The Actuarial Profession
making financial sense of the future

Mortality and Longevity one-day seminars, March 2010
Neil Robjohns

Update on the latest work of the CMI

17 March 2010 (London) and 25 March 2010 (Leeds)

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CMI Update
Agenda

Update on Investigations
- CMI Life Office Mortality
- CMI SAPS Mortality
- The CMI Library of Mortality Projections.

The CMI Mortality Projections Model
- Background and overview of the Model
- Implementation: some common questions
- Next steps.

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Update on Investigations
CMI Life Office Mortality

Recent outputs
- Working Paper 40 – proposed revisions to the Per Policy Coding Guide
- Version 1.6 of the Per Policy Coding Guide
- Working Paper 42 – Life Office Mortality experience 2003-2006.

Future outputs
- Consultation on analysis methodology for Per Policy data
- Consultation on results format for Per Policy data
- 2007 All Office results.

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Update on Investigations
CMI SAPS Mortality

Recent outputs
- Draft Experience Report on data collected to June 2008.

Future outputs
- Experience Report on data collected to June 2009
- Mortality improvements within the SAPS dataset
- Draft Experience Report on data collected to June 2010
- Analysis by Industry
- Consider S2 graduations?

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Update on Investigations
The CMI Library of Mortality Projections

Recent outputs
- Version 1.1 of the Library was issued in March 2009 with Working Paper 37.

Future outputs
- Version 1.2
  – PSAP, PSAC and Lee-Carter using ONS data to 2008
  – Selected projections from CMI_2009
  – ONS 2008-based National Population Projections.

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The CMI Mortality Projections Model
Background and overview of the Model

Background and motivation
- Interim Cohort Projections valued as a common currency
- But are significantly and increasingly out-of-date
- CMI Working Party established to produce a projection model which:
  - reflects the latest experience on trends in mortality;
  - is relatively straightforward to understand and describe;
  - allows users the flexibility to modify projections to suit their own views and purpose; and
  - can be regularly updated over time to reflect emerging experience.

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The CMI Mortality Projections Model
Background and overview of the Model

Key development stages and outputs
- Published in June / July 2009 for Consultation
  - A prototype version of the CMI Model: CPMv0.0
  - CMI Working Paper 38: Part I – Outline
  - CMI Working Paper 39: Part II – Detailed Analysis
- Launch of the CMI Model, November 2009:
  - CMI Working Paper 41: Feedback on the consultation
  - Updated version of the Model: CMI_2009
  - Updated User Guide (with documentation of default values)
  - Updated Parameter Sensitivity Test results spreadsheet
  - Webinar, 8th December 2009.

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The CMI Mortality Projections Model
Background and overview of the Model

The Structure of the Model
- Project annual mortality <u>improvement</u> rates
  - Relatively simple; accessible; flexible
  - Not a mathematical model of mortality fitted to data
- Deterministic projection driven by user inputs
  - Initial rates of mortality improvement
  - Long-term rate(s) of mortality improvement
  - Speed & pattern of convergence
  - Split projection by age or by year-of-birth cohort
- Core and Advanced parameter layers.

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The CMI Mortality Projections Model
Background and overview of the Model

Core parameter layer
- Allows users to focus on two simplified parameters:-
  - A Long-Term Rate of Mortality Improvement
  - A Constant Additional Rate of Mortality Improvement
- Default values are applied to other parameters.

Advanced parameter layer
- Gives users considerable flexibility; allowing specification of:-
  - Initial Rates of Mortality Improvement
  - Cohort and Age/Period components of Initial Rates (by individual age & birth cohort)
  - Long-term Rates of Mortality Improvement (by individual age & birth cohort)
  - Period of Convergence (by individual age & birth cohort)
  - Proportion of Convergence remaining after Mid-point (by individual age & birth cohort)
  - Base Rates of Mortality.

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CMI Update
Agenda

Update on Investigations
The CMI Mortality Projections Model
- Implementation: some common questions
  - How is the projection timing defined?
  - How robust are the Model and its default parameters?
  - Why are the initial rates based on population data?
  - How do CMI_2009 Core Projections compare to the Interim Cohort Projections?
  - How do I set the Long-Term Rate of Mortality Improvement?

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The CMI Mortality Projections Model
How is the projection timing defined?

Timing definition in CMI_2009
- Projection timing is defined by 3 dates (user input)
  - Base mortality rates
    - q_x at dd/mm/yy is probability of life aged x exact at dd/mm/yy dying before dd/mm/yy+1
  - Rates of mortality improvement
    - RMI = $1 - q'_x/q'_{x-1}$, so define in terms of date definition for underlying q'_x
  - Calculation date (for annuity and expectation of life values).

Rates of mortality improvement
- Calendar year data (ONS, CMI) naturally leads to 01/01/yy definition.

CMI Library of Mortality Projections
- Sets timing definition of 01/07/yy for all rates of mortality improvement
  - Set in line with appropriate timing definitions for Interim Cohort Projections
- Beware! Take care not to introduce 'accidental' change in timing!

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The CMI Mortality Projections Model
How robust are the Model and default parameters?

Consultation and Review
- Wide consultation (July / August 2009)
  - Model structure, default parameters and supporting analysis
  - 2 discussion meetings; 31 written responses received
- Disclosure
  - Open structure: Model mechanics are open for users to see
  - Supporting analysis and rationale disclosed for default parameters
- P-Spline models (used to smooth mortality data in two dimensions)
  - Published and peer reviewed in both actuarial and statistical fields
  - Also used in analysis supporting Interim Cohort Projections.

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The CMI Mortality Projections Model
How robust are the Model and default parameters?

Controlled Evolution
- Balance responsiveness to new data with stability of structure
- Limited annual updates
  - Core default for Initial Rates of Mortality Improvement
  - Incorporate each successive year's population data
  - Process designed for 'smooth evolution'
- Structure and other default parameters
  - Subject to periodic general review
  - Avoid potential confusion / disruption of frequent change
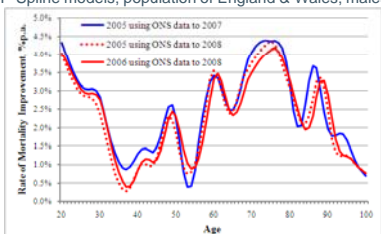 - Do 'when necessary' (say every 3 to 5 years).

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The CMI Mortality Projections Model
How robust are the Model and default parameters?

Change arising from incorporation of data for 2008
Annual rates of mortality improvement, by age, 2005 & 2006
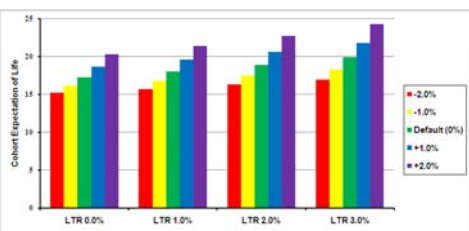P-Spline models; population of England & Wales; males

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The CMI Mortality Projections Model
How robust are the Model and default parameters?

Sensitivity of results to changes in the Core Parameters
Variation in e_{70} , for male lives, by Long-term Rate of Mortality Improvement
and for changes in the Constant Additional Rate of Mortality Improvement

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The CMI Mortality Projections Model
How robust are the Model and default parameters?

Sensitivity of results to parameters
• For illustration, measure change in cohort e_{70}

Core Parameters
• Long-Term Rate of Mortality Improvement
  – e_{70} increases by ~0.9 years for each 1% in Long-Term Rate
• Constant Additional Rate of Mortality Improvement
  – e_{70} increases by ~1.6 years for each 1% Constant Addition

The CMI Mortality Projections Model
How robust are the Model and default parameters?

Sensitivity of results to parameters

Advanced Parameters (where default values set for Core layer)

- Initial Rates of Mortality Improvement
  – e_{70} changes by 0.6 to 0.9 years for each 1% pa change in Initial Rates
  – e_{70} changes by ~0.3 years for a 1% pa switch between Cohort and Age Components
- Long-Term Rates of Mortality Improvement at high ages
  – e_{70} only increase by 0.1 to 0.2% even if improvement rates don't run to zero until age 150
- Period of Convergence
  – e_{70} changes by around 0.1 years for a 10 year change in Period
- Pattern of Convergence
  – e_{70} changes by 0.2 to 0.4 years for a 25% change in proportion remaining at mid-point

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The CMI Mortality Projections Model
How robust are the Model and default parameters?

Summary

- The Model and parameters have been exposed to review
  – Wide consultation and peer review
  – Comprehensive disclosure of supporting analysis
- The CMI has committed to controlled evolution of the Model
  – Balance responsiveness and stability
  – Update process for new data is designed for 'smooth evolution'
- Sensitivity of results to default parameters is generally low
  – Higher sensitivity to Initial Rates, but no viable alternative
  – Sensitivity to methodology also assessed and disclosed.

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Estimating current rates of mortality improvement

- CMI_2009 Core layer default derived from E&W population data
- Estimates may also be derived from other datasets
  – eg: pensioner data; insured lives data
  – These datasets may be more relevant but less credible
- Each dataset yields a different best estimate
  – Sub-population datasets yield lower resolution picture
  – 'Blurring' of features can create impression of differences
- So, are the differences in 'observed' level and pattern 'real' ?
  – Need a measure / test of statistical significance.

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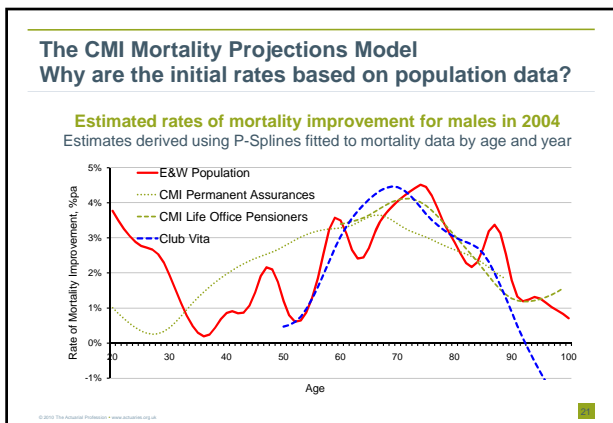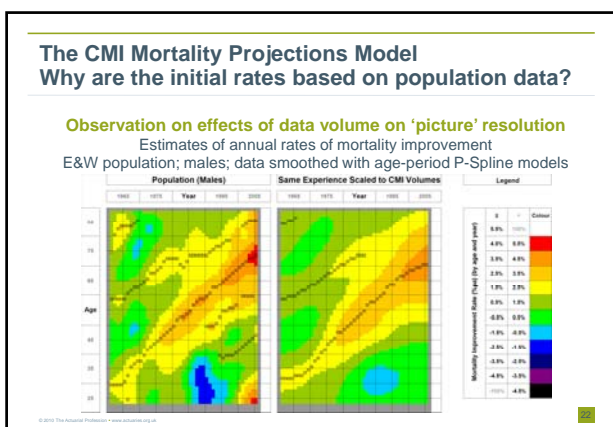
The CMI Mortality Projections Model
Why are the initial rates based on population data?

Estimated rates of mortality improvement for males in 2004
Estimates derived using P-Splines fitted to mortality data by age and year

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Observation on effects of data volume on 'picture' resolution
Estimates of annual rates of mortality improvement
E&W population; males; data smoothed with age-period P-Spline models

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Estimating Mortality Rates
- Assume $d_{i,j}$ deaths and $N_{i,j}$ life-years exposure in data cell (i,j)
  - Mortality rate, $\quad q_{i,j} \quad = \quad d_{i,j} \div N_{i,j}$
  - Standard error, $\quad \sigma(q_{i,j}) \quad \approx \quad \sqrt{(d_{i,j})} \div N_{i,j}$
- Rules of Thumb
  - Standard error is $100 \sqrt{(d_{i,j}^{-1})}$ % of estimated mortality rate
  - 1% error on mortality rate is around 0.1 years on e_{70}
- Reduce estimation error by grouping data cells
  - If group n similar cells, $\sigma(\text{group } q) \approx \sigma(q_{i,j}) \div \sqrt{(n)}$

The CMI Mortality Projections Model
Why are the initial rates based on population data?

Estimating Rates of Mortality Improvement (RMI)

- Assume $d_{i,j}$ deaths and $N_{i,j}$ life years exposure in data cell (i,j)
  - $RMI_{i,j}$ = 1 - $q_{i,j} \div q_{i,j-1}$ = $1 - (d_{i,j} \div N_{i,j}) \div (d_{i,j-1} \div N_{i,j-1})$
  - $\sigma(RMI_{i,j}) \approx [q_{i,j} \div q_{i,j-1}] \times [exp\{\sqrt{(d_{i,j}^{-1} - N_{i,j}^{-1} + d_{i,j-1}^{-1} - N_{i,j-1}^{-1})}\} - 1]$
- Rules of Thumb
  - Standard error is roughly $100\sqrt{(d_{i,j}^{-1} + d_{i,j-1}^{-1})}$ %pa
  - 1% pa error on Initial RMI is around 0.75 years on e_{70}
- Reduce estimation error by grouping data or extending period
  - If average RMI over t years, $\sigma(RMI_{i,j-t\ to\ j}) \approx \sigma(RMI_{i,j}) \div t$

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Comparing Investigations

- Typical data cells: males, averaged over 2002-06, ages 65-85

	E&W Population	CMI Life Office Pensioners	CMI SAPS
Typical $d_{i,j}$	7,000	270	1,350
Typical $N_{i,j}$	160,000	7,000	33,500
95% CI on $q_{i,j}$	± 2.4%	± 12.2%	± 5.4%
95% CI on $RMI_{i,j}$	± 3.4% pa	± 17.2% pa	± 7.7% pa

- Estimating differences between two investigations, A & B
  - σ(Difference: A-B) $\approx \sqrt{(\sigma_A^2 + \sigma_B^2)}$ [assumes independence].

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Comparing Investigations

- Estimating Mortality Rates

95% CI on $q_{i,j}$	E&W Population	CMI Life Office Pensioners	CMI SAPS
Single data cell	± 2.4%	± 12.2%	± 5.4%
Grouping cells	5 ages x 1 year	10 ages x 5 years	5 ages x 3 years
Smoothed data	± 1.1%	± 1.7%	± 1.4%

- Can easily achieve workable accuracy by grouping / smoothing
  - by age for population
  - over age and years, perhaps heavily, for CMI data sets.

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Comparing Investigations

- Estimating Rates of Mortality Improvement

95% CI on RMI$_{i,j}$	E&W Population	CMI Life Office Pensioners	CMI SAPS
Single data cell	± 3.4% pa	± 17.2% pa	± 7.7% pa
Grouping cells	5 ages x 1 year	10 ages x 5 years	5 ages x 3 years
Smoothed data	± 1.5%	± 2.4%	± 2.0%
Extend period	5 x 1 x 3-yr RMI	10 x 5 x 5-yr RMI	5 x 3 x 4-yr RMI
Smooth avg	± 0.5%	± 0.5%	± 0.5%

- Difficult to achieve workable accuracy even at population level
- Need heavy smoothing and extended period to compare RMIs for CMI.

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The CMI Mortality Projections Model
Why are the initial rates based on population data?

Summary and conclusions

- We have sufficient data volumes to estimate mortality rates well
- Need orders of magnitude larger volume for reliable RMI estimates!
- Examples show difficulty when comparing Population and CMI RMIs
  - Need heavy smoothing and averaging over time
  - And estimation error bounds are even wider in the real world
- Can show historical differences, but say little about current differences
- Can only see detail pattern by age / cohort at population level
- We are developing estimation error measures for RMIs from P-Spline.

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The CMI Mortality Projections Model
How do CMI_2009 Core Projections compare to ICP?

Actual & projected mortality improvement rates for males in 2006
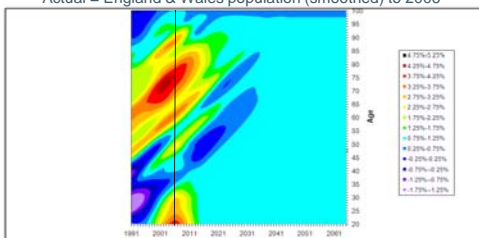CMI_2009 uses estimated actual derived from E&W population data

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The CMI Mortality Projections Model
How do CMI_2009 Core Projections compare to ICP?

Heat Map: CMI_2009_M [1.0%]
Actual & Projected Mortality Improvement Rates; Males
Actual = England & Wales population (smoothed) to 2006

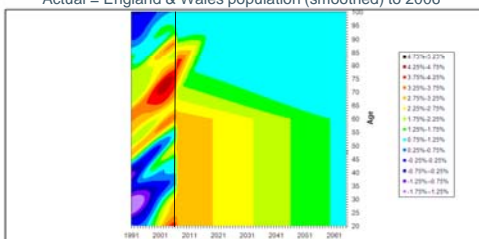**The CMI Mortality Projections Model**
How do CMI_2009 Core Projections compare to ICP?

Heat Map: Medium Cohort, 1.0% underpin
Actual & Projected Mortality Improvement Rates; Males
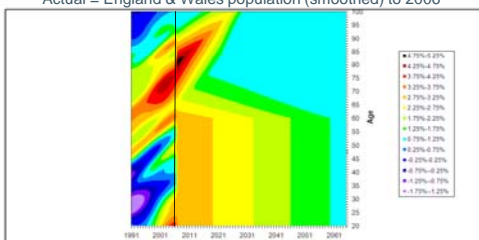Actual = England & Wales population (smoothed) to 2006

The CMI Mortality Projections Model
How do CMI_2009 Core Projections compare to ICP?

Heat Map: Long Cohort, 1.0% underpin
Actual & Projected Mortality Improvement Rates; Males
Actual = England & Wales population (smoothed) to 2006

The CMI Mortality Projections Model
How do CMI_2009 Core Projections compare to ICP?

Projected Expectation of Life, e_{65} , for age 65 exact as at 31/12/2009
Base Mortality : 100% PCMA00 for age exact on 01/07/2000

x%	CMI_2009_M [x%]	Medium Cohort, x% Underpin	Long Cohort, x% Underpin
0%	21.5	21.6	23.2
1%	22.6	22.1	23.5
2%	23.8	23.6	24.4
3%	25.1	26.0	26.3

- Broad similarity of CMI_2009 and Medium Cohort ?
  – Yes, when LTR = Underpin; age = 65; gender = males
- But patterns of projected mortality improvement vary significantly
  – So EoL comparisons vary significantly by age and over time.

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The CMI Mortality Projections Model
How do CMI_2009 Core Projections compare to ICP?

Projected Cohort Annuity Values relative to Medium Cohort
males; age exact as at 31/12/2009; value at 5%p.a.
Base Mortality : 100% PCMA00 for life aged x exact on 01/07/2000

CMI_2009 [1%]
Medium_1%
Long_1%
CMI_2009 [2%]
Medium_2%
Long_2%

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The CMI Mortality Projections Model
How do I set the Long-term Rate of Improvement?

Some possible sources to help inform opinion
- National and international mortality data
  – Observed trends and long-term rates of mortality improvement
- Other mortality projections and projection tools
  – Mathematical models: CBD, Lee-Carter, P-Spline, ...
  – National and international 'governmental' population / mortality projections
- Analysis / modelling of trends by cause-of death or disease processes
- Research on past, current and expected medical and social changes
- Expert opinion.

The role the CMI will play
- Encourage debate.

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The CMI Mortality Projections Model
Next Steps

Implementation and use of the Model
- Encourage use of the Model and debate on key assumptions
- Continuing feedback from users is welcomed!

Annual Updates
- Core default for Initial Rates of Mortality Improvement
- Incorporate each successive year's population data
- Late October ? (dependent on ONS publication dates).

General Reviews
- No other changes planned for 2010
- Possible informal survey in 2011 to assess usage and issues?

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