Practical Aspects of Mortality Improvement Modeling

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Actuaries' Club of the Southwest 2014 Fall Meeting
Presentation Outline

- Insurance vs. Population Data
- Consideration for Smoking Trends
- Methodologies
- Mortality Improvement Examples
Insurance vs. Population Data
Male select vs. ultimate period

<table>
<thead>
<tr>
<th>Issue Age</th>
<th>Duration 1</th>
<th>Duration 5</th>
<th>Duration 10</th>
<th>Duration 20</th>
<th>Attained Age</th>
<th>Ultimate</th>
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<td>2.4%</td>
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Female select vs. ultimate period

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<th>Duration 10</th>
<th>Duration 20</th>
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<th>Ultimate</th>
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<td>4.9%</td>
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<td>25</td>
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Comparison of SOA Ultimate Table Rates

### Male Mortality Rates

<table>
<thead>
<tr>
<th>Age</th>
<th>57-60</th>
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<th>75-80</th>
<th>85-90</th>
<th>90-95</th>
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<td>1.01</td>
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<td>30-39</td>
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<td>40-49</td>
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<td>50-59</td>
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<td>80-89</td>
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</table>

### Female Mortality Rates

<table>
<thead>
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<th>Age</th>
<th>57-60</th>
<th>65-70</th>
<th>75-80</th>
<th>85-90</th>
<th>90-95</th>
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<tr>
<td>20-29</td>
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<td>30-39</td>
<td>1.10</td>
<td>0.95</td>
<td>0.78</td>
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<td>0.77</td>
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<tr>
<td>40-49</td>
<td>2.33</td>
<td>2.43</td>
<td>2.08</td>
<td>1.56</td>
<td>1.46</td>
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<tr>
<td>50-59</td>
<td>5.62</td>
<td>5.48</td>
<td>4.75</td>
<td>4.16</td>
<td>4.28</td>
</tr>
<tr>
<td>60-69</td>
<td>13.65</td>
<td>12.54</td>
<td>10.87</td>
<td>10.04</td>
<td>10.76</td>
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<tr>
<td>70-79</td>
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<td>25.33</td>
<td>26.45</td>
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<tr>
<td>80-89</td>
<td>109.24</td>
<td>104.10</td>
<td>83.22</td>
<td>73.17</td>
<td>73.87</td>
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</tbody>
</table>
Comparison of SOA Ultimate to Population – Male

SOA Ultimate as a Percent of USA Population 1958-1992

SOA Ultimate as Percent of Population

Male Attained Age

1958
1967
1977
1987
1992
Comparison of SOA Ultimate to Population – Female

SOA Ultimate as a Percent of USA Population 1958-1992

Female Attained Age

SOA Ultimate as Percent of Population

1958
1967
1977
1987
1992
Comparison of SOA Ultimate to Population – Male

SOA Ult vs. USA Pop Improvement Comparison 1958-1992

Annualized Improvement Rate
Male Attained Age

Comparison of SOA Ultimate to Population – Male
Comparison of SOA Ultimate to Population – Female

SOA Ult vs. USA Pop Improvement Comparison 1958-1992

Female Attained Age

Annualized Improvement Rate

SOA

USA
Consideration for Smoking Trends
US Population Historical Smoking Trends

Cigarette Smoking, by Decade

<table>
<thead>
<tr>
<th>Decade</th>
<th>Average % who smoke</th>
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<tbody>
<tr>
<td>1940s</td>
<td>43</td>
</tr>
<tr>
<td>1950s</td>
<td>44</td>
</tr>
<tr>
<td>1960s*</td>
<td>40</td>
</tr>
<tr>
<td>1970s</td>
<td>40</td>
</tr>
<tr>
<td>1980s</td>
<td>32</td>
</tr>
<tr>
<td>1990s</td>
<td>26</td>
</tr>
<tr>
<td>2000s</td>
<td>24</td>
</tr>
</tbody>
</table>

* 1960s includes only one measurement

Source: Gallop Poll - July 24, 2008; U.S. Smoking Rate Still Coming Down
US Population Current Smoking Trends by Age

Source: Gallop Poll - July 24, 2008; U.S. Smoking Rate Still Coming Down
### Smoking Adjusted Improvement Rates

- **How much improvement is due to reduced smoking?**
- **Example for male ages 40-50**
- **Constant S/N ratio shouldn’t really be constant**
- **25% of annual improvement could be from S/N changes**

<table>
<thead>
<tr>
<th>Year</th>
<th>%Smoker</th>
<th>U.S. Pop Male Mort Ages 40-50</th>
<th>Improvement AG Factor Since 1946</th>
<th>Tillinghast S/N Ratio</th>
<th>Implied NS Mort Since 1946</th>
<th>Improvement NS Factor Since 1946</th>
<th>Implied SM Mort Since 1946</th>
<th>Improvement SM Factor Since 1946</th>
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</thead>
<tbody>
<tr>
<td>1946</td>
<td>43.0%</td>
<td>0.00729</td>
<td>1.000</td>
<td>2.35</td>
<td>0.00461</td>
<td>1.000</td>
<td>0.00922</td>
<td>1.000</td>
</tr>
<tr>
<td>1955</td>
<td>44.0%</td>
<td>0.00614</td>
<td>0.842</td>
<td>2.35</td>
<td>0.00385</td>
<td>0.835</td>
<td>0.00770</td>
<td>0.835</td>
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<tr>
<td>1965</td>
<td>40.0%</td>
<td>0.00607</td>
<td>0.832</td>
<td>2.35</td>
<td>0.00394</td>
<td>0.854</td>
<td>0.00788</td>
<td>0.854</td>
</tr>
<tr>
<td>1975</td>
<td>40.0%</td>
<td>0.00541</td>
<td>0.743</td>
<td>2.35</td>
<td>0.00352</td>
<td>0.762</td>
<td>0.00703</td>
<td>0.762</td>
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<tr>
<td>1985</td>
<td>32.0%</td>
<td>0.00424</td>
<td>0.582</td>
<td>2.35</td>
<td>0.00296</td>
<td>0.642</td>
<td>0.00592</td>
<td>0.642</td>
</tr>
<tr>
<td>1995</td>
<td>26.0%</td>
<td>0.00435</td>
<td>0.596</td>
<td>2.35</td>
<td>0.00322</td>
<td>0.698</td>
<td>0.00644</td>
<td>0.698</td>
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<tr>
<td>2004</td>
<td>24.0%</td>
<td>0.00367</td>
<td>0.504</td>
<td>2.35</td>
<td>0.00277</td>
<td>0.601</td>
<td>0.00555</td>
<td>0.601</td>
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</table>

**1946-2004 Annualized Improvement Rate**

- 1.2%
- 0.9%
- 0.9%
Methodologies
Methodologies to Analyze Mortality Improvement

- **Lee-Carter**
  - Pro: Widely used by biostatisticians
  - Con: Overly complex and difficult to explain to laymen

- **Use raw mortality rates**
  - Pro: Produces a mean improvement rate and a standard deviation
  - Con: Uses raw mortality rates and makes no attempt to smooth or trend the data

- **Create a regression model from the raw rates**
  - Pro: Impact of anomalous values (or outliers) is minimized and thus may represent a better view of mortality trends
  - Con: Cannot be used to calculate a standard deviation for the dataset
**Lee-Carter**

- \( \ln(mx,t) = a_x + (b_x)(k_t) + \varepsilon_{x,t} \)
  - \( m_{x,t} \) is central death rates at age \( x \) in year \( t \)
  - \( k_t \) is the index of mortality change
  - \( a_x \) and \( b_x \) are the age specific constant vectors
  - \( \varepsilon_{x,t} \) is the residual error term with mean 0 and variance \( \sigma^2 \)

**Normalization**
- \( a_x = \) average of \( \ln(m_{x,t}) \)
- \( b_x \) sum to 1
- \( k_t \) sum to 0

**Two stage approach to fitting the model**
1. Singular value decomposition applied to matrix of \( [\ln(m_{x,t}) - a_x] \) to obtain estimates of \( b_x \) and \( k_t \)
2. Time series of \( k_t \) is re-estimated so total number of deaths in model matches total number of actual deaths

**Annual Improvement rate** \( a_{x,t} \sim 1 - \exp[b_x \times (k_{t+1} - k_t)] \)
Use Raw Mortality Rates

<table>
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<th>Year</th>
<th>Qx Raw</th>
<th>Ann Imp</th>
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<tbody>
<tr>
<td>1950</td>
<td>0.013065</td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td>0.013245</td>
<td>-1.4%</td>
</tr>
<tr>
<td>1952</td>
<td>0.013095</td>
<td>1.1%</td>
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<tr>
<td>1953</td>
<td>0.012932</td>
<td>1.2%</td>
</tr>
<tr>
<td>1954</td>
<td>0.012351</td>
<td>4.5%</td>
</tr>
<tr>
<td>1955</td>
<td>0.012185</td>
<td>1.3%</td>
</tr>
<tr>
<td>1956</td>
<td>0.011977</td>
<td>1.7%</td>
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<td>1957</td>
<td>0.012423</td>
<td>-3.7%</td>
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<td>1958</td>
<td>0.012335</td>
<td>0.7%</td>
</tr>
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<td>1959</td>
<td>0.012177</td>
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<td>1960</td>
<td>0.012391</td>
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<tr>
<td>1961</td>
<td>0.011984</td>
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<td>1962</td>
<td>0.012191</td>
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<td>1963</td>
<td>0.012274</td>
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<td>1964</td>
<td>0.012088</td>
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<tr>
<td>1965</td>
<td>0.012208</td>
<td>-1.0%</td>
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<tr>
<td>1966</td>
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<td>0.011997</td>
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<td>1968</td>
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<td>-1.6%</td>
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<td>1969</td>
<td>0.011834</td>
<td>2.9%</td>
</tr>
<tr>
<td>1970</td>
<td>0.011663</td>
<td>1.4%</td>
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Mean 1.24%
Stdev 1.80%
CLT Stdev 0.23%
Create a Regression Model

<table>
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<th>Year</th>
<th>qx(actual)</th>
<th>qx(trend)</th>
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<td>0.012932</td>
<td>0.013157</td>
<td>0.013656</td>
</tr>
<tr>
<td>1954</td>
<td>0.012351</td>
<td>0.013021</td>
<td>0.013455</td>
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<td>0.012885</td>
<td>0.013257</td>
</tr>
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<td>1956</td>
<td>0.011977</td>
<td>0.012748</td>
<td>0.013061</td>
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<td>1957</td>
<td>0.012423</td>
<td>0.012612</td>
<td>0.012869</td>
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<td>1958</td>
<td>0.012335</td>
<td>0.012476</td>
<td>0.012680</td>
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<td>1959</td>
<td>0.012177</td>
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<td>0.012493</td>
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<td>0.011600</td>
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<td>0.010771</td>
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<td>1970</td>
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<td>0.010840</td>
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Model Parameters:

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<th>Parameter</th>
<th>Linear</th>
<th>Exponential</th>
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<tr>
<td>m</td>
<td>-0.00014</td>
<td>0.98528</td>
</tr>
<tr>
<td>b</td>
<td>27.940%</td>
<td>5.1695E+10</td>
</tr>
<tr>
<td>Ann'l Imp</td>
<td>1.53%</td>
<td>1.47%</td>
</tr>
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Long-Term Improvement Using the Central Limit Theorem

- It is important to understand that the standard deviation we have calculated represents the fluctuation in yearly improvement rates.

- In projecting future mortality, we need to calculate the fluctuation in the long-term mean of improvement rates.

- We use the Central Limit Theorem to determine the standard deviation of the mean of our historical sample dataset from the standard deviation of the annual improvement rates.

- \[ \text{Std dev (imp rate means)} = \frac{\text{std dev (dataset imp rates)}}{\sqrt{\text{dataset size}}} \]
Choosing Appropriate Historical Periods

- In determining average historical improvement rates, it is important to use only the most appropriate time periods from the available dataset.

- We begin by looking at the pattern of mortality rates since 1950 by age group and gender.

- A year in which a significant and permanent change occurred in the pattern for a specific age group and gender may be used to censor the data prior to that year.

- However, care is always taken to ensure that we are using a reasonable number of data points.

- For example, a change that occurred in 2003 would not normally warrant excluding prior data without a sufficiently strong rationale.
Examples
US Population – Males

US Mortality Rate Historical Trend 1950-2007
US Population – Males

US Mortality Male 45-49 Trended Annual Improvement = .84%
US Population – Males

US Mortality Male 50-54 Trended Annual Improvement = .69%
US Population – Males

US Mortality Male 60-64 Trended Annual Improvement = 2.18%

Calendar Year

Mortality Rate per 1000
US Mortality Rate Historical Trend 1950-2007

Mortality Rate per 1000
Calendar Year

US Population – Females
US Mortality Female 40-44 Trended Annual Improvement = .11%
US Population – Females

US Mortality Female 50-54 Trended Annual Improvement = .54%

Mortality Rate per 1000 Calendar Year

Calendar Year


1000qx Trend
US Population – Females

US Mortality Female 60-64 Trended Annual Improvement = 1.69%

Mortality Rate per 1000 Calendar Year

US Mortality Female 60-64 Trended Annual Improvement = 1.69%

1000qx Trend
Mortality Experience: The Funnel Effect

David N. Wylde, FSA, MAAA
Pricing Research Actuary, SCOR Global Life Americas

Actuaries' Club of the Southwest 2014 Fall Meeting
Defining the Problem

- Companies with very similar underwriting practices, guidelines, preferred criteria, and marketing strategies often have very different experience.
- Even after normalizing for underwriting mortality class distributions and other identifiable characteristics, credible actual-to-expected ratios for these supposedly similar companies can differ significantly.

- “The Funnel Effect”
  - A company’s mortality experience is partially determined by the population “funneled” to it via distribution channels and market forces.
  - Even though a company’s underwriting process selects and segments this applicant pool, if a company’s funnel draws from a population having worse/better than average mortality, such mortality deviations will permeate the company’s segmented experience due to unspecified, but relevant, population characteristics.

- Let’s take a look at some SCOR reinsurance experience…
Company A/E Ratio Distribution

- SCOR reinsurance experience database
- Exposure years 2004-2011
- Original face amounts $100,000 and above
- Filter on 2, 3, 4, 5, and 6 nontobacco class systems
- Actual to expected ratios by amount based upon SOA 2001 VBT
- Companies with 35 or more claims
Company A/E Ratio Distribution

![Bar chart showing the distribution of A/E ratios for companies. The x-axis represents A/E ratio buckets (30-35%, 35-40%, 40-45%, 45-50%, 50-55%, 55-60%, 60-65%, 65-70%, 70-75%, 75-80%). The y-axis represents the number of companies in each bucket. The highest number of companies (30) is in the 50-55% bucket, and the lowest (2) is in the 75-80% bucket.]

Number of Companies

A/E Ratio Bucket

30-35% 35-40% 40-45% 45-50% 50-55% 55-60% 60-65% 65-70% 70-75% 75-80%
Defining the Experiment

- The funnel effect implies that a company’s early duration mortality experience does not converge at some point to an industry average as measured by, for example:
  - Society of Actuaries Inter-company study
  - Reinsurer’s combined experience table

- The experiment was designed to see if a company’s mortality remained stable over durational time.
  - Did a company with high early duration mortality also have high mortality in later durations?
  - Did a company with low early duration mortality have low mortality in later durations?
Defining the Experiment

- An ideal experiment would look at current early duration actual-to-expected (A/E) ratios for a wide variety of companies and then follow these closed blocks of business for the next 30+ years to see if the initial A/E ratios hold steady into the future (all else being equal).
  - This would provide good evidence that individual company experience does not converge to a common level.

- Unfortunately, I did not have the luxury of waiting this long for results!
  - This allowed me to view A/E ratio trends by company for durations 1-5, 6-10, 11-15, 16-20, and 21-25.
Defining the Experiment

- This form of the experiment is far from perfect due to marketplace evolution over the issue periods surveyed.

- Elements such as target market, product characteristics, distribution channels, underwriting philosophy, company reputation, and mergers/acquisitions could have affected historical mortality experience.

- The data was filtered as much as possible to compensate for these items.
Preliminary Analysis

- Data obtained from 20 companies’ experience.

- The analysis entailed ranking the company A/E ratios (2008 VBT) from lowest (1) to highest (20) for each of the five issue era periods.

- Results for 7 companies appeared to have very stable rankings from period to period.

- An additional 9 companies had rankings that were reasonably stable (one anomalous period).

- The final 4 companies had rankings that varied from period to period.
Consistent Mortality Rank

Consistent Rankings Over Time

- A
- C
- E
- J
- K
- O
- S

Rank

2000-2004, 1-5
1995-1999, 6-10
1990-1994, 11-15
1985-1989, 16-20
1980-1984, 21-25

Rank
One Anomaly

One Anomaly - Fairly Consistent

- B
- D
- F
- H
- I
- M
- T
- P
- R
One Anomaly - Worsening Mortality
Outliers

1 Better, 1 Worse, and 2 Up and Down

Rank

G  L  N  Q
Further Analysis

- These preliminary results were promising since they showed that many companies have maintained their relative mortality position in the marketplace over the past 25 to 30 years.
  - However, the question still persisted as to whether the A/E ratios used to rank the companies remained reasonably stable over that time period.

- The problem I was trying to solve was:
  - Is a company’s early duration mortality experience predictive of later duration mortality?
  - Can pricing actuaries be confident that overall A/E ratios derived from a client’s experience study covering, say, the first 8-10 durations predict later duration A/E ratios?

- To provide an answer to this question, I used the A/E ratio data from the 20 companies and averaged the ratios for durations 1-10 (issue years 1995-2004) and for durations 11-25 (issue years 1980-1994).
### Early Duration vs. Late Duration A/E Ratios

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<thead>
<tr>
<th>Company</th>
<th>Average A/E Ratios (%)</th>
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<tr>
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<tr>
<td>T</td>
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</table>

#### Correlation of Durational AE Ratios by Company

![Graph showing correlation of durational AE ratios by company](image-url)
Analyzing the A/E Ratios

- In statistics, the Pearson product-moment correlation coefficient is a measure of the linear dependence between two variables.
  - Values can range between +100% percent and −100%.
  - 100% is total positive correlation,
  - 0% is no correlation,
  - −100% is total negative correlation.

- \[
r = \frac{1}{n-1} \sum_{i=1}^{n} \left( \frac{X_i - \bar{X}}{s_X} \right) \left( \frac{Y_i - \bar{Y}}{s_Y} \right)
\]
Analyzing the A/E Ratios

- If our predictions of duration 11-25 A/E ratios based upon duration 1-10 A/E ratios were absolutely perfect, all of the data points would fall along the diagonal red line and would produce a correlation coefficient of 100%.
- In reality, the data shows a correlation of around 54%, which indicates a fairly strong positive linear relationship.
What Does it All Mean?

- In general, companies with lower than average A/E ratios for business issued today tend to have lower than average A/E ratios for business issued 10 years ago, 15 years ago, 20 years ago, and so forth. The same holds for companies with higher than average A/E ratios.

- While not conclusive, I believe the results provide some evidence that the level of a company’s early duration experience is predictive of the level of their later duration experience and will not necessarily grade back to an industry average as a block ages.

- A company can make some improvement in its mortality experience by refining underwriting and marketing practices, but as long as it is “fishing in the same pond,” better bait will not necessarily attract better fish.
What Causes the Funnel Effect?

- The Short Answer:
  - I DON’T KNOW!

- The Long Answer:
  - Socio-economic factors may play a bigger part in mortality experience than we traditionally thought.
Socio-economic Factors: A Selection Hypothesis

- Variables from the group of socio-economic measures are candidates to describe and account for some of the differences in mortality experience.

- While likely not directly responsible for the mortality differences, they are proxies for certain behaviors and dynamics on the individual level that can influence mortality significantly.

- Many of these socio-economic measures are easier to record and analyze than some complex individual behavior patterns.
Can We Test the Hypothesis?

- We need a data set that includes:
  - Traditional life insurance selection parameters
    - Health history
    - Biometrics
    - Lab results
    - Tobacco use
  - Socioeconomic measures
    - Income, education, ethnicity, marital status and others
  - Mortality feedback
    - Significant and complete enough to be credible
    - Detailed with date of death and cause of death
Using NHANES as a Data Source

- **NHANES database**
  - Survey designed to measure the health and nutritional status of children/adult US population conducted periodically since the 1960’s
  - Consists of detailed questions, physical exams and extensive laboratory testing
  - Overall >6000 variables measured in continuous NHANES
  - Data is available freely for download, extensively documented
  - Mortality follow-up is available for participants through year 2004 as of year-end 2006.

- **Underwriting NHANES to simulate an insured population**
  - Limit to adult applicants (Age 18+)
  - Use the data that ‘duplicates’ the typical information a US life insurance company would obtain (extensive health questions, exam, labs)
  - Classify tobacco use the way a typical life insurance company would (self reported use plus cotinine testing)
  - Underwrite ‘applicants’ towards a ‘likely std’ / ‘likely substd’ category
The NHANES Mortality Study

- Traditional life insurance mortality study
- Calculate A/E ratios taking age, gender, duration, tobacco status into account
- Express results in terms of Social Security annual tables
- Combine with all available measures (health history, biometric, labs, socio-economic, cause of death)
Typical Socio-economic Measures

- Income
- Educational achievement
- Profession / industry
- Marital status
- Geography
Face Amount as a Socio-economic Measure

Income and Applied Face Amt Data from SCOR Facultative Cases

Avg Applied Face Amt

Income Range

1 to 5000
40,001 to 50,000
90,001 to 100,000
140,001 to 150,000
190,001 to 200,000
240,001 to 250,000
290,001 to 300,000

0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
3,500,000
4,000,000
4,500,000
5,000,000

Avg Face Amt Male
Avg Face Amt Female

1 to 5000
40,001 to 50,000
90,001 to 100,000
140,001 to 150,000
190,001 to 200,000
240,001 to 250,000
290,001 to 300,000

0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
3,500,000
4,000,000
4,500,000
5,000,000

Avg Face Amt Male
Avg Face Amt Female
Mortality Outcomes by Income

Mortality by Income, Males 18-49, Std only, NT only

Mortality by Income, Males 50-79, Std only, NT only

*Expected basis: Social Security annual tables
Mortality Outcomes by Educational Achievement

Mortality by Education, Males 18-49, Std only, NT only

- All: 0.0%
- < HS Graduate: 45.4%
- HS Graduate: 39.4%
- College: 10.0%

Mortality by Education, Males 50-79, Std only, NT only

- All: 0.0%
- < HS Graduate: 39.4%
- HS Graduate: 39.4%
- College: 10.0%

*Expected basis: Social Security annual tables
Conclusion / Summary

- Even after controlling for age, gender, health history and tobacco use, certain socio-economic measures remain predictive of differences in mortality outcomes.

- In the life insurance context, face amounts and income are closely and predictably linked.

- Differences in socio-economic mix by face amount range may contribute more to mortality differences than individual underwriting selection.

- Applying similar individual underwriting to applicant groups of different socio-economic mix is unlikely to result in comparable mortality outcomes.

- While often unsuitable for use as primary individual selection parameters, socio-economic measures can aid in describing overall target groups for certain products more precisely and result in products that are more appropriately structured.
The Reality of Preferred Risk Classification

- The theory
  - Classification accurately system identifies health characteristics of potential insureds
  - Insureds with similar health profiles are grouped together into underwriting classes

- The reality
  - This system is far from perfect!
  - Demarcation of risks is not clean
  - System produces a very fuzzy boundary that puts many insureds into the wrong underwriting class
The Reality of Preferred Risk Classification

- Cox Proportional Hazards Model
  - Model is used very frequently in clinical research studies
  - Analyzes relative mortality among groups having different medical conditions

- My model
  - Created from a database of approximately 435,000 recently underwritten lives
  - Indicators for age, gender, and smoking status
  - Values for build, blood pressure, total cholesterol, and HDL ratio
  - Model was tested and validated using data from SCOR’s proprietary mortality experience database
### Illustrative Extract from Model Input / Output

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</table>
Mortality Distribution – All Lives Combined

![Mortality Distribution Graph]

- Distribution
- Relative Mortality
- Standard
Theoretical Mortality Distribution by Underwriting Class
Actual Mortality Distribution by Underwriting Class
Actual Mortality Distribution by Underwriting Class

![Mortality Distribution Graph]

- **Super Preferred**
- **Preferred**
- **Residual**
Comments About the Results

- To be fair, the majority of today’s knock-out classification methods vary criteria values by age groups and include motor vehicle and personal/family history indicators.

- More companies are using debit/credit classification systems that try to fairly balance positive and negative risk factors.

- These enhancements tend to lessen the mortality overlaps, but certainly will not eliminate them entirely.
Mortality Trends

Thank You!