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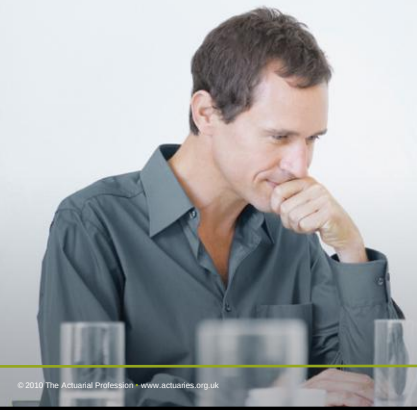
Pensions Conference
Jon Palin (jon.palin@rms.com)



A structural model of mortality

31 May 2012

Agenda

- A new kind of model for mortality improvements
  - Difficulties with a purely statistical approach
  - Incorporating underlying drivers of mortality
  - Challenges of this approach
- Segmented mortality improvements
- Summary

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Difficulties with a purely statistical approach

Modelling pandemic risk

- Pure statistical approach
  - Not much data – large pandemics are rare
  - Hard to fit a distribution to past data
  - Conditions change – medical care, transportation, and virus mutation

Modelling pandemic risk

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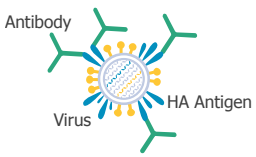
  - Conditions change – medical care, transportation, and virus mutation
- Structural model
  - Probability distributions of virus mutation, transmission, vaccines, government response (eg shutting schools)
  - Acknowledge uncertainty
  - Test versus past history and alternative models

Modelling pandemic risk – details

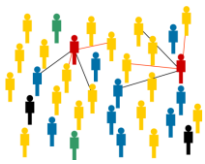
Pathogen Characteristics



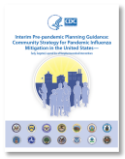
Probabilistic model of virus characteristics:
- Frequency of antigenic shift mutations
- Virulence: Death per Case (DpC)
- Infectiousness: Initial Reproductive Number (R0)
- Other qualitative factors including
  - pathology mechanism (e.g. cytokine storm)
  - Incubation time and symptomatic period

Epidemiological Model

Susceptible, Infected, Recovered (SIR) Modelling



Population Spread Model
- International Spread
- Age response
- Background immunity
- Behaviour assumptions



National Government Response Model
- Public health capability and strategy
- Anti-Viral Administration
- Vaccine Development
- Non-Pharmaceutical Interventions

CMI mortality projections model

- CMI model provides a useful framework
- But doesn't specify the long-term rate

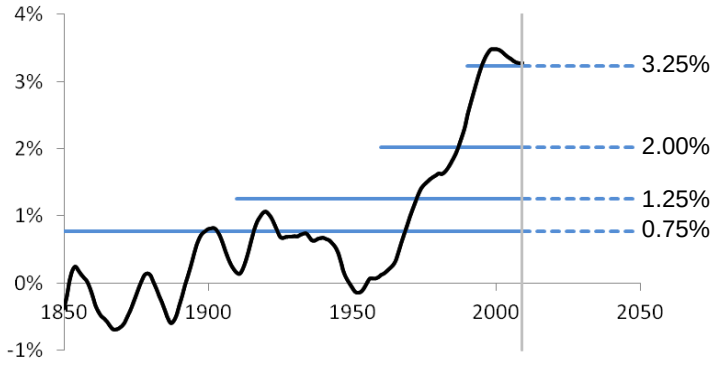
Please enter a value for the Core parameter for Long-Term Rates of Mortality Improvement	
Long-term Rate of Mortality Improvement up to age 90	?

"In the long-term, the forces driving mortality change may be very different from those currently influencing patterns of improvement. Therefore, the long-term rate is better informed by "expert opinion" and analysis of long-term patterns of change and the causes driving them."
– CMI Working Paper 38

6

Modelling longevity – historical/statistical approach

- Improvements for England & Wales males aged 65
- Project based on 20-50 years? or 100-150 years?



7

Regenerative Medicine – Stem Cell Therapy

Transplant using trachea grown from patient's own stem cells a world first

November 20, 2008

- **Clinical transplantation of a tissue-engineered airway pioneered in June 2008 (Reported Nov 2008)**
- **Stem Cell therapy means that transplants 'take' without suffering rejection from the body's defense mechanisms**
- **Wide range of other potential applications of the technique**
- **Major advance in treating several life-threatening conditions**

"*Engineering a trachea is the holy grail of tracheal replacement*"
Dr. Paolo Macchiarini,
The Journal of Thoracic and Cardiovascular Surgery, 2004

Modelling longevity risk

- Pure statistical approach
  - Not much data – only one history
  - Conditions have changed – lifestyle, medical research, drugs, medical spending, new technology
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Modelling longevity risk

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Incorporating underlying drivers of mortality

Causes of death

- Causes of death
  - Cardio-vascular disease
  - Cancer
  - Respiratory
  - Accident
  - and many others
- Highly correlated
  - eg smoking affects both CVD and cancer

Causes and drivers of death

- Causes of death
  - Cardio-vascular disease
  - Cancer
  - Respiratory
  - Accident
  - and many others
- Highly correlated
  - eg smoking affects both CVD and cancer
- Underlying drivers of death
  - Lifestyle
  - Medical intervention
  - Health environment
  - Regenerative medicine
  - Retardation of ageing
- Treat as independent
- “Vitagions”

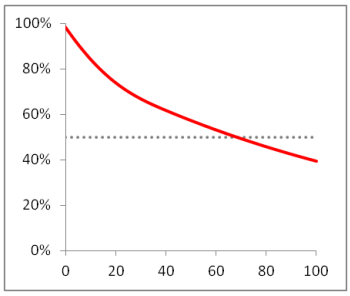
Vitagions – drivers of mortality changes

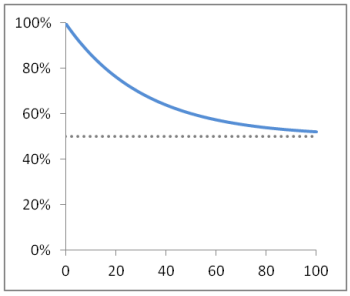
- **Lifestyle**
  - Smoking, diet, alcohol, exercise, obesity, stress
- **Medical intervention**
  - Drugs, surgery, screening, paramedics
- **Health environment**
  - Sanitation, housing, pollution
- **Regenerative medicine**
  - Stem cell therapy, nanomedicine
- **Retardation of ageing**
  - Telomerase activation, caloric restriction

14

Vmax – maximum improvement for a vitagion

- Don't focus on long-term annual improvements
- Instead look at long-term maximum total improvement...
- ...and how long it takes to achieve this



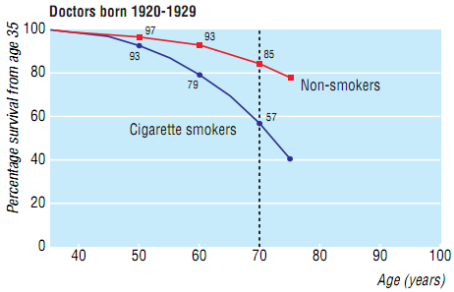


15

Epidemiological studies

Mortality in relation to smoking: 50 years' observations on male British doctors

Richard Doll, Richard Peto, Jillian Boreham, Isabelle Sutherland



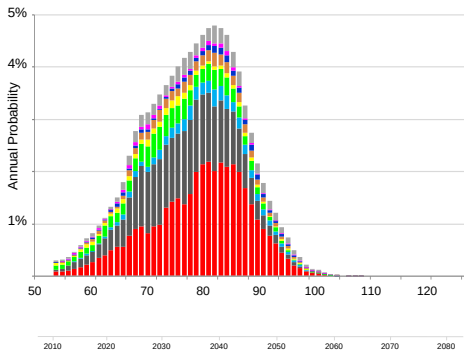
Age range (years)	Mortality ratio (cigarette smoker *v* non-smoker)
35-44	1.6†
45-54	2.3
55-64	2.5
65-74	2.7
75-84	2.2

Calibrating the model

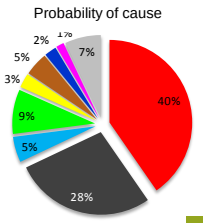
RMS Prognosys

Risk Factor Inputs

Name:	Andrew Coburn
Gender	Male
Date of Birth:	24-Dec-56
Current Age:	55
Anthropometrics	
Hip (cms):	105 cm (41")
Waist (cms):	99 cm (39")
Height (meters):	1.70 m (5' 7")
Weight (kg):	84 kg (186 lbs)
Waist-to-hip ratio:	0.95
Waist-to-hip risk:	Normal
BMI	29.1
BMI Classification:	Overweight
Lifestyle	
Smoker?	No
Cigarette consumption:	0
Stress:	Moderate
Daily Fruit and Veg?	0
Exercise mins/week	0
Alcohol Units/week	14
Current Medical Data	
Cholesterol TC:	270
Cholesterol HDL ratio:	7
Systolic blood pressure:	129
Medical History	
CVD History?	No
Diabetes?	No
Premature Parent CVD?	No



RMS Prognosys: 50,000 simulations	
Mean (Life expectancy):	**81.3**
Modal Year of death:	**85**
Prob of exceeding 90 yrs old:	**20.5%**
Prob of exceeding 100 yrs old:	**1.7%**



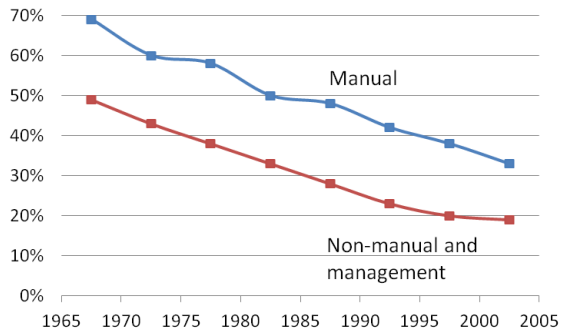
Lifestyle Vmax

- If everyone stops smoking, mortality at 65 falls by 20%

- Diet, exercise, BMI, blood pressure, cholesterol, stress, ...
- Other (small) unknown factors
- Overall 40-50% improvement from better lifestyle

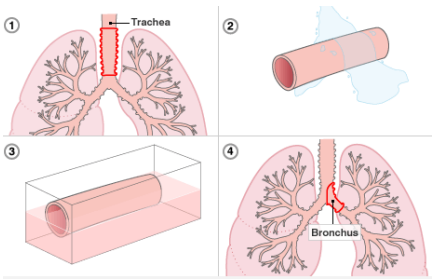
Lifestyle – time to Vmax

- It has taken a generation for smoking rates to halve
- Former-smokers have higher mortality than never-smokers



Regenerative medicine – Vmax and time to Vmax

- eg stem cell therapy – transplants with patients' own cells
- Only reduces deaths due to damaged tissue
- Successful but experimental and expensive
- Development, clinical trials, adoption take decades

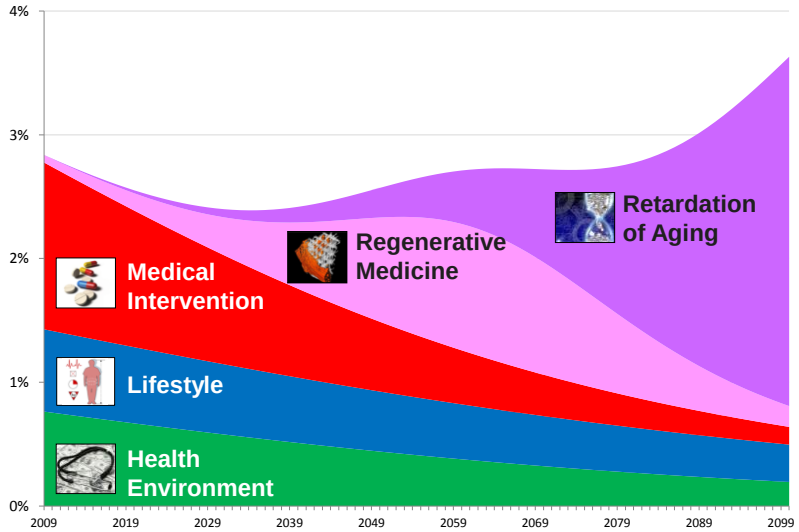


Putting it all together

- Short-term – current improvements
- Long-term – limits per vitagion – "biological plausibility"
- Stochastic model – acknowledge uncertainty
- Cohorts as well as age-period effects

- Indicative results – long-term rate a little above 2.0% pa

Putting it all together – example scenario



22

Narrative

- Drivers of mortality better understood by lay people
- Pension fund trustees, but also investors

	Reduction in Premature Deaths (per 1000)
Twice as Many Smokers Quit as Expected	1.41
Prostate Cancer Mortality Falls Twice as Much as Expected	0.53
Colon Cancer Mortality Falls One Third Further than Expected	0.18
Overall	**2.12**

23

Comparison with other approaches

- Like CMI, Lee-Carter, Renshaw-Haberman etc:
  - Statistically based
  - Fitted to current mortality and current improvements
  - Allows for cohort effects
  - Stochastic projection giving a range of outcomes
- Some subjectivity, as in any model
  - CMI: choice of long-term rate, reversion period
  - Pure statistical models: which period of data to fit to; how to extrapolate
- Not a 'naive extrapolation' cause of death model

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Challenges of this approach

Challenges of this approach (1)

- Data quality
  - Challenge: Complex terminology. Changes/ambiguity in data recording.
  - Our approach: Use a doctor. Publications on coding changes. Statistical checks.
- Correlations between causes of death
  - Challenge: Correlations become competing causes of death.
  - Our approach: Use a small number of vitagion categories. Vitagions chosen to have low dependence.

Challenges of this approach (2)

- Future causes of improvements
  - Challenge: Potential for bias if we only include current causes of improvement.
  - Our approach: Two vitagions explicitly covering new developments.
- Different improvements for different social classes
  - Challenge: Different lifestyles. Wealth and access to new treatments.
  - Our approach: Population segmentation and different improvement rates.

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Segmented mortality improvements

Historic mortality

Mortality rates (per 1,000) in England & Wales for males aged 60-69

1974	2004
31	15

Mortality rates halved in 30 years – historically unprecedented

Historic mortality

Mortality rates (per 1,000) in England & Wales for males aged 60-69

Class	1974		
Class V	**38**	Unskilled	eg labourer, cleaner, messenger
All	31		
Class I	**24**	Professional	eg actuary, doctor, engineer
Ratio V:I	1.6		

Significant differences between social classes in 1974

Historic mortality

Mortality rates (per 1,000) in England & Wales for males aged 60-69

Class	1974	2004
Class V	38	23
All	31	15
Class I	24	8
Ratio V:I	**1.6**	**2.9**

Ratio between classes has grown rapidly

Historic mortality

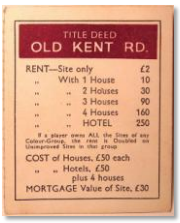
Mortality rates (per 1,000) in England & Wales for males aged 60-69

Class	1974	2004	Reduction	Improvement
Class V	38	23	40%	**1.6% pa**
All	31	15	52%	2.6% pa
Class I	24	8	67%	**3.8% pa**
Ratio V:I	1.6	2.9		

Improvements over 2% pa higher for class I than class V

Typical practice

- Current mortality rates:
  - Age
  - Gender
  - Status: postcode, affluence



- Future mortality improvements:
  - Age
  - Gender
  - **NOT** Status: CMI uses general population for all

Why are segmented improvements important?

- BIG difference in historic improvements by social class
- Pension populations differ from the general population
  - Particularly when weighted by amount
- Potential for different improvements to the general population
- Predicting the future better allows for better pricing, reserving, transactions and risk management
  - In particular, basis risk for index-based transactions

Challenges and approach

- Challenges
  - Smaller groups means more noise and uncertainty
  - National population gives better statistical estimate
- Approach
  - Structural model rather than purely statistical model
  - Understand the underlying drivers of class differences

Lifestyle and mortality

- Lifestyle (smoking, obesity, diet, drinking, exercise) affects mortality
- Lifestyle tends to be worse in lower social classes
- **Does lifestyle explain the 3x difference in mortality?**

Lifestyle and mortality – smoking

- Smoking prevalence:
  - Class I: 12% Class V: 24%
- Potential improvement from stopping smoking:
  - Class I: 18% Class V: 28%

- Smoking explains a 12% difference in mortality between classes
  - Important to go from smoker to non-smoker (100% to 0%)
  - Much smaller impact between classes (24% to 12%)

Lifestyle and mortality

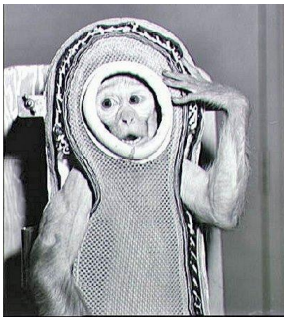
- Lifestyle (smoking, obesity, diet, drinking, exercise) affects mortality
- Lifestyle tends to be worse in lower social classes
- **Does lifestyle explain the 3x difference in mortality?**
- To explain a 3x difference would require
  - **all** of class I : non-smokers, good diet, exercise, ...
  - **all** of class V : smokers, bad diet, no exercise, ...
- So there's more to it than lifestyle

Do social structures themselves affect mortality?

- Experiment – randomly put people into social classes and measure their mortality

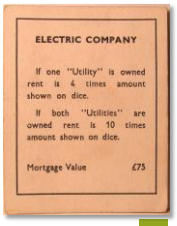
Do social structures themselves affect mortality?

- Experiment – randomly put people into social classes and measure their mortality
- Can't do it with humans ... but can do it with monkeys
  - Social rank correlated to gene activity
  - Can predict social status from blood
  - Links to "general inflammation"
  - Genes adapt to changing status



Whitehall study

- Study of British civil servants
- Social gradient of 3x mortality rates
- Gradient of 2.1x remains for CHD after controlling for typical risk factors
- Low "job control" linked to 2x mortality rate for CHD
- Persistence of the social gradient (at a reduced level) into retirement
- French (GAZEL) study – similar results, but less explained by lifestyle



Scenarios for future mortality improvements

- Current trend continues
  - Higher improvement for higher classes persists
- Lifestyles converge
  - Faster improvements for lower classes
- Improved cancer treatments
  - Higher improvements in higher classes due to higher prevalence
- Access to high-cost and/or experimental treatments
  - Early access for the very wealthy through private medicine

Financial risk from different improvements by class

- Potential for significant deviation from national improvements
- National historic improvements understate portfolio risk
- Risk greater for concentrated portfolios such as occupational pension plans
  - “single class” portfolio risk around 1/3 greater than pooled
- An argument in favour of risk transfer and pooling populations

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Summary

Summary

- Structural model is an evolution of existing models
- Still statistically based; but incorporates information on future changes in lifestyle and medicine
- Uncertainty is an integral part of the model
- Relates changes in future longevity to real-world scenarios
- Allows us, and laymen, to challenge and understand output of other models
- Offers the possibility of segmented mortality improvements

Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

The views expressed in this presentation are those of the presenter.

jon.palin@rms.com