Stress Analysis on Longevity Risk
(Session 7B)

Jeffrey M. Brown, Swiss Re

October 28, 2020
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Polling Question #1

Relative to past mortality improvements, do you anticipate future mortality improvements to be...?

A. Higher
B. About the same
C. Lower
Longevity Risk Modeling

SOA Annual Meeting
Stuart Silverman, FSA, MAAA, CERA
October 28, 2020
Modeled Sources of Mortality / Longevity Volatility*

- Poisson Risk
- Basis Risk
- Trend Risk
- Extreme Long-Term Events
- Catastrophic Short-Term Events
- Selection / Anti-Selection Effect

Articles, Research Papers & Presentations

* Modeling approach used in REVEAL (which stands for Risk and Economic Volatility Evaluation of Annuitant Longevity), which is a system developed to analyze longevity risk. REVEAL generates stochastic mortality projections for life insurance, pension and annuity liabilities. For more information about REVEAL, and case studies performed with REVEAL, please see milliman.com/en/products/reveal
1. Poisson Risk ("Date of Death")

Consider the Law of Large Numbers:

as a sample size grows, its mean will get closer and closer to the average of the whole population

However, we may need to model risk associated with small sample sizes.

Poisson Method Applied to Survival Model:

In each scenario, for each life, select a random number between 0 and 1, and compare that value to the cumulative survival rates \( p_x \) and model death as occurring at the first time \( t \) at which the random number > \( p_x \).
Stochastic Mortality / Longevity Projection
MODELED SOURCES OF VOLATILITY

Poisson Risk – Simple Example: $1 per year payable  Annual Mortality is a constant 10%

Compare Modeling to Life Expectancy to Deterministic to Poisson

Comparison of Annual Cash Flows

- To Life Expectancy
- Deterministic
- Poisson 5 Lives
- Poisson 25 Lives
- Poisson 100 Lives
2. Volatility Around Baseline Expected Mortality Table (*Basis Risk*)

Assumed mortality based on standard industry tables but business placed with any given insurer may reflect different characteristics from those underlying standard tables.

**Annuity example** – The risks associated with annuitant lives may vary by occupation, size of policy, or region.

**Life insurance example** – The underwriting process assigns each life to discrete underwriting classes, each of which may cover a range of expected mortality.
Stochastic Mortality / Longevity Projection

Volatility Around Baseline Expected Mortality Table

Distribution of Basis Adjustment Factors
Mean = 100%

- Std Dev = 2.50%
- Std Dev = 5.00%
- Std Dev = 10.00%
Stochastic Mortality / Longevity Projection
MODELED SOURCES OF VOLATILITY

3. Trend Risk (Mortality Improvement Volatility)

   A. Long term mortality improvement trends
   B. Short-Term (annual) mortality improvement volatility
   C. Correlation in mortality improvement trend volatility

Varies by Age, Gender and Population
Stochastic Mortality / Longevity Projection
Historic US Mortality Improvement

Annual Improvement Male
5-Year Age Groups

1950-1975

Correlation = 71%
Std Dev_{40} = 2.8%
Std Dev_{75} = 2.1%

1975-2007

Correlation = 16%
Std Dev_{40} = 3.5%
Std Dev_{75} = 1.4%

Ages 38-43
Ages 73-78


-0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1
Stochastic Mortality / Longevity Projection

US Mortality Improvement 1970-2010 for Males Ages 70-79 and 80-89

<table>
<thead>
<tr>
<th>Year</th>
<th>Ages 70-79</th>
<th>Ages 80-89</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>10-Yr Avg</td>
<td>10-Yr Avg</td>
</tr>
<tr>
<td>1973</td>
<td>1.41%</td>
<td>1.79%</td>
</tr>
<tr>
<td>1975</td>
<td>1.00%</td>
<td>0.98%</td>
</tr>
<tr>
<td>1977</td>
<td>0.50%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1979</td>
<td>0.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1981</td>
<td>1.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1983</td>
<td>2.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1985</td>
<td>3.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1987</td>
<td>4.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1989</td>
<td>5.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1991</td>
<td>6.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1993</td>
<td>7.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1995</td>
<td>8.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1997</td>
<td>9.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>1999</td>
<td>10.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>2001</td>
<td>11.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>2003</td>
<td>12.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>2005</td>
<td>13.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>2007</td>
<td>14.00%</td>
<td>0.84%</td>
</tr>
<tr>
<td>2009</td>
<td>15.00%</td>
<td>0.84%</td>
</tr>
</tbody>
</table>

Correlation Coefficient
- Short-Term: 88.10%
- Long-Term: 96.14%

Short-Term: 1.41%
Long-Term: 0.50%

Correlation Coefficient
- Short-Term: 88.10%
- Long-Term: 96.14%
Stochastic Mortality / Longevity Projection
Stochastic Mortality / Longevity Projection

and Scenario 1 Sample Stochastic Projections for 100 years
Stochastic Mortality / Longevity Projection

and Scenario 2 Sample Stochastic Projections for 100 years
4. Mortality Volatility by Cause of Death (Extreme Long Term Events)

Events that cause mortality rates to change faster and more abruptly than anticipated in the other sources.

Examples:
- Effective new treatments for specific diseases (increasing longevity)
- Evolution of drug-resistant infections (increasing mortality)

*How will COVID impact long term mortality rates?*
Stochastic Mortality / Longevity Projection
Male Lives (US Population 2000-2010) - Mortality Rate by Cause of Death

Assume 25% Reduction in Coronary Disease Starting At Age 80

Unadjusted 2000 US Annuity Basic

Assume 25% Reduction in Coronary Disease Starting At Age 80
5. Catastrophes (*Catastrophic Short Term Events*)

*Abrupt temporary deviations in mortality trends*

Examples:
- Pandemic – unfortunately, all too real now
- Terrorism
- Natural Disaster

May not be 100% correlated across ages, genders and segments of the population.
6. Selection / Anti-Selection Effect

Effect of underwriting wears off ➔ Select and Ultimate Mortality Tables

➔ preferred or substandard selection risk may wear off, and
➔ anti-selection risk may wear off, too

That produces uncertainty:

a) around the length of the initial selection period,
b) around years over which preferred or substandard rating takes to wear off
c) around ultimate level of mortality after the completion of the wearing off.
Stochastic Mortality / Longevity Projection

MODELED SOURCES OF VOLATILITY

1. Poisson Risk
   *Random distribution of date of death*

2. Volatility Around Baseline Expected Mortality Table (Basis Risk)
   *Scalar applied to all baseline mortality rates before improvement and adjustments*

3. Mortality Improvement Volatility (Trend Risk)
   *Adjustments to expected improvement by attained age and calendar year*

4. Mortality Volatility by Cause of Death (Extreme Long Term Events)
   *Mortality rates change faster and more abruptly than anticipated in the other sources.*

5. Catastrophic Short Term Events
   *Abrupt temporary deviations in mortality rates*

6. Selection / Anti-Selection Effect
   *How long does (anti-) selection last and how quickly does it grade off?*
Stochastic Mortality / Longevity Projection

MODELED SOURCES OF VOLATILITY

Historic and Projected Annual Mortality Rates
Age 70 Male – 25 Scenarios
Stochastic Longevity Analysis
Articles, Research Papers & Presentations

A. Article: Evaluating the cost of longevity volatility on VA guaranteed living benefits

1. Investment hedging may not fully offset longevity risks.
2. Longevity volatility may cause unforeseen losses
3. However, deterministic margins may not recognize diversification of investment and longevity risks
4. The actuary can use stochastic projections to assign value of longevity risk to various risk tolerances.
   • Tool For Fine Tuning Risk Tolerance
   • Provides Measures To Balance Risk Management And Product Pricing
   • May Identify Unrecognized Excess Embedded In Static Margins
   • May Help Find Redundancies In Asset Requirements Of Existing Blocks
   • Enhance Economic Capital Measurements
Stochastic Longevity Analysis
Articles, Research Papers & Presentations

B. Research Paper: Diversification of Longevity and Mortality Risk

Provide insight into the diversification of mortality and longevity risks

Areas in which stochastic liability modeling can be helpful

- Pricing - Guide the setting of fixed margins which will affect profitability and competitiveness
- Economic Capital - Insight into underlying risk metrics for management of capital resources
- Mix of Business - Analysis may provide insight into managing the mix of business to optimize profitability
Thank you
Polling Question #2

In today’s low interest rate environment, how important do you consider the longevity assumption in the valuation of longevity-exposed liabilities?

A. Quite important
B. Having growing importance, but only somewhat important
C. Not that important
Term Certain Immediate Annuity
Term Certain Reserve Comparison

Reserve Development

Reserve Development

Reserve Development
Term Certain Reserve Comparison
Term Certain Reserve Comparison

Reserve Development

Reserve Development

Reserve Development
Life Contingency
Immediate Annuity
Term Certain Reserve Comparison
Mortality Comparison
Term Certain Reserve Comparison
Term Certain Reserve Comparison

Mortality Comparison
Male at Age 65
Term Certain Reserve Comparison

Mortality Comparison
Male at Age 65

Graph showing mortality comparison at age 65 with two labeled points A and B.
Life Contingency with TC Immediate Annuity
Term Certain with Life Contingency Reserve

Reserve Development

10-year term certain

Annuity Factor

Benefit Amount

Benefit amount
Term Certain with Life Contingency Reserve
Inforce Study
### Immediate Annuity Attained Age Study

#### Empirical Study

<table>
<thead>
<tr>
<th>Age</th>
<th>CDF Count</th>
<th>PFD Count</th>
<th>TC</th>
<th>NTC</th>
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<tr>
<td>10</td>
<td>96</td>
<td>36</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>157</td>
<td>161</td>
<td>117</td>
<td>44</td>
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<td>30</td>
<td>607</td>
<td>410</td>
<td>288</td>
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<tr>
<td>40</td>
<td>1,305</td>
<td>597</td>
<td>361</td>
<td>236</td>
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<tr>
<td>50</td>
<td>2,640</td>
<td>1,436</td>
<td>701</td>
<td>738</td>
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<td>60</td>
<td>7,692</td>
<td>5,052</td>
<td>2,149</td>
<td>2,902</td>
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<tr>
<td>70</td>
<td>44,717</td>
<td>37,026</td>
<td>8,125</td>
<td>28,900</td>
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<tr>
<td>80</td>
<td>75,458</td>
<td>30,741</td>
<td>5,371</td>
<td>25,370</td>
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<tr>
<td>90</td>
<td>87,890</td>
<td>12,462</td>
<td>2,591</td>
<td>9,641</td>
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<tr>
<td>100</td>
<td>99,862</td>
<td>11,972</td>
<td>3,260</td>
<td>8,704</td>
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<tr>
<td>110</td>
<td>100,000</td>
<td>128</td>
<td>75</td>
<td>62</td>
</tr>
</tbody>
</table>

#### Total

- **100,000**
- **23,075**
- **78.92%**

#### Empirical Attained Age Distribution

- CDF Count
- PFD Count

#### Term Certain

- Attained Age Distribution

#### Life Contingency with TC

- Attained Age Distribution
Risk Management
Immediate Annuity Attained Age Study

<table>
<thead>
<tr>
<th>Current age</th>
<th>Life expectancy from now</th>
<th>1 in 4 chance of reaching</th>
<th>1 in 10 chance of reaching</th>
<th>Chance of reaching 100</th>
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</thead>
<tbody>
<tr>
<td>25</td>
<td>88</td>
<td>99</td>
<td>104</td>
<td>20.7%</td>
</tr>
<tr>
<td>35</td>
<td>87</td>
<td>97</td>
<td>101</td>
<td>17.0%</td>
</tr>
<tr>
<td>45</td>
<td>86</td>
<td>96</td>
<td>102</td>
<td>12.7%</td>
</tr>
<tr>
<td>55</td>
<td>86</td>
<td>95</td>
<td>100</td>
<td>10.9%</td>
</tr>
<tr>
<td>65</td>
<td>87</td>
<td>94</td>
<td>99</td>
<td>8.6%</td>
</tr>
<tr>
<td>75</td>
<td>88</td>
<td>94</td>
<td>99</td>
<td>7.4%</td>
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<td>85</td>
<td>92</td>
<td>95</td>
<td>99</td>
<td>6.9%</td>
</tr>
<tr>
<td>95</td>
<td>98</td>
<td>100</td>
<td>102</td>
<td>20.5%</td>
</tr>
<tr>
<td>105</td>
<td>106</td>
<td>107</td>
<td>108</td>
<td></td>
</tr>
</tbody>
</table>

A male currently aged 65 has an average life expectancy of 87; however he has a one in four chance of living to 94 and a one in ten chance of living to 99. If individuals in this cohort saved expecting to live to 87 (this is assuming underestimation is not an issue), a quarter will have under-saved and live for a further 7 years, potentially without an adequate income.

© Source quoted from Office for National Statistics (ONS)
Percentage Population Age 65 and over: 2013 - 2017

Note: Counties with coefficient of variation less than 30 percent and 50 or more unweighted respondents aged 65 and over meet statistical standards for reliability.
Population Percentage Change

Under 18 population: 2010 to 2019

65 and older population: 2010 to 2019

© Source quoted from U.S Department of Commerce
Retirement Service Market Risk Implication
SPIA and Annuitization
Asset Under Management (Annuity Products)

<table>
<thead>
<tr>
<th>Deferred Annuity Net Flows</th>
<th>Variable</th>
<th>Fixed Rate</th>
<th>Indexed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning Assets (06/30/17)</td>
<td>$2,652.6</td>
<td>$456.6</td>
<td>$303.4</td>
<td>$2,412.7</td>
</tr>
<tr>
<td>Inflows</td>
<td>22.9</td>
<td>7.4</td>
<td>13.6</td>
<td>43.2</td>
</tr>
<tr>
<td>Outflows</td>
<td>39.8</td>
<td>11.9</td>
<td>6.5</td>
<td>58.1</td>
</tr>
<tr>
<td>- Full Surrenders</td>
<td>26.1</td>
<td>9.5</td>
<td>2.6</td>
<td>38.2</td>
</tr>
<tr>
<td>- Other Outflows</td>
<td>13.7</td>
<td>2.4</td>
<td>3.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Investment Earnings</td>
<td>56.6</td>
<td>3.4</td>
<td>3.6</td>
<td>63.9</td>
</tr>
<tr>
<td>OTHER</td>
<td>0.4</td>
<td>0.1</td>
<td>-0.6</td>
<td>-0.3</td>
</tr>
<tr>
<td>Ending Assets (09/30/17)</td>
<td>$2,091.8</td>
<td>$455.6</td>
<td>$403.8</td>
<td>$2,551.3</td>
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</table>
Questions?
Polling Question #3

Socio-economic factors can be a variable in mortality assumption setting. In the future, do you anticipate differences in mortality experience of these sub-populations to...

A. Grow
B. Stay about the same
C. Decline
Longevity Risk: Drivers of Historic Mortality Improvements and the Impact of Socioeconomics on Trend Risk

J. Douglas Fullam, ASA
SOA – Session 7B Stress Analysis on Longevity Risk
How Are We Evaluating Risk?

Today

• Mortality tables built with limited information, e.g., age, sex, and smoking status and duration

Looking Deeper

• Differences in absolute mortality correlated with differences in trend
• Non-smokers – Faster Improvement in mortality
• High Incomes – Faster Improvement in mortality
• …
Industry – Mortality Projection Tables (i.e. MP 2014 to 2019)

Improvements are Dropping

Age 70: Improvement Rates

Not improved accuracy, function of ultimate assumption
Drivers of Change on Population

• Behavior Changes: Biggest driver of change in mortality
  – May exist in perpetuity or for a period of time
  – Historical Examples
    ▪ Drop in smoking rates
    ▪ Increased Obesity and Diabetes
    ▪ Change in health screenings

• Medical Advancements
  – Exist in perpetuity
  – Specific to disease and profile of the individual
Improvement Rates per Annum – SSA Data (MP 2019 Table)
Long-Term Demographic Impacts

Male Age-Adjusted Mortality rates
Improvement Rates per Annum: SSA Data (MP Table) vs. Actual Pension
2004 to 2016

70-90% of most plans’ participants fall in this box

* Actual is pulled from experience study data published by SOA
Mortality Rates for Various Socioeconomic and Behavior Diverged Between 2005 and 2015
Overview of Adjustments

<table>
<thead>
<tr>
<th>Absolute Adjustments</th>
<th>Trend Adjustments</th>
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<tbody>
<tr>
<td><strong>Base Mortality</strong></td>
<td></td>
</tr>
<tr>
<td>Cause of Death A</td>
<td></td>
</tr>
<tr>
<td>Cause of Death B</td>
<td></td>
</tr>
<tr>
<td><strong>Yr. 2020</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Underwriting Adjustment</strong></td>
<td></td>
</tr>
<tr>
<td>Cause of Death A</td>
<td>Profile 1</td>
</tr>
<tr>
<td>Cause of Death B</td>
<td>Profile 2</td>
</tr>
<tr>
<td><strong>Yr. 2020</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td></td>
</tr>
<tr>
<td>Cause of Death A</td>
<td></td>
</tr>
<tr>
<td>Cause of Death B</td>
<td></td>
</tr>
<tr>
<td><strong>Yr. 2020</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lines indicate slope of trend</strong></td>
<td></td>
</tr>
<tr>
<td>Cause of Death A</td>
<td></td>
</tr>
<tr>
<td>Cause of Death B</td>
<td></td>
</tr>
<tr>
<td><strong>Yr. 2020</strong></td>
<td></td>
</tr>
<tr>
<td>Cause of Death A</td>
<td></td>
</tr>
<tr>
<td>Cause of Death B</td>
<td></td>
</tr>
<tr>
<td><strong>Yr. 2021</strong></td>
<td></td>
</tr>
<tr>
<td>Cause of Death A</td>
<td></td>
</tr>
<tr>
<td>Cause of Death B</td>
<td></td>
</tr>
<tr>
<td><strong>Yr. 2022</strong></td>
<td></td>
</tr>
</tbody>
</table>
How Do We Find and Weigh Correlations in Mortality Risk Factors?
Understanding the Impact of Correlation

- **Artificial neural networks** enable us to better understand how individual socioeconomic risk factors correlate with one another and impact overall mortality.
- Income is related to mortality but is also correlated with **other factors**:

  - Breaking down **biomedical information** and leveraging machine learning capabilities provides a more informed view of risk.
Derive Risk Relative to Societal or Medical Changes

50-Year-Old Male: Average Mortality Rate by Year and Blood Pressure Quintile

Mortality Rate

2010 2020 2030 2040 2050 2060 2070 2080 2090

Quintile 1  Quintile 2  Quintile 3  Quintile 4  Quintile 5
Overall Mortality: 45-54 Years Old, Male
Combining Aggregate and Detailed Risk

Improved Aggregate Modeling

- Better Liability Estimate
- Better Longevity Assessment
- Improved Portfolio Selection

Individualized Risk Assessment
Stochastic Solutions Improve Risk Assessments

Range of Risk
# Example – Liability Distribution

<table>
<thead>
<tr>
<th>Group</th>
<th>Comment</th>
<th>1%</th>
<th>5%</th>
<th>10%</th>
<th>20%</th>
<th>50%</th>
<th>80%</th>
<th>90%</th>
<th>95%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Similar to Industry</td>
<td>15,359,507</td>
<td>15,782,838</td>
<td>16,057,188</td>
<td>16,346,478</td>
<td>16,925,016</td>
<td>17,505,762</td>
<td>17,799,214</td>
<td>18,038,620</td>
<td>18,466,364</td>
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<tr>
<td>Underwriting Only</td>
<td>Lower Incomes &amp; Increased Smoking Risk</td>
<td>14,832,292</td>
<td>15,072,413</td>
<td>15,471,703</td>
<td>15,595,153</td>
<td>16,082,785</td>
<td>16,684,523</td>
<td>16,892,344</td>
<td>17,226,657</td>
<td>17,499,188</td>
</tr>
<tr>
<td>Underwriting + Trend</td>
<td>Applied Trend Differences</td>
<td>14,804,616</td>
<td>14,960,807</td>
<td>15,425,733</td>
<td>15,471,975</td>
<td>15,923,947</td>
<td>16,544,497</td>
<td>16,715,057</td>
<td>17,099,099</td>
<td>17,302,528</td>
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## Why is this important?

- **Risk Differentiation**
  - Improved price differentiating for pricing actuaries
  - Incorporating trend differences increase risk assessment
- **Longevity Modeling**
  - Set risk tolerances
  - Incorporate
  - Improved portfolio selection for ERM
  - Better ALM assessment

## Assumptions & Methods & Data

- PRT In-pay Block
- DR = 4.00%
- Average Age = ~78
- Average Annual Benefit = ~4600
- COLA = No
- Individuals = 500
- Stochastic Model Output
  - Results based on Verisk's Life Risk Navigator software

<table>
<thead>
<tr>
<th>Liability – Est. from Industry Tables</th>
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<td>Underwriting + Trend</td>
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Questions?

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Visit:
Verisk.com/Life
Polling Question #4

Which of the following statements about COVID-19's impact on future longevity do you most agree with?

A. The short-term effect of additional deaths will prove to be more significant than any long-term effects

B. The long-term effect of more robust, healthier individuals surviving will significantly extend longevity

C. The long-term negative health effects to be experienced by COVID-19 survivors, as well as the decrease in preventive care by the wider population, will significantly shorten longevity

D. The pandemic's knock-on impacts of depressed, low interest rates completely outweighs any longevity impacts
2020 VIRTUAL ANNUAL MEETING & EXHIBIT