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Aging and Retirement

Pri-2012 Private Retirement Plans Mortality Tables Report

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Pri-2012 Private Retirement Plans Mortality Tables Report

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CONTENTS

Section 1: Executive Summary

1.1 Purpose

As part of its ongoing[1] review of retirement plan mortality assumptions, in early 2016, the Society of Actuaries' (SOA) Retirement Plans Experience Committee (RPEC or the Committee) initiated a study of private-sector retirement plans in the U.S. This report provides an update to the *RP-2014 Mortality Tables Report* (SOA 2014) and the accompanying RP-2006[2] Mortality Tables (SOA 2018). In addition to presenting the results of this study, this report includes insights into various participant- and plan-specific factors, some of which were found to be correlated with meaningful differences in mortality.

This report, along with the accompanying sets of mortality tables, has been designated Pri-2012. Consistent with the naming convention initiated with the release of the *Pub-2010 Public Retirement Plans Mortality Tables Report* ("Pub-2010") (SOA 2019), "Pri" is short for "Private retirement plan" and "2012" represents the central year of the final dataset from which mortality tables were developed.

1.2 Summary of Data Collected

The final dataset upon which this study has been based includes approximately 16.1 million life-years of exposure and 343,000 deaths from private-sector pension plans across the U.S. Both of these amounts are approximately 50% larger than the corresponding counts included in the RP-2014 study. Data were received from a total of 18 different entities that submitted information for 402[3] plans, and the study's final dataset included all but approximately 8% of the data processed. Unlike the RP-2014 study (which had minimal multiemployer data), the Pri-2012 study includes a substantial amount of data from multiemployer plans; approximately 41% of the total Pri-2012 dataset and approximately 70% of the blue collar dataset came from multiemployer plans.

The mortality experience in the final dataset came almost exclusively from calendar years 2010 through 2014. Based on the tabulation rules described in subsection 13.3 and the weighted average of the exposures included in the study, the Pri-2012 mortality rates should be considered to be one-year probabilities of death as of January 1, 2012.

As was the case in the study that produced the RP-2006 tables, information regarding participants' collar type and salary/benefit amount was collected and analyzed as part of this study. It is important to note that the final datasets underpinning the RP-2006 and Pri-2012 tables have (1) significantly different collar concentrations and (2) considerably different—and generally lower—quartile breakpoints; see Section 3 for details. These differences in dataset characteristics complicate the direct comparison of certain Pri-2012 tables (and the resulting 2019 annuity values) with their RP-2006 counterparts.

In particular, an important difference from the RP-2006 dataset is the considerably higher concentration of Unknown Collar data in the Pri-2012 study. Subsection 13.1 contains additional commentary regarding the treatment of this subgroup and the implications for application of the Pri-2012 tables.

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[1] The timing of this report is consistent with the SOA's intention to review both private- and public-sector retirement plan mortality experience on a cycle of approximately every five years.

[2] In July 2018, the SOA released the *RP-2006 Mortality Tables*, which are based on the same data as the *RP-2014 Mortality Tables* but removing Scale MP-2014 mortality improvement from the *RP-2014 Mortality Tables* for the years 2007–2014 such that the mortality rates are as of the year 2006, the central year of the RP-2014 study dataset.

[3] Many of the plans for which data was received covered only a small number of participants. For example, 242 of the 402 plans each contributed fewer than 2,000 life-years of exposure over the five years of the study period.

1.3 Mortality Tables Developed

Based on the multivariate analysis described in Section 4, the Committee developed gender-specific amount- and headcount-weighted versions of the following mortality tables:

Employee Tables (ages 18 through 80)
- Total
- Blue Collar
- White Collar
- Bottom Quartile (based on salary)
- Top Quartile (based on salary)

Retiree Tables (ages 50 through 120)
- Total
- Blue Collar
- White Collar
- Bottom Quartile (based on benefit amount)
- Top Quartile (based on benefit amount)

Contingent Survivor Tables (ages 50 through 120)
- Total
- Blue Collar
- White Collar

Disabled Retiree Table (ages 18 through 120)
- Total

Consistent with the RP-2006 tables, the Committee also developed gender-specific Juvenile tables covering ages 0 through 17.

In a departure from RP-2006, the Pri-2012 report includes separate mortality tables for primary retirees (Retiree tables) and surviving beneficiaries (Contingent Survivor tables). This has important implications for the calculation of joint-and-survivor annuity values; see subsection 12.4 for details. Primarily for illustration purposes, a comparison of 2019 annuity values based on (1) RP-2006 Healthy Annuitant rates and (2) blended Pri-2012 Retiree and Contingent Survivor rates is displayed in Appendix D.4.

RPEC compared the multiemployer plan data to the single-employer plan data to determine whether separate tables were required for multiemployer plans. After controlling for other factors, such as collar type and income level, participants in multiemployer plans did not exhibit significantly different mortality than participants in single employer plans. Therefore, RPEC did not produce separate tables for multiemployer plans. The Committee also decided not to develop separate tables based on the plan sponsor's industry code or the plan's lump sum provisions. See Section 4 for details.

1.4 Impact on Deferred-to-62 Annuity Values

Table 1.1 summarizes the percentage change in 2019 monthly deferred-to-age-62 annuity due values (at an annual interest rate of 4.0 percent) when moving from an amount-weighted RP-2006 table to the corresponding amount-weighted Pri-2012 table, with all mortality rates projected generationally using Scale MP-2018[4]. In each case, rates under age 62 were based on the appropriate set of Employee rates. For ages 62 and older, RP-2006 values reflected the appropriate set of Healthy Annuitant rates, whereas the Pri-2012 values were based on the corresponding set of Retiree rates. The underlying annuity values from which the percentage changes in Table 1.1 were developed can be found in Section 11.

Table 1.1

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES
PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012[5] AS OF 1/1/2019

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	0.3%	−1.2%	−0.5%	0.4%	−1.3%
	35	0.3%	−1.3%	−0.5%	0.5%	−1.3%
	45	0.3%	−1.3%	−0.5%	0.6%	−1.3%
	55	0.3%	−1.3%	−0.6%	0.6%	−1.3%
	65	0.0%	−1.3%	−0.7%	0.6%	−1.7%
	75	−1.1%	−1.1%	−1.2%	0.6%	−4.5%
	85	−1.4%	−1.3%	−1.8%	−0.4%	−6.9%
	95	0.7%	0.7%	0.1%	0.7%	−6.5%
Males	25	0.6%	1.4%	−0.3%	−1.4%	−2.9%
	35	0.8%	1.6%	−0.2%	−1.1%	−2.9%
	45	1.0%	1.7%	0.0%	−0.8%	−2.8%
	55	0.8%	1.3%	−0.1%	−0.8%	−2.8%
	65	0.1%	0.5%	−0.3%	−1.3%	−3.1%
	75	−0.9%	0.0%	−1.3%	−1.0%	−4.7%
	85	−2.5%	−1.3%	−2.9%	−0.6%	−4.7%
	95	−2.6%	−1.6%	−2.9%	−2.3%	−1.7%

The largest percentage changes are for the Top Quartile dataset. As alluded to in subsection 1.2 above, the Pri-2012 quartile breakpoints are almost always lower than their RP-2006 counterparts despite being six years more current; see subsection 3.8 for details. The above percentage changes in annuity values should be considered in the context of this difference between the two datasets. In particular, given the downward shift in most quartile breakpoints, some actuaries might conclude that Pri-2012 White Collar tables are more appropriate than Pri-2012 Top Quartile tables for plans covering highly compensated individuals. Furthermore, mortality for relatively select groups of high income participants could be significantly lower than Pri-2012 Top Quartile or Pri-2012 White Collar. See subsection 12.2.3 for additional details.

[4] In October 2019, the SOA published Scale MP-2019, an update to Scale MP-2018 that incorporates historical data for calendar year 2017. To maintain consistency with the May 2019 exposure draft, comparisons in this report have not been updated to use Scale MP-2019. See the Scale MP-2019 report for an overview of the effect of the new scale. The use of Scale MP-2018 throughout this report is for illustrative purposes only; using other mortality improvement scales may also be reasonable.

[5] It is important to note the distinction between RP-2006 Healthy Annuitant rates and the Pri-2012 Retiree rates. RP-2006 Healthy Annuitant rates reflect the combined experience for Retirees and Contingent Survivors. The Pri-2012 Retiree tables exclude Contingent Survivor experience (to the extent known), which makes a direct comparison of the two sets of tables less straightforward. See Section 4 for the rationale for this change and subsection 12.3 for further discussion of separate Retiree and Contingent Survivor tables.

1.5 Application of Pri-2012 Mortality Tables

The Committee encourages stakeholders in the financial viability of U.S. private-sector retirement plans—both single-employer and multiemployer—to review the findings presented in this report. The Pri-2012 tables should be considered as part of the relevant "assumption universe" described in Actuarial Standard of Practice No. 35, *Selection of Demographic and Other Noneconomic Assumptions for Measuring Pension Obligations* (ASOP 35) for the measurement of private plan obligations (ASB 2014). In conjunction with knowledge of the individual characteristics and recent experience of the covered group, actuaries could use the Pri-2012 tables (possibly blended or otherwise adjusted using appropriate credibility techniques) from the ASOP 35 assumption universe for mortality.

For example, the statistical analyses summarized in this report support the observation that participants in white collar jobs tend to have lower rates of mortality than those in blue collar positions. Consistent with the principles of ASOP 35 and subject to other relevant criteria, knowledge that the population being valued falls predominantly in the white (or blue) collar category could indicate that the corresponding White Collar (or Blue Collar) tables developed in this report may more accurately model the mortality patterns of the covered population than the "total population" tables.

The Committee believes that for most pension-related actuarial applications, the Pri-2012 mortality rates (including those for Disabled Retirees) should be projected with an appropriate mortality improvement scale and that generational projection should be considered as an approach to projecting future mortality rates. In all cases, the selection of a mortality improvement assumption must satisfy the applicable requirements of ASOP 35.

1.6 Acknowledgments

The SOA would like to thank RPEC and especially the Private Plans Subcommittee for their support, guidance, direction and feedback throughout the project.

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(Members of the Private Plans Subcommittee are denoted with an asterisk)

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Special Recognition of Others Not Formally on RPEC

RPEC would like to thank the companies that submitted data for this study. In particular, the Committee would like to express its gratitude to those who worked to compile the submissions and respond to data questions, many of which were detailed and required extensive research. For confidentiality reasons, the contributing companies have not been listed by name.

The Committee would like to thank Ruark Consulting, LLC for its efforts to compile and process the data, especially given that the data collection and processing phases were extended well beyond the study's original timeline. Ruark's efforts to provide the necessary output to the Committee were greatly appreciated, especially given the iterative nature of the work. Ruark's timely responses to Committee requests were integral to the study's completion.

Michelle Xia, PhD, and Lei Hua, ASA, PhD, of Northern Illinois University, performed the multivariate analysis for this study, and the Committee greatly appreciates their deep, technical knowledge that enabled the Committee to make important decisions regarding table creation. This phase of the project required many iterations and custom models, and their consistent, prompt attention to the Committee's needs was extremely helpful.

Philip Adams, FSA, CERA, MAAA, a volunteer who performed graduations for the 2015 Valuation Basic Tables, was an invaluable source of expertise on Generalized Additive Models (GAMs). His work on the previous Pub-2010 study

laid the foundation for the GAM graduations that were used to develop the Pri-2012 tables. The Committee is very grateful to Philip for all his efforts.

Section 2: Background and Process

2.1 Reason for New Study

The publication of the *RP-2014 Mortality Tables Report* in October 2014 represented the SOA's first comprehensive update of pension-related mortality rates since its release of the *RP-2000 Mortality Tables Report*. The RP-2014 Mortality Tables utilized study data with a 2006 central year and applied mortality projection according to the MP-2014 improvement scale to adjust the tables to the 2014 release year. In 2018, RPEC released the *RP-2006 Mortality Tables* (SOA 2018), which removed the mortality improvement for the years 2007–2014 from the RP-2014 tables, moving their effective date back to the study's central year, 2006.

In the discussions with the retirement actuarial community regarding the release of the significant updates represented by the RP-2014 tables, it was indicated that more frequent updates[6] to the base mortality tables would be advantageous. More frequent updates would reduce the likelihood of large swings in valuation liabilities on account of the updates and provide more current data to the community for valuation and other purposes.

As a result of the preference for more frequent updates, RPEC adopted an intention to develop new mortality tables on a five-year cycle. Consistent with this goal, RPEC initiated a data collection exercise in 2016 to obtain data for the years 2010 through 2014, inclusive. The data, thus collected, has a central year of 2012.

RPEC encourages all members of the U.S. pension actuarial community, in particular those practicing with private-sector pension plans, to carefully review this report and to consider using the Pri-2012 tables as benchmarks in their ongoing review of pension-related mortality assumptions.

2.2 RPEC's Process

RPEC has maintained a Private Plans Subcommittee on an uninterrupted basis since completion of the *RP-2014 Mortality Tables Report*. Beginning in 2016, this group generally met once per week via conference call throughout most stages of the project. These meetings were not open to the public. Status updates of the subcommittee's progress on this study were shared with all RPEC members once per month. The RPEC Industry Advisory Group (RIAG) was formed in fall 2016 with the purposes of (1) apprising key actuarial stakeholders in the U.S. of ongoing RPEC projects and (2) soliciting real-time feedback on those projects. RPEC initiated such conference calls with RIAG about three times per year.

In a departure from the RP-2014 process in which smaller subteams were created to focus on particular aspects of the project, all members of the Private Plan Subcommittee participated in each of the associated project subtasks. The following three subprojects required the services of external resources:

- For data collection, processing and validation, RPEC engaged Ruark's services; see Section 3 for details.
- For multivariate analysis of the final datasets, RPEC engaged a research team of Lei Hua, ASA, PhD, and Michelle Xia, PhD, both from Northern Illinois University; see Section 4 for details.
- For the graduation of raw mortality rates, RPEC enlisted the help of Philip Adams, FSA, CERA, MAAA, a volunteer who performed graduations for the 2015 Valuation Basic Tables and the Pub-2010 Tables. In

[6] In January 2019, RPEC also completed its first study of public pension plan mortality, producing the Pub-2010 tables.

addition to providing valuable expertise in this area, Philip wrote most of the code required for RPEC to perform graduations for the mortality tables summarized in this report.

2.3 Naming Conventions

2.3.1 Participant Status

RPEC has used the following capitalized terms throughout this report to describe various subgroups of plan participants:

- *Employee*: A nondisabled plan participant who is actively employed (including those in plans that no longer have ongoing benefit accruals).
- *Retiree*: A former Employee in benefit receipt who was not reported as disabled at the date of retirement.
- *Contingent Survivor*: A surviving beneficiary (of a former participant) who is older than age 17 and in benefit receipt.
- *Disabled Retiree*: A retired participant in benefit receipt who was reported to be disabled as of the date of retirement.
- *Juvenile*: A participant's beneficiary who is under age 18.

The term "Nondisabled Annuitant" is used both when it is not necessary to distinguish between a Retiree and a Contingent Survivor and to reference the tables developed from a blend of Retiree and Contingent Survivor experience. The term "Annuitant " is used when it is unnecessary to distinguish between any participant in payment status.

2.3.2 Collar Type

Similar to the RP-2014 study, the data request for this study asked for a designation of a collar type for each plan. If at least 70 percent of the plan's participants were either hourly or union, the plan was designated as Blue Collar. If at least 70 percent of the plan's participants were both salaried and nonunion, the plan was designated as White Collar. All other plans were designated as Unknown[7] Collar.

However, there was one important change from the RP-2014 process of collecting collar information. Each submitter was asked whether collar type was available for individual participants. Some contributors were able to provide this information, and participant-specific indicators determined the collar type for slightly more than one-fourth of the final dataset. Therefore, the White Collar dataset for this study consists of both participants specifically identified as White Collar and participants in plans designated as White Collar (per the above 70 percent threshold) that were not specifically identified as Blue Collar participants. Similarly, the Blue Collar dataset for this study consists of participants specifically identified as Blue Collar and participants in plans designated as Blue Collar that were not specifically identified as White Collar participants.

[7] Unknown Collar includes a number of plans submitted as "Mixed Collar"; see subsection 13.1

2.3.3 Mortality Table Names

RPEC wanted the names of the individual tables presented in this report to clearly identify various important features reflected in those tables, specifically:

- The tables were developed with data provided exclusively by private-sector retirement plans and insurance companies that had assumed benefit obligations from private-sector retirement plans.
- Certain subpopulations (based on collar type or amount quartile) exhibited statistically distinct mortality patterns from that of the total population.
- The research team developed two full sets of mortality tables, one set with amount-weighted rates and the other with headcount-weighted rates.
- The central year of the study's observation period began in 2012.

To capture all these features succinctly, RPEC adopted the following naming convention. The amount-weighted mortality tables for the total population are denoted Pri-2012. The corresponding names for the headcount-weighted tables are Pri.H-2012. Where applicable, the Blue Collar and White Collar versions of a given table are designated by (BC) or (WC), respectively, immediately following the corresponding total population table name. The Bottom and Top Quartile versions of a given table are designated by (BQ) or (TQ). For example, Pri.H-2012(TQ) designates the headcount-weighted, Top Quartile tables and Pri-2012(BC) designates the amount-weighted, Blue Collar tables.

Section 3: Data Collection and Validation

3.1 Overview

Five general steps guided development of the final dataset that was used in the construction of mortality tables for this study:

1. Data collection;
2. Review for reasonableness and completeness;
3. Data consolidation and validation;
4. Month-by-month death pattern review;
5. Actual-to-expected (A/E) ratio analysis.

3.2 Data Collection

RPEC distributed a data request letter to the largest actuarial consulting firms and insurance companies known to have a sizeable block of group annuity business. The request documents were also posted on the SOA website in hopes that others may also respond to the call for data. The formal data request package consisted of the following seven documents (three of which had two separate versions depending on the data submission layout that the contributor chose):

1. A cover letter outlining the study's goals, an approximate timetable, and the required file formats;
2. A plan-level information questionnaire, which requested details regarding the plan's submission format and characteristics;
3. A document containing instructions for completing the plan-level information questionnaire;
4. A participant-level information specification worksheet, which showed the information that must be provided for each participant and denoted the situations for which each field is required;
5. A document containing instructions regarding each item in the participant-level information specification worksheet;
6. An Excel file showing a sample submission;
7. A file that summarized the list of acceptable inputs for some categorical data fields.

To maintain data confidentiality, SOA staff, working directly with an outside data compiler, Ruark Consulting, LLC, coordinated the project's data-collection and data-processing phases.[8] Ruark performed validation tests on the data, provided the Committee with statistics, computed exposures and deaths,[9] and—per approval by the Committee—imputed missing information where needed. In many cases, Ruark made direct contact with the submitters (coordinated through and including SOA staff) to address specific data issues.

The SOA's intent was to collect data for the five calendar years 2010–2014. However, the SOA still wanted to allow for receipt of data for a full five-year period for plans that have noncalendar-year valuation cycles. These plans were instructed to provide data for a consecutive five-year period ended in calendar year 2014. This resulted in the

[8] The contract between Ruark and the SOA included confidentiality requirements that restricted the distribution of confidential information to other parties.
[9] See subsection 13.3 for a description of the tabulation rules used in this study.

submission of some data for the 2009 calendar year, which was included in the study. Overall, the SOA received raw data for 402 pension plans[10] from 18 different contributors.

The central year of the study's observation period was 2012. Based on the exposure and death tabulation rules described in subsection 13.3, the Pri-2012 mortality rates at each age, *x*, should be interpreted as one-year probabilities of death for a person exactly age *x* on January 1, 2012.

3.3 Review for Reasonableness and Completeness

Before the data was processed, Ruark reviewed the data submissions to determine whether each was provided in a format consistent with the data request specifications and whether all of the critical information was provided. The high-level checks performed at this stage included the following:

- Confirmation that, for most participants, all critical data fields were populated and had valid entries per the format requested;
- Review of record identifiers to assess feasibility of linking data across multiple years (where necessary);
- Review of record pairs with duplicate identifiers to confirm that the correct data could be determined;
- Review that information for Contingent Survivors was provided consistently in accordance with one of the two options[11] provided in the data request.

In the event that this initial review revealed issues with processing a given submission, the SOA worked with Ruark to follow up with the contributors to determine whether the problems could be resolved. The study contributors sent clarifications or additional information that enabled Ruark to process the submissions. Although adjustments to the data were needed in some cases (per contributor feedback), all of the submitted plans were eventually deemed fit for processing.

3.4 Data Consolidation and Validation

RPEC requested data at the participant level in compliance with one of the following two layouts:

1. One record per participant for the entirety of the study period, including annual updates of participant status (i.e., Employee, terminated[12], Retiree, Contingent Survivor, Disabled Retiree, or deceased), salary[13] (for Employees) and monthly pension amount (for Annuitants).

[10] Many of the plans for which data was received covered only a small number of participants. For example, 242 of the 402 plans each contributed fewer than 2,000 life-years of exposure over the five years of the study period. Three other submitters were insurance companies that submitted blocks of their pension annuity buyout business. For purposes of counting the number of plans, the data from each of these three insurance companies were treated as a single plan.
[11] Contributors could choose to either provide Contingent Survivor information on the same record as the original participant in specially designated Contingent Survivor fields or provide Contingent Survivor information on separate records. Ruark's review involved ensuring that the chosen method was employed consistently across all records and that it was clear which demographic information applied to the Contingent Survivor.
[12] Terminated participants (i.e., participants neither actively employed nor receiving pension benefits), regardless of vesting status, were not included in the study. This is because mortality experience for terminated vested participants is often not tracked with precision. The exposure for an Employee that terminated during the study period was included up to the date of termination.
[13] RPEC attempted to collect information on the types of compensation included in salary by plan. However, the definitions received were very diverse and did not lend themselves to quantifiable adjustments that could be used to ensure a consistent salary definition throughout the study. RPEC was, therefore, unable to reflect these varying definitions of salary in its analysis.

2. Six annual snapshots of census data with a unique identifier for participants that would allow information from different years to be linked across the study period.

For submissions using the second layout, Ruark used the provided identifiers to link together information across the study period to make the record of each participant's experience as complete as possible. Consolidated records were important for reviewing participant data for consistency and to accurately count exposures and deaths.

Ruark's review of individual records led to the identification of potential issues in the contributed data. Some issues were resolved by utilizing standardized assumptions, but other issues were more complex or critical and required the contributor to answer data questions. Situations for which missing or invalid data were resolved via an assumption included the following:

Missing Dates (e.g., Date of Death, Date of Termination, Date of Retirement)

Event dates other than the date of death were assumed to occur on the participant's birthday during the 12-month period during which the corresponding change in status code was observed. The purpose of this approach was to distribute imputed status change dates uniformly throughout the calendar year. This methodology is best illustrated by an example:

- 1/1/2012 status: Employee
- 1/1/2013 status: Terminated
- Date of birth: 8/1/1972
- Date of termination: (blank)

In this situation, the assumed date of termination would be 8/1/2012.

For missing dates of death, RPEC used the participant's half birthday rather than the participant's birthday. In the above example, had the participant died (with a blank date of death) rather than terminated employment, the assumed date of death would be 2/1/2012. The reason for this pertains to the actuarial method for tabulating exposures, which was used for this study. Under the actuarial method, a participant who dies during the study period is credited with exposure through the individual's next birthday. An assumed death date on the participant's birthday would, therefore, add a full extra year of exposure after death, whereas an assumed death date on the participant's half birthday only credits an additional half year after death. The additional half year is a better approximation for the average additional exposure credited to participants provided with valid dates of death.

Missing Salary or Monthly Pension Amount

In the event that a given participant had a valid amount provided for a different year, that amount was assumed for the year(s) in which the provided value was invalid or missing. Otherwise, the amount was assumed to be the plan-wide average for the applicable gender and collar type. If these values were not provided for any participants for a given plan, the study-wide average for the applicable collar type, status and gender was assumed.

There were several data issues that required data questions for contributors, including the following:

Undocumented Disappearances

Some participants disappeared from one snapshot date to the next. Ruark sent these records back to the contributor to confirm whether they should be treated as deaths. In some cases, these disappearances turned out to be deaths, but often the record disappeared for other reasons, such as an erroneous record, the end of a temporary annuity, or an Employee terminating without a vested benefit and dropping off of the data register.

Missing Gender or Date of Birth

Ruark sent records with either a missing date of birth or gender to the contributor to attempt to obtain the missing information. All records that were still missing a birth date or gender after this follow-up attempt to collect the data were excluded from the study.

Large Monthly Pension Amounts

Unusually large monthly pension amounts were sent to contributors for confirmation. Often, contributors confirmed these values to be either annual benefit amounts or lump sum distributions. In some cases, however, the contributors confirmed these large monthly pensions were valid.

Unclear Disability Status

The data request for the study stated that a status of Disabled Retiree should apply if the participant was disabled under the plan's terms at the time of their retirement. Using this definition, it is not possible to transition from Disabled Retiree to Retiree status or vice versa. However, some plans contained data with participants exhibiting these movements. Ruark sent contributors listings of such records for clarification. The most common finding of this inquiry was that some employers were not distinguishing Retirees and Disabled Retirees past a certain age, causing Disabled Retirees to "change" to Retirees in the data. In these cases, Ruark corrected the data by changing Retiree statuses to Disabled Retiree to treat the participants as disabled throughout their retirement.

Status Progression Inconsistencies

Many plans submitted some records with discrepancies between the status progressions and the associated event dates. If the number of such discrepancies were small, the Committee trusted the status progression if the event date occurred (1) after the date of the reported status change or (2) more than 15 months prior to the date of the reported status change (with 15 months being used rather than 12 to account for potential reporting lag). See the below examples:

Example 1

- 1/1/2012 status: Employee
- 1/1/2013 status: Employee
- 1/1/2014 status: Retiree
- Date of retirement: 11/1/2012

In this situation, because the date of retirement was within 15 months of the date at which the data indicated a movement to Retiree status (i.e., 1/1/2014), the date of retirement of 11/1/2012 was treated as the beginning of the participant's exposure as a Retiree, and the participant was considered to be retired from that date, including as of 1/1/2013 when the participant was indicated to be an Employee.

Example 2

- 1/1/2012 status: Employee
- 1/1/2013 status: Employee
- 1/1/2014 status: Retiree
- Date of retirement: 8/1/2011
- Date of birth: 4/1/1950

In this situation, the reported date of retirement was not within 15 months of the date at which the data indicated a movement to Retiree status (i.e., 1/1/2014). The difference is greater than could typically be attributed to a lag in updating the participant's status information. Therefore, the date of retirement was assumed to be on 4/1/2013, the participant's birthday during the 12-month period of the change in status (in accordance with the procedure for missing dates, noted above).

For plans with a large number of such discrepancies, Ruark asked contributors questions to determine whether the status progression or the dates provided should be trusted. In most cases, contributors replied that the status progressions were more reliable than the dates. If the contributors could not assist with this information, RPEC's default decision was to rely upon the status progression provided by the contributor.

The only exception to the above procedure was the date of death field. Any reasonable date of death that the contributor provided was given greater credence than the associated status progression.

Exposure After Death

In some instances, records were provided with either a status of "deceased" or a date of death, followed by subsequent dates or status codes implying either Employee or Annuitant exposure after the time of death. Ruark sent the listings of such records to contributors to determine the correct date of death. In most cases, contributors were able to confirm the proper course of action, but in the small number of situations in which the Committee did not receive an answer, the Committee relied on the earliest indication of death in the record.

3.5 Month-by-Month Death Pattern Review

After RPEC validated the individual records, the Committee reviewed tabulations of deaths by month and status group (original participant versus Contingent Survivor) within each plan. The purpose of this review was to identify any unusual patterns in death counts during the study period.

The most common issue discovered was a drop in deaths in the final months of the study period, which was typically indicative of reporting lag (i.e., deaths were not reported on the register as of the time of the final snapshot date). This review also uncovered several other patterns that required attention. Some plans had entire years of data within the study period that had unreasonably low or high death counts compared to the other experience years. In a few cases, there were particularly large death counts in a specific month, which suggested that death dates in the data were defaulted to a specific date during the year. RPEC questioned contributors individually about each of these issues.

In response to the Committee's inquiries, some contributors were able to provide an updated register of deaths to correct the problem. In the case of deaths being concentrated in a single month, the Committee generally treated the death dates as missing and distributed them throughout the year using the participants' half birthdays, as described in subsection 3.4. Some contributors acknowledged the unreasonableness of the observed patterns and stated that they did not have enough information to correct the data. In the event that contributors could not confirm the reasonableness of the data or provide corrections, RPEC excluded from the study the time periods for which the data appeared unreasonable. Slightly more than 1% of the study data was excluded at this stage of the analysis.

3.6 Actual-to-Expected (A/E) Ratio Analysis

In an attempt to identify individual plans that exhibited atypical mortality experience relative to the full dataset (and hence may have required further follow-up), the Committee performed a plan-by-plan A/E analysis using an expected basis of RP-2006 projected with Scale MP-2016[14] to the appropriate year in the observation period. For each status/collar combination, the Committee developed an exposure-weighted average A/E ratio, which was used to normalize all plan A/E ratios in that subgroup such that the average A/E ratio was 100%. The Committee did this to ensure an appropriate basis of comparison for flagging outlier A/E ratios.

Next, the Committee developed 95% confidence intervals for the normalized A/E ratios for each plan, status and collar combination based on the number of observed deaths. If the low end of the confidence interval was greater than 110% or if the high end of the interval was less than 90%, the plan was flagged for additional examination. For example, assume that the Blue Collar Retirees in plan X produced a normalized A/E ratio of 1.35, with a corresponding 95% confidence interval of 1.24 to 1.46. Since 1.24 (the low end of the confidence interval) is greater than 1.10, the Blue Collar Retirees in plan X would have been flagged for additional examination.

The Committee sent outlier mortality statistics for plan, status and collar groups to contributors to confirm their reasonableness. In most cases, contributors were able to either provide confirmation of the statistics or send corrected data. The Committee excluded from the study outliers that contributors could not confirm. Approximately 6.5% of the study data was excluded for this reason, and the vast majority of the excluded data came from Employee groups with suspiciously low reported mortality experience.

[14] Scale MP-2016 was chosen because it was the most recently released mortality improvement scale in the SOA-published "MP" series when experience analytics were calculated.

3.7 Summary of the Final Dataset

Table 3.1 presents a summary of the final Pri-2012 dataset by status, gender and job category. This does not include any data the Committee excluded during the data validation stages described above or the small amount of data that fell outside of the age ranges presented in the tables shown in Appendix B. A reconciliation of excluded data can be found in Appendix A.

Table 3.1
SUMMARY OF EXPOSURES AND DEATHS IN THE FINAL DATASET

		Blue Collar		White Collar		Unknown Collar		Total	
		Exposures	Deaths	Exposures	Deaths	Exposures	Deaths	Exposures	Deaths
Employee	**Female**	1,222,258	1,724	522,076	454	883,507	825	2,627,841	3,003
	Male	3,272,188	6,060	474,419	603	815,043	1,172	4,561,650	7,835
	Total	4,494,446	7,784	996,495	1,057	1,698,551	1,997	7,189,492	10,838
Retiree	**Female**	773,240	25,588	533,781	13,126	947,152	30,296	2,254,173	69,010
	Male	3,099,213	121,624	916,660	30,946	1,261,959	45,939	5,277,831	198,509
	Total	3,872,453	147,212	1,450,441	44,072	2,209,111	76,235	7,532,004	267,519
Contingent Survivor	**Female**	625,826	29,105	146,598	7,191	176,774	9,382	949,197	45,678
	Male	35,185	2,146	20,573	1,643	19,765	1,114	75,523	4,903
	Total	661,011	31,251	167,171	8,834	196,539	10,496	1,024,720	50,581
Disabled Retiree	**Female**	41,388	1,354	3,935	114	3,808	134	49,131	1,602
	Male	275,435	11,777	2,053	93	6,034	273	283,523	12,143
	Total	316,824	13,131	5,988	207	9,843	407	332,654	13,745
Total	**Female**	2,662,711	57,771	1,206,389	20,885	2,011,242	40,637	5,880,342	119,293
	Male	6,682,022	141,607	1,413,704	33,285	2,102,801	48,498	10,198,528	223,390
	Total	9,344,733	199,378	2,620,094	54,170	4,114,043	89,135	16,078,870	342,683

When comparing the aggregate Pri-2012 dataset to the aggregate RP-2006 dataset, it is important to note the differences in the data distribution by collar type. Table 3.2 presents a comparison of the collar breakdown between the two studies by status and gender.

Table 3.2
COMPARISON OF COLLAR CONCENTRATION OF PRI-2012 AND RP-2006 DATASETS

		Collar Concentration[15] (Life-Years of Exposure)					
		Females			Males		
		Blue	White	Unknown	Blue	White	Unknown
Employee	RP-2006	68.1%	27.8%	4.1%	61.3%	33.6%	5.1%
	Pri-2012	46.5%	19.9%	33.6%	71.7%	10.4%	17.9%
Retiree	RP-2006	56.1%	31.4%	12.5%	52.2%	27.6%	20.1%
	Pri-2012	34.3%	23.7%	42.0%	58.7%	17.4%	23.9%
Contingent Survivor	RP-2006	59.1%	28.5%	12.4%	56.3%	31.9%	11.9%
	Pri-2012	65.9%	15.4%	18.6%	46.6%	27.2%	26.2%
Disabled Retiree	RP-2006	73.3%	13.8%	12.9%	60.1%	11.9%	28.0%
	Pri-2012	84.2%	8.0%	7.8%	97.1%	0.7%	2.1%
Total	RP-2006	62.5%	28.7%	8.8%	56.4%	29.5%	14.1%
	Pri-2012	45.3%	20.5%	34.2%	65.5%	13.9%	20.6%

The concentration of Unknown Collar data is generally higher in the Pri-2012 study than it was in the RP-2006 dataset, particularly for females. See subsection 13.1 for additional commentary regarding the Unknown Collar group. The Pri-2012 dataset contains a lower concentration of White Collar data than the previous study for both genders. For males, a greater percentage of the Pri-2012 dataset is Blue Collar than in RP-2006, but for females, the total Blue Collar concentration is considerably lower in Pri-2012, particularly for Employees and Retirees.

3.8 Determination of Amount-based Quartiles

To analyze results by annual benefit amount (Annuitants) and annual salary (Employees), RPEC divided the data into four amount quartiles, with unique breakpoints determined for each of the eight gender and status combinations. The Committee excluded data provided with missing amounts from this process. The breakpoints were set to split the original seriatim data into four quartiles with an equal number of records. Because some records generated more exposure than others (e.g., a person may have a partial year of exposure due to retirement in the middle of a particular year), the number of life-years of exposure was not exactly equal across the four quartiles, though the distribution was reasonably even.

Table 3.3
PRI-2012 INCOME QUARTILE BREAKPOINTS BY GENDER AND STATUS

	Employees		Retirees		Contingent Survivors		Disabled Retirees	
Percentile	Female	Male	Female	Male	Female	Male	Female	Male
25th	$ 25,880	$ 35,590	$ 1,490	$ 3,220	$ 1,650	$ 1,300	$ 3,940	$ 6,020
50th	$ 42,170	$ 48,840	$ 3,380	$ 8,710	$ 3,450	$ 3,090	$ 6,310	$ 9,000
75th	$ 68,070	$ 67,090	$ 7,920	$ 17,440	$ 6,660	$ 6,340	$ 9,550	$ 14,710

[15] The portion of the data labeled in Table 3.2 as "Unknown" collar for RP-2006 was designated as "Mixed" collar in the *RP-2014 Mortality Tables Report*.

It should be emphasized that the above income percentiles effectively represent values as of 2012, the study's central year. They are presented here to provide additional context for the study data. An actuary seeking to use these percentiles as benchmarks to characterize participants of a given plan should consider what adjustments, if any, are necessary to make them more temporally relevant to the application date.

Sections 10 and 11 show comparisons between RP-2006 and Pri-2012 mortality rates and annuity factors developed using each set of tables, respectively. The Top Quartile and Bottom Quartile comparisons should be analyzed with the added context of how the quartile breakpoints have shifted between the two studies. For reference, Table 3.4 shows the corresponding income breakpoints used in generating the RP-2006 quartiles.

Table 3.4
RP-2006 INCOME QUARTILE BREAKPOINTS BY GENDER AND STATUS

	Employees		Retirees		Beneficiaries		Disabled Retirees	
Percentile	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
25th	$ 30,824	$ 44,916	$ 3,888	$ 8,208	$ 3,972	$ 2,304	$ 5,088	$ 5,508
50th	$ 46,596	$ 60,216	$ 8,784	$ 14,496	$ 6,048	$ 4,320	$ 7,584	$ 8,796
75th	$ 62,820	$ 77,232	$ 13,932	$ 24,756	$ 8,376	$ 6,576	$ 10,872	$ 13,068

Comparison of the values in Tables 3.3 and 3.4 shows that despite being six years more current, the Pri-2012 breakpoints are almost always lower than their RP-2006 counterparts, particularly for nondisabled participants. Some potential implications of this shift in quartiles are discussed in subsection 12.2.3.

Section 4: Multivariate Analysis

4.1 Overview

Consistent with prior RPEC mortality studies, it was assumed that different tables would be created by gender and separate tables within gender for active employees versus those receiving annuities. Disabled retirees are typically segregated for analysis because they tend to have higher mortality rates than nondisabled participants. The RP-2000 and RP-2014 studies included separate male and female tables for employees, healthy annuitants and disabled retirees. Additional employee and annuitant rate sets were created in the RP-2014 study for top and bottom income quartile and for blue collar and white collar subpopulations.

RPEC collected several potentially predictive variables (also known as "covariates") for this study, including annuitant status (Retiree, Disabled Retiree, Contingent Survivor); industry category (construction, financial institutions, manufacturing, retail, other—based on two-digit industry codes per Form 5500); and lump sum availability (none, full, partial, unknown). In addition, nondisabled participants were grouped by collar type (Blue, White, Unknown) and by benefit amount (or salary) into income quartiles. Regression data also contained a plan ID (for each submission) and indicators for calendar year (2009–2014), duration[16] (<5 years, 5+ years, unknown), and plan type (multiemployer, other).

RPEC engaged Michelle Xia and Lei Hua from Northern Illinois University (NIU) to investigate which predictor variables appeared statistically significant and evaluate each variable's contribution to estimation. In addition to the NIU analysis, RPEC performed supplementary analysis using pivot tables and graphs that are also discussed below.

4.2 Nature of Analyses

The NIU analysis based modeling on a Poisson or negative binomial distribution, with negative binomial used when data dispersion was higher than suitable for a Poisson assumption. The underlying shape of log-mortality was expressed as a polynomial in age (nearest birthday), with differences for male versus female. The other variables (such as collar type or income quartile) were expressed as indicators. NIU assessed each variable's significance based on Type III analysis[17] using the likelihood ratio test, after adjusting for all other variables in the model. NIU also explored a small number of two-way interaction terms among these variables, such as age and collar type. These interaction terms sometimes showed statistical significance, indicating that separate tables—as opposed to simpler loading factors—may be desirable if enough data existed for those splits.

4.3 Summary and Conclusions for Employees

4.3.1 Variations by Income Quartile

Results of the multivariate analysis indicate that after controlling for age and gender, the income quartile was the most predictive variable in the study for Employees. This was true whether the regression included many variables—such as industry, lump sum availability, etc.—or was in a smaller universe of variables with collar type and income quartile. The highest two quartiles showed similar tendencies toward lower mortality rates. The second-lowest quartile indicated higher mortality, and the bottom quartile showed the highest relative mortality. Considered

[16] For each status group, duration was measured from the date in which the participant transitioned to that status, i.e., date of hire for Employees, date of retirement for Retirees and Disabled Retirees, and contingent benefit start date for Contingent Survivors.

[17] Rather than producing individual tests of significance for each coefficient of a class variable (such as amount quartile, or collar), the Type III analysis tests the significance of the null hypothesis that all the coefficients in the entire set are equal to zero. This allows easy comparisons and rankings of all the variables in the model, both class and numeric.

individually, the highest two quartiles and the bottom quartile were highly statistically significant, while the second-lowest quartile was significant but less so.

These results indicated two potential approaches for modeling income differences, either through above-median (highest two quartiles) versus below-median (lowest two quartiles) rates or by separate tables for Top Quartile and Bottom Quartile as distinguished from the population at large. With an eye toward applications, and for consistency with the RP-2014 study, RPEC decided to use the second approach. Top-quartile tables, in particular, have been found useful for valuing nonqualified plans offered only to highly compensated employees.

4.3.2 Variations by Collar

Collar type (Blue, White, Unknown) was also determined to be significantly correlated with mortality, especially in simpler models including fewer independent variables. Regression coefficients indicated significantly lower mortality for White Collar than Blue Collar Employees. The final dataset also contained a sizable component of Unknown Collar experience, more in fact than White Collar exposures. This Unknown Collar segment showed relative mortality similar to White Collar data. However, it was not clear how separate Unknown Collar tables would be useful to practitioners, whereas the Blue Collar and White Collar tables—which are more specific in their participant profiles—have proven to be useful in pension valuations.

It must be noted that there is significant correlation between the collar type and income quartile distributions for Employees. The overwhelming majority of mortality experience for Blue Collar Employees comes from the two lowest quartiles, with almost one-half from the Bottom Quartile alone. Similarly, about three-fourths of the White Collar mortality experience comes from the highest two quartiles. Data for Unknown Collar are somewhat skewed toward higher income, with about two-thirds of deaths coming from the two highest quartiles.

4.3.3 Variations by Lump Sum Availability

RPEC did not anticipate that the availability of lump sums upon retirement would be a useful predictor of employee mortality prior to retirement. Such plan design choices are not necessarily intended to correlate with mortality, especially as an Employee, and in fact, the availability of lump sums may be higher in White Collar settings. Initial regression results indicated that in the presence of other predictive variables, the lowest mortality was correlated with no lump sum availability (none) in the plan. The statistical significance of the individual indicators (none, full, partial, unknown) was not overwhelming, and lump sum availability did not seem to be a strong predictor of mortality; rather, it appeared to simply be a factor correlated with industry category.

4.3.4 Variations by Industry Category

RPEC requested each plan's NAICS code (found on line 2d of Form 5500) to categorize plans and study mortality by industry. Broad industry categories (construction, financial institutions, manufacturing, retail, other—based on the first two digits of the NAICS code) were provided for multivariate analysis. Initial regression results indicated that in the presence of other predictive variables, industry category did have some statistical significance. However, deeper analysis uncovered issues that undermined its inclusion as a significant predictor of mortality.

There was a significant concentration of experience in the two largest plans from each industry. With one exception, the top two plans represented more than 50% of the total exposures (ranging from 50% to more than 70%) for each industry category. In addition to the potential concern that rates could be dominated by the experience of the largest plans, the top two plans within each industry often exhibited opposite relative mortality coefficients. In the one industry in which the top two plans indicated the same directionality, the other submitters within the industry category indicated the opposite.

As a result, the Committee decided the current data did not support industry category as a useful predictor of mortality. Note that the Committee, through analysis, did not conclude that industry was unimportant, just that the data collected for this study did not support development of separate tables by industry category.

4.3.5 Variations by Duration

RPEC included duration since hire (<5 years, 5+ years) in initial regression models that did not indicate statistical significance, with or without the inclusion of the lump sum availability and industry category variables. It omitted duration from subsequent analyses for Employees.

4.3.6 Variations by Plan Type

RPEC also considered plan type (multiemployer, other) as a potential predictor of mortality level within the Blue Collar data. However, when controlling for income quartile, the coefficient for multiemployer plan type was not statistically significant and did not contribute materially to the likelihood ratio.[18] As a result, subsequent analyses regarding Blue Collar Employee data did not distinguish between plan types.

4.3.7 Interactions by Age

The study used a regression analysis of not only collar and income but additional interaction terms with age / collar type and age / income quartile. The regression analysis did not indicate strong statistical significance in these interaction effects, which suggested to the Committee that simple loading factors (through age 65) could be used to determine separate mortality tables by collar type and income quartile.

4.4 Summary and Conclusions for Retirees

4.4.1 Retiree and Contingent Survivor Experience

The NIU team specifically investigated whether data for Nondisabled Annuitants indicated that Contingent Survivor mortality was different than Retiree mortality. The overall mortality for Contingent Survivors, the dataset for which was predominantly female, was found to be higher than that for Retirees at a statistically significant level. The Committee performed subsequent analyses by segregating Retiree experience from that of Contingent Survivors, with the intent to revisit the issue during table development.

4.4.2 Variations by Income Quartile

Results of the multivariate analysis indicated that after controlling for the age, gender and collar type covariates, the income quartile was still a significant predictor of Retiree mortality. Results across the four quartiles showed an inverse relationship between income and mortality, with mortality decreasing with increasing retirement benefit amount. Considered individually, all quartiles were highly statistically significant. Consistent with the corresponding analysis for Employees (as discussed above) and the RP-2014 study, the Committee decided to generate separate Retiree tables for Top Quartile and Bottom Quartile.

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[18] Specifically, the relative mortality factor was approximately 5% (higher for multiemployer) with a standard error of 0.0334. Its contribution to the likelihood ratio test was trivial, less than 1% of that for income quartile.

4.4.3 Variations by Collar

Similar to the conclusions for Employees in subsection 4.3.2, RPEC determined collar type (Blue, White, Unknown) to be significantly correlated with Retiree mortality, showing materially lower mortality for White Collar than Blue Collar Retirees. However, the degree of overlap in the collar and income quartile subpopulations is smaller for Retirees than it is for Employees. A relatively smaller portion of the Blue Collar Retiree experience comes from the Top Quartile, though all three other quartiles are well represented. The White Collar mortality experience is broadly spread across all quartiles, except perhaps for the relative underrepresentation of females in the Bottom Quartile. In general, the Blue Collar and White Collar data for Retirees were more evenly distributed across quartiles than for Employees.

4.4.4 Variations by Lump Sum Availability

Commenters to the RP-2014 study questioned whether there may be a correlation between lump sum availability and mortality. The rationale was that people who had elected annuities over a lump sum option may be healthier and believe they would live longer than average. Regression results were mixed and did not lead to stable predictive value. For example, when lump sum availability was considered with age, gender and income quartile, Retirees with no lump sum option had the highest mortality level, full and unknown availability the next highest, and the lowest mortality was associated with partial availability.

Aside from being somewhat counterintuitive (why would unknown lump sum availability have statistically lower mortality than Retirees without lump sum availability, and what characteristic of partial lump sum availability could drive mortality significantly below all other lump sum indicators?), the results for full availability changed materially when various combinations of other covariates were included or excluded from the model. This contrasts with more stable correlations, such as income quartile (higher benefits with lower mortality) and collar type (Blue Collar higher mortality than White Collar) that maintained their relationships. It was decided that lump sum availability was probably correlated to other variables in the study (such as industry or collar) or plan design trends and not itself as reliable a predictor of mortality level as either collar or income quartile.

4.4.5 Variations by Industry Category

Similar to Employees, initial regression results indicated that in the presence of other predictive variables, industry category did have some statistical significance.

However, the concentration and consistency issues noted previously for Employees were also problematic for Retiree experience. The top two plans for Retirees generally represented 30%–40% of the total exposures for each industry category. When indicator variables for the top two plans within each industry category were included in the regression, they were very significant predictors of mortality. This result emphasizes the importance of incorporating plan-specific experience into the assumption-setting process, particularly for larger plans.

Another observation is that the collar type and income quartile coefficients maintained their relative ordering (higher benefits showing lower mortality, and Blue Collar having higher mortality than White Collar) even when all the additional industry category, top two plans, and lump sum availability indicators were present. This further supported including separate tables for Blue/White Collar and Top/Bottom Quartile as fundamental distinctions, leaving industry and plan differences up to the actuary based on plan-specific experience, if credible.

4.4.6 Variations by Duration

RPEC included duration since retirement (<5 years, 5+ years) in initial regression models that did not indicate statistical significance, with or without the inclusion of the lump sum availability and industry category covariates. It omitted duration from subsequent Retiree analyses.

4.4.7 Variations by Plan Type

RPEC also considered plan type (multiemployer, other) as a potential predictor of mortality level within the Blue Collar data. However, when income category was included in the model, the relative mortality for multiemployer plan type was within 3% (higher) and did not contribute materially to the likelihood ratio.[19] As a result, subsequent analyses regarding Blue Collar Retiree data did not distinguish between plan types.

4.4.8 Interactions with Age

A regression model including not only collar type and income quartile but additional interaction terms with age / collar type and age / income quartile, demonstrated the statistical significance of interaction effects. This indicated to the Committee that separate tables, as opposed to simple loading factors, are desirable as long as sufficient data for each split (Blue/White Collar, and Top/Bottom Quartile) is available.

4.5 Summary and Conclusions for Contingent Survivors

As noted above, an initial regression of the data for Nondisabled Annuitants indicated that Contingent Survivor mortality tended to be higher than Retiree mortality, and the difference was statistically significant. It should be stressed that Contingent Survivor experience tracked beneficiary exposures and deaths only *after the primary participant's death*. Similar to the situation for terminated vested participants, records for beneficiaries prior to the primary annuitant's death are generally not precisely maintained.

The Committee considered several potentially predictive factors in the regression models. Duration (since the primary participant's death) was moderately significant but contributed very little to the likelihood ratio and indicated a modestly lower mortality level at shorter durations. This is somewhat inconsistent with past research indicating that widow(er) mortality is significantly higher in the first few years following a spouse's death (Frees 1996); however, in the Pri-2012 study, the indicator was for duration less than five years, versus five or more. RPEC decided not to model this impact with separate mortality tables due to its modest impact, the significant administrative burden of select-and-ultimate rates, and the fact that Contingent Survivor mortality experience across ages does include representative samples of new beneficiaries.

Of the other potentially predictive variables, the most significant was collar type. Income quartile was much less powerful, comparable to duration in its likelihood ratio contribution. It appears that the plan participant's collar type is a more effective indicator of Contingent Survivor mortality—perhaps via correlation to socioeconomic status—than other indicators available in this study. RPEC concluded separate tables by Blue Collar and White Collar should be produced for females. For males, there were insufficient data to justify creating separate tables by collar type.[20]

It is also worth noting that, similar to the Retiree experience, indicator variables for the top two plans in each industry category were found to be significant predictors of Contingent Survivor mortality after those variables were introduced into the regression analysis. The circumstances of individual plans—even after taking into account other potential predictors—was often relevant in situations where credible data were available. However, the relative mortality level for Contingent Survivors was not always in the same direction as for Retirees of the same plan.

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[19] Specifically, the relative mortality factor was approximately 3% higher for multiemployer. However, its contribution to the likelihood ratio test was very small, less than 5% of that of income quartile.

[20] For convenience, the Pri-2012 tables include male Blue Collar and White Collar Contingent Survivor rates, but they are equal to the total population Contingent Survivor rates.

4.6 Summary and Conclusions for Disabled Retirees

Among Disabled Retirees, regression analysis showed income quartile (of the benefit amount) and duration were significant indicators. Collar was not determined to be a significant predictor, though it should be noted that the vast majority of Disabled Retiree data (more than 90%) was Blue Collar. Higher income was associated with lower mortality, as is almost always the case in mortality studies. For duration, earlier durations (<5) were associated with higher mortality. This follows intuition; if a person survives for an extended period after disability, the individual's mortality patterns may trend back toward broader norms.

This did not, however, lead the Committee to establish different rate tables by income quartile, or on a select-and-ultimate basis. There was insufficient data for such refined distinctions. Even if sufficient data had been available, select-and-ultimate rate sets can be hard for practitioners to implement and scale appropriately to their populations.

With respect to income, there were also less data than desirable for separate quartiles, especially for females. It must be noted that "disability" has many meanings across pension plans, ranging from total and permanent disability with the inability to perform any job duties to much less severe cases of partial or temporary inability to do one's job. The relative richness of plan provisions is also wide ranging, with some programs attempting to replicate long-term disability benefit levels (partial pay replacement) and other plans merely providing the vested accrued benefit (sometimes with immediate commencement).

Based on these considerations, the Committee decided to produce only sex-distinct rates, without adjustments for duration or income.

Section 5: Graduation of Raw Rates

RPEC developed raw mortality rates under two bases: (1) amount-weighted rates, which reflected annualized salary for Employees and annualized retirement plan benefits for Retirees, Contingent Survivors and Disabled Retirees and (2) headcount-weighted rates. As is typical with empirical datasets, each set of gender- and age-specific raw mortality rates that the Committee developed exhibited a certain degree of random fluctuations around a smooth trend curve.

The objective of any graduation methodology is to smooth observed experience in a way that maintains an appropriate degree of fit with the underlying raw dataset. RPEC developed smoothed mortality rates under both the Whittaker-Henderson (Type B) with the "Lowrie variation" (W-H-L) methodology that was used in the SOA's RP-2014 study and a technique based on the Generalized Additive Model (GAM) methodology that was used in the SOA's Pub-2010 study.

Central to both the W-H-L and GAM graduation methodologies is the concept of an "objective function" that needs to be minimized. Both of the W-H-L and GAM objective functions include two components: one that measures the overall fit and the other that measures the overall smoothness of the graduated values. For example, given a set of raw mortality rates, q_x, over the age range x_{min} to x_{max}, with weights w_x, the GAM objective function RPEC used was equivalent to[21]

$$\sum_{x} w_x \left(\ln q_x - f(x)\right)^2 + \lambda \int_{x_{min}}^{x_{max}} [f''(x)]^2 dx$$

RPEC used the "mgcv" package in R, a widely used language and environment for statistical computing and graphics, to solve for the minimizing function, *f(x)*. Further information on the GAM graduation methodology that RPEC used can be found in Appendix C.

Comparisons of the smoothed rates developed under the W-H-L and GAM methodologies indicated that the two techniques produced very similar results. Given the closeness of the two sets of graduated rates and the large number of distinct tables that required graduation, the Committee ultimately decided to proceed with the GAM methodology, which allowed RPEC to generate graduated rates very efficiently using the readily available R packages.

[21] Note that for the sake of exposition, some details are omitted. The theory of GAMs is based on maximum likelihood, and the binomial likelihood with log link was used for the RPEC graduations. It can be shown that the likelihoods in the GAM framework are equivalent to optimizing this objective function via Iteratively Reweighted Least Squares (IRLS). Under IRLS, the formula provided here has two adjustments. For each iteration, the weights are updated to reflect the fitted model (to that point) and a special residual, in this case $(q_x - \hat{q}_x)/\sqrt{\hat{q}_x}$, is added to the error $\ln q_x - f(x)$. Each iteration is then a weighted least squares calculation.

Section 6: Construction of Employee Tables

6.1 Overview

The Pri-2012 Employee mortality tables start at age 18 and extend through age 80.

The sparseness of the final Employee dataset at ages less than 35 and ages greater than 65, in conjunction with data that were submitted without salary information, created several challenges for RPEC. As a result, the graduation and extension techniques described in this section are somewhat more complex than those for the other participant subgroups.

RPEC used the following process to construct both the amount-weighted and headcount-weighted mortality tables for Employees:

1. Extrapolated raw amount-weighted mortality rates[22] for the total Employee populations using the subpopulation of Employees for whom salary information was submitted.
2. Developed GAM graduated gender-specific mortality rates for the total Employee populations, starting at age 35 and continuing through age 65.
3. Extended each set of graduated total population rates first between ages 18 and 25 using an appropriately scaled version of 2015 Valuation Basic Tables (VBT) Unismoke mortality rates (SOA 2015) followed by cubic polynomial interpolation between ages 25 and 35.
4. Developed Employee subpopulation (collar and quartile) rates for ages 18 through 65 based on scaled versions of a suitably selected set of total Employee population rates determined in Steps 1 through 3 above.
5. Extended each set of graduated Employee rates from age 66 through age 80 using exponential increases, starting with age 65 rates.

In total, RPEC produced 10 separate sets of gender-specific Pri-2012 Employee tables: amount- and headcount-weighted versions of the total population and the Blue Collar, White Collar, Top Quartile, and Bottom Quartile subpopulations.

6.2 Treatment of Employee Data Submitted without Salary Information

As can be seen from Tables B.1 and B.2 in Appendix B, the percentage of Employee records submitted without any salary information was not insignificant. Rather than simply using the imputed salaries to develop amount-weighted mortality rates or excluding large segments of data from the study, RPEC used the following five-step process (separately for males and females) for the total Employee, Blue Collar Employee, and White Collar Employee datasets:

1. Developed raw *amount-weighted* mortality rates for those Employees who had salary information submitted within the dataset to be graduated.
2. Developed raw *headcount-weighted* mortality rates for those Employees who had salary information submitted within the dataset to be graduated.
3. Developed raw *headcount-weighted* mortality rates for all Employees within the dataset to be graduated.
4. Divided the raw rate from Step 1 by the raw rate from Step 2 on an age-by-age basis.
5. Applied the ratios from Step 4 to the raw *headcount-weighted* mortality rates developed in Step 3.

[22] This step was not necessary for the headcount-weighted rates.

It should be noted that this process was not required for the amount-weighted Employee mortality rates for either the Bottom Quartile or Top Quartile datasets, since those raw rates reflected deaths and exposures for only those records for which salaries were submitted.

6.3 Total Employee Population Rates for Ages 35 through 65

The Committee determined that the final Employee dataset was sufficiently credible to warrant separate GAM graduations between ages 35 and 65 for the total female and total male populations, but that none of the collar- or quartile-specific Employee subpopulations was large enough to permit separate gender-specific graduations. As a result, the collar- and quartile-specific Employee rates for ages 18 through 65 were based on suitably scaled versions of the gender-specific total Employee population rates; see subsection 6.5 for details.

6.4 Extension of Total Employee Population Rates Down to Age 18

As was the case with the RP-2014 dataset, the sparseness of Employee data under age 35 was of particular concern to the Committee. Rather than developing graduated Employee rates at ages below 35 based on scant data, RPEC decided it would be preferable to make use of an existing SOA table, namely the gender-specific 2015 VBT Unismoke age-nearest-birthday, as reference tables on which the youngest Pri-2012 Employee rates could be based (SOA 2015). The underlying data used in developing the 2015 VBT was the SOA Individual Life Experience Committee's 2002-2009 industry experience, which contained considerably more exposures and deaths between ages 18 and 35 than did the final Pri-2012 Employee dataset.

The 2015 VBT rates were first adjusted back to calendar year 2012 (the central year of the final Pri-2012 datasets) using the Scale MP-2018 mortality improvement rates. RPEC then developed gender-specific scaling factors based on a ratio of actual deaths to expected deaths between ages 18 and 35 calculated[23] using the adjusted 2015 VBT rates. The scaling factors were then applied to the respective adjusted 2015 VBT rates for ages 18 through 25. Finally, RPEC completed the remaining rates between ages 25 and 35 using cubic polynomial interpolation that matched the gender-specific rates at ages 24, 25, 35 and 36.

In summary, the total Employee rates for ages 18 through 65 were developed in three steps:

1. Ages 35 through 65: Standard GAM graduation;
2. Ages 18 through 25: Scaled version of the 2015 VBT rates adjusted back to 2012;
3. Ages 26 through 34: Cubic polynomial interpolation.

6.5 Development of Collar- and Quartile-Specific Rates through Age 65

At this point, RPEC had developed gender-specific mortality rates for ages 18 through 65 for the total Employee population. Given its concerns with subpopulation dataset credibility, the Committee decided to set each of the Employee collar and quartile rates (for ages 18 through 65) equal to a constant factor times a suitably selected set of total Employee rates. The constant factor was calculated as the ratio of actual to expected deaths between ages 18 and 65 separately for each subpopulation (White Collar, Blue Collar, Top Quartile and Bottom Quartile), weighting methodology (amount and headcount) and gender.

[23] For the amount-weighted Employee tables, the actual and expected deaths were weighted by actual (or, if missing, imputed) salaries.

For example, the ratio of actual salary-weighted deaths for Top Quartile amount-weighted males (ages 18 through 65) to expected[24] salary-weighted deaths was approximately 77.7%. The Top Quartile amount-weighted male rates at ages 18 through 65 were, therefore, set equal to 77.7% of the corresponding total amount-weighted male rates.

6.6 Extension of Employee Rates through Age 80

The final step in the construction of the Pri-2012 Employee tables entailed extension of mortality rates from age 65 through age 80 for each table. The underlying extension methodology was based on the assumption that individuals who continue to work beyond age 65 are generally in better health than the average Retiree at those corresponding ages. The Employee mortality rates for ages 66 through 80 were developed by solving for the constant exponential increase factor (separately for each of the 10 sets of gender-specific tables) that when applied repeatedly to the age-65 rate for 25 years would exactly equal 50% of the corresponding age 90[25] Retiree mortality rate.

For example, the headcount-weighted female, Blue Collar Employee rate at age 65 equals 0.00537, and the headcount-weighted female, Blue Collar Retiree rate at age 90 equals 0.13046. The constant factor that when applied to 0.00537 for 25 years produces a value of 0.06523 (i.e., 50% of 0.13046) is approximately 1.1050. Hence, the headcount-weighted female, Blue Collar Employee mortality rate for each of the ages 66 through 80 was calculated as 1.1050 times the rate at the preceding age.

6.7 Adjustments of Certain Employee Mortality Rates

RPEC reviewed each of the Employee tables for overall consistency and, as a result, slightly modified some Employee mortality rates. The amount-weighted female, Bottom Quartile rates at ages 50 through 57 were slightly larger than the corresponding headcount-weighted rates. As a result, those amount-weighted rates were set equal to the corresponding headcount-weighted rates. In addition, the male White Collar Employee tables (both amount- and headcount-weighted) were set equal to the corresponding male Top Quartile Employee tables.

[24] This is based on the total amount-weighted male rates.

[25] Various percentages of the age 90 Retiree mortality rates were tested, and values close to 50% tended to produce the smoothest extension pattern. Age 90 was chosen because it was the highest age at which Retiree rates were taken directly from graduations of mortality data; see Section 7.

Section 7: Construction of Retiree and Contingent Survivor Tables

7.1 Overview

The Pri-2012 Retiree and Contingent Survivor mortality tables start at age 50 and extend through age 120.

As displayed in Tables B.3 through B.6 in Appendix B, the percentage of Annuitants who did not have any benefit amount submitted was relatively small. For purposes of developing amount-weighted mortality rates, RPEC imputed benefit amounts for each Annuitant record with the missing amount, using the average[26] retirement benefit for those Annuitants in the same plan with submitted benefit amounts.

RPEC took the following steps to construct both the amount- and headcount-weighted mortality tables for Retirees and Contingent Survivors:

1. Developed gender-specific mortality rates at ages 100 and above based on an exposure-weighted average of the GAM graduated Retiree, Contingent Survivor and Disabled Retiree rates.
2. Developed the following graduated gender-specific Retiree mortality rates, starting at age 55, 60 or 65 (based on data credibility considerations) and continuing through age 95:

    a. Total Retiree population
    b. Blue Collar subpopulation
    c. White Collar subpopulation
    d. Top Quartile (based on benefit amount) subpopulation
    e. Bottom Quartile (based on benefit amount) subpopulation.

3. Developed the following graduated female Contingent Survivor mortality rates, starting at age 60 and continuing through age 95:

    a. Total Retiree population
    b. Blue Collar subpopulation
    c. White Collar subpopulation.

4. Developed a single table of male Contingent Survivor rates, starting at age 60 and continuing through age 90.
5. Used quintic polynomials to interpolate each of the Retiree and Contingent Survivor tables smoothly between ages 90 and 100.
6. Extended each of the resulting Retiree and Contingent Survivor tables from the youngest graduated rate down to age 50.

Primarily to enable comparisons to prior tables, the Committee also produced gender-specific Nondisabled Annuitant tables (Total Dataset, Blue Collar and White Collar) based on age-by-age weighted averages of corresponding Retiree and Contingent Survivor rates; see subsection 12.6 for details.

7.2 Development of Mortality Rates at Ages 100 and Above

The Committee decided that the gender-specific mortality rates at ages 100 and above for all annuitants (including Disabled Retirees) should coincide, because there was insufficient evidence to support the contrary. RPEC developed mortality rates at ages 100 through 119 using projection methodology originally developed by Kannisto (Kannisto 1992). The Committee fit Kannisto's logistic model by simultaneously (1) matching the total number of

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[26] Average benefit amounts within a plan were determined separately by gender and collar.

expected deaths based on the gender-specific aggregated[27] mortality rates from age 75 through age 95 and (2) minimizing the root mean squared error over that age range. RPEC capped the resulting annual mortality rates at 0.5 and set the annual mortality rate at age 120 equal to 1.0.

7.3 Graduation of Retiree and Contingent Survivor Mortality Rates

Sufficient amounts of credible Retiree data were submitted for the Committee to graduate the raw mortality rates for the total Retiree populations as well as for the collar type (Blue and White) and income quartile (Top and Bottom) Retiree subpopulations through age 95.

Based on the results of the multivariate analysis that indicated very low predictive value of benefit value for Contingent Survivor mortality rates, the Committee decided not to develop separate quartile-specific mortality tables for Contingent Survivors. The Contingent Survivor data submitted for females were sufficiently credible to graduate for the total population and collar-specific populations through age 95. The size of the Contingent Survivor dataset for males, on the other hand, was not deemed credible enough to graduate using the standard GAM methodology, even for the total male Contingent Survivor dataset. RPEC decided to use a graduation technique for this dataset based on a weighted[28] quadratic regression on the natural logarithm of the raw headcount-weighted Contingent Survivor rates for males between ages 60 and 90. The resulting quadratic polynomial values at integral ages 60 through 90 were exponentiated to generate smooth male Contingent Survivor rates at those ages.

7.4 Further Extensions of Mortality Rates for Retirees and Contingent Survivors

At this point, the Committee had developed smoothed mortality rates:

- From the youngest graduated age, denoted as "YGA" in this subsection, through age 95 using the GAM graduation methodology described in Section 5.[29]
- At ages 100 and above using Kannisto's methodology.

Given the relatively small amount of data at ages greater than 90, RPEC decided to complete each of these tables between ages 90 and 100 by fitting a quintic polynomial to rates at the following six ages: 88, 89 and 90 (from the GAM graduation) and 100, 101 and 102 (from the Kannisto projection).

RPEC extended each of the graduated sets of mortality rates for the total Retiree and total Contingent Survivor populations from the YGA down to age 50 using a technique based on ratios to corresponding final total Employee population rates. Specifically, the Committee calculated ratios of the Retiree (respectively, Contingent Survivor) rate to the corresponding graduated Employee rate for all ages between YGA and YGA+4. Those ratios were extended backwards from the YGA to age 50 using the slope of the best-fit linear regression passing through the five ratios from YGA through YGA+4. The Committee applied those extrapolated ratios to the corresponding total Employee population mortality rates to generate smooth total population Retiree (respectively, Contingent Survivor) rates for ages 50 through YGA-1.

RPEC accomplished the extension of rates downward to age 50 for each of the collar and quartile[30] subpopulation tables by applying a constant factor to the corresponding total Retiree or Contingent Survivor population rates at ages 50 through YGA-1. These constant factors were calculated as the ratio at the YGA of the subpopulation mortality rate to the corresponding total population mortality rate. For example, the YGA for the male White Collar

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[27] The exposure-weighted averages of the graduated headcount-weighted Retiree, Contingent Survivor and Disabled Retiree mortality rates.
[28] The quadratic regression was weighted at each age by the number of actual male Contingent Survivor deaths in the final dataset.
[29] This is except for the male Contingent Survivor rates, which RPEC developed for ages 60 through 90 using the weighted quadratic regression technique.
[30] Due to lack of credible data, RPEC did not develop any separate mortality tables for the quartile-specific Contingent Survivor subpopulations.

Retiree subpopulation was age 65 and the amount-weighted age-65 subpopulation and total population mortality rates were 0.00812 and 0.01083, respectively. Therefore, the amount-weighted male White Collar Retiree rates at ages 50 through 64 were set equal to approximately 75.0% (0.00812 / 0.01083) of the corresponding amount-weighted total male population rates.

7.5 Adjustments of Certain Retiree and Contingent Survivor Mortality Rates

After generating mortality rates using the techniques described above, RPEC checked each of the Retiree and Contingent Survivor tables for internal consistency. In addition to large-scale monotonicity checks, the Committee compared various sets of preliminary tables for a variety of “cross-over” issues—e.g., Contingent Survivor rates that were smaller than corresponding Retiree rates or headcount-weighted rates that were smaller than corresponding amount-weighted rates. Whenever the Committee identified such an issue, it made small adjustments to resolve these rate cross-overs. For example, RPEC observed that the amount-weighted graduated rates for female Contingent Survivors between ages 88 and 90 were slightly smaller than the corresponding Retiree rates. The Committee resolved this issue by setting the Contingent Survivor rates equal to the Retiree rates at these ages.

In a few cases, the mortality rates calculated as described in this section were extremely close to the rates that RPEC calculated for a different table (of the same gender and status). In lieu of publishing separate tables that were extremely close to each other, the Committee decided to select one of the tables as representative of all the similar tables. In particular:

- The female Bottom Quartile Retiree subpopulation tables (both amount- and headcount-weighted) were set equal to the headcount-weighted total female Retiree population table.
- The amount-weighted male Retiree Bottom Quartile table was set equal to the headcount-weighted male Retiree Bottom Quartile table.
- The amount-weighted male Contingent Survivor table was set equal to the headcount-weighted male Contingent Survivor table.

In addition, the small size of the male Contingent Survivor dataset meant that the Committee could not justify producing separate sets of rates by collar type. Therefore, the Committee set the collar-specific Contingent Survivor tables for males equal to the corresponding total population male Contingent Survivor tables.

Section 8: Construction of Disabled Retiree Tables

8.1 Overview

The Pri-2012 Disabled Retiree mortality tables start at age 18 and extend through age 120.

The total male Disabled Retiree population dataset was deemed sufficiently robust to graduate from age 45 through age 95. Due to the small size of the dataset for the total female Disabled Retiree population, the Committee used a weighted quadratic regression technique to develop rates for female Disabled Retirees between the ages 50 and 90. The Committee subsequently extended these Disabled Retiree rates upward through age 120 and downward to age 18 as described below.

8.2 Development of Disabled Retiree Rates for Males

RPEC first extended the graduated rates for the total male Disabled Retiree population to age 100 by first fitting a quintic polynomial to rates at six ages: 88, 89 and 90 (from the GAM graduation) and 100, 101 and 102 (from the Kannisto projection). The rates for ages 100 through 120 are the same as the corresponding (nondisabled) Retiree rates.

The male Disabled Retiree mortality rates for ages 18 through 44 were developed as a constant multiple of the corresponding Employee rates, with the multiplicative factor equal to the weighting-specific ratio of the Disabled Retiree rate at age 45 to the total male Employee population rate at age 45. For example, the constant multiple for the headcount-weighted male rates was approximately 16.4 (0.02030/0.00124).

8.3 Development of Disabled Retiree Rates for Females

RPEC first developed smoothed mortality rates for the total female Disabled Retiree population for ages 45 through 90 by (1) applying a weighted[31] quadratic regression formula to the natural logarithm of the raw rates for ages 50 through 90 and (2) exponentiating the values of the resulting quadratic polynomial at integral ages 45[32] through 90. As described above, the Committee first extended these rates to age 100 by fitting a quintic polynomial to rates at six ages: 88, 89, 90, 100, 101 and 102, and subsequently extended to age 120 by setting the female Disabled Retiree rates equal to the corresponding (nondisabled) Retiree rates.

The female Disabled Retiree mortality rates for ages 18 through 44 were developed as a constant multiple of the corresponding Employee rates, with the multiplicative factor equal to the weighting-specific ratio of the Disabled Retiree rate at age 45 to the total population female Employee rate at age 45. For example, the constant multiple for the amount-weighted female rates is approximately 20.4 (0.01328/0.00065).

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[31] RPEC weighted the quadratic regression at each age by the benefit amount or number (depending on whether amount- or headcount-weighted) of actual female Disabled Retiree deaths in the final dataset.

[32] The female Disable Retiree data submitted below the age of 50 were not sufficiently credible to be included in the weighted quadratic regression.

Section 9: Construction of Juvenile Tables

For completeness, RPEC has included a set of gender-specific Juvenile mortality rates for ages 0 through 17. For ages 0 through 12, the rates were set equal to the Social Security Administration's historical probabilities of death for the year 2012, as published in the *2019 Trustees' Report* (SSA 2019). RPEC calculated the juvenile rates for ages 13 through 17 by fitting a cubic polynomial to the Juvenile rates at ages 11 and 12 and the corresponding Employee rates at ages 18 and 19.

Section 10: Comparison of Rates

10.1 Overview

RPEC produced sets of Pri-2012 mortality tables similar to those in the previously published private plan SOA tables, RP-2006. The Committee viewed the comparison to RP-2006 as most appropriate, since it believes most practitioners currently use some version of that table, given its widespread application in U.S. funding and accounting valuation work. RPEC also made comparisons to mortality rates from the White Collar, Blue Collar, Top Quartile and Bottom Quartile versions of RP-2006 because these variations are also used widely in practice and have become a benchmark for the variation in mortality experience by socioeconomic status.

When comparing the rates under Pri-2012 to analogous rates under RP-2006, it is important to understand the differences in the datasets underlying the two tables. In particular, practitioners should be aware of the following:

- *Changes in the Collar Distribution and Identification Approach:*
  - Table 3.2 shows a comparison of collar concentration by gender and status group. Note that Unknown Collar[33] data make up a more significant portion of the Pri-2012 dataset than the RP-2006 dataset, especially for females. Males (except Contingent Survivors) have a higher concentration of Blue Collar data than in RP-2006, while female Employees and Retirees have a substantially lower concentration of Blue Collar data than in RP-2006.
  - In addition to being identified on a plan-wide basis, the Pri-2012 dataset included collar type specified by individual participant. In fact, slightly more than one-fourth of the final dataset was determined by participant-specific collar indicators. Therefore, the “White Collar” dataset for this study consists of both participants specifically identified as White Collar and participants in plans designated as White Collar (per the 70 percent threshold noted in subsection 2.3.2). Analogously, the “Blue Collar” dataset for this study consists of participants specifically identified as Blue Collar and participants in plans designated as Blue Collar that were not specifically identified as White Collar participants.
- *Changes in the Distribution of Submitted Salaries and Benefit Amounts:*
  - A comparison of the Pri-2012 quartile breakpoints in Table 3.3 to the corresponding RP-2006 breakpoints in Table 3.4 reveals that the salaries for Employees and benefit amounts for Retirees and Contingent Survivors in the current study’s dataset are generally smaller than those in the prior study, sometimes significantly so.[34]
  - In addition to the impact of generally lower salary and benefit amounts on the comparison of Pri-2012 and RP-2006 quartile-specific tables, there is a related impact on the comparison of the two studies’ collar-specific tables. The Blue Collar subpopulation in the Pri-2012 dataset, for example, has much lower average Employee salaries and much lower average Retiree benefit amounts than the RP-2006 Blue Collar dataset. The corresponding salary and benefit amount comparisons for

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[33] This includes experience for “Mixed Collar” groups; see subsection 13.1.
[34] See also Figures 12.1 and 12.2.

the White Collar subpopulations of Pri-2012 versus RP-2006 are considerably less disparate than the comparisons for the Blue Collar subpopulations.[35]

All the graphs presented in Section 10 are based on amount-weighted[36] mortality rates projected with Scale MP-2018 to January 1, 2019. from the central year of study data (2006 for RP-2006 and 2012 for Pri-2012). A ratio less than 1.0 means that the projected Pri-2012 mortality rate is smaller than the corresponding projected RP-2006 mortality rate.[37]

Finally, it should be noted that the RP-2006 tables combined data for Retirees and Contingent Survivors into a "Healthy Annuitant" table. This complicates the direct comparisons of those historical rates to the Pri-2012 Retiree rates and the Pri-2012 Contingent Survivor rates presented in Subsections 10.3 and 10.4, respectively.

10.2 Comparison of Employee Rates

Figure 10.1 shows that the projected Pri-2012 rates are lower than the projected RP-2006 rates after age 44 for both genders. Prior to that age, the male rates in Pri-2012 are moderately higher, while the female rates track the prior table fairly closely. For advanced ages above 60, the male rates are significantly lower than under the prior table; this effect is less pronounced for females.

It should be noted that the ratios for all of the Employee subpopulation tables presented later in this section have a similar shape—shifted up or down—to those in Figure 10.1. This is because (as discussed in Section 6 and in the RP-2014 report) the Pri-2012 and RP-2006 versions of the collar- and quartile-specific Employee tables were constructed as scalar multiples of the corresponding total dataset tables between ages of 18 and 65.

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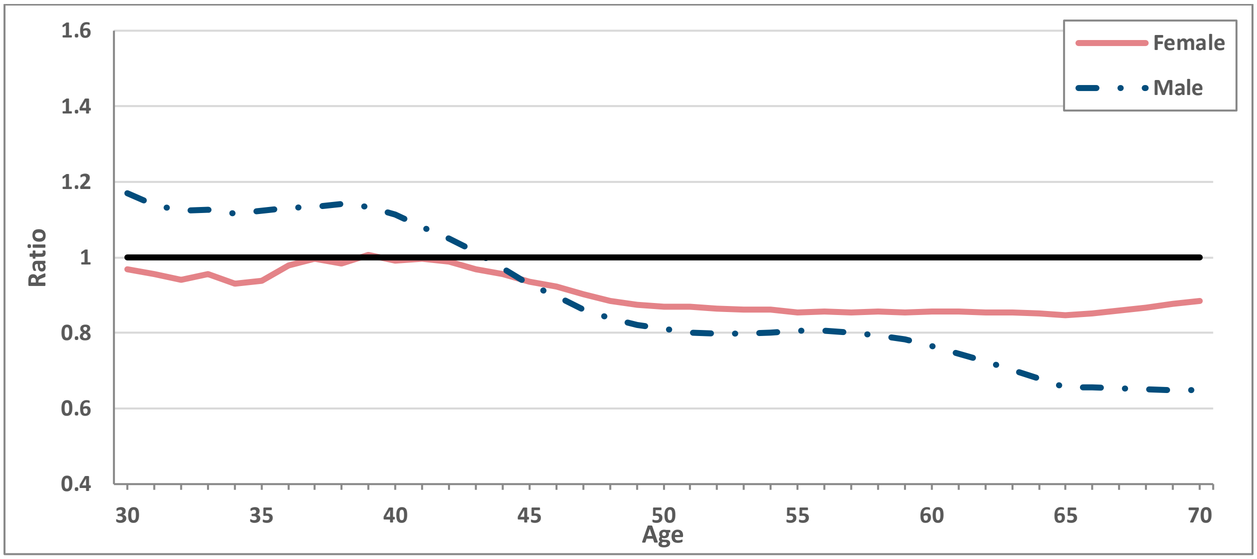
[35] These comparisons were developed by dividing the "Exposed $-Years" by the "Exposed Life-Years" in the tables in Appendix B of this report and Appendix C of the *RP-2014 Mortality Tables Report*.

[36] Comparisons of headcount-weighted rates were reviewed and were very similar to the amount-weighted rate comparisons shown in this section.

[37] Note that the corresponding Section 10 of the RP-2014 Report used the opposite convention, with ratios less than 1.0 implying that the projected RP-2014 rate was larger than the corresponding projected RP-2000 rate.

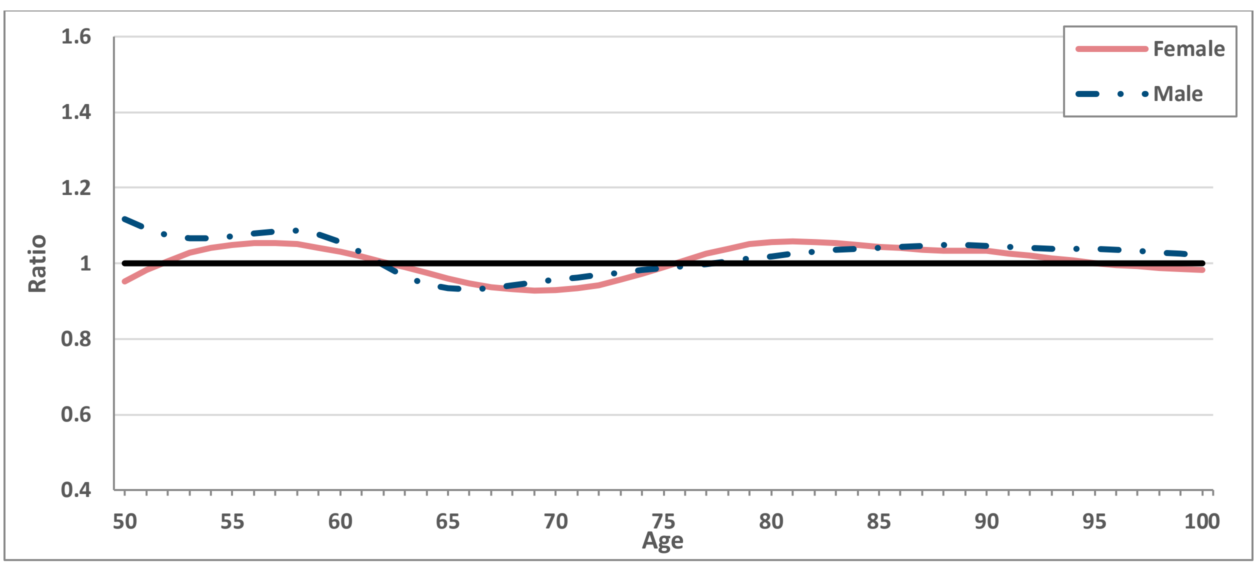
Figure 10.1
RATIO OF PRI-2012 EMPLOYEE TO RP-2006 EMPLOYEE
MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



10.3 Comparison of Retiree Rates

Figure 10.2 shows a comparison between the projected Pri-2012 Retiree rates and RP-2006 Healthy Annuitant rates, both projected to 2019 using MP-2018. The two tables indicate similar comparisons for both genders with the Pri-2012 rates moderately lower between ages 61 and 76 but otherwise slightly higher. RPEC noted that mortality experience for younger Retirees, especially those who had presumably retired early was generally higher than expected.

Figure 10.2
RATIO OF PRI-2012 RETIREE TO RP-2006 HEALTHY ANNUITANT
MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



10.4 Comparison of Contingent Survivor Rates

Figure 10.3 compares the Pri-2012 Contingent Survivor rates to the RP-2006 Healthy Annuitant rates. The Contingent Survivor rates are higher than the RP-2006 rates at all ages, with the highest differences at the earliest ages. It is expected that a table of Contingent Survivors would display higher mortality than the RP-2006 Healthy Annuitant tables, which combine Retiree and Contingent Survivor experience. Table 11.5 details the difference between annuity factors produced by the RP-2006 Healthy Annuitant tables and the Pri-2012 Contingent Survivor tables.

Figure 10.3

RATIO OF PRI-2012 CONTINGENT SURVIVOR TO RP-2006 HEALTHY ANNUITANT MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018

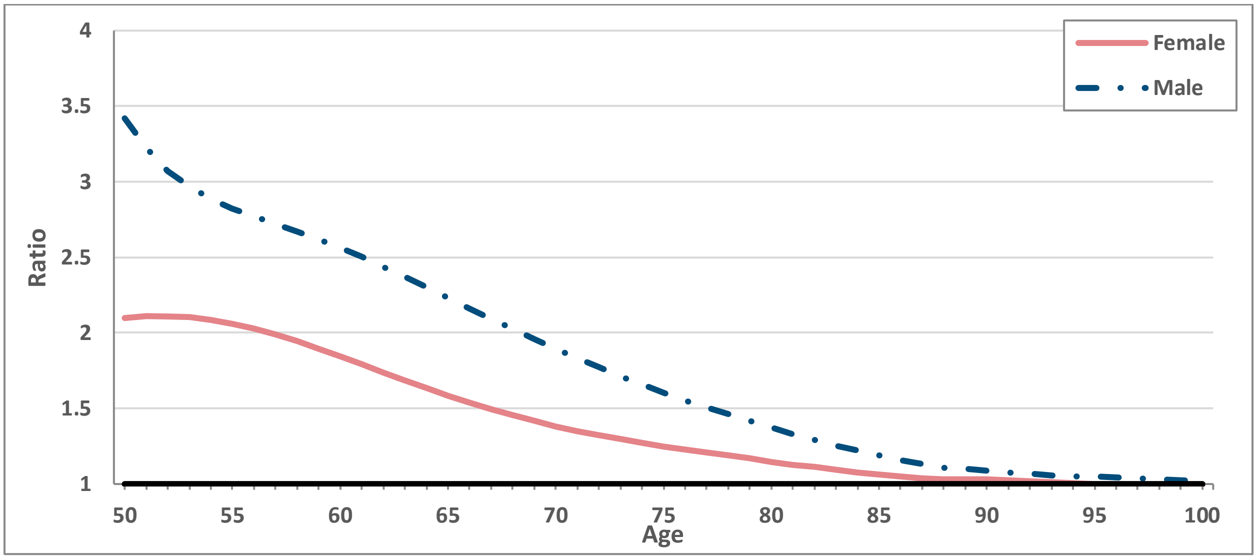
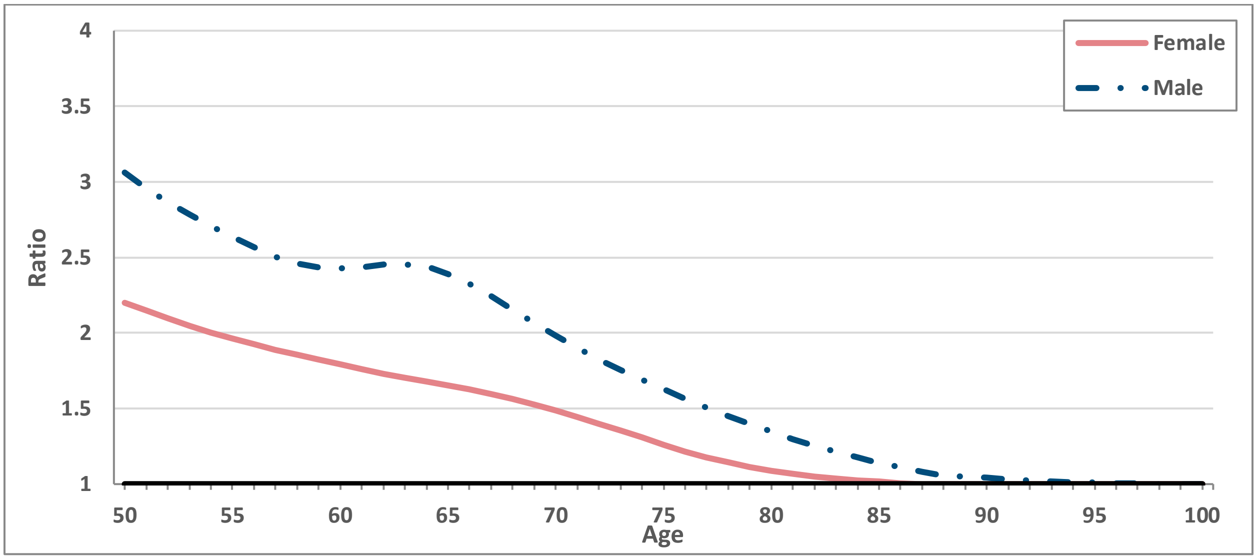


Figure 10.4 compares the projected Pri-2012 Contingent Survivor rates to the projected Pri-2012 Retiree rates. The multivariate analysis showed that Contingent Survivor mortality was determined to be higher than Retiree mortality[38] (see subsection 4.4.1) and that this observation was statistically significant. Male Contingent Survivor rates are higher than the corresponding Retiree rates at all ages, with the highest ratios observable at the youngest ages. The Pri-2012 female Contingent Survivor and Retiree rates converge just before age 90, with the female rates consistently higher at younger ages. The Committee notes that the total dataset for male Contingent Survivors was very small compared to that for females.

[38] Note that this observation is consistent with the RP-2014 study. Although there were not enough data to perform meaningful statistical analysis on the RP-2014 male Beneficiary data, footnote 22 on page 23 of the RP-2014 report indicates that the age-specific ratios of (a) female Beneficiary mortality rates to (b) female Healthy Retiree rates decreased from approximately 2.5 at age 50 to approximately 0.9 at age 90; the crossover point (ratio of 1.0) occurred between ages 78 and 79.

Figure 10.4

RATIO OF PRI-2012 CONTINGENT SURVIVOR TO PRI-2012 RETIREE
MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018

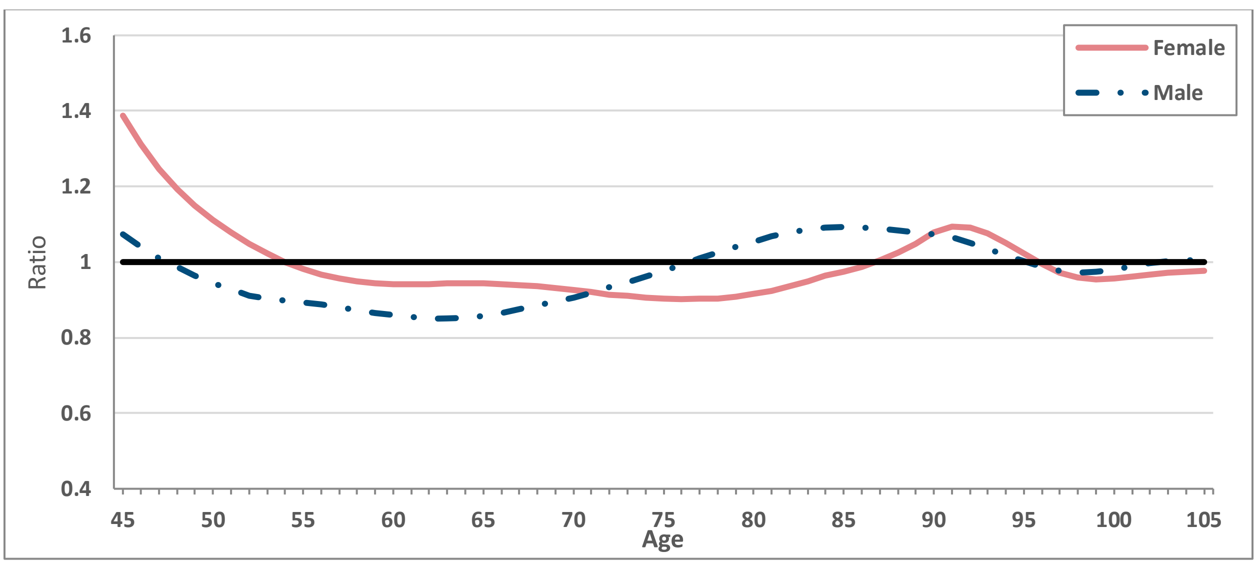


10.5 Comparison of Disabled Retiree Rates

Subsection 12.5 discusses some of the challenges presented in developing mortality rates for disabled lives. Those challenges notwithstanding, Figures 10.5 shows that the projected Pri-2012 Disabled Retiree rates generally track the projected RP-2006 Disabled Retiree rates within a reasonable range for both genders.

Figure 10.5

RATIO OF PRI-2012 DISABLED RETIREE TO RP-2006 DISABLED RETIREE
MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



10.6 Comparison of Blue Collar Rates

Figure 10.6 compares the projected Pri-2012 Employee rates for the Blue Collar dataset to the projected RP-2006 Blue Collar Employee rates. For males, the Pri-2012 rates are significantly lower after age 42. For females, the rates are higher prior to age 50 and then are slightly higher but close to the prior table after that age.

Figure 10.6

RATIO OF PRI-2012 BLUE COLLAR EMPLOYEE TO RP-2006 BLUE COLLAR EMPLOYEE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018

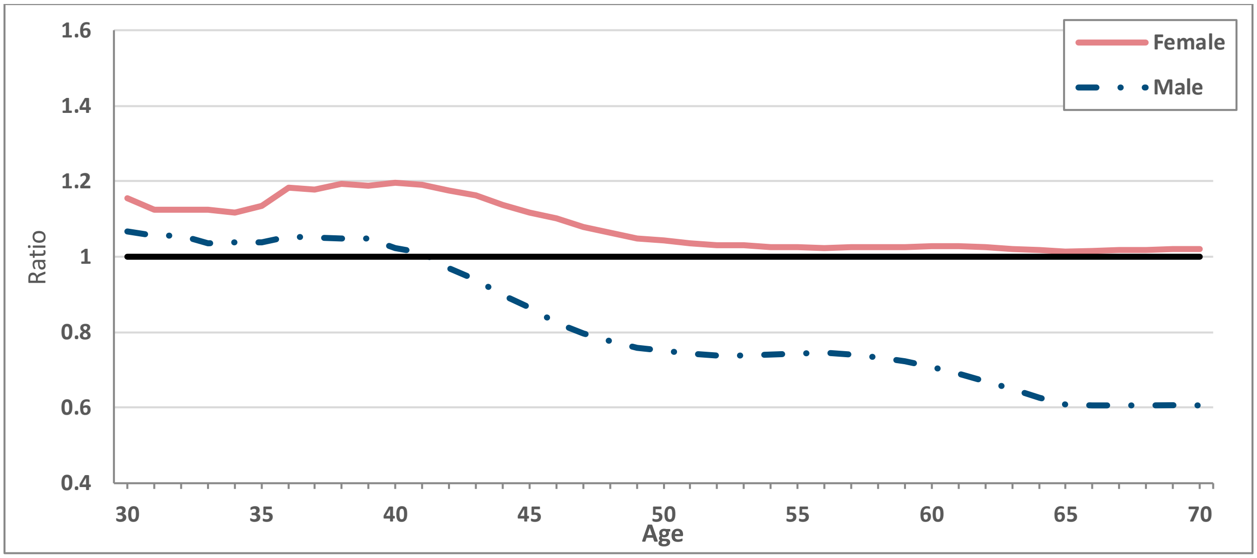
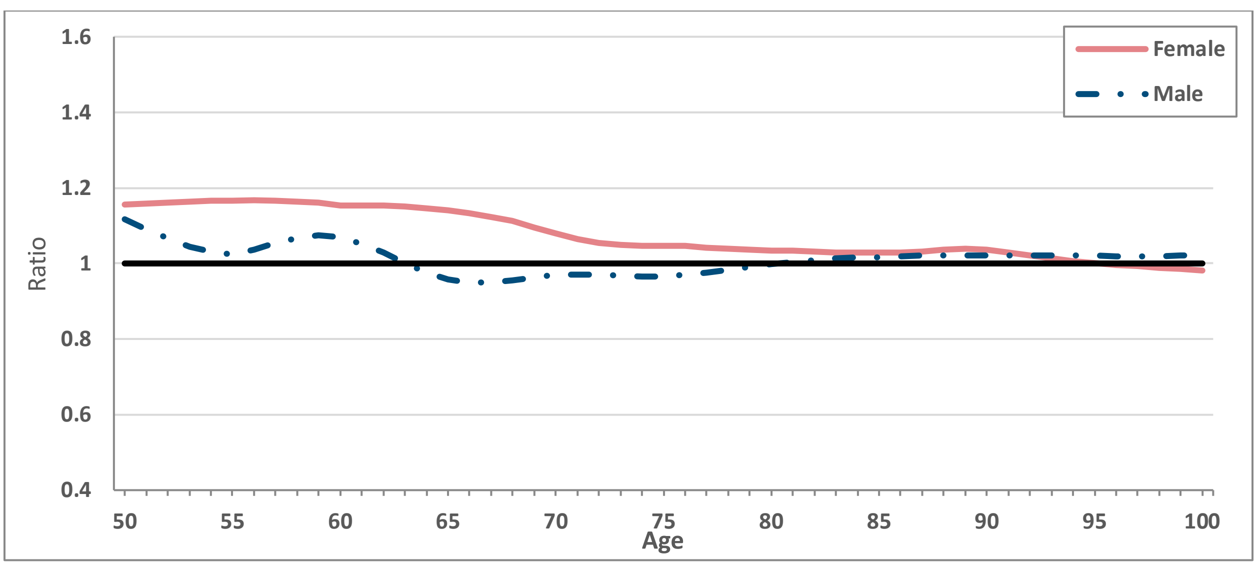


Figure 10.7 compares the projected Pri-2012 Retiree rates for the Blue Collar dataset to the projected RP-2006 Blue Collar Healthy Annuitant rates. For males, rates are very similar between the two tables. For females, rates are generally higher at all ages with the effect being most pronounced prior to age 70.

Figure 10.7

RATIO OF PRI-2012 BLUE COLLAR RETIREE TO RP-2006 BLUE COLLAR RETIREE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



10.7 Comparison of White Collar Rates

Figure 10.8 shows that the projected Pri-2012 Employee rates from the White Collar dataset show a similar but slightly more extreme pattern compared to the total dataset Employee rates. Prior to age 45, the male rates in Pri-2012 are higher, while the female rates track more closely with the prior table. For ages above 60, the male rates are significantly lower than under the prior table.

Figure 10.8

RATIO OF PRI-2012 WHITE COLLAR EMPLOYEE TO RP-2006 WHITE COLLAR EMPLOYEE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018

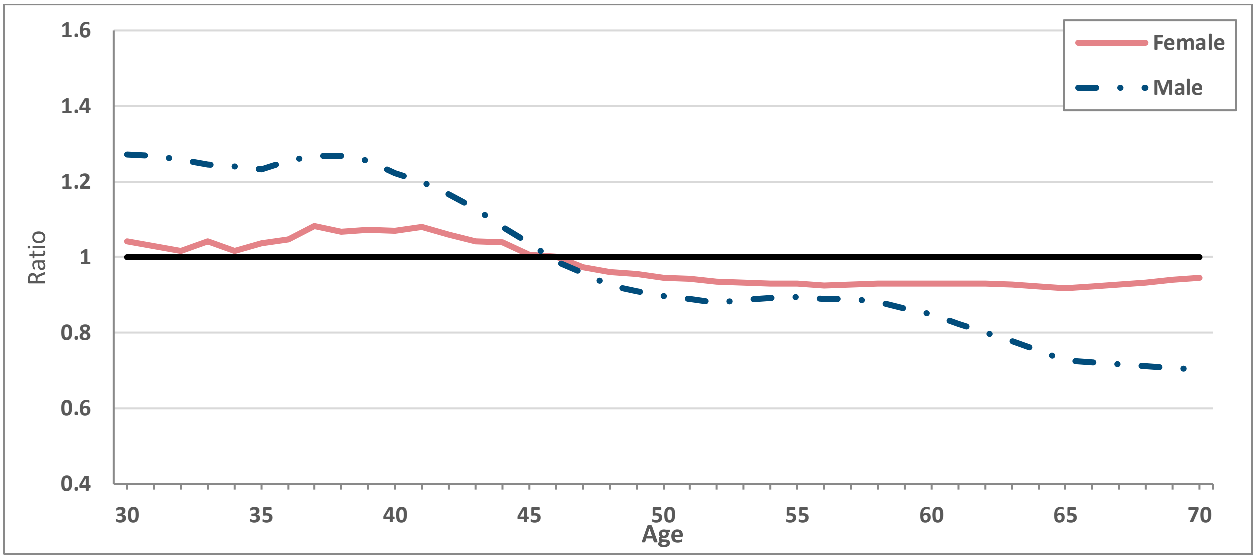
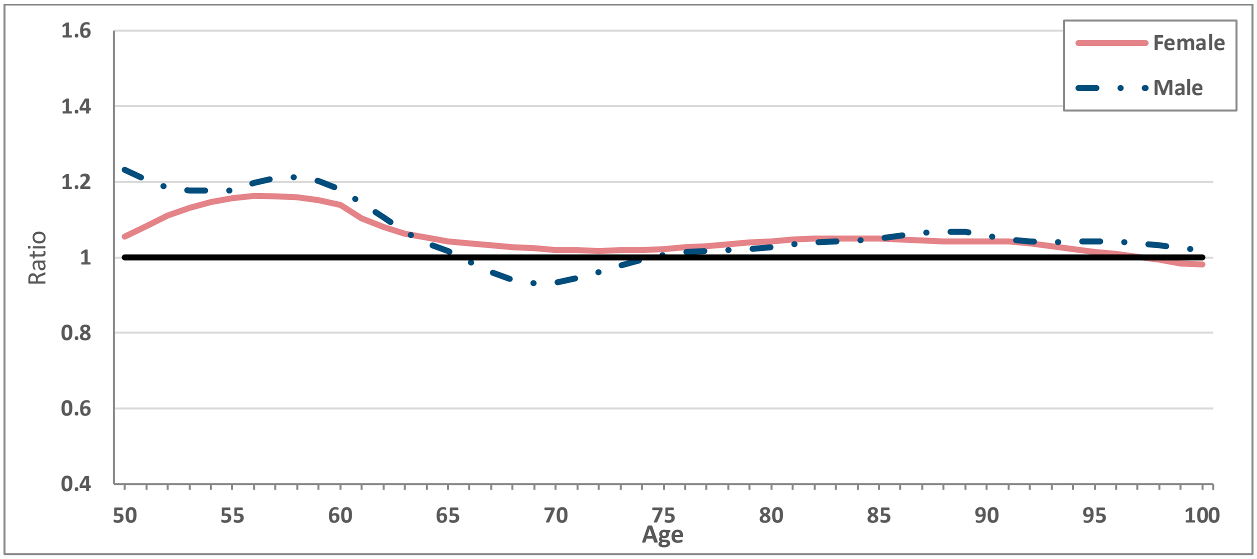


Figure 10.9 shows that the projected Pri-2012 Retiree rates from the White Collar dataset generally track the projected RP-2006 Retiree rates from the White Collar dataset, except for early retirement ages (generally under age 65) where the Pri-2012 rates are higher.

Figure 10.9

RATIO OF PRI-2012 WHITE COLLAR RETIREE TO RP-2006 WHITE COLLAR RETIREE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



10.8 Comparison of Bottom Quartile Rates

Figure 10.10 compares the projected Pri-2012 Employee rates for the Bottom Quartile dataset to the projected RP-2006 Bottom Quartile Employee rates. The female rates track the prior table fairly well for all ages, with rates slightly higher for ages prior to 46. For males, rates under Pri-2012 are significantly higher for employees prior to age 40, then begin to trend toward the rates under the prior table.

Figure 10.10

RATIO OF PRI-2012 BOTTOM QUARTILE EMPLOYEE TO RP-2006 BOTTOM QUARTILE EMPLOYEE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018

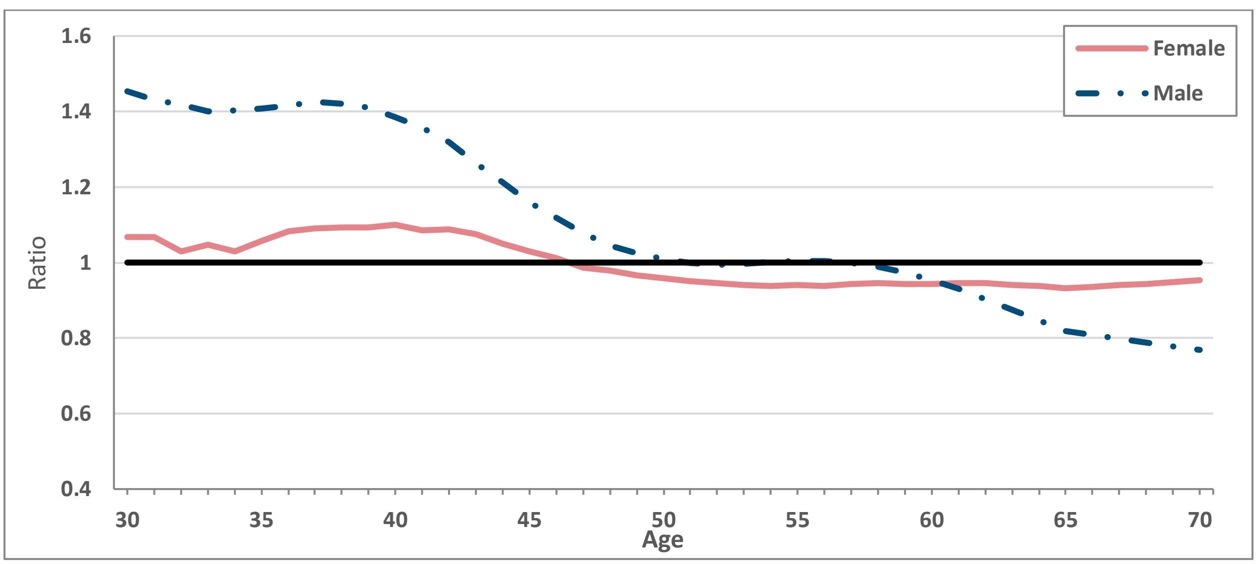
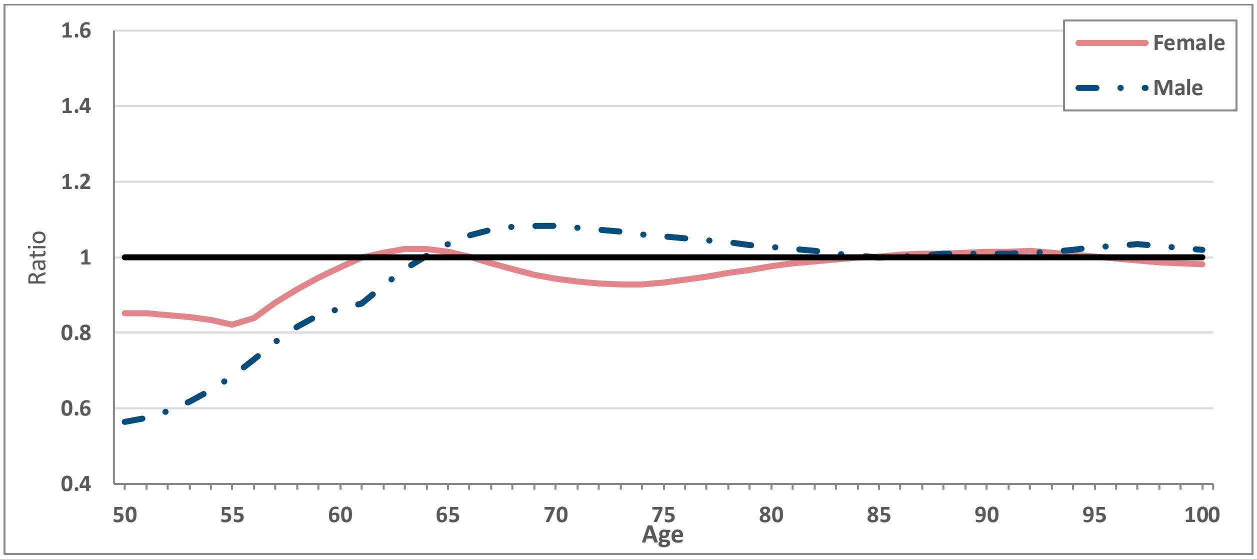


Figure 10.11 compares the projected Pri-2012 Retiree rates for the Bottom Quartile dataset to the projected RP-2006 Bottom Quartile Healthy Annuitant rates. Above age 65, the Pri-2012 mortality rates are similar to the

projected RP-2006 mortality rates for both genders, with male rates slightly higher and female rates slightly lower through age 82. Prior to age 65, both genders exhibit lower rates of mortality under Pri-2012, with the effect more pronounced for males.

Figure 10.11
RATIO OF PRI-2012 BOTTOM QUARTILE RETIREE TO RP-2006 BOTTOM QUARTILE RETIREE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



10.9 Comparison of Top Quartile Rates

Figure 10.12 compares the projected Pri-2012 Employee rates for the Top Quartile dataset to the projected RP-2006 Top Quartile Employee rates. Male rates from Pri-2012 exceed those from RP-2006 significantly until age 65. The female curve tracks the prior table rates more closely but does exhibit higher rates at younger ages prior to age 50.

Figure 10.12
RATIO OF PRI-2012 TOP QUARTILE EMPLOYEE TO RP-2006 TOP QUARTILE EMPLOYEE MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018

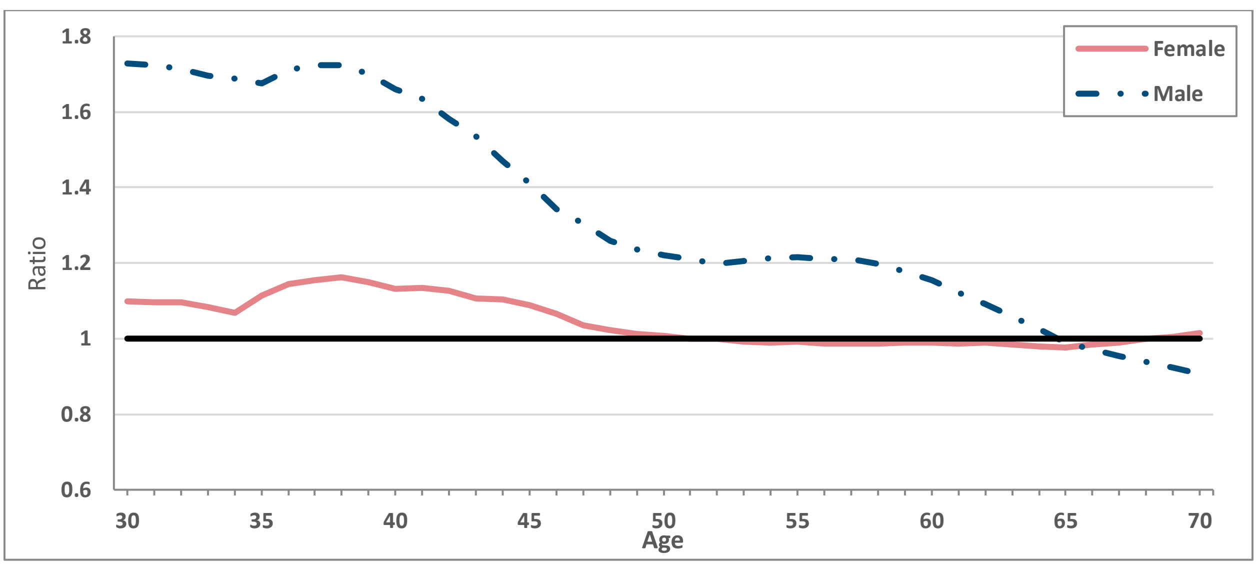
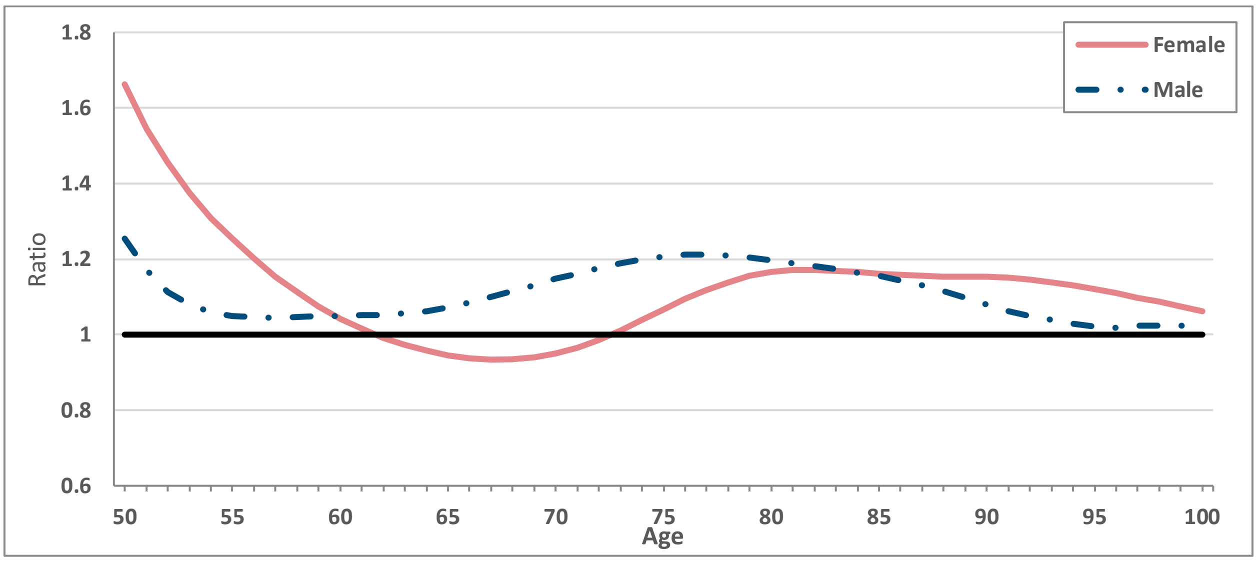


Figure 10.13 compares the projected Pri-2012 Retiree rates for the Top Quartile dataset to the projected RP-2006 Top Quartile Retiree rates. Curves for both genders exhibit similar shapes with Pri-2012 rates higher than RP-2006 at the earliest retirement ages. Differences decline at older ages and increase again after typical normal retirement ages. The male curve tracks the prior table more closely but is uniformly above the old rates until extreme old ages. The female ratios are much higher than the male ratios at the youngest ages, and female projected Pri-2012 rates are higher than the projected RP-2006 rates, except between ages 62 and 72.

As mentioned in subsection 10.1, benefit amounts are generally smaller in the Pri-2012 study than the RP-2006 study, and the income threshold for the Top Quartile has been lowered. A Top Quartile categorization has a less pronounced effect on mortality in the Pri-2012 study than it did for the RP-2006 tables.

Figure 10.13

RATIO OF PRI-2012 TOP QUARTILE RETIREE TO RP-2006 TOP QUARTILE RETIREE
MORTALITY RATES PROJECTED TO 2019 WITH SCALE MP-2018



Section 11: Annuity Comparisons

11.1 Comparison of Annuity Values to Other Published SOA Tables

11.1.1 Basis of Annuity Calculations

Using a discount rate of 4.0%, RPEC calculated the annuity values shown in this section as of January 1, 2019. The mortality rates for both Pri-2012 and RP-2006 were projected generationally from the respective central year of underlying data using Scale MP-2018. RPEC chose the 4.0% rate to be broadly representative of discount rates recently used in the accounting valuations of private-sector retirement plans. Additional annuity comparisons using discount rates of 0% and 6% can be found in Appendix D.

Annuity values indicated to be "deferred-to-62" assume Employee mortality rates are used for ages less than 62, and Annuitant[39] mortality rates are used for ages 62 and older. The Committee calculated all monthly annuity values using the standard approximation to Woolhouse's formula:

$$ {}_{n|}\ddot{a}^{(12)} \approx {}_{n|}\ddot{a}_x - (11/24)\ {}_{n|}E_x $$

11.1.2 Comparisons of Amount-Weighted Deferred-to-62 Annuities for Nondisabled Participants

The Committee developed deferred-to-62 annuity due values for nondisabled members for the total Pri-2012 dataset along with the four primary subsets of the data (Blue Collar, White Collar, Bottom Quartile, Top Quartile). RPEC compared the annuity values for each data subset to those produced by the Pri-2012 Total Dataset mortality rates. In addition, RPEC compared the annuity factors for each set of tables to the corresponding data subsets from RP-2006.

Table 11.1 shows the amount-weighted annuity values developed using the Pri-2012 tables for each dataset. Table 11.2 compares each subset to the Total Dataset by displaying the percentage change in annuity values resulting from moving from Pri-2012 Total Dataset to the corresponding mortality tables for each subpopulation. For females, the White Collar dataset produces the highest annuity factors, while the Blue Collar dataset produces the lowest annuity factors. During the course of the study, the Committee observed that the effect of income quartile was substantially lower for females than for males, and the annuity factors shown support the idea that collar type tends to be a better predictor of mortality for females.

For males, the Bottom Quartile mortality rates generally produce the lowest annuity factors, while White Collar rates generally produce the highest annuity factors, with exceptions for both cases around and/or above age 85. This somewhat stands in contrast to the RP-2006 tables, in which Top Quartile mortality produced the highest annuity factors. Even in the male dataset, where the effects of plan benefit amount appear to be substantially greater than those for females, the data is showing that collar type may be becoming a stronger predictor of mortality than income quartile.

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[39] For RP-2006 annuity value calculations, Healthy Annuitant rates were used with the exception of the annuity factors shown in subsection 11.3, which were based on RP-2006 Disabled Retiree rates. For Pri-2012 annuity value calculations, Retiree rates were used in subsection 11.1, Contingent Survivor rates were used in subsection 11.2, and Disabled Retiree rates were used in subsection 11.3.

Table 11.1

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AS OF JANUARY 1, 2019, PRI-2012 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	3.7443	3.6281	3.8175	3.6639	3.7992
	35	5.4463	5.2679	5.5596	5.3270	5.5288
	45	7.9356	7.6682	8.1092	7.7698	8.0543
	55	11.6119	11.2276	11.8737	11.4131	11.7673
	65	14.2767	13.8433	14.6208	14.1478	14.4279
	75	10.2859	10.0268	10.6620	10.2195	10.4278
	85	6.2450	6.0971	6.4424	6.2249	6.3364
	95	3.3856	3.3698	3.4059	3.3856	3.3903
Males	25	3.5116	3.3958	3.6700	3.2640	3.6310
	35	5.1095	4.9353	5.3503	4.7431	5.2878
	45	7.4480	7.1892	7.8102	6.9170	7.7100
	55	10.9073	10.5322	11.4416	10.1709	11.2805
	65	13.4072	12.9471	14.0645	12.6146	13.8647
	75	9.4920	9.1116	9.9790	8.9885	9.9471
	85	5.5376	5.3416	5.7730	5.3771	5.8127
	95	2.9144	2.8897	2.9492	2.9030	2.9482

Table 11.2

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AS OF JANUARY 1, 2019, PRI-2012 SUBPOPULATIONS TO PRI-2012 TOTAL DATASET

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	N/A	−3.1%	2.0%	−2.1%	1.5%
	35	N/A	−3.3%	2.1%	−2.2%	1.5%
	45	N/A	−3.4%	2.2%	−2.1%	1.5%
	55	N/A	−3.3%	2.3%	−1.7%	1.3%
	65	N/A	−3.0%	2.4%	−0.9%	1.1%
	75	N/A	−2.5%	3.7%	−0.6%	1.4%
	85	N/A	−2.4%	3.2%	−0.3%	1.5%
	95	N/A	−0.5%	0.6%	0.0%	0.1%
Males	25	N/A	−3.3%	4.5%	−7.1%	3.4%
	35	N/A	−3.4%	4.7%	−7.2%	3.5%
	45	N/A	−3.5%	4.9%	−7.1%	3.5%
	55	N/A	−3.4%	4.9%	−6.8%	3.4%
	65	N/A	−3.4%	4.9%	−5.9%	3.4%
	75	N/A	−4.0%	5.1%	−5.3%	4.8%
	85	N/A	−3.5%	4.3%	−2.9%	5.0%
	95	N/A	−0.8%	1.2%	−0.4%	1.2%

Table 11.3 contains deferred-to-62 annuities for the analogous[40] RP-2006 tables, while Table 11.4 shows the impact of moving from an RP-2006 table to the corresponding Pri-2012 table. For females, the Total Dataset comparison shows values between 0.0% and 0.5% for ages under 65 and values between −1.5% and 1.0% for participants 65 and older. For males, the Pri-2012 tables produce higher annuity factors than RP-2006 at ages 65 and younger but lower annuity factors at ages over 65, ranging from −3.0% through 0.0%.

For both males and females, the Pri-2012 Top Quartile tables produce substantially lower annuity factors than the corresponding RP-2006 tables, consistent with the above observations that plan benefit amount has declined as a mortality predictor compared to the RP-2006 study. The Pri-2012 White Collar tables produce mostly lower annuity factors than their RP-2006 counterparts, while the Blue Collar comparisons show mixed results. For Blue Collar females, Pri-2012 annuity factors are lower than those from RP-2006 except at the oldest ages, while males show higher annuity factors under Pri-2012 except at the oldest ages.

Table 11.3

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AS OF JANUARY 1, 2019,
RP-2006 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	3.7339	3.6738	3.8354	3.6490	3.8498
	35	5.4293	5.3371	5.5864	5.3016	5.6030
	45	7.9084	7.7694	8.1484	7.7250	8.1610
	55	11.5829	11.3808	11.9399	11.3488	11.9240
	65	14.2766	14.0233	14.7243	14.0601	14.6781
	75	10.4033	10.1430	10.7922	10.1585	10.9169
	85	6.3317	6.1783	6.5603	6.2491	6.8036
	95	3.3619	3.3471	3.4034	3.3619	3.6274
Males	25	3.4910	3.3500	3.6815	3.3104	3.7403
	35	5.0700	4.8591	5.3601	4.7977	5.4455
	45	7.3771	7.0671	7.8132	6.9723	7.9329
	55	10.8241	10.3927	11.4542	10.2496	11.6019
	65	13.3901	12.8874	14.1047	12.7827	14.3084
	75	9.5830	9.1154	10.1142	9.0825	10.4421
	85	5.6775	5.4093	5.9476	5.4093	6.1018
	95	2.9923	2.9369	3.0361	2.9716	2.9988

[40] While analogous in terms of the socioeconomic indicators that determine the subgroups, the comparison is not completely apples to apples, because the Pri-2012 Annuitant mortality rates are for Retirees only, whereas the RP-2006 Healthy Annuitant rates combine experience for Retirees and Contingent Survivors.

Table 11.4

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AS OF JANUARY 1, 2019, PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	0.3%	−1.2%	−0.5%	0.4%	−1.3%
	35	0.3%	−1.3%	−0.5%	0.5%	−1.3%
	45	0.3%	−1.3%	−0.5%	0.6%	−1.3%
	55	0.3%	−1.3%	−0.6%	0.6%	−1.3%
	65	0.0%	−1.3%	−0.7%	0.6%	−1.7%
	75	−1.1%	−1.1%	−1.2%	0.6%	−4.5%
	85	−1.4%	−1.3%	−1.8%	−0.4%	−6.9%
	95	0.7%	0.7%	0.1%	0.7%	−6.5%
Males	25	0.6%	1.4%	−0.3%	−1.4%	−2.9%
	35	0.8%	1.6%	−0.2%	−1.1%	−2.9%
	45	1.0%	1.7%	0.0%	−0.8%	−2.8%
	55	0.8%	1.3%	−0.1%	−0.8%	−2.8%
	65	0.1%	0.5%	−0.3%	−1.3%	−3.1%
	75	−0.9%	0.0%	−1.3%	−1.0%	−4.7%
	85	−2.5%	−1.3%	−2.9%	−0.6%	−4.7%
	95	−2.6%	−1.6%	−2.9%	−2.3%	−1.7%

11.2 Contingent Survivor Annuity Values

As discussed previously, the Pri-2012 annuity factors in subsection 11.1 were developed using Employee mortality up until age 62 and Retiree mortality at ages 62 and above. The RP-2006 tables combined Retiree and Contingent Survivor experience into a "Healthy Annuitant" table. This means that for ages 62 and up, the above exhibits effectively compare Retiree-only mortality from the Pri-2012 tables to a blend of Retiree and Contingent Survivor mortality from the RP-2006 tables.

The Pri-2012 tables include separate sets of mortality rates for Retirees and Contingent Survivors. Table 11.5 shows comparisons of immediate annuity values developed using these separate Retiree and Contingent Survivor tables to those developed using the RP-2006 Healthy Annuitant rates. The Contingent Survivor annuity factors are generally substantially lower than those shown for either of the other two bases, especially for males.

Table 11.5

COMPARISON OF MONTHLY IMMEDIATE ANNUITY DUE VALUES AS OF JANUARY 1, 2019,
PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012 CONTINGENT SURVIVOR

					Percentage Change of Moving from RP-2006 Healthy Annuitant to:	
	Age	RP-2006 Healthy Annuitant	Pri-2012 Retiree	Pri-2012 Contingent Survivor	Pri-2012 Retiree	Pri-2012 Contingent Survivor
Females	55	17.4111	17.3922	16.4109	−0.1%	−5.7%
	65	14.2766	14.2767	13.5868	0.0%	−4.8%
	75	10.4033	10.2859	10.0320	−1.1%	−3.6%
	85	6.3317	6.2450	6.2343	−1.4%	−1.5%
	95	3.3619	3.3856	3.3856	0.7%	0.7%
Males	55	16.5900	16.5610	14.2094	−0.2%	−14.3%
	65	13.3901	13.4072	11.5732	0.1%	−13.6%
	75	9.5830	9.4920	8.5559	−0.9%	−10.7%
	85	5.6775	5.5376	5.3308	−2.5%	−6.1%
	95	2.9923	2.9144	2.9030	−2.6%	−3.0%

11.3 Disabled Retiree Annuity Values

Table 11.6 shows comparisons of Disabled Retiree mortality under the Pri-2012 and RP-2006 tables as of January 1, 2019. As can be seen from the percentage changes shown, the effects of moving from RP-2006 to Pri-2012 vary considerably by age and gender.

For both males and females aged 85, the Pri-2012 Disabled Retiree tables produce lower annuity factors than the corresponding RP-2006 Disabled Retiree tables. However, at age 95, the comparison is reversed, and the Pri-2012 factors become higher. This is partially due to a methodological change described in subsection 7.2. RPEC made the decision to create a single set of gender-specific mortality rates at ages 100 and above for all annuitants, including Disabled Retirees. In the RP-2006 tables, this convergence occurs at an older age, and Disabled Retiree mortality rates are higher than Healthy Annuitant rates until age 105. Figure 10.5 displays a comparison between the two sets of rates and shows that, for each gender, the Pri-2012 rates become lower than the corresponding RP-2006 rates starting around age 95.

Table 11.6

COMPARISON OF MONTHLY IMMEDIATE ANNUITY DUE VALUES AS OF JANUARY 1, 2019,
PERCENTAGE CHANGE OF MOVING FROM RP-2006 DISABLED RETIREE TO PRI-2012 DISABLED RETIREE

	Age	RP-2006 Disabled	Pri-2012 Disabled	Percentage Change
Females	35	18.9380	18.4448	−2.6%
	45	16.9025	16.8032	−0.6%
	55	14.5776	14.8108	1.6%
	65	11.9720	12.2307	2.2%
	75	8.6375	8.8437	2.4%
	85	5.4652	5.3862	−1.4%
	95	3.2034	3.2437	1.3%
Males	35	16.7799	16.4779	−1.8%
	45	14.9868	15.2661	1.9%
	55	12.9981	13.4198	3.2%
	65	10.5613	10.7618	1.9%
	75	7.7155	7.5499	−2.1%
	85	4.7744	4.5444	−4.8%
	95	2.7701	2.8010	1.1%

Section 12: Application of Tables

12.1 General Use

The Pri-2012 tables contain one-year mortality probabilities as of January 1, 2012. Consistent with the RP-2006 tables, these probabilities are applicable on an age-nearest-birthday basis. The Committee believes that for most pension-related actuarial applications, the Pri-2012 mortality rates (including those for Disabled Retirees) should be projected beyond 2012 with an appropriate mortality improvement scale and that generational projection should be considered as an approach to projecting future mortality rates. In all cases, the selection of mortality assumptions must satisfy the applicable requirements of ASOP 35.

12.2 Selecting Appropriate Benchmark Mortality Tables

12.2.1 General

The potential uses of the Pri-2012 tables as published depend to a certain extent on the size and credibility of the underlying population to which the tables would be applied. For example, sponsors that have performed a recent mortality experience study on a large retirement plan may compare those results to one or more of the Pri-2012 tables or blends and adjustments thereof, taking collar and pay/benefit amount into consideration. Practitioners working with covered populations that are not large enough to support fully credible mortality results may use suitably selected Pri-2012 tables as benchmark starting points; i.e., tables that in conjunction with a recent mortality experience study could be used with appropriate adjustments or as reference tables for credibility-weighted blended mortality rates.

As detailed in Section 4, the multivariate analyses performed on nondisabled participants revealed that collar type and income quartile were both statistically significant covariates for virtually all status groups. Therefore, consistent with the principles of ASOP 35, actuaries are encouraged to take such characteristics of the covered population into consideration when selecting appropriate benchmark mortality tables. Accordingly, given the high statistical significance of collar and income as predictors of mortality, the Blue / White Collar tables or the Top / Bottom Quartile tables developed in this report should be considered as an alternative to the corresponding “total population” table, whenever appropriate.

12.2.2 Use of Collar Tables

As mentioned in subsection 2.3.2, similar to the RP-2014 study, the data request for this study asked for a designation of a collar type for each plan. If at least 70 percent of the plan’s participants were <u>either</u> hourly or union, the plan was designated as Blue Collar. If at least 70 percent of the plan’s participants were <u>both</u> salaried and nonunion, the plan was designated as White Collar. All other plans were designated as Unknown Collar.

However, unlike in the RP-2014 study, contributors were also asked for collar type for individual participants. This participant-level information was incorporated as well. Therefore, the White Collar dataset for this study consists of both participants specifically identified as White Collar and participants in White Collar plans (per the above 70 percent threshold) who were not specifically identified as Blue Collar participants. Similarly, the Blue Collar dataset for this study consists of both participants specifically identified as Blue Collar and participants in Blue Collar plans who were not specifically identified as White Collar participants.

For plans whose covered populations meet either of these criteria, the corresponding collar-specific table may more accurately model the mortality patterns of the covered population than the “total population” table. For plans that do not meet these criteria, one option is to use the “total population” table. Another alternative would be to segment the population into Blue Collar and White Collar and apply the corresponding tables to those two subpopulations. A third alternative would be to apply a blended Blue/White Collar table to the population, where the proportions used in the blending are based upon the proportions of Blue Collar and White Collar data in the underlying population. If amount-weighted tables are used, as is the case with most pension plans, then amount-weighted proportions should generally be used in the blending.

12.2.3 Use of Income Quartile Tables

Consistent with the RP-2006 tables, the Committee developed male and female mortality tables associated with segments of the participant population in the highest income quartile (Top Quartile table) and the lowest income quartile (Bottom Quartile table). Income was defined as salary or pay rate for Employees and benefit amount for Annuitants. As discussed in Section 4, income was found to be a significant predictor of mortality.

Subsection 3.8 details the income thresholds for the Bottom Quartile and Top Quartile datasets for both the Pri-2012 study and the RP-2006 tables. In most cases, these breakpoints are lower for the Pri-2012 study, indicating generally smaller income amounts provided for this study. As a result, there may be cases where the Top or Bottom Quartile tables from the RP-2014 study closely fit the income levels of a particular plan population, but the Pri-2012 version of the tables do not (or vice-versa). Figures 12.1 and 12.2 display a comparison of the Pri-2012 and RP-2006 thresholds for Employees and Retirees. Each rectangular bar ranges from the upper limit of the Bottom Quartile (25th percentile) to the lower limit of the Top Quartile (75th percentile), split by the population median income in the middle. For example, female Employees with a salary greater than $68,070 are in the Top Quartile for the Pri-2012 study.

Figure 12.1

COMPARISON OF PRI-2012 AND RP-2006 ANNUAL INCOME QUARTILE BREAKPOINTS FOR EMPLOYEES
25TH, 50TH and 75TH PERCENTILES

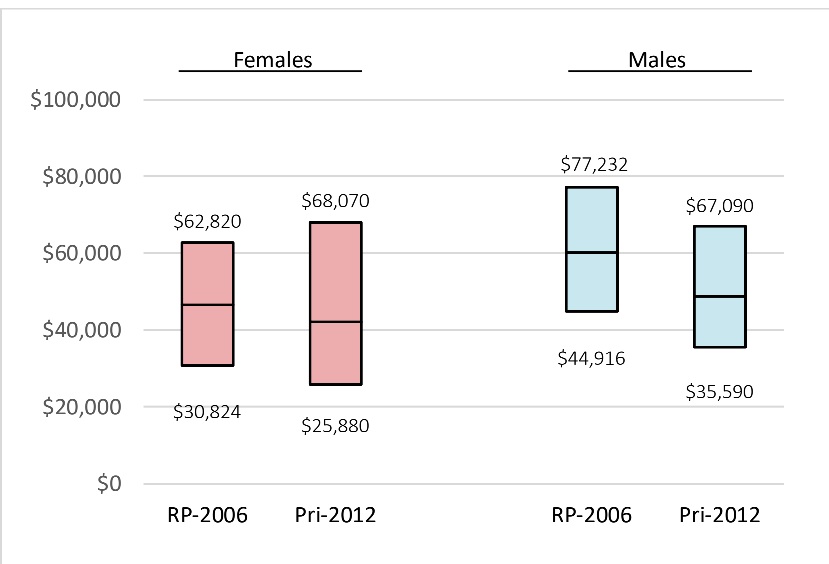
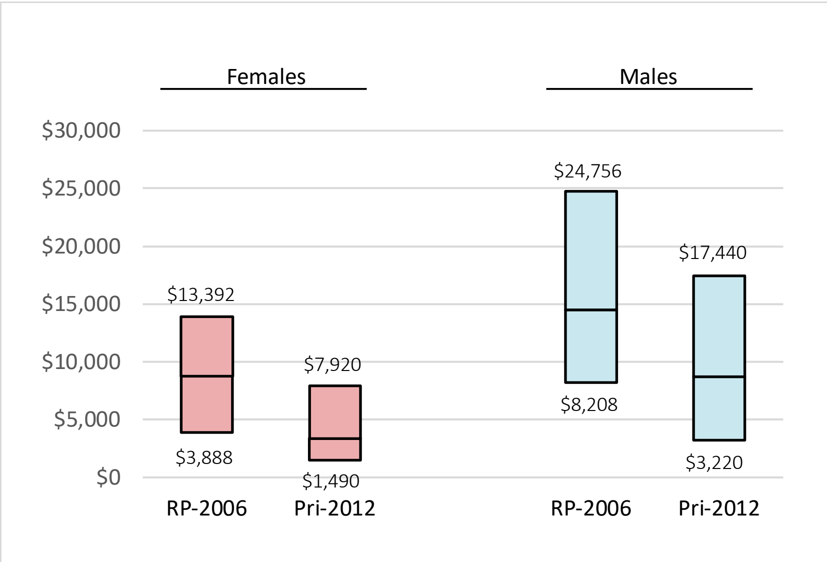


Figure 12.2

COMPARISON OF PRI-2012 AND RP-2006 ANNUAL INCOME QUARTILE BREAKPOINTS FOR RETIREES
25TH, 50TH and 75TH PERCENTILES



Actuaries should also be aware of some additional limitations with these income tables. Specifically, for Annuitants, the Committee did not adjust for the following factors:

- Form of benefit payment;
- Possible cost-of-living adjustments in the benefits;
- Generational issues (i.e., participants retiring more recently will tend to have higher benefit amounts than those who retired decades ago).

Although RPEC did not collect information with respect to each plan's ongoing benefit accrual status, it seems plausible that the Pri-2012 dataset includes a larger concentration of "frozen" defined benefit plans than did the RP-2006 dataset. Such an increase in frozen plan data would tend to lessen the correlation between benefit level and socioeconomic status. Given the well-established (inverse) relationship between socioeconomic status and underlying mortality rates, a higher concentration of frozen plans would likely diminish the overall effectiveness of selecting a Pri-2012 mortality table based solely on retirement benefit amounts.

Unlike the situation with the RP-2006 tables, the Pri-2012 White Collar rates are generally lower than their Top Quartile counterparts[41]. As noted elsewhere in this report, much of this change in relative mortality values is likely caused by a change in the data comprising the Top Quartile rather than an actual change in underlying mortality rates. Therefore, actuaries who are currently using RP-2006 Top Quartile as their base mortality benchmark may want to consider options other than an automatic switch to Pri-2012 Top Quartile tables. In some cases, Pri-2012 White Collar tables might be more appropriate than Pri-2012 Top Quartile tables for plans covering highly

[41] See Tables 11.1 and 11.2 for a comparison of the two sets of resulting deferred annuity values.

compensated individuals. Furthermore, mortality for relatively select groups of high income participants could be significantly lower than Pri-2012 Top Quartile or Pri-2012 White Collar.

12.3 Comments on Retiree and Contingent Survivor Tables

The RP-2006 tables included Healthy Annuitant tables developed from the combined experience of nondisabled primary retirees and surviving beneficiaries.[42] Because the multivariate analysis indicated that differences in mortality patterns between Retirees and Contingent Survivors were statistically significant (see subsection 4.4.1), separate Retiree and Contingent Survivor tables were developed for the Pri-2012 study.

When developing the data submission package described in subsection 3.2, the Committee considered requesting mortality experience for beneficiaries prior to the primary plan participant's death. However, past efforts at collecting this information were unsuccessful, and RPEC members agreed that pension administration systems do not reliably maintain such data. Therefore, RPEC constructed the Pri-2012 Contingent Survivor tables using experience specifically from designated beneficiaries who had survived deceased plan members, with exposure starting upon the primary retiree's death. These rates are intended to be applicable to current Contingent Survivors within plan populations. Refer to subsection 12.4 for possible application of these tables while the primary Retiree is still alive for purposes of valuing joint-and-survivor annuities.

12.4 Comments on the Calculation of Joint-and-Survivor Annuity Values

When using the Pri-2012 tables, RPEC anticipates that practitioners will consider applying the Pri-2012 Retiree tables to Retirees currently receiving payments (groups A and B, below). Furthermore, the Committee believes practitioners will consider applying the Contingent Survivor tables to beneficiaries who are currently receiving payments after the death of the primary Retiree (group D, below). The calculation of joint-and-survivor annuity values could theoretically involve separate mortality tables applied to the following groups:

A. Primary Retirees while the beneficiary is alive.

B. Primary Retirees when the beneficiary is no longer alive.

C. Beneficiaries while the primary Retiree is alive.

D. Beneficiaries when the primary Retiree is no longer alive.

However, few plan sponsors accurately monitor beneficiary survivorship while the primary Retiree is alive. Hence, the Committee did not request data for the construction of separate mortality tables based on experience for primary Retirees on a "before-and-after-beneficiary-death" basis (separately for groups A and B, above) and for beneficiaries prior to the primary retiree's death (group C, above).

RPEC used the combined experience of the participants in groups A and B above to develop the Pri-2012 Retiree mortality tables and the experience of participants in group D above to develop the Pri-2012 Contingent Survivor mortality tables. The absence of reliable mortality experience specifically for the participants in group C necessitates the selection of some approximating methodology for determining the beneficiary mortality when calculating joint-and-survivor annuities in the Pri-2012 environment. RPEC has considered several possibilities for this, including but

[42] These two groups were denoted as Healthy Retirees and Beneficiaries, respectively, in the RP-2014 report.

not limited to the three approaches discussed below. The Committee does not endorse any of these three methods in particular, and other approaches could also be reasonable.

1. Approach 1 would be to assume the same mortality basis as the retiree[43] for both groups C and D, except using the rates applicable to the beneficiary's gender. It should be noted that Pri-2012 Retiree experience includes many participants with joint-and-survivor annuities and presumably additional participants with spouses or partners not designated under joint-and-survivor options. Over the years, a percentage of these Retirees will lose a spouse or partner, and any grieving widow(er) effect would be reflected in the Retiree experience. On average, the Retiree rates may contain a reasonable provision for this impact.

2. Approach 2 would use the retiree basis (with beneficiary gender, as in Approach 1 above) while the Retiree is alive (group C) but utilize Contingent Survivor mortality rates after the Retiree's death (group D). The rationale for this approach would be that the portions of the present value calculation that specifically address the beneficiary's experience after the death of the primary annuitant may be appropriately modeled by the Contingent Survivor rates, while other portions may reflect broader retiree experience with similar characteristics. This approach, in which the applicable beneficiary mortality rates (Retiree or Contingent Survivor) depend on whether the primary Retiree is alive, may not be easy to implement in the typical valuation software in use today.

3. Approach 3 would be to assume Contingent Survivor mortality rates for the beneficiary both before and after the original participant's death (for both groups C and D). It is possible that the Contingent Survivor mortality experience in Pri-2012 shows higher mortality due to a number of factors correlated with beneficiary status, apart from a grieving widow(er) effect. In that case, Contingent Survivor mortality may be appropriate both before and after the original participant's death.

Comparisons of joint-and-100%-survivor annuity values calculated using each of these approaches to those developed using RP-2006 Healthy Annuitant rates can be found in Appendix D.6. Although Approach 2 values fall between the corresponding Approach 1 and Approach 3 values, the magnitude and direction of the differences among the three approaches will vary by collar type, income quartile and the joint annuitants' ages.

Per ASOP 35, the selection of mortality assumptions, including the development of beneficiary mortality rates, should reflect the actuary's judgement, consider the intended purpose, and incorporate actual plan experience to the extent it is deemed credible and predictive under Actuarial Standard of Practice No. 25, *Credibility Procedures* (ASOP 25) (ASB 2013).

12.5 Comments on Disabled Retiree Tables

Developing reliable mortality rates for Disabled Retirees has always presented special challenges to those tasked with the construction of mortality tables for retirement plans. These challenges include the following:

- Issues with the accurate tracking of those who initially retire under a disability retirement provision but are automatically reclassified as Retirees upon attainment of some fixed age. See the discussion of unclear disability status in subsection 3.4, for example.

[43] This is not meant to necessarily suggest one of the Pri-2012 Retiree tables, but whichever mortality assumption is in use for the plan's retirees. For example, this could be developed from a suitable blend of Retiree and Contingent Survivor experience, if applicable; see subsection 12.6.

- The more subjective nature of disability retirement eligibility criteria compared to other (nondisabled) retirement provisions. This includes not only variations in the definition of disability but also the loose correlation between disability occurrence and economic conditions.

Some plan sponsors do not distinguish healthy retirees from disabled retirees, and some others may not distinguish healthy retirees from disabled retirees past some fixed age (as noted in the first bullet above). For instance, this is common for retiree medical plans for those past age 65. It is possible that using the Pri-2012 Retiree tables for such a population could understate mortality rates because Disabled Retiree experience, whenever identified, was excluded in the development of the Pri-2012 Retiree tables.

An actuary could estimate and adjust for such an understatement of mortality by incorporating actual plan experience to the extent it is deemed credible per ASOP 25. For plans not large enough to have credible experience, another option would be to blend the Pri-2012 Retiree and Disabled Retiree tables together and apply the blended table to participants with unknown disability status. This can present challenges because the appropriate blending weights specific to a plan's population are likely difficult (if not impossible) to determine given the aforementioned data limitations. In the absence of credible plan-specific experience or information from which to develop such blending weights, an actuary may consider using the relative concentration of Retirees and Disabled Retirees by age and gender in the Pri-2012 dataset. Appendix B contains tables showing the amount of exposures included in the Pri-2012 dataset by age group, gender and status.

In accordance with ASOP 35, actuaries should use professional judgment when applying the Disabled Retiree mortality tables developed in this report, especially when the plan's disability retirement provisions—particularly the eligibility criteria—are known to be particularly strict or broad.

12.6 Comments on Nondisabled Annuitant Tables

For the Pri-2012 study, the Committee decided to track mortality experience of Retirees and Contingent Survivors separately with the intent of replacing the RP-2006 Healthy Annuitant tables with these separate tables. Using these separate tables for Retirees and Contingent Survivors would likely reflect these participants' mortality patterns more accurately than using a single combined table.

If the actuary has a need for a single table, for instance due to actuarial system or coding limitations, then a blended table could be produced from the Retiree and Contingent Survivor tables by blending the two based upon the relative weights of the target covered population. For example, the Committee produced the Pri-2012 Nondisabled Annuitant tables, primarily for purposes of comparison to the RP-2006 Healthy Annuitant tables. Those choosing to use the Pri-2012 Nondisabled Annuitant tables for nonillustrative purposes should be aware of their limitations, which include the following:

- These tables were constructed as an exposure-weighted blend of the final Retiree and Contingent Survivor tables by age and gender. Another method would be to combine the raw experience of the Retirees and Contingent Survivors and graduate the resulting mortality rates. While this would produce slightly different tables than the Nondisabled Annuitant tables that were developed, the Committee believes the Nondisabled Annuitant table was sufficiently accurate, given that its primary purpose was comparison to a past study.

- Use of the Nondisabled Annuitant tables implicitly assumes the same concentration of Contingent Survivors as in the study data. To the extent such concentration is different for an actuary's target plan population, use of the separate Retiree and Contingent Survivor tables would be more appropriate for estimating the mortality patterns of the target plan population than the Nondisabled Annuitant tables.

12.7 Amount- and Headcount-Weighted Tables

The reason for using a weighted version of a mortality table—either amount-weighted or headcount-weighted—is to obtain the most appropriate result for the particular application at hand. For the measurement of most pension obligations, tables weighted by amount (salary for Employees and benefit amount for Annuitants) generally produce the most appropriate results. On the other hand, headcount-weighted tables may be more appropriate for applications such as the measurement of obligations for retirement programs with benefit structures less directly correlated with income, such as many retiree medical programs.

Consequently, this report includes both amount- and headcount-weighted versions of each of the Pri-2012 mortality tables. Per ASOP 35, the actuary should select a mortality assumption that is appropriate for the purpose of the measurement. Therefore, it would not necessarily be inappropriate—or inconsistent—to use amount-weighted tables to measure pension obligations and the corresponding headcount-weighted tables to measure most postretirement medical obligations, even when the two covered populations are identical.

Section 13: Observations and Other Considerations

13.1 Data Submitted with Unknown Collar Type

The Pri-2012 study included a significant amount of data designated as either Mixed or Unknown Collar. There were several ways data could be reported under this category. An entire plan could be reported as Mixed (the participant composition did not satisfy the criteria for Blue Collar or White Collar designations) or Unknown (the submitter did not know). In other cases, the submitter identified specific participants as Blue Collar or White Collar; within those plan records, there could be participants for whom the collar was unknown. All such census records that could not be labeled as Blue Collar or White Collar were considered in the analyses as having Unknown Collar. The Unknown Collar group therefore also includes participants in Mixed Collar plans that did not have participant-specific collar identifiers.

Data of Unknown Collar represents a significantly higher percentage of data in this study than it did in the RP-2006 dataset. As noted previously, mortality for Unknown Collar data in the Pri-2012 study was closer to White Collar mortality than Blue Collar mortality. However, that could be partly due to the generally lower income levels—as illustrated in Figures 12.1 and 12.2—that could lead to White Collar (and Top Quartile) mortality less differentiated from aggregate mortality than was the case in the RP-2006 tables. This seems to be borne out in the tables of annuity values shown previously.

This leaves open the question of how an actuary may select or create a relevant mortality assumption from the Pri-2012 rate sets. RPEC would expect that, in general, the Blue Collar rates would be appropriate as benchmark tables for a plan population that satisfies the criteria for Blue Collar; and similarly, the White Collar rates would, in general, be appropriate as benchmark tables for a plan population that satisfies the criteria for White Collar. Subsection 12.2.2 describes some potential alternatives for plans with a mix of participants that meets neither the Blue Collar or White Collar criteria.

In the case of a plan with truly unknown collar information, the actuary could use the aggregate rate sets (amount basis or headcount basis as appropriate) by gender and status for benchmarking purposes. In all cases, the actuary would likely want to consider any credible plan-specific experience, and its degree of credibility, for blending with benchmark rates selected or created from the Pri-2012 tables.

13.2 Comments on “Bump” in Young Employee Rates

Some Employee rates show a decline in mortality rates with advancing age at some point between the ages of 20 and 30. This “bump” in young Employee rates is basically inherited from the 2015 VBT tables used for development of Pri-2012 rates at ages below 35. These characteristics may or may not be present in Employee populations. There is so little mortality at young ages that this study’s data could not be used to attribute a specific shape for mortality rates. However, such rates have an extremely small impact on pension liabilities and only for the youngest Employees.

13.3 Tabulation of Exposures and Deaths

Exposures and deaths were tabulated using the actuarial method on an age-last-birthday basis. For example, on a headcount-weighted basis, a retiree would have been credited with one year of age 70 exposure for the period of time between the ages of 70.0 and 71.0 and would have generated one death if the individual died after attaining age 70.0 but before attaining age 71.0. These tabulation rules, in conjunction with the study’s central year, produced raw one-year mortality probabilities as of January 1, 2012.

Notwithstanding the age-last-birthday tabulation rules described above, the Pri-2012 rates have been specifically developed to be applied on an age-nearest-birthday basis. Consider, for example, a retiree exactly age 69.9 as of a measurement date. It is more appropriate to apply the age 70 rate to this retiree, since 90% of the first measurement year occurs after the retiree has attained age 70 on an age-last-birthday basis. Since the typical covered population tends to have birthdays close to being uniformly distributed throughout the calendar year, applying the Pri-2012 rates based on age-nearest-birthday as of the measurement date would generally produce the most reliable results.

13.4 Unused Data Elements

RPEC made an attempt to collect information regarding each plan's definition of disability (Social Security, own occupation, any occupation, split definition, no disability provision in plan, other) for benefit purposes. Plans sometimes indicated multiple definitions over different time periods or participant groups. Potential distinctions were further clouded by the possibility of the submitter not 100% maintaining disabled status after certain ages (e.g. 65). Therefore, the Committee was not able to analyze or utilize this information effectively.

The Committee also requested the monthly accrued benefit as of each census date for Employees. The purpose of trying to collect this information was to use it as a potential alternative to salary for amount-weighting the final mortality tables. It was indicated as an optional field in the data request, and submitters were not able to provide this information for the vast majority of plans. Therefore, monthly accrued benefit was not used in developing the Pri-2012 mortality tables.

13.5 Comparison to Pub-2010 Tables

The SOA published the Pub-2010 Public Retirement Plans Mortality Tables in January 2019. The Pub-2010 study included separate sets of mortality tables for three different job categories: Teachers, Public Safety and General plan members. The projected[44] total population Pri-2012 mortality rates for Employees and Retirees are larger than the corresponding rates for each of three projected Pub-2010 job-category tables.

Comparisons of Pri-2012 and Pub-2010 deferred-to-62 annuity values can be found in Appendix D.5. Those comparisons show that the White Collar versions of the Pri-2012 tables tend to produce annuity values closer to the Pub-2010 annuity values, especially for the General job category. The Pub-2010 deferred annuity values for Teachers, however, are considerably greater than even the corresponding Pri-2012 White Collar values.

13.6 Age-65 Life Expectancy Comparison

Table 13.1 presents a comparison of 2019 complete cohort life expectancy values at age 65. These values are based on the headcount-weighted Pri.H-2012 tables and the headcount-weighted RPH-2006 tables.

Table 13.1

COMPARISON OF AGE-65 COHORT LIFE EXPECTANCIES (COMPLETE) AS OF JANUARY 1, 2019, PROJECTED GENERATIONALLY WITH MP-2018

Gender	RPH-2006	Pri.H-2012	Percentage Change
Females	22.39	22.37	−0.1%
Males	19.97	19.70	−1.3%

[44] Projected to 2019 using Scale MP-2018

Section 14: Reliance and Limitations

The Pri-2012 Private Retirement Plans Mortality Tables released in conjunction with this report have been developed from private pension mortality experience in the U.S and are intended for use in connection with actuarial applications related to private-sector retirement programs. No assessment has been made concerning the applicability of these tables to other purposes.

Appendixes

Appendix A: Reconciliation of Excluded Data

Table A.1 summarizes the amount of data received for the study and the amount of data that was excluded from the final dataset. Nearly 92% of all the data submitted was included in the Pri-2012 study, compared to an 82% inclusion rate for the RP-2014 study. In particular, the Retiree exclusion rate was only about 1% compared to 15% in the RP-2014 study. The largest component of excluded data for the Pri-2012 study was attributable to Employee groups with outlier actual-to-expected death ratios that could not be confirmed by the contributor.

Table A.1
RECONCILIATION OF EXCLUDED DATA

		Life-Years of Exposure (in thousands)				
		Employees	Retirees	Contingent Survivors	Disabled Retirees	Total
(a)	**Total Beginning Exposures**	8,385	7,621	1,185	343	17,534
(b)	Estimated exposures for months with anomalous death counts that the contributor could not confirm	144	64	24	2	234
(c)	Exposures for data subgroups with outlier A/E ratios that the contributor could not confirm	1,015	-	116	2	1,133
(d)	Exposures with ages outside of age ranges	37	25	20	6	88
(e)	**Exposures in Final Dataset**	7,189	7,532	1,025	333	16,079

Below is a more detailed description of the intermediate line items in Table A.1

(b) Estimated exposures for months with anomalous death counts that the contributor could not confirm

These counts represent the estimated amount of data excluded for time periods for which a plan had an unusual pattern of month-by-month counts that the contributor did not confirm, as detailed in subsection 3.5. Because these exclusions took place before exposure was calculated, these were mostly estimated from the contributor-provided counts of annual records provided in each status group. In the few cases in which a contributor did not provide this information, the counts were estimated from a given plan's total included exposure and the fraction of the study period that was excluded for that plan.

(c) Exposures for data subgroups with outlier A/E ratios that the contributor could not confirm

As discussed in subsection 3.6, some subgroups within certain plans exhibited outlier mortality experience that could the contributor could not confirm, which suggested there were issues with the reliability of death indicators in the provided data.

(d) Exposures with ages outside of age ranges

Appendix B provides a summary of the final datasets that the Committee considered in developing the mortality tables. For each status group, the Committee considered a different range of ages. These ranges were determined based on the ages for which a sufficiently robust amount of data was provided. This had the effect of excluding a relatively small amount of submitted data for the oldest and youngest participants within each status group.

Appendix B: Summary of Final Datasets

Table B.1
SUMMARY OF FINAL FEMALE EMPLOYEE DATASET

	Number		Number with Amount		Annual Salary Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
20–24	139,766	36	115,626	31	2,459,377	425	0.00026	0.00027	0.00017
25–29	246,215	55	201,021	40	8,400,473	907	0.00022	0.00020	0.00011
30–34	289,857	106	240,372	64	12,872,260	2,782	0.00037	0.00027	0.00022
35–39	301,852	117	255,640	91	14,990,285	3,968	0.00039	0.00036	0.00026
40–44	343,675	233	292,201	180	17,126,038	7,982	0.00068	0.00062	0.00047
45–49	375,719	334	317,889	249	18,026,469	12,696	0.00089	0.00078	0.00070
50–54	382,599	548	321,959	430	18,259,587	20,738	0.00143	0.00134	0.00114
55–59	309,674	621	262,061	498	15,074,136	22,709	0.00201	0.00190	0.00151
60–64	173,522	545	145,730	443	7,958,390	20,075	0.00314	0.00304	0.00252
65–69	48,605	245	39,782	181	1,791,102	6,306	0.00504	0.00455	0.00352
70–74	12,433	103	10,519	72	334,707	1,932	0.00828	0.00684	0.00577
75–79	3,924	60	3,459	48	89,066	852	0.01529	0.01388	0.00956
TOTAL	2,627,841	3,003	2,206,260	2,327	117,381,890	101,372			

Blue Collar	1,222,258	1,724	932,830	1,211	26,871,689	29,019
White Collar	522,076	454	519,522	443	33,000,814	27,242
Unknown Collar	883,507	825	753,908	673	57,509,387	45,111

Bottom Quartile			520,114	792	7,806,157	11,708
Top Quartile			566,905	406	61,070,500	42,787

Table B.2
SUMMARY OF FINAL MALE EMPLOYEE DATASET

	Number		Number with Amount		Annual Salary Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
20–24	207,366	137	146,906	84	3,666,098	1,657	0.00066	0.00057	0.00045
25–29	417,744	237	295,323	140	12,849,289	5,288	0.00057	0.00047	0.00041
30–34	532,400	356	373,157	224	20,016,439	9,741	0.00067	0.00060	0.00049
35–39	597,336	531	430,582	381	25,190,083	18,232	0.00089	0.00088	0.00072
40–44	642,854	631	460,315	432	28,665,776	20,974	0.00098	0.00094	0.00073
45–49	688,070	974	489,618	667	31,011,844	33,353	0.00142	0.00136	0.00108
50–54	677,347	1,511	482,417	1,036	30,936,666	53,639	0.00223	0.00215	0.00173
55–59	492,823	1,669	362,729	1,212	23,583,532	65,230	0.00339	0.00334	0.00277
60–64	237,697	1,187	178,042	888	11,451,249	48,569	0.00499	0.00499	0.00424
65–69	52,906	403	40,155	289	2,324,504	13,876	0.00762	0.00720	0.00597
70–74	11,704	126	9,329	92	389,139	3,757	0.01077	0.00986	0.00965
75–79	3,404	73	2,724	57	89,770	1,629	0.02144	0.02092	0.01815
TOTAL	4,561,650	7,835	3,271,299	5,502	190,174,390	275,945			

Blue Collar	3,272,188	6,060	2,160,641	4,014	96,780,765	161,218
White Collar	474,419	603	470,196	576	43,379,609	51,962
Unknown Collar	815,043	1,172	640,462	912	50,014,016	62,764

Bottom Quartile	781,562	1,823	17,548,369	38,834
Top Quartile	841,238	1,108	89,373,568	112,858

Table B.3
SUMMARY OF FINAL FEMALE RETIREE DATASET

Age Band	Number		Number with Amount		Annual Benefit Amount ($ thousands)		Raw Death Rates Based on		
	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
50–54	33,087	198	32,719	152	145,352	1,000	0.00598	0.00465	0.00688
55–59	159,918	999	158,628	890	1,313,826	6,317	0.00625	0.00561	0.00481
60–64	342,516	2,659	339,995	2,498	2,836,090	18,850	0.00776	0.00735	0.00665
65–69	497,675	5,356	494,115	5,124	3,359,465	32,056	0.01076	0.01037	0.00954
70–74	408,878	7,008	406,439	6,739	2,372,325	36,223	0.01714	0.01658	0.01527
75–79	307,845	9,178	305,656	8,833	1,584,537	44,805	0.02981	0.02890	0.02828
80–84	238,260	12,248	236,302	11,790	1,084,547	52,710	0.05141	0.04989	0.04860
85–89	168,293	14,931	166,486	14,376	689,685	59,122	0.08872	0.08635	0.08572
90–94	77,484	11,537	76,280	11,091	275,941	40,260	0.14889	0.14540	0.14590
95–99	18,109	4,198	17,734	4,021	54,457	12,766	0.23181	0.22674	0.23442
100–104	2,108	698	2,028	661	5,753	1,941	0.33115	0.32593	0.33740
TOTAL	2,254,173	69,010	2,236,382	66,175	13,721,978	306,050			
Blue Collar	773,240	25,588	765,175	25,081	4,869,135	124,557			
White Collar	533,781	13,126	532,230	13,079	4,547,106	81,733			
Unknown Collar	947,152	30,296	938,977	28,015	4,305,737	99,760			
Bottom Quartile			549,151	19,319	477,882	16,625			
Top Quartile			558,383	11,277	8,962,710	157,829			

Table B.4

SUMMARY OF FINAL MALE RETIREE DATASET

	Number		Number with Amount		Annual Benefit Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
50–54	53,103	444	52,351	367	467,337	4,132	0.00836	0.00701	0.00884
55–59	322,764	2,987	319,230	2,781	5,038,791	36,509	0.00925	0.00871	0.00725
60–64	763,695	8,795	756,618	8,486	12,130,272	111,302	0.01152	0.01122	0.00918
65–69	1,225,708	19,174	1,215,675	18,747	16,649,804	216,573	0.01564	0.01542	0.01301
70–74	1,075,869	26,572	1,068,416	26,096	13,327,173	279,122	0.02470	0.02442	0.02094
75–79	797,277	32,953	791,623	32,430	9,161,940	327,213	0.04133	0.04097	0.03571
80–84	567,303	39,744	562,779	39,041	5,993,425	375,689	0.07006	0.06937	0.06268
85–89	329,142	38,627	325,769	37,769	3,089,473	336,146	0.11736	0.11594	0.10880
90–94	119,587	22,557	118,252	22,066	967,464	175,125	0.18862	0.18660	0.18101
95–99	21,541	5,972	21,242	5,844	143,987	39,595	0.27724	0.27511	0.27499
100–104	1,843	684	1,795	665	10,197	3,806	0.37108	0.37039	0.37331
TOTAL	5,277,831	198,509	5,233,749	194,292	66,979,863	1,905,211			
Blue Collar	3,099,213	121,624	3,073,276	120,923	37,529,030	1,099,081			
White Collar	916,660	30,946	909,484	30,720	15,984,426	404,532			
Unknown Collar	1,261,959	45,939	1,250,989	42,649	13,466,407	401,599			
Bottom Quartile			1,309,595	55,103	2,225,582	93,746			
Top Quartile			1,299,975	29,947	40,685,322	861,169			

Table B.5

SUMMARY OF FINAL FEMALE CONTINGENT SURVIVOR DATASET

	Number		Number with Amount		Annual Benefit Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
50–54	22,874	209	22,603	207	138,551	1,305	0.00914	0.00916	0.00942
55–59	49,023	512	48,314	499	291,455	3,113	0.01044	0.01033	0.01068
60–64	86,037	1,142	84,901	1,119	521,108	6,233	0.01327	0.01318	0.01196
65–69	124,278	2,153	122,862	2,100	749,618	11,591	0.01732	0.01709	0.01546
70–74	146,003	3,565	144,686	3,474	838,188	18,847	0.02442	0.02401	0.02249
75–79	159,430	5,761	158,294	5,613	865,291	29,350	0.03614	0.03546	0.03392
80–84	163,321	9,098	162,211	8,861	843,321	44,427	0.05571	0.05463	0.05268
85–89	127,268	11,606	126,488	11,374	604,842	51,754	0.09119	0.08992	0.08557
90–94	57,630	8,488	57,248	8,312	245,544	35,763	0.14729	0.14519	0.14565
95–99	12,138	2,791	12,033	2,733	46,845	10,436	0.22994	0.22712	0.22278
100–104	1,195	353	1,188	350	5,017	1,581	0.29544	0.29455	0.31502
TOTAL	949,197	45,678	940,829	44,642	5,149,781	214,398			

Blue Collar	625,826	29,105	622,776	29,003	2,986,940	117,406
White Collar	146,598	7,191	144,640	7,136	1,302,744	56,348
Unknown Collar	176,774	9,382	173,413	8,503	860,097	40,643

Table B.6
SUMMARY OF FINAL MALE CONTINGENT SURVIVOR DATASET

	Number		Number with Amount		Annual Benefit Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
50–54	2,282	59	2,242	55	8,793	432	0.02586	0.02453	0.04914
55–59	4,284	112	4,229	109	16,490	469	0.02614	0.02578	0.02846
60–64	7,597	152	7,492	146	32,369	885	0.02001	0.01949	0.02735
65–69	10,492	312	10,316	303	43,525	1,653	0.02974	0.02937	0.03797
70–74	11,874	460	11,747	450	44,750	2,008	0.03874	0.03831	0.04488
75–79	11,907	657	11,773	639	42,962	2,873	0.05518	0.05428	0.06688
80–84	11,676	914	11,531	892	40,523	4,137	0.07828	0.07736	0.10210
85–89	8,842	1,073	8,696	1,039	30,995	4,561	0.12136	0.11949	0.14716
90–94	4,799	818	4,740	798	16,748	3,589	0.17044	0.16834	0.21432
95–99	1,508	302	1,492	297	4,177	1,222	0.20024	0.19906	0.29257
100–104	263	44	254	44	522	132	0.16753	0.17314	0.25333
TOTAL	75,523	4,903	74,512	4,772	281,855	21,963			

Blue Collar	35,185	2,146	34,728	2,122	111,217	6,846
White Collar	20,573	1,643	20,419	1,638	109,962	12,364
Unknown Collar	19,765	1,114	19,365	1,012	60,675	2,753

Table B.7

SUMMARY OF FINAL FEMALE DISABLED RETIREE DATASET

	Number		Number with Amount		Annual Benefit Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
45–49	2,066	45	2,029	43	15,842	379	0.02178	0.02119	0.02390
50–54	5,162	89	5,081	88	43,264	682	0.01724	0.01732	0.01577
55–59	8,667	158	8,555	154	74,927	1,095	0.01823	0.01800	0.01461
60–64	10,391	198	10,228	193	86,329	1,439	0.01906	0.01887	0.01667
65–69	8,874	224	8,742	222	69,597	1,597	0.02524	0.02539	0.02294
70–74	5,693	202	5,609	197	38,096	1,231	0.03548	0.03512	0.03232
75–79	3,702	199	3,681	197	19,873	1,007	0.05375	0.05351	0.05066
80–84	2,383	175	2,378	173	11,233	764	0.07344	0.07274	0.06802
85–89	1,529	175	1,526	174	6,660	777	0.11444	0.11401	0.11667
90–94	552	103	552	103	2,265	394	0.18668	0.18668	0.17387
95–99	103	31	103	31	465	141	0.29998	0.29998	0.30426
100–104	7	3	7	3	22	9	0.41399	0.41399	0.38258
TOTAL	49,131	1,602	48,494	1,578	368,574	9,514			

Blue Collar	41,388	1,354	40,785	1,332	295,936	7,741
White Collar	3,935	114	3,901	113	47,721	1,087
Unknown Collar	3,808	134	3,808	133	24,917	686

Table B.8

SUMMARY OF FINAL MALE DISABLED RETIREE DATASET

	Number		Number with Amount		Annual Benefit Amount ($ thousands)		Raw Death Rates Based on		
Age Band	Exposed Life Years	Deaths	Exposed Life Years	Deaths	Exposed $-Years	$-Weighted Deaths	Number	Number with Amount	Amount
45–49	10,487	215	10,330	214	115,453	2,278	0.02050	0.02072	0.01973
50–54	26,151	625	25,948	623	336,797	7,259	0.02390	0.02401	0.02155
55–59	45,219	1,134	45,009	1,132	627,543	14,317	0.02508	0.02515	0.02282
60–64	62,413	1,731	62,202	1,719	798,275	19,634	0.02773	0.02764	0.02460
65–69	55,796	1,996	55,522	1,990	648,885	21,193	0.03577	0.03584	0.03266
70–74	38,297	1,872	37,858	1,855	411,299	18,608	0.04888	0.04900	0.04524
75–79	24,438	1,771	24,138	1,746	235,202	15,781	0.07247	0.07233	0.06709
80–84	12,769	1,360	12,608	1,342	103,574	10,876	0.10650	0.10644	0.10501
85–89	5,681	891	5,626	880	37,701	5,775	0.15685	0.15643	0.15319
90–94	1,939	446	1,926	444	11,324	2,547	0.23003	0.23056	0.22492
95–99	311	98	303	96	1,485	534	0.31560	0.31672	0.35975
100–104	22	4	22	4	104	30	0.17930	0.17930	0.28982
TOTAL	283,523	12,143	281,491	12,045	3,327,640	118,833			

Blue Collar	275,435	11,777	273,472	11,681	3,226,955	114,671
White Collar	2,053	93	1,984	91	45,113	1,724
Unknown Collar	6,034	273	6,034	273	55,572	2,439

Appendix C: Discussion of GAM Graduation[45]

The splines that underlie the GAM models have a long history. Before the advent of computers, engineers and drafting technicians used "splines" to draw curves. Such splines were thin flexible strips of wood or metal. The technician would place wooden or metal dowels vertically on the drawing surface and position the spline strip such that the strip passed through the dowels and then was flexed to the desired curve. By both arranging the positions and orientations of the dowels and setting the length of the strip between each dowel, a technician could obtain a wide range of smooth curves.

With the advent of computer-aided drafting and design, practitioners developed mathematical representations of splines with the desired features that were needed to solve problems specific to their fields. The Renault engineer Pierre Bézier is remembered for his introduction of Bézier splines, which can be thought of as a weighted average of *n* control points, with the weighting determined by the binomial formula. Since then, computer representations of splines have found uses throughout engineering, statistics and visual effects.

There is a large and growing diversity of spline types of one and higher dimensions. The GAM framework is agnostic with respect to spline type, but the most natural and easiest-to-understand type for the purposes of one-dimensional mortality modeling is the class of cubic regression splines. A cubic spline is a type of spline constructed using piecewise cubic polynomials that pass through a certain set of points called knots. The cubic splines used in the GAM models are set up in a way similar to traditional drafting. In R's `mgcv` package, 10 knots are placed evenly by default over the attained age range of the data, with one knot reserved for each end. For example, if the attained ages run from 50 to 95, then knots are placed at ages 50 and 95, and eight other knots are placed evenly, in this case at quinquennial ages. Then a model matrix is set up in R. The model matrix is configured such that, when combined with the model coefficients, (a) the function is a cubic polynomial between knots, expressed relative to some basis, and (b) each of the zeroth, first and second derivatives of the cubic polynomials, agree at the knots. Model coefficients are then determined using optimization routines. If the GAM model equation is specified as

$$\ln q_x = f(x) + \varepsilon_x$$

where $f(x)$ is the function of cubic splines and ε_x is the error term (as is encountered for the RPEC graduations using a binomial likelihood with log link), then subject to appropriate weighting w_x, and other considerations related to the fitting algorithm, the goal of the optimization is to find the function $f(x)$ such that the following is minimized:

$$\sum_x w_x\big(\ln q_x - f(x)\big)^2 + \lambda \int_{x_{min}}^{x_{max}} [f''(x)]^2 dx$$

The formula represents a trade-off between rewarding a tight fit of the data (the summation on the left) and rewarding a curve with low curvature (the integral on the right). The parameter λ is the smoothness penalty, with higher values increasing the penalty for curvature.

[45] Note: This Appendix is the same as Appendix C in the *Pub-2010 Public Retirement Plans Mortality Tables Report*.

Compare this with the objective function of Whittaker-Henderson (Type B) graduation. For every raw mortality rate q_x and weighting factor w_x, find $\hat{q}_x$ that minimizes

$$\sum_x w_x(q_x - \hat{q}_x)^2 + h\sum_x (\Delta^n \hat{q}_x)^2$$

where h is the smoothing penalty, and $\Delta^n \hat{q}_x$ is the *n*th difference of the fitted rates.

Any Whittaker-Henderson graduation can be recast as a regression using penalized splines, or p-splines.[46] To translate, set a knot at every age, use a p-spline basis dimension of zero (hence step functions at every age), and set the order of difference penalty equal to n.[47] The smoothness parameter can be either specified or made part of the minimization.

Technical discussion

A GAM extends the generalized linear model (GLM) by including specifications for a smooth function of one or more predictors (e.g., a smooth function of age) and a penalty term to penalize the "wigglyness" of that function. The main advantage to this approach is that the modeler is freed of the chore of hunting for an appropriate polynomial or other smooth function that both fits the data and permits stable predictions from the model. Since GAMs extend GLMs, many of the intuitions from fitting GLMs carry over to GAMs.

In turn, GLMs extend linear models to broader types of data. In linear models, a response is regressed linearly onto a collection of predictor variables using least squares minimization, and it is assumed that the response data are independent normally distributed random variables with mean equal to a linear combination of the predictors. Least-squares minimization is equivalent to maximizing the likelihood of the independent normally distributed data. Replacing the likelihood function with exponential families (e.g., binomial, Poisson etc.) leads to GLMs.

The remainder of Appendix C is meant to provide a high-level overview of statistical techniques underpinning GAMs. Readers interested in learning more about GAM's mathematical underpinnings are advised to consult *Generalized Additive Models: An Introduction in R,* 2nd edition, by Simon Wood (Wood 2017) from which much of Appendix C is adapted.

The methodology for fitting GAMs tracks these extensions. First, convert the GAM problem to a penalized GLM problem by setting up model and penalty matrices that reflect the specified spline structure. Second, convert the GLM problem into an iteratively reweighted least squares problem, and finally iterate the fit by alternating between optimizing the regression parameters for fixed smoothing parameter, and optimizing the smoothing penalty for fixed regression parameters. In addition, the R package `mgcv` automates this procedure in the function "`gam`."

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[46] P-splines are B-splines that add a difference penalty on the regression coefficients for the spline. The penalties are analogous to the penalties in Whittaker-Henderson graduation.

[47] Currie, Iain. n.d. Back to the Future with Whittaker Smoothing. *Longevitas*, https://www.longevitas.co.uk/site/informationmatrix/whittaker.html (accessed July 10, 2018).

The algorithm in gam does the following:

1. Set up the matrices and other parameters for the problem, along with any computational optimizations.
2. Minimize generalized cross-validation (GCV) with respect to λ using a version of Newton's method for a fixed vector of regression parameters (the so-called "outer loop").
    a. For fixed λ, fit GLM using penalized iteratively reweighted least squares (the so-called "inner loop").
    b. Compute derivative information to enable the minimization in the outer loop.
3. Generate statistics for final model.

When the algorithm is done, the modeler receives a model that both fits the data optimally (up to the limitations of its specifications) *and* has the optimal smoothness, all without the need for hand-tuning the smoothness parameter. This is an improvement on the process that is commonly carried out in Whittaker-Henderson graduation, in which the modeler uses trial-and-error and visual inspection to get to an acceptable smoothing parameter.

Appendix D: Additional Annuity Factor Comparisons

D.1 Annuity Factor Comparisons at 6.0% Interest

Table D.1

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 6.0% INTEREST AS OF JANUARY 1, 2019,
PRI-2012 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	1.4901	1.4484	1.5144	1.4593	1.5099
	35	2.6325	2.5548	2.6781	2.5771	2.6686
	45	4.6591	4.5182	4.7440	4.5662	4.7217
	55	8.2819	8.0382	8.4367	8.1485	8.3795
	65	11.8380	11.5196	12.0761	11.7421	11.9442
	75	8.9743	8.7682	9.2712	8.9204	9.0857
	85	5.7193	5.5914	5.8907	5.7014	5.7988
	95	3.2153	3.2006	3.2342	3.2153	3.2196
Males	25	1.4105	1.3696	1.4664	1.3189	1.4520
	35	2.4934	2.4187	2.5963	2.3293	2.5684
	45	4.4158	4.2817	4.6032	4.1288	4.5490
	55	7.8578	7.6236	8.1913	7.3801	8.0855
	65	11.2314	10.8973	11.7100	10.6396	11.5541
	75	8.3624	8.0565	8.7531	7.9500	8.7240
	85	5.1176	4.9455	5.3236	4.9760	5.3579
	95	2.7860	2.7629	2.8185	2.7753	2.8177

Table D.2

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 6.0% INTEREST AS OF JANUARY 1, 2019,
PRI-2012 SUBPOPULATIONS TO PRI-2012 TOTAL DATASET

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	N/A	−2.8%	1.6%	−2.1%	1.3%
	35	N/A	−3.0%	1.7%	−2.1%	1.4%
	45	N/A	−3.0%	1.8%	−2.0%	1.3%
	55	N/A	−2.9%	1.9%	−1.6%	1.2%
	65	N/A	−2.7%	2.0%	−0.8%	0.9%
	75	N/A	−2.3%	3.3%	−0.6%	1.2%
	85	N/A	−2.2%	3.0%	−0.3%	1.4%
	95	N/A	−0.5%	0.6%	0.0%	0.1%
Males	25	N/A	−2.9%	4.0%	−6.5%	2.9%
	35	N/A	−3.0%	4.1%	−6.6%	3.0%
	45	N/A	−3.0%	4.2%	−6.5%	3.0%
	55	N/A	−3.0%	4.2%	−6.1%	2.9%
	65	N/A	−3.0%	4.3%	−5.3%	2.9%
	75	N/A	−3.7%	4.7%	−4.9%	4.3%
	85	N/A	−3.4%	4.0%	−2.8%	4.7%
	95	N/A	−0.8%	1.2%	−0.4%	1.1%

Table D.3

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 6.0% INTEREST AS OF JANUARY 1, 2019, RP-2006 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	1.4852	1.4648	1.5198	1.4543	1.5237
	35	2.6228	2.5847	2.6879	2.5665	2.6928
	45	4.6405	4.5709	4.7610	4.5430	4.7634
	55	8.2563	8.1348	8.4728	8.1086	8.4536
	65	11.8286	11.6519	12.1449	11.6780	12.0912
	75	9.0649	8.8599	9.3704	8.8682	9.4534
	85	5.7955	5.6623	5.9926	5.7226	6.1932
	95	3.1947	3.1809	3.2333	3.1947	3.4360
Males	25	1.4012	1.3511	1.4692	1.3359	1.4892
	35	2.4723	2.3815	2.5979	2.3528	2.6328
	45	4.3708	4.2093	4.5995	4.1558	4.6579
	55	7.7929	7.5236	8.1907	7.4259	8.2739
	65	11.2076	10.8474	11.7280	10.7653	11.8606
	75	8.4288	8.0548	8.8536	8.0268	9.1156
	85	5.2377	5.0035	5.4734	5.0023	5.6104
	95	2.8577	2.8061	2.8986	2.8382	2.8639

Table D.4

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 6.0% INTEREST AS OF JANUARY 1, 2019, PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	0.3%	−1.1%	−0.4%	0.3%	−0.9%
	35	0.4%	−1.2%	−0.4%	0.4%	−0.9%
	45	0.4%	−1.2%	−0.4%	0.5%	−0.9%
	55	0.3%	−1.2%	−0.4%	0.5%	−0.9%
	65	0.1%	−1.1%	−0.6%	0.5%	−1.2%
	75	−1.0%	−1.0%	−1.1%	0.6%	−3.9%
	85	−1.3%	−1.3%	−1.7%	−0.4%	−6.4%
	95	0.6%	0.6%	0.0%	0.6%	−6.3%
Males	25	0.7%	1.4%	−0.2%	−1.3%	−2.5%
	35	0.9%	1.6%	−0.1%	−1.0%	−2.4%
	45	1.0%	1.7%	0.1%	−0.6%	−2.3%
	55	0.8%	1.3%	0.0%	−0.6%	−2.3%
	65	0.2%	0.5%	−0.2%	−1.2%	−2.6%
	75	−0.8%	0.0%	−1.1%	−1.0%	−4.3%
	85	−2.3%	−1.2%	−2.7%	−0.5%	−4.5%
	95	−2.5%	−1.5%	−2.8%	−2.2%	−1.6%

D.2 Annuity Factor Comparisons at 0.0% Interest[48]

Table D.5

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 0.0% INTEREST AS OF JANUARY 1, 2019,
PRI-2012 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	27.7093	26.6329	28.4995	27.0604	28.2190
	35	26.9052	25.8008	27.7211	26.2594	27.4191
	45	26.1634	25.0512	26.9988	25.5574	26.6637
	55	25.5447	24.4609	26.3916	25.0449	25.9983
	65	22.6619	21.7777	23.4488	22.4077	22.9992
	75	14.1881	13.7543	14.8257	14.0822	14.4315
	85	7.6249	7.4215	7.8940	7.5988	7.7492
	95	3.7936	3.7752	3.8174	3.7936	3.7991
Males	25	25.2716	24.1730	26.7809	23.1404	26.4516
	35	24.5327	23.4255	26.0690	22.4127	25.7160
	45	23.8536	22.7489	25.4052	21.7798	25.0264
	55	23.2979	22.2144	24.8421	21.3367	24.4347
	65	20.6729	19.7206	22.0277	19.1282	21.6780
	75	12.7635	12.1454	13.5599	11.9769	13.5228
	85	6.6144	6.3538	6.9298	6.4033	6.9842
	95	3.2171	3.1887	3.2573	3.2040	3.2562

Table D.6

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 0.0% INTEREST AS OF JANUARY 1, 2019,
PRI-2012 SUBPOPULATIONS TO PRI-2012 TOTAL DATASET

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	N/A	−3.9%	2.9%	−2.3%	1.8%
	35	N/A	−4.1%	3.0%	−2.4%	1.9%
	45	N/A	−4.3%	3.2%	−2.3%	1.9%
	55	N/A	−4.2%	3.3%	−2.0%	1.8%
	65	N/A	−3.9%	3.5%	−1.1%	1.5%
	75	N/A	−3.1%	4.5%	−0.7%	1.7%
	85	N/A	−2.7%	3.5%	−0.3%	1.6%
	95	N/A	−0.5%	0.6%	0.0%	0.1%
Males	25	N/A	−4.3%	6.0%	−8.4%	4.7%
	35	N/A	−4.5%	6.3%	−8.6%	4.8%
	45	N/A	−4.6%	6.5%	−8.7%	4.9%
	55	N/A	−4.7%	6.6%	−8.4%	4.9%
	65	N/A	−4.6%	6.6%	−7.5%	4.9%
	75	N/A	−4.8%	6.2%	−6.2%	5.9%
	85	N/A	−3.9%	4.8%	−3.2%	5.6%
	95	N/A	−0.9%	1.2%	−0.4%	1.2%

[48] Note that the annuity factors for ages older than 62 are not exactly equal to the life expectancies shown in Table D.20. This is due to two reasons. First, the life expectancies were computed using the headcount-weighted Pri.H-2012 tables rather than the amount-weighted Pri-2012 tables. Second, a monthly annuity due has beginning-of-month payments, making the average duration of 12 monthly payments shorter than a half year. This is reflected in the "minus 11/24ths" adjustment shown in the standard approximation to Woolhouse's formula shown in subsection 11.1.1. In the calculation of the complete cohort life expectancies in Table D.20, this factor is minus one-half.

Table D.7

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 0.0% INTEREST AS OF JANUARY 1, 2019, RP-2006 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	27.6791	27.0570	28.7223	26.9099	28.9831
	35	26.8701	26.2328	27.9473	26.0937	28.1739
	45	26.1240	25.4792	27.2252	25.3683	27.4004
	55	25.5324	24.8966	26.6376	24.8602	26.7244
	65	22.7165	22.1447	23.7051	22.2320	23.7540
	75	14.3939	13.9506	15.0614	13.9952	15.3520
	85	7.7392	7.5299	8.0556	7.6304	8.4267
	95	3.7615	3.7444	3.8103	3.7615	4.0880
Males	25	25.1982	23.8636	26.9778	23.5541	27.5821
	35	24.4138	23.0768	26.2265	22.7549	26.8242
	45	23.6932	22.3715	25.5210	22.0387	26.0974
	55	23.1822	21.9254	24.9722	21.5877	25.4855
	65	20.7096	19.6385	22.1868	19.4561	22.6906
	75	12.9426	12.1727	13.8177	12.1265	14.3561
	85	6.8099	6.4489	7.1741	6.4529	7.3730
	95	3.3102	3.2457	3.3610	3.2866	3.3176

Table D.8

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 0.0% INTEREST AS OF JANUARY 1, 2019, PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	0.1%	−1.6%	−0.8%	0.6%	−2.6%
	35	0.1%	−1.6%	−0.8%	0.6%	−2.7%
	45	0.2%	−1.7%	−0.8%	0.7%	−2.7%
	55	0.0%	−1.8%	−0.9%	0.7%	−2.7%
	65	−0.2%	−1.7%	−1.1%	0.8%	−3.2%
	75	−1.4%	−1.4%	−1.6%	0.6%	−6.0%
	85	−1.5%	−1.4%	−2.0%	−0.4%	−8.0%
	95	0.9%	0.8%	0.2%	0.9%	−7.1%
Males	25	0.3%	1.3%	−0.7%	−1.8%	−4.1%
	35	0.5%	1.5%	−0.6%	−1.5%	−4.1%
	45	0.7%	1.7%	−0.5%	−1.2%	−4.1%
	55	0.5%	1.3%	−0.5%	−1.2%	−4.1%
	65	−0.2%	0.4%	−0.7%	−1.7%	−4.5%
	75	−1.4%	−0.2%	−1.9%	−1.2%	−5.8%
	85	−2.9%	−1.5%	−3.4%	−0.8%	−5.3%
	95	−2.8%	−1.8%	−3.1%	−2.5%	−1.9%

D.3 Headcount-weighted Pri.H-2012 Annuity Factor Comparisons at 4.0% Interest

Table D.9

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, PRI.H-2012 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	3.6957	3.6004	3.7651	3.6586	3.7891
	35	5.3751	5.2302	5.4802	5.3228	5.5149
	45	7.8342	7.6189	7.9888	7.7679	8.0349
	55	11.4729	11.1668	11.6887	11.4111	11.7374
	65	14.1478	13.8122	14.4011	14.1478	14.3956
	75	10.2195	9.9884	10.4599	10.2195	10.4140
	85	6.2249	6.0760	6.3327	6.2249	6.3353
	95	3.3856	3.3659	3.4059	3.3856	3.3903
Males	25	3.3895	3.3146	3.5530	3.2477	3.5884
	35	4.9243	4.8118	5.1668	4.7192	5.2220
	45	7.1755	7.0092	7.5272	6.8906	7.6131
	55	10.5174	10.2776	11.0068	10.1527	11.1408
	65	12.9521	12.6681	13.5204	12.6146	13.6824
	75	9.1289	8.9034	9.5981	8.9885	9.7941
	85	5.3771	5.2586	5.6376	5.3771	5.7350
	95	2.9030	2.8841	2.9403	2.9030	2.9435

Table D.10

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, PRI.H-2012 SUBPOPULATIONS TO PRI.H-2012 TOTAL DATASET

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	N/A	−2.6%	1.9%	−1.0%	2.5%
	35	N/A	−2.7%	2.0%	−1.0%	2.6%
	45	N/A	−2.7%	2.0%	−0.8%	2.6%
	55	N/A	−2.7%	1.9%	−0.5%	2.3%
	65	N/A	−2.4%	1.8%	0.0%	1.8%
	75	N/A	−2.3%	2.4%	0.0%	1.9%
	85	N/A	−2.4%	1.7%	0.0%	1.8%
	95	N/A	−0.6%	0.6%	0.0%	0.1%
Males	25	N/A	−2.2%	4.8%	−4.2%	5.9%
	35	N/A	−2.3%	4.9%	−4.2%	6.0%
	45	N/A	−2.3%	4.9%	−4.0%	6.1%
	55	N/A	−2.3%	4.7%	−3.5%	5.9%
	65	N/A	−2.2%	4.4%	−2.6%	5.6%
	75	N/A	−2.5%	5.1%	−1.5%	7.3%
	85	N/A	−2.2%	4.8%	0.0%	6.7%
	95	N/A	−0.7%	1.3%	0.0%	1.4%

Table D.11

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, RPH-2006 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	3.6825	3.6279	3.8069	3.6288	3.8244
	35	5.3515	5.2680	5.5431	5.2725	5.5650
	45	7.7958	7.6706	8.0855	7.6878	8.1052
	55	11.4378	11.2587	11.8582	11.3197	11.8467
	65	14.1473	13.9361	14.6437	14.1006	14.5961
	75	10.2863	10.0929	10.6991	10.2102	10.8503
	85	6.2807	6.1633	6.5264	6.2492	6.7298
	95	3.3574	3.3425	3.3857	3.3574	3.4224
Males	25	3.3841	3.2823	3.6089	3.2971	3.7150
	35	4.9118	4.7602	5.2518	4.7808	5.4074
	45	7.1464	6.9247	7.6540	6.9517	7.8760
	55	10.5043	10.1987	11.2311	10.2271	11.5212
	65	13.0495	12.7086	13.8696	12.7767	14.2195
	75	9.3180	9.0240	9.9414	9.1025	10.4264
	85	5.5462	5.3883	5.8730	5.4085	6.2576
	95	2.9831	2.9649	3.0213	2.9675	3.0730

Table D.12

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, PERCENTAGE CHANGE OF MOVING FROM RPH-2006 TO PRI.H-2012

	Age	Total Dataset	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Females	25	0.4%	−0.8%	−1.1%	0.8%	−0.9%
	35	0.4%	−0.7%	−1.1%	1.0%	−0.9%
	45	0.5%	−0.7%	−1.2%	1.0%	−0.9%
	55	0.3%	−0.8%	−1.4%	0.8%	−0.9%
	65	0.0%	−0.9%	−1.7%	0.3%	−1.4%
	75	−0.6%	−1.0%	−2.2%	0.1%	−4.0%
	85	−0.9%	−1.4%	−3.0%	−0.4%	−5.9%
	95	0.8%	0.7%	0.6%	0.8%	−0.9%
Males	25	0.2%	1.0%	−1.5%	−1.5%	−3.4%
	35	0.3%	1.1%	−1.6%	−1.3%	−3.4%
	45	0.4%	1.2%	−1.7%	−0.9%	−3.3%
	55	0.1%	0.8%	−2.0%	−0.7%	−3.3%
	65	−0.7%	−0.3%	−2.5%	−1.3%	−3.8%
	75	−2.0%	−1.3%	−3.5%	−1.3%	−6.1%
	85	−3.0%	−2.4%	−4.0%	−0.6%	−8.4%
	95	−2.7%	−2.7%	−2.7%	−2.2%	−4.2%

D.4 Nondisabled Annuitant Annuity Factor Comparisons at 4.0% Interest

The following tables compare monthly deferred-to-62 annuities using Employee mortality rates at ages younger than 62 and Pri-2012 Nondisabled Annuitant rates or RP-2006 Healthy Annuitant rates (as indicated) at ages 62 and above. As discussed in subsection 12.6, the Pri-2012 Nondisabled Annuitant rates were produced from an exposure-weighted blend of the Retiree and Contingent Survivor tables. The purpose of these tables is to compare RP-2006 annuity factors to a Pri-2012 basis that, as in RP-2006, combines experience of Retirees and Contingent Survivors.

Table D.13

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, PRI-2012 NONDISABLED ANNUITANT[49] PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar
Females	25	3.7111	3.5841	3.7985
	35	5.3937	5.1985	5.5297
	45	7.8522	7.5584	8.0619
	55	11.4793	11.0534	11.7990
	65	14.1029	13.6196	14.5174
	75	10.1917	9.8931	10.5729
	85	6.2400	6.0863	6.4202
	95	3.3856	3.3698	3.4059
Males	25	3.5101	3.3951	3.6664
	35	5.1072	4.9342	5.3447
	45	7.4442	7.1875	7.8015
	55	10.9014	10.5294	11.4279
	65	13.3996	12.9435	14.0465
	75	9.4861	9.1093	9.9637
	85	5.5353	5.3413	5.7625
	95	2.9140	2.8897	2.9465

[49] Nondisabled Annuitant rates were used for ages 62 and older. Pri-2012 Employee rates were used for ages under 62.

Table D.14

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, RP-2006 PROJECTED GENERATIONALLY WITH MP-2018

	Age	Total Dataset	Blue Collar	White Collar
Females	25	3.7339	3.6738	3.8354
	35	5.4293	5.3371	5.5864
	45	7.9084	7.7694	8.1484
	55	11.5829	11.3808	11.9399
	65	14.2766	14.0233	14.7243
	75	10.4033	10.1430	10.7922
	85	6.3317	6.1783	6.5603
	95	3.3619	3.3471	3.4034
Males	25	3.4910	3.3500	3.6815
	35	5.0700	4.8591	5.3601
	45	7.3771	7.0671	7.8132
	55	10.8241	10.3927	11.4542
	65	13.3901	12.8874	14.1047
	75	9.5830	9.1154	10.1142
	85	5.6775	5.4093	5.9476
	95	2.9923	2.9369	3.0361

Table D.15

COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF JANUARY 1, 2019, PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012 NONDISABLED ANNUITANT

	Age	Total Dataset	Blue Collar	White Collar
Females	25	−0.6%	−2.4%	−1.0%
	35	−0.7%	−2.6%	−1.0%
	45	−0.7%	−2.7%	−1.1%
	55	−0.9%	−2.9%	−1.2%
	65	−1.2%	−2.9%	−1.4%
	75	−2.0%	−2.5%	−2.0%
	85	−1.4%	−1.5%	−2.1%
	95	0.7%	0.7%	0.1%
Males	25	0.5%	1.3%	−0.4%
	35	0.7%	1.5%	−0.3%
	45	0.9%	1.7%	−0.1%
	55	0.7%	1.3%	−0.2%
	65	0.1%	0.4%	−0.4%
	75	−1.0%	−0.1%	−1.5%
	85	−2.5%	−1.3%	−3.1%
	95	−2.6%	−1.6%	−3.0%

D.5 Pub-2010 Annuity Factor Comparisons at 4.0% Interest

Table D.16

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF 2019[50]
COMPARISON OF PRI-2012 TABLES TO PUB-2010 TEACHERS (PubT-2010)

						Ratio of Pri-2012 Annuity Factors to PubT-2010 Annuity Factors		
	Age	PubT-2010	Pri-2012	Pri-2012(BC)	Pri-2012(WC)	Pri-2012	Pri-2012(BC)	Pri-2012(WC)
Females	25	3.9932	3.7443	3.6281	3.8175	*93.8%*	*90.9%*	*95.6%*
	35	5.8309	5.4463	5.2679	5.5596	*93.4%*	*90.3%*	*95.3%*
	45	8.5267	7.9356	7.6682	8.1092	*93.1%*	*89.9%*	*95.1%*
	55	12.5087	11.6119	11.2276	11.8737	*92.8%*	*89.8%*	*94.9%*
	65	15.4372	14.2767	13.8433	14.6208	*92.5%*	*89.7%*	*94.7%*
	75	11.3630	10.2859	10.0268	10.6620	*90.5%*	*88.2%*	*93.8%*
	85	6.9611	6.2450	6.0971	6.4424	*89.7%*	*87.6%*	*92.5%*
	95	3.5701	3.3856	3.3698	3.4059	*94.8%*	*94.4%*	*95.4%*
Males	25	3.7953	3.5116	3.3958	3.6700	*92.5%*	*89.5%*	*96.7%*
	35	5.5303	5.1095	4.9353	5.3503	*92.4%*	*89.2%*	*96.7%*
	45	8.0743	7.4480	7.1892	7.8102	*92.2%*	*89.0%*	*96.7%*
	55	11.8446	10.9073	10.5322	11.4416	*92.1%*	*88.9%*	*96.6%*
	65	14.5589	13.4072	12.9471	14.0645	*92.1%*	*88.9%*	*96.6%*
	75	10.4331	9.4920	9.1116	9.9790	*91.0%*	*87.3%*	*95.6%*
	85	6.1567	5.5376	5.3416	5.7730	*89.9%*	*86.8%*	*93.8%*
	95	3.1312	2.9144	2.8897	2.9492	*93.1%*	*92.3%*	*94.2%*

[50] The Pub-2010 base tables contain mortality rates as of July 1, 2010. For purposes of these comparisons, and consistent with the Pub-2010 report, the Pub-2010 tables have been projected with full calendar years of improvement beginning with 2011.

Table D.17

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF 2019
COMPARISON OF PRI-2012 TABLES TO PUB-2010 SAFETY (PubS-2010)

						Ratio of Pri-2012 Annuity Factors to PubS-2010 Annuity Factors		
	Age	PubS-2010	Pri-2012	Pri-2012(BC)	Pri-2012(WC)	Pri-2012	Pri-2012(BC)	Pri-2012(WC)
Females	25	3.7849	3.7443	3.6281	3.8175	*98.9%*	*95.9%*	*100.9%*
	35	5.5131	5.4463	5.2679	5.5596	*98.8%*	*95.6%*	*100.8%*
	45	8.0447	7.9356	7.6682	8.1092	*98.6%*	*95.3%*	*100.8%*
	55	11.7713	11.6119	11.2276	11.8737	*98.6%*	*95.4%*	*100.9%*
	65	14.4115	14.2767	13.8433	14.6208	*99.1%*	*96.1%*	*101.5%*
	75	10.4538	10.2859	10.0268	10.6620	*98.4%*	*95.9%*	*102.0%*
	85	6.4506	6.2450	6.0971	6.4424	*96.8%*	*94.5%*	*99.9%*
	95	3.5114	3.3856	3.3698	3.4059	*96.4%*	*96.0%*	*97.0%*
Males	25	3.6033	3.5116	3.3958	3.6700	*97.5%*	*94.2%*	*101.9%*
	35	5.2449	5.1095	4.9353	5.3503	*97.4%*	*94.1%*	*102.0%*
	45	7.6465	7.4480	7.1892	7.8102	*97.4%*	*94.0%*	*102.1%*
	55	11.1875	10.9073	10.5322	11.4416	*97.5%*	*94.1%*	*102.3%*
	65	13.6290	13.4072	12.9471	14.0645	*98.4%*	*95.0%*	*103.2%*
	75	9.5643	9.4920	9.1116	9.9790	*99.2%*	*95.3%*	*104.3%*
	85	5.5830	5.5376	5.3416	5.7730	*99.2%*	*95.7%*	*103.4%*
	95	3.0479	2.9144	2.8897	2.9492	*95.6%*	*94.8%*	*96.8%*

Table D.18

MONTHLY DEFERRED-TO-62 ANNUITY DUE VALUES AT 4.0% INTEREST AS OF 2019
COMPARISON OF PRI-2012 TABLES TO PUB-2010 GENERAL (PubG-2010)

						Ratio of Pri-2012 Annuity Factors to PubG-2010 Annuity Factors		
	Age	PubG-2010	Pri-2012	Pri-2012(BC)	Pri-2012(WC)	Pri-2012	Pri-2012(BC)	Pri-2012(WC)
Females	25	3.8789	3.7443	3.6281	3.8175	*96.5%*	*93.5%*	*98.4%*
	35	5.6522	5.4463	5.2679	5.5596	*96.4%*	*93.2%*	*98.4%*
	45	8.2508	7.9356	7.6682	8.1092	*96.2%*	*92.9%*	*98.3%*
	55	12.0871	11.6119	11.2276	11.8737	*96.1%*	*92.9%*	*98.2%*
	65	14.8684	14.2767	13.8433	14.6208	*96.0%*	*93.1%*	*98.3%*
	75	10.8475	10.2859	10.0268	10.6620	*94.8%*	*92.4%*	*98.3%*
	85	6.5950	6.2450	6.0971	6.4424	*94.7%*	*92.5%*	*97.7%*
	95	3.5197	3.3856	3.3698	3.4059	*96.2%*	*95.7%*	*96.8%*
Males	25	3.6112	3.5116	3.3958	3.6700	*97.2%*	*94.0%*	*101.6%*
	35	5.2510	5.1095	4.9353	5.3503	*97.3%*	*94.0%*	*101.9%*
	45	7.6586	7.4480	7.1892	7.8102	*97.3%*	*93.9%*	*102.0%*
	55	11.2320	10.9073	10.5322	11.4416	*97.1%*	*93.8%*	*101.9%*
	65	13.7905	13.4072	12.9471	14.0645	*97.2%*	*93.9%*	*102.0%*
	75	9.8001	9.4920	9.1116	9.9790	*96.9%*	*93.0%*	*101.8%*
	85	5.7950	5.5376	5.3416	5.7730	*95.6%*	*92.2%*	*99.6%*
	95	3.1007	2.9144	2.8897	2.9492	*94.0%*	*93.2%*	*95.1%*

D.6 Approaches for Computing Joint-and-Survivor Annuities

As discussed in subsection 12.4, several possible approaches can be taken to compute a joint-and-survivor annuity value, including:

- Approach 1 uses Retiree mortality for the beneficiary for the entire duration of the annuity.
- Approach 2 uses Retiree mortality for the beneficiary while the primary Retiree is still alive and uses Contingent Survivor mortality for the beneficiary after the primary Retiree has died.
- Approach 3 uses Contingent Survivor mortality for the beneficiary for the entire duration of the annuity.

Table D.19 compares the joint-and-100%-survivor annuity values at 4.0% interest as of January 1, 2019, using each of the three methods, using the RP-2006 Healthy Annuitant table as a basis of comparison. The gender shown is the gender for the primary Retiree, and the opposite gender is assumed for the Contingent Survivor. In all calculations, males are assumed to be three years older than females and mortality rates are projected generationally with Scale MP-2018.

Table D.19

COMPARISON OF MONTHLY IMMEDIATE JOINT-AND-100%-SURVIVOR ANNUITY DUE VALUES AT 4.0% INTEREST
PERCENTAGE CHANGE OF MOVING FROM RP-2006 TO PRI-2012 USING THREE DIFFERENT APPROACHES

						Percentage Change of Moving from RP-2006 to:		
	Age	RP-2006	Pri-2012 Approach 1	Pri-2012 Approach 2	Pri-2012 Approach 3	Pri-2012 Approach 1	Pri-2012 Approach 2	Pri-2012 Approach 3
Females	55	18.9722	18.9415	18.8022	18.5426	−0.2%	−0.9%	−2.3%
	65	15.9404	15.8916	15.7791	15.5491	−0.3%	−1.0%	−2.5%
	75	11.9514	11.8208	11.7589	11.6252	−1.1%	−1.6%	−2.7%
	85	7.5184	7.4026	7.3896	7.3632	−1.5%	−1.7%	−2.1%
	95	4.1686	4.1639	4.1639	4.1634	−0.1%	−0.1%	−0.1%
Males	55	19.7087	19.6787	19.5785	19.3687	−0.2%	−0.7%	−1.7%
	65	16.9476	16.9118	16.8252	16.6218	−0.2%	−0.7%	−1.9%
	75	13.2402	13.1363	13.0899	12.9657	−0.8%	−1.1%	−2.1%
	85	8.8145	8.6779	8.6730	8.6528	−1.5%	−1.6%	−1.8%
	95	4.9923	4.9509	4.9509	4.9509	−0.8%	−0.8%	−0.8%

D.7 Cohort Life Expectancies

Similar to the annuity factor calculations shown in this report, the below life expectancies were calculated using Employee mortality prior to age 62 and Retiree mortality (for Pri-2012) or Healthy Annuitant mortality (for RP-2006) thereafter.

Table D.20

COHORT LIFE EXPECTANCIES (COMPLETE) AS OF JANUARY 1, 2019, COMPARISON OF RPH-2006 AND PRI.H-2012 PROJECTED GENERATIONALLY WITH MP-2018

	Age	RPH-2006	Pri.H-2012	Percentage Change
Females	25	63.78	63.87	0.1%
	35	53.04	53.16	0.2%
	45	42.42	42.55	0.3%
	55	32.02	32.08	0.2%
	65	22.39	22.37	−0.1%
	75	14.16	14.04	−0.8%
	85	7.63	7.56	−0.9%
	95	3.71	3.75	1.0%
Males	25	60.48	60.41	−0.1%
	35	49.90	49.86	−0.1%
	45	39.40	39.41	0.0%
	55	29.16	29.08	−0.3%
	65	19.97	19.70	−1.3%
	75	12.47	12.14	−2.6%
	85	6.59	6.36	−3.5%
	95	3.26	3.16	−2.9%

Appendix E: Summary of Tables Produced

The following tables summarize the various Pri-2012 mortality tables, along with the methods used to produce each. Several abbreviations are used in the table with the following definitions:

- "GAM" – Rates for age range shown were developed using Generalized Additive Model methodology
- "WQR" – Rates for age range shown were developed using weighted quadratic regression
- "SSA" – Rates for age range shown were taken directly from Social Security Administration data
- "CPI" – Rates for age range shown were calculated using cubic polynomial interpolation
- "EWA" – Exposure-weighted average

Table E.1

SUMMARY OF PRI-2012 AMOUNT-WEIGHTED TABLES

Status	Age Range	Gender	Total	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Employee	18 - 80	F	Pri-2012; GAM: 35 - 65; then extended	Pri-2012(BC); Scaled Total to age 65; then exponential	Pri-2012(WC); Scaled Total to age 65; then exponential	Pri-2012(BQ); Scaled Total to age 65; then exponential	Pri-2012(TQ); Scaled Total to age 65; then exponential
		M	Pri-2012; GAM: 35 - 65; then extended	Pri-2012(BC); Scaled Total to age 65; then exponential	Pri-2012(WC); Set equal to Top Quartile Employee Rates	Pri-2012(BQ); Scaled Total to age 65; then exponential	Pri-2012(TQ); Scaled Total to age 65; then exponential
Retiree	50 - 120	F	Pri-2012; GAM: 60 - 95; then extended	Pri-2012(BC); GAM: 60 - 95; then extended	Pri-2012(WC); GAM: 60 - 95; then extended	Pri-2012(BQ); Set equal to Total headcount-weighted Retiree rates	Pri-2012(TQ); GAM: 60 - 95; then extended
		M	Pri-2012; GAM: 55 - 95; then extended	Pri-2012(BC); GAM: 55 - 95; then extended	Pri-2012(WC); GAM: 65 - 95; then extended	Pri-2012(BQ); Set equal to Bottom Quartile headcount-weighted Retiree rates	Pri-2012(TQ); GAM: 55 - 95; then extended
Contingent Survivor	50 - 120	F	Pri-2012; GAM: 60 - 95; then extended	Pri-2012(BC); GAM: 60 - 95; then extended	Pri-2012(WC); GAM: 60 - 95; then extended	No Table produced	No Table produced
		M	Pri-2012; Set equal to Total headcount-weighted Contingent Survivor rates	Pri-2012(BC); Same as Total	Pri-2012(WC); Same as Total	No Table produced	No Table produced
Disabled Retiree	18 - 120	F	Pri-2012; WQR: 50 - 90; then extended	No Table produced	No Table produced	No Table produced	No Table produced
		M	Pri-2012; GAM: 45 - 95; then extended	No Table produced	No Table produced	No Table produced	No Table produced
Nondisabled Annuitant	50 - 120	F	Pri-2012; EWA of Retiree and Contingent Survivor Tables	Pri-2012(BC); EWA of Retiree and Contingent Survivor Tables	Pri-2012(WC); EWA of Retiree and Contingent Survivor Tables	No Table produced	No Table produced
		M	Pri-2012; EWA of Retiree and Contingent Survivor Tables	Pri-2012(BC); EWA of Retiree and Contingent Survivor Tables	Pri-2012(WC); EWA of Retiree and Contingent Survivor Tables	No Table produced	No Table produced
Juvenile	0 - 17	F	Pri-2012; SSA: 0-12; CPI: 13-17; equal to headcount-weighted rates	No Table produced	No Table produced	No Table produced	No Table produced
		M	Pri-2012; SSA: 0-12; CPI: 13-17; equal to headcount-weighted rates	No Table produced	No Table produced	No Table produced	No Table produced

Table E.2

SUMMARY OF PRI-2012 HEADCOUNT-WEIGHTED TABLES

Status	Age Range	Gender	Total	Blue Collar	White Collar	Bottom Quartile	Top Quartile
Employee	18 - 80	F	Pri.H-2012; GAM: 35 - 65; then extended	Pri.H-2012(BC); Scaled Total to age 65; then exponential	Pri.H-2012(WC); Scaled Total to age 65; then exponential	Pri.H-2012(BQ); Scaled Total to age 65; then exponential	Pri.H-2012(TQ); Scaled Total to age 65; then exponential
		M	Pri.H-2012; GAM: 35 - 65; then extended	Pri.H-2012(BC); Scaled Total to age 65; then exponential	Pri.H-2012(WC); Set equal to Top Quartile Employee Rates	Pri.H-2012(BQ); Scaled Total to age 65; then exponential	Pri.H-2012(TQ); Scaled Total to age 65; then exponential
Retiree	50 - 120	F	Pri.H-2012; GAM: 60 - 95; then extended	Pri.H-2012(BC); GAM: 60 - 95; then extended	Pri.H-2012(WC); GAM: 60 - 95; then extended	Pri.H-2012(BQ); Set equal to Total Retiree rates	Pri.H-2012(TQ); GAM: 60 - 95; then extended
		M	Pri.H-2012; GAM: 55 - 95; then extended	Pri.H-2012(BC); GAM: 55 - 95; then extended	Pri.H-2012(WC); GAM: 65 - 95; then extended	Pri.H-2012(BQ); GAM: 55 - 95; then extended	Pri.H-2012(TQ); GAM: 55 - 95; then extended
Contingent Survivor	50 - 120	F	Pri.H-2012; GAM: 60 - 95; then extended	Pri.H-2012(BC); GAM: 60 - 95; then extended	Pri.H-2012(WC); GAM: 60 - 95; then extended	No Table produced	No Table produced
		M	Pri.H-2012; WQR: 60 - 90; then extended	Pri.H-2012(BC); Same as Total	Pri.H-2012(WC); Same as Total	No Table produced	No Table produced
Disabled Retiree	18 - 120	F	Pri.H-2012; WQR: 50 - 90; then extended	No Table produced	No Table produced	No Table produced	No Table produced
		M	Pri.H-2012; GAM: 45 - 95; then extended	No Table produced	No Table produced	No Table produced	No Table produced
Nondisabled Annuitant	50 - 120	F	Pri.H-2012; EWA of Retiree and Contingent Survivor Tables	Pri.H-2012(BC); EWA of Retiree and Contingent Survivor Tables	Pri.H-2012(WC); EWA of Retiree and Contingent Survivor Tables	No Table produced	No Table produced
		M	Pri.H-2012; EWA of Retiree and Contingent Survivor Tables	Pri.H-2012(BC); EWA of Retiree and Contingent Survivor Tables	Pri.H-2012(WC); EWA of Retiree and Contingent Survivor Tables	No Table produced	No Table produced
Juvenile	0 - 17	F	Pri.H-2012; Set equal to amount-weighted rates	No Table produced	No Table produced	No Table produced	No Table produced
		M	Pri.H-2012; Set equal to amount-weighted rates	No Table produced	No Table produced	No Table produced	No Table produced

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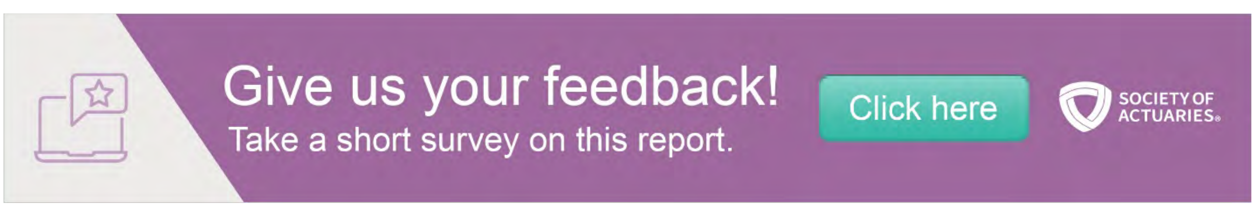

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