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SOA/CAS Spring Meeting

Application of Predictive Modeling in Life Insurance

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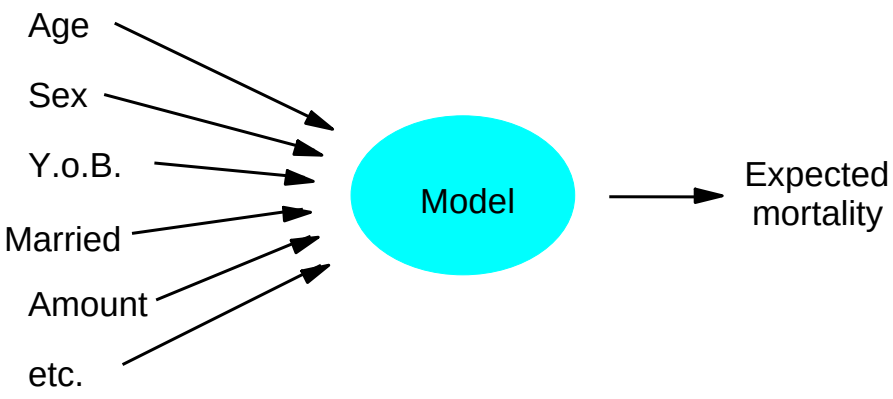
Predictive Modeling

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



Application of Predictive Modeling In Life Insurance

- Predictive Modeling techniques offer an alternative way to analyze mortality experience compared to Traditional “One-Way” analysis
- One way analysis looks at a single risk factor at a time
- However, a Predictive Modeling Approach will allow for interactions between all risk factors when analyzing the true impact of the factor under investigation
- E.g. Annuitants with larger benefit amounts tend to show lighter mortality than others, but this could also be influenced by the underlying mix of gender, occupation, duration, marital status, etc.
- In this presentation we will show the impact of analyzing various risk factors using Predictive Modeling techniques versus traditional one-way analysis.

Current Approach of Mortality Analysis

- Focus on limited risk factors that impact mortality
  - Age, Sex, may extend to other factors (i.e. amount, marital status, and geographical location)
  - Company experience is sub-divided into categories to examine the relationship of actual to expected mortality experience (A/E ratio). This ratio is typically applied to a standard table varying by age and sex
- Limitations
  - Mortality is simultaneously impacted by all risk factors and has to be analyzed with all factors together
  - The subdivision process is limited by the credibility of the experience developed for each sub category. Based on the lack of data it may not be possible to identify and evaluate all factors impacting mortality.
  - The current approach does not quantify the impact of each risk factor on the mortality result.
- Describe a more sophisticated mathematical approach to be used to identify the risk factors affecting the mortality of the selected block of business, and assign weights to each factor in order to develop the mortality experience assumption

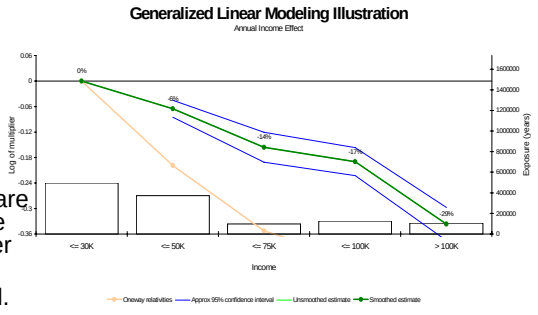
Generalized Linear Models (GLMs)

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

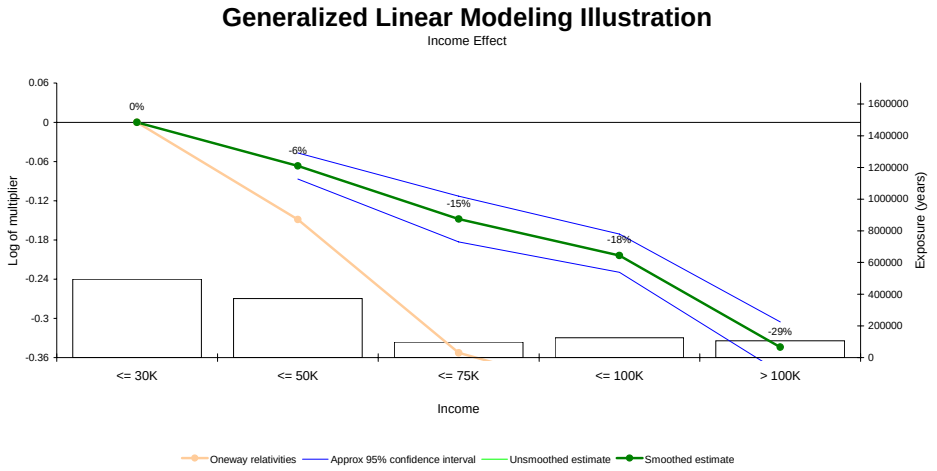
  as a function of
  - some factors
- For instance, a GLM can model
  - Motor claim amounts as a function of driver age, car type, no claims discount, etc …
  - Motor claim frequency (as a function of similar factors)
- Historically associated with non-life personal lines pricing (where there was a pressing need for multivariate analysis)
- In this presentation we will be applying GLM techniques to the analysis of the mortality experience for a block of annuity business

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 than the base level.
- Colors
  - Green: 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.

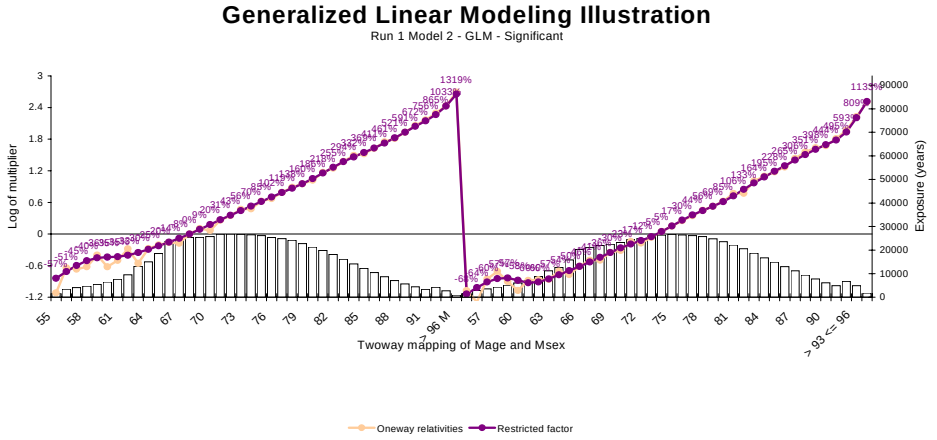


Example 1: Effect of Annuity Amount



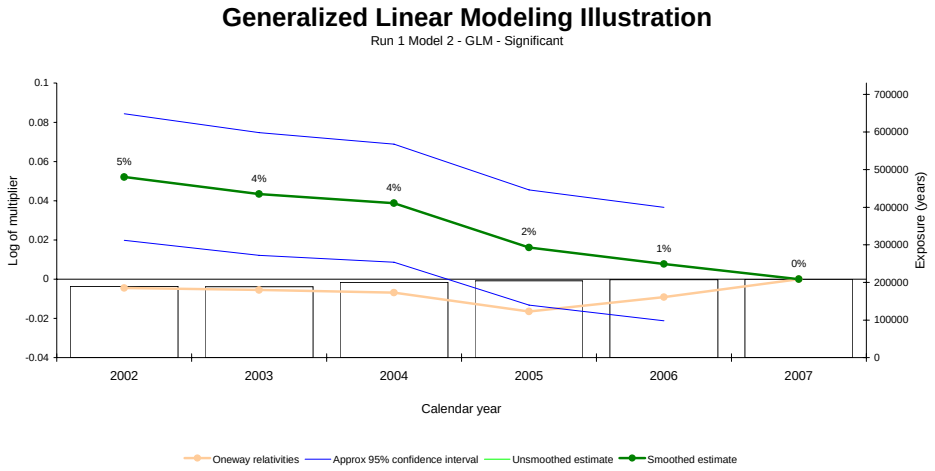
Results show evidence of reduced mortality with increased benefits

Example 2: Impact of age/sex



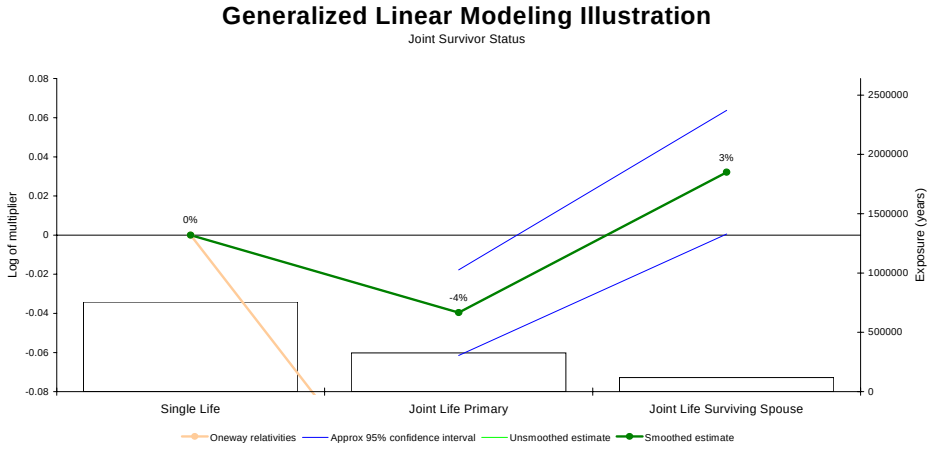
A mortality table is fitted using experience data and the variation of mortality by age is fixed in subsequent analysis of other risk factors

Example 3: Calendar Year Trend



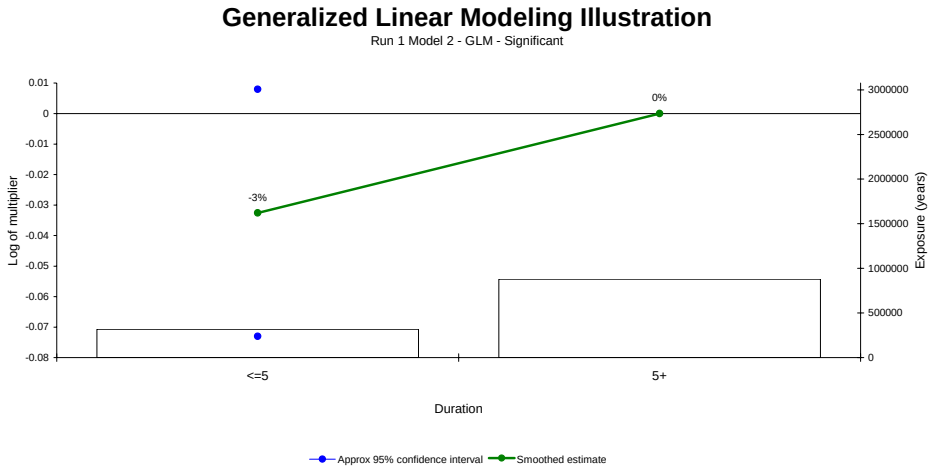
Mortality improvements 1% per annum over previous six years

Example 4: Effect of Joint Life Status



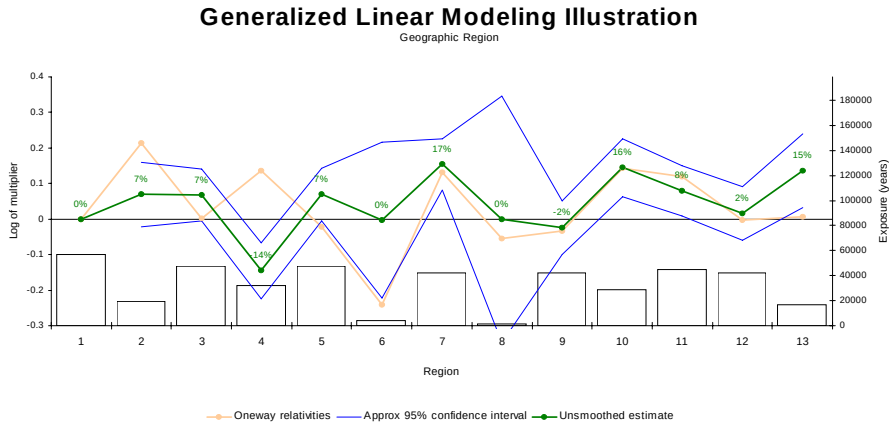
Evidence of “broken heart syndrome” which may influence pricing

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 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

Summary

- GLM techniques are widely used in P&C for pricing purposes, but its application in Life Insurance may not be as well established.
- 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.
- We demonstrated that for some risk factors, the application of GLM showed significantly different mortality patterns when compared to results of traditional analysis.
- The advantage of additional knowledge on the mortality characteristics of the annuity block will allow management to make better pricing decisions and to gain business advantage over competitors.

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Applications of Predictive Modeling in Employee Benefits

Ron Littler, FSA
June 18, 2008

Watson Wyatt Worldwide

Applications of Predictive Modeling in Employee Benefits

- Predictive Modeling techniques are used to value employee benefits, measure risks associated with benefit plans and model alternative plan designs.
- Valuation techniques in use include binomial lattice modeling and Monte Carlo simulation.
- Monte Carlo simulation is typically employed to determine the probability of threshold outcomes (eg, VaR), assess the impact of funding and investment policies and various plan designs.
- There is increasing application of option pricing techniques to pension obligations, eg there are emerging markets for plan buyouts and longevity trading.

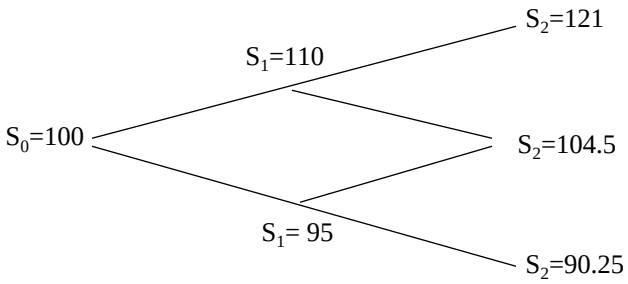
Valuation Example - Share-Based Compensation

Valuation Models – Share-Based Compensation

- The Black-Scholes 'model' is the traditional and most widely used method for valuing share options.
  - Unlike tradable share options, employee share options are longer-term, typically have performance conditions and are non-transferable.
  - Consequently, Black-Scholes does not effectively reflect the impact of anticipated employee exercise behavior and performance conditions.
- A binomial model tends to produce a more realistic estimate of the option's true value.
  - The method divides the option's term into small time increments, enabling the model to take into account most revelant assumptions about an option grant's features.
- In some cases, Monte-Carlo simulation is required to fully capture particular design features.

Binomial Model

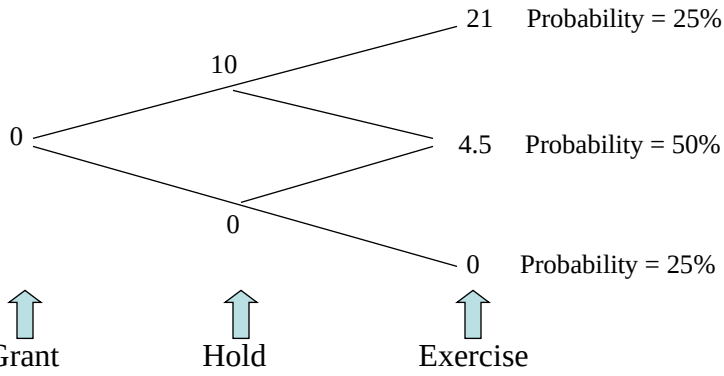
Scenario: Stock price will either increase by 10% or decrease by 5% each time period.



Let's look at an option granted with a $100 exercise price.

Binomial Model

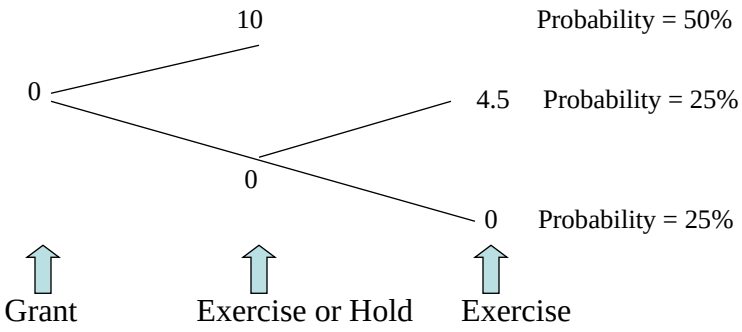
The option will have the following payoffs at each "node":



Option Value = 25% x 21 + 50% x 4.5 + 25% x 0 = $7.50

Binomial Model – Early Exercise

The option will have the following payoffs at each "node":



Option Value = 50% x 10 + 25% x 4.5 + 25% x 0 = $6.13

Valuation Models – Share-Based Compensation

	Black-Scholes	Lattice	Monte Carlo
Ease to set up	Easy	Moderate	Difficult
Ability to capture unique features of employee awards	No	Yes	Yes
Relative P&L Expense	Generally highest	Generally lower than B-S	Generally lower than B-S
Assumption Flexibility	Not flexible	Very flexible	Very flexible
Ability to handle performance features	No	Yes, but may be limited	Yes

Pension Funding, Investing and Design

Modeling the impact of investment policy on pension risk

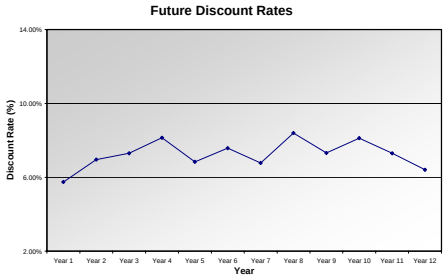
Inflation?
Interest rates?
Investment returns?

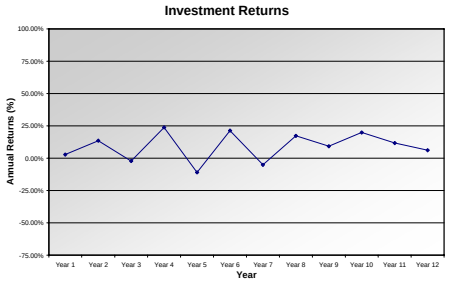
→

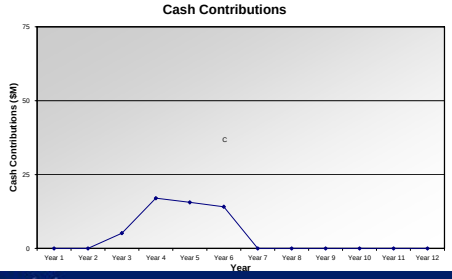
Cash contributions?
Income/expense?
Balance sheet impact?

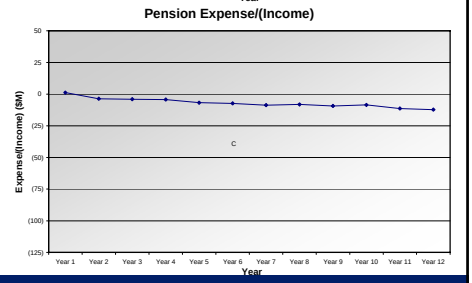
- Future economic environment is uncertain
- Financial results are uncertain
- The purpose of an integrated asset/liability study is to:
  - Simulate the future economy by generating thousands of possible scenarios (stochastic modeling)
  - Develop financial results for each scenario for potential asset allocations
  - Summarize results by calculating key risk measures
  - Evaluate risk/reward tradeoff of different asset allocations through efficient frontier framework and summary statistics
  - Implement decisions into investment policy and assets
  - Identify other (non-investment) risk management opportunities

Stochastic Simulations – One Scenario

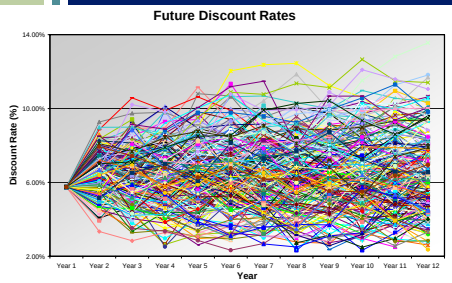


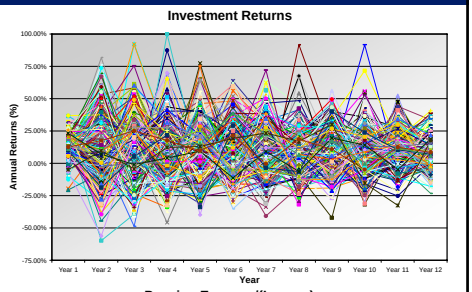


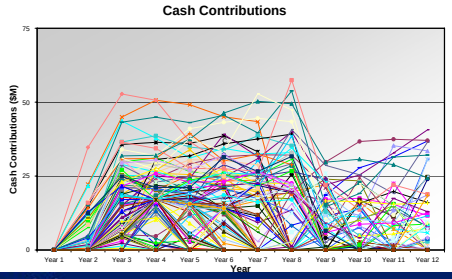


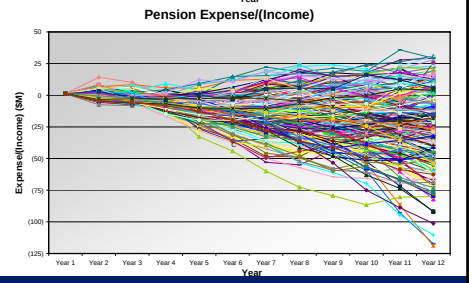


Stochastic Simulations – Many Scenarios









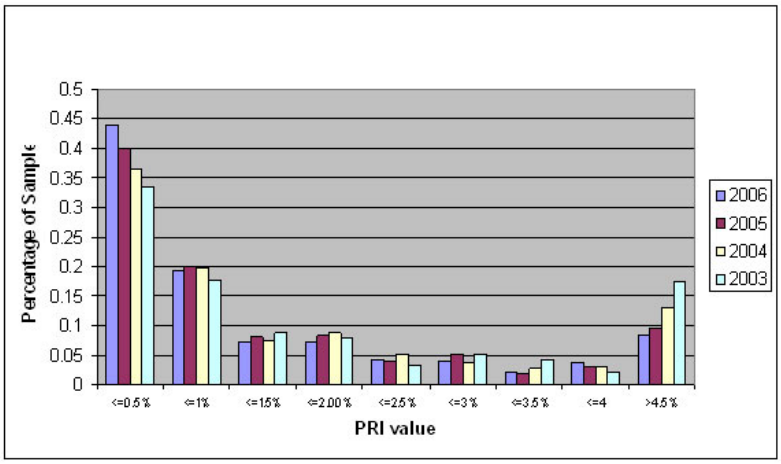
Measuring Risk of Pension Obligation

Watson Wyatt's Pension Risk Index

- One way to quantify the additional risk the pension fund implies for a company's core business is a value-at-risk (VaR) measure developed by Watson Wyatt called the Pension Risk Index (PRI).
- The VaR is the dollar reduction in the pension fund's funded position under adverse financial market conditions (95th percentile worst outcome) given the plan's asset allocation, liability structure and sensitivity to interest rates.
- The VaR is calculated using Watson Wyatt's capital market assumptions and proprietary asset/liability modeling technology. The dollar value of this outcome is then compared with the market capitalization of the plan sponsor.

Pension Risk Index for the *FORTUNE* 1000

Distribution of Pension Risk Index Values, 2003-2006



Analyzing Policy Decisions

Simulated Investment Performance: Comparison of Balanced and Life Cycle Funds

- Motivation of simulation – DOL proposed regulation for individual account plans; also (implicit) comparison of DC and DB plan investment approaches
- Assumes steady contributions of 6% of earnings over a 40 year career, with earnings, starting at $40,000 at age 25, growing 4% annually thereafter through age 50 and flat thereafter– best case scenario of no plan leakages and continual work profile.
- Assumes stochastic asset real returns based on 1960 – 2004 experience; investment expenses are not included.
- Assumes equity/bond/cash mixes of average Balanced and Life Cycle funds in the marketplace.

Simulated Investment Performance: Comparison of Balanced and Life Cycle Funds

- Table shows distribution of account balance outcomes (inflation-indexed) at end of career.
- Overall mean is $529K for balanced fund vs. $515K for life cycle; life cycle outcome is higher in first two deciles. Balanced fund outperforms life cycle 57.3 percent of the time. But standard deviation for balanced fund, particularly in the age 55 to 65 period (not shown), is much higher than for life cycle fund.
- Interpretations – life cycle fund makes more sense for individual account investor with shortening horizon, but longer investment horizon of DB plan sponsor (balanced fund) gives a higher expected return.

Simulated Investment Performance: Comparison of Balanced and Life Cycle Funds

Terminal Wealth at 65 ($1000)

	Median		Mean		Standard Deviation	
Decile	Balanced Fund	Lifecycle Fund	Balanced Fund	Lifecycle Fund	Balanced Fund	Lifecycle Fund
1	194.5	200.7	187.8	194.9	32.1	30.3
2	260.5	263.3	260.1	262.9	15.9	15.3
3	313.9	312.6	313.4	312.5	15.1	13.7
4	363.9	360.4	364.3	360.4	14.9	14.0
5	417.9	410.9	418.2	411.2	16.5	15.5
6	479.0	468.3	479.5	468.8	19.1	17.9
7	553.3	537.0	553.8	537.9	24.1	22.3
8	650.8	627.8	652.5	629.7	33.4	31.5
9	796.0	764.7	802.7	770.2	57.5	53.8
10	1136.2	1082.4	1254.6	1202.4	391.2	377.2
Overall	447.5	438.6	528.7	515.1	324.8	307.2

Summary

- Valuation models such as Black-Scholes are inadequate for many contingent obligations.
- Lattice models and Monte Carlo simulation offer more flexibility than Black-Scholes or other closed form solutions.
- Applications of predictive modeling for employee benefits include valuation and the determination of risks inherent in the plans.
- Predictive modeling can be used to help illustrate the impact of policy decisions by plan sponsors.