for males 65 and older, inequality in mortality is increasing significantly.

All the results in this section are robust to ordering counties using the fraction of high school dropouts, median income, or average life expectancy rather than poverty (Figure A9). The patterns look extremely similar when counties are ranked by the fraction of high school dropouts or by life expectancy. When we sort by median income, the reductions in mortality appear to be more evenly distributed.

Age and Race-Specific Mortality

As discussed above, the Census now allows people to describe themselves as belonging to more than one race. Figure 4 (A) shows a striking exponential growth in the fraction of people identifying as multiple races across birth cohorts, as reported in the 2000 and 2010 Census. While the fraction reporting multiple races is below 2.5 percent among those born in the first half of the past century, it strongly increased in more recent cohorts. For the 2010 cohort, it reached 10 percent for whites and 20 percent for African-Americans. Importantly, these patterns do not reflect age effect. The curves for 2000 and 2010 virtually match, even though the cohorts grew 10 years older between the two Censuses. As we show in panel (B) of Figure 4, if the observed exponential growth of multiple-race reporting continues into the future, the last single-race African-American and single-race white persons will be born in 2050 and 2080, respectively. While continuing exponential growth is a strong assumption, the patterns in Figure 4 suggest that multiple race reporting will become more important in the future. It is important to account for this development when studying trends in race-specific mortality, particularly among younger cohorts. We therefore report mortality rates based both on single and multiple race population counts.[12]

[12] The Census has responded to these problems by producing "bridged" estimates that attempt to allocate the entire population to one of four races (white, African-American, Native American, Asian) following an imputation procedure estimation procedure. Figure A6 provides an example of how these differences in reporting can influence the calculated death rates for those aged 20 to 24. Overall the results suggest that changes in race reporting may have important effects on estimated trends in mortality among groups

Figure 5 shows an analysis of age-specific 3-year mortality rates by race.[13] Recall that only one race is reported on the death certificates, even for people who consider themselves biracial. However, in the total population data, we have counts for people who consider themselves biracial. The lines with triangles or circles are based on rates calculated using, for the denominator, people who consider themselves only white or black. For 2010, we have also added a second line, marked with squares, that in the denominator also includes those who identify with more than one race. Of course, adding these individuals to the denominator without increasing the numerator lowers the estimated mortality rates.

Panel A shows mortality rates for children under five. What is most striking in these figures is the truly remarkable reduction in black mortality rates between 1990 and 2000, and the continuing, though smaller, decline for blacks between 2000 and 2010. In 1990, young black male children in the richest counties had mortality rates of 6.2 per 1000, while white male children in the poorest counties had mortality rates of about 4 per 1000. Thus, racial disparities trumped any inequality based on geographic areas. By 2010, the mortality rate for young black male children in the richest counties was still above the mortality rate for young white males in the poorest counties, but the gap had narrowed greatly. Moreover, if we use the rates calculated including people with multiple races in the denominator, the estimated black mortality rate falls even further.

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where the changes in mortality are relatively small, either because mortality does not change, or because changes start from a very low baseline and are small in absolute terms.

[13] As before we rank counties by their overall poverty rate. The figure looks similar when ranking counties by race-specific poverty rates, but there seems to be a considerable sampling error for black poverty estimates in 1990, which is why we continue to use overall county poverty levels for these figures. Ranking counties the same way with the figures for both blacks and whites also facilitates comparisons.

Panel B shows similar figures for children aged 5 to 19. In this age group, differences between black and white females are less apparent than for those under five. However for males, there is still a very large disparity in death rates, albeit one that was greatly reduced over the 20-year period. For both black and white males, death rates fell much more in the poorest county groups. By 2010, there was actually some overlap between the distributions of death rates for black and white males. By 2010, there was actually some overlap between the distributions of death rates for black and white males. Including those with multiple races makes much less difference in these figures than in those for the children under five, though it still impacts the estimated mortality rate for black males.

Panel C of Figure 5 focuses on people aged 20 to 49. A striking finding from this figure is the stagnation in white female mortality rates between 1990 and 2010. There is even a slight increase in the mortality among the poorest county groups. This result is of course completely consistent with those of Case and Deaton (2015), who document strong increases in middle-age mortality among non-Hispanic whites between 2000 and 2010.[14] Black females show reductions in mortality rates in both rich and poor counties, while white males experienced reductions only in the poorer counties, resulting in reduced mortality inequality for that group. The results for black males show, once again, huge reductions in mortality, which are greater in the poorest counties. By 2010, black males in the richest counties had considerably lower mortality than white males in the poorest counties, which had not been the case in 1990.

Results for people over 50 are shown in Panel D. Mortality fell for each of the four race and gender categories. Among females and among white males, it fell slightly more in the richest

[14]In Appendix Figure A7 we show US-wide age-specific mortality trends for non-Hispanic females and males, based on different population counts. The strong mortality increases in middle age between 2000 and 2010, highlighted by Case and Deaton (2015), are clearly visible across all measures, i.e. they are hardly affected by the way the non-Hispanic white population is counted.

county groups, while for black males, mortality fell similarly in poor and rich county groups. Multiple race reporting appears to be a relatively insignificant issue in this age category, as one would expect given the low rate of multiple race reporting in this age range (Figure 4).

Important Drivers of Mortality Trends in Different Cohorts

Given that there is so much dispute about the nature of the trends in inequality in mortality rates, perhaps it is unsurprising that there is so little research seeking to establish the causes of the trends. Aizer and Currie (2014) document the fall in mortality inequality among infants and cite many possible explanations including increases in maternal education, expansions of health insurance for pregnant women, the Supplemental Nutrition Program for Women, Infants, and Children, and expansions of the Earned Income Tax Credit.

Other than Currie and Schwandt (2016), we are not aware of any research that has looked systematically at the causes of reductions in mortality among older children. Some possibilities include expansion of public health insurance (Brown, Kowlaski and Lurie 2015; Cahodes et al. 2014; Currie, Decker, and Lin, 2008; Miller and Wherry 2015; Wherry and Meyer 2015; Wherry, et al. 2015), other social safety net programs such as Head Start (Ludwig and Miller 2007; Almond, Hoynes, Schanzenbach, forthcoming), and reductions in pollution (Isen et al. 2015).

We are also unaware of research that has investigated the role of immigration in driving inequalities in mortality. To the extent that Hispanic immigrants tend to be both poorer and healthier than the average American (the so-called “Hispanic paradox”), areas that receive a lot of immigrants might see improvements in mortality differentials. One might also be more likely to see this pattern for the young than for the old, given that immigrants tend to be young.

Smoking is a major driver of spatial mortality differences among older adults in the U.S.[15] In our context, at least some of the increasing disparities that we observe in old age mortality might reflect differences in taking up smoking and smoking cessation by socioeconomic status. De Walque (2010) shows that better-educated people stopped smoking much more quickly following the 1964 Surgeon General's report on the dangers of smoking than less-educated people. Moreover, males started with much higher smoking rates than females, but quickly reduced their rates, while smoking continued to gain ground among less-educated women for some time after the Surgeon General's report. These cohorts in which more-educated women had already reduced smoking while the less educated still smoked at increasing rates, entered old age over the past two decades, implying that lifetime smoking rates between the elderly rich and the poor likely diverged during that time period.

Figure 6 shows, based on smoking histories from the National Health Interview Survey, how these patterns have continued to play out during the time period that we analyze. Among those 50 and over, men are much more likely to have ever smoked than women, but lifetime smoking rates decreased strongly between 1990 and 2010 for both rich and poor men. The decrease was somewhat stronger for rich men, which implies that the smoking gap between rich and poor men 50 and over widened during that time period. This pattern could explain why we observe strong reductions in mortality among elderly men both in rich and poor county groups, with somewhat stronger improvements among the rich.

In the cohorts of women who passed age 50 over the past two decades, smoking rates declined among rich women, but increased strongly among the poor. In fact, in 1990, lifetime smoking rates were substantially lower among cohorts of poor women but by 2010, their rate had

[15] Fenelon and Preston (2012) estimate that smoking can explain 60% of the differences in age 50-plus mortality across U.S. states.

surpassed that of rich women. The smoking gap between these two groups increased by 11 percentage points during the past 20 years, almost twice as much as the increase for men (6.4 percentage points). This pattern is in line with the increasing inequality in female old-age mortality that we observe between rich and poor counties between 1990 and 2010 (note the significant steepening of the line for females age 50+ in Figure 3).

These findings suggest that at least part of the diverging mortality rates currently observed at older ages might be a temporary phenomenon driven by a strong improvement in health behavior which simply occurred with some lag among the poor. Once the later-born cohorts, which experienced strong reductions in smoking among both rich and poor, enter old age and replace these transition cohorts, smoking-induced mortality among the elderly is likely to converge to lower levels. The right panel of Figure 6 shows that the fraction who ever smoked is already much lower among adults aged 18 to 40. Moreover, the rates look quite similar regardless of poverty status for men. Among women, the poor are still more likely to smoke, but the rates are falling at roughly similar rates across all groups. When these cohorts reach old age in the coming decades, society will fully reap the benefits of the "anti-smoking dividend," resulting ceteris paribus in lower mortality and decreasing inequality in mortality at these ages.

Other factors also may have impacted inequality in mortality between counties. Improvements in medical care, such as for heart disease, seem likely to have reduced health inequality as they have diffused over time, other things being equal. The gap in obesity rates between rich and poor has also been narrowing, but this development is driven by increasing obesity among the rich, which may in fact auger higher death rates for rich and poor in future (NRC, 2015). Case and Deaton (2015) highlight another factor that may be driving increased inequality in some segments of the population: the opioid epidemic. It may be possible to address these questions using the cause of death in the Vital Statistics Mortality data. However, given the issues discussed above with respect to changes in measurement, measurement error, and missing data about causes, these data are unlikely to provide a definitive answer.

Discussion and Conclusions

In contrast to many recent analyses of mortality inequality, we find improvements in overall life expectancy in both rich and poor counties. Our focus on life expectancy at birth rather than life expectancy in middle age may explain this finding. We find that inequality in mortality has fallen greatly among children. It is worth emphasizing that the reductions in mortality among African Americans, especially African-American males of all ages, are stunning and that is a major driver of the overall positive picture. This positive finding has been largely neglected in much of the discussion of overall mortality trends. Although our overall message is more positive than some earlier studies, we do find increases in mortality among white women aged 20 to 49, which are stronger in the poorest counties, indicating increasing inequality in mortality in that group.

It sometimes seems as if the research literature on mortality is compelled in some way to emphasize a negative message, either about a group that is doing less well or about some aspect of inequality that is rising. In contrast, this study is one of comparatively few, along with Aizer and Currie (2014) and Currie and Schwandt (2016), that have emphasized improvements in life expectancy across the broad U.S. population. Our results point to strong health improvements and decreasing inequality, particularly among the younger cohorts who will form the future adult population of the U.S. Given the growing literature demonstrating a connection between health in childhood and future health (c.f. Currie and Rossin-Slater, 2015), this improvement in health among young people in poor counties suggests that these cohorts may well be healthier and suffer less mortality inequality in the future than those who are currently middle aged and older. In addition, much of the increase in inequality in older cohorts in the past 20 years has been driven by historical smoking patterns. Current cohorts have much lower lifetime smoking rates, which is also likely to lead to more convergence in mortality rates.

We believe that a balanced approach to the mortality evidence, which recognizes real progress as well as areas in need of improvement, is more likely to result in sensible policy-making. After all, emphasizing the negative could send the message that "nothing works," especially in the face of seemingly relentless increases in income inequality. We have emphasized considerable heterogeneity in the evolution of mortality inequality by age, gender, and race. Going forward, identifying social policies that have helped the poor and reduced mortality inequality is an important direction for future research. Similarly, understanding the reasons that some groups and age ranges have seen stagnant mortality rates will be important for mobilizing efforts to reduce inequality in mortality and improve the health of the poor.

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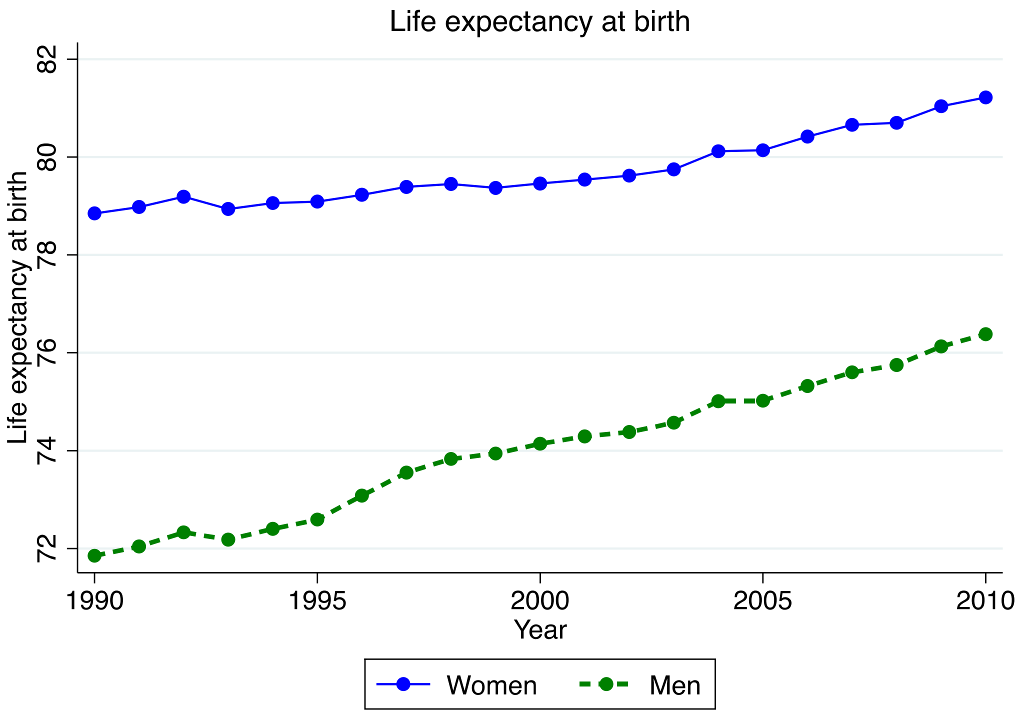
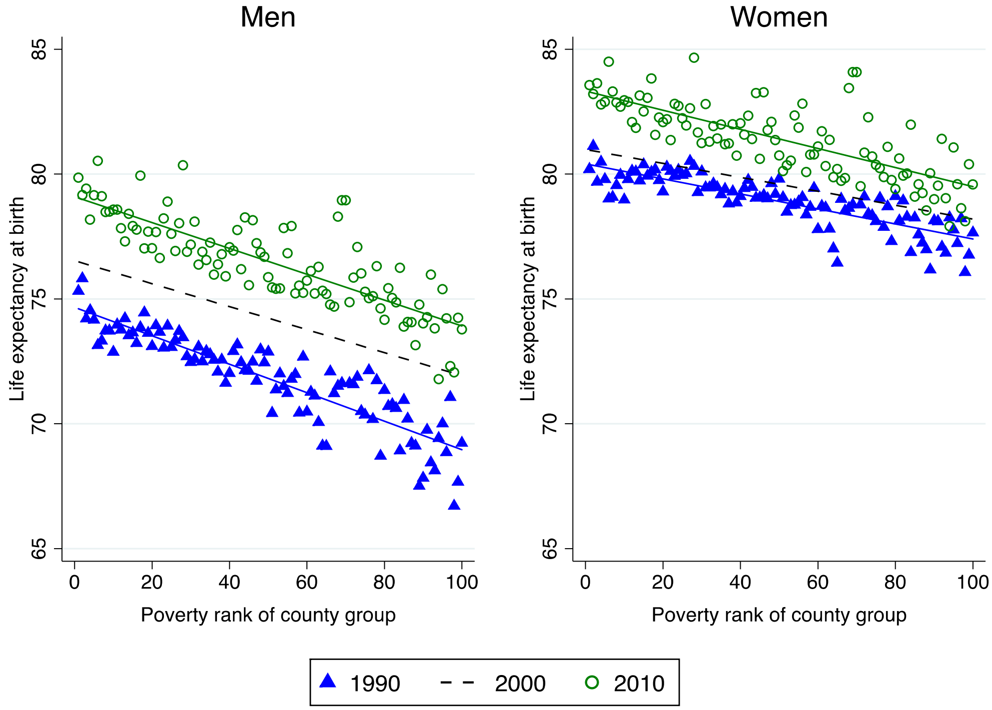
Figures and Tables

Figure 1: Life expectancy at birth by gender and year



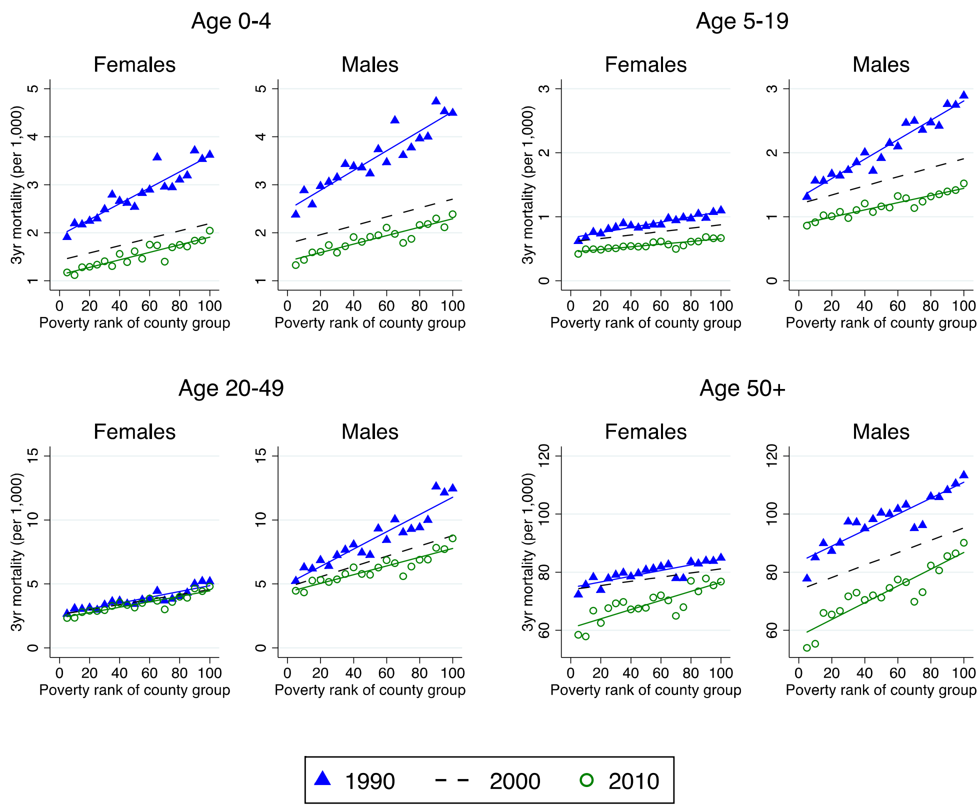
Notes: Data source: HMD (2015).

Figure 2: Life expectancy at birth across poverty percentiles



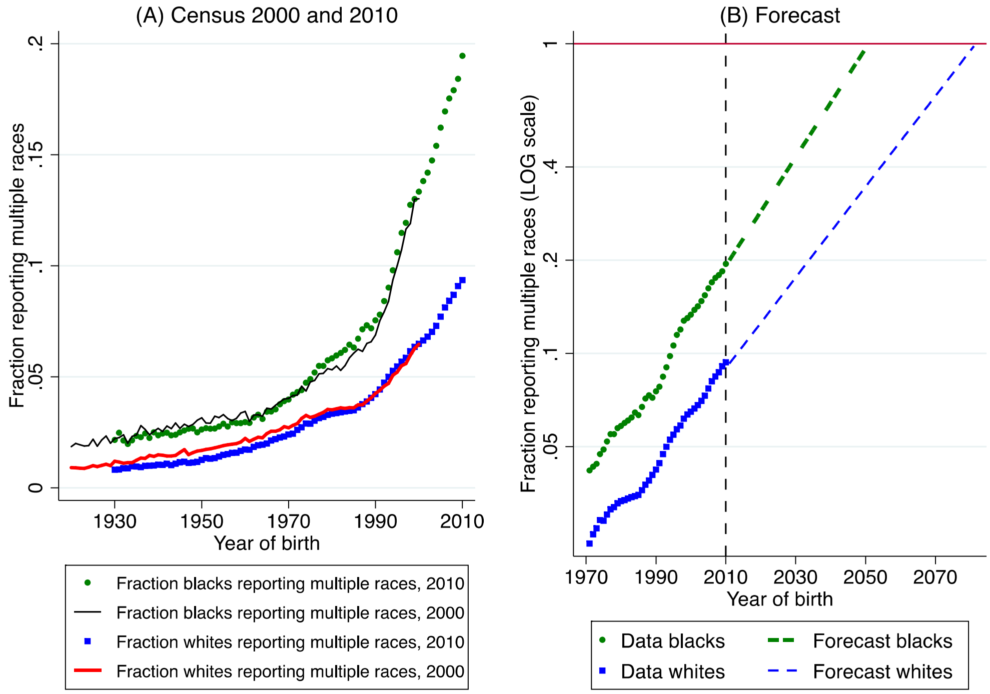
Notes: Counties are ranked by their poverty rate in 1990, 2000, and 2010, and divided into groups each representing about 1% of the overall population. Each marker represents the life expectancy at birth in a given county group. Lines are fitted using OLS regression. For 2000, markers are omitted and only the regression line is shown. Table A2 provides magnitudes for individual life expectancy estimates and for the slopes of the fitted lines.

Figure 3: 3-year mortality rates across groups of counties ranked by their poverty rate



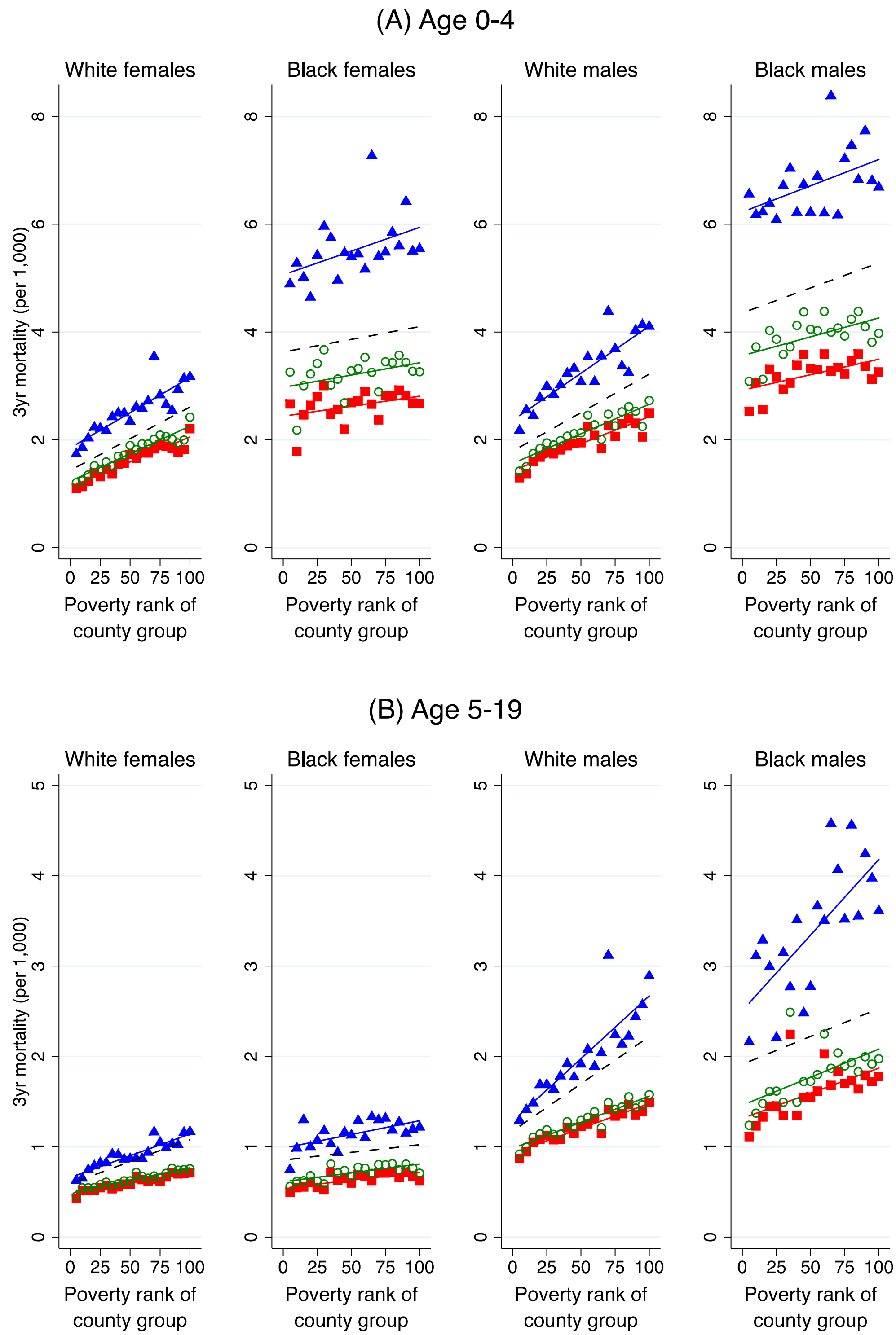
Notes: 3-year mortality rates for four different age groups are plotted across county groups ranked by their poverty rate. For further details, see the comments below Figure 2 and in the text. Mortality rates in 2000 and 2010 are age-adjusted using the 1990 population, i.e. they account for changes in the age structure within age, gender, and county groups since 1990. Table A3 provides magnitudes for individual mortality estimates and for the slopes of the fitted lines.

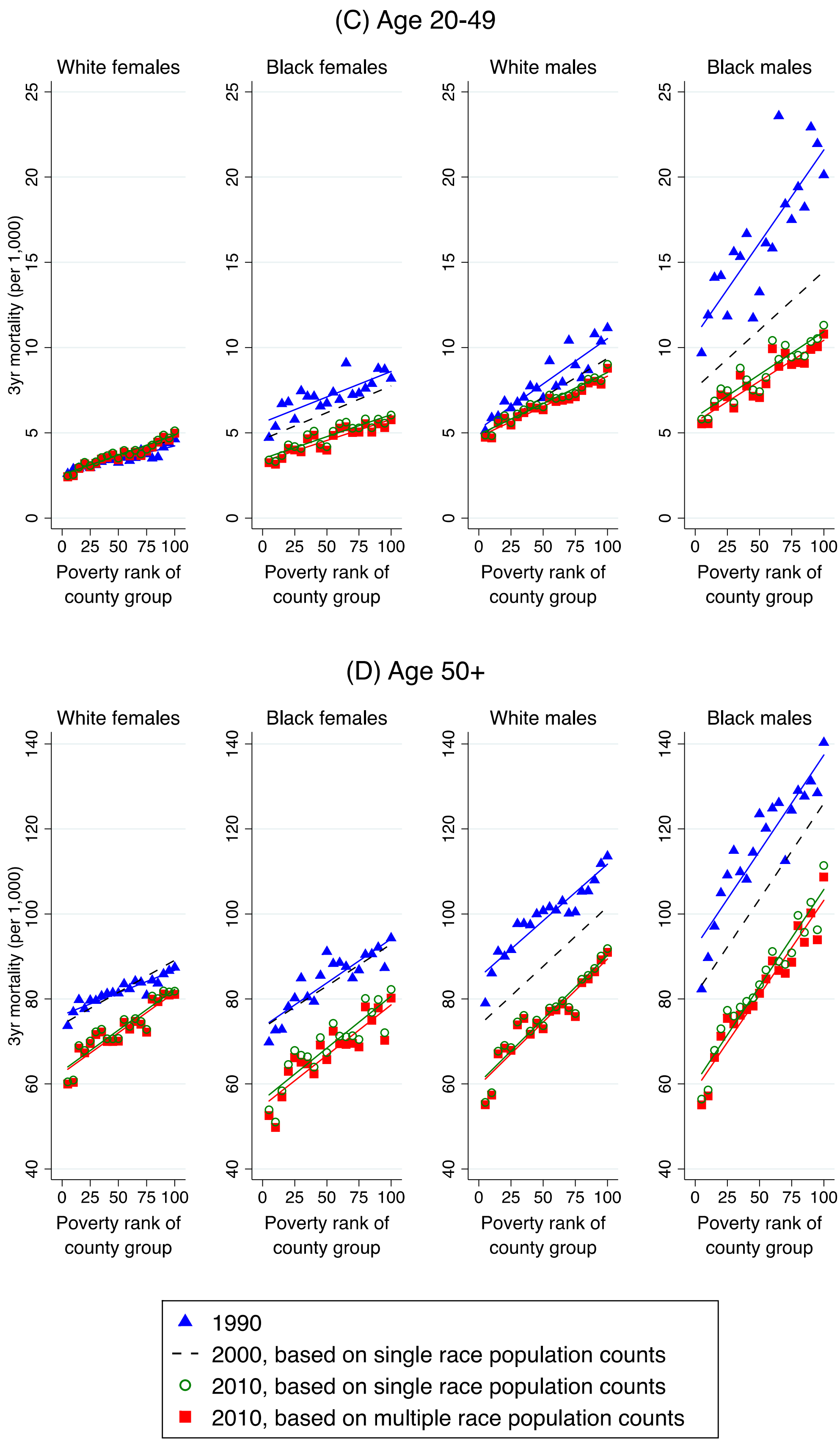
Figure 4: Fraction of the black and white U.S. population reporting multiple races



Notes: Panel (A) plots the fraction of people reporting multiple races among all those reporting that they are black (or white) alone or in combination, in the 2000 and 2010 Census. Panel (B) forecasts the fraction reporting multiple races among future birth cohorts. Assuming that the exponential growth continues, we fit a linear trend through the log fraction reporting multiple races for birth cohorts 1970 to 2010 in the 2010 Census and project this trend up to the 2080 birth cohort. The projected fraction reaches unity in 2051 for blacks and in 2081 for whites.

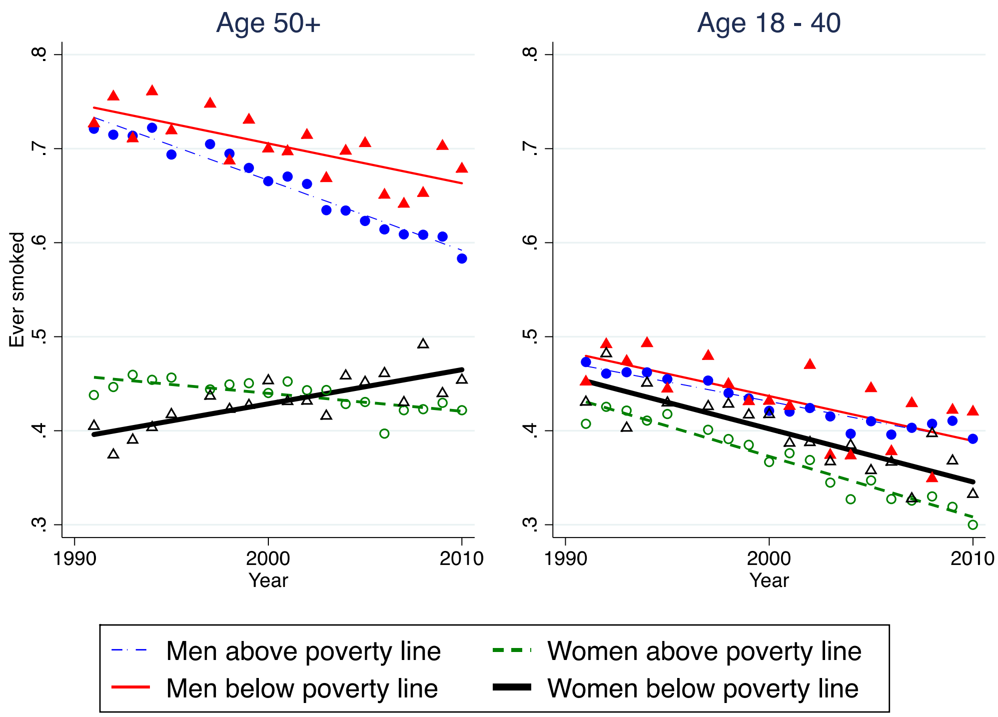
Figure 5: 3-year white and black mortality rates across poverty percentiles, based on single and multiple race population counts




(C) Age 20-49
White females
Black females
White males
Black males
3yr mortality (per 1,000)
0
5
10
15
20
25
0 25 50 75 100
Poverty rank of county group
(D) Age 50+
White females
Black females
White males
Black males
3yr mortality (per 1,000)
40
60
80
100
120
140
0 25 50 75 100
Poverty rank of county group
1990
2000, based on single race population counts
2010, based on single race population counts
2010, based on multiple race population counts

Notes: 3-year mortality rates for four different age groups are plotted separately for whites and African-Americans across county groups ranked by their overall poverty rate. For further details see the comments below Figure 2 and in the text. Green circles represent mortality rates constructed as the ratio of race-specific death counts in the Vital Statistics divided by single race population counts in the 2010 Census. The mortality rates represented by red squares are based on the same death counts, but divided by population counts including multiple race reports. Mortality rates in 2000 and 2010 are age-adjusted using the 1990 population, i.e. they account for changes in the age structure within age, gender, race, and county groups since 1990.

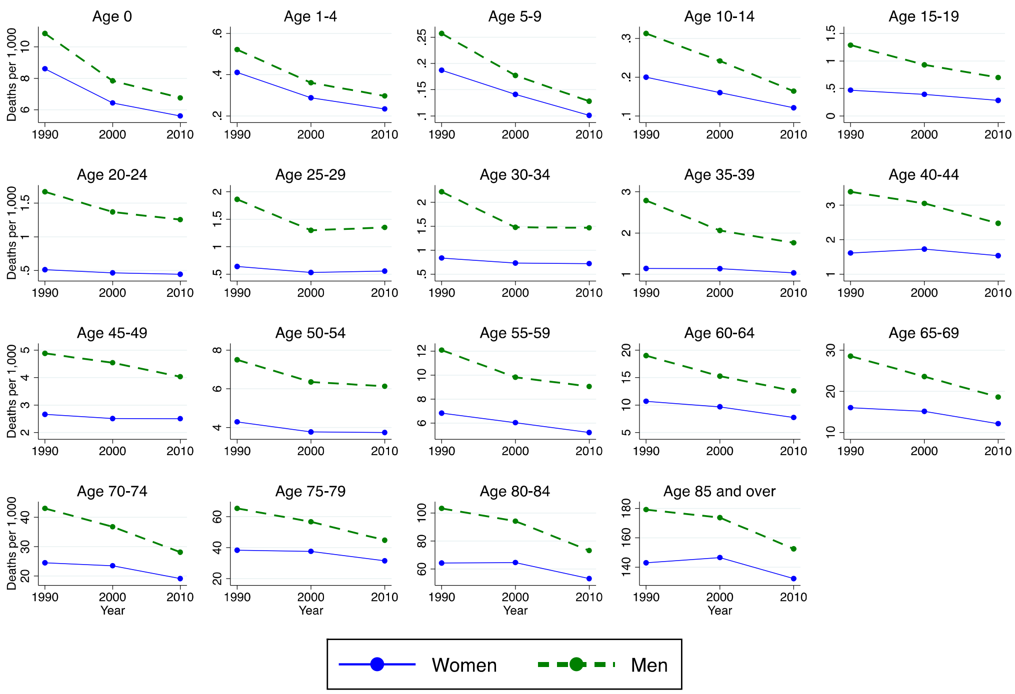
Figure 6: Fraction that ever smoked in old and young population by poverty status and gender, 1990-2010



Notes: Smoking rates in the overall old and young adult U.S. population, divided by poverty status, are plotted from 1990 to 2010. Lines are fitted based on OLS regressions. Data source is the National Health Interview Survey.

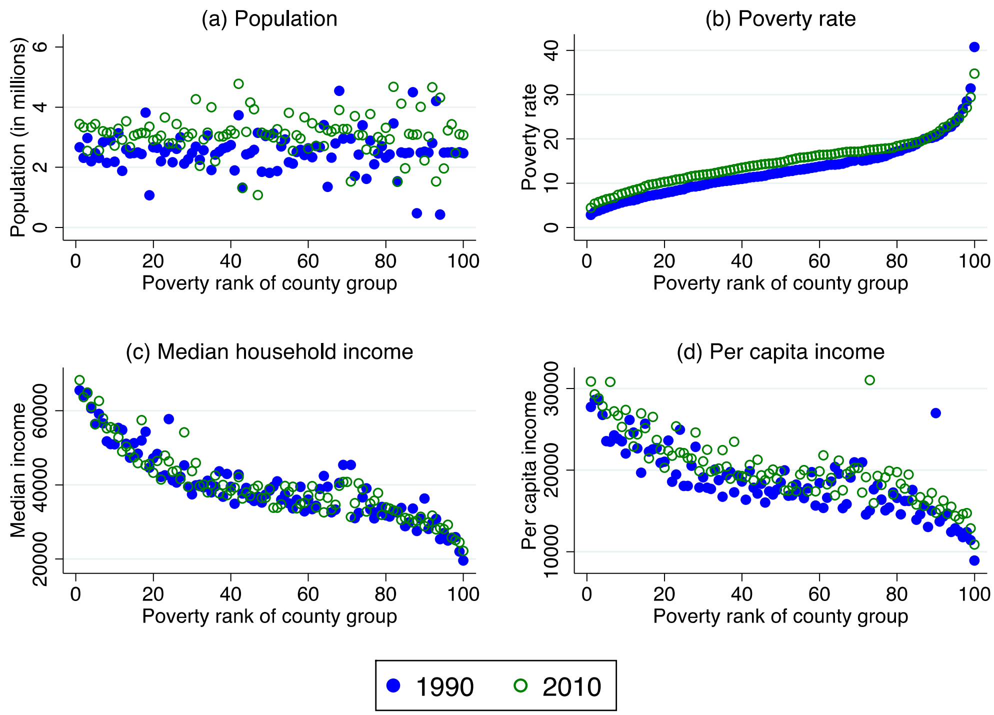
Appendix

Figure A1: 1-year mortality rates by age, overall U.S. 1990-2010



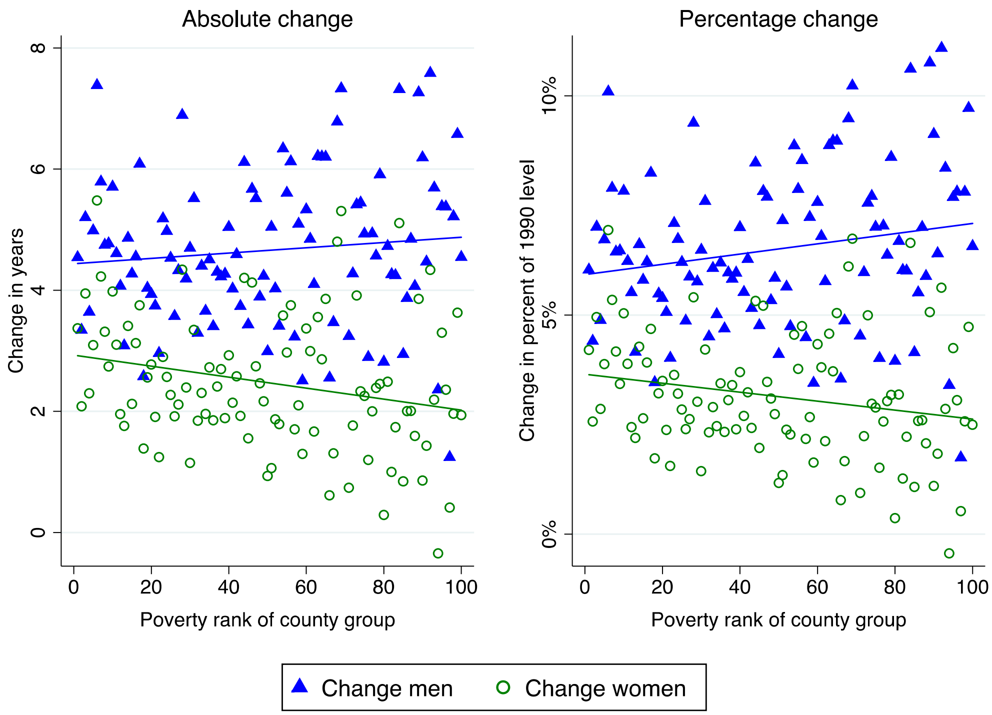
Notes: 1-year age-specific mortality rates are plotted for the overall U.S., unlike other figures in this paper which focus on 3-year mortality rates across county groups. Data source is HMD (2015).

Figure A2: County group characteristics



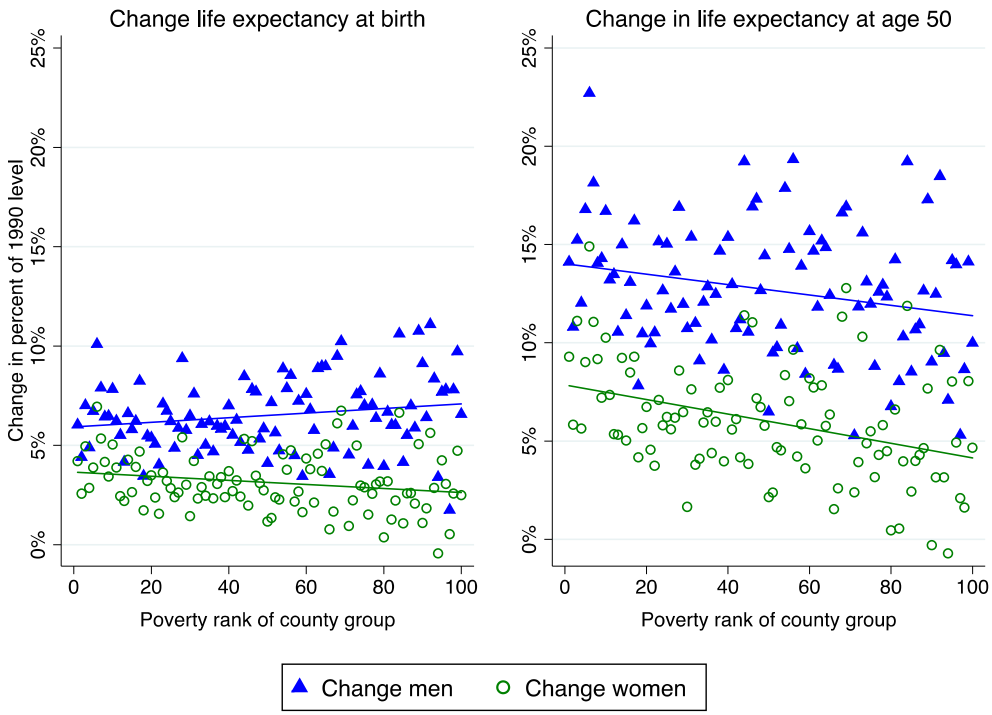
Notes: Median and per capita income are adjusted for inflation and reported in constant 1999 dollars. Median income refers to counties' median income averaged across counties in each county group, weighted by counties' population size. The outliers in panel (d) are driven by New York County, NY, a big county with both a high poverty rate and high per capita income.

Figure A3: 2010-1990 change in life expectancy at birth, in years and in percent of 1990 level



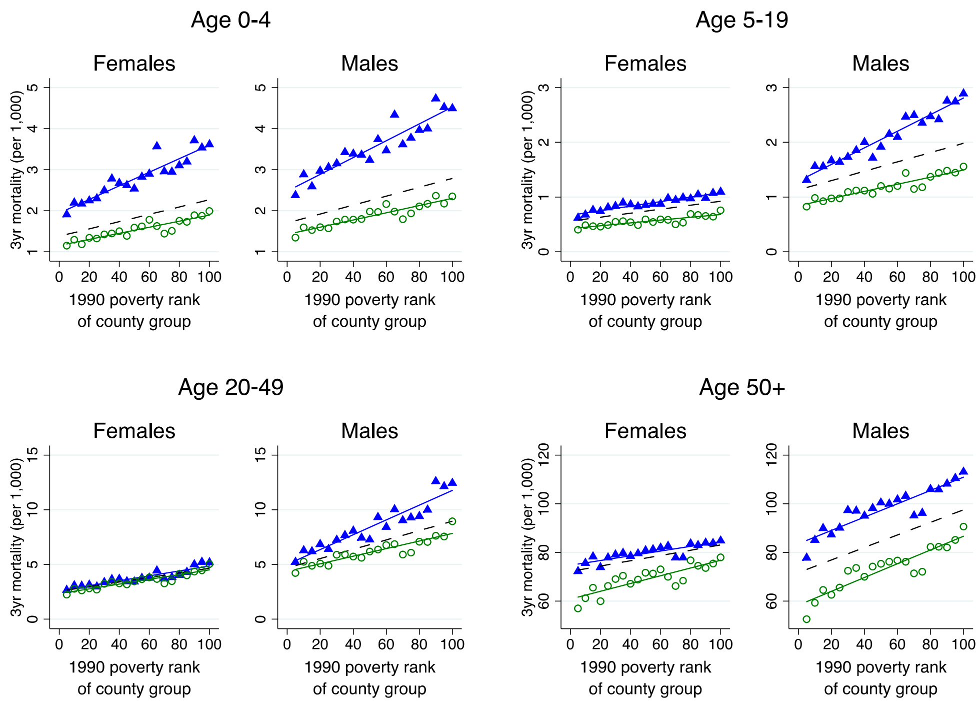
Notes: The left panel plots the change in life expectancy at birth between 2010 and 1990 for county groups ranked by their poverty rate (for the levels in 1990 and 2010 see Fig. 2). The right panel shows the same changes, as percent of the 1990 level. Lines are fitted using OLS regression. The fitted line in the left panel has a slope of 0.004 (SE=0.004, p=0.317) for men and for women a slope of -0.009 (SE=0.004, p=0.02). The slope in the right figure is 0.012 (SE=0.006, p=0.066) for men and -0.01 (SE=0.005, p=0.04) for women. For further explanations, see the notes below Fig. 2.

Figure A4: 2010-1990 change in life expectancy across poverty percentiles at birth and at age 50



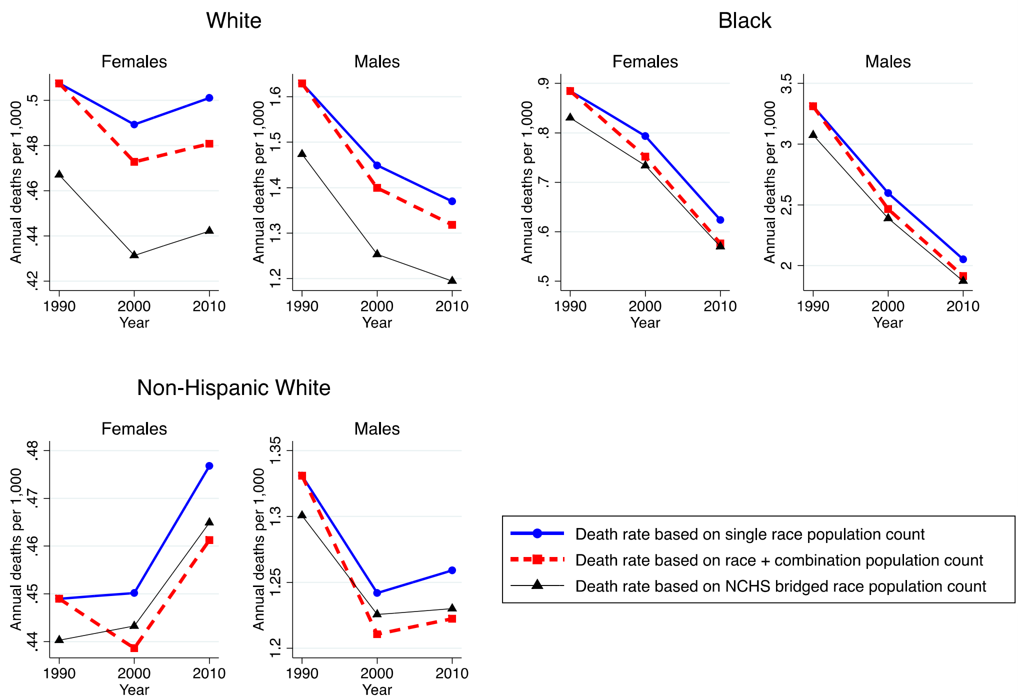
Notes: The left panel plots the county group-specific change in life expectancy between 2010 and 1990 as a percent of the 1990 level (as in Fig. A3). The right panel shows the same percentage changes for life expectancy at age 50. Lines are fitted using OLS regression. For further explanations, see the notes below Fig. 2.

Figure A5: 3-year mortality rates across groups of counties ranked by their poverty rate in 1990



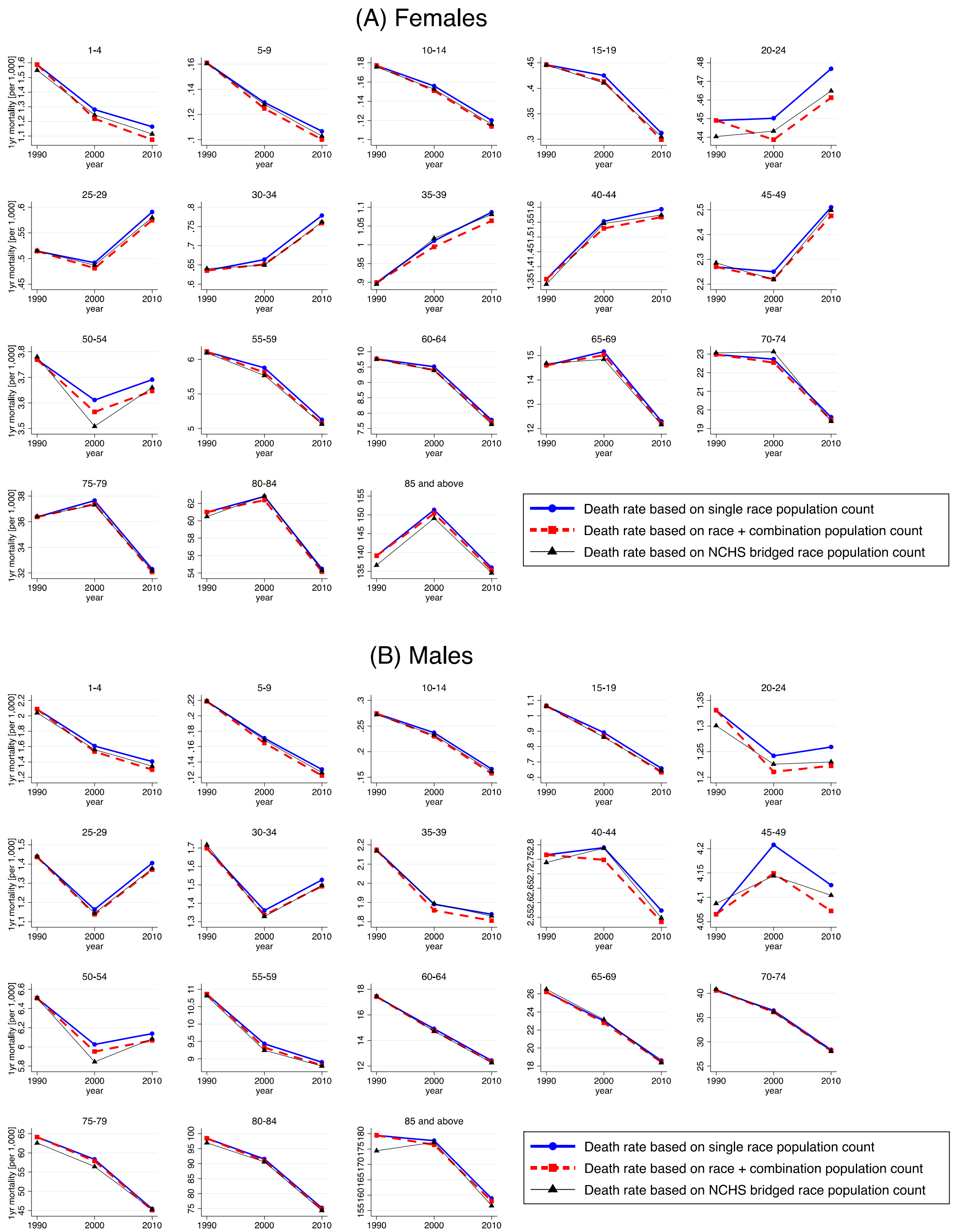
Notes: This figure replicates Fig. 4, holding the 1990 poverty rank of county groups fixed. Counties are ranked and divided into groups in 1990, and these groups are followed over time without reordering until 2010. For further explanations, see comments below Fig. 4.

Figure A6: 1-year mortality rates at age 20-24, by race, based on different population counts



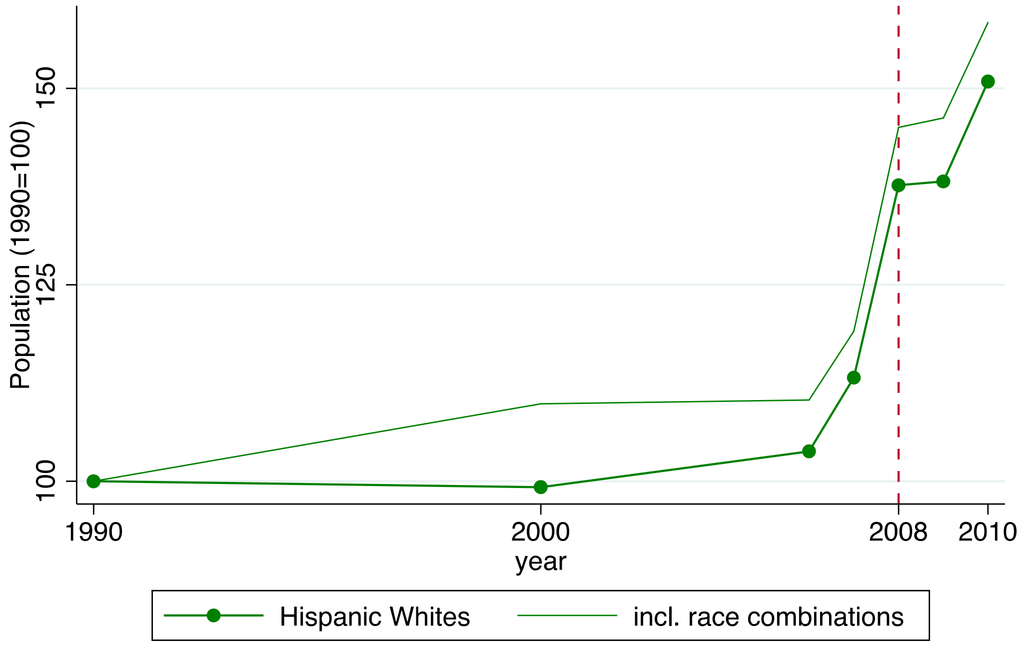
Notes: These figures show race and gender-specific mortality rates (death counts divided by population counts) at age 20 to 24, based on same death counts but using different population counts. For the blue dots, these death counts are divided by single race population counts. The red squares, on the other hand, are based on population counts that include multiple race reports in 2000 and 2010. This results in a larger population denominator and thereby in a lower mortality rate. The black triangles, instead, use the *Vintage 2010 Bridged-Race Postcensal Population Estimates* provided by the National Center for Health Statistics (NCHS). These bridged estimates divide the entire population into four race categories (white, black, native American, and Asian), with the majority of multiple race or "other race" reports being assigned to Hispanic white. This inflates the white population denominator and attenuates the white mortality rate.

Figure A7: 1-year mortality rates for non-Hispanic whites, based on different population counts



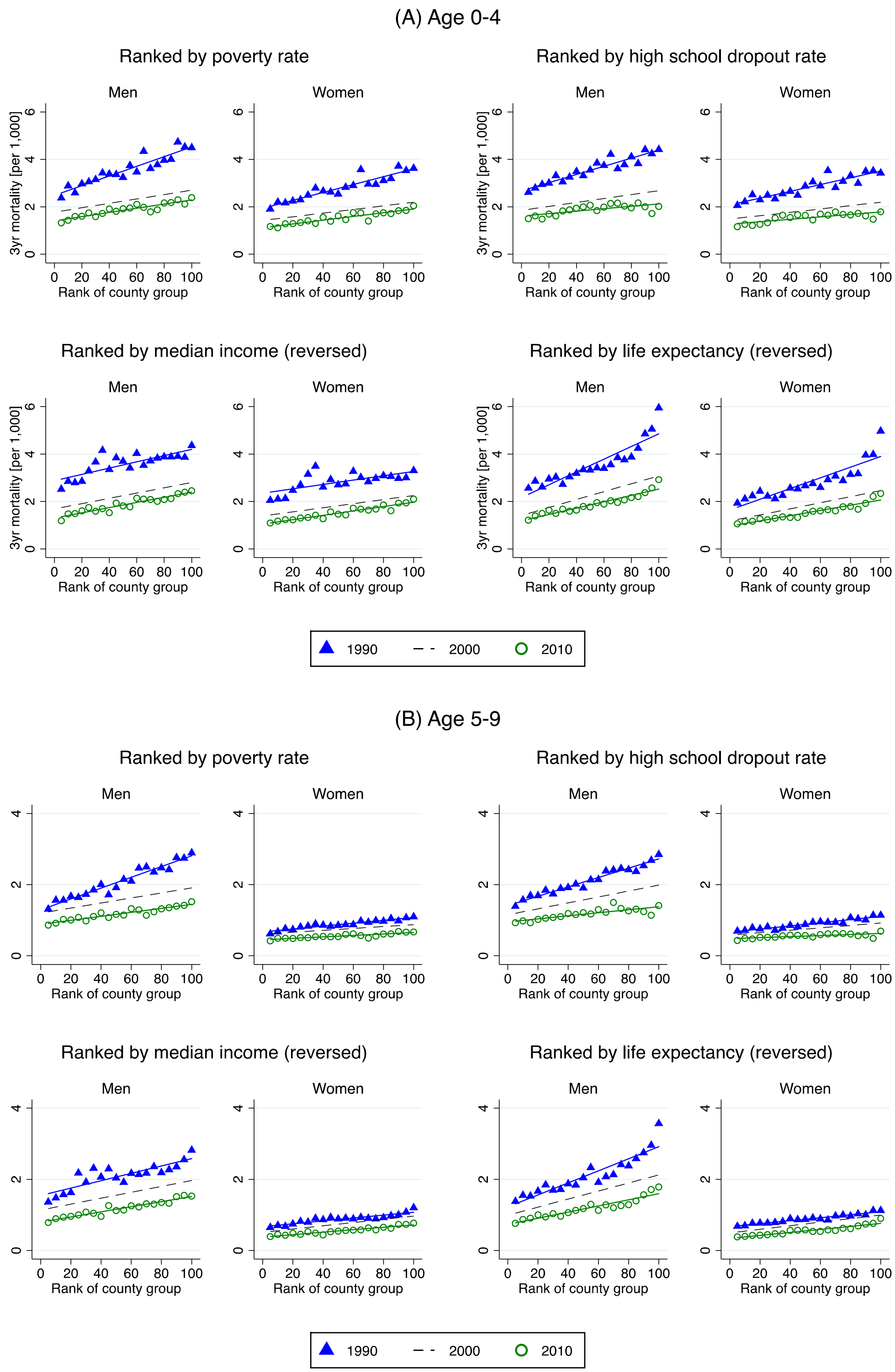
Notes: These figures show death rates for non-Hispanic white females and males across age groups, based on different population counts. For further comments see the notes below the previous figure.

Figure A8: Size of U.S.-born Hispanic white birth cohorts born 1969-1971 (1990=100)

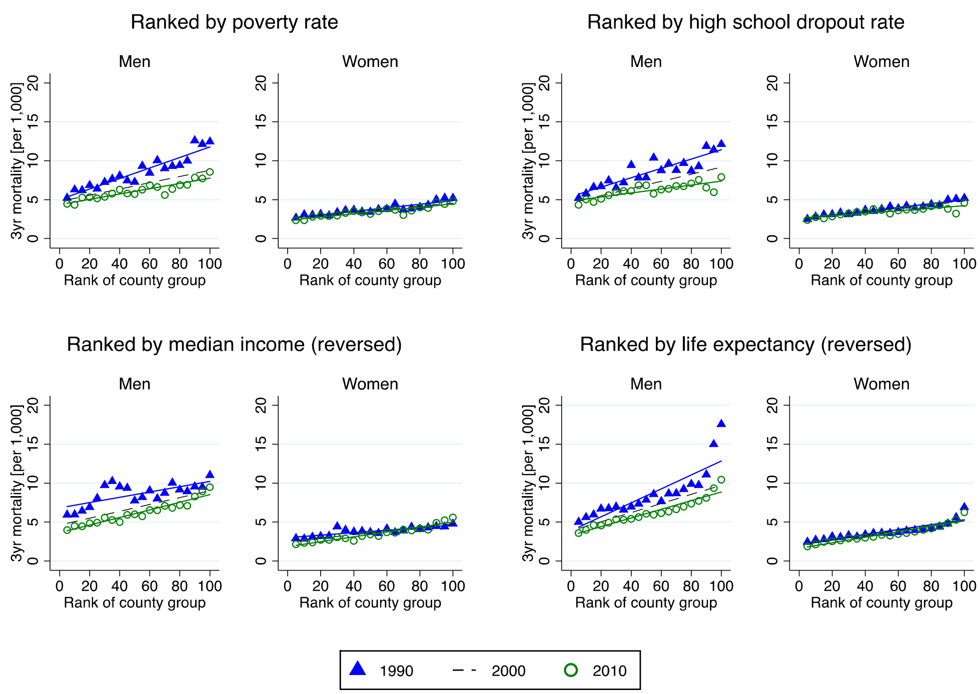


Notes: The sample consists of Hispanic whites born in the U.S. between 1969--1971. The population size is plotted relative to 1990. The size of this group should shrink over time, as people die and as more people might leave the country than return (after having left beforehand). Data sources are the 1990/2000 Census and the 2006-2010 ACS. In 2008, the question regarding Hispanic origin was changed, likely extending the measure to U.S.-born Hispanics who had not identified as Hispanics before. A comparison with the 2010 Census is not possible, since information about the respondent's birth place is not available in the short form used for that Census wave.

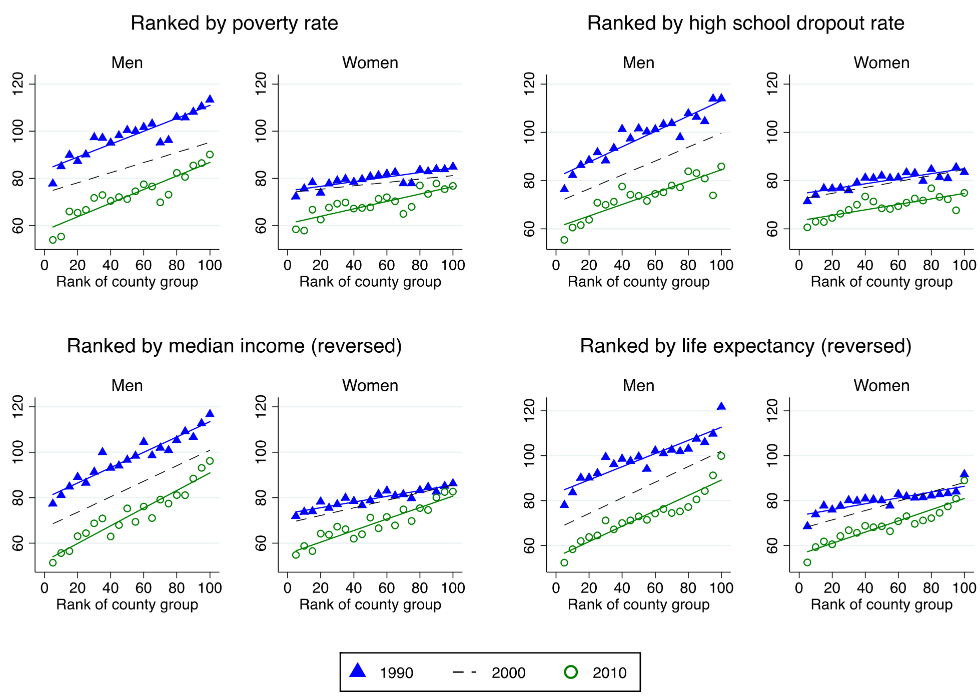
Figure A9: 3-year mortality rates ranked using alternative county characteristics



(C) Age 40-49



(D) Age 50+



Notes: These figures replicate the age-specific mortality rates across county groups shown in Figure 3, using alternative characteristics to rank counties. The rankings for median income and life expectancy are reversed, such that a higher ranking refers to a lower value. The ranking by life expectancy requires life expectancy estimates at the county level, which are provided by IHME (2013). Mortality rates in 2000 and 2010 are age-adjusted using the 1990 population.

Table A1: Changes in life expectancy and population share by education and individual counties

A. By education groups (following Olshansky et al. 2012)

White non-Hispanic females, age 25-84	<12 years of education	16+ years of Education
Change in life expectancy at birth, 1990-2008 (*)	-3.94	4.12
Population share in 1990	7.10%	9.75%
Population share in 2010	2.42%	10.90%
Percentage change in population share	-65.97%	11.71%

(*) Reported by Olshansky et al. (2012)

B. By counties ranked in terms of life expectancy change (following Wang et al. 2013)

	20 counties with strongest *decrease*	20 counties with strongest *increase*
	in female life expectancy from 1985 to 2010	
Change in female life expectancy at birth, 1985-2010 (**)	-2.68	6.16
Combined population share in 1985	0.18%	4.50%
Average population growth, 1985-2010	-6.15%	101.39%
Population weighted population growth, 1985-2010	-1.51%	44.68%
US population growth, 1985-2010	30.39%	

(**) Reported by Wang et al. (2013)

Notes: This table shows life expectancy and population changes for different subgroups defined by education and location that were used in Olshansky et al. (2012) and Wang et al. (2013). The changes in life expectation are taken from the respective publication, while the population growth estimates are the authors' calculations based on US Census data.

Table A2: Life expectancy for selected county groups and slope of regression lines, 1990 vs. 2010

	Life expectancy at birth across gender, years, and county groups							
	Males				Females			
	1990		2010		1990		2010	
	value	std. err.	value	std. err.	value	std. err.	value	std. err.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a) LE at birth by poverty ranking of county group								
1	75.32	0.13	79.86	0.11	80.20	0.13	83.57	0.10
25	73.07	0.15	77.60	0.12	79.96	0.14	82.23	0.11
50	72.88	0.17	75.87	0.12	79.81	0.16	80.74	0.12
75	70.36	0.19	75.29	0.14	78.11	0.18	80.37	0.13
100	69.23	0.16	73.78	0.13	77.65	0.14	79.59	0.12
(b) Slope of fitted regression line								
	Slope 1990		Slope 2010		Slope 1990		Slope 2010	
	-0.0570		-0.0518		-0.0300		-0.0383	
(c) p-value of test Slope1990=Slope2010								
	0.2748				0.0436			

Notes: Panel (a) shows life expectancy along with standard errors for the counties in the 1st, 25th, 50th, 75th and 100th poverty percentile, as plotted in Fig. 2. Panel (b) reports the slopes of the fitted regression lines plotted in Figure 2. Panel (c) reports the p-value of the difference between the two slopes.

Table A3: Age-specific mortality in the richest and poorest county groups and slope of regression lines, 1990 vs. 2010

	3-year mortality (per 1,000) in 5% of the population living in								Slope of fitted regression line		
	counties with lowest poverty rate				counties with highest poverty rate						
	1990		2010		1990		2010				p-value of
	rate	std. err.	rate	std. err.	rate	std. err.	rate	std. err.	1990	2010	difference
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Males											
Age 0-4	2.38	0.07	1.32	0.05	4.49	0.09	2.39	0.07	0.020	0.009	<0.001
Age 5-19	1.31	0.03	0.86	0.03	2.89	0.04	1.52	0.03	0.015	0.006	<0.001
Age 20-49	5.23	0.04	4.46	0.04	12.44	0.07	8.56	0.06	0.068	0.034	<0.001
Age 50+	77.74	0.23	53.93	0.19	113.10	0.27	90.10	0.25	0.274	0.288	0.734
Age 65+	154.96	0.50	108.25	0.43	185.41	0.49	147.15	0.45	0.246	0.322	0.096
Females											
Age 0-4	1.91	0.07	1.17	0.05	3.61	0.09	2.04	0.07	0.017	0.008	<0.001
Age 5-19	0.62	0.02	0.42	0.02	1.10	0.03	0.67	0.02	0.004	0.002	<0.001
Age 20-49	2.66	0.03	2.34	0.03	5.19	0.04	4.80	0.04	0.023	0.021	0.665
Age 50+	72.27	0.20	58.42	0.18	84.80	0.21	76.76	0.20	0.097	0.157	0.046
Age 65+	132.35	0.39	109.46	0.35	136.18	0.35	124.04	0.34	0.052	0.155	0.007

Notes: Columns (1) to (8) show mortality rates for the bottom and top ventile of county groups, as plotted in Fig. 3 (age group 65+ is added), along with standard errors. Columns (9) and (10) report the slope of the fitted regression lines for 1990 and 2010 in Fig. 3, and (11) reports the p-value of the difference between the two slopes.