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Human Longevity and Implications for Social Security Actuarial Status

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HUMAN LONGEVITY AND IMPLICATIONS FOR SOCIAL SECURITY ACTUARIAL STATUS

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Introduction

Changes in long-term Social Security actuarial status are influenced principally by demographic changes. While both the revenue and cost of the program are affected similarly by changes in economic factors such as average earnings growth and price inflation, albeit with different lags, this is not the case for changes in demographic factors. Demographic changes affect the age distribution of the adult population, which is a critical determinant of actuarial status. The age distribution of the population determines the size relationship between the working age population and the "aged" population, the latter of which accounts for the large majority of Social Security beneficiaries and cost. There is no automatic mechanism in the program structure to compensate for changes in the age distribution of the population.

Among the principal demographic factors (mortality, fertility, and immigration), changes in fertility experience (the birth rate) will have the greatest effect on the age distribution of the adult population for the future, and thus the cost of the program. The graph below shows that the sustained drop in the total fertility rate (TFR) after the baby-boom period is responsible for a large and seemingly permanent level shift in the ratio of the population over age 65 to the population at ages 20 through 64, the principal working ages. Mortality improvement is also important, as it also affects the age distribution of the population, but at a gradual and steady pace. The gradual, steady change in the aged dependency ratio due to mortality improvement can be better seen in the graph below, by focusing on the lines where TFRs are assumed to have remained high after the baby boom period.
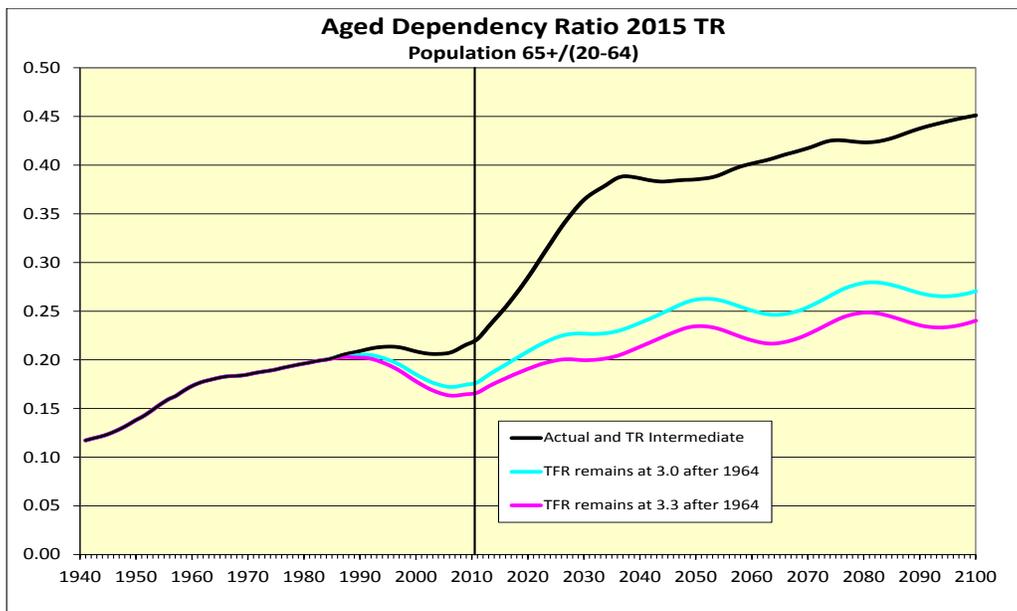
This note is focused on considerations in projecting human longevity and the implications of these projections for the age distribution of the population and thus for Social Security cost, income, and actuarial status. The fundamental aspects of future mortality that affect age distribution are (1) the rate of decline (improvement) in death rates by age and gender, and (2) the degree to which mortality improvement will accelerate or decelerate in the future. Different trends in mortality improvement by income and earnings level are also important for the cost and income of the Social Security program. Making assumptions about future mortality improvement requires careful consideration of the conditions that have contributed to past improvement, and reasoned judgment about the conditions that are likely to determine the rate of improvement in the future.

In this note, we show that the rate of mortality improvement has varied greatly by age, and such age variation seems likely to continue in the future. Use of different "age gradients" for future mortality decline has strong implications for the age distribution of the population. We present our analysis of recent mortality projections made by Ronald Lee (University of California, Berkeley) that incorporate historical mortality rates for ages 65 and over based on Medicare enrollment data, and the implications of his projections for the actuarial status of the Social Security trust funds. We note that the Social Security Advisory Board's 2015 Technical Panel on Assumptions and Methods concurred with the use of a mortality age gradient, as well as with the use of cause-specific rates of decline, the latter of which results in a degree of deceleration for mortality improvement in the future.

Life Expectancy

Life expectancy at birth has been a popular way to characterize changes in mortality. However, focusing solely on life expectancy at birth can be misleading. The greatest increases in this measure have been obtained by reducing infant and childhood mortality. For example, reducing the death rate during infancy by 1 percentage point can increase life expectancy at birth by about 1 percent. But with infant mortality now so low, future increases in life expectancy will have to come from reductions in death rates at older ages, where fewer people are still alive, and where fewer additional years of life result for any reduction in death rates. Thus, unless unprecedented reductions in death rates at older ages can be sustained, increases in life expectancy at birth will slow.

An illustration of "best-practice" life expectancy at birth across nations over the last 160 years developed by Jim Oeppen and James Vaupel in 2002[1] suggested that this measure had been increasing at a linear rate. Oeppen and Vaupel conjectured that this linearity would continue into the future. Many have been skeptical about this assertion, as it would require substantial acceleration of mortality reduction at older ages compared to historical trends. In 2003, Lee published a paper[2] in which he called into question the nature of the underlying historical trend. He looked at the average annual rates of decline for various subperiods, and concluded that the shape of the decline in life expectancy better resembles an S shape. More

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[1] Oeppen, Jim and James W. Vaupel. 2002. Broken Limits to Life Expectancy. *Science* 296:1029-31. Available at http://www.econ.ku.dk/okocg/VV/VV-Economic%20Growth/articles/artikler-2006/Broken-limits-to-life-expectancy.pdf.

[2] Lee, Ronald D. 2003. Mortality Forecasts and Linear Life Expectancy Trends. Center for the Economics and Demography of Aging, 2003. Available at http://escholarship.org/uc/item/3sd9m7d5.

recent work by Jacques Vallin and France Meslé[3,4] has also helped clarify the real nature of the measure and its likely track for the future. As seen in the graph below of maximum female life expectancy among developed nations, Vallin and Meslé show that the trend is best characterized as an "S" curve that has been decelerating since 1960.
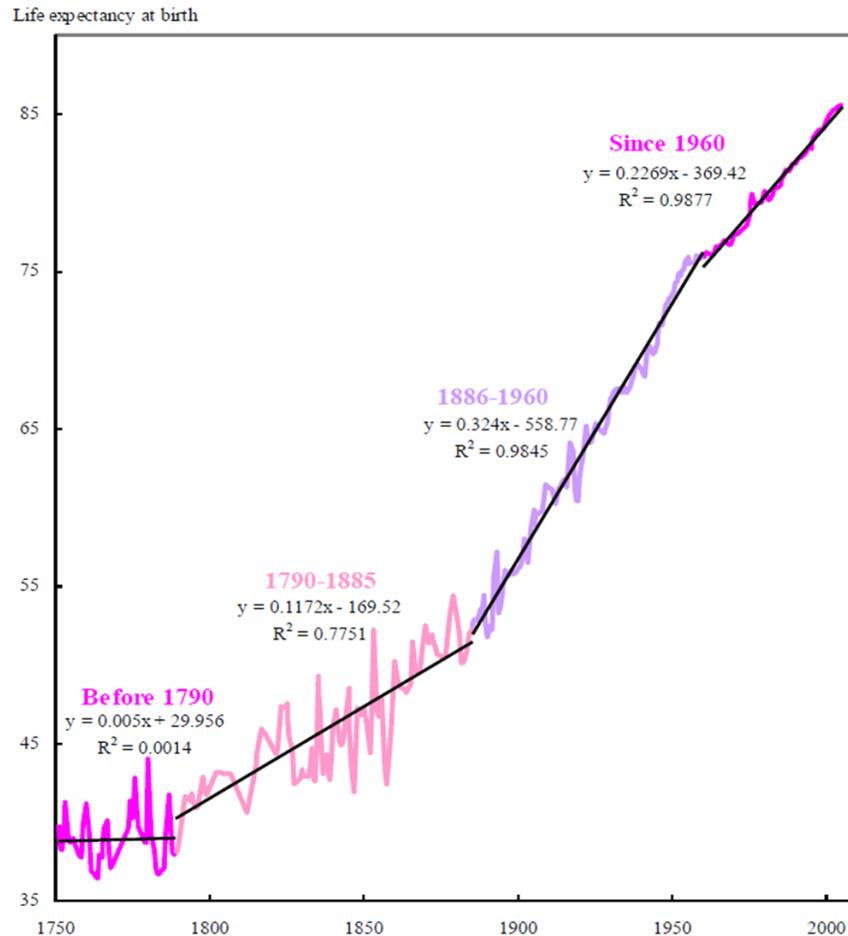
Life expectancy at birth

Since 1960
$y = 0.2269x - 369.42$
$R^2 = 0.9877$

1886–1960
$y = 0.324x - 558.77$
$R^2 = 0.9845$

1790–1885
$y = 0.1172x - 169.52$
$R^2 = 0.7751$

Before 1790
$y = 0.005x + 29.956$
$R^2 = 0.0014$

Figure 2. Maximum female life expectancy at birth since 1750 but excluding Norway (until 1866) and New Zealand
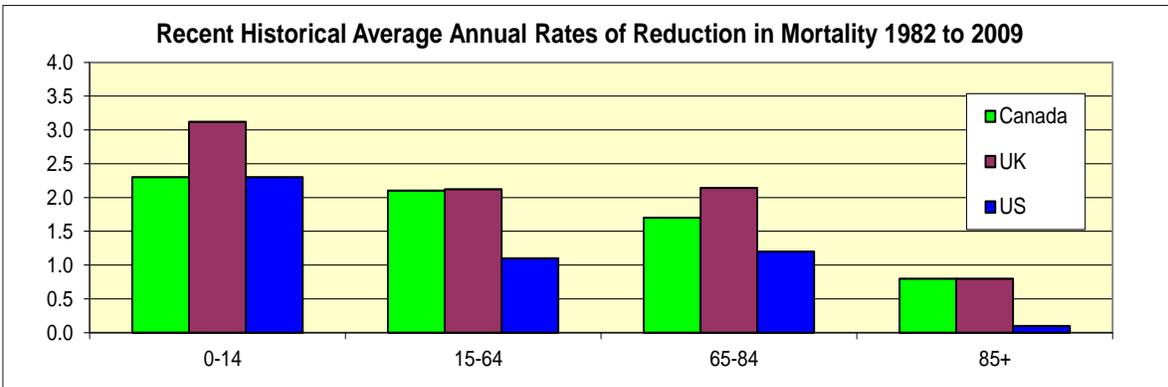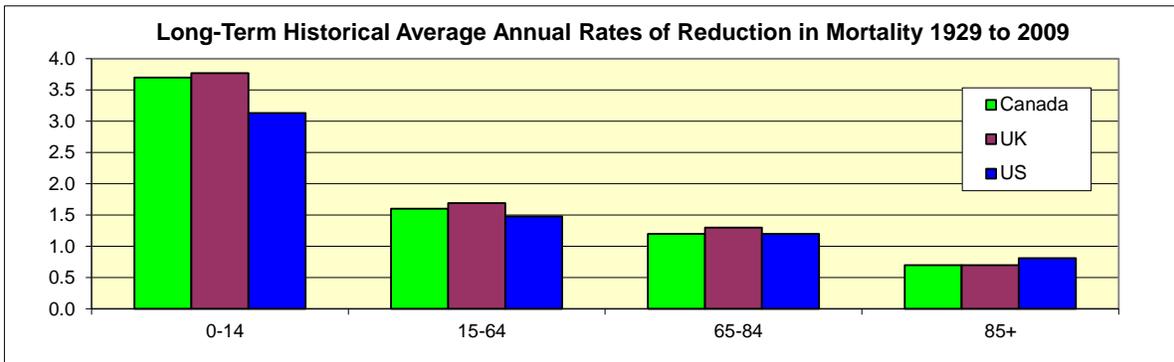*Source: Vallin and Meslé 2008*

Age Gradient in the Rate of Mortality Improvement

The two charts below illustrate relative rates of historical mortality decline by age group for the United States, Canada, and the United Kingdom. These historical rates were developed by the government actuaries in each country based on the best available national data, and were presented at the Society of Actuaries 2014 Annual Meeting and Exhibit.[5] As shown in the charts, the age gradient has been similarly strong among these three countries in the past.

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[3] Vallin, J. and F. Meslé. 2009. The Segmented Trend Line of Highest Life Expectancies. *Population and Development Review* 35(1): 159-187. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1728-4457.2009.00264.x/pdf.
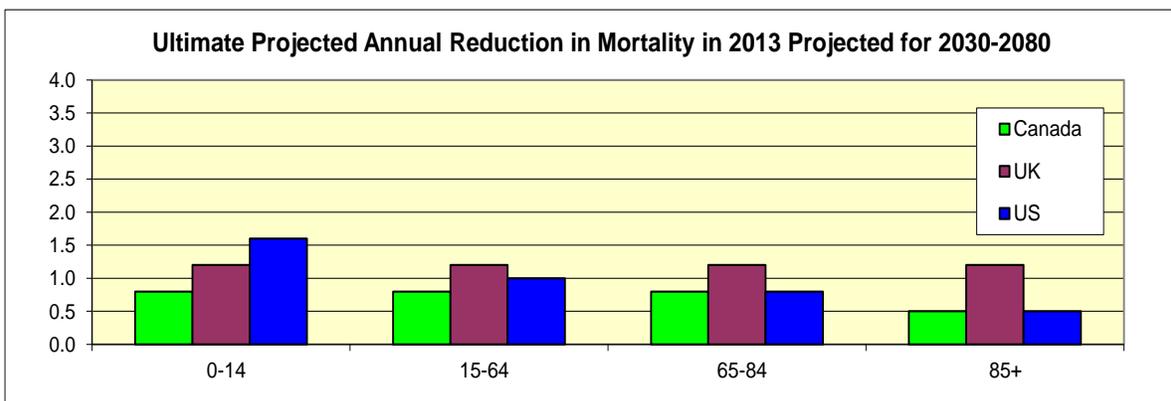[4] Vallin, J. and F. Meslé. 2016. Highest Life Expectancies: Which Leader after Japan? Presentation to the 2016 Annual Meeting of the Population Association of America. Extended abstract available at https://paa.confex.com/paa/2016/mediafile/ExtendedAbstract/Paper1788/extended-abstract.pdf.
[5] Additional information available at https://www.soa.org/Files/Pd/2014/annual-mtg/2014-orlando-annual-mtg-26-0op.pdf.

Long-Term Historical Average Annual Rates of Reduction in Mortality 1929 to 2009

Legend: Canada, UK, US

Categories: 0-14, 15-64, 65-84, 85+

Recent Historical Average Annual Rates of Reduction in Mortality 1982 to 2009

Legend: Canada, UK, US

Categories: 0-14, 15-64, 65-84, 85+

Comparing the two charts also shows that the relative rate of decline in mortality at ages under 15 has decelerated somewhat for all three countries, but has remained higher than other ages. The age gradient in mortality reduction has flattened in the more recent period, due in part to the effects of HIV at younger ages and extraordinary advances in treating cardiovascular and respiratory disease at older ages.

Based on considered judgment, the government actuaries in the U.S. and Canada assume that the age gradient will persist in the future, but to different degrees.

Ultimate Projected Annual Reduction in Mortality in 2013 Projected for 2030-2080

Legend: Canada, UK, US

Categories: 0-14, 15-64, 65-84, 85+

U.S projections maintain a relatively larger portion of the historical age gradient in mortality improvement than do the Canadian projections, while the U.K. Government Actuary assumes no future age gradient at all. Some extrapolation approaches retain even more of the age gradient than assumed by the U.S. government actuaries. For example, extrapolations using the Lee and Carter method, which will be discussed later, presume no change in the historical age gradient at all.

Mortality Improvement and Health Spending

Any credible analysis of past experience and projection into the future must consider the basis for mortality improvement in the past and expected conditions that will determine future improvement. The twentieth century experienced a dramatic reduction in mortality in developed nations as living conditions improved, adequacy of nutrition and access to medical care greatly expanded, and spending on medicine and health research exploded. These factors propelled unprecedented declines in death rates at all ages.

The broad economic expansion after World War II, along with the introduction of antibiotics and greater health access, led to great mortality improvement through 1954. Another dramatic surge in mortality improvement at all ages occurred between 1968 and 1982, with the implementation of Medicare and Medicaid expanding primary health care access to the elderly, the poor, and the disabled. Through the latter half of the twentieth century, national health expenditures expanded dramatically, rising from 4 percent of GDP in 1952 to over 17 percent in 2009. It seems probable that this expansion of health care access and spending is related to the reductions in death rates.

National Health Expenditures With and Without Medicare and Medicaid as a Percent of GDP
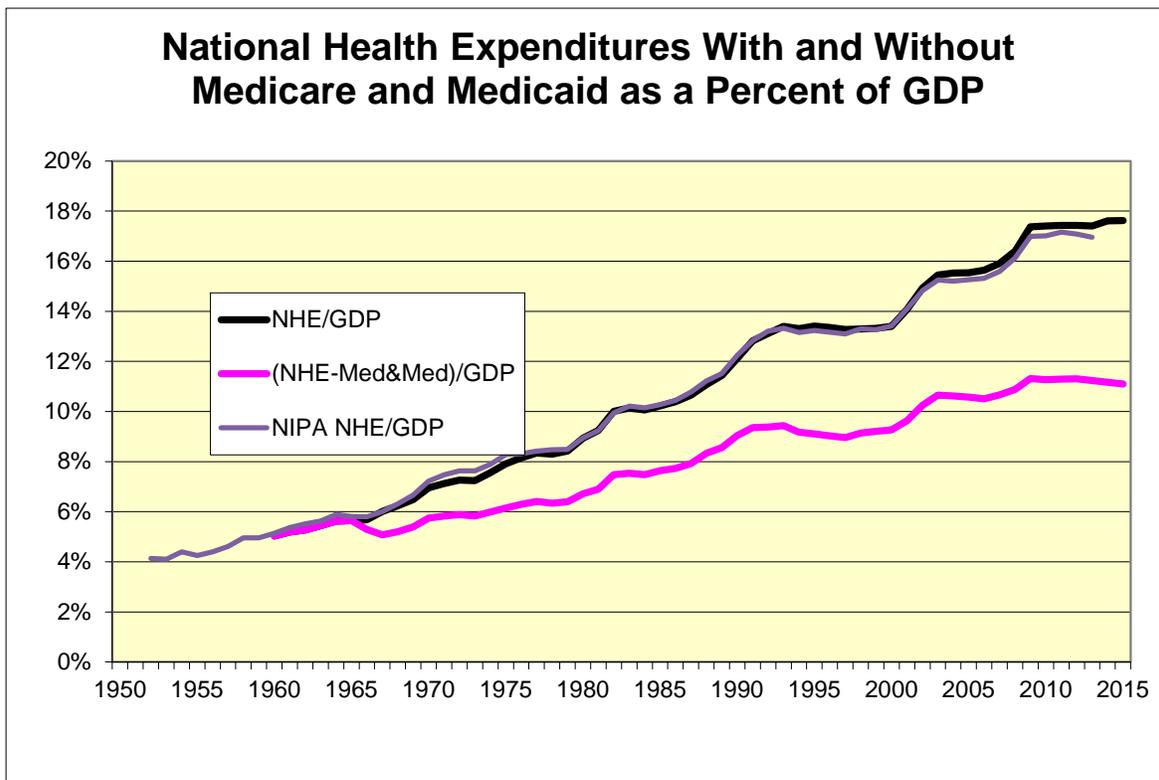
In the future, we cannot expect to replicate the impact of Medicare and Medicaid on mortality improvement. The Affordable Care Act will expand health care access to the uninsured population much more modestly. Since 2009, national health expenditures have remained nearly flat as a percent of GDP. In addition, as projected in the 2015 Medicare Trustees Report, Medicare spending per enrollee will decelerate in the future, even as the enrolled population ages, contributing to the inevitable slowdown in the growth of national health spending as a share of GDP.

Annual Percent Change in Medicare Cost per Beneficiary Relative to GDP per Worker: 2015 TR
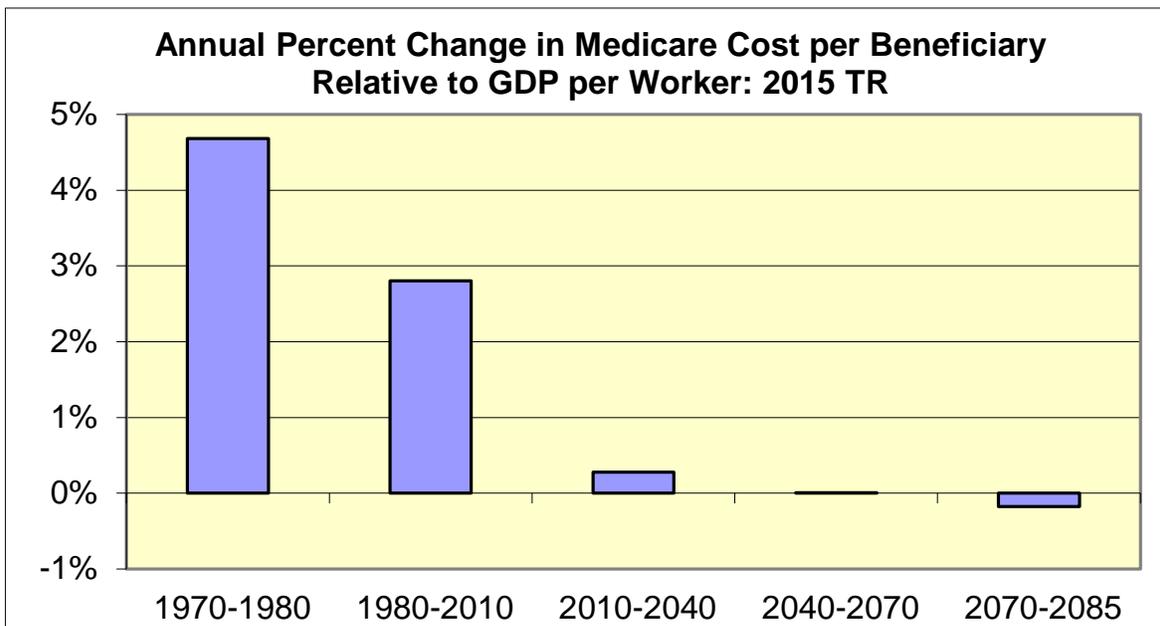
The degree to which this deceleration in health spending will slow future declines in death rates is the subject of considerable debate. However, all evidence suggests that the maximum life span for a human being has not been increasing, so future medical advances will only lead to more people living longer, closer to the maximum life span. This strongly suggests a future deceleration in mortality improvement.

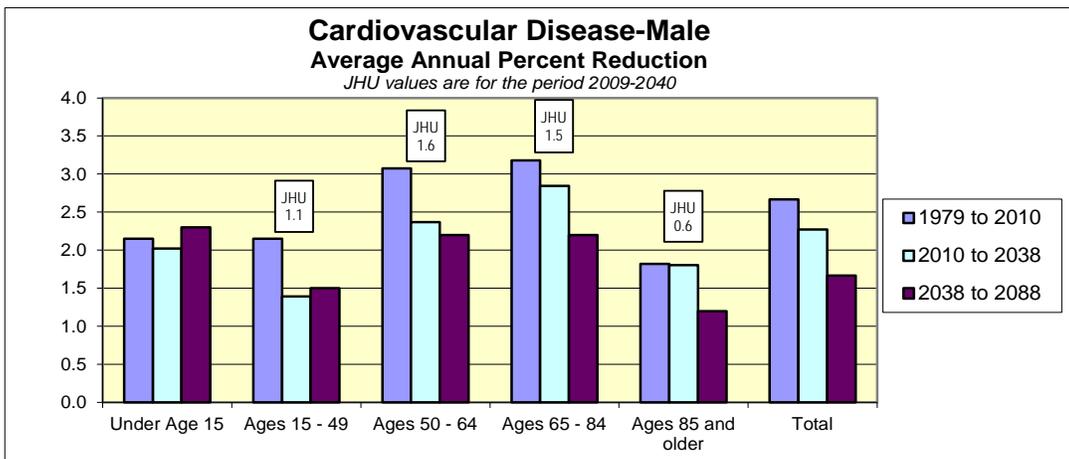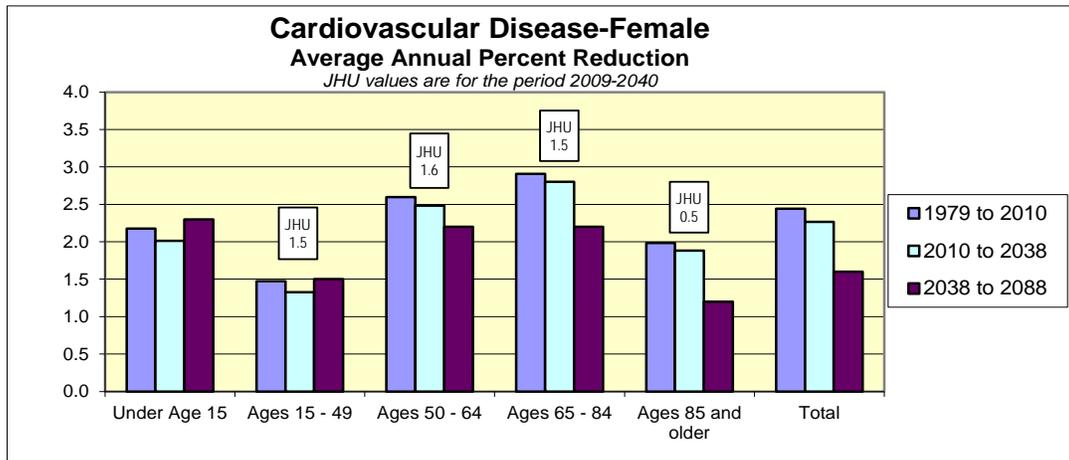**Mortality Improvement by Cause: Past and Future Conditions**

Projecting mortality reduction by cause of death allows for a more detailed analysis of past declines in death rates. Setting different assumptions for ultimate rates of decline in mortality by cause, as well as age, fosters more informed speculation about future trends based on current medical research and expectations. Setting different ultimate rates of decline by cause of death also results in modest deceleration in the projected overall rate of mortality improvement. Limitations on human physiology, as well as on the capacity for expansion of health spending, suggest that deceleration will be inevitable in the long run. For many years, the Social Security Administration's Office of the Chief Actuary has used this approach for mortality projections. These projections are used as a basis for the annual Social Security and Medicare Trustees Reports and many other estimates.

Clinicians and researchers at Johns Hopkins University performed an independent analysis of past trends in mortality improvement by age and cause, producing a projection of death rates for 2040.[6] The resulting projected mortality improvements by age and cause were remarkably close to those projected for recent Trustees Reports. These findings were previewed at the Society of Actuaries 2014 Annual Meeting and Exhibit[7] in graphs similar to those shown below. These graphs illustrate the historical and projected rates of decline in death rates for cardiovascular disease, respiratory disease, and cancer, based on the 2014 Trustees Report and the Johns Hopkins study.
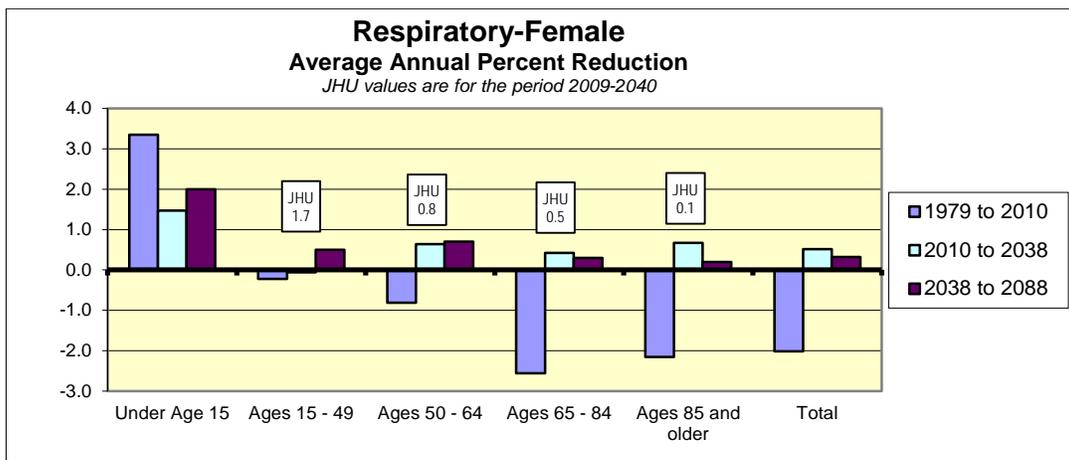

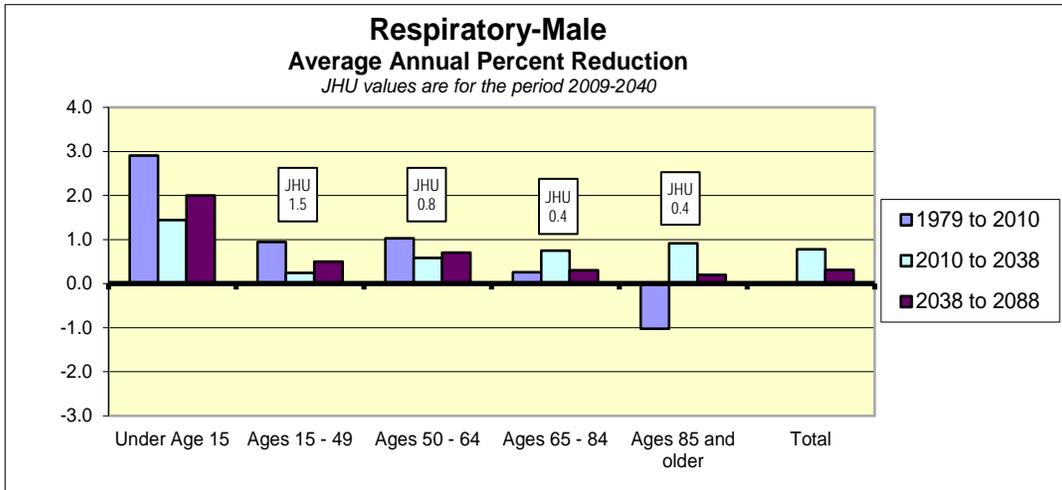[6] Paper by Vladimir Canudas-Romo and co-authors expected to be published in the *North American Actuarial Journal* in 2016.

[7] Additional information available at https://www.soa.org/Files/Pd/2014/annual-mtg/2014-orlando-annual-mtg-26-0op.pdf.

The Johns Hopkins expectations for improvement in mortality due to cardiovascular disease through 2040 are much lower at ages 50 and older than was assumed in the 2014 Trustees Report through 2038 and even beyond.

Cardiovascular Disease-Female
Average Annual Percent Reduction
JHU values are for the period 2009-2040

Cardiovascular Disease-Male
Average Annual Percent Reduction
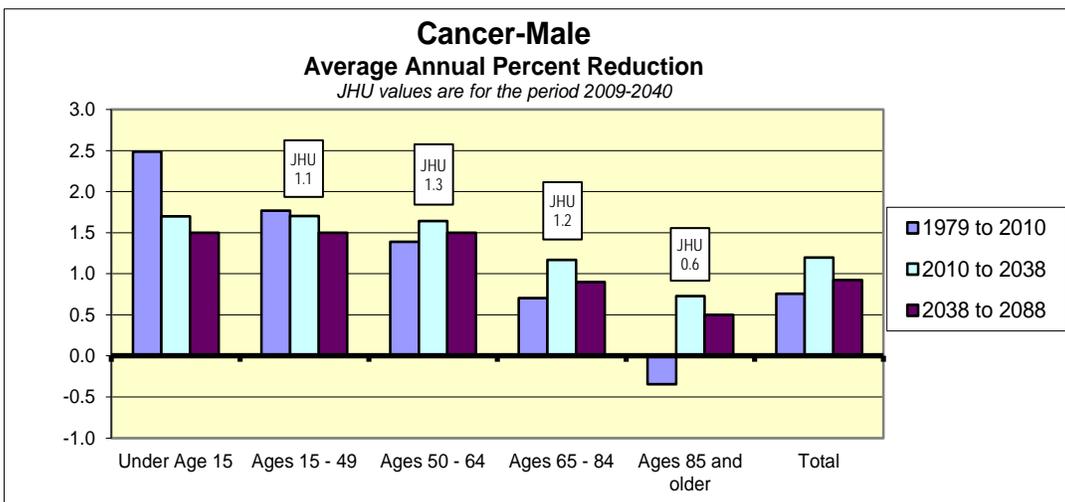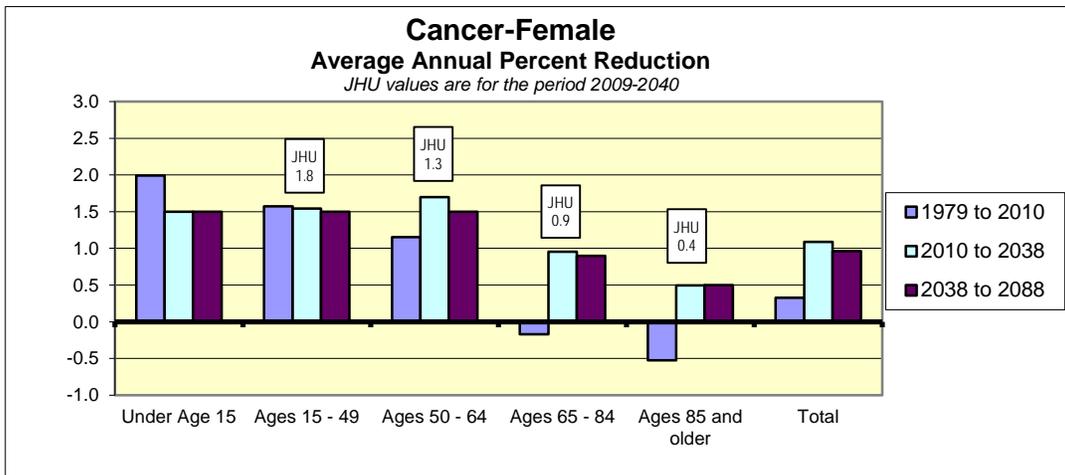*JHU values are for the period 2009-2040*

The Johns Hopkins expectations for improvement in mortality due to respiratory disease are more optimistic under age 50, similar between 50 and 84, and less optimistic at ages 85 and older than was assumed in the 2014 Trustees Report. The Johns Hopkins results suggest a stronger age gradient in mortality decline for this cause of death.

Respiratory-Female
Average Annual Percent Reduction
JHU values are for the period 2009-2040

Respiratory-Male
Average Annual Percent Reduction
JHU values are for the period 2009-2040

For improvement in mortality due to cancer, the Johns Hopkins expectations are very similar overall to those assumed in the Trustees Report, with a slightly stronger age gradient for females, and a slightly weaker age gradient for males.

Cancer-Female
Average Annual Percent Reduction
JHU values are for the period 2009-2040

Cancer-Male
Average Annual Percent Reduction
JHU values are for the period 2009-2040

8

Mortality Experience by Earnings Level

We have long recognized that mortality rates and rates of mortality improvement have varied by the earnings level of workers, and similarly by income and economic opportunity. Differences in mortality and longevity by career earnings level are significant for the projected cost and actuarial status of the Social Security program. Cost projections for the Social Security program have long reflected this difference by increasing average benefit levels within a cohort as the cohort ages to reflect the fact that surviving beneficiaries typically have higher benefit levels. This effect is discernable in the historical experience by considering the degree to which the average benefit for retired workers of a generation increases faster than would otherwise be accounted for by annual cost of living adjustments.

In addition, we have been studying the changes over time in mortality trends by relative career-average earnings, which determine the size of benefits under the Social Security program. Considered by quartile of career earnings level, some dispersion has clearly occurred for death rates at ages 65 through 69 between 1990 and 2010, as shown in the charts below, which were presented at the August 2014 Social Security Retirement Research Consortium Annual Meeting.[8] We are doing further work in this area and plan to publish our results soon.

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[8] Additional information available at http://crr.bc.edu/about-us/events/2014-retirement-research-consortium-meeting/.

Recent Experience: Are We in Another Extended Slowdown?

While mortality generally improved rapidly between 1968 and 1982, improvement was slower between about 1982 and 1999. Between 1999 and 2009, mortality improvement was more rapid, particularly at older ages, largely due to strong 1-year declines in 2004 and 2009. However, since 2009, overall mortality reduction has greatly slowed at older ages. It is not clear whether this slowdown since 2009 for older ages will persist. However, this recent slowdown is a reality check for those who believe that rapid declines in mortality will happen consistently and indefinitely.

Age-Sex-Adjusted Death Rates (Ages 65 and Older)
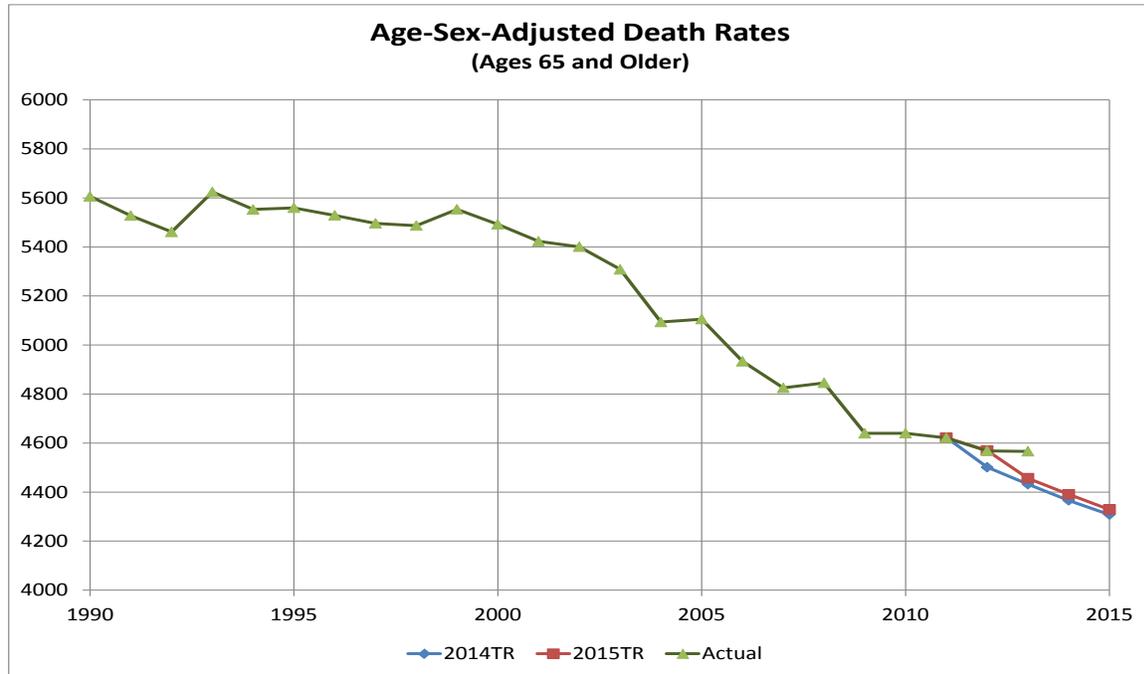
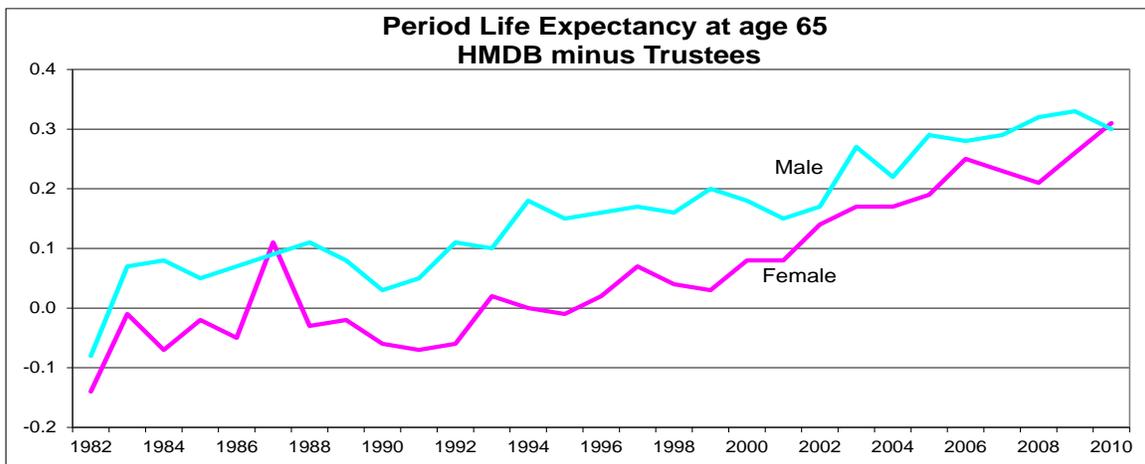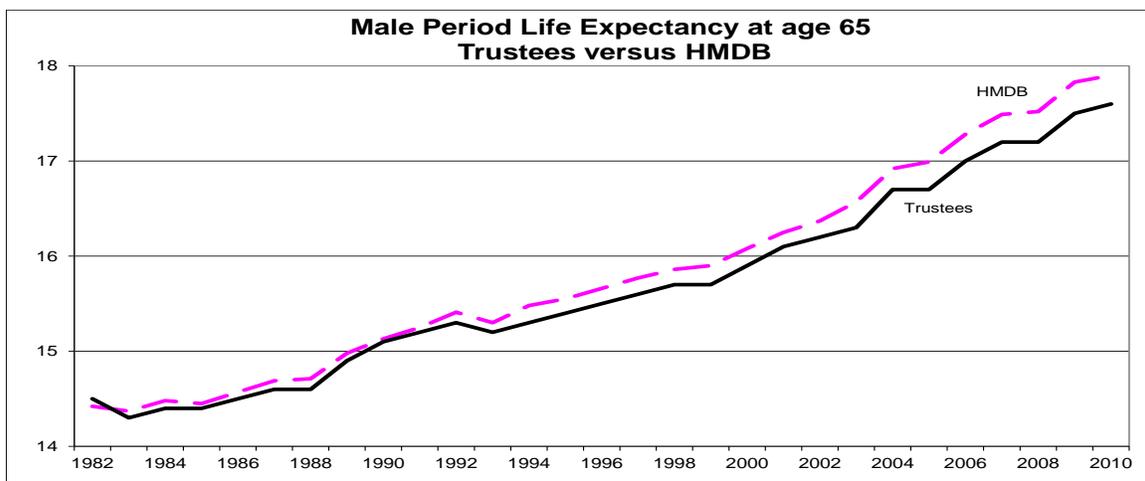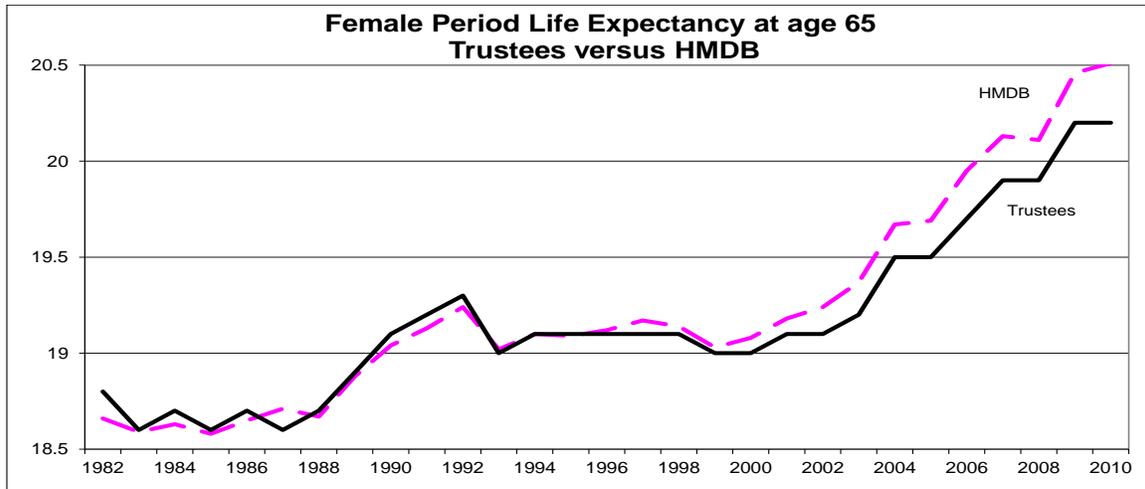## Projections: Age Gradient, Overall Trend, and Deceleration

The Social Security Advisory Board's 2011 Technical Panel on Assumptions and Methods recommended an ultimate rate of decline in death rates of over 1.2 percent per year, for all ages, with no deceleration in the future.[9] The 2015 Technical Panel recommended using an age gradient and cause-of-death driven deceleration, but settled on a 1.0-percent overall 75-year average annual rate of decline on an age-sex-adjusted basis, on par with the average experience of the last 50 years.[10] This is a somewhat faster rate of mortality decline and resulted in a greater shift in the age distribution than that used for the Trustees Reports. Therefore, the panel recommendations would result in higher cost as a percent of taxable payroll and less favorable actuarial status for the Social Security trust funds.

At the time of the deliberations of the 2015 Technical Panel, most outside demographers, including those who were consulted by the panel, were not yet fully aware of the deceleration in mortality improvement at older ages since 2009, as data was only available through 2011.

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[9] The full report is available at http://ssab.gov/Details-Page/ArticleID/216/2011-Technical-Panel-on-Assumptions-and-Methods-A-Report-to-the-Board-September-2011.

[10] The full report is available at http://ssab.gov/Details-Page/ArticleID/656/2015-Technical-Panel-on-Assumptions-and-Methods-A-Report-to-the-Board-September-2015.

Currently, data is available through 2013, with additional preliminary data available through 2015. In addition, most demographers generally used historical mortality experience from the Human Mortality Database (HMD), which has suggested faster mortality reduction over the last 30 years at older ages than has been seen in the more consistent data developed from Medicare-enrollee experience. A discussion of this difference, including the graphs below, was presented in the Office of the Chief Actuary's Actuarial Note 156.[11]

Female Period Life Expectancy at age 65
Trustees versus HMDB

Male Period Life Expectancy at age 65
Trustees versus HMDB

Period Life Expectancy at age 65
HMDB minus Trustees

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[11] Available at http://www.ssa.gov/oact/NOTES/pdf_notes/note156.pdf.

For reasons not fully understood, the HMD death rates at age 65 and older were generally slightly higher than those derived from the Medicare-enrollment data in 1982, but declined steadily at a faster rate thereafter. The Medicare-enrollment data are from consistent sources with robust age verification. Thus, we conclude that there is a small bias in the HMD data that is growing.

Comparison to Other Projections

A further comparison of death-rate projections illustrates the importance of age gradient and the data used for fitting a model. Lee recently re-estimated his projections for future mortality rates using the Medicare-enrollee experience data for ages 65 and older, rather than the data in the HMD.[12] He reran his projections using the Medicare-enrollee data through 2011.

Comparison of Historical, 2015 Trustees Report, and Lee*
### Average Annual Rates of Decline in Age-Sex-Adjusted Death Rates

AGE	Historical (Dec 2015 data)			2015TR Intermediate			Lee		
	1982-1999	1999-2009	2009-2013	2011-2039	2011-2089	2039-2089	2011-2039	2011-2089	2039-2089
0-14	2.79	1.22	2.14	1.58	1.57	1.57	2.77	2.74	2.72
15-49	0.63	0.61	1.06	0.97	0.93	0.90	1.07	1.06	1.05
50-64	1.61	1.27	0.05	1.17	1.09	1.06	1.34	1.34	1.34
65-84	0.92	2.11	0.91	1.09	0.86	0.74	1.06	1.06	1.05
85+	-0.18	1.30	-0.11	0.64	0.53	0.48	0.65	0.64	0.63
65+	0.51	1.78	0.48	0.89	0.71	0.61	0.88	0.86	0.85
Total	0.75	1.59	0.48	0.95	0.80	0.71	0.99	0.96	0.94

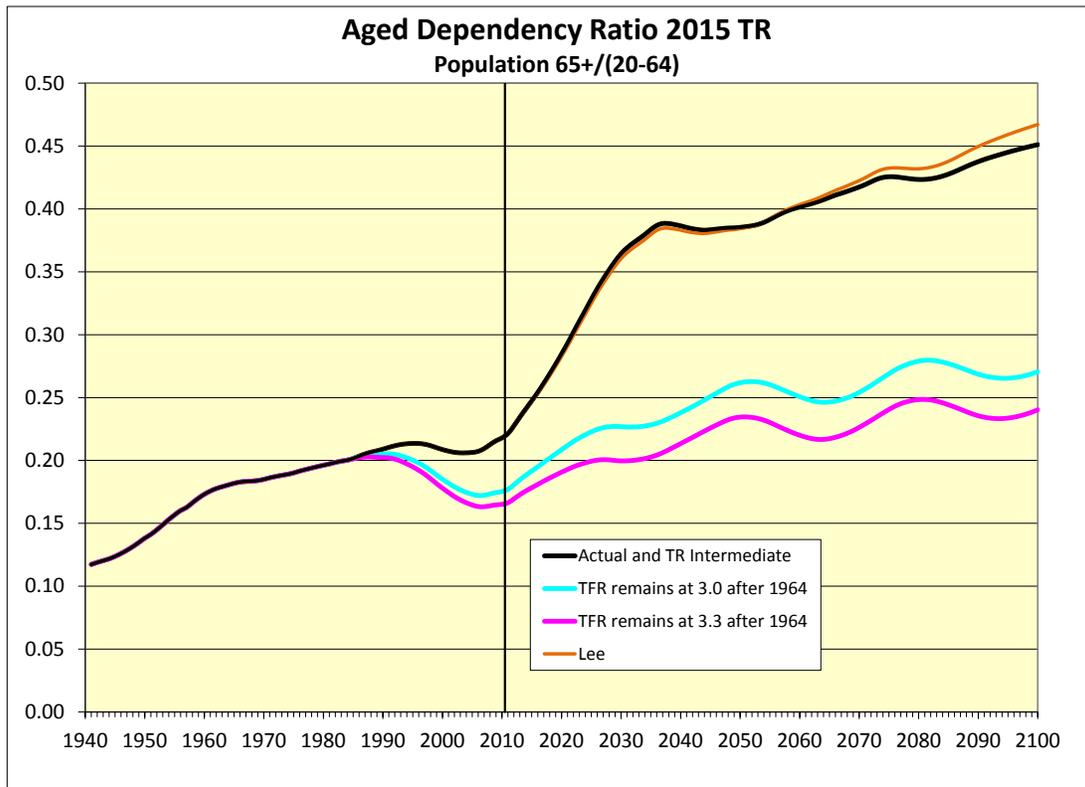* Fit 1950-2011, using Medicare-enrollment data for 65 and over, rather than HMD data

Lee's new results are striking. Using the Lee and Carter (LC) extrapolation method, he projects the average annual rate of decline in mortality for all ages combined at 0.99 percent per year through 2039, slightly higher than the average 0.95 percent annual reduction used in the 2015 Trustees Report. Because the LC method essentially allows for no deceleration in age-specific death rates, this approach sustains indefinitely the age-specific rates of improvement derived from the historical experience for 1950 through 2011, including the dramatic post-WWII and post-Medicare/Medicaid periods.

Mortality Rate Comparison Age 0-14 Unisex
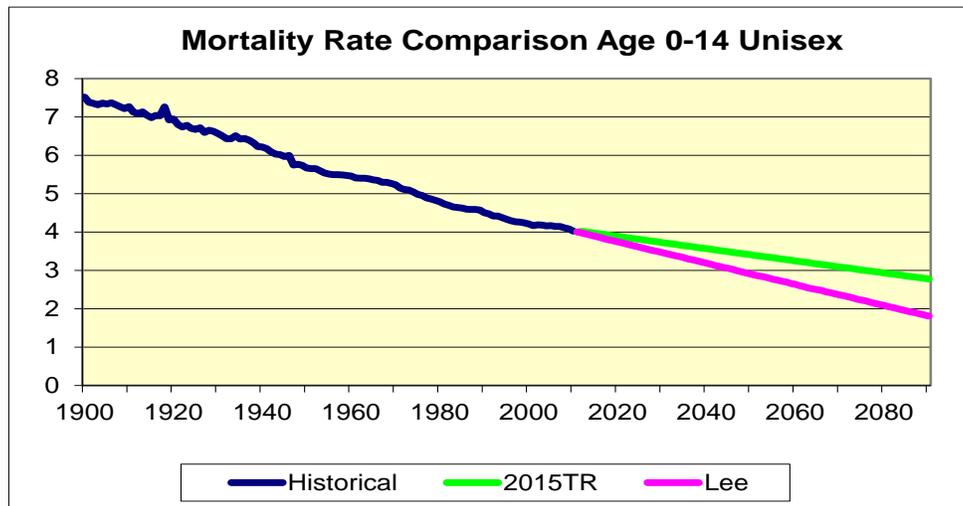
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[12] Unpublished analysis sent by Dr. Lee to the Office of the Chief Actuary in January 2016.

**Mortality Rate Comparison Age 65+ Unisex**

Legend: Historical, 2015TR, Lee
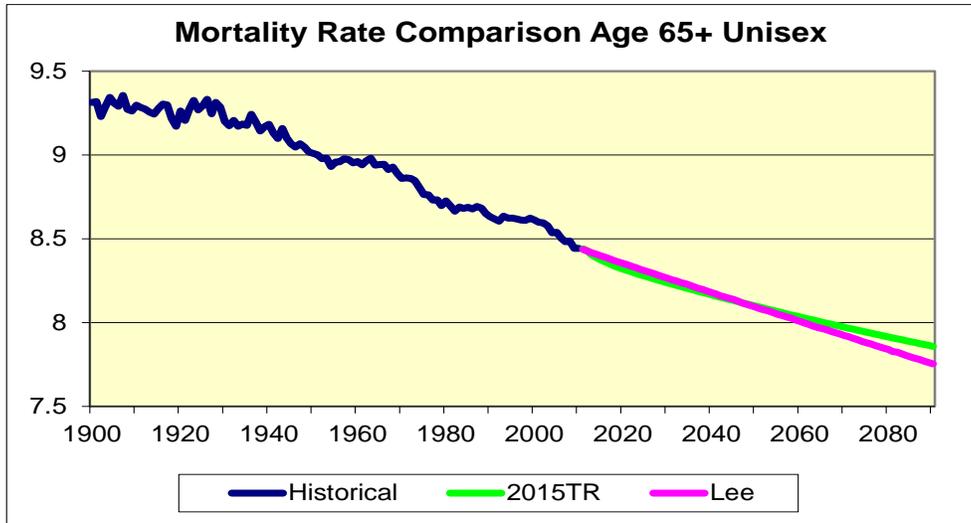
Because the LC method fits to each age-gender group separately, this projection captures and maintains the entirety of the strong age gradient in past mortality improvement experience. With this relatively strong age gradient, Lee's projections expand the younger working-age population faster than the aged population for many years into the future, to a greater degree than the actuarial projections in the 2015 Trustees Report. The graph below illustrates that the age distribution of the population under Lee's mortality projection is more favorable for Social Security financing than it is using the 2015 Trustees Report mortality projection, until a point after 2050. At that point, the lack of any deceleration in Lee's projections overwhelms the stronger age gradient and the aged dependency ratio becomes less favorable (higher) under Lee's projection.

Aged Dependency Ratio 2015 TR
Population 65+/(20-64)

Legend: Actual and TR Intermediate; TFR remains at 3.0 after 1964; TFR remains at 3.3 after 1964; Lee

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Overall, Lee's age distribution is more favorable for the first half of the 75-year projection period and less favorable for the latter half. As a result, incorporating his results into the Trustees Report model leads to an actuarial status over the full 75-year projection period that is very close to the results in the 2015 Trustees Report. This finding illustrates the power of a mortality improvement age gradient to affect the age distribution of the population and, in turn, the actuarial status of the Social Security trust funds.

In essence, Lee's latest projection retains both the age gradient and the rate of decline of the period from 1950 to 2011 as a basis for the future projection. The actuarial mortality projections for the 2015 Trustees Report assumed some compression of the age gradient, but also some gradual deceleration in the rate of mortality decline, presuming that the exceptional gains from 1950 to 2011 will not continue at the same rate indefinitely. While the two approaches result in the same actuarial status for the next 75 years as a whole, Lee's projections result in lower Social Security cost as a percent of payroll through 2056, with the reverse thereafter, because Lee's method allows for no deceleration of mortality improvement. (See the graph below.) If Lee's method were modified to allow for some deceleration in future mortality reduction relative to the experience of 1950-2011, his projections would result in a more favorable actuarial status for the Social Security trust funds over the next 75 years than is shown in the 2015 Trustees Report.
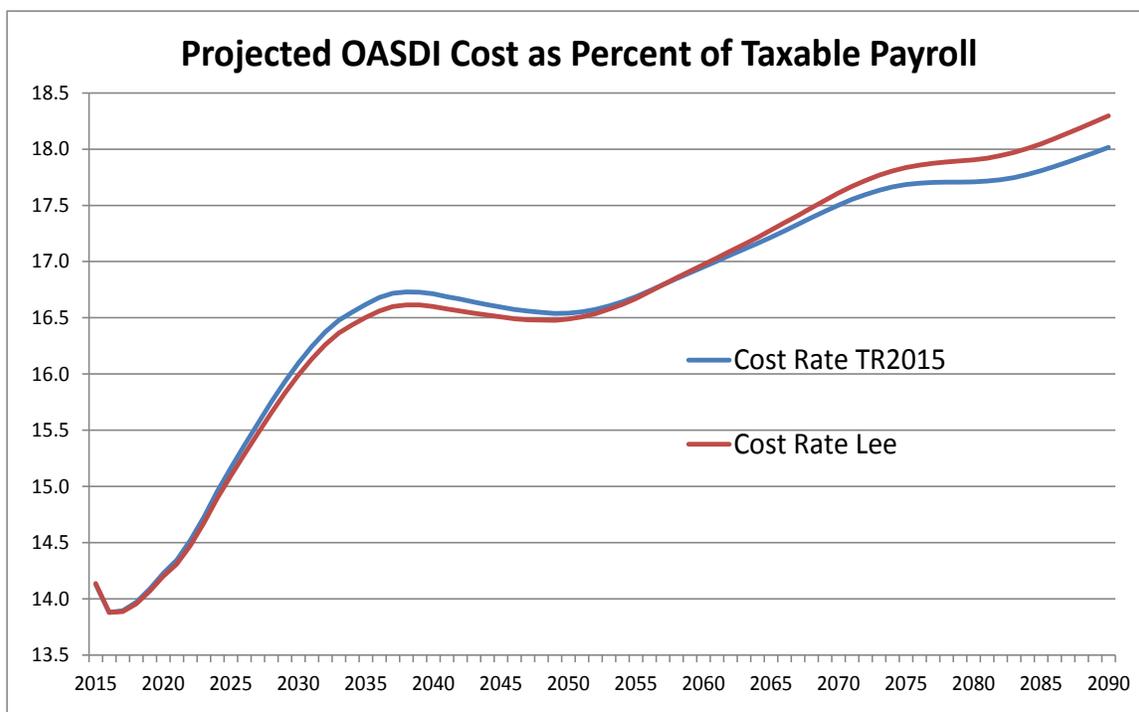
A final note on the projections by both Lee and the Office of the Chief Actuary is that mortality experience since 2011 has continued to show much less improvement than expected. Incorporating this more recent experience in the same projection methods will result in lower projected improvement in mortality in the future, and thus more favorable estimates of actuarial status for the Social Security trust funds.

Conclusion

By law, the Trustees report to the Congress annually on the actuarial status of the Social Security and Medicare programs. The Office of the Chief Actuary's mortality projections have been fairly accurate over the years and have provided a sound basis for evaluating the actuarial status of both programs.

Mortality improvement in the twentieth century was remarkable, reflecting dramatic improvement in the economy, personal income, health research, national health expenditures, and broad access to health care. With inevitable deceleration in health care expenditures as a percent of GDP and a rising share of the population in retirement, the conditions that contributed to the mortality declines in the twentieth century are unlikely to be sustained in the future. In addition, limitations on human physiology and senescence seem likely to contribute to deceleration. Assumptions for future reduction in death rates by cause of death used in recent Trustees Reports have been corroborated by recent independent analysis from clinicians and medical researchers at Johns Hopkins University.

The historical age-gradient in mortality decline is undeniable, and uncertain only in the degree to which it will persist. Recent work by Lee demonstrates that retention of the full historical age-gradient in mortality improvement with no future deceleration in improvement, through use of the Lee and Carter method, has essentially the same implications for Social Security actuarial status as the mortality projections used in the Trustees Reports. The actuarial projections used in the Trustees Report assume a reduced age gradient relative to the past and a modest deceleration in age-specific mortality improvement.

Future analysis and experience will continue to evolve, and future projections will undoubtedly vary. The results presented in this note suggest that current mortality projections used in the Trustees Reports provide a solid basis for evaluating the actuarial status of the Social Security program.