Mortality and Longevity

Diversity, Equity and Inclusion

Mortality Improvement Trends

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Mortality Improvement Trends

Independent Analysis on Socioeconomic and Other Drivers

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The purpose of this report is to quantify differences in mortality improvement between key socioeconomic groups and to demonstrate how these differences are changing over time.

Mortality improvement is an important assumption for projecting future liability cash flows and can have a material financial impact. In practice, a general population mortality improvement assumption is often used. However, this approach may result in significant over-or-underestimation depending on the demographics of the underlying population. Practitioners who understand the socioeconomic factors that differentiate mortality improvement may be better positioned to capture future mortality changes more accurately.

Section 1: Executive Summary

1.1 LITERATURE REVIEW

A literature review was performed on mortality improvement, socioeconomic differences in mortality and their links to specific causes of death, and methods for analysis. It highlighted the fact that socioeconomic status (e.g., income and education) is closely linked to differences in mortality and that the longevity gap between socioeconomic groups is growing over time. It also informed the selection of key variables and the need to view mortality improvement as a complex interaction between specific causes of death.

Existing literature lacked analysis that covered individuals (rather than ZIP code or county-level groupings) and multiple socioeconomic variables (rather than just income) across multiple causes of death. The research represented in this report seeks to address these gaps.

For more detail on the literature review, see Appendix A: Literature Review and Appendix G: References.

1.2 DATA, METHODS, AND KEY RESEARCH QUESTIONS

In collaboration with the U.S. Census Bureau, a dataset spanning 35 years, containing 330,000+ deaths, and 7+ million survey records, was analyzed for mortality improvement patterns across key variables and causes of death. The observation period spans 1980 to 2015 and does not include COVID-related mortality. For more detail on the data, see Appendix B: Data Source and Preparation.

The following variables were added one at a time to a Cox (proportional hazards) regression model to assess if they had sufficient additional explanatory power to be incorporated into the analysis:

- Attained Age Group
- Sex
- Smoker Status
- Household Income Decile
- Educational Attainment

- Race/Ethnicity[†]
- Employment Status
- Marital Status
- Occupational Group

Each variable was analyzed individually while controlling for all other variables across five major causes of death. The goal was to answer the following research questions:

1. How does mortality improvement differ across selections for each variable?
2. Are these differences changing over time?
3. What are the drivers (i.e., causes of death) for these differences?
4. Are the patterns likely to continue in the future?

For more detail on the methodology, see **Appendix C: Methodology**.

1.3 RESULTS AND CONCLUSIONS

Between 1980 and 2006, mortality improvement has generally accelerated, reaching a peak mortality improvement of nearly 5% annually between 2006 and 2008. Since that peak, there has been a rapid deceleration and general improvement is closer to 1% at the end of the study period. The acceleration between 1980 and 2006 is primarily driven by improvements in cancer and pulmonary disease-related improvements (likely as a result of decreased smoking rates since 1970). After 2006, cancer and pulmonary disease-related mortality improvement stop accelerating, while heart disease experiences rapid deceleration. To the extent unhealthy lifestyle habits like poor diet, lack of exercise, and obesity continue to be common, this deceleration and negative mortality improvement linked to heart disease is likely to continue. For baseline results and figures showing these trends, see **Section 2: Baseline Results**.

High-level results for the main drivers of mortality improvement are noted below. For more detailed results, see **Section 3: Detailed Results**.

- **Attained age:** There appears to be near-parallel acceleration across age groups during the first half of the study period followed by a divergence, particularly with ages 85+. Cancer is one driver where younger ages are experiencing greater mortality improvement throughout the study period, while improvement for ages 85+ is much more modest. Pulmonary is a second driver where older ages experience much more rapid acceleration in mortality improvement and have since converged with other age groups. For more detailed results, see **Section 3.1.**
- **Educational attainment:** The difference in mortality improvement between those with a college degree versus those without a college degree is less than 0.2% at the start of the study period and has grown to 1.8%. All causes of death follow this pattern of segmentation, but the gap appears strongest in heart and pulmonary-related mortality improvement, moderately present for stroke, and weakest for cancer. For more detailed results, see **Section 3.2.**
- **Household income:** The difference in mortality improvement between those in the top over the bottom income deciles was minimal until 2006. After 2006, rapid divergence created an annual improvement gap of 2.6% between those groups at the end of the study. Pulmonary demonstrated the most significant

[†] The terms for race and ethnicity used in the report are the terms used by the U.S. Census Bureau, the data source, and may not reflect SOA preferred language. Definitions of the terms may be found in Appendix B.

gradient and a striking inflection point near 2000 where the gradient reverses across deciles. For more detailed results, see **Section 3.5.**

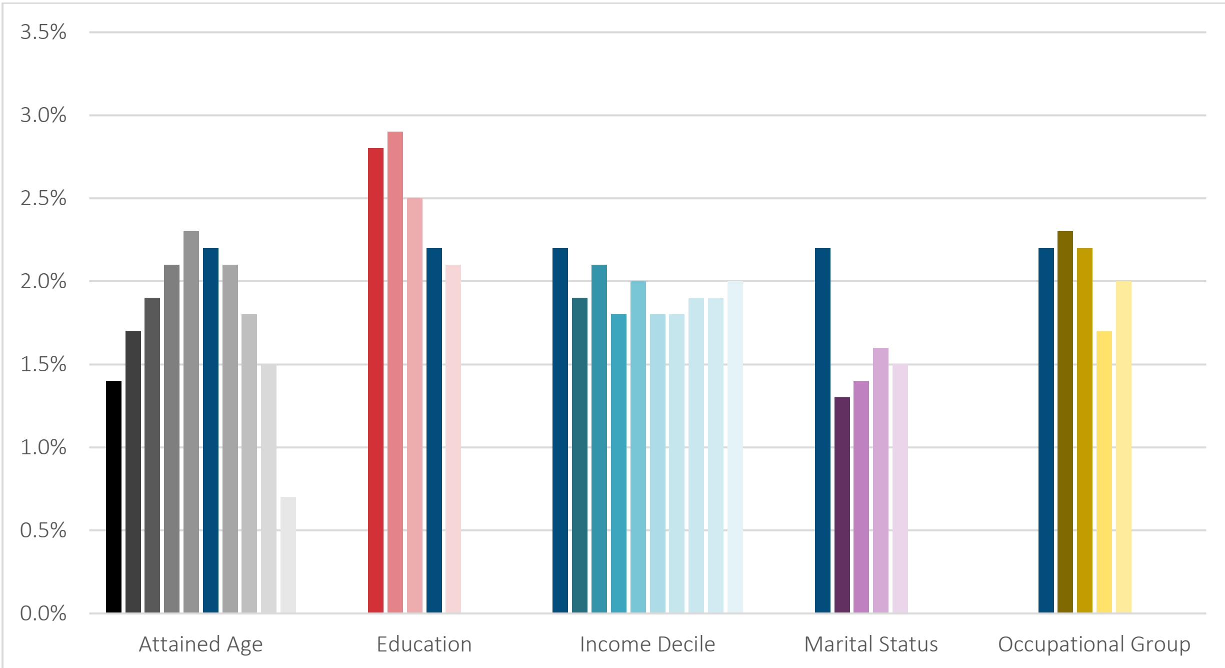
- **Marital status:** Results were mixed prior to 2003; however, after 2003, rapid divergence created a mortality improvement gap of 2.4% between those who are married over those who have never been married. Individual causes of death were generally consistent with this trend, although the pattern was greatest for cancer, heart and stroke. For more detailed results, see **Section 3.6.**
- **Occupational group:** On an annualized basis white collar groups (professional and skilled/sales) experienced roughly 2.2% annual mortality improvement over the study period. In contrast, blue collar groups (light and heavy physical duties) experienced 1.7% and 2.0% annual mortality improvement respectively. Individual causes of death drivers were mixed; however, it is notable that professionals had the greatest mortality improvement gains from cancer while experiencing the lowest (most negative) mortality improvement from all other causes analyzed. For more detailed results, see **Section 3.7.**

Annualized improvement rates for across the study period for the variables previously noted are shown in **Figure 1**, and sex, race/ethnicity and employment status are shown in **Figure 2**. Note that the baseline results listed below are shown in blue consistently across the charts:

- Sex = Male
- Smoker Status = Not Asked
- Income Decile = 10 (most affluent)
- Education = Completed High School
- Race/Ethnicity = White Non-Hispanic
- Employment Status = Employed
- Marital Status = Married
- Occupation = Professional
- Attained Age Group = 65–69

Figure 1

ANNUALIZED MORTALITY IMPROVEMENT DIFFERENTIALS – 1980 TO 2015



U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

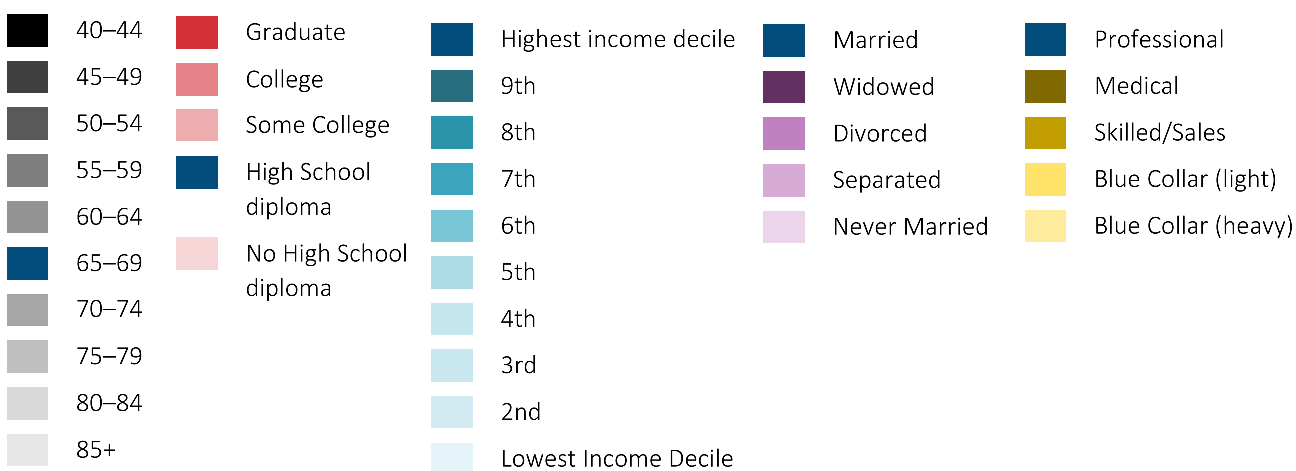
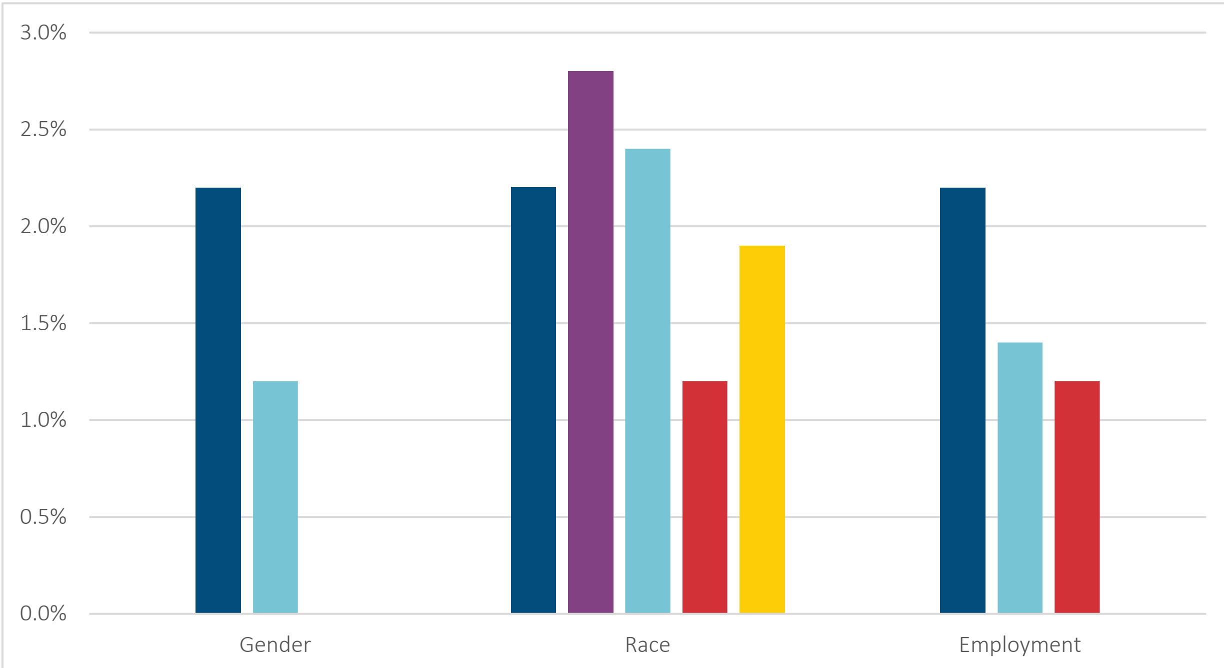
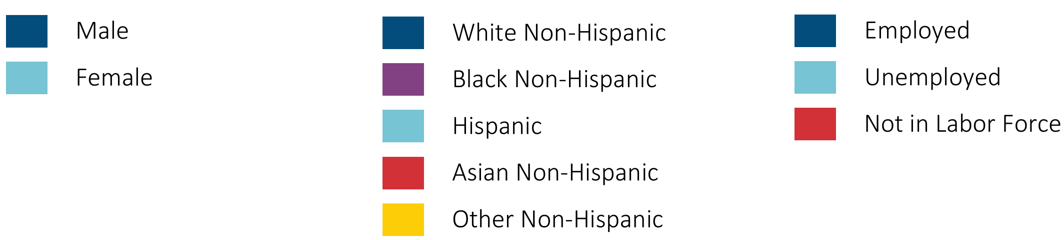


Figure 2
ANNUALIZED MORTALITY IMPROVEMENT DIFFERENTIALS – 1980 TO 2015 (CONTINUED)



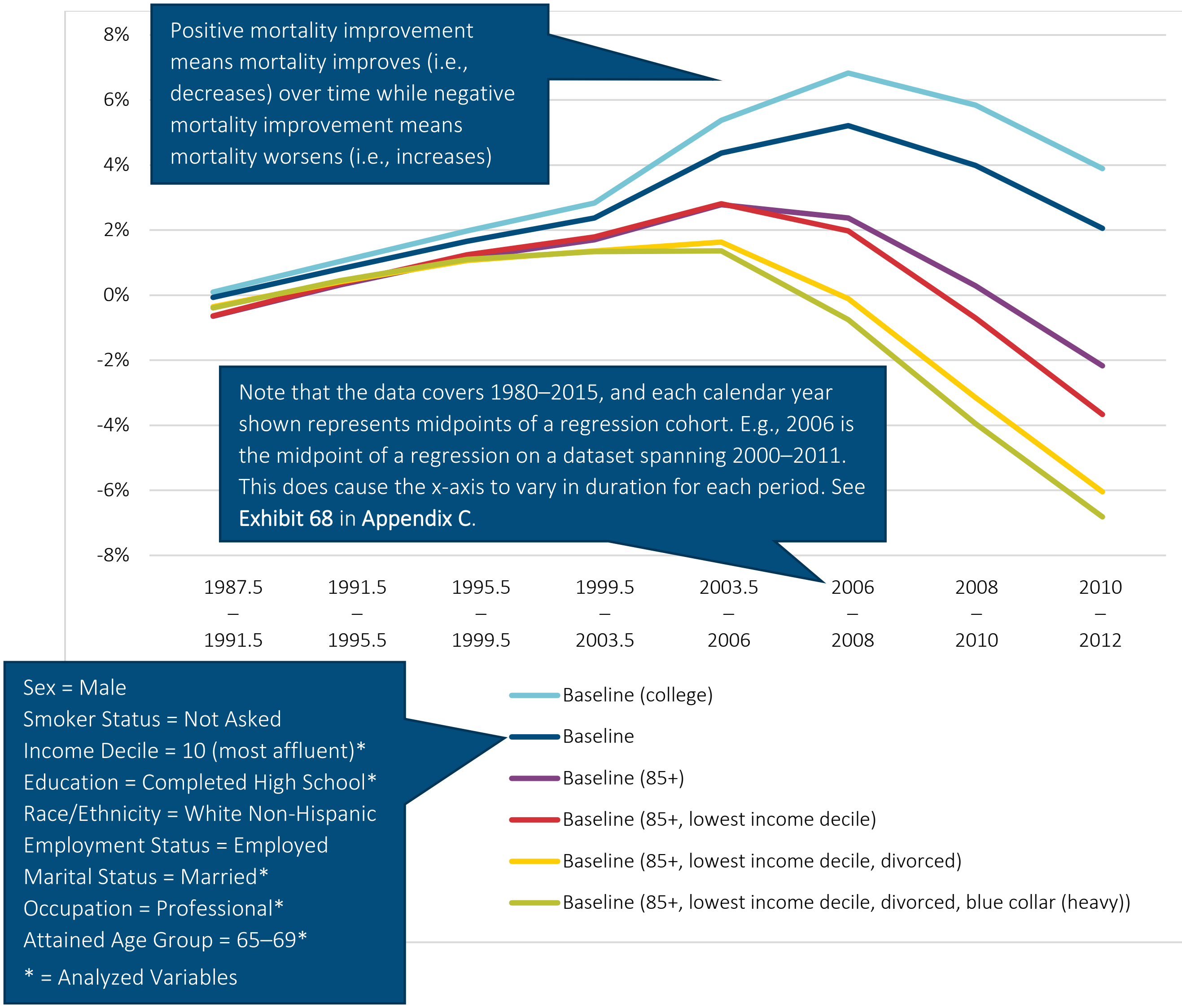
U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038



Annualized results over a 35-year period mask accelerating or decelerating trends over time and ignore absolute levels of underlying mortality. It should be noted that the modeling approach used isolates the impact of a single variable while controlling for other variables. In effect, this means that the individual differentials effectively stack up across variables. The net result is even more extreme differentials across socioeconomic groups. **Figure 3** demonstrates how the combined effects show compounded divergence over the study period. For more detail on how the results interact and how a practitioner may apply some of the results (including a workbook with model parameters), see **Section 4: Application for Practitioners**.

Figure 3

MORTALITY IMPROVEMENT BY YEAR GROUP - COMBINED EFFECTS OF KEY VARIABLES OVER TIME (DEVIATIONS FROM BASELINE)



U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Many of the patterns previously noted are likely to continue in the future. Younger ages are going to experience more mortality improvement than older ages, particularly ages 85+, where the trend is towards negative mortality improvement. The presence of a college degree will continue to act as a social barrier and be related to access to health care and lifestyle habits. Similarly, the economic and social benefits from marriage will continue to sharply divide the affluent and the poor/working class. White collar occupational groups may continue to experience greater levels of overall mortality improvement; however, that group may have already reaped the benefits of historical changes related to smoking rates and may be losing ground in lifestyle-related behavior affecting heart health.

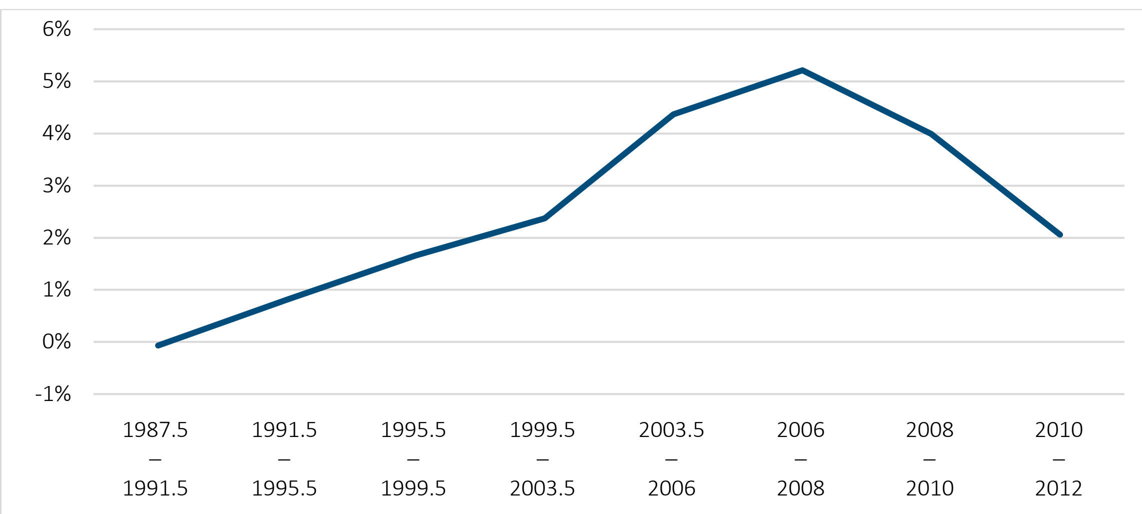
Section 2: Baseline Results

One challenge with making observations related to changes about mortality improvement is that words like "increase" and "decrease" can become confusing, particularly when the discussion revolves around changes in the rate of change. For example, mortality is improving (i.e., decreasing) any time the annual improvement is greater than 0%, whether it be 0.5% or 5%. Therefore, it is important to explicitly define the descriptive language used throughout this report.

The following observations refer to the baseline all-cause mortality regression results that are presented in **Figure 4:**

- There is **moderate** (0–2%) mortality improvement prior to 2000. This observation is strictly referring to the range of mortality improvement, not the change in improvement over time.
- For most of the periods after 2000, there is **significant** (2%+) mortality improvement. As above, this observation is strictly referring to the range of improvement, not the change in improvement over time.
- Mortality improvement is **accelerating/speeding up** through 2008. This observation refers to positive slope or rate of change of mortality improvement (i.e., second derivative of mortality).
- Between 2006 and 2008, mortality improvement **peaks** at 5% annual improvement.
  - Note that the data covers 1980–2015, and the years are the midpoints of the regression cohorts (see **Appendix C: Methodology** for more detail).
  - In other words, the label 2006 represents the time period between 2000 and 2012, with study period entry years between 2000–2004; the label 2008 represents the time period between 2004 and 2012, with study period entry years between 2004–2007.
- Mortality improvement **decelerates/slows down** after 2008. This observation is focused on the negative slope of the graph and not whether mortality improvement is positive or negative.
- For the baseline results, there are no periods of material **negative** mortality improvement or mortality **deterioration.**

Figure 4
ALL-CAUSE – BASELINE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

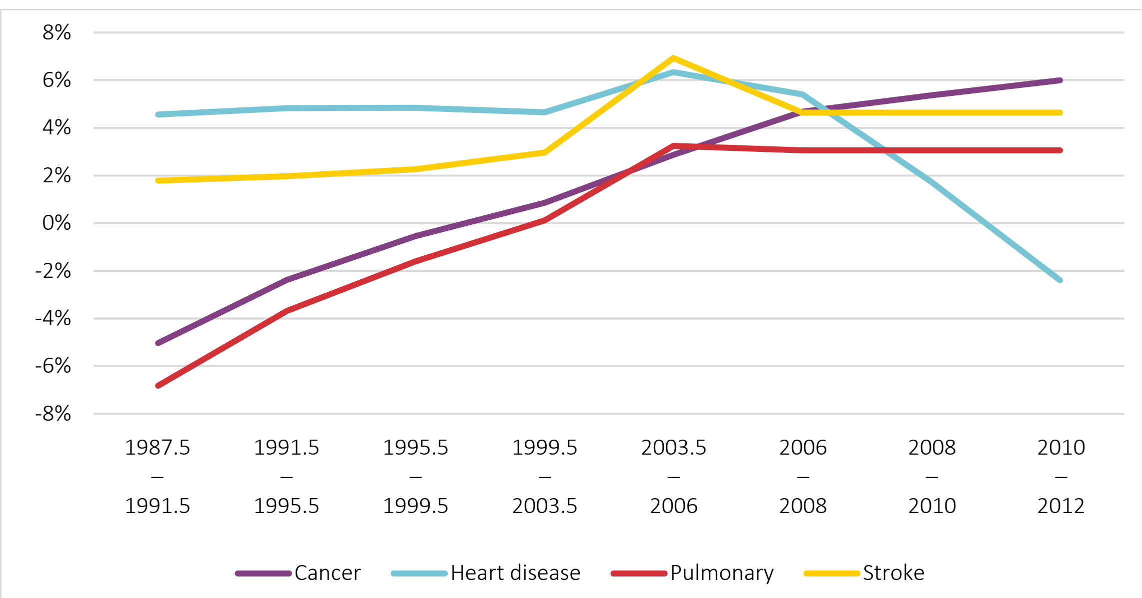
The baseline mortality improvement regression results present a pattern of acceleration followed by deceleration that will be observable throughout the remainder of this report. In each of those sections, one explanatory variable will be adjusted, holding the rest constant. In this way, the impact of each explanatory variable can be isolated while controlling for other explanatory variables. This will allow for the impact of one variable (e.g., household income) to be explored without confounding effects changes in other variables (e.g., education or race/ethnicity). In particular, the selection of baseline variables do not materially affect the improvement deltas within a variable group.

Although there may be macro-level drivers for this pattern of mortality improvement acceleration, peak, and more recent deceleration, the baseline results shown in Figure 4 is the combined effects of different causes of death and the associated impacts on different socioeconomic subgroups. Therefore, we reserve further observations about why this pattern has emerged for the detailed cause of death and socioeconomic variable sections.

While many causes of death were investigated (e.g., opioid deaths) only four leading causes of death produced regression results sufficiently robust to include in this analysis. The combined effect of cancer, heart-related diseases, pulmonary-related illnesses, and stroke are the primary drivers of the all-cause mortality improvement results. Each cause of death contributes to the pattern of acceleration, peak, and deceleration in a slightly different way (see **Figure 5**):

- Cancer and pulmonary illnesses start the study period with significantly negative mortality improvement. In other words, mortality from these causes of death is getting worse year over year.
- Mortality improvement for both cancer and pulmonary illnesses accelerate throughout the study period, ultimately plateauing in more recent years.
- Heart disease starts the study period with very significant and stable mortality improvement but decelerates sharply after 2006, ultimately landing at significant negative mortality improvement.
- Stroke mortality improvement accelerates slightly over the study period but is much more stable than the other causes of death.

Figure 5
CANCER, HEART, PULMONARY, AND STROKE – BASELINE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Stroke and pulmonary deaths are flat between 2006 and 2012. This is because the 2008 and 2010 cohorts had insufficient data to perform regressions. For the remainder of this report, stroke and pulmonary graphs will show mortality improvement grouped between the years 2006 and 2012.

Mortality improvement is prone to uncertainty because it is calculated as one less the ratio of two already small mortality rates, each with their own levels of uncertainty. To address this challenge, three methods have been applied in this report. First, rounded death counts for all five causes of death are presented across all the variables in each subsections of **Section 3**. Readers can identify results that are highly credible (e.g., all-cause mortality results for males at 178,000 deaths) and results that are not credible (e.g., Asian Non-Hispanic pulmonary at 200 deaths). Second, each regression parameter prepared by the U.S. Census Bureau was accompanied by a maximum standard error. We used Monte Carlo simulation to generate 1,000 new parameters according to that standard error (one variable at a time), calculated the resulting mortality improvement, ranked the results, and measured the 95% confidence intervals. Most cases had a 95% confidence interval less than 0.1%. This uncertainty seemed unusually small, so we also applied a formulaic approach to calculating variance of a mortality improvement estimate. Although the application of the formulaic approach is problematic in this context and produces confidence intervals that are too wide, they do serve as a meaningful reminder as to which results are more certain than others. For more detail on why the formulaic confidence intervals are biased too wide and complete set of confidence intervals, see **Appendix E: Confidence Intervals**. The baseline results shown previously have the following 75% confidence intervals via the formulaic approach:

Figure 6

75% CONFIDENCE INTERVAL RADIUS – BASELINE VARIABLE SELECTION

Cause of Death	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2008	2008–2010	2010–2012
All-cause	2.1%	2.4%	2.4%	2.4%	2.6%	2.9%	4.4%	4.0%
Cancer	4.6%	4.9%	4.6%	4.6%	4.8%	4.9%	7.6%	6.7%
Heart	2.8%	3.5%	3.7%	4.2%	4.9%	5.8%	10.1%	9.8%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 7

75% CONFIDENCE INTERVAL RADIUS – BASELINE VARIABLE SELECTION

Cause of Death	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2012
Pulmonary	10.0%	10.8%	10.4%	9.5%	9.6%	7.1%
Stroke	7.5%	9.9%	9.7%	10.4%	11.7%	8.1%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Section 3: Detailed Results

3.1 ATTAINED AGE GROUP

Observations:

- **All-cause**—No clear gradient across age bands.
    - There appears to be near-parallel acceleration during the first half of the study period followed by a divergence, particularly with ages 85+ where older ages saw lower mortality improvement.
    - Annualized mortality improvement was strongest between 60–64 at 2.3% with minimal improvement after age 85+ at 0.7%.
- **Cancer**—A very strong gradient across age groups.
    - Younger ages experiencing greater cancer-related mortality improvement. This pattern is most visible in Figure 8.

Figure 8
CANCER – ANNUALIZED MORTALITY IMPROVEMENT

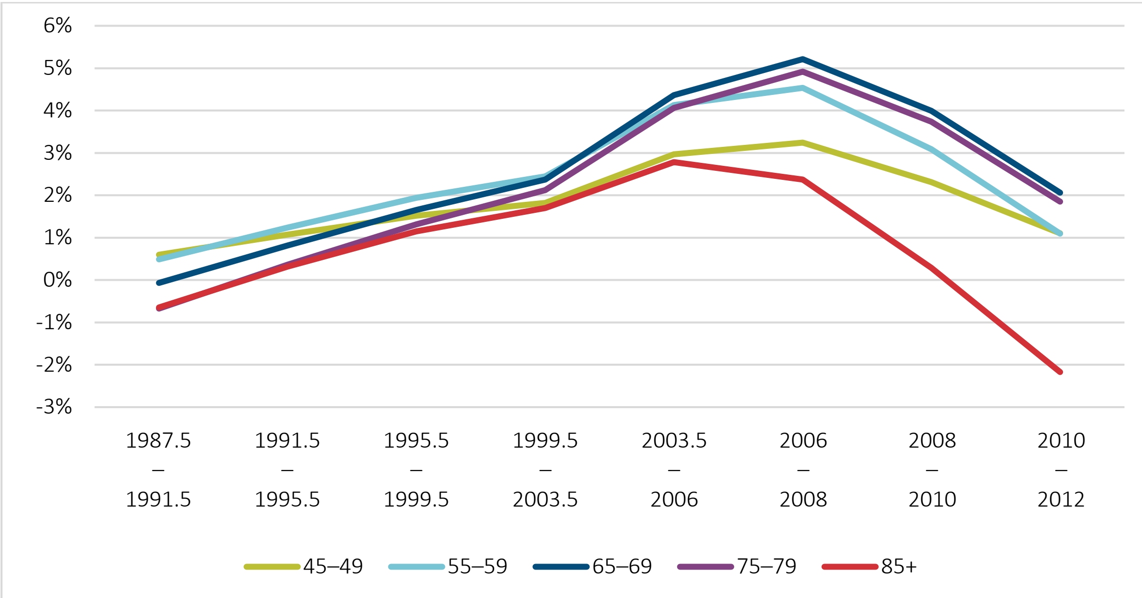
Age Group	Annualized Improvement
40–44	1.4%
45–49	1.3%
50–54	1.3%
55–59	1.1%
60–64	0.8%
65–69	0.3%
70–74	0.1%
75–79	-0.3%
80–84	-1.0%
85+	-1.0%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

- **Heart**—No clear gradient across age bands although improvement for ages 85+ is consistently the lowest.
- **Pulmonary**—Like cancer, there is a very strong gradient across age groups with convergence in recent years.
    - Younger ages experienced some acceleration mortality improvement over time, transitioning between significantly negative mortality improvement to significantly positive mortality improvement.
    - Older ages started with extremely negative mortality improvement before 2000, accelerating much more drastically throughout the study period.
- **Stroke**—Ages above 60 show a weak gradient that emerges over the study period, with notable divergence starting around year 2000.
    - For these ages, there is a near-parallel but weak acceleration during the first half of the study period that becomes more volatile.

Figure 9

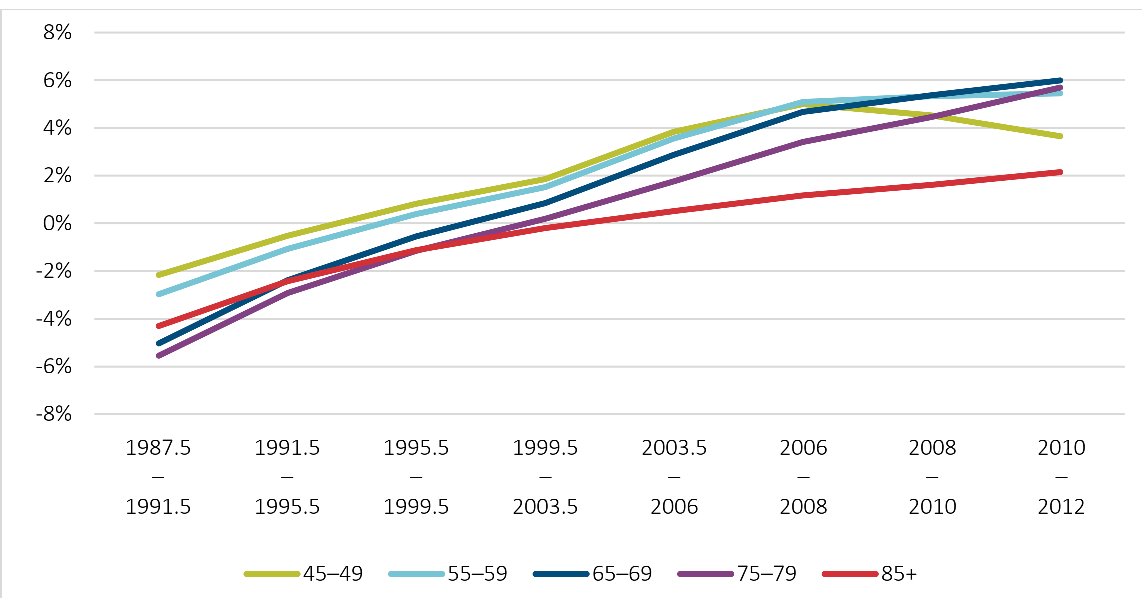
ALL-CAUSE – ATTAINED AGE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. Only some age groups are displayed to make the figure easier to read. Results with all age bands are not materially different than what is shown. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 10

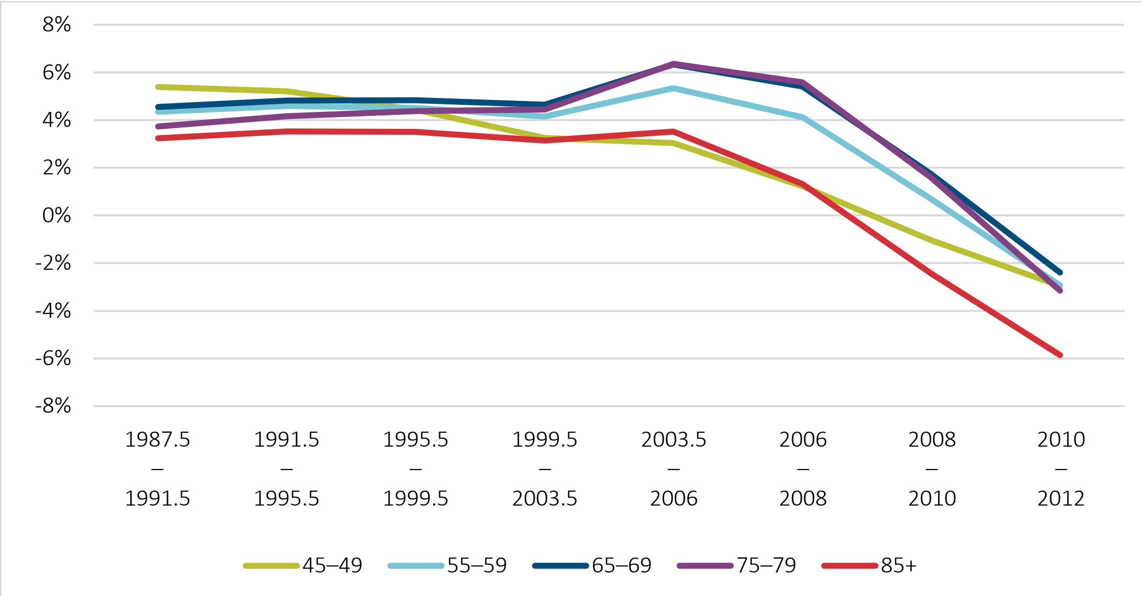
CANCER – ATTAINED AGE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 11

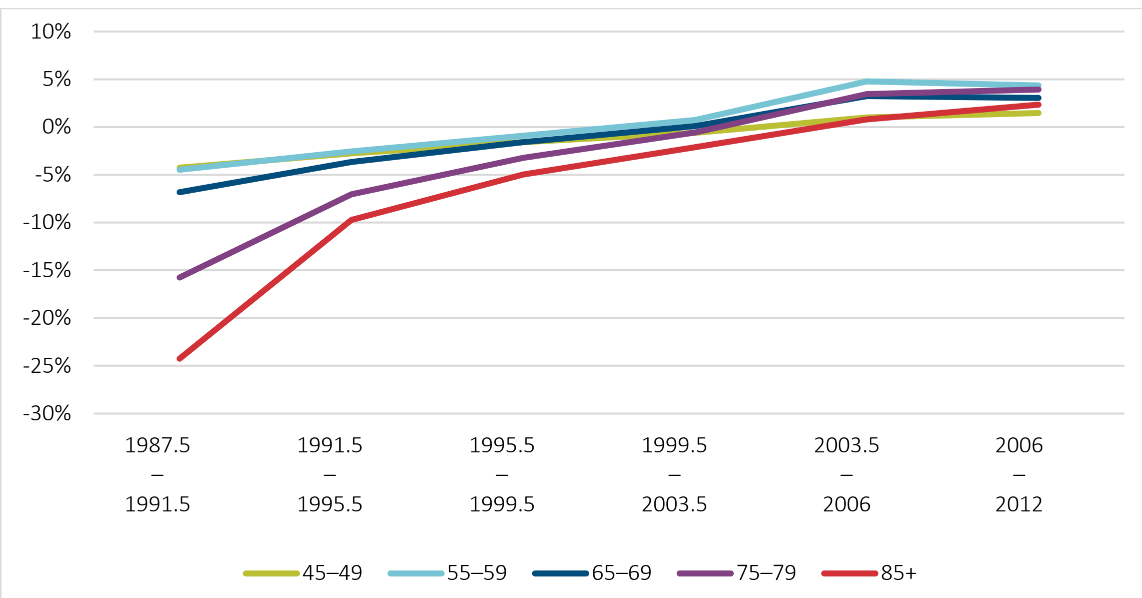
HEART – ATTAINED AGE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

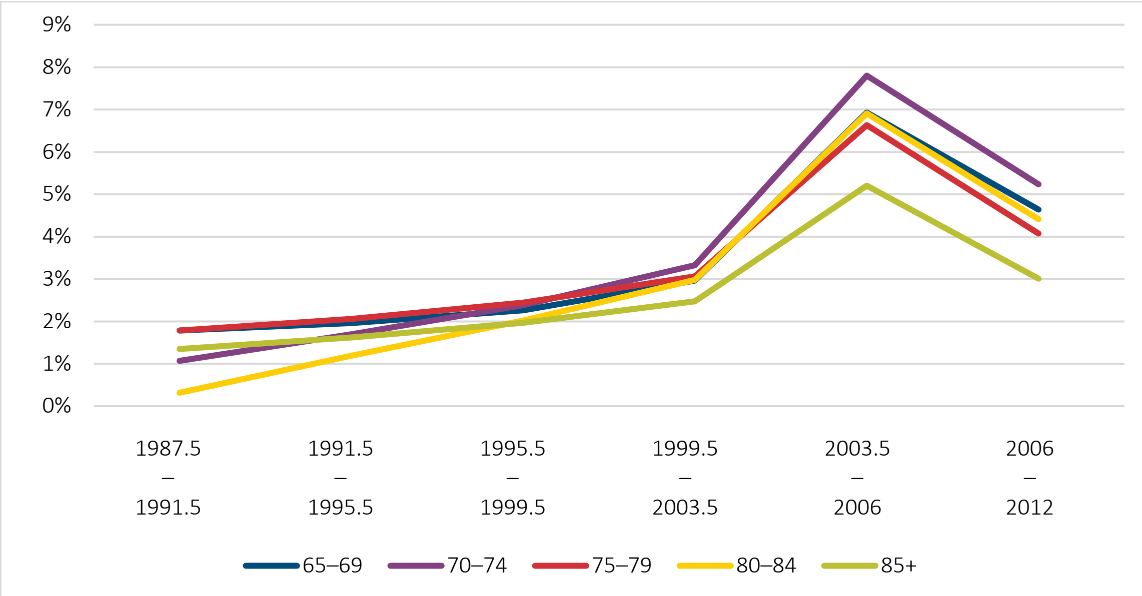
Figure 12

PULMONARY – ATTAINED AGE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 13
STROKE – ATTAINED AGE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. Younger ages are replaced with intermediate age groups in order to showcase the trend noted in the observation. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 14
DEATH COUNTS – ALL REGRESSION COHORTS

Attained Age Group	All-cause	Cancer	Heart	Pulmonary	Stroke
40–44	9,200	2,700	2,100	150	300
45–49	13,500	4,600	3,200	350	550
50–54	19,500	7,200	4,800	700	700
55–59	26,000	9,900	6,800	1,300	950
60–64	34,000	12,500	8,800	2,100	1,500
65–69	42,000	14,000	11,500	3,000	2,200
70–74	48,500	13,500	14,000	3,300	3,100
75–79	52,500	12,000	16,500	3,200	3,800
80–84	47,500	8,100	15,500	2,600	3,800
85+	40,500	4,700	15,000	1,700	3,400

U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

3.2 EDUCATIONAL ATTAINMENT

Observations:

- **All-cause**—Very clear grouping by educational attainment with greatest mortality improvement for those with a college or graduate degree.
  - o Differentiation increasing significantly after 1999.
- **Cancer**—Small but clear grouping with population segmented by presence of a college degree.
  - o After a period of convergence, differentiation across educational attainment groups increase after 1999 with greatest mortality improvement for those with a college or graduate degree.
- **Heart**—Very clear grouping by educational attainment with greatest mortality improvement for those with a college or graduate degree.
  - o Differentiation increases after 1999.
- **Pulmonary**—Very clear grouping by educational attainment with greatest mortality improvement for those with a college or graduate degree and weakest for those without a high school degree.
- **Stroke**—A clear gradient across educational attainment although the ordering is not as strict as the other causes of death.

Figure 15

ALL-CAUSE – EDUCATIONAL ATTAINMENT MORTALITY IMPROVEMENT

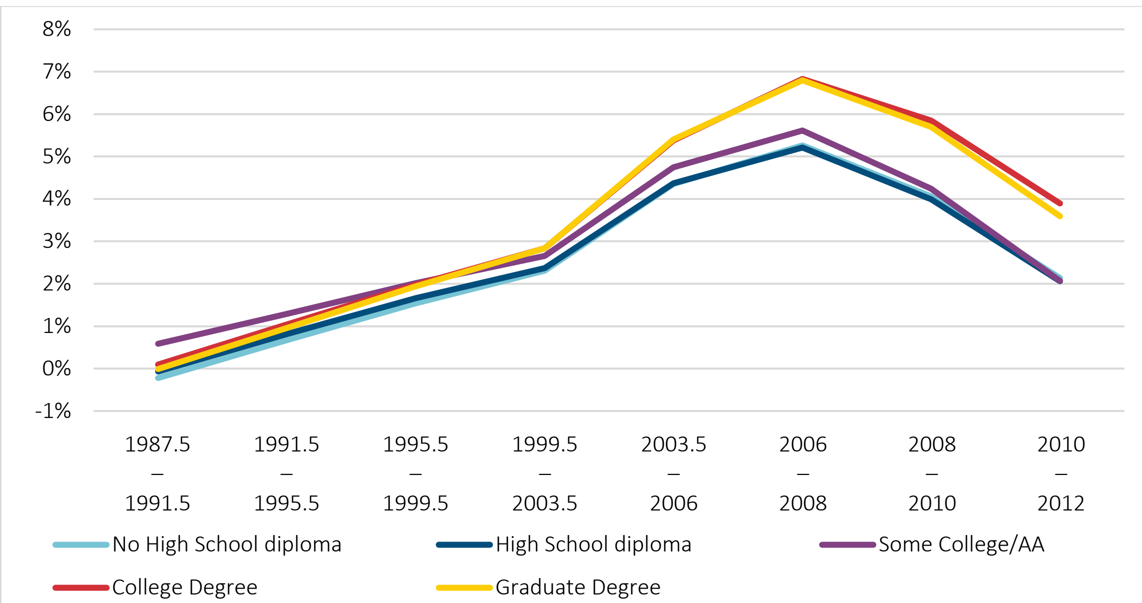


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Figure 16

CANCER – EDUCATIONAL ATTAINMENT MORTALITY IMPROVEMENT

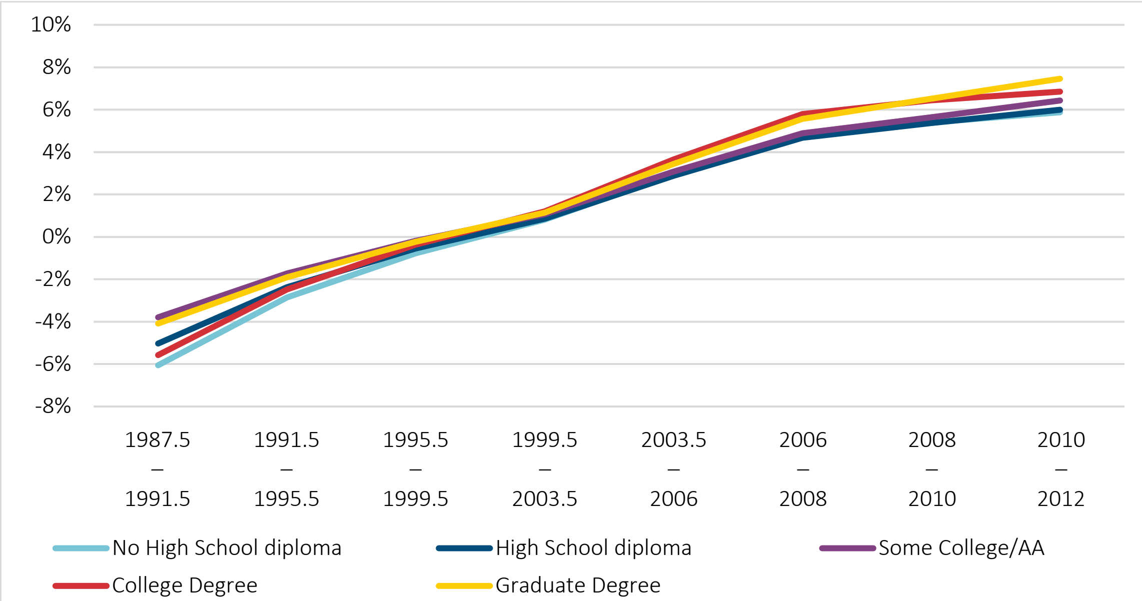

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Figure 17

HEART – EDUCATIONAL ATTAINMENT MORTALITY IMPROVEMENT

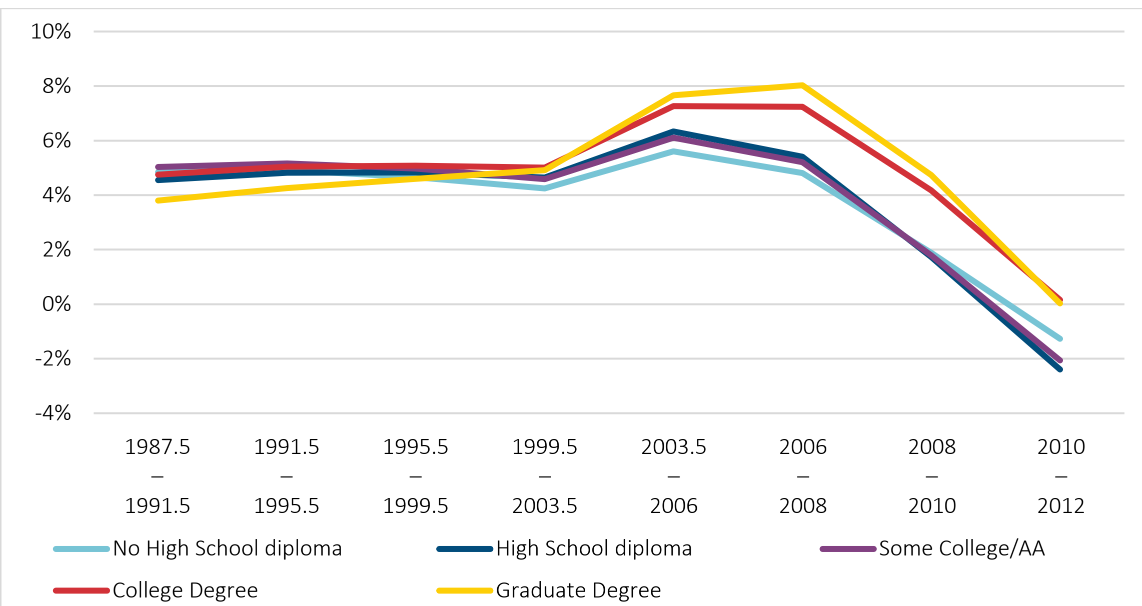

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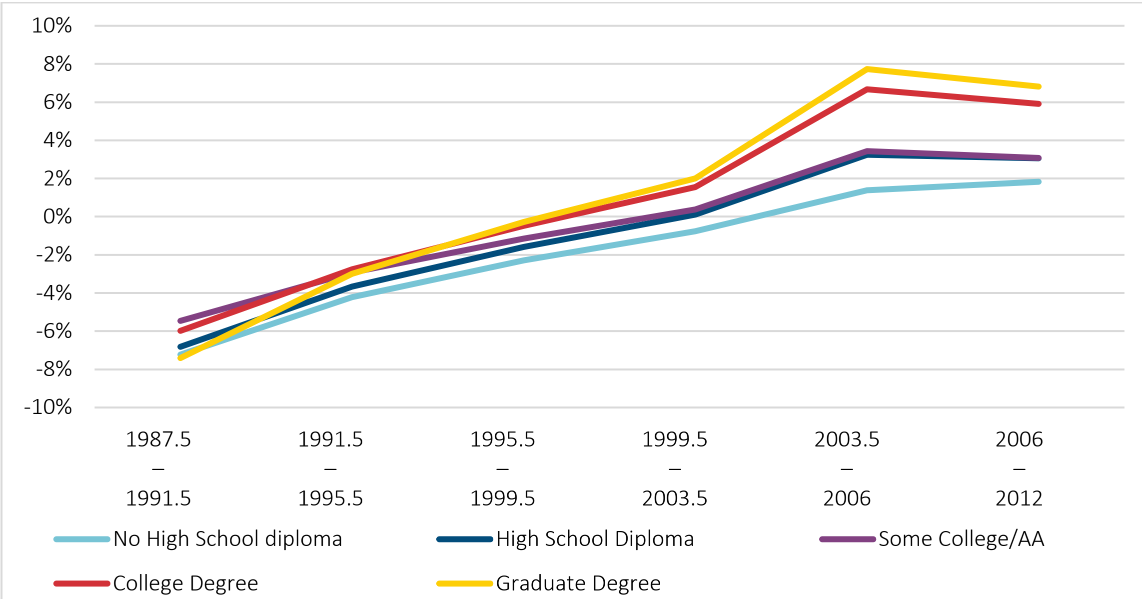
Figure 18

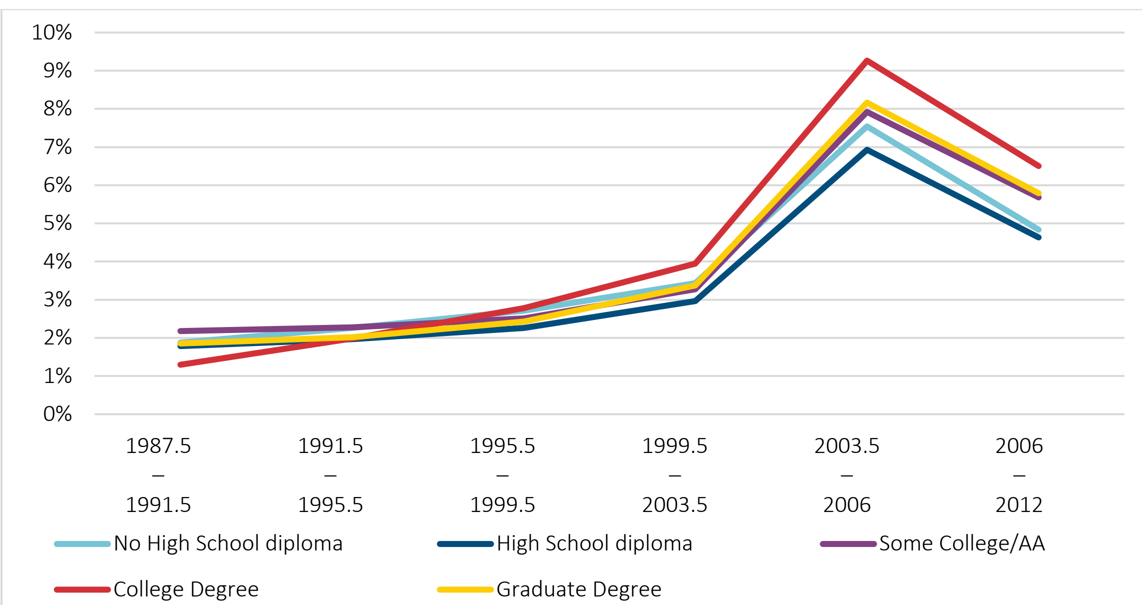
PULMONARY – EDUCATIONAL ATTAINMENT MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 19

STROKE – EDUCATIONAL ATTAINMENT MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 20

DEATH COUNTS – ALL REGRESSION COHORTS

Educational Attainment	All-cause	Cancer	Heart	Pulmonary	Stroke
No High School diploma	120,000	27,500	40,000	7,100	8,100
High School diploma	112,000	31,000	31,500	6,500	6,600
Some College/AA	58,500	17,500	15,500	3,200	3,200
College Degree	27,000	8,200	7,200	1,100	1,600
Graduate Degree	15,000	4,700	4,100	500	800

U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

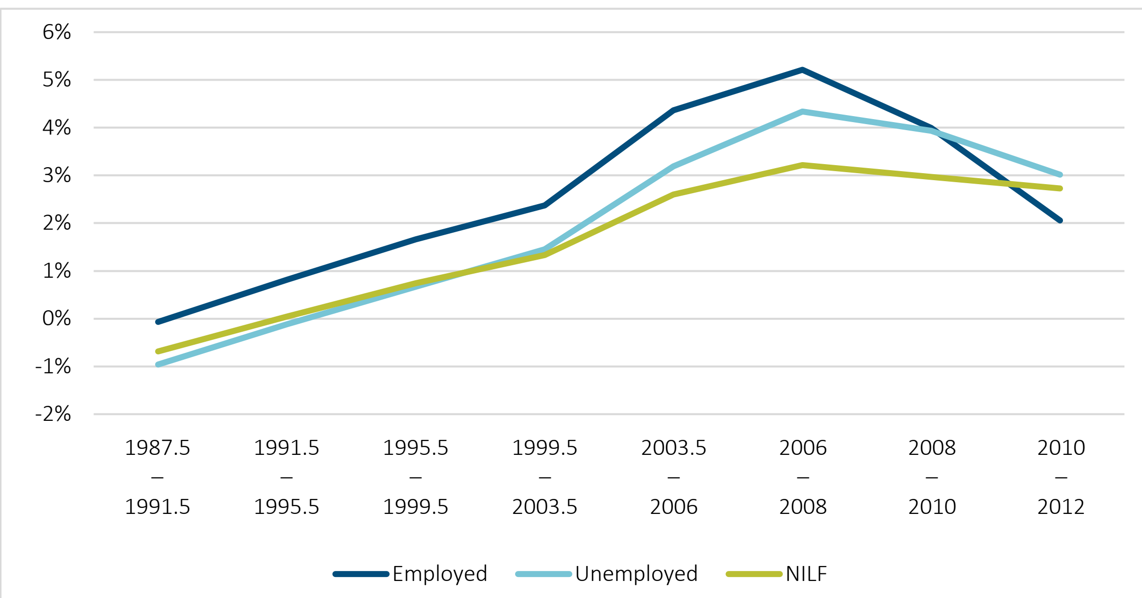
3.3 EMPLOYMENT STATUS

Note that employment status refers to the status at the time of the interview and subsequent changes in employment status are not captured. The population that is not in the labor force (NILF) is generally made up of older retirees. National unemployment trends may help correct for macroeconomic bias (i.e., the effects of recessions and boom periods). The boom period unemployed are a more at-risk population than those who are unemployed during a recession (who exhibit more similarities with the general population).

Observations:

- All-cause—Clear gradient with those who are employed having the greatest improvement and those who are not in the labor force generally having the worst improvement.
- Cancer—No clear gradient or differentiation between annualized mortality improvement rates.
- Heart—Significant differentiation emerges after 2003 with those who are employed having the greatest improvement, and those who are not in the labor force generally having the worst improvement.
- Pulmonary—Similar trend for unemployed and not in labor force and not in labor force (NILF) with negative mortality improvement and minimal change; whereas employed individuals have seen very strong acceleration in mortality improvement over the study.
    - o The employed had the lowest absolute levels of mortality for most of the study period and small changes resulted in highly visible changes in mortality improvement.
- Stroke—Prior to 2003, clear gradient with those who are employed having the greatest improvement and those who are not in the labor force generally having the worst improvement; however, after 2003 this trend disappears.

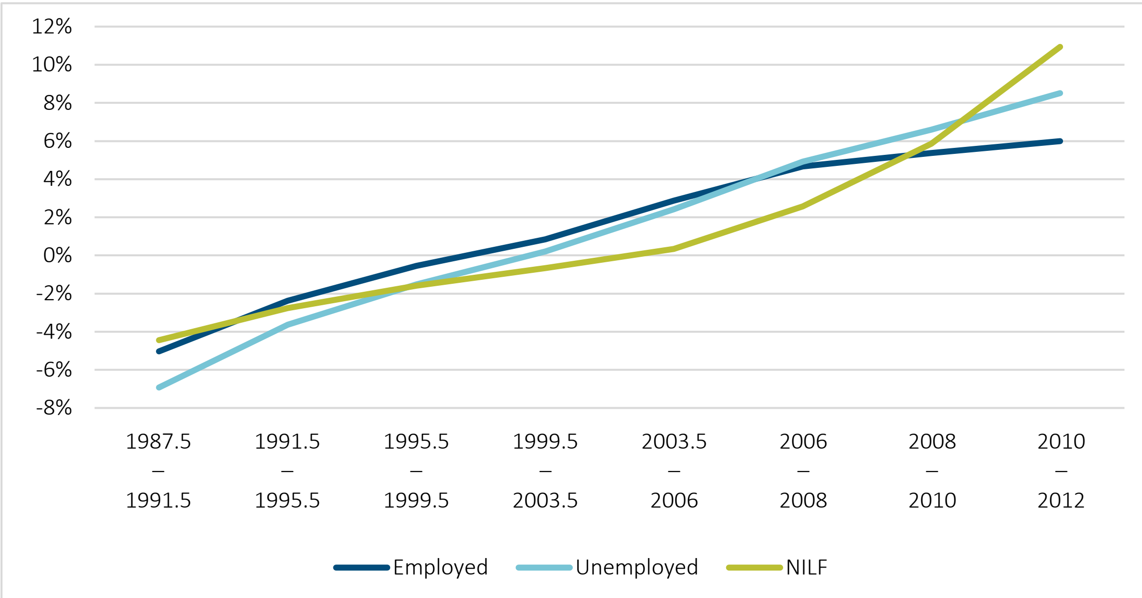
Figure 21
ALL-CAUSE – EMPLOYMENT STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. NILF = Not in labor force. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 22

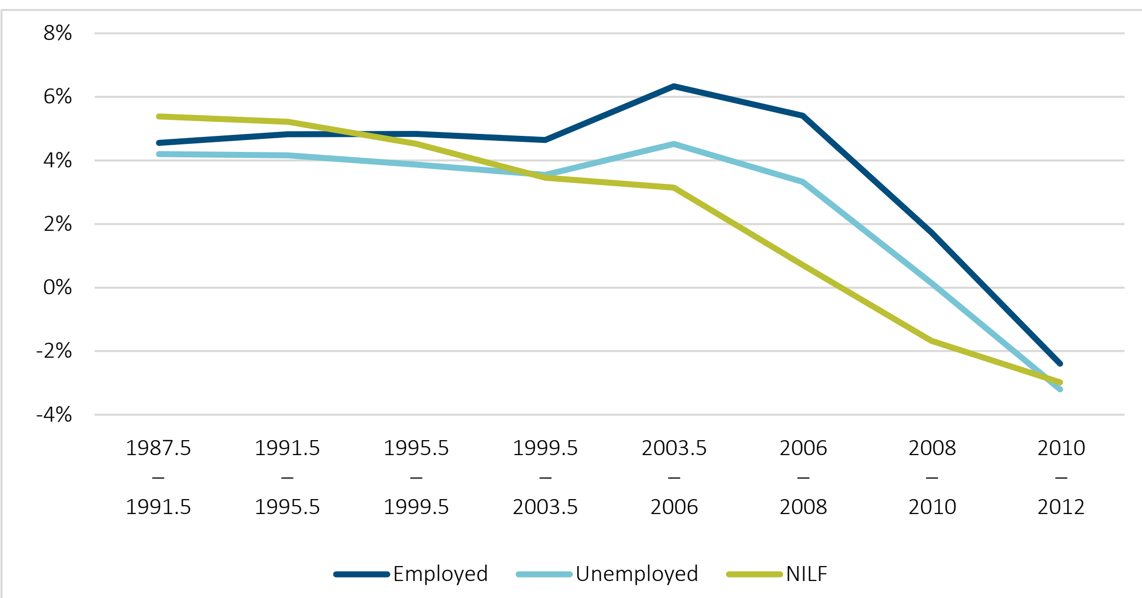
CANCER – EMPLOYMENT STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. NILF = Not in labor force. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

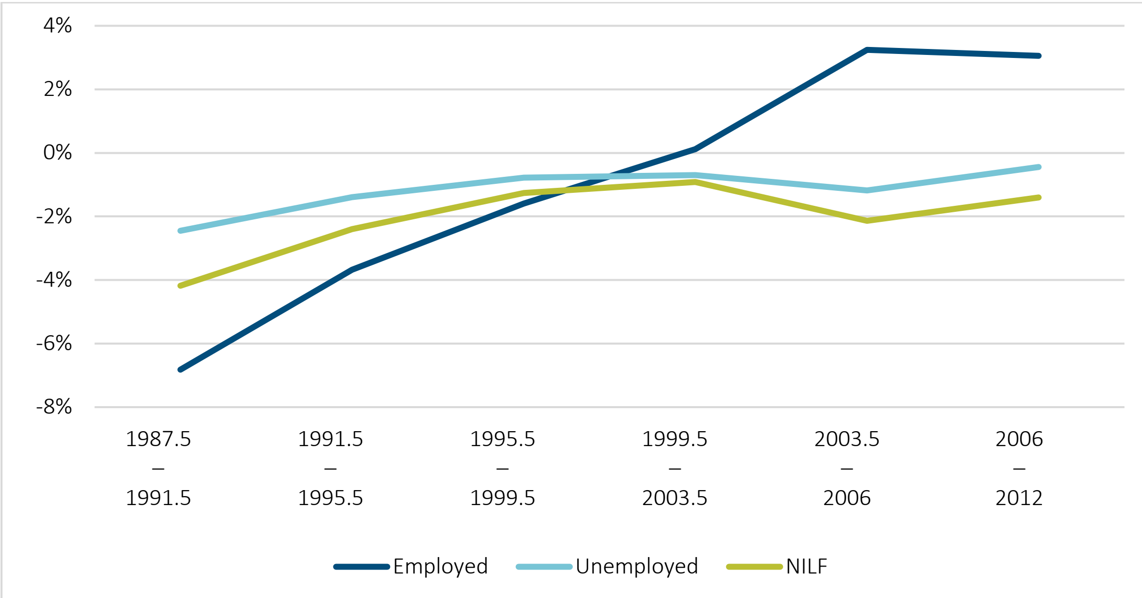
Figure 23

HEART – EMPLOYMENT STATUS MORTALITY IMPROVEMENT



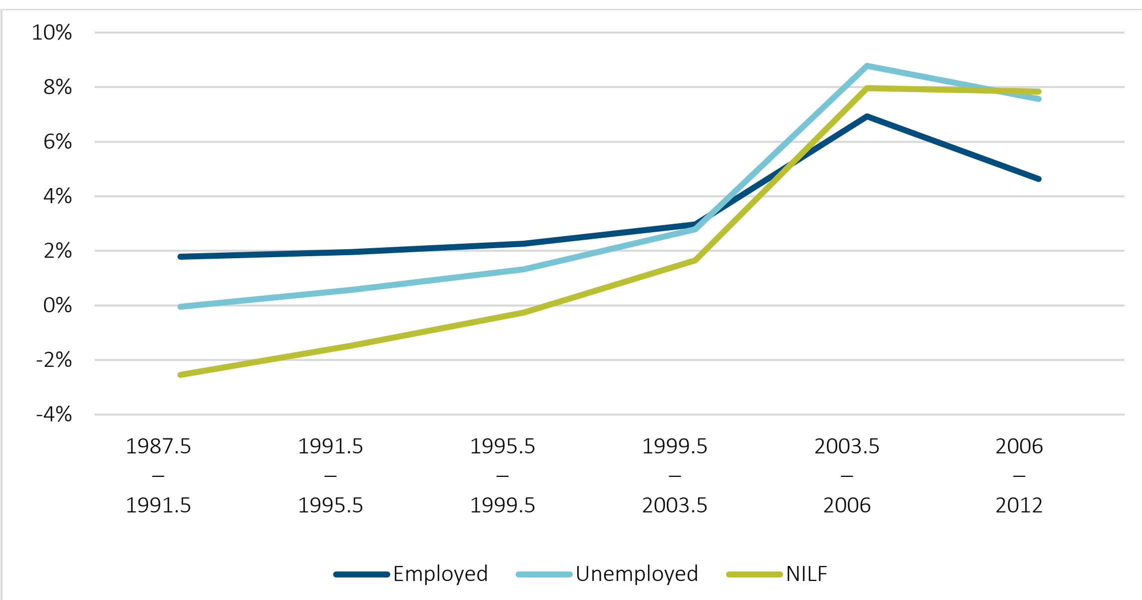
Note: See Appendix C.1 for more detail on x-axis year categories. NILF = Not in labor force. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 24
PULMONARY – EMPLOYMENT STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. NILF = Not in labor force. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 25
STROKE – EMPLOYMENT STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. NILF = Not in labor force. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 26

DEATH COUNTS – ALL REGRESSION COHORTS

Employment Status	All-cause	Cancer	Heart	Pulmonary	Stroke
Employed	70,000	27,000	18,000	2,300	2,900
Unemployed	4,200	1,300	1,100	150	200
NILF	260,000	60,500	79,500	16,000	17,000

Note: NILF = Not in labor force. U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

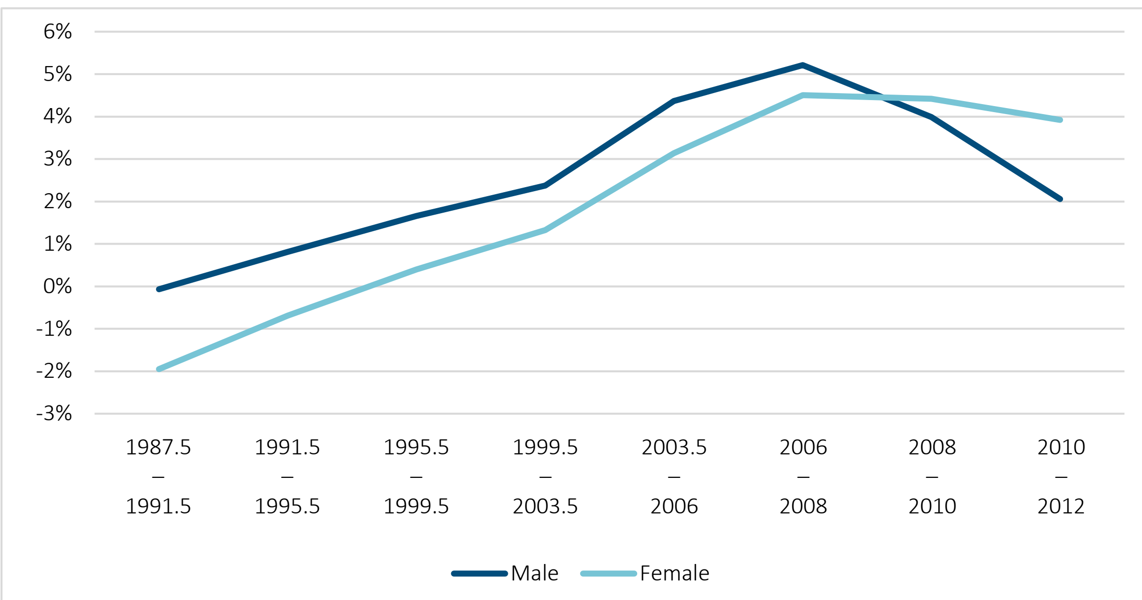
3.4 SEX

Observations:

- **All-cause**—Male improvement was greater than female improvement until 2008.
    - o Both sexes experienced near parallel levels of acceleration in mortality improvement until 2006, when males experienced more rapid deceleration.
- **Cancer**—Although the differences are more muted, the differences between sex is similar to all-cause, where female improvement surpassed male improvement in 2008.
- **Heart**—Female mortality improvement saw significant acceleration in improvement from the start of the study until 2008 followed by deceleration in improvement, whereas males saw level improvement until 2008 followed by decreases in mortality improvement.
    - o The absolute levels of mortality are lower for females than for males so similar levels of absolute improvement result in greater mortality improvement ratios for females.
- **Pulmonary**—Similar trend to all-cause where female improvement surpassed male improvement in 2006 after a period of convergence.
- **Stroke**—Similar trend to all-cause where female improvement surpassed male improvement in 2006.

Figure 27

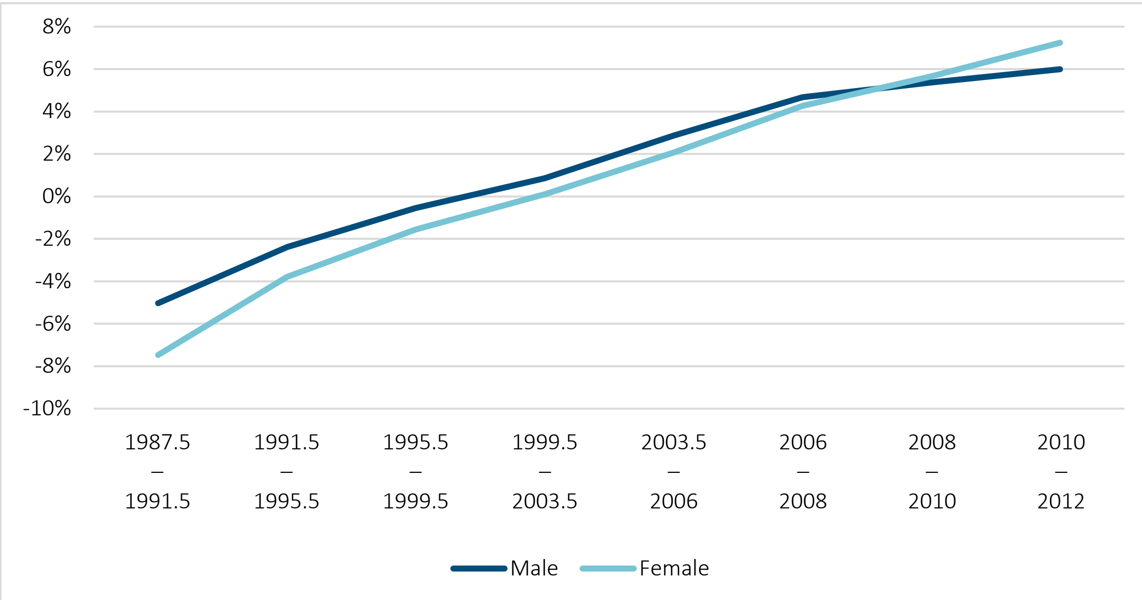
ALL-CAUSE – MORTALITY IMPROVEMENT BY SEX



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 28

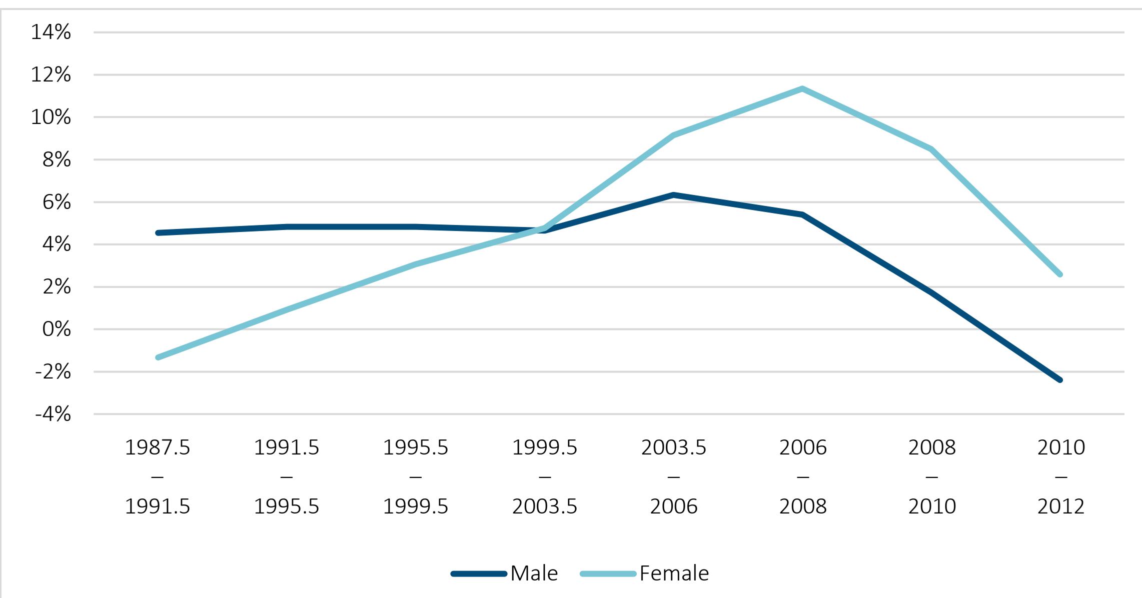
CANCER – MORTALITY IMPROVEMENT BY SEX



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 29

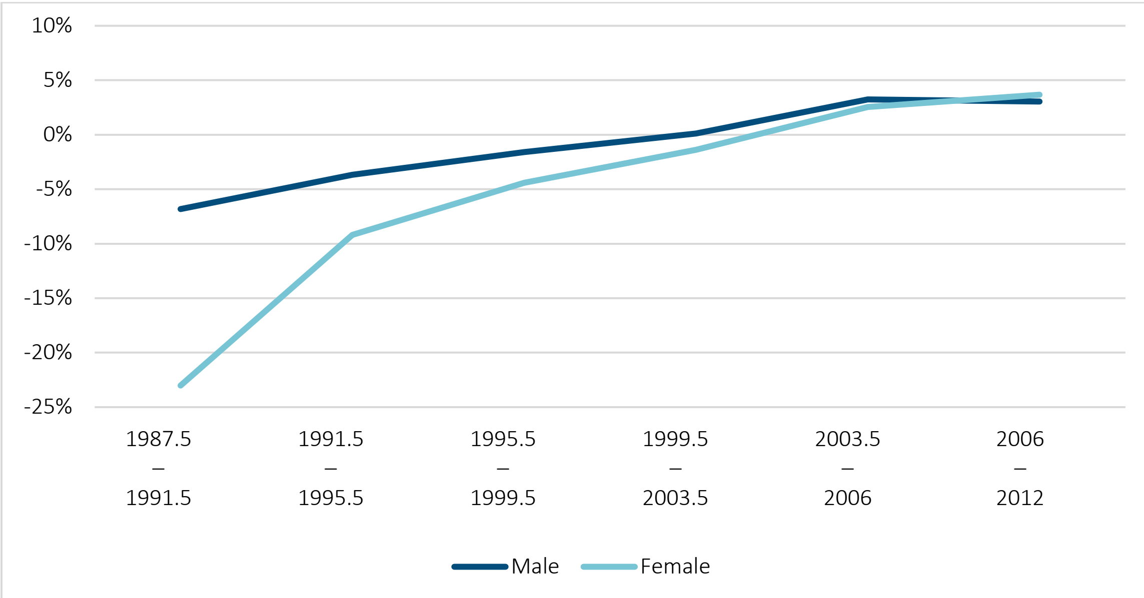
HEART – MORTALITY IMPROVEMENT BY SEX



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 30

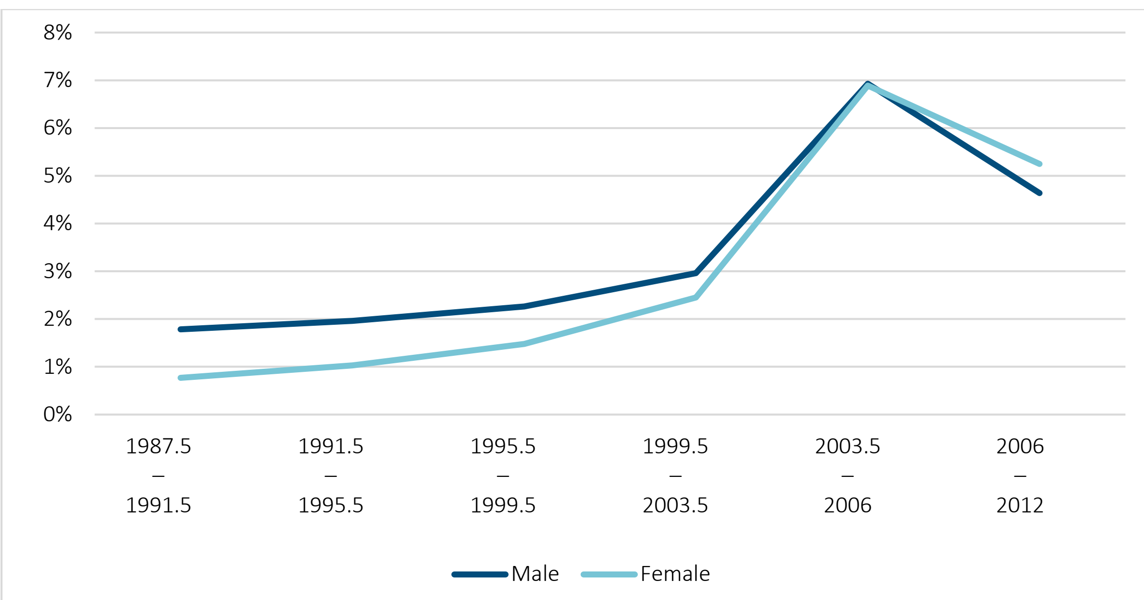
PULMONARY – MORTALITY IMPROVEMENT BY SEX



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 31

STROKE – MORTALITY IMPROVEMENT BY SEX



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 32

DEATH COUNTS – ALL REGRESSION COHORTS

Sex	All-Cause	Cancer	Heart	Pulmonary	Stroke
Male	178,000	49,000	54,000	9,900	8,900
Female	155,000	40,000	44,500	8,400	11,500

U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

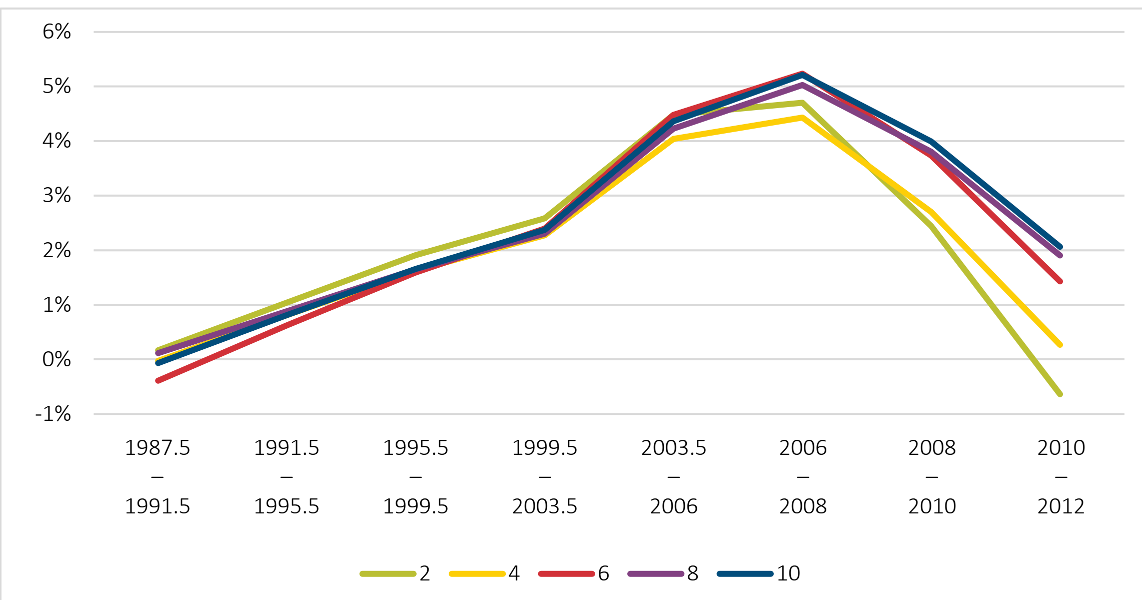
3.5 INCOME DECILE

Observations:

- **All-cause**—A very clear gradient emerges after 2003 with higher income individuals having the greatest improvement; the gap between affluence groups is widening.
- **Cancer**—Similar to all-cause, a gradient emerges after 2003 with higher income individuals having the greatest improvement.
- **Heart**—No clear gradient or trend in annualized rates.
- **Pulmonary**—Very clear gradient with the clearest example of reversal observed in this report.
    - o In early durations, higher income groups had the worst mortality improvement which lower income groups had greater mortality improvement.
    - o Higher income groups experienced greatest accelerates throughout most of the study period while lower income groups experienced minimal changes in mortality improvement over time.
    - o The net effect is a gradient low-to-high which switches to high-to-low around the year 2000.
    - o Note that more affluent deciles have lower levels of absolute mortality so similar changes in absolute mortality results in much more volatile mortality improvement ratios.
- **Stroke**—Weak gradient emerging since 2003, with higher income individuals having the greatest improvement.

Figure 33

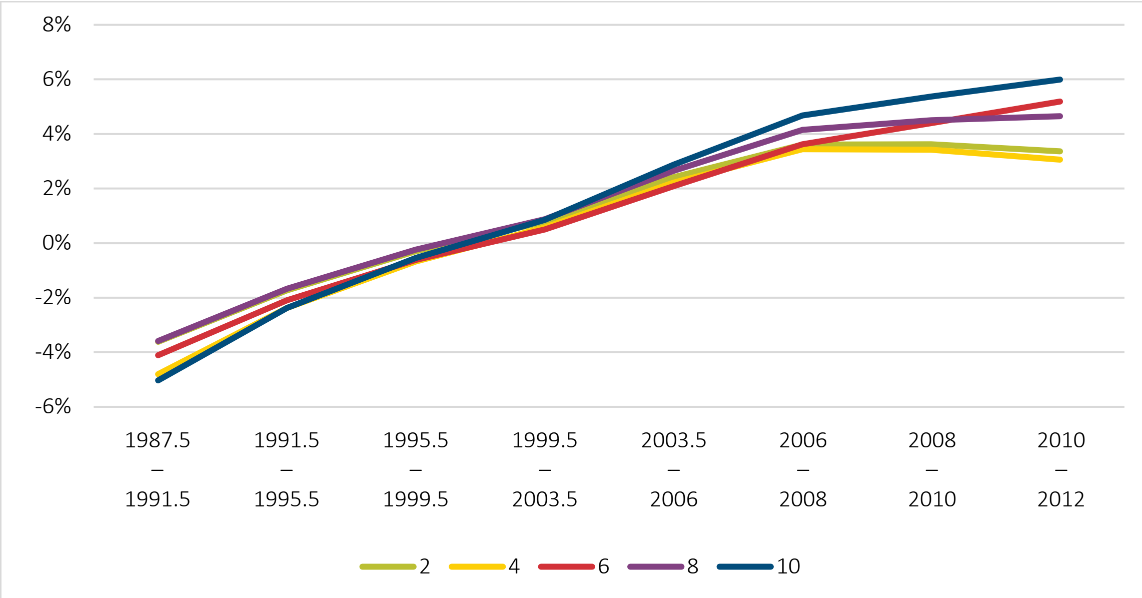
ALL-CAUSE – INCOME DECILE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 34

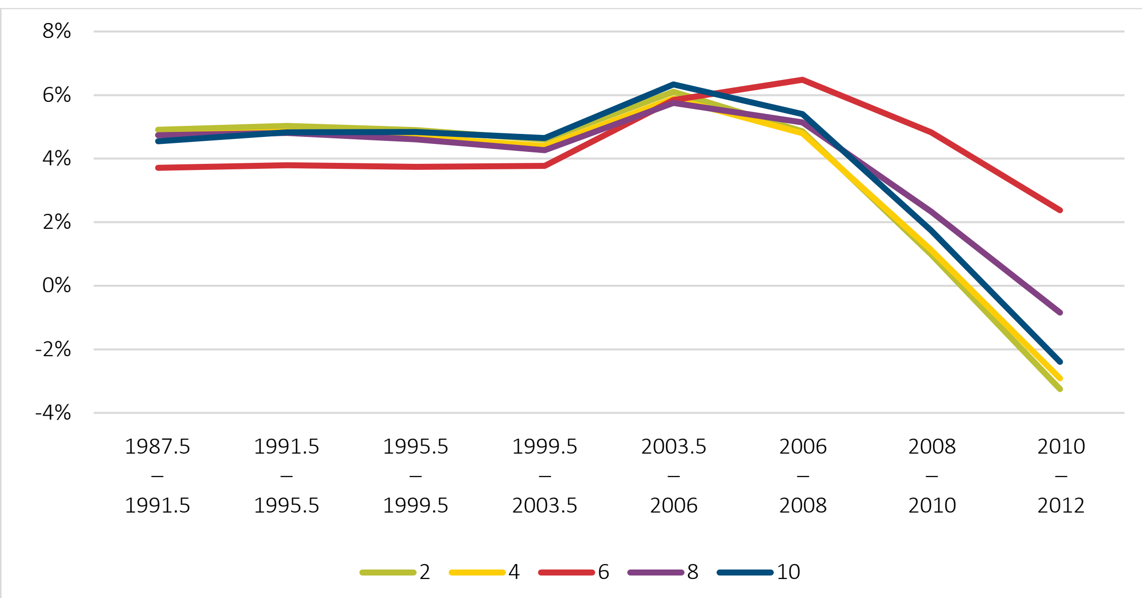
CANCER – INCOME DECILE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 35

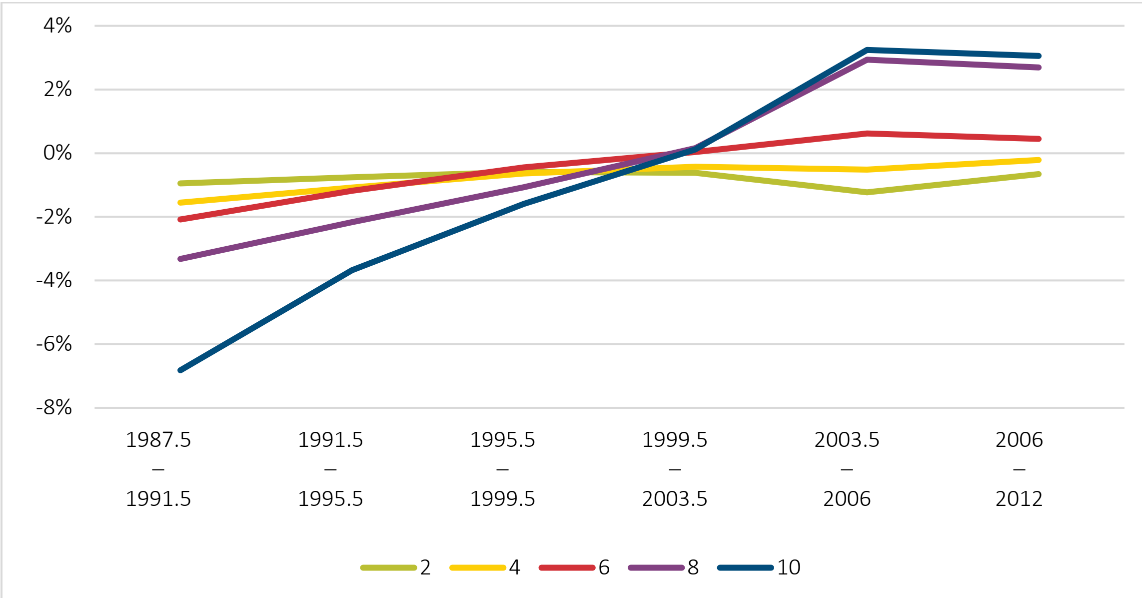
HEART – INCOME DECILE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 36

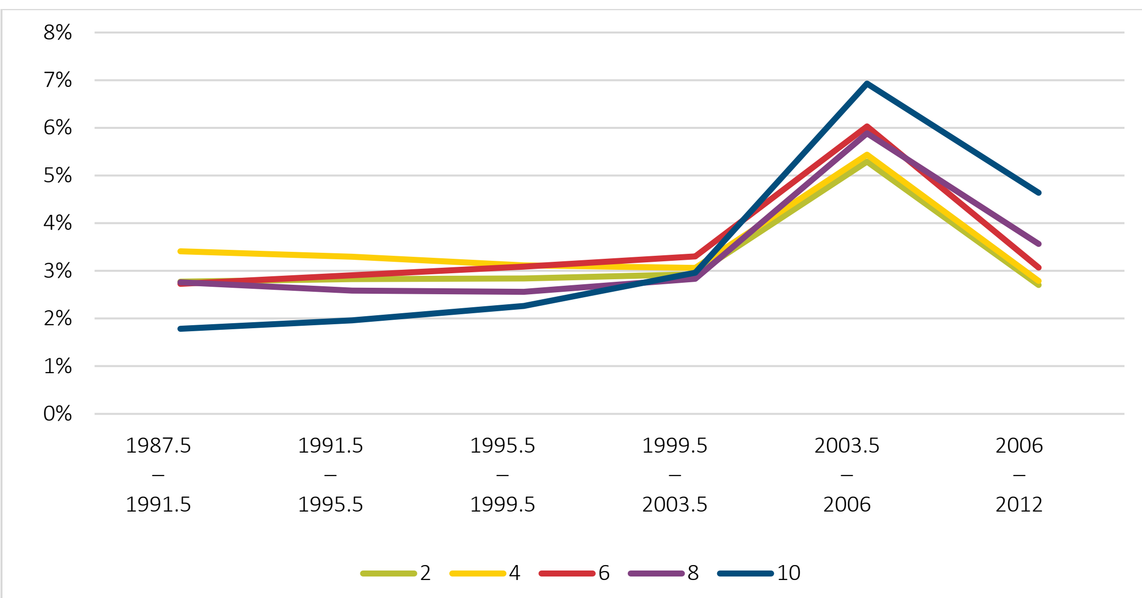
PULMONARY – INCOME DECILE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 37

STROKE – INCOME DECILE MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 38

DEATH COUNTS – ALL REGRESSION COHORTS

Income Decile	All-cause	Cancer	Heart	Pulmonary	Stroke
1-Lowest	46,000	9,900	15,500	2,500	3,300
2	63,000	14,500	20,000	4,000	4,200
3	49,000	12,500	14,500	3,000	3,100
4	42,000	11,500	12,000	2,500	2,500
5	34,000	10,000	9,500	1,800	2,000
6	27,000	8,200	7,500	1,400	1,500
7	22,000	6,600	5,600	1,000	1,200
8	19,500	6,200	5,400	850	1,000
9	15,500	5,000	4,100	600	800
10-Highest	15,000	5,000	3,800	550	4,400

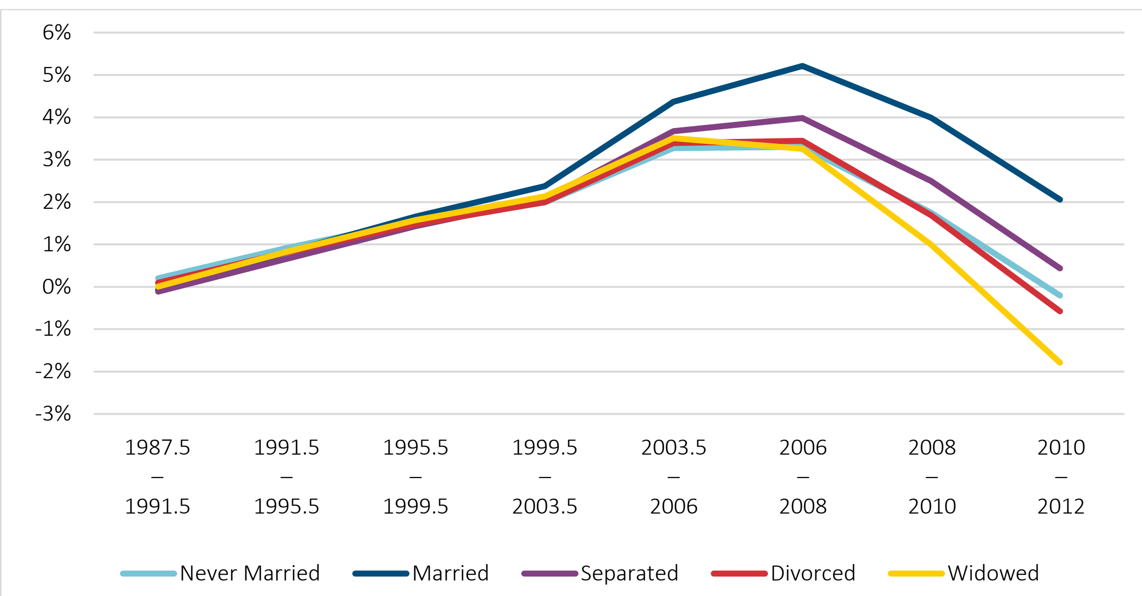
U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

3.6 MARITAL STATUS

Observations:

- **All-cause**—Very clear gradient emerging after 2003 with married individuals having the greatest improvement; the gap between groups appears to be widening.
- **Cancer**—Very clear gradient emerging after 2006 with married individuals having the greatest improvement.
  - Married and never-married individuals experience acceleration in mortality improvement throughout the study period.
  - Widowed, divorced, and separated individuals peak in 2006 followed by a period of deceleration.
- **Heart**—Mixed gradient emerging after 2003.
  - Separated individuals appear to avoid the strong deterioration in later years that the other groups experience.
  - Except for separated individuals, married individuals having the greatest improvement.
- **Pulmonary**—A very striking gradient prior to 1999 which completely reverses in later years.
  - Separated and divorced individuals are very similar and experience weak deceleration over the study period; this group has negative mortality improvement throughout the study period.
  - Widowed individuals experience weak acceleration over the study period and also has negative mortality improvement throughout the study period.
  - Married and never married individuals start with very significant negative mortality improvement and experience strong acceleration and ultimately experience very significant mortality improvement in later years.
  - Note that married and never married have lower levels of absolute mortality so similar changes in absolute mortality results in much more volatile mortality improvement ratios.
- **Stroke**—Three groups emerge very clearly: married and divorced, widowed and separated, and never married; however, the absolute levels of mortality across the groups converge over the study period.

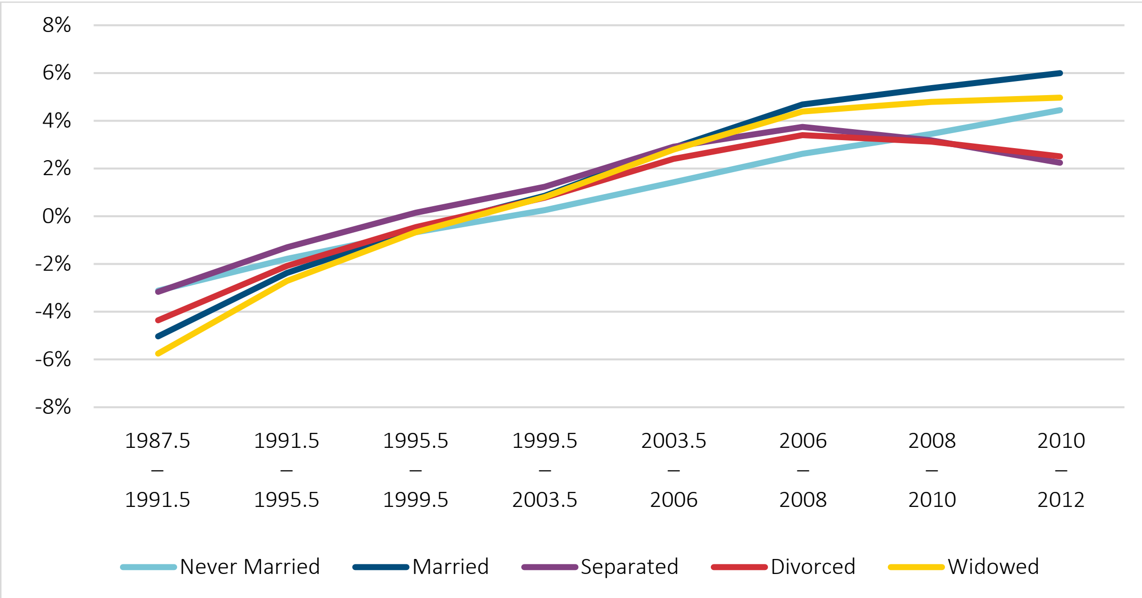
Figure 39
ALL-CAUSE – MARITAL STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 40

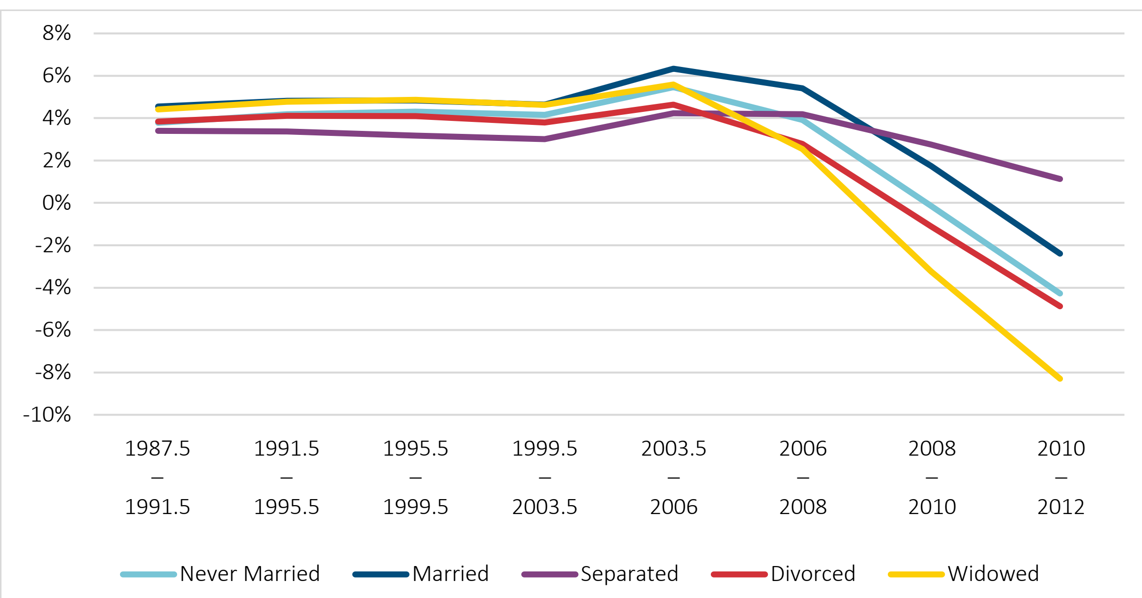
CANCER – MARITAL STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 41

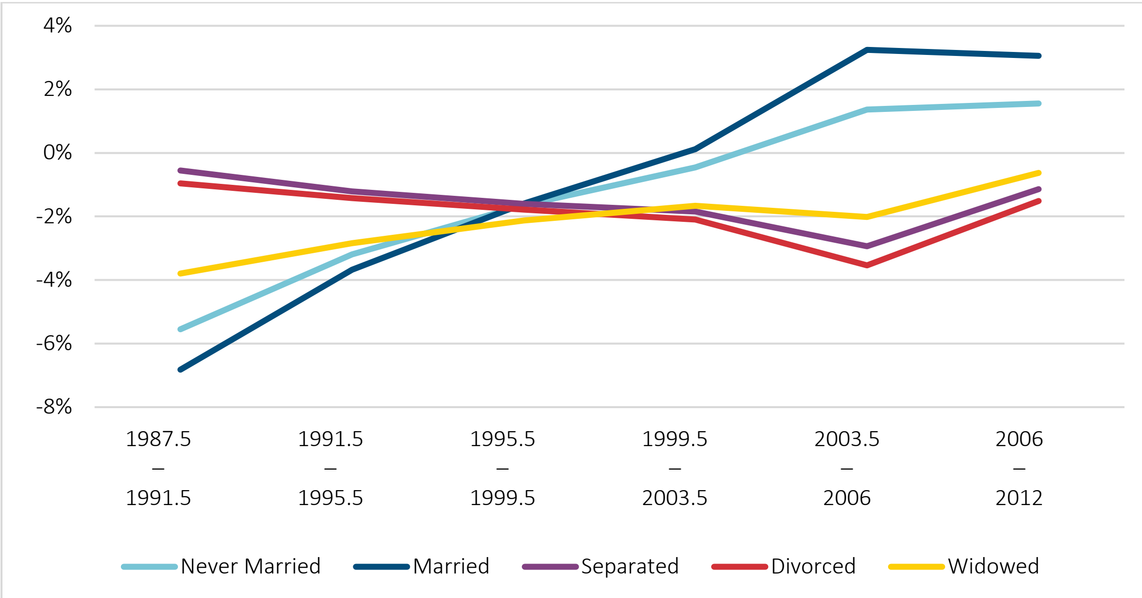
HEART – MARITAL STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 42

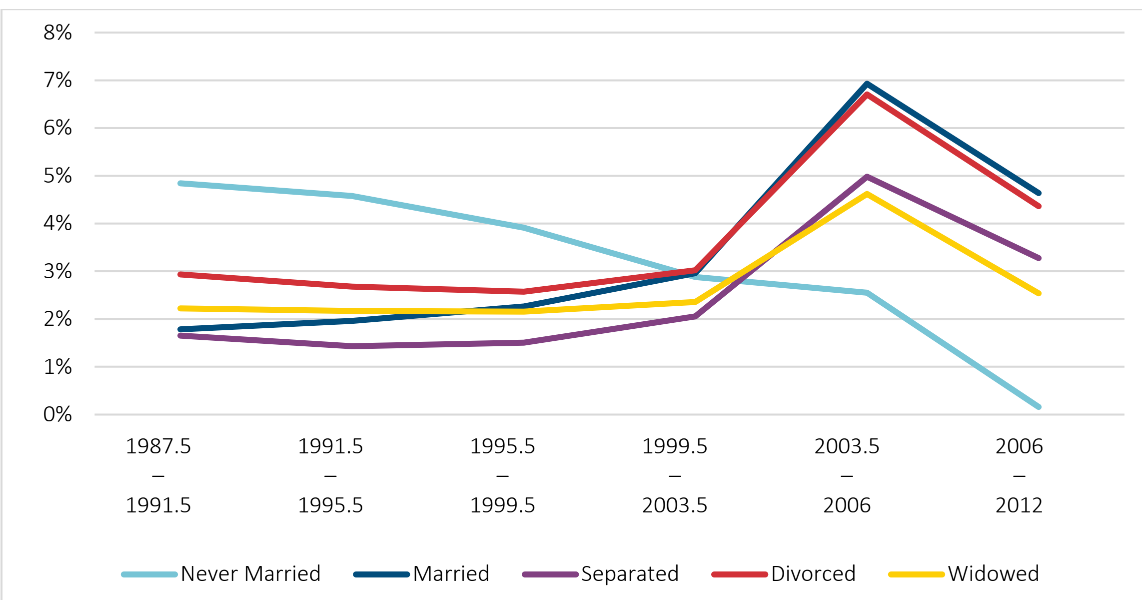
PULMONARY – MARITAL STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 43

STROKE – MARITAL STATUS MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 44

DEATH COUNTS – ALL REGRESSION COHORTS

Marital Status	All-cause	Cancer	Heart	Pulmonary	Stroke
Married	218,000	64,000	60,000	12,000	12,000
Widowed	73,000	13,500	25,500	4,000	5,900
Divorced	22,500	6,300	6,000	1,600	1,100
Separated	4,500	1,300	1,300	250	200
Never Married	16,000	3,700	5,000	600	900

U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

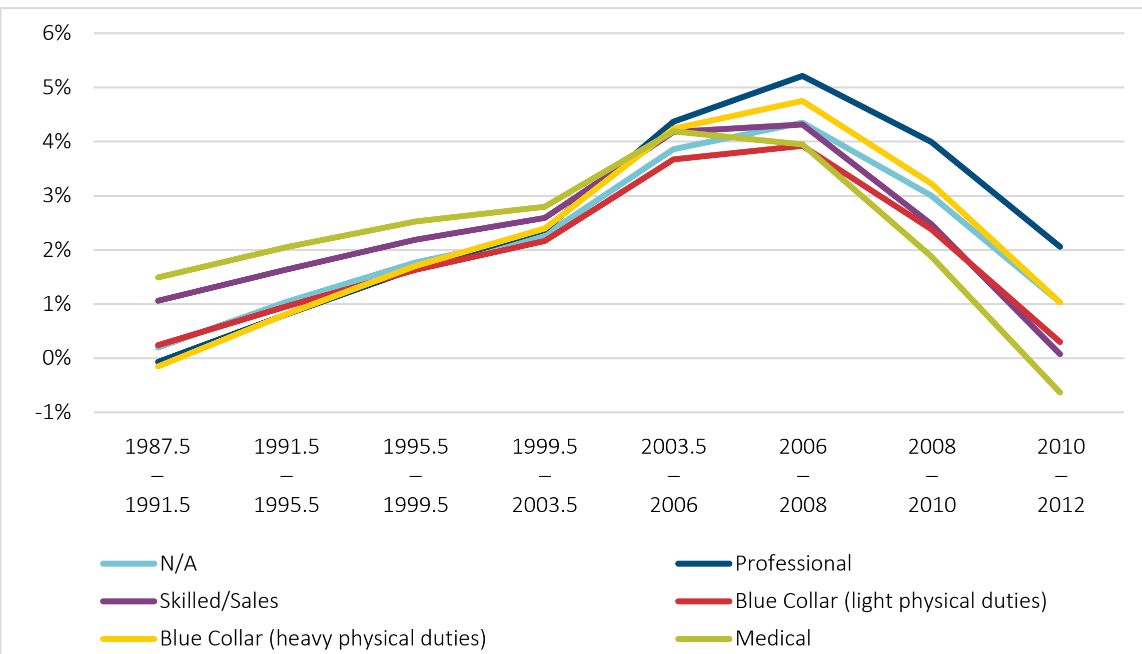
3.7 OCCUPATION

Observations:

- All-cause—Segmentation appears to increase after 2003; however, the gradient appears to mix white/blue collar groups.
    - Professionals appear to have the highest improvement starting in 2003 (and lowest absolute mortality throughout the study period), but results for other groups are mixed.
    - Medical personnel had absolute levels of mortality very close to Professionals in 2003; however, this group has experienced the lowest improvement in recent years and are now closer to skilled/sales and Blue Collar (light physical duties).
- Cancer—After a period of convergence between 1999 and 2003, segmentation increases significantly with professionals experiencing an acceleration in mortality improvement while every other group experience deceleration.
- Heart—No clear gradient across the study period; notably in recent years, professionals experience more rapid deceleration in mortality improvement than all other occupations.
    - The pattern for the N/A group is notable, however the credibility for this subset is relatively low.
- Pulmonary—Like other variable groups (e.g., marital status, income decile, employment status), there is a very striking gradient prior to 1999 which partially reverses in later years; notably, professionals experience the slowest acceleration in mortality improvement throughout the study period.
- Stroke—There are minimal differences across most occupational groups; notably, professionals experience the slowest acceleration in mortality improvement throughout the study period.

Figure 45

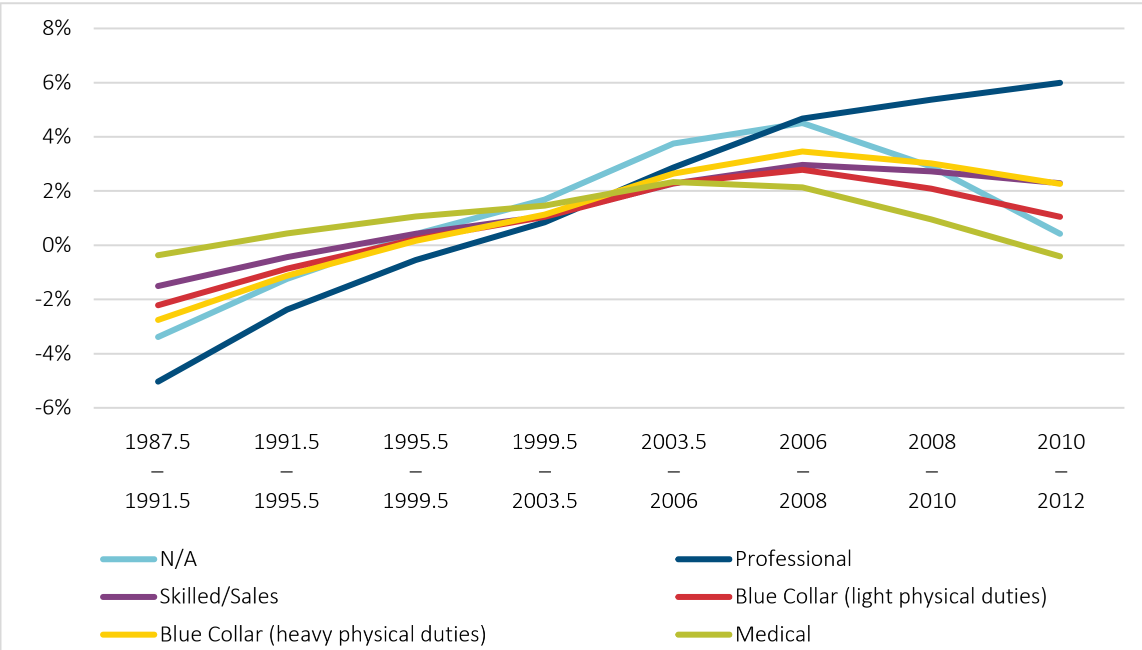
ALL-CAUSE – OCCUPATION MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 46

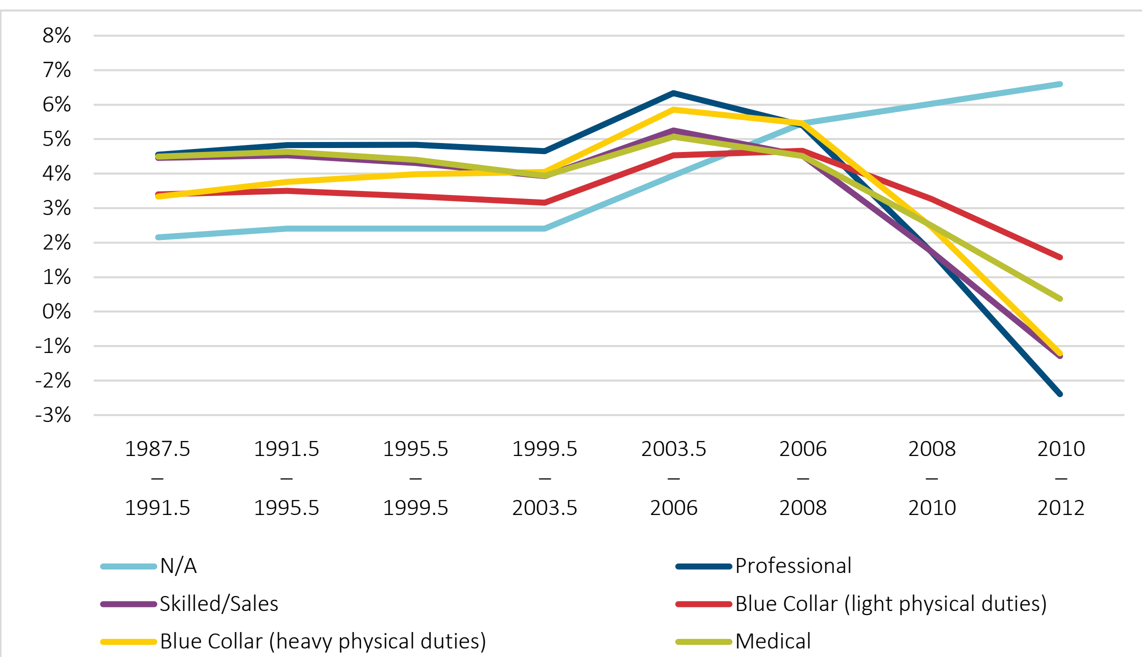
CANCER – OCCUPATION MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 47

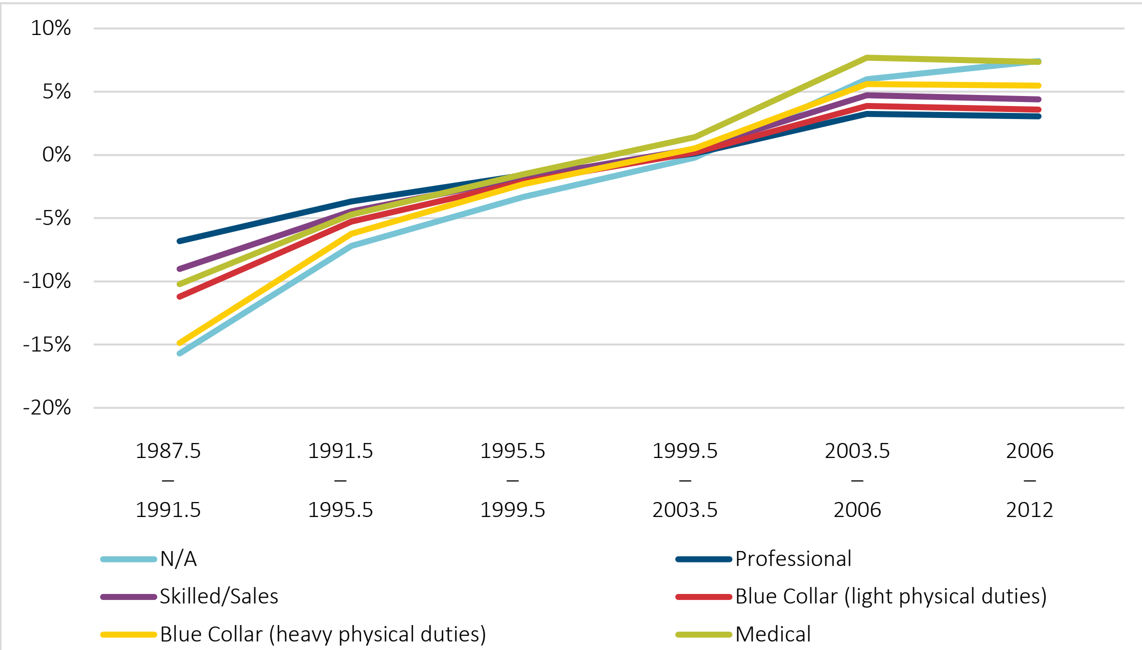
HEART – OCCUPATION MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 48

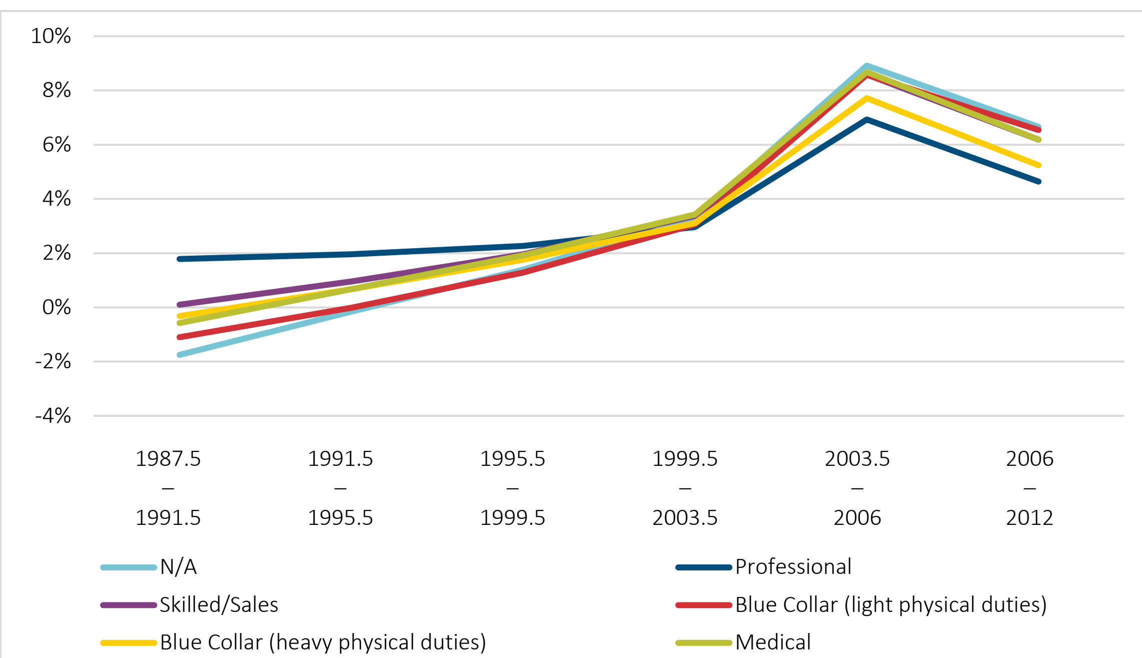
PULMONARY – OCCUPATION MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 49

STROKE – OCCUPATION MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 50

DEATH COUNTS – ALL REGRESSION COHORTS

Occupation	All-cause	Cancer	Heart	Pulmonary	Stroke
Professional	13,000	5,100	3,100	350	500
Skilled/Sales	24,500	9,600	5,900	1,000	1,100
Blue Collar (light)	22,500	8,200	5,600	1,050	950
Blue Collar (heavy)	32,000	11,000	8,700	1,400	1,500
Medical	4,700	2,000	1,000	150	200
N/A	236,000	53,000	73,500	14,500	16,000

U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

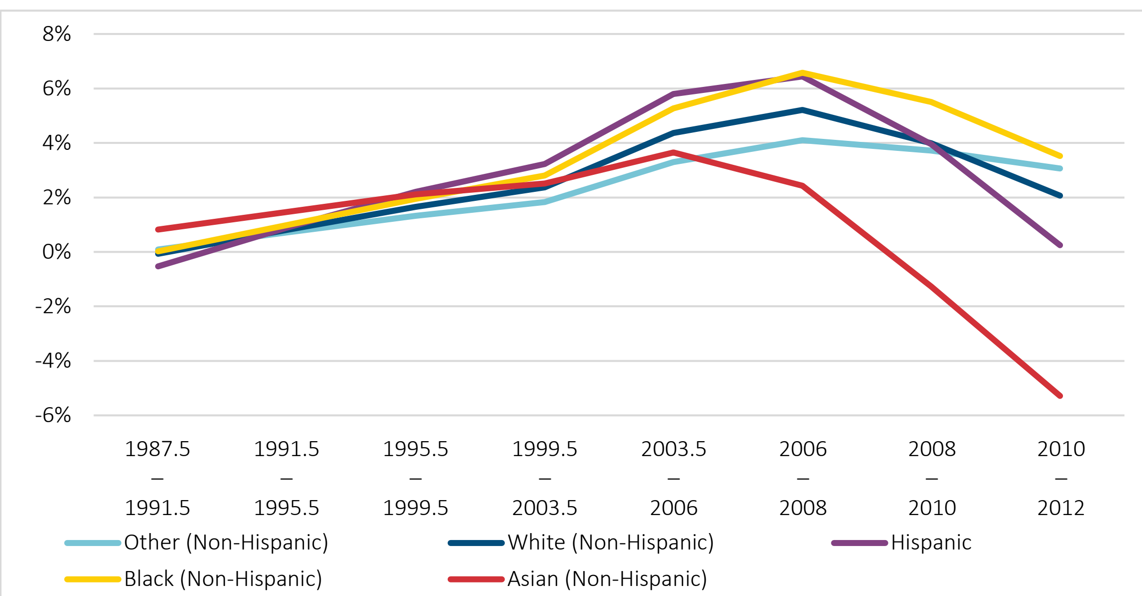
3.8 RACE/ETHNICITY

Note: There are some counterintuitive results that are driven by limited data.

Observations:

- **All-cause**—No clear gradient; however, there is a trend in the annualized rates where groups with the highest mortality at the start of the study also experience the most improvement (except for Hispanic individuals).
  - The population identified as Asian experienced significant divergence from other racial groups starting in 2006 with the most rapid deceleration; this divergence or lower mortality improvement overall is observable across all four individual causes of death.
  - For other racial groups there appears to be mixed results with some divergence in mortality improvement rates over time.
- **Cancer**—All groups start with significant negative mortality improvement at the start of the study and see some degree of acceleration.
  - Mortality improvement levels for the population identified as Asian begins to decelerate starting in 2006 with negative mortality improvement at the end of the study.
- **Heart**—Little difference in mortality improvement rates until 2003 when groups begin to diverge.
- **Pulmonary**—The population identified as Asian experienced high mortality improvement at the start of the study followed by deceleration, whereas this trend is reversed for all other groups.
  - This result was investigated for issues and proved to be an accurate depiction of the data; however this pattern is based on only 200 deaths.
- **Stroke**—The populations identified as Asian and Hispanic showed lower levels of improvement than most other racial groups through 2003 when the population identified as Hispanic converged with other racial groups, while the population identified as Asian did not.

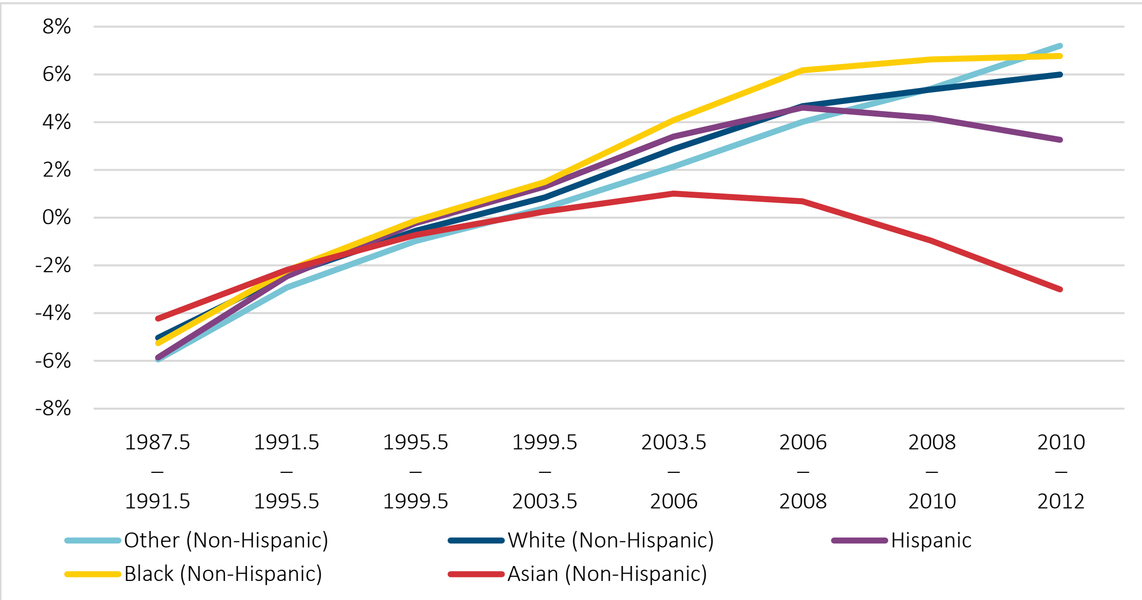
Figure 51
ALL-CAUSE – RACE/ETHNICITY MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 52

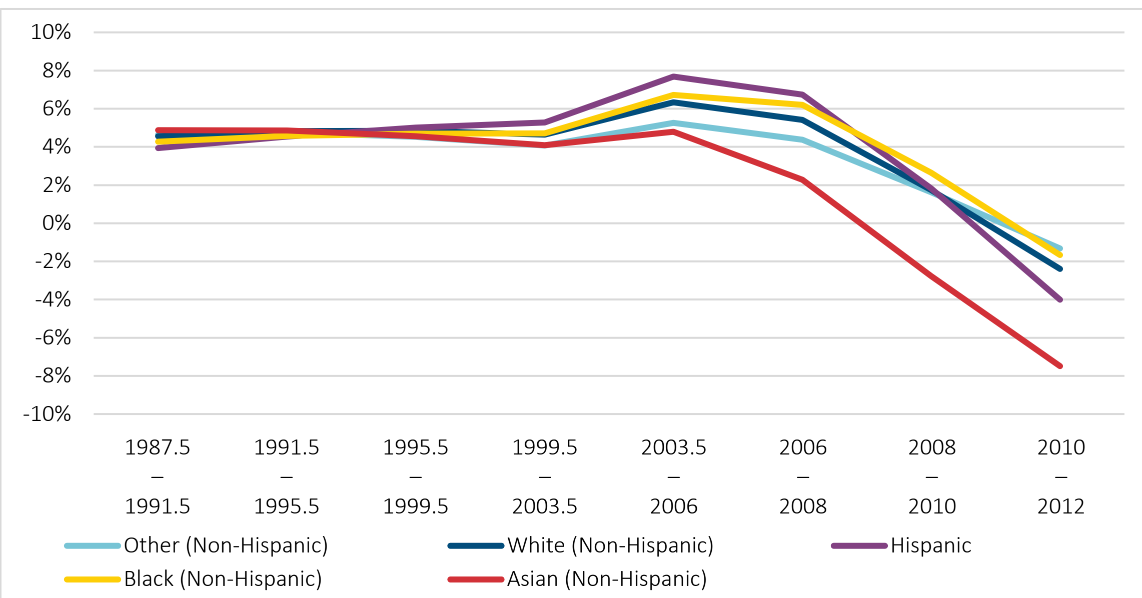
CANCER – RACE/ETHNICITY MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 53

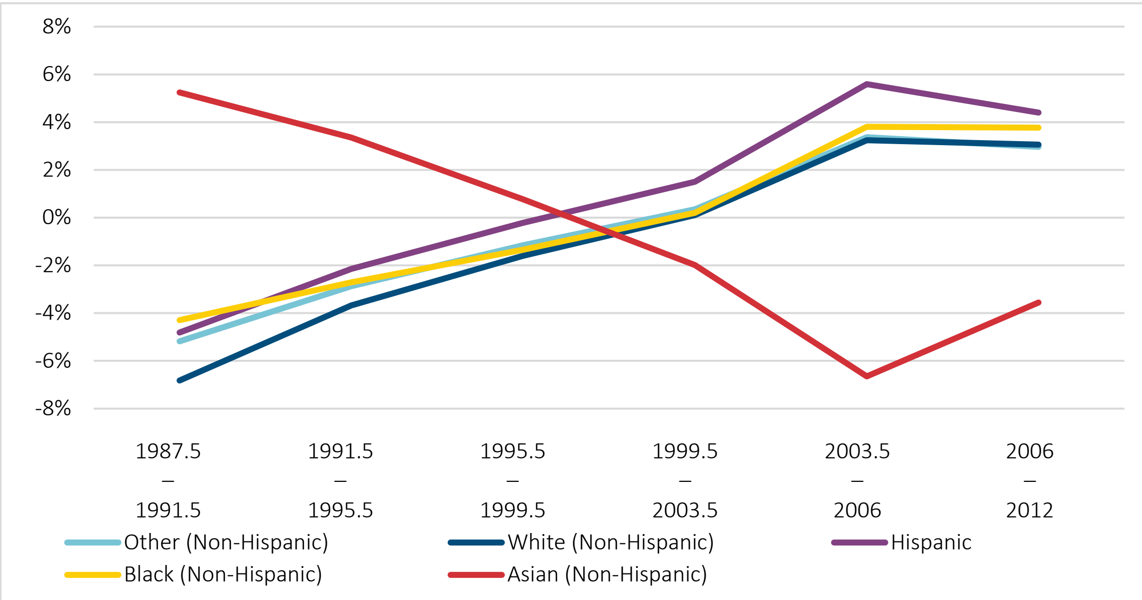
HEART – RACE/ETHNICITY MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 54

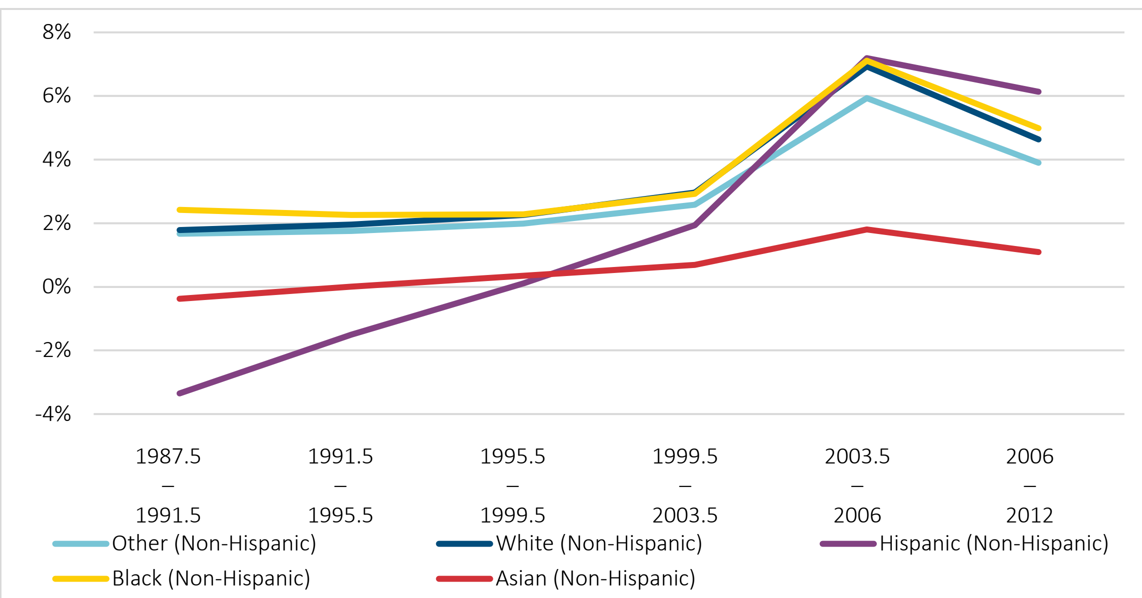
PULMONARY – RACE/ETHNICITY MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 55

STROKE – RACE/ETHNICITY MORTALITY IMPROVEMENT



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 56

DEATH COUNTS – ALL REGRESSION COHORTS

Race/Ethnicity	All-cause	Cancer	Heart	Pulmonary	Stroke
White (Non-Hispanic)	263,000	70,500	77,500	15,500	15,500
Black (Non-Hispanic)	29,000	7,700	8,900	900	2,000
Asian (Non-Hispanic)	7,100	2,300	1,700	200	600
Hispanic	16,500	4,100	4,500	550	1,000
Other (Non-Hispanic)	18,000	4,600	5,800	1000	1,200

U.S. Census Bureau's Disclosure Review Board release authorization number CBDRB-FY22-CES004-038

Section 4: Application for Practitioners

The detailed results highlight an important pattern: the clear divergence in mortality improvement rates across certain socioeconomic groups. In most cases, this trend begins around the year 2000, after which the longevity gap grows. Setting population-specific mortality improvement assumptions prior to this pivot point may have had little effect; however, it is becoming increasingly important to have this assumption be appropriately segmented.

For example, an actuary performing analysis related to a pension liability should review the population distribution and consider adjusting the mortality improvement assumption. If benefits are generally very large and the plan participants were generally white-collar professionals with a college education, then a general population improvement of 1% may need to be adjusted.

This report does not use predictive modeling techniques to extrapolate historical trends into the future, so the question becomes how such a company should use these results to inform assumption setting. To answer this question, a workbook containing the regression parameters and necessary logic to convert the parameters to modeled mortality, smoothed mortality, and mortality improvement rates is included as an accompanying figure to this report (see **Appendix F**). The purpose for this is to allow practitioners to explore different combinations of socioeconomic variables and resulting differentials in mortality improvement.

The workbook can be used to calculate the annualized mortality improvement for a starting selection representative of general population (center column) and population-specific (right column) mortality improvement. After controlling for other variables (e.g., race/ethnicity and sex), the difference between the two groups is about 1% (see **Figure 57**).

Figure 57

DEMONSTRATION OF ILLUSTRATIVE SELECTIONS ON ANNUALIZED MORTALITY IMPROVEMENT (MALE, 65–69)

Variable	Starting Selection	Population Specific Selection
Income Decile	5th	10th (most affluent)
Education	Completed High School	College
Occupation	Skilled/Sales	Professional
Annualized Mortality Improvement	1.9%	2.9%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

A skeptical practitioner may object to the use of baseline variable selections for all variables not presented in Figure 57. For example, one objection is that these results are only for ages 65–69. These objections are valid for changes to absolute levels of mortality improvement; however, difference between groups will stay essentially constant (within rounding and smoothing). **Figure 58** repeats the illustration but uses a different sex (female) and attained age group (80–84).

Figure 58

DEMONSTRATION OF ILLUSTRATIVE SELECTIONS ON ANNUALIZED MORTALITY IMPROVEMENT (FEMALE, 80–84)

Variable	Starting Selection	Population Specific Selection
Income Decile	5th	10th (most affluent)
Education	Completed High School	College
Occupation	Skilled/Sales	Professional
Annualized Mortality Improvement	0.3%	1.3%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

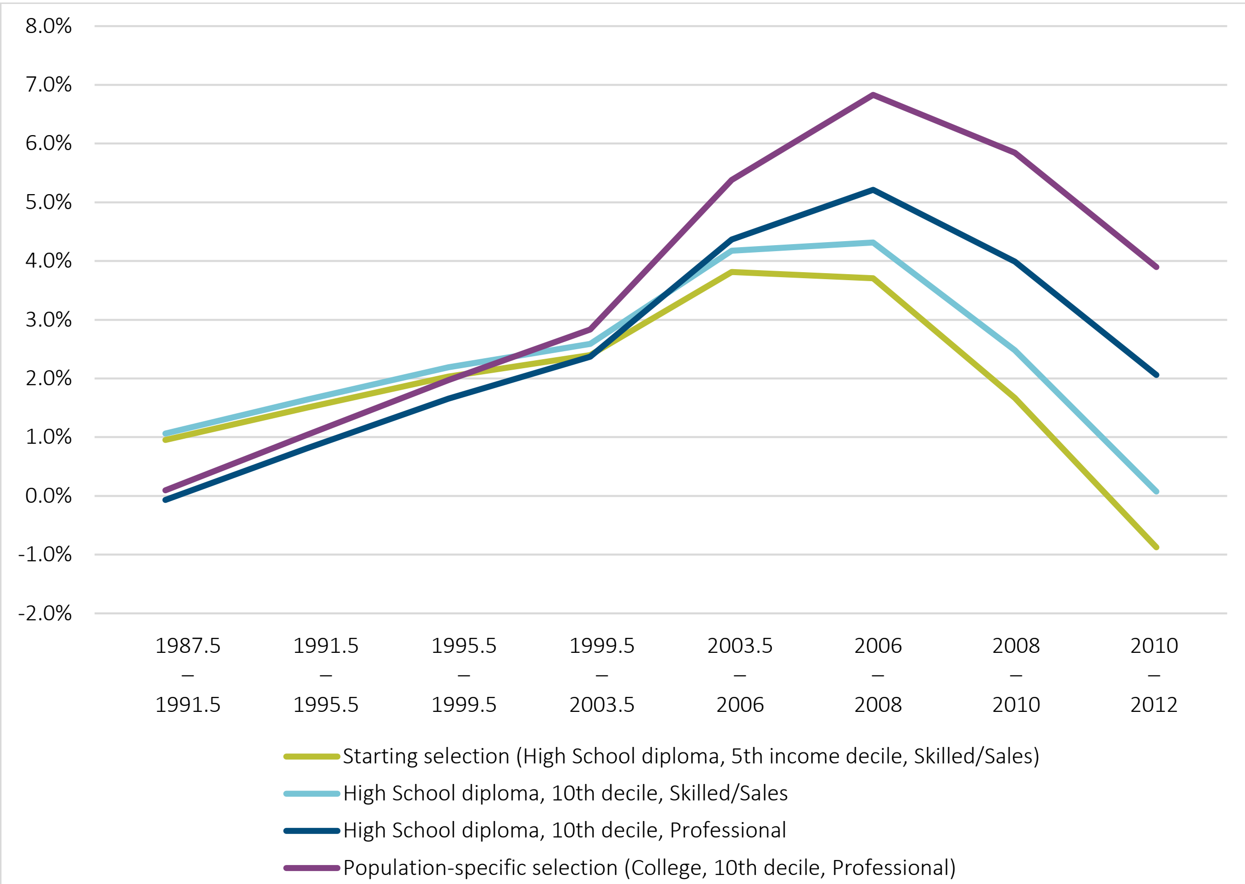
While the absolute levels of annualized mortality improvement change, the difference between the groups remains near-constant at 1%. The Cox (proportional hazards) regression approach uses an exponential transformation of a linear combination of explanatory variables which allows for other variables, including attained age, to be effectively controlled.

This delta of 1% may be used as a historical adjustment factor so that a general population mortality improvement assumption is customized to the liability population in question.

One limitation of this approach is that the differences between socioeconomic subgroups are growing, and the annualized mortality improvement blends small differences in early years with much larger differences in later years. Therefore, a more robust application would compare these two selections over time. **Figure 59** compares walks from the starting selection to the population-specific selection.

Figure 59

ALL-CAUSE MORTALITY IMPROVEMENT – COMPARISON BETWEEN ILLUSTRATIVE POPULATION

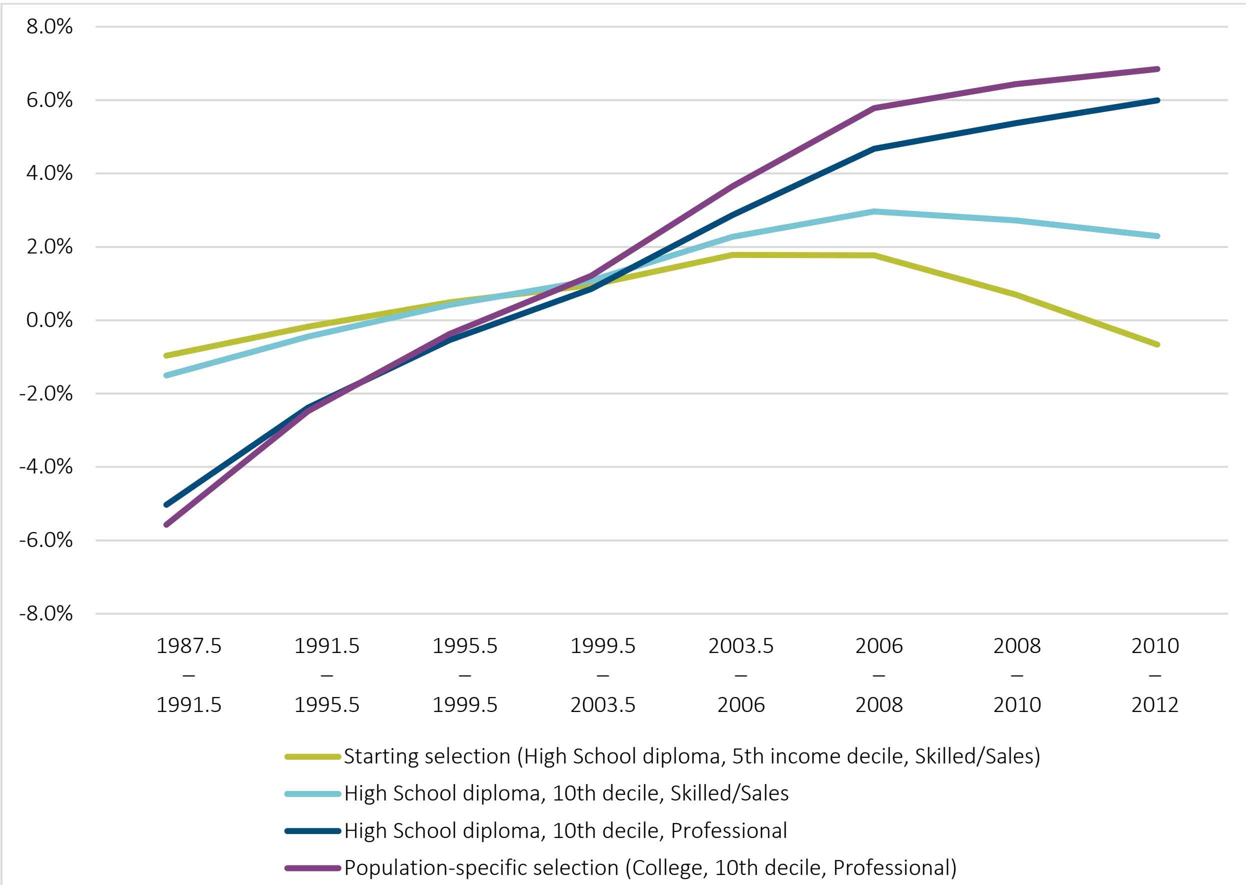


Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

This view confirms the observation that the blended annualized mortality improvement mutes a widening gap. The difference between these groups was close to zero midway through the study period and grew to 4.7% by the end. Assuming a 1% future gap between these two groups going forward would appear to underestimate the true difference. This delta of 4.7% may be used as a historical adjustment factor instead as it represents the most recent delta.

This approach may result in an adjustment factor that would appear to be fairly extreme to a cautious practitioner. Questions like "What is causing the differences between these two groups?" and "Are these causes expected to continue?" would be the natural next steps in assessing reasonability. To answer these questions, the comparison analysis may be repeated for individual causes of death as shown in **Figure 60, 61, 62, and 63**.

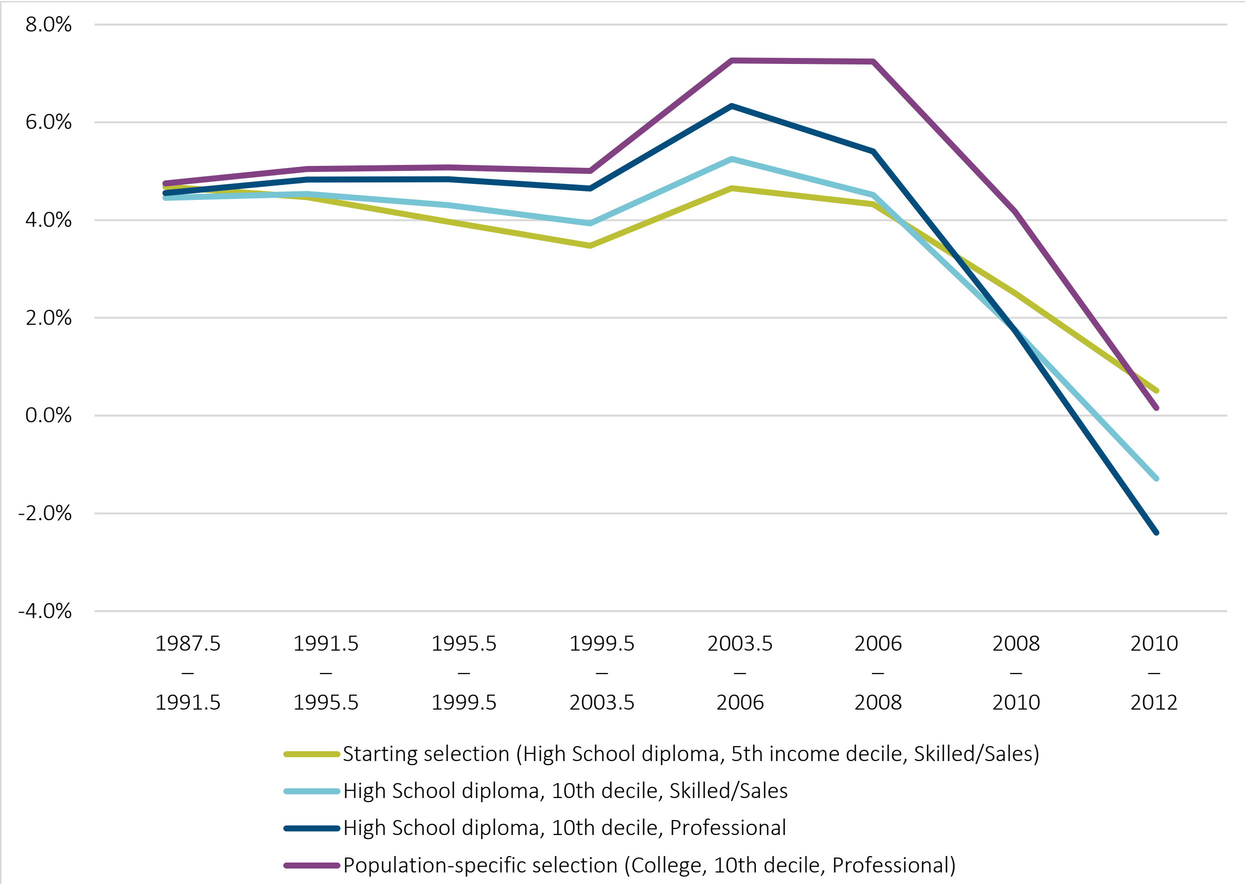
Figure 60
CANCER MORTALITY IMPROVEMENT – COMPARISON BETWEEN ILLUSTRATIVE POPULATION



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 61

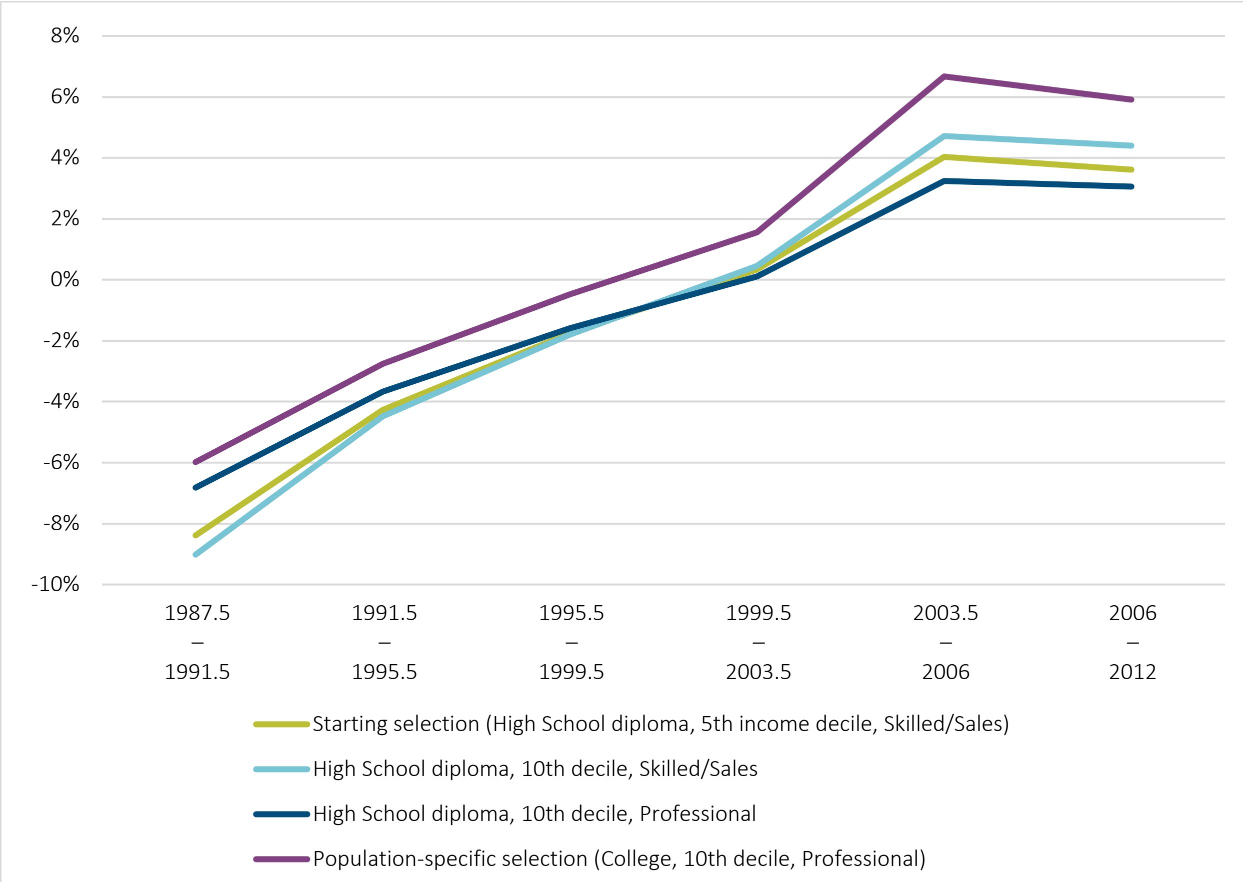
HEART MORTALITY IMPROVEMENT – COMPARISON BETWEEN ILLUSTRATIVE POPULATION



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 62

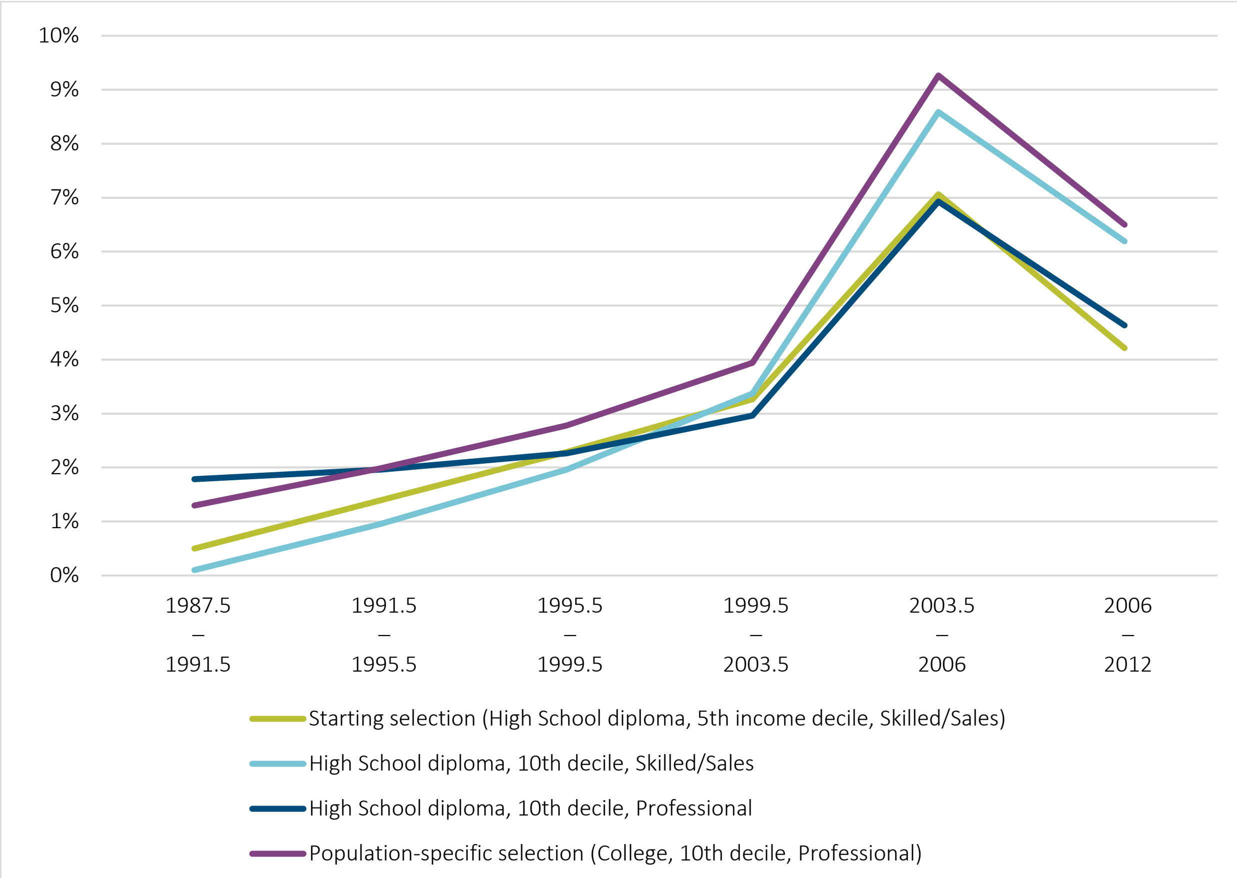
PULMONARY MORTALITY IMPROVEMENT – COMPARISON BETWEEN ILLUSTRATIVE POPULATION



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 63

STROKE MORTALITY IMPROVEMENT – COMPARISON BETWEEN ILLUSTRATIVE POPULATION



Note: See Appendix C.1 for more detail on x-axis year categories. U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

The individual cause of death analysis highlights the fact that cancer and pulmonary diseases are key contributors to mortality differentials during the most recent period for these groups, while heart disease is not. For most of the study period, stroke had mixed results, and only in the most recent periods has emerged as a major differentiator. A cautious practitioner may elect to do additional research into those specific causes of death and trends in medical advances in treatment and preventions. After all, mortality improvement is driven by concrete changes in medicine, healthcare, and lifestyle.

After additional research, a cautious practitioner may conclude that the mortality improvement gap driven by cancer is temporary as current treatments, screening procedures, and lifestyle activities become more accessible and common to less affluent individuals. Similarly, they may conclude that the gap from pulmonary illnesses is expected to be static going forward since smoking cessation rates have plateaued. Lastly, they may observe the mixed results for heart- and stroke-related deaths to indicate the need for more data to fully support an extreme adjustment factor. The combined effect of this analysis may give the cautious practitioner confidence in a prospective adjustment factor of 2% grading, down to 1% over 20 years.

Note that this is an illustrative example only intended to demonstrate how a practitioner may use the historical data and results presented in this report to inform analysis and the assumption setting process.

Section 5: Acknowledgements

The authors' deepest gratitude goes to those without whose efforts this project could not have come to fruition: the volunteers who generously shared their wisdom, insights, advice, guidance, and arm's-length review of this study prior to publication. Any opinions expressed may not reflect their opinions nor those of their employers. Any errors belong to the authors alone.

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Appendix A: Literature Review

The goal of this section is to build a foundation of research previously performed by:

- Identifying fundamental findings that have repeatedly been shown to be true;
- Illustrating the complexity of the observed mortality patterns;
- Highlighting methodology used to investigate key questions; and
- Posing potential answers to the critical question: What could be causing these patterns in mortality and how they can be predicted going forward?

Mortality is a complex function of many factors. However, a fundamental finding that has been shown time and time again is that socioeconomic status (e.g., income and education) is closely linked to mortality. Conceptually, this makes sense. People with more money can afford to have healthier lifestyles, can live and work in safer and cleaner environments, and have easier access to higher quality health care. The research shows the link is strong and growing stronger over time:

1. 2007—A study conducted using Social Security Administration (SSA) data showed that in 1972, life expectancy at age 60 for the top 50% of earners was only 1.2 years more than the bottom 50% of earners. This gap grew to 5.8 years in 2001.[1]
2. 2015—A refreshed SSA study used more granular income groups and found that in 1980, the life expectancy gap at age 50 for the top and bottom 20% of income earners was 5.1 years for males and 4.0 years for females. This gap expanded to 12.7 years for males and 13.6 years for females in 2010.[2]
3. 2018—A third SSA study used a different metric and found consistent results. It focused on the relative mortality ratio of those with high and low Average Indexed Monthly Earnings (AIME) divided by average mortality (e.g., 1.00 represents average mortality while 1.50 represents mortality that is 50% higher than average). In 1995, for male retirees between ages of 62 and 64, the mortality ratio was 1.65 for the lowest earners and 0.59 for the highest earners. By 2015, the ratios were further apart at 1.77 and 0.52 respectively.[3]

This evidence establishes that there is a significant longevity gap and that the gap is growing. These studies do not investigate whether there are other important socioeconomic variables besides income that impact longevity. As other researchers have pointed out, it is challenging to get other socioeconomic variables and mortality in the same dataset. A common approach to overcome this challenge is to use geographic data such as census tracts, ZIP codes, and county-level data to match up mortality with socioeconomic information. The research using this approach extends the results above:

4. 2020—Barbieri used an approach validated by Singh (2002,[4] 2003,[5] 2006[6]) to construct a single socioeconomic index score (SIS) in each U.S. county. The scores were built from a combination of 11 county-level variables reflecting the population's level of education, income, income inequality, poverty, occupation, employment, housing cost, and housing quality, using Principal Component Analysis. Counties were ranked on their SIS and grouped into ten deciles. Lifetables for every year from 1982 to 2018 were calculated for each socioeconomic decile of counties. The results showed a clear socioeconomic gradient of mortality at the beginning of the study period, progressively increasing over time. Differences in the mortality rates across socioeconomic decile were largest for children and adults between the ages of 35 and 50 years and smallest for the elderly (especially those aged 80 years and above).[7]
5. 2021—Holman and MacDonald also used an SIS for each U.S. county and compared mortality results by quintile. In addition, they introduced cause of death (COD) analysis and highlighted results for suicides, accidents, opioids, heart disease, and stroke. This approach demonstrated that the rank order of income quintiles over time is not consistent for individual causes of death.[8] For example, **Figure 64** shows that

individuals in the top 20% socioeconomic (SES) group experienced greater improvement than those in the bottom 20% SES in six of eight leading physiological causes of death. Note SES gap presented in **Figure 64** do not account for the magnitude of uncertainty in either of the two 2014–2019 MI rates. An SES gap of 0.2% might not be statistically different from zero when allowing for the uncertainties of the estimates. Similarly, **Figure 65** shows that individuals in the top 20% socioeconomic (SES) group experienced greater improvement than those in the bottom 20% SES in three of four leading external causes of death.

Figure 64

ANNUAL MORTALITY IMPROVEMENT RATE FOR PHYSIOLOGICAL CAUSES OF DEATH (HOLMAN ET AL., 2021)

2014-2019 MI Rate by COD	Highest SES Quintile	Lowest SES Quintile	SES Gap
Heart	0.9%	0.7%	0.2%
Cancer	2.2%	1.6%	0.6%
Alzheimer's/Dementia	0.9%	1.6%	-0.7%
Pulmonary	1.9%	-0.1%	2.0%
Stroke	-1.2%	0.6%	-1.8%
Diabetes	-0.3%	-1.3%	1.0%
Flu/Pneumonia	4.5%	4.2%	0.3%
Liver	-1.2%	-2.2%	1.0%
Total	1.3%	0.9%	0.4%

Figure 65

ANNUAL MORTALITY IMPROVEMENT RATE FOR EXTERNAL CAUSES OF DEATH (HOLMAN ET AL., 2021)

2014-2019 MI Rate by COD	Highest SES Quintile	Lowest SES Quintile	SES Gap
Accidents	-3.6%	-3.1%	-0.5%
Suicide	-0.2%	-1.6%	1.4%
Assaults	-3.6%	-4.2%	0.6%
Total	-2.8%	-2.9%	0.1%

These two pieces of research add significant complexity to the patterns of observed mortality. They show that overall cause of death mortality and mortality improvement are linked to more than just income. In particular, they show a) the necessity of focusing on key ages where the differentials are most observable, b) that education, household income, and percent below the federal poverty line are key differentiators for mortality, and c) that socioeconomic groups do not equally share the changes in individual cause of death mortality over time.

Using geography to tie socioeconomic status and mortality trends over time is a useful approach, but questions remain. Two different geographic regions could fall in the same "average" bucket but look very different. There could also be movement between regions. Ideally, we would like to explore the relationships between socioeconomic variables for individuals. The next piece of research used 1.4 billion declassified tax records cross-referenced with SSA death records to draw similar conclusions and put the differentials in context.

6. 2016—Chetty confirmed that higher income was associated with greater longevity throughout the income distribution, and that inequality for life expectancy has increased over time. Chetty also put the differentials in meaningful context. For example, the difference in life expectancy between the top 1% and bottom 1% of income earners (10+ years) is equivalent to the drop in longevity from a lifetime of smoking. Similarly, the life expectancy gains between 1999 and 2014 for the top 5% of income earners is comparable to the complete elimination of cancer. The bottom 5% enjoyed no material gains in life expectancy during the same period. Lastly, Chetty showed that geographic differences in life expectancy were NOT significantly correlated with access to medical care, physical environmental factors, income inequality, or labor market

conditions. Instead, the strongest patterns showed that smoking and education explained the shorter life expectancy for low-income individuals.[9]

The question of why the patterns exist remains unanswered. Higher smoking rates among lower income earners is certainly a reasonable explanation. Education appears again as a critical differentiator, but why this is the case is a subject for speculation. Other circumstantial research shows two trends that would combine to have a compounding effect on mortality:

7. Socioeconomic inequality in the U.S. is growing steadily. Roser & Ortiz-Ospina found that the U.S. Gini index grew from 37% in 1970 to 45% in 2005,[10] and various sources extend this result to 48–50% in 2020.[11]
8. The health and lifestyle differences between socioeconomic groups are becoming more pronounced. For example, Drope et al. found that in 2016, those living below the federal poverty line smoke more than three times their wealthier counterparts. In 1990, this number was less than two times.[12] In addition, Rehm et al. found that in 2012, those living with incomes above 300% of the poverty line had a diet score 1.62 times greater than those with incomes below 130% of the poverty line. In 2004, this number was 1.52 times.[13] The diet score was constructed based on the AHA 2020 Strategic Impact Goals for diet associated with cardiovascular and metabolic outcomes. The dietary components that make up this score are total consumption of fruits and vegetables; fish and shellfish; sodium; sugar-sweetened beverages; whole grains, nuts, seeds, and legumes; processed meat; and saturated fat.

In other words, income and wealth inequality is increasing, and the behaviors of the rich and poor are diverging. Two very influential researchers, Case and Deaton, tie all of these ideas together in a series of publications starting in 2015 that connect mortality with education, race/ethnicity, capitalism, and health care. They have popularized the phrase “Deaths of Despair” to represent the combined effects of mortality and socioeconomic factors.

9. 2017—Case and Deaton found differences in mortality by race/ethnicity and education with white, non-Hispanic individuals experiencing mortality increases without a college degree while decreasing for those with a college degree. The responsible causes are drug overdoses, suicides and alcohol-related liver mortality. Of particular note: Case and Deaton point out that Deaths of Despair is not equivalent to Diseases of Poverty. Subgroups of the general population that have seen their prospects fall (e.g., doing worse than their parents) would fare worse than other subgroups at the same socioeconomic level that experienced no such disappointment.[14]

10. 2019—Case and Deaton argued in their *New York Times* and *Wall Street Journal* bestseller book that “deaths of despair reflect a long-term and slowly unfolding loss of a way of life for the white, less educated, working class." They point out that the trend observed in the research above is “… the result of a tug-of-war. On one side we have progress against heart disease, pulling mortality rates down. On the other, we have deaths of despair tugging, weakly at first, to pull mortality rates up. In 1990, heart disease progress was ‘winning,’ and overall mortality fell. But, over time, heart disease progress lost strength, while deaths of despair grew stronger and overall mortality stopped declining.”[15]

Essentially, Case and Deaton show that the economic and social wellbeing of those without a college education is measurably deteriorating and becoming more pronounced.

This research provides us with insights into key variables that could be driving mortality improvement differences; however, many of these variables could be correlated. A regression can be used to determine the impact of each variable while controlling for others. Zhu and Li[16] used regression when analyzing factors that affect insured mortality. One key benefit to this approach is that it generates models based on multiple explanatory factors and provides the impact for each factor. Additionally, we can use credibility statistics to verify the reliability of the results. An additional benefit that makes it stand out from an experience table approach is that it can be adapted to be predictive of future trends.

Question: What does all this research tell us and how should we use it as a springboard into our own research?

Answer: It narrows our research by providing clues as to what data splits should be reviewed in detail.

- Key differentiators will be college education, household income and marriage; the spread within each of these variable groups has grown over time.
- Ages between 40 and 85 are where mortality differences in subgroups will be most visible and most impactful to life expectancy calculations.
- Mortality differences between socioeconomic groups are not uniform by age, so ages should be reviewed in small bands.
- Key causes of death should be reviewed individually because the net improvement may mask offsetting trends.

Appendix B: Data Source and Preparation

B.1 DATA SOURCES

The data is from the National Longitudinal Mortality Study[17] (NLMS) dataset and the Mortality Disparities in American Communities[18] (MDAC) dataset from the U.S. Census Bureau. The intended purpose of both datasets is to facilitate research that links demographic and socioeconomic variables with mortality.

Figure 66
DATASET

	NLMS	MDAC	Combined
Time span of interviews	1980–2011*	2008	1980–2008
Maximum follow-up time	11 years from interview	All person-years are less than 11 after interview	11 years from interview
Time span of mortality data from NCHS	1980–2011	2008–2015	1980–2015
Records	1.26 million	2.28 million	3.54 million
Deaths	193,000	296,000	489,000
Person-years of exposure	30 million p-y	34.84 million p-y	65 million p-y
Person information	Current Population Survey	American Community Survey	Current Population Survey and American Community Survey
Death information	National Center for Health Statistics	National Center for Health Statistics	National Center for Health Statistics

*(each respondent interviewed only once)

Both datasets are based on demographic survey information cross referenced to death certificate records. Notably, 91% of the American Community Survey records were successfully matched with specific Social Security numbers which makes tracking down death information more likely.

Survey responses covered geography, birth information, race/ethnicity, household relationships, marital status, education, nativity and language, employment variables, income/poverty, health insurance, disability status, veteran status, and housing unit characteristics. Death certificate information includes date of death and cause of death. Individual entries in each dataset are weighted to account for under- or over-sampling so that across a multitude of splits, the sample is representative of the entire U.S. population.

B.2 DATA PREPARATION

Data was accessed indirectly through cooperation with statisticians at the U.S. Census. Mortality and exposure figure requests were submitted to them. The figures were coded and prepared and then reviewed by the U.S. Census Bureau's Disclosure Review Board (DRB) to ensure anonymity and privacy.

Other variables were grouped to improve model fit and preserve individual privacy:

- Attained ages were grouped into five-year age bands.
- Nine overlapping calendar year cohorts were created based on entry year into the study.
- Household income was grouped into 10 deciles after adjusting for inflation using the Consumer Price Index.
- 1,000+ occupation codes were grouped into five disability underwriting groups: professional, skilled/sales, blue collar (light physical duties), blue collar (heavy physical duties), and medical; this grouping was reviewed by multiple reviewers but still subjective. The line between professional and skilled/sales may be

blurry. For example, a head pharmacist may be classified as medical while retail pharmacy staff may reasonably be classified as medical, skilled/sales, or blue collar (light physical duties)

B.3 GLOBAL FILTERS

Records were eliminated from each study so that the remaining records could come as closely as possible to a common denominator population. The studies differ in treatment of persons in the armed forces. Also, some years of NLMS exclude children.

The following limitations are placed on the data output due to privacy reasons:

1. Cells with < 15 deaths are not shown.
2. Exposures with 10–100 deaths are shown rounded to the nearest 10.
3. Exposures with 100–1,000 deaths are shown rounded to the nearest 50.

Survey-based demographic information is subject to change over time. For example, a survey participant may get married a year or two after the point-in-time survey. Therefore, the maximum follow-up period was set to 11 years.

B.4 DATA LIMITATIONS

As noted in Section B.1, the NLMS and the MDAC datasets have been joined for this research. The datasets are similar in terms of data definitions and development methods, and that this approach is a reasonable way to research long-term trends. However, it has been observed that there are changes in mortality between 2007 and 2008 which are likely attributable to the transitioning between datasets rather than changes in the underlying population.

To address this limitation in the tabular presentation:

1. Appropriate smoothing has been applied and
2. Sharp discontinuities between 2007 and 2008 have not driven key conclusions.

This limitation is does not affect the way regression results have been presented.

B.5 DEATHS AND EXPOSURES

Figures 67 and 68 show the resulting lives and deaths used for the regression (after the data had been fully prepared).

Figure 67
DATASET COMPARISON - LIVES

	1980–1991	1984–1995	1988–1999	1992–2003	1996–2007	2000–2011	2004–2012	2008–2012	2008–2016
Lives	252,000	98,000	91,000	114,000	106,000	142,000	193,000	187,000	1,683,000

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Figure 68
DATASET COMPARISON – DEATHS BY CAUSE OF DEATH

	1980–1991	1984–1995	1988–1999	1992–2003	1996–2007	2000–2011	2004–2012	2008–2012	2008–2016
All-cause	56,000	21,500	20,000	22,500	17,500	18,500	14,000	5,000	155,000
Cancer	14,000	5,600	5,400	5,800	4,400	4,900	3,800	1,400	43,000
Heart	22,000	7,900	6,900	7,300	5,300	5,200	3,800	1,300	38,500
Pulmonary	2,400	1,100	1,000	1,200	1,100	1,100	0	0	9,300
Stroke	4,200	1,500	1,400	1,600	1,100	1,100	0	0	8,200

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

B.6 DEFINITIONS OF RACE AND ETHNICITY

This subsection provides the explanation and definitions of race and ethnicity used by the U.S. Census Bureau verbatim.* The U.S. Census Bureau collects race data in accordance with guidelines provided by the U.S. Office of Management and Budget (OMB), and these data are based on self-identification. The racial categories included in the census questionnaire generally reflect a social definition of race recognized in this country and not an attempt to define race biologically, anthropologically, or genetically. In addition, it is recognized that the categories of the race item include racial and national origin or sociocultural groups. People may choose to report more than one race to indicate their racial mixture, such as "American Indian" and "White." People who identify their origin as Hispanic, Latino, or Spanish may be of any race.

OMB requires that race data be collected for a minimum of five groups: White, Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander. OMB permits the Census Bureau to also use a sixth category - Some Other Race. Respondents may report more than one race.

The concept of race is separate from the concept of Hispanic origin. Percentages for the various race categories add to 100 percent, and should not be combined with the percent Hispanic.

Definition

White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa. It includes people who indicate their race as "White" or report entries such as Irish, German, Italian, Lebanese, Arab, Moroccan, or Caucasian.

Black or African American. A person having origins in any of the Black racial groups of Africa. It includes people who indicate their race as "Black or African American," or report entries such as African American, Kenyan, Nigerian, or Haitian.

American Indian and Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment. This category includes people who indicate their race as "American Indian or Alaska Native" or report entries such as Navajo, Blackfeet, Inupiat, Yup'ik, or Central American Indian groups or South American Indian groups.

Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. This includes people who reported detailed Asian responses such as: "Asian Indian,"

* U.S. Census Bureau, Population Estimates Program (PEP), accessed September 19, 2022, https://www.census.gov/quickfacts/fact/note/US/RHI625221#:~:text=OMB%20requires%20that%20race%20data,report%20more%20than%20one%20race..

"Chinese," "Filipino," "Korean," "Japanese," "Vietnamese," and "Other Asian" or provide other detailed Asian responses.

Native Hawaiian and Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands. It includes people who reported their race as "Fijian," "Guamanian or Chamorro," "Marshallese," "Native Hawaiian," "Samoan," "Tongan," and "Other Pacific Islander" or provide other detailed Pacific Islander responses.

Two or more races. People may choose to provide two or more races either by checking two or more race response check boxes, by providing multiple responses, or by some combination of check boxes and other responses. For data product purposes, "Two or More Races" refers to combinations of two or more of the following race categories: "White," "Black or African American," American Indian or Alaska Native," "Asian," Native Hawaiian or Other Pacific Islander," or "Some Other Race"

Data users should be aware of methodology differences that may exist between different data sources.

Appendix C: Methodology

The research required two different approaches due to data privacy concerns from the U.S. Census. The first approach was a tabular approach which produced mortality tables and mortality improvement tables by attained age and calendar year. This was suitable for analyzing one variable; however, it could not describe the interactions between variables. For example, the number of deaths for a particular calendar year, attained age, sex, income decile, and cause of death was often less than 10 deaths. In those cases, the results did not convey useful information. In addition, the U.S. Census did not allow such granular figures to be published due to privacy concerns. Therefore, to explore the relationships between demographic and cause of death variables, we implemented a regression approach. The regression approach protected individual privacy while also allowing for the effect of a variable to be observed in isolation while controlling for other variables.

C.1 REGRESSION APPROACH

The goal of this approach was to identify and isolate the effects of statistically significant variables on mortality rates, while controlling for the effects of other known variables that also correlate with mortality. The tabular approach was able to provide us with information on which variables have mortality differentiation, but it could not tell us what was driving these changes. The regression approach was able to provide these insights.

A Cox (proportional hazards) regression was selected to model our data. This regression is used to evaluate the relationship between predictor variable and survival time. Cox regression takes on the form:

$$h(t;\ x_1, x_2, \ldots, x_p) = h_0(t) * e^{(B_1 x_1 + B_2 x_2 + \ldots + B_p x_p)}$$

where:

1. x_i is an indicator that identifies the presence of a characteristic within the set of explanatory variables
2. $h_0(t)$ is the baseline hazard rate (all x_i are 0)

We began this modeling process by ranking variables in order of their expected explanatory power. The variables used for these models are shown in **Figure 69**:

Figure 69
REGRESSION VARIABLE LIST

Expected Explanatory Power	Explanatory Variables	Description
High	Attained age group	5-year age bands (40 to 85+)
	Sex	Male Female
	Smoker status	Never Current Former Not asked
	Household income (deciles)	10 deciles
	Education (5 groups)	No high school degree Completed high school Some college / Associate degree College degree Graduate degree
	Race/Ethnicity (5 groups)	White Non-Hispanic Black Non-Hispanic Hispanic Asian Non-Hispanic Other Non-Hispanic
	Employment status	Employed Unemployed Not in labor force
	Marital status	Married Widowed Divorced Separated Never married
Low	Occupation (6 groups)	Professional Skilled/Sales Blue collar (light physical duties) Blue collar (heavy physical duties) Medical Not applicable

These variables were added incrementally to the model and tested for sufficient explanatory power. Records that were below age 40 or had missing values for these variables (except smoker status and occupation which are coded as N/A) were removed from our dataset. A smoker status variable is highly predictive, so it was included in the regressions where possible. However, data for smoker status was present for some participants in the NLMS dataset but not available for the MDAC dataset. Regression results for the smoker status variable did not convey meaningful trends due to this sparsity of data and so detailed results were excluded from the detailed analysis in **Section 3**.

The remaining dataset had approximately 2.87 million records and 330,000 deaths. The resulting model parameter estimates were nearly all different from zero with a p-value of less than 0.0001.

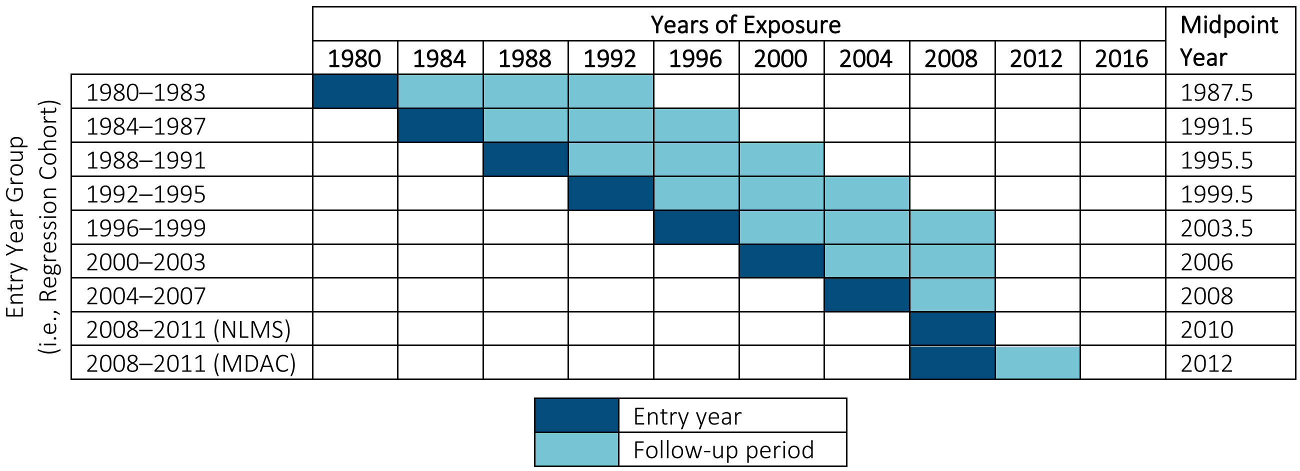
To calculate the mortality for any given individual, we needed to first calculate the hazard rate and mortality of the average individual in our study. We were able to calculate this hazard rate by using the proportion of the population that fit each characteristic as the values for x_i. We also calculated the average annualized mortality rate for the average individual by dividing the number of weighted deaths by weighted exposures. The weights adjust the sample composition to be representative of the U.S. adult population. By calculating these two values, the expected mortality rate for an individual with any selected characteristics would be as follows:

$$q(x_1, x_2, \ldots, x_p) = q(means) * \frac{h(t; means)}{h(t;\ x_1, x_2, \ldots, x_p)}$$

For the purpose of our study, the data was divided by entry year into four-year cohorts with a separate regression performed on each cohort. Each row in **Figure 70** is a single regression cohort. The reason for this approach was practical since data existed in longitudinal cohorts rather than by calendar year and privacy concerns from the U.S. Census.

Figure 70

ENTRY YEAR, YEARS OF EXPOSURE, AND MIDPOINT YEAR FOR EACH REGRESSION COHORT



The overlapping time periods for each cohort presented a conceptual challenge. To overcome this challenge, mortality rates generated by each regression were assigned to the midpoint of the years of exposure, and mortality improvement between the models was calculated on the difference between midpoints. This allowed the coefficients generated by each model to vary and capture relationships over time.

The result of this approach was nine sets of parameter estimates, one set for each regression. This process was repeated for all-cause mortality as well as leading causes of death including cancer, heart disease, pulmonary illnesses, and stroke. See **Appendix E** for more information regarding how uncertainty in the parameter estimates was assessed.

C.2 ANALYSIS

The Cox (proportional hazards) regression model noted above does not have explicit interaction terms between variables, so the results can be presented using baseline results with only one variable adjusted at a time. The following baseline variables were selected because they had the most exposure:

- Sex = Male
- Smoker Status = Not Asked
- Income Decile = 10 (most affluent)
- Education = Completed High School
- Race/Ethnicity = White Non-Hispanic
- Employment Status = Employed
- Marital Status = Married
- Occupation = Professional
- Attained Age Group = 65–69

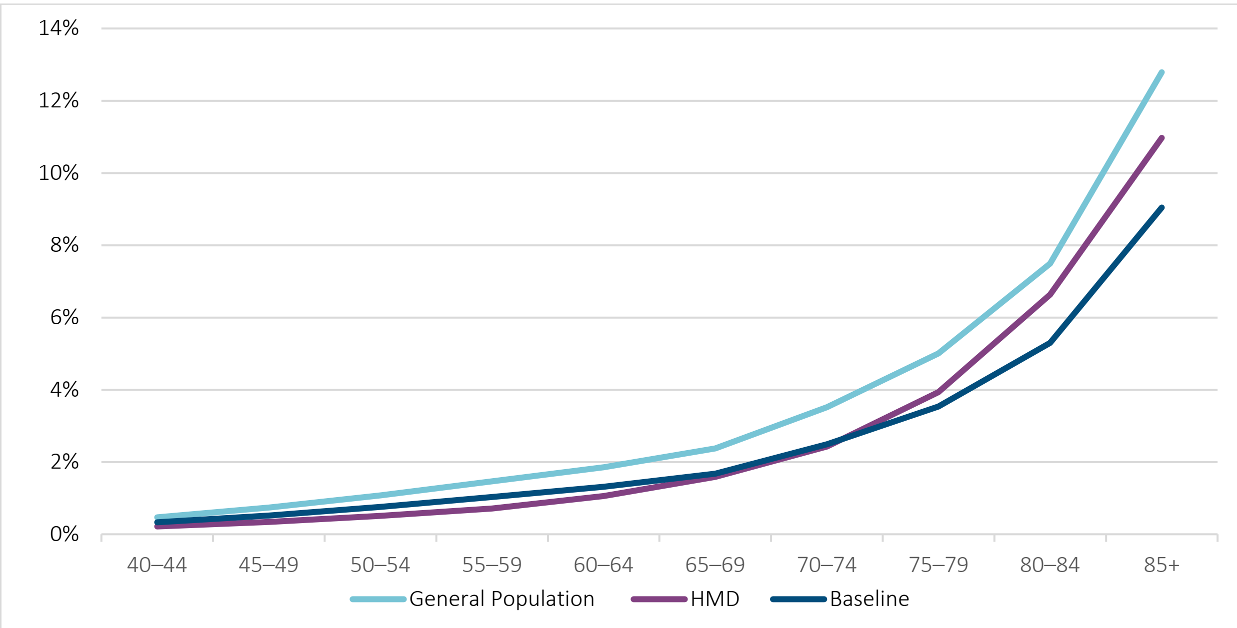
Despite having the most exposure within each category, the intersection of all the categories may make this baseline selection very uncommon. Therefore, analysis should focus on the delta when one variable is changed. Those differences show the spread attributable to that particular variable. Adjusting two or more variables would result in essentially additive changes due to the structure of the model. Figures 57 and 58 demonstrate how a user may select a different starting selection and properly focus on the deltas when variables are adjusted.

Appendix D: Dynamic Validation

The results of the all-cause regressions were benchmarked against the Human Mortality Database (HMD) project. HMD data from 2008 was compared against the general population and baseline regression output centered around 2008. The general population line in **Figure 71** shows the estimated mortality for the average individual in our study. This line shows greater mortality than the HMD but follows the same trend. We also included the mortality for the baseline group which is used as the standard for comparison for each variable split.

Figure 71

DYNAMIC VALIDATION



U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Mortality improvement for the general population in our data was compared against the MP-2021. The all-cause regressions showed the same trend of low improvement in earlier years that increases until 2004–2008, where it peaks. This is then followed by years with lower improvement. Although the dataset used in this study follows the same mortality improvement trend, the results are more volatile than those shown in the MP scale.

Appendix E: Confidence Intervals

As noted in **Appendix D**, mortality improvement calculations are prone to a great degree of uncertainty. For example, a particular subset of a population may experience mortality of 1.0% one year and 0.9% in the next, representing improvement of 10%. If the 95% confidence interval for each estimate is ±0.1% then we are really comparing a range of [0.9%, 1.1%] to [0.8%, 1.0%]. The resulting mortality improvement confidence interval would range from [-11.1%, 27.3%]:

		95% CI for 1st Year	
		0.9%	**1.1%**
95% CI for 2nd Year	**0.8%**	11.1%	27.3%
	1.0%	-11.1%	9.1%

Note that this range is not a 95% confidence interval. To precisely arrive at a 95% range there are issues related to independence that would need to be settled (Stuart Klugman's approach addresses this analytically below). Still, this example demonstrates that a radius of 0.1% for two consecutive years compounds to a radius of over 8%.

One method used to address this challenge is to simulate 1,000 different mortality rates using point estimates and their standard errors provided in each regression. Then, in an expanded approach to the example above, we calculated and then ranked the resulting mortality improvement rates to measure the 95% confidence intervals. Most cases had a 95% confidence interval less than 0.1%.

A second method used to quantify uncertainty and calculate confidence intervals was to apply a formulaic approach. In 2017, Stuart Klugman provided guidance to SOA research staff and experience study committees on credibility for mortality improvement ratios which included a formula based on exposure and mortality.[19]

$$Variance = \frac{q_1}{q_2^2 \cdot E_1} + \frac{q_2^2}{q_2^3 \cdot E_2}$$

Inputs to this approach are mortality rates and exposures with lower mortality and lower exposures both resulting in greater variance. While practical to apply, this simplified model produces confidence intervals that are too wide and introduce bias in this particular context.

1. **Too wide:** This approach is useful for calculating variance of improvement between two independent point estimates. However, the values in this project are the result of regression and smoothing. Because exposure is assumed to be a point estimate in Stuart Klugman's approach, it underestimates the true amount of exposure used in the regression.

2. **Introduces bias:** The mechanics of the formula make it that lower mortality rates produce greater variance. The effect is that if female was selected (lower mortality than males) as the baseline then the confidence intervals for all the other variables would be wider. This is undesirable because it introduces bias not previously present. For example, it is undesirable that the width of the confidence intervals for the educational attainment variable be affected by the sex selection of the baseline. In **Figures 57** and **58**, we already demonstrated that the selection of baseline variables did not have a substantial effect on the mortality improvement deltas within a variable. The same cannot be said for confidence intervals based on the formulaic approach.

Despite these drawbacks, the formulaic approach is still useful as a comparative measure across variables or causes of death. For example, data for married and widowed individuals is much more robust than for separated individuals. Similarly, all-cause mortality is much more robust than for stroke. Results for all variables are presented in **Figures 72–76**. Note that for each row, all variables not identified are baseline.

Example: To get the 75% confidence intervals on the mortality improvement point estimate for ages 40–44 between 1987.5 and 1991.5 (0.3% from the data supporting **Figure 9**), take the point estimate and add/subtract the radius noted in **Figure 72** (4.8%). The result for this example is [-4.5%, 5.1%].

E.1 ALL-CAUSE

Figure 72
75% CONFIDENCE INTERVAL RADIUS – ALL-CAUSE

Group	Variable	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2008	2008–2010	2010–2012
Attained Age	40–44	4.8%	5.6%	5.2%	5.1%	4.9%	5.0%	8.2%	7.5%
	45–49	4.1%	4.9%	4.7%	4.4%	4.2%	4.3%	6.5%	5.8%
	50–54	3.2%	4.0%	3.9%	3.8%	3.8%	3.8%	6.3%	6.0%
	55–59	2.6%	3.3%	3.3%	3.4%	3.5%	3.5%	5.0%	4.6%
	60–64	2.2%	2.7%	2.7%	2.9%	3.0%	3.2%	4.8%	4.3%
	65–69	2.1%	2.4%	2.4%	2.4%	2.6%	2.9%	4.4%	4.0%
	70–74	2.0%	2.3%	2.2%	2.1%	2.3%	2.6%	4.1%	3.7%
	75–79	2.1%	2.4%	2.3%	2.1%	2.1%	2.3%	3.7%	3.4%
	80–84	2.5%	2.8%	2.5%	2.3%	2.3%	2.4%	3.7%	3.4%
	85+	2.9%	3.3%	3.0%	2.7%	2.8%	2.8%	3.3%	3.0%
Sex	Male	1.0%	1.2%	1.2%	1.2%	1.2%	1.2%	1.9%	1.7%
	Female	1.2%	1.3%	1.3%	1.2%	1.2%	1.3%	1.9%	1.8%
Smoker Status	Never	N/A	N/A	N/A	1.7%	1.5%	2.0%	4.7%	N/A
	Current	N/A	N/A	N/A	2.8%	2.4%	3.1%	6.6%	N/A
	Former	N/A	N/A	N/A	1.9%	1.7%	2.3%	5.2%	N/A
	Not asked	0.7%	0.9%	1.0%	1.2%	1.5%	1.4%	1.5%	1.4%
Marital Status	Married	1.0%	1.2%	1.1%	1.1%	1.1%	1.2%	2.0%	1.8%
	Widowed	1.4%	1.7%	1.6%	1.5%	1.6%	1.7%	2.6%	2.5%
	Divorced	3.0%	3.5%	3.1%	2.8%	2.6%	2.6%	4.0%	3.8%
	Separated	5.8%	6.9%	6.4%	6.3%	6.5%	6.5%	9.9%	9.4%
	Never married	3.0%	3.7%	3.6%	3.5%	3.5%	3.5%	5.1%	4.8%
Income Decile	1-Lowest	1.7%	2.2%	2.0%	1.9%	2.0%	2.1%	3.1%	3.0%
	2	1.6%	2.0%	1.9%	1.8%	1.9%	2.0%	3.2%	3.0%
	3	2.1%	2.3%	2.2%	2.1%	2.1%	2.3%	3.7%	3.5%
	4	2.2%	2.6%	2.5%	2.4%	2.4%	2.7%	4.4%	4.1%
	5	2.5%	3.0%	2.8%	2.8%	2.8%	3.1%	4.9%	4.5%
	6	2.8%	3.2%	3.1%	3.1%	3.1%	3.4%	5.5%	5.2%
	7	3.8%	3.5%	3.5%	3.4%	3.3%	3.5%	5.6%	5.1%
	8	3.1%	3.9%	3.9%	3.9%	3.8%	4.1%	6.3%	5.6%
	9	4.4%	3.9%	3.9%	3.8%	3.6%	3.8%	5.6%	5.0%
	10-Highest	3.9%	4.2%	4.0%	3.9%	3.7%	3.8%	6.1%	5.6%
Educational Attainment	No High School diploma	1.0%	1.3%	1.3%	1.3%	1.4%	1.6%	2.5%	2.4%
	High School diploma	1.4%	1.6%	1.5%	1.4%	1.4%	1.5%	2.2%	2.0%
	Some College / AA	2.3%	2.7%	2.3%	2.0%	1.9%	2.0%	3.1%	2.8%
	College degree	3.2%	3.6%	3.3%	2.9%	2.7%	2.8%	4.4%	4.0%
	Graduate degree	3.9%	4.4%	4.0%	3.9%	3.7%	3.7%	5.8%	5.4%
Race/Ethnicity	White (Non-Hispanic)	1.0%	1.2%	0.9%	0.9%	0.9%	1.0%	1.6%	1.5%
	Black (Non-Hispanic)	2.9%	3.4%	2.9%	2.7%	2.6%	2.4%	3.3%	3.1%
	Asian (Non-Hispanic)	9.7%	10.7%	8.1%	7.3%	6.5%	5.7%	8.7%	8.4%
	Hispanic	4.1%	4.3%	3.8%	3.3%	3.1%	3.2%	5.2%	4.9%
	Other (Non-Hispanic)	2.6%	3.0%	4.0%	4.1%	4.0%	4.5%	7.7%	7.2%
Employment Status	Employed	1.6%	1.9%	1.9%	1.9%	1.8%	2.0%	3.4%	3.2%
	Unemployed	6.6%	8.6%	8.3%	8.4%	8.7%	8.6%	12.7%	11.3%
	NILF	0.9%	1.0%	1.0%	1.0%	1.0%	1.0%	1.5%	1.4%
Occupation	Professional	4.5%	5.2%	5.0%	5.0%	4.8%	5.1%	8.0%	7.2%
	Skilled/Sales	2.7%	3.2%	3.2%	3.3%	3.3%	3.9%	7.0%	6.5%
	Blue Collar (light physical duties)	3.2%	3.9%	3.9%	4.1%	4.0%	4.1%	6.9%	6.5%
	Blue Collar (heavy physical duties)	2.3%	2.9%	3.0%	3.1%	3.2%	3.4%	6.1%	5.7%
	Medical	6.6%	8.1%	8.0%	7.6%	7.5%	8.3%	14.2%	13.2%
	N/A	0.9%	1.0%	1.0%	0.9%	0.9%	1.0%	1.5%	1.4%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

E.2 CANCER

Figure 73

75% CONFIDENCE INTERVAL RADIUS – CANCER

Group	Variable	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2008	2008–2010	2010–2012
Attained Age	40–44	9.0%	10.1%	9.4%	9.4%	9.1%	10.2%	15.7%	13.9%
	45–49	7.9%	8.7%	7.8%	7.5%	7.3%	7.6%	12.3%	11.2%
	50–54	6.1%	7.1%	6.6%	6.5%	6.4%	6.3%	9.5%	8.4%
	55–59	5.0%	6.0%	5.9%	5.7%	5.6%	5.6%	7.9%	6.9%
	60–64	4.6%	5.2%	5.0%	5.0%	5.0%	5.4%	7.8%	6.7%
	65–69	4.6%	4.9%	4.6%	4.6%	4.8%	4.9%	7.6%	6.7%
	70–74	4.8%	5.2%	4.6%	4.4%	4.6%	4.8%	6.8%	5.7%
	75–79	5.8%	6.1%	5.4%	5.1%	4.8%	4.9%	6.9%	5.9%
	80–84	8.1%	8.6%	7.3%	6.4%	6.0%	5.8%	8.3%	7.2%
	85+	10.0%	11.9%	10.4%	8.7%	9.3%	8.3%	8.9%	7.4%
Sex	Male	2.4%	2.7%	2.5%	2.4%	2.3%	2.4%	3.4%	3.0%
	Female	2.9%	3.0%	2.7%	2.6%	2.5%	2.6%	3.7%	3.1%
Smoker Status	Never	N/A	N/A	N/A	3.9%	3.4%	4.4%	10.2%	N/A
	Current	N/A	N/A	N/A	5.2%	4.3%	5.1%	10.8%	N/A
	Former	N/A	N/A	N/A	4.0%	3.5%	4.3%	8.9%	N/A
	Not asked	1.8%	1.9%	2.1%	2.5%	3.1%	2.8%	2.9%	2.5%
Marital Status	Married	2.2%	2.4%	2.2%	2.2%	2.2%	2.3%	3.4%	3.0%
	Widowed	4.0%	4.2%	3.8%	3.7%	3.7%	3.7%	5.1%	4.7%
	Divorced	7.0%	7.4%	6.2%	5.5%	5.2%	5.1%	7.2%	6.4%
	Separated	12.1%	13.9%	13.0%	12.4%	13.0%	13.2%	18.1%	16.7%
	Never married	7.6%	8.9%	8.2%	8.1%	8.0%	7.4%	9.9%	8.7%
Income Decile	1-Lowest	4.5%	5.4%	4.9%	4.6%	4.8%	4.7%	6.8%	6.2%
	2	4.1%	4.8%	4.4%	4.3%	4.2%	4.3%	6.2%	5.5%
	3	4.9%	5.2%	4.7%	4.7%	4.6%	4.6%	6.9%	6.1%
	4	5.3%	5.7%	5.2%	5.1%	5.0%	5.2%	8.0%	7.1%
	5	5.5%	6.1%	5.6%	5.6%	5.7%	6.0%	9.7%	8.7%
	6	5.7%	6.4%	6.2%	6.3%	6.1%	6.2%	9.5%	8.3%
	7	7.8%	7.0%	6.8%	6.5%	6.1%	6.5%	10.1%	8.7%
	8	6.0%	7.3%	7.4%	7.4%	7.0%	7.3%	11.4%	10.0%
	9	8.1%	7.0%	6.9%	6.8%	6.7%	6.8%	10.3%	9.0%
	10-Highest	8.3%	8.4%	7.5%	7.2%	6.8%	6.5%	9.9%	8.7%
Educational Attainment	No High School diploma	2.7%	3.1%	3.0%	3.0%	3.1%	3.3%	5.0%	4.4%
	High School diploma	3.1%	3.3%	3.0%	2.9%	2.8%	2.8%	4.1%	3.5%
	Some College / AA	5.1%	5.5%	4.8%	4.1%	3.8%	3.7%	5.4%	4.7%
	College degree	7.9%	7.8%	6.5%	5.9%	5.4%	5.2%	7.5%	6.6%
	Graduate degree	9.0%	9.2%	7.6%	7.4%	7.2%	7.0%	10.1%	8.9%
Race/Ethnicity	White (Non-Hispanic)	2.5%	2.6%	2.0%	1.9%	1.9%	2.0%	3.0%	2.6%
	Black (Non-Hispanic)	7.2%	7.6%	5.9%	5.6%	5.3%	4.7%	6.4%	5.8%
	Asian (Non-Hispanic)	21.4%	22.7%	16.9%	14.6%	12.9%	12.1%	17.0%	15.4%
	Hispanic	10.6%	10.3%	8.6%	7.3%	6.9%	6.8%	10.1%	9.2%
	Other (Non-Hispanic)	7.1%	7.0%	8.6%	8.4%	7.9%	8.3%	13.1%	11.6%
Employment Status	Employed	3.2%	3.6%	3.4%	3.2%	3.1%	3.2%	5.3%	4.7%
	Unemployed	14.4%	17.6%	16.1%	15.4%	15.8%	16.1%	N/A	N/A
	NILF	2.1%	2.4%	2.2%	2.2%	2.2%	2.1%	2.9%	2.2%
Occupation	Professional	8.6%	9.1%	8.5%	8.3%	8.2%	7.9%	11.9%	10.5%
	Skilled/Sales	4.8%	5.6%	5.6%	5.8%	5.7%	6.1%	10.8%	9.8%
	Blue Collar (light physical duties)	5.8%	6.8%	6.7%	7.1%	6.9%	6.8%	11.1%	10.1%
	Blue Collar (heavy physical duties)	4.5%	5.3%	5.3%	5.6%	5.7%	6.1%	10.2%	9.3%
	Medical	11.5%	14.1%	13.7%	13.5%	13.2%	13.3%	22.5%	20.8%
	N/A	2.1%	2.3%	2.1%	2.0%	2.0%	2.1%	3.2%	2.9%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

E.3 HEART

Figure 74

75% CONFIDENCE INTERVAL RADIUS – HEART

Group	Variable	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2008	2008–2010	2010–2012
Attained Age	40–44	7.5%	9.3%	9.5%	10.7%	10.7%	12.1%	24.3%	23.3%
	45–49	6.5%	8.1%	8.3%	8.3%	8.7%	9.8%	15.3%	14.1%
	50–54	5.1%	6.5%	6.7%	6.9%	7.4%	8.2%	13.6%	13.0%
	55–59	3.9%	5.2%	5.5%	6.0%	6.4%	7.1%	11.2%	10.5%
	60–64	3.2%	4.1%	4.4%	5.1%	5.9%	7.0%	11.9%	11.7%
	65–69	2.8%	3.5%	3.7%	4.2%	4.9%	5.8%	10.1%	9.8%
	70–74	2.7%	3.3%	3.3%	3.5%	4.1%	5.1%	8.4%	7.9%
	75–79	2.8%	3.4%	3.3%	3.4%	3.7%	4.4%	8.2%	8.1%
	80–84	3.1%	3.8%	3.7%	3.5%	3.6%	4.2%	7.4%	7.2%
	85+	3.6%	4.3%	4.2%	4.0%	4.5%	4.7%	6.1%	5.7%
Sex	Male (sex)	1.4%	1.7%	1.8%	1.9%	2.0%	2.3%	3.9%	3.8%
	Female (sex)	1.9%	2.1%	2.0%	1.9%	1.9%	2.1%	3.6%	3.6%
Smoker Status	Never	N/A	N/A	N/A	2.6%	2.5%	3.8%	8.8%	N/A
	Current	N/A	N/A	N/A	4.9%	4.6%	7.0%	13.9%	N/A
	Former	N/A	N/A	N/A	3.1%	3.0%	4.4%	11.6%	N/A
	Not asked	1.0%	1.3%	1.5%	2.0%	2.7%	2.7%	3.2%	3.1%
Marital Status	Married	1.3%	1.7%	1.7%	1.9%	2.1%	2.4%	4.4%	4.3%
	Widowed	1.8%	2.3%	2.3%	2.3%	2.6%	3.0%	5.3%	5.3%
	Divorced	4.5%	5.3%	5.1%	5.0%	5.0%	5.4%	8.8%	8.6%
	Separated	9.1%	11.5%	10.5%	11.0%	12.5%	12.3%	21.2%	20.7%
	Never married	4.2%	5.3%	5.3%	5.4%	5.8%	6.7%	10.7%	10.4%
Income Decile	1-Lowest	2.3%	3.0%	3.1%	3.2%	3.5%	3.8%	6.2%	5.9%
	2	2.2%	2.9%	2.9%	3.0%	3.2%	3.7%	6.4%	6.3%
	3	2.8%	3.3%	3.3%	3.4%	3.8%	4.2%	7.8%	7.7%
	4	3.0%	3.7%	3.8%	4.0%	4.3%	5.3%	8.6%	8.0%
	5	3.5%	4.3%	4.4%	4.6%	4.9%	5.7%	9.9%	9.3%
	6	4.0%	4.8%	4.9%	5.2%	5.7%	6.5%	12.7%	12.4%
	7	5.2%	5.0%	5.3%	5.8%	6.2%	7.1%	11.9%	11.2%
	8	4.2%	5.9%	6.3%	6.9%	7.2%	8.1%	12.4%	11.3%
	9	6.7%	6.3%	6.7%	6.7%	6.8%	7.3%	11.9%	11.1%
	10-Highest	5.6%	6.6%	6.8%	7.0%	7.1%	8.0%	14.2%	13.7%
Educational Attainment	No High School diploma	1.3%	1.8%	1.9%	2.1%	2.4%	2.9%	5.0%	4.8%
	High School diploma	1.9%	2.3%	2.3%	2.4%	2.5%	2.8%	4.8%	4.6%
	Some College / AA	3.3%	4.0%	3.7%	3.4%	3.5%	4.0%	6.5%	6.1%
	College degree	4.3%	5.4%	5.3%	4.9%	5.0%	5.6%	9.5%	9.2%
	Graduate degree	5.6%	6.4%	6.3%	6.3%	6.4%	7.0%	12.0%	12.0%
Race/Ethnicity	White (Non-Hispanic)	1.4%	1.6%	1.4%	1.5%	1.7%	1.9%	3.3%	3.2%
	Black (Non-Hispanic)	4.3%	5.1%	4.4%	4.5%	4.6%	4.4%	6.9%	6.9%
	Asian (Non-Hispanic)	14.8%	17.1%	12.6%	11.8%	12.4%	12.1%	19.7%	19.4%
	Hispanic	5.8%	6.3%	6.0%	5.7%	5.5%	6.1%	11.1%	11.2%
	Other (Non-Hispanic)	3.7%	4.7%	6.6%	6.8%	6.9%	9.4%	16.2%	15.3%
Employment Status	Employed	2.3%	2.9%	3.0%	3.3%	3.5%	4.2%	8.0%	7.9%
	Unemployed	9.6%	12.6%	13.0%	16.6%	18.9%	19.7%	N/A	N/A
	NILF	1.1%	1.4%	1.4%	1.5%	1.7%	2.0%	3.3%	3.0%
Occupation	Professional	6.3%	7.6%	8.2%	9.6%	9.7%	10.8%	18.7%	17.7%
	Skilled/Sales	4.2%	5.3%	5.7%	6.0%	6.6%	8.2%	15.6%	15.0%
	Blue Collar (light physical duties)	4.9%	6.4%	6.6%	7.2%	7.8%	8.6%	15.1%	14.1%
	Blue Collar (heavy physical duties)	3.5%	4.4%	4.9%	5.7%	6.2%	7.1%	12.7%	12.2%
	Medical	10.7%	14.3%	14.8%	15.6%	16.4%	18.4%	N/A	N/A
	N/A	1.3%	1.6%	1.6%	1.6%	1.7%	1.8%	2.8%	2.5%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

E.4 PULMONARY

Figure 75

75% CONFIDENCE INTERVAL RADIUS – PULMONARY

Group	Variable	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2012
Attained Age	40–44	N/A	N/A	N/A	N/A	N/A	23.4%
	45–49	31.0%	34.9%	N/A	N/A	27.5%	17.9%
	50–54	17.3%	21.9%	21.7%	21.0%	22.5%	18.1%
	55–59	15.1%	17.7%	16.5%	15.2%	14.8%	9.9%
	60–64	11.6%	14.0%	13.1%	12.0%	12.5%	8.6%
	65–69	10.0%	10.8%	10.4%	9.5%	9.6%	7.1%
	70–74	12.0%	11.8%	10.1%	9.1%	8.9%	6.0%
	75–79	17.8%	14.8%	11.4%	9.2%	9.0%	6.0%
	80–84	24.9%	18.5%	13.7%	10.7%	9.8%	6.0%
	85+	43.8%	28.2%	22.7%	17.5%	14.9%	10.2%
Sex	Male (sex)	5.8%	6.4%	5.9%	5.4%	5.3%	3.6%
	Female (sex)	12.2%	8.3%	6.5%	5.7%	5.3%	3.5%
Smoker Status	Never	N/A	N/A	N/A	12.3%	9.6%	N/A
	Current	N/A	N/A	N/A	9.1%	7.4%	N/A
	Former	N/A	N/A	N/A	7.5%	5.9%	N/A
	Not asked	4.4%	4.6%	4.9%	5.7%	7.2%	5.4%
Marital Status	Married	5.6%	6.1%	5.6%	5.2%	5.1%	3.5%
	Widowed	8.2%	8.9%	7.7%	7.0%	6.9%	5.5%
	Divorced	12.8%	15.7%	15.1%	12.7%	11.0%	8.7%
	Separated	N/A	N/A	31.5%	31.0%	30.1%	23.8%
	Never married	18.7%	21.4%	21.9%	19.4%	18.3%	14.4%
Income Decile	1-Lowest	8.7%	10.7%	9.8%	8.4%	8.4%	6.8%
	2	7.8%	9.7%	9.0%	8.7%	8.4%	6.1%
	3	9.9%	11.1%	10.3%	9.8%	10.1%	7.5%
	4	10.2%	11.3%	11.0%	10.5%	10.1%	7.5%
	5	14.2%	14.8%	13.7%	12.6%	12.1%	8.7%
	6	14.0%	16.0%	15.9%	15.6%	15.0%	10.6%
	7	21.0%	18.1%	16.3%	14.9%	15.6%	11.5%
	8	18.1%	22.4%	21.3%	18.3%	17.1%	12.9%
	9	24.9%	22.2%	21.3%	21.7%	20.8%	14.3%
	10-Highest	29.1%	25.6%	23.5%	20.7%	17.6%	12.9%
Educational Attainment	No High School diploma	6.1%	6.9%	6.4%	6.1%	6.2%	4.4%
	High School diploma	8.4%	8.3%	6.9%	6.2%	6.1%	4.3%
	Some College / AA	14.0%	14.5%	11.7%	9.6%	9.0%	5.7%
	College degree	19.0%	19.4%	17.7%	14.9%	13.1%	8.3%
	Graduate degree	26.1%	24.8%	26.4%	23.9%	19.3%	11.9%
Race/Ethnicity	White (Non-Hispanic)	5.9%	5.9%	4.4%	4.0%	3.9%	2.7%
	Black (Non-Hispanic)	25.6%	27.7%	20.5%	17.3%	14.9%	9.8%
	Asian (Non-Hispanic)	N/A	N/A	N/A	N/A	N/A	N/A
	Hispanic	27.0%	28.9%	24.5%	19.3%	18.7%	11.8%
	Other (Non-Hispanic)	15.6%	15.3%	19.2%	17.7%	16.5%	12.7%
Employment Status	Employed	11.3%	12.2%	11.2%	10.3%	9.6%	6.7%
	Unemployed	N/A	N/A	N/A	N/A	N/A	N/A
	NILF	4.5%	5.0%	4.4%	4.0%	4.0%	3.1%
Occupation	Professional	32.8%	33.4%	N/A	N/A	N/A	N/A
	Skilled/Sales	19.8%	22.1%	20.6%	17.6%	17.0%	11.5%
	Blue Collar (light physical duties)	26.4%	25.1%	22.1%	21.3%	20.9%	13.6%
	Blue Collar (heavy physical duties)	21.2%	18.9%	18.3%	17.5%	15.7%	9.7%
	Medical	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	6.6%	5.7%	4.8%	4.2%	4.0%	2.3%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

E.5 STROKE

Figure 76

75% CONFIDENCE INTERVAL RADIUS – STROKE

Group	Variable	1987.5–1991.5	1991.5–1995.5	1995.5–1999.5	1999.5–2003.5	2003.5–2006	2006–2012
Attained Age	40–44	27.0%	28.4%	23.8%	N/A	N/A	15.7%
	45–49	21.7%	26.2%	24.0%	26.5%	25.2%	15.9%
	50–54	12.6%	18.9%	22.7%	23.6%	21.5%	14.4%
	55–59	13.5%	16.6%	16.8%	16.4%	16.5%	11.8%
	60–64	8.3%	11.1%	12.7%	14.0%	15.1%	11.6%
	65–69	7.5%	9.9%	9.7%	10.4%	11.7%	8.1%
	70–74	6.6%	7.9%	7.6%	7.6%	8.6%	6.3%
	75–79	6.2%	7.4%	7.3%	7.2%	7.3%	5.3%
	80–84	7.3%	8.4%	7.7%	7.2%	7.1%	5.1%
	85+	7.8%	9.3%	8.6%	8.9%	9.7%	7.0%
Sex	Male	4.0%	4.9%	4.9%	4.9%	5.0%	3.4%
	Female	3.6%	4.3%	4.1%	4.2%	4.3%	2.9%
Smoker Status	Never	N/A	N/A	N/A	6.0%	5.4%	N/A
	Current	N/A	N/A	N/A	12.5%	11.5%	N/A
	Former	N/A	N/A	N/A	7.3%	6.5%	N/A
	Not asked	2.6%	3.2%	3.7%	4.7%	6.1%	4.5%
Marital Status	Married	3.6%	4.4%	4.4%	4.4%	4.6%	3.2%
	Widowed	4.2%	5.1%	5.0%	5.1%	5.5%	4.5%
	Divorced	12.0%	14.5%	13.0%	12.2%	11.7%	8.3%
	Separated	22.2%	27.5%	27.4%	N/A	N/A	19.6%
	Never married	9.3%	11.9%	12.6%	17.4%	18.4%	12.3%
Income Decile	1-Lowest	5.6%	7.2%	6.7%	7.1%	7.9%	6.5%
	2	5.3%	6.8%	6.5%	6.7%	7.0%	5.4%
	3	6.4%	7.3%	7.3%	7.7%	7.9%	5.8%
	4	7.7%	9.4%	8.8%	8.7%	9.2%	6.8%
	5	8.4%	11.0%	10.8%	10.7%	11.3%	8.0%
	6	9.8%	11.7%	11.8%	12.5%	13.5%	10.1%
	7	13.5%	13.0%	13.4%	13.0%	12.9%	9.2%
	8	12.8%	15.4%	14.7%	16.6%	16.8%	11.3%
	9	18.7%	15.9%	16.0%	15.9%	15.6%	10.6%
	10-Highest	14.0%	17.4%	17.2%	15.4%	14.7%	9.9%
Educational Attainment	No High School diploma	3.5%	4.4%	4.5%	5.0%	5.5%	4.0%
	High School diploma	5.1%	5.8%	5.5%	5.4%	5.5%	3.8%
	Some College / AA	8.1%	9.7%	8.6%	7.6%	7.7%	5.1%
	College degree	11.1%	13.5%	12.8%	11.5%	11.0%	7.0%
	Graduate degree	16.0%	16.8%	14.6%	16.2%	15.3%	9.3%
Race/Ethnicity	White (Non-Hispanic)	3.5%	4.1%	3.5%	3.6%	3.7%	2.7%
	Black (Non-Hispanic)	10.1%	12.6%	10.9%	10.5%	10.0%	6.3%
	Asian (Non-Hispanic)	N/A	N/A	28.9%	27.7%	24.4%	15.8%
	Hispanic	20.3%	19.8%	15.5%	13.2%	11.7%	7.4%
	Other (Non-Hispanic)	9.3%	10.3%	14.0%	16.3%	16.2%	12.4%
Employment Status	Employed	7.0%	8.5%	9.1%	9.3%	8.3%	5.4%
	Unemployed	25.3%	N/A	N/A	N/A	N/A	N/A
	NILF	3.3%	3.8%	3.6%	3.5%	3.5%	2.1%
Occupation	Professional	19.1%	24.6%	26.5%	25.5%	24.4%	16.4%
	Skilled/Sales	12.1%	15.1%	15.4%	15.0%	13.8%	8.6%
	Blue Collar (light physical duties)	17.1%	19.4%	17.3%	18.1%	17.3%	10.0%
	Blue Collar (heavy physical duties)	10.8%	12.7%	14.7%	15.7%	14.0%	8.8%
	Medical	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	3.3%	3.8%	3.4%	3.2%	3.2%	2.1%

U.S. Census Bureau's Disclosure Review Board release authorization numbers CBDRB-FY22-CES004-012, CBDRB-FY22-CES004-014, CBDRB-FY22-CES004-015, and CBDRB-FY22-CES004-016, CBDRB-FY22-CES004-037, and CBDRB-FY22-CES004-038

Appendix F: Parameter Excel File

Users interested in exploring the results in more detail (or recreating the figures) can find the parameter and results Excel file available to download where this report is published.

Users will also need to download a separate dynamic link library called WHGrad64.dll. This file is available to download from http://www.howardfamily.ca/graduation/[20]. The methodology is a Whittaker-Henderson smoothing (or graduation) that uses the exposure of the underlying data to smooth the rates. Note that other industry mortality improvement tables (e.g., MP-2021) use this source and follow a consistent approach.

Detailed instructions:

1. Download <Parameters and results.xlsm>
2. Download <WHGrad64.dll> and note the file location (e.g., C:\desktop\WHGrad64.dll) – As noted in **Appendix G: References**, that this is available from http://www.howardfamily.ca/graduation/
3. Open <Parameters and results.xlsm> without enabling macros
4. Edit the VBA in Module 1 (line 100 and 119) so that the code references the correct file location of WHGrad64.dll on your computer
5. Save and close <Parameters and results.xlsm> locally then reopen it and enable macros

User guide:

1. Enter user selections via the <Control> tab:

User input	
Sex	Male
Smoker Status	Not Asked
Income Decile	10
Education	High School diploma
Race/Ethnicity	White Non-Hispanic
Employment Status	Employed
Marital Status	Married
Occupation	Professional
Cause of Death	All cause

2. View results on the <Results> tab for the following:
    a. Smoothed mortality (all-cause, cancer and heart)
    b. Smoothed mortality (pulmonary and stroke)—Note this a separate table because regression cohorts were grouped slightly differently due to limitations in the data
    c. Mortality improvement (all-cause, cancer and heart)
    d. Mortality improvement (pulmonary and stroke)
    e. Annualized mortality improvement based on unsmoothed and smoothed mortality

Appendix G: Limitations and Disclosures

This report was written in compliance with the applicable Actuarial Standards of Practice.

The title page introduces and identifies the responsible actuary, Mark Spong, FSA, CERA, MAAA. The form, content, and language used in the report is consistent with the expectations of our intended users, the actuarial community, and covers our data sources, assumptions, methodology, procedures, and findings. The actuarial report discloses the scope of project, limits and constraints, and the details of the data.

The specific nature of this project required a data source with both demographic and income information. The U.S. Census Bureau data is reasonably current and sufficiently large (8.3 million records). The data source and its limitations are outlined in Appendix B: Data Source and Preparation. The U.S. Census Bureau's Disclosure Review Board reviewed all data files before they were provided to us to ensure confidentiality. A review was performed on the data by our actuaries where we validated the data against the SOA MP-2021 to ensure its reasonability. The dataset meets the standards for acceptable quality for the purposes of this report.

Oliver Wyman was commissioned by the Society of Actuaries to identify how mortality improvement varies by key drivers. The primary audience for this report includes actuaries and members of the public interested in how mortality is changing over time. There are no third-party beneficiaries with respect to this report, and Oliver Wyman does not accept any liability to any third party.

Information furnished by others, upon which all or portions of this report are based, is believed to be reliable but has not been independently verified, unless otherwise expressly indicated. Public information and industry and statistical data are from sources we deem to be reliable; however, we make no representation as to the accuracy or completeness of such information. The findings contained in this report may contain predictions based on current data and historical trends. Any such predictions are subject to inherent risks and uncertainties. Oliver Wyman accepts no responsibility for actual results or future events.

The opinions expressed in this report are valid only for the purpose stated herein and as of the date of this report. No obligation is assumed to revise this report to reflect changes, events, or conditions, which occur subsequent to the date hereof.

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