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Stochastic Mortality

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ERM Symposium, April 14-16, 2008, Chicago, Illinois

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Agenda

- Background
- Introducing Stochastic Techniques
- Parameterization
- Case Study
- Continued Research
- Conclusions

BACKGROUND

Key Uses of Mortality

- Traditional
  - Pricing
  - Valuation
  - Financial planning
  - Reinsurance Analysis
- Emerging trends
  - Stochastic modeling
  - Economic capital, management decisions
  - Securitization

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Key Uses of Mortality

- Life settlements
- Mortality hedging
- Reverse mortgages
- Index construction
- Lapse/mortality relationship
- Optimization of risk profile

History of Mortality Projections

- Traditional Approach
  - Standard actuarial tables, produced by industry/professional body
  - Companies assume a simple percentage of a base table
  - Stress test
  - Generally a percentage increase (e.g., 20% higher)
  - Sometimes grading over time

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History of Mortality Projections

- Advantages of traditional approaches
  - Quick run time
  - Simplified results – ease of communication
- Disadvantages of traditional approaches
  - Provides "worst case" or "best case" scenario, but limited insight on the distribution of results
  - Scenarios selected may be limited to practitioner's expectation/bias

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History of Mortality Projections

- Emerging Trends
  - Stochastic modeling
  - Standard statistical models, researched and produced by leading mortality experts
  - Companies can use publicly available data or their own (if sufficient) to parameterize the models
  - Public disclosures requiring risk exposures
  - Evolving regulations including FAS 157, C3P2, PBR, other?
  - Evolving product trends, requiring more analysis of mortality risk

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History of Mortality Projections

- Advantages of emerging trends
  - Greater understanding of risk profile
- Disadvantages of emerging trends
  - Parameterization can be difficult and subjective
  - Increased run times

INTRODUCING STOCHASTIC TECHNIQUES

Stochastic Mortality Elements

- Volatility
  - Variation around central best estimate
  - Inversely proportional to the size of the population
  - Period-to-period volatilities are independent

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Stochastic Mortality Elements

- Trend
  - The change in mortality over time
  - Requires a view of the future – past experience may not be a good guide (medical advancements, lifestyle changes)
  - Limited guidance on parameterization of trend
  - Note: underwriting benefit is reflected in the underlying table (S&U), not in the trend

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Stochastic Mortality Elements

- Underwriting
  - The risk that the best estimate assumption is incorrect
  - New products might be underwritten to different standards, shifting the mortality curve
  - Ignoring might introduce bias into the projections
  - For some products this is the largest risk (e.g., term, where mis-estimation cannot be passed on)

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Stochastic Mortality Elements

- Catastrophe
  - Terrorism
  - Pandemic/epidemic
  - Natural disasters
  - Incidence and severity are the key considerations

Mortality Models

- Lee-Carter (1992)
  – Widely used with industry acceptance (US Bureau of Census)
  – Simple AR(1) process
  – Backcasting to parameterize
  – Trend forecasted only
  – Can generate sample paths

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Mortality Models

- Cairns (2000)
  – Widely used with industry acceptance
  – Backcasting to parameterize
  – Trend forecasted only
  – Can generate sample paths
- P-Spline
  – Newest, most complex, and least understood
  – Much interest in development
  – Produces percentiles of forecasted mortality
  – Can't generate sample paths

Lee Carter Model

- $\log m(x;t) = a(x) + b(x)k(t) + z(x;t)$
- a(x) = average level of the force of mortality, for age x
- b(x) = coefficient of the trend parameter, for age x
- k(t) = trend in mortality over time, t
- Z(x;t) = stochastic element (IID N(0, σ2))
- Autoregressive (AR(1))

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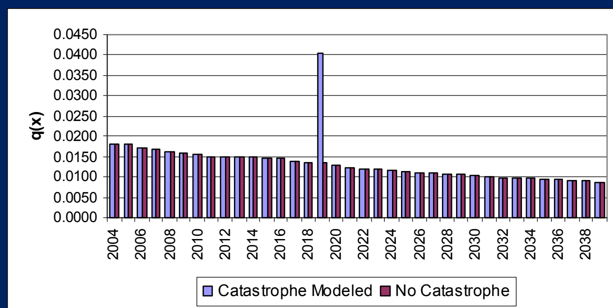
Lee Carter Model

- Parameterization through statistical packages (R)
- Parameters produced by the models need adjusting for "common sense"
  - Smoothing b(x)
  - Can have jumps from last year of the data to the first year of the projection
  - Is mortality improvement going to continue at recent rates?

Lee Carter plus Catastrophe

- q(x) projected through time
- Single-scenario comparison (catastrophe impact is 300% normal expected rate)



Building a Simple Model

- Consider the risk elements
  - Trend, volatility
  - Product being modeled and use of model will dictate the selection of risk elements
- Select distributions
  - Normal volatility
  - Normal/lognormal trend and underwriting
  - Binomial catastrophe element
  - Cumulative impacts through structure of model (multiplicative factors)

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Building a Simple Model

- Select parameters
  - Reflects historic curve fitting
  - Expectations of future
- Key is understanding bias and limitations of the model

PARAMETERIZATION

Parameterization

- Powerful curve fitting, but need to use insights and common sense to create a useful model
- Biased by historical events
- Models don't capture underwriting or catastrophe risk explicitly (effects might be included in historic data)
- Parameters produced might be good in the short term, but will probably need to be adjusted for longer-term projections

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Parameterization

- Granularity
  - More granular analysis introduces less credibility and more bias
  - Product type might be the lowest level (UL, Term, DA, etc.)
- Volatility (variation around best estimate)
  - Fitted parameter could be appropriate, based on size of population
- Trend (view of mortality improvement)
  - Compression of mortality curve versus medical advancements
  - Anti-selection (impact of lapses on mortality)

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Parameterization

- Underwriting (impact on average class of lives)
  - How have underwriting standards changed over time?
- Historical catastrophic events
  - Epidemics (e.g., SARS) frequency ~ 7.4%[1]
  - Pandemics (e.g., Spanish flu) frequency ~ 1% to 3%[2]
  - Severity can cause excess mortality to increase 30%
  - SOA research on pandemic influenza
    - Shapes of different excess mortality curves (--- , V , V\ , and W)

1: Lazzari and Stohr, "Avian Influenza and Influenza Pandemics," *Bulletin of the World Health Organization*, April 2004
2: Toole, "Potential Impact of Pandemic Influenza on the U.S. Life Insurance Industry," SOA, May 2007

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Parameterization and Data Limitations

- The models require historic data to estimate projection parameters
- UK has Continuous Mortality Investigation Bureau (CMIB)
- US has no centralized repository for insured lives
- Population data not relevant for the requirements of insurers
- Few insurers/reinsurers have large enough or good enough pools of historic data
- Smoothing of parameters removes some of the problem

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CASE STUDY

Case Study

- 20-year term insurance product
- 21 years of level sales of 1,000 policies per year
  - Three issue ages (35, 45, 55)
  - Three face amounts ($250K, $1M, $5M)
- $22.6 billion in face at valuation
- Male, non-smoker assumed

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Case Study

- Stochastic Mortality
  - Factor approach
  - Underwriting factor by scenario
  - Volatility and catastrophe by year

Stochastic Mortality Risk Element Distributions			
Stochastic Element	**Underlying Distribution**	**Mean**	**Standard Deviation**
Underwriting factor	Lognormal	100%	5%
Annual mortality volatility	Lognormal	100%	5%
	Underlying Distribution	**Incident**	**Probability**
Catastrophe shock	Binomial	300%	1 in 100 years event

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Case Study

- Stochastic lapse
- Standard actuarial modeling software customized to incorporate scenario file for mortality and lapse
- Deterministic asset returns
- 10,000 scenarios

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Case Study

- 30-year projection

Present Value of Cashflows ($Millions)			
Cashflow Component	**Deterministic**	**Poor Mortality**	**Good Mortality**
Premium and Inv Income	1,198.6	1,135.7	1,228.8
Death Claims	-1,338.9	-1,591.5	-1,202.1
Other Expenses	-38.1	-36.9	-38.8
Gross Cashflows	-178.4	-492.7	-12.1
Reinsurance Premiums	0.0	0.0	0.0
Reinsurance Receivable	0.0	0.0	0.0
Net Reinsurance Cashflows	0.0	0.0	0.0
Net Cashflows	-178.4	-492.7	-12.1

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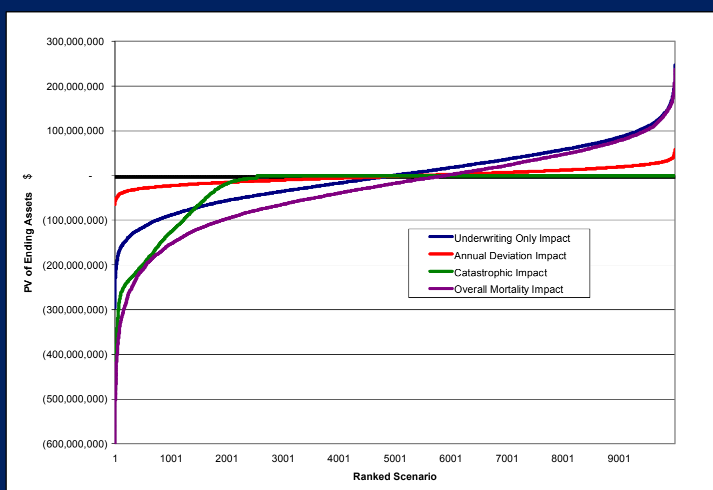
Case Study — results



CONTINUED RESEARCH

Current/Recent Research

- Older age mortality – data is even more scarce
- Different approaches to fitting the data[1]
  - Semi-parametric bootstrap
  - Residual bootstrap
- Modeling a jump in trend parameter in the historic data[2]
- Cause of death analysis and modeling (UK)

1: Haberman and Renshaw, "On Simulation-Based Approaches to Risk Measurement in Mortality…", 2008
2: Yue, Yang and Huang, "A Study of the Lee-Carter Model With a Jump", 2008

CONCLUSIONS

Conclusions

- Ignoring the variance in mortality reduces credibility of risk management decisions for insurers
- No one knows what the “right” model is
- Can build simple models that capture the stochastic elements
- Parameterization and understanding the bias is key

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Conclusions

- US faces problem of lack of data for insured lives for use with curve fitting models
- Continued developments, many from academics