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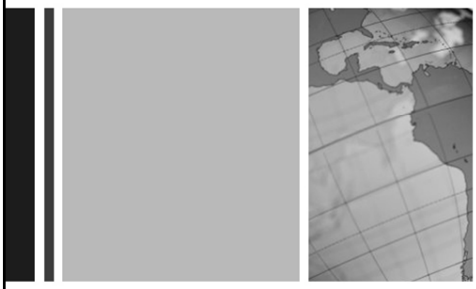

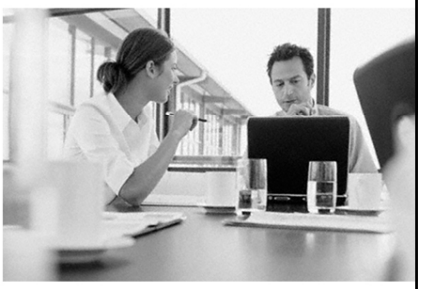

Actuaries' Club of the Southwest

Generalized Linear Modeling for Life Insurers

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Watson Wyatt Worldwide

Agenda

- Current method disadvantages
- GLM background and advantages
- Study case analysis
- Applications

Current Approach of Mortality Analysis (One-Way Analysis)

- Focus on limited risk factors that impact mortality
  - Age, sex, smoker status, may extend to other factors
  - Company experience is sub-divided into categories to examine the relationship of actual to expected mortality experience (A/E ratio)
- Limitations
  - Mortality is simultaneously impacted by all risk factors
  - The subdivision process is limited by the credibility of the experience developed for each sub category.
  - Does not quantify the impact of each risk factor on the mortality result

Application of Predictive Modeling In Life Insurance

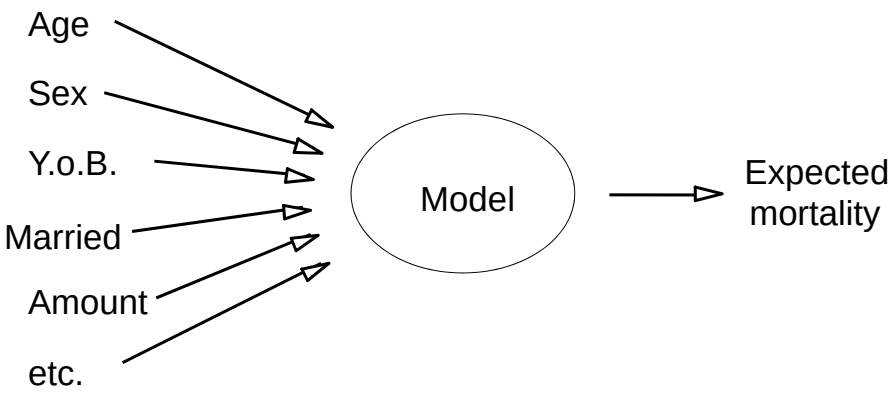
- Offer an alternative to analyze mortality experience compared to Traditional “One-Way” analysis
- One way analysis looks at a single risk factor at a time
- Predictive Modeling Approach will allow for interactions between all risk factors when analyzing the true impact of the factor under investigation

Benefits of Predictive Modeling In Life Insurance

- Better understanding of the factors influencing the mortality rates, lapse rates or option selection
- Better understanding of the interaction between factors
- Better understanding of the profitability of different lines of business
- Overall competitive advantages

Predictive Modeling

- Statistical model that relates an event (death) with a number of risk factors (age, sex, YOB, amount, marital status, etc.)



Generalized Linear Models (GLMs)

- Special type of predictive modelling
- A method that can model
  - a number

  as a function of
  - some factors
- For instance, a GLM can model
  - Motor claim amounts as a function of driver age, car type, no claims discount, etc …
  - Motor claim frequency (as a function of similar factors)
- Historically associated with non-life personal lines pricing (where there was a pressing need for multivariate analysis)

$$E[\underline{Y}] = \underline{\mu} = g^{-1}(\mathbf{X}.\underline{\beta} + \underline{\xi})$$

$$Var[\underline{Y}] = \phi.V(\underline{\mu}) / \underline{\omega}$$

$$E[\underline{Y}] = \underline{\mu} = g^{-1}(\mathbf{X}.\underline{\beta} \quad)$$

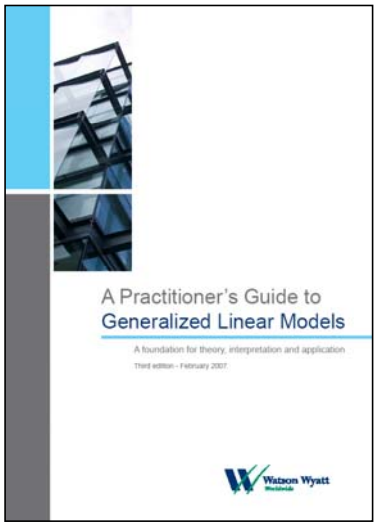
Some function
(user defined)

Parameters to be
estimated
(the answer!)

Observed thing
(data)

Some matrix based on data
(user defined)
as per linear models

Further Theory and Background



- CAS 2004 Discussion Paper Programme
- On CAS Exam 9 syllabus
- Copies available at www.watsonwyatt.com/glm

Generalized Linear Models

- What the mathematics means in practice:
  Probability of death in year =
  Base level for observed population ×
  Factor 1 (based on age/sex) ×
  Factor 2 (based on duration) ×
  Factor 3 (based on amount) …
- Each factor is a series of multiplicative coefficients
- All factors considered simultaneously, allowing for correlations in the data automatically
- Allow for nature of the random process involved
- Provide information about certainty of result
- Robust and transparent

Factor level	Multiplier
F	0.8700
M	1.0000

Factors Often Found to Influence Mortality

- Age, sex, duration
- Amount of benefit
- Geographical
- Lifestyle cluster
- Product type (eg flat or escalating annuity)
- Medical information
- Calendar year of exposure
- Calendar year of birth

Data Considerations

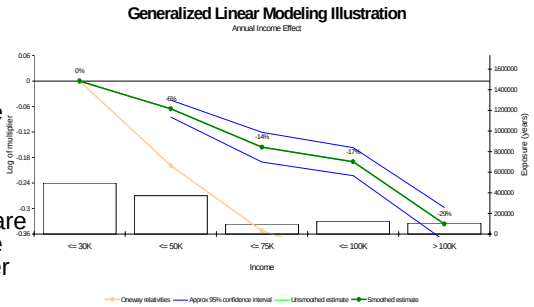
- Bad news: we need around 1,000+ events for a GLM analysis to work
- Good news: because we can have calendar year as a factor in the analysis to pick up trends, we can use more years than normally considered 'safe'
- So GLMs viable with eg 20,000 annuities × 5 years observation
- Can obtain more value from our data

GLM Steps

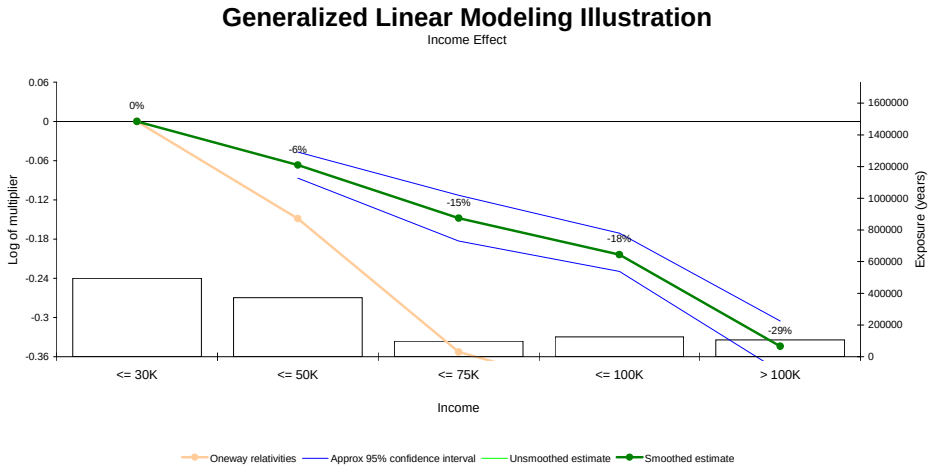
- Pre-modeling analysis
- Model iteration
- Model refinement
- Interpretation of the results

How to Read the Graphs

- All graphs show relative Qx of different categories of one factor against a base level identified by "0%" label. Qx for other levels are "x%" higher or lower than the base level.
- Colors
  - Green: Expected GLM results
  - Orange: "One-way" relatives are the relative death rates for the factor before considering other factors simultaneously.
  - Blue: 95% confidence interval. Tight confidence interval indicates statistical significance.
- Exposure
  - The amount of exposure for a category is indicated by the bar on the x-axis.

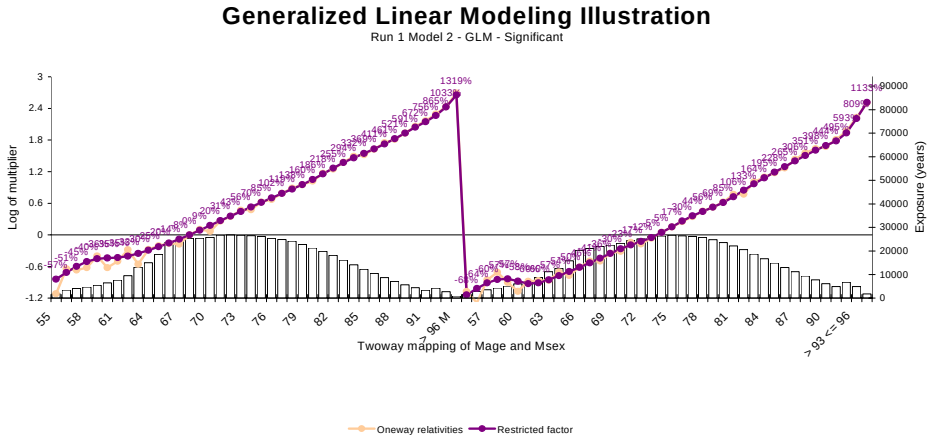


Example 1: Effect of Annuity Amount



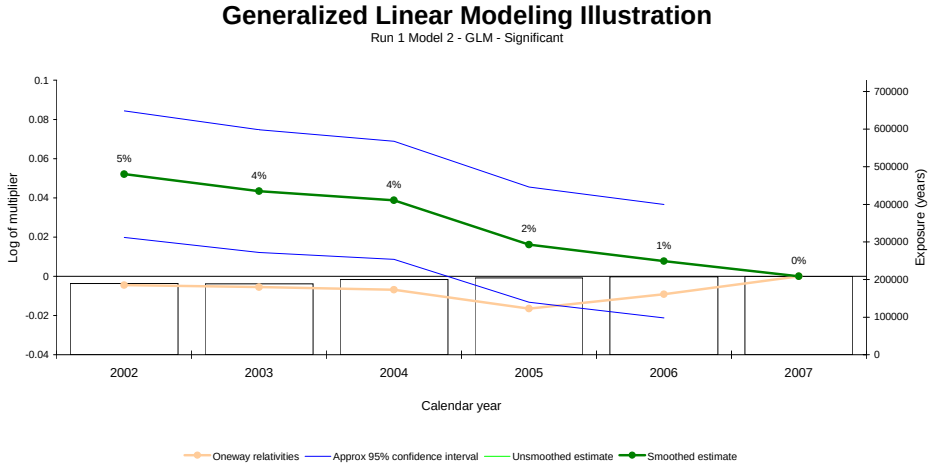
Results show evidence of reduced mortality with increased benefits

Example 2: Impact of age/sex



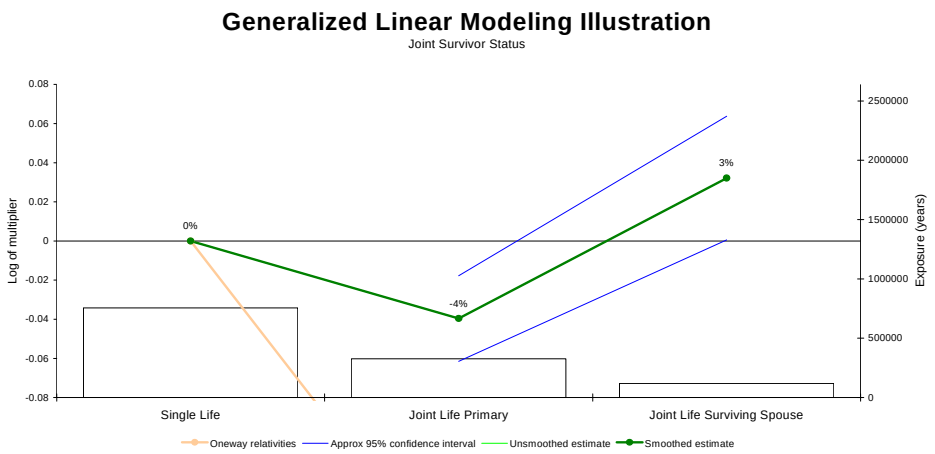
A mortality table is fitted using experience data and the variation of mortality by age is fixed in subsequent analysis of other risk factors

Example 3: Calendar Year Trend



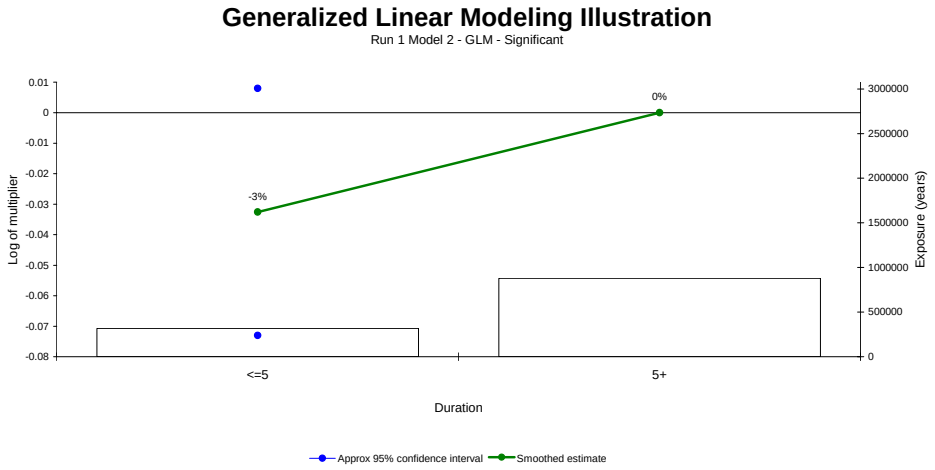
Mortality improvements 1% per annum over previous six years

Example 4: Effect of Joint Life Status



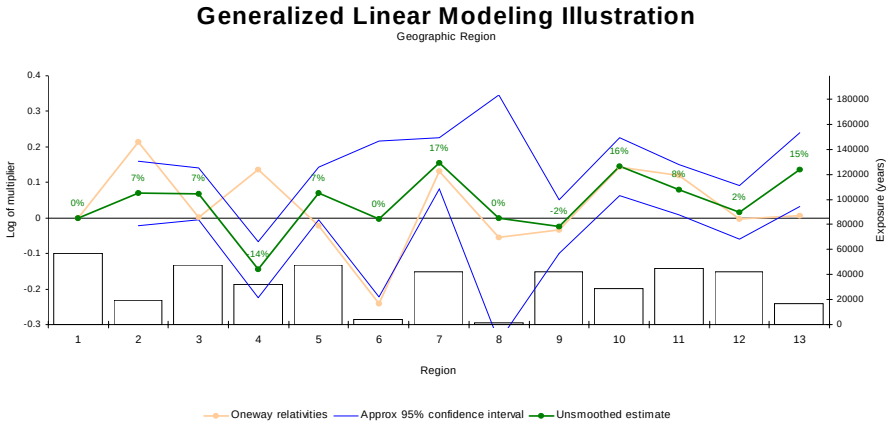
Evidence of "broken heart syndrome" which may influence pricing

Example 5: The Selection Effect



Selection effect is not conclusive

Example 6: Geographic Region Effect



Some regions were found to be statistically significant (4, 7, 10 and 13).

However, we excluded this factor mainly because of the wide confidence interval for the other regions.

How to Derive Mortality Assumptions

Mortality Table
based on 2007 and income < 35K

Age	Female	Male
55	0.00795	0.00955
56	0.00892	0.01077
57	0.00978	0.01201
58	0.01025	0.01307
59	0.01003	0.01373
60	0.00913	0.01387
61	0.00836	0.01394
62	0.00830	0.01438
63	0.00878	0.01518
64	0.00956	0.01617
65	0.01040	0.01721
66	0.01129	0.01835
67	0.01230	0.0197
68	0.01350	0.02138
69	0.01483	0.02338
70	0.01613	0.02562
71	0.01726	0.02802
72	0.01842	0.03059
73	0.01989	0.03337
74	0.02201	0.0364
75	0.02471	0.03969

Calendar year

Factor level	Loading
2002	5.00%
2003	4.00%
2004	4.00%
2005	2.00%
2006	1.00%
2007	0.00%

Income

Factor level	Loading
35K	0.00%
50K	-6.00%
75K	-15.00%
100K	-18.00%
>100K	-29.00%

Joint Status

Factor level	Loading
Joint Life Alive	-4.00%
Surviving Spouse	3.00%
Single	0.00%

Mortality Assumption @ 2007 level, income > 100K Married with Joint Life Status Female

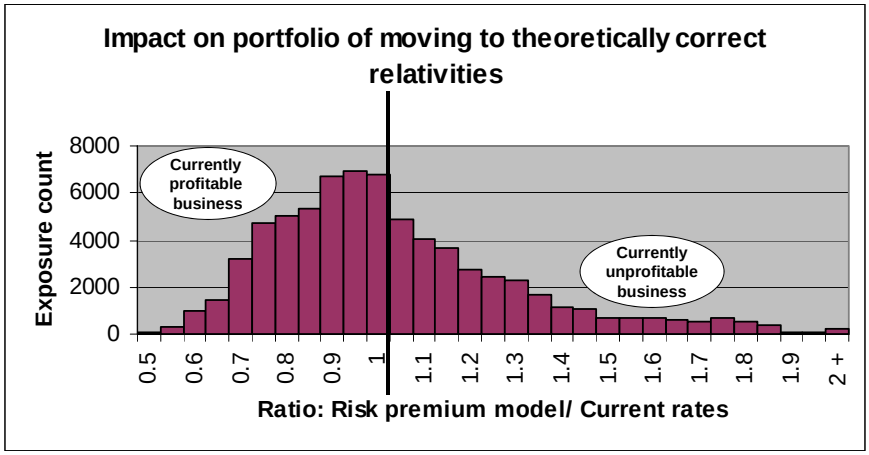
55	0.00542
56	0.00608
57	0.00667
58	0.00699
59	0.00683
60	0.00622
61	0.00570
62	0.00565
63	0.00599
64	0.00652
65	0.00709
66	0.00769
67	0.00838
68	0.00920
69	0.01011
70	0.01099
71	0.01177
72	0.01255
73	0.01356
74	0.01500
75	0.01684

Mortality Assumption for female, 55, income>100K, Married with joint life @2007 level = 0.00795 *(1+0%)*(1-29%)*(1-4%) = 0.00542

Retention Modeling Using GLMs

- Some products profitability depends on lapse or conversion
  - Improve pricing
  - Improve profitability forecasts
  - Improve marketing

Profitability Analysis



Summary

- GLM techniques are widely used in P&C for pricing purposes, but its application in Life Insurance may not be as well established.
- GLMs are robust, transparent and easy to understand.
- By using GLM techniques in the analysis of annuitant mortality, we were able to identify the true impact of various risk factors while allowing for the interactions between these factors.
- The advantage of additional knowledge of product characteristics will allow management to make better underwriting, pricing and marketing decisions to gain business advantage over competitors.