



# Mortality Projections

Current Issues in Life Assurance seminar  
23 / 31 May 2007

*Dave Grimshaw*  
*Secretary, CMI*

# Mortality Projections

- Background
- Recent CMI research
- The “library” of projections
- Recent CMI experience
- Mortality improvements – where next?

# Mortality Projections – the background

- "92" Series tables included projection of future mortality
- Single projection basis, derived from past trends
- Quickly found to understate actual mortality improvements
- Plus evidence had emerged of a "cohort effect"
- CMI published the "interim cohort projections" late in 2002
- MPWP established to explore possible projection methodologies for use with the "00" Series tables
- April 2006 – Working Paper 20 – Penalised-spline models
- March 2007 – Working Paper 25 – Lee-Carter models

# Recent CMI research: P-splines

- Regression model fitted to past data
- P-splines impose a penalty on differences in adjacent co-efficients
- Choice of penalties determines balance between smoothness and closeness of fit
- Model fitted to a surface, either:
  - age and calendar year (Age-Period) or
  - age and year of birth (Age-Cohort)
- Fitting process provides:
  - Fitted  $\log(\mu) \Rightarrow$  mean values
  - Standard deviations  $\Rightarrow$  determine confidence intervals

# Recent CMI research: Lee-Carter

- Structured time-series model

$$\log \mu(x, t) = a(x) + b(x)k(t) + e(x, t)$$

- No allowance for parameter uncertainty, so CMI have introduced through bootstrapping
- Basic model does not capture cohort effects  
⇒ Poor fit when back-testing from 1992
- Renshaw & Haberman Lee-Carter APC model

$$\log \mu(x, t, c) = a(x) + b_1(x)k(t) + b_2(x)I(c) + e(x, t, c)$$

- Introduces extra parameter to model cohort effects

# Recent CMI research: Conclusions

| <b>Objective</b>                | <b>P-Spline<br/>age-cohort</b> | <b>P-Spline<br/>age-period</b> | <b>Lee-Carter</b> | <b>Lee-Carter<br/>APC</b> |
|---------------------------------|--------------------------------|--------------------------------|-------------------|---------------------------|
| <b>Ease of use</b>              | <b>Y</b>                       | <b>Y</b>                       | <b>Y</b>          | <b>Y</b>                  |
| <b>Parameter Interpretation</b> | <b>N</b>                       | <b>N</b>                       | <b>Y</b>          | <b>Y</b>                  |
| <b>Structure &amp; fit</b>      | <b>Y</b>                       | <b>Y</b>                       | <b>N</b>          | <b>?</b>                  |
| <b>Cohort effects</b>           | <b>Y</b>                       | <b>N</b>                       | <b>N</b>          | <b>Y</b>                  |
| <b>Best estimate</b>            | <b>Y</b>                       | <b>Y</b>                       | <b>Y</b>          | <b>Y</b>                  |
| <b>Confidence Intervals</b>     | <b>Y</b>                       | <b>Y</b>                       | <b>Y</b>          | <b>Y</b>                  |
| <b>Sample paths</b>             | <b>N</b>                       | <b>N</b>                       | <b>Y</b>          | <b>Y</b>                  |

# Recent CMI research: Conclusions

- Issues with both P-spline & Lee-Carter
- Both dependent on improvements within past data
- CMI cannot recommend any specific method
- No “Holy Grail” !!

# Mortality Projections – further work

- CMI recognised its research not accessible to many actuaries
- Task Force formed to:
  - Illustrate the CMI's recent research to make it more accessible
  - Propose terminology to facilitate disclosure of mortality projections
  - Develop sets of projections which can be used as benchmarks
  - Collaborate with ECPD Board on education needs
- Membership of Task Force include life and pensions actuaries



# Mortality Projections – further work

- Task Force initial proposal is to construct a “library” of projections
- “Library” will comprise a “spreadsheet” with numerous projections and a supporting document
- Projections can be combined with any base table
- Library will be published in draft with the supporting document as a CMI Working Paper
- Consultation document including specific questions for feedback

# Mortality Projections – further work

Initial “library” of projections will include:

- Existing projections:
  - “92” Series
  - Cohort Projections
  - ONS population projections
- Variations on existing projections in current use:
  - Imposing a minimum improvement on a Cohort Projection
  - Using a percentage of a Cohort Projection
- Examples of P-spline and Lee-Carter projections

# Mortality Projections – further work

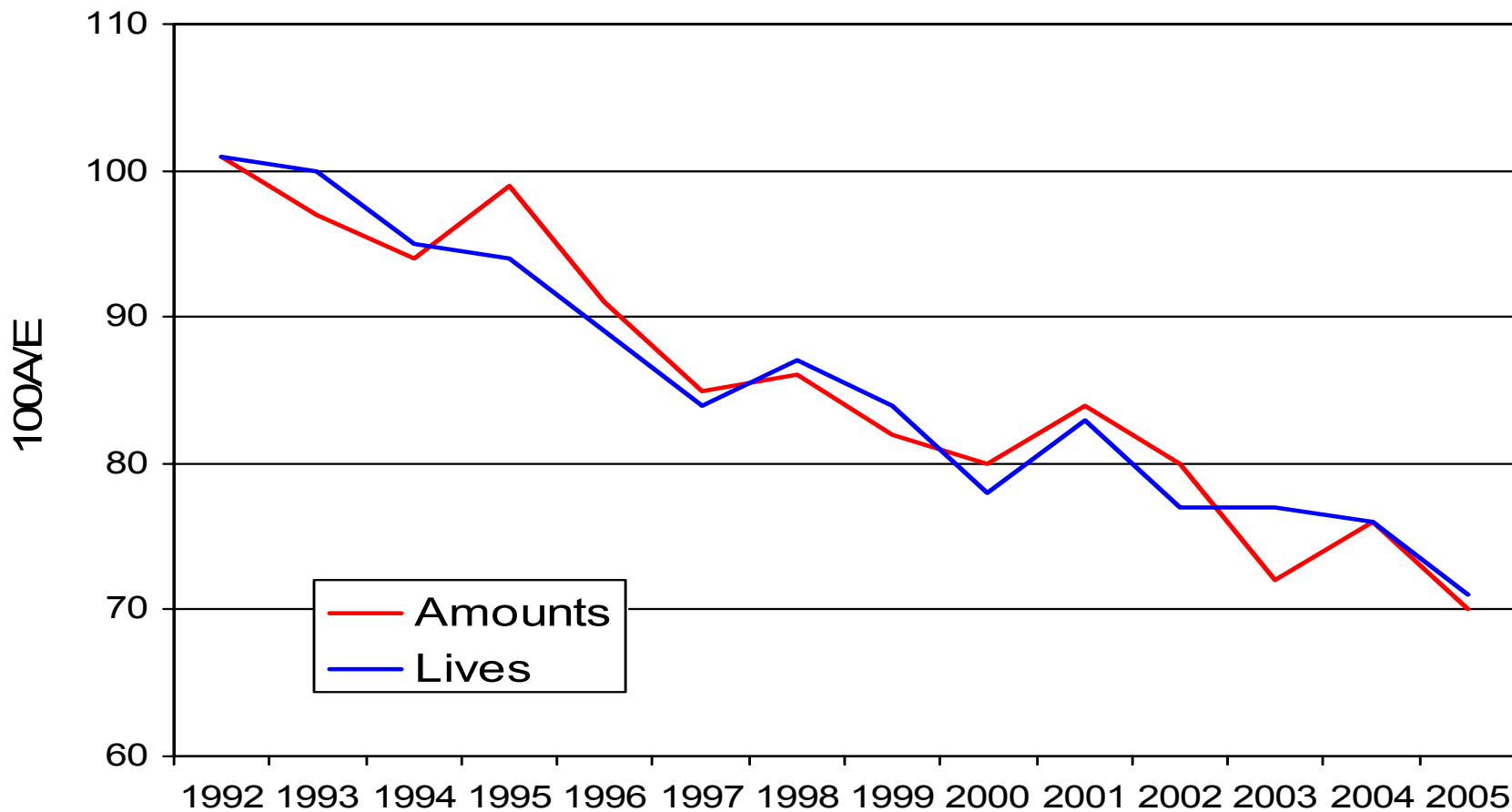
- What will the “library” achieve?
  - Single source of “recognised” projections
  - Standardisation of terminology for these
- What will the “library” not achieve?
  - No guidance on choice of projection
- Does this meet your needs?

# Recent CMI experience

- Results released to members for 2003 and 2004
- Assured lives data to 2004 also made available with software
- 2005 results will be released to members soon

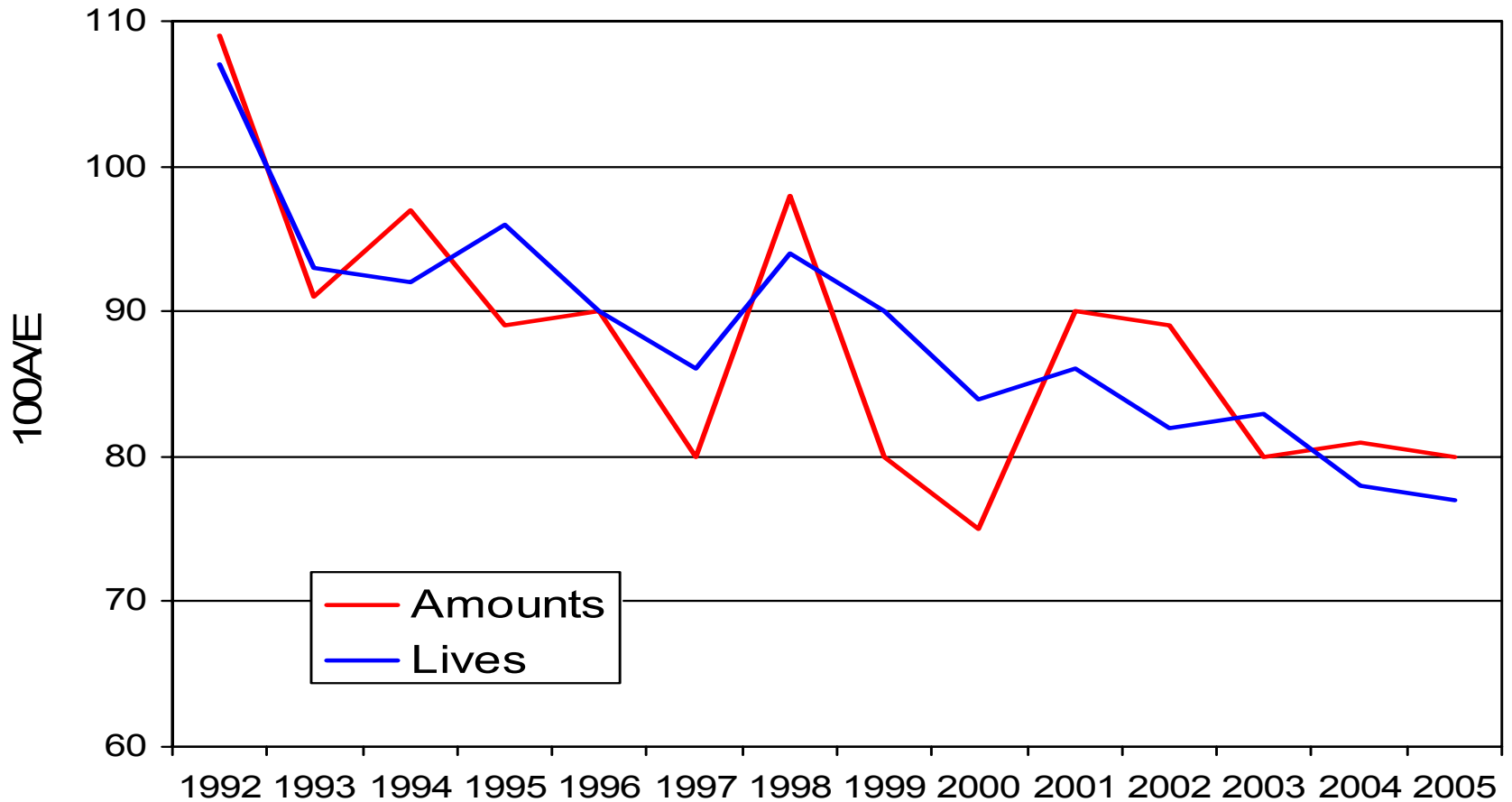
# Recent CMI experience

Male Life Office Pensioners 100A/E, E= "92" Series mortality rates, Normals



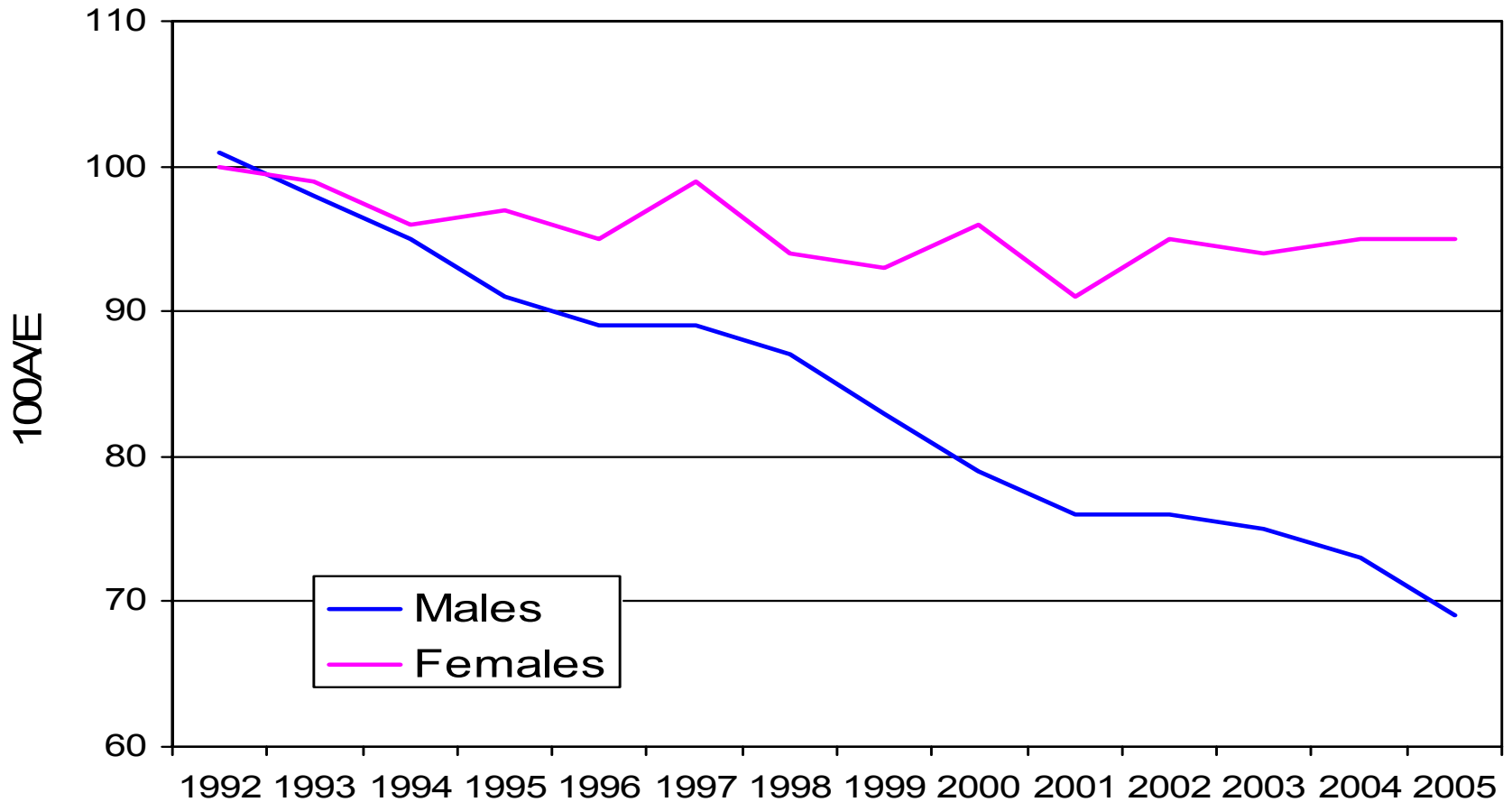
# Recent CMI experience

Female Life Office Pensioners 100A/E, E= "92" Series mortality rates, Normals



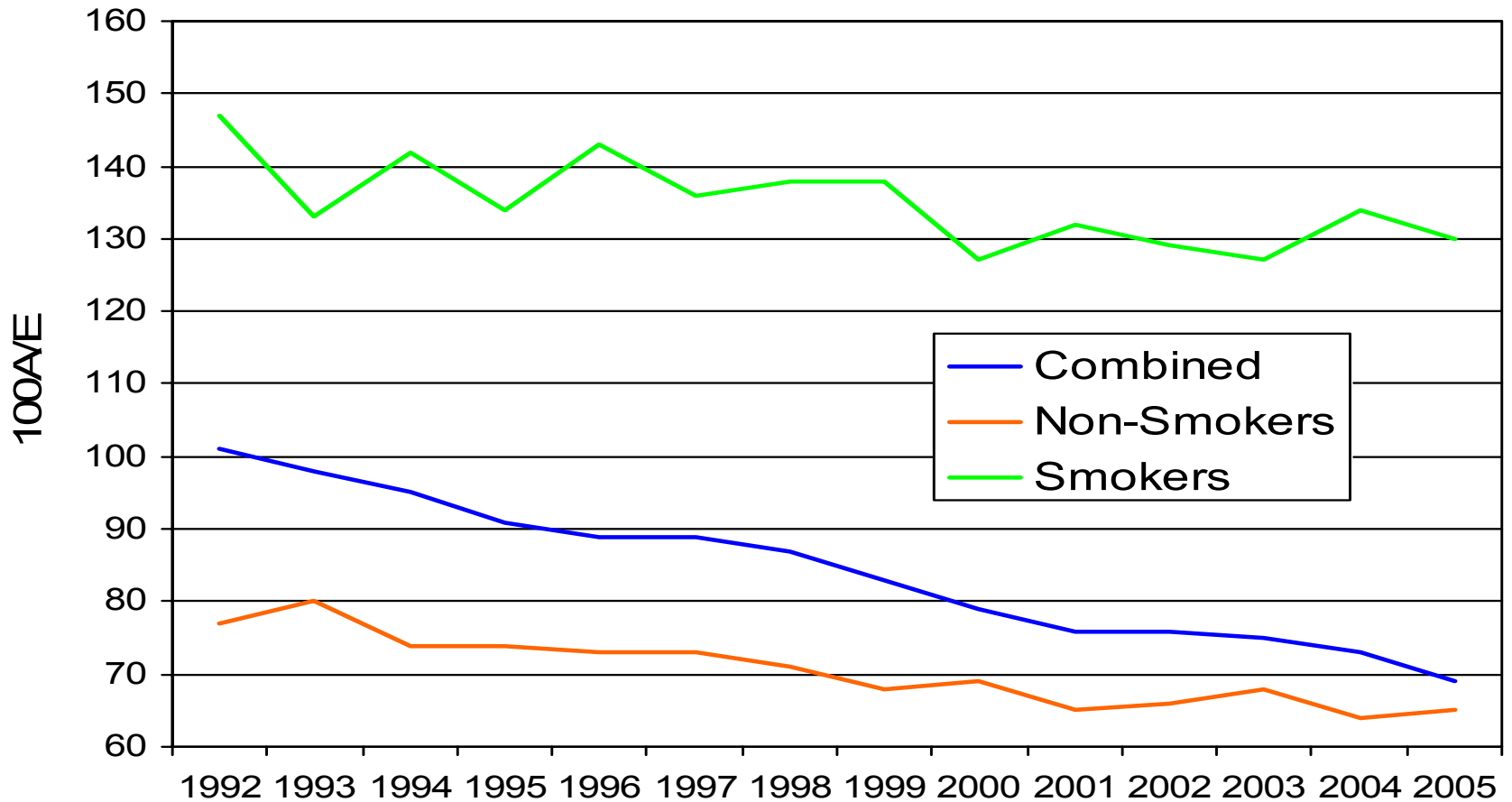
# Recent CMI experience

Assured Lives 100A/E, E= "92" Series mortality rates



# Recent CMI experience

Assured Lives 100A/E, E= "92" Series mortality rates, Males





# Recent CMI experience

- Male experience has continued to improve to 2005
- Female experience appears to have improved for Life Office Pensioners, not so for Assured lives
- Improvements on Assured Lives at least partially explained by changes in prevalence of smoking
- Individual year results vulnerable to changing mix of offices
- All-ages results mask changes by age

# Mortality Projections

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Dave Grimshaw,  
CMI Secretary

Dave Grimshaw,  
A perplexed actuary

# Mortality improvements – where next?

- Statistical methods:
  - P-spline – *age-period or age-cohort?*
  - Lee-Carter – *Basic or age-period-cohort?*  
+ *choice of dataset, parameterisation, etc*
- ... or something simpler?

# Mortality improvements – where next?

Assumption on future improvements in male mortality from selected 31/12/2006 FSA Returns:

*(All unchanged from 31/12/2005)*

- Friends Provident: Average (MC,LC) min 0.50%
- L&G: Average (MC,LC) min 0.80%
- Norwich Union: MC min 2.00%
- Prudential: MC min 1.25%
- Standard Life: MC min 1.50%

# Mortality improvements – where next?

- “Should projections of mortality improvements be subject to a minimum value?”

*Steven Baxter, Institute sessional meeting, 26 Feb 2007*

- “Possibly...”

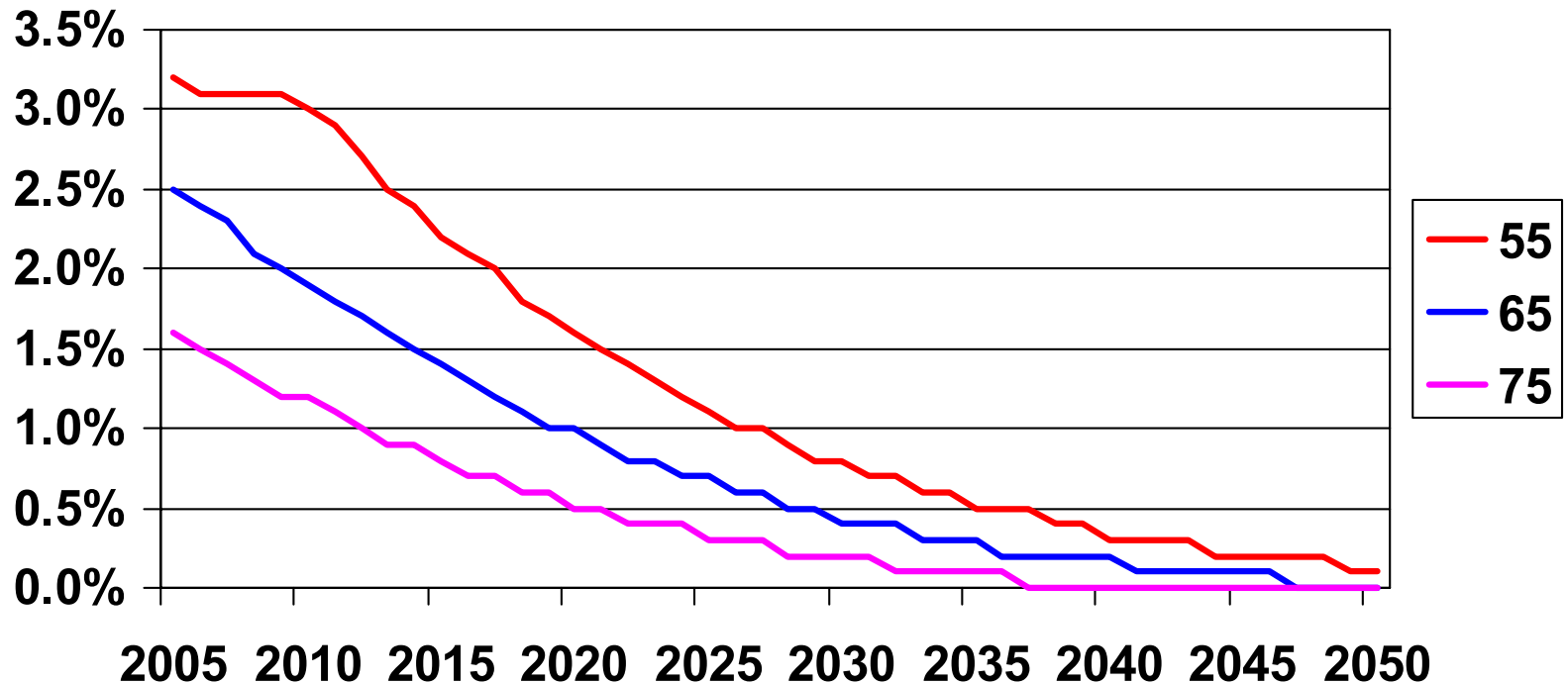
*Dave Grimshaw, CILA, 23 May 2007*

➔ Which projection?

➔ What minimum value?

# Mortality improvements – which projection?

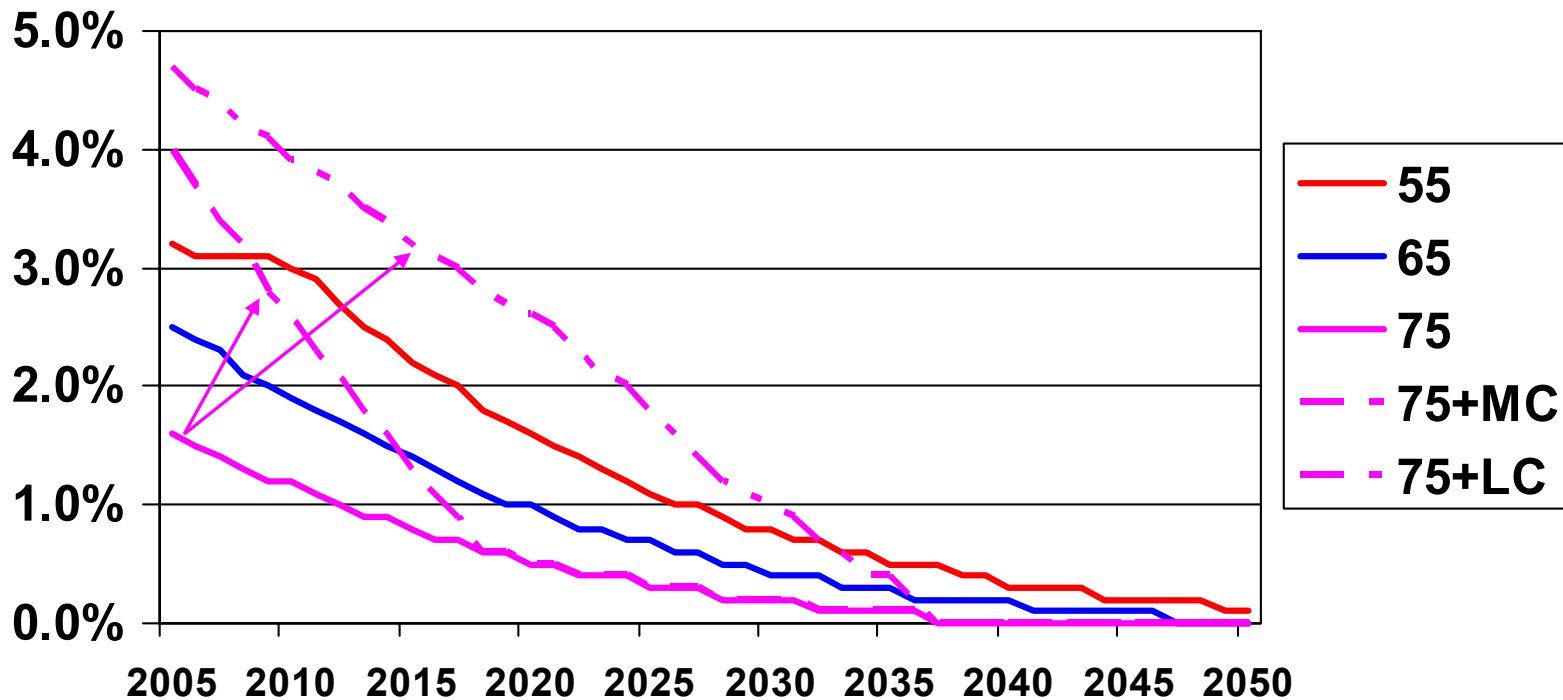
“92” Series implies a rapid slow-down in mortality improvements



Age in 2005

# Mortality improvements – which projection?

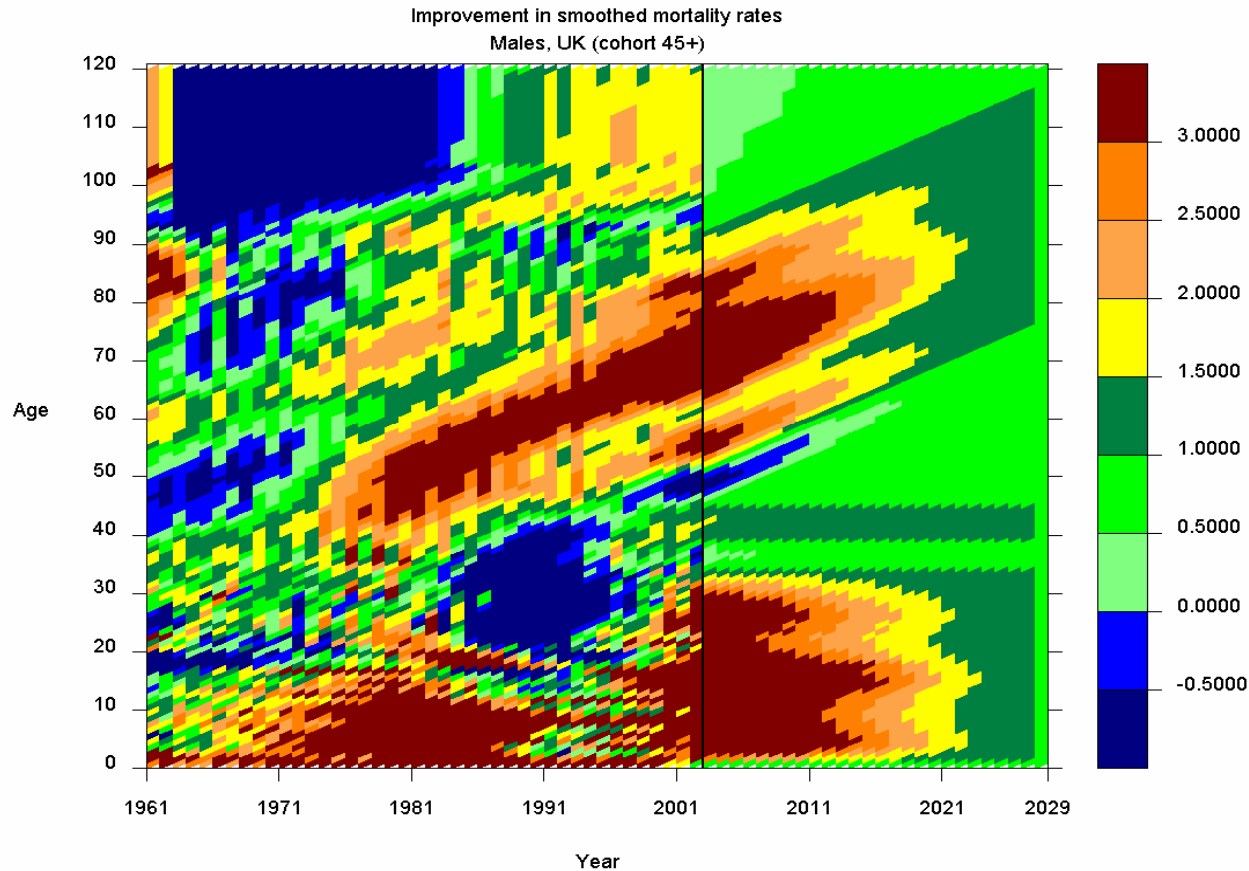
“92” Series implies a rapid slow-down in mortality improvements  
...Cohort projections are ad hoc adjustments to some ages



Age in 2005

# Mortality improvements – what minimum?

1% minimum improvement is much lower than in recent past



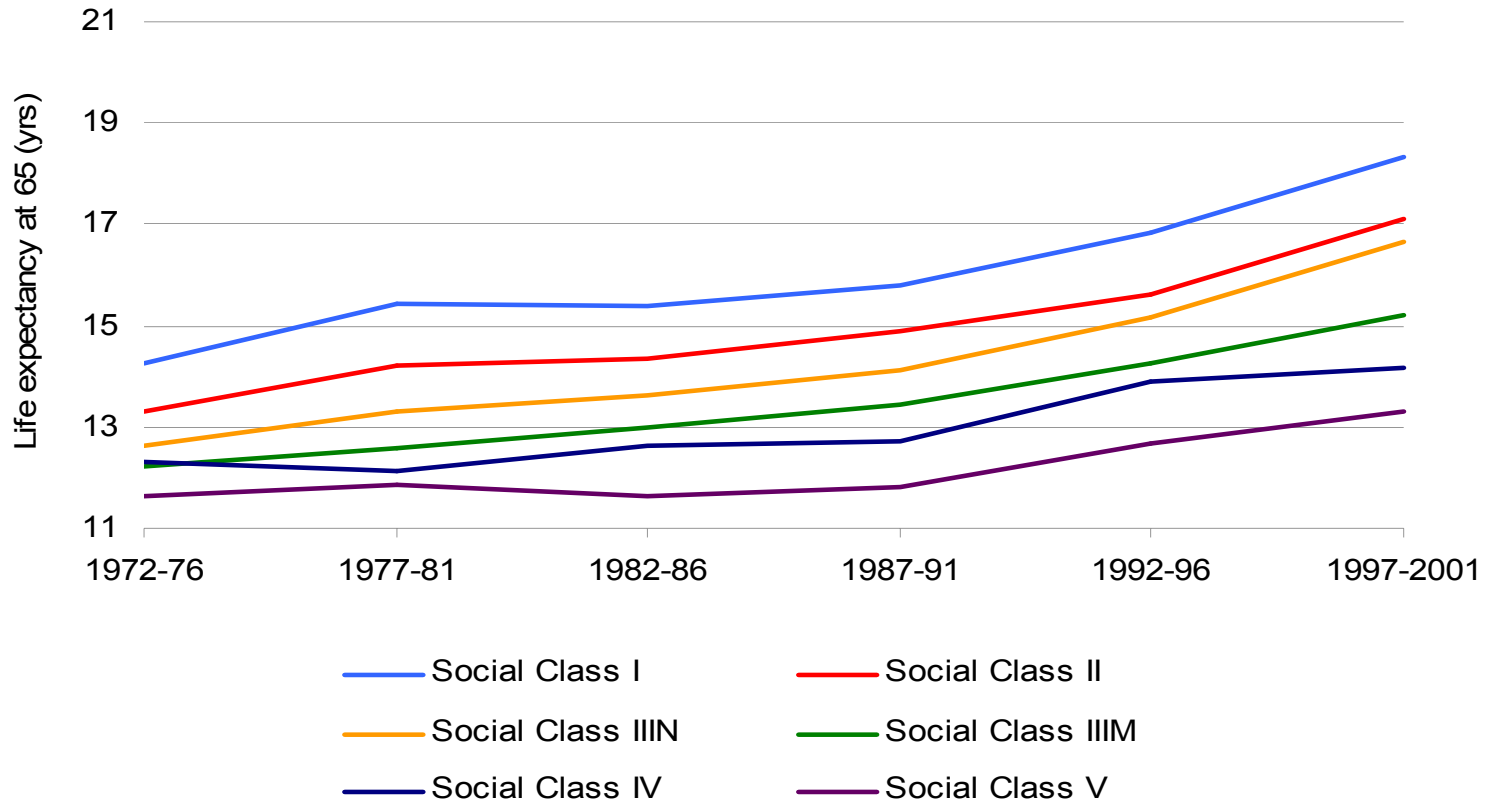
Annual improvement in smoothed mortality rates, Males, UK

Source: Adrian Gallop, Mortality seminar, 26 April 2007



# Mortality improvements – what minimum?

Mortality improvements have been faster for higher social classes



Trend in male period life expectancy at age 65 by social class, 1972-2001

Source: Adrian Gallop, Mortality seminar, 26 April 2007

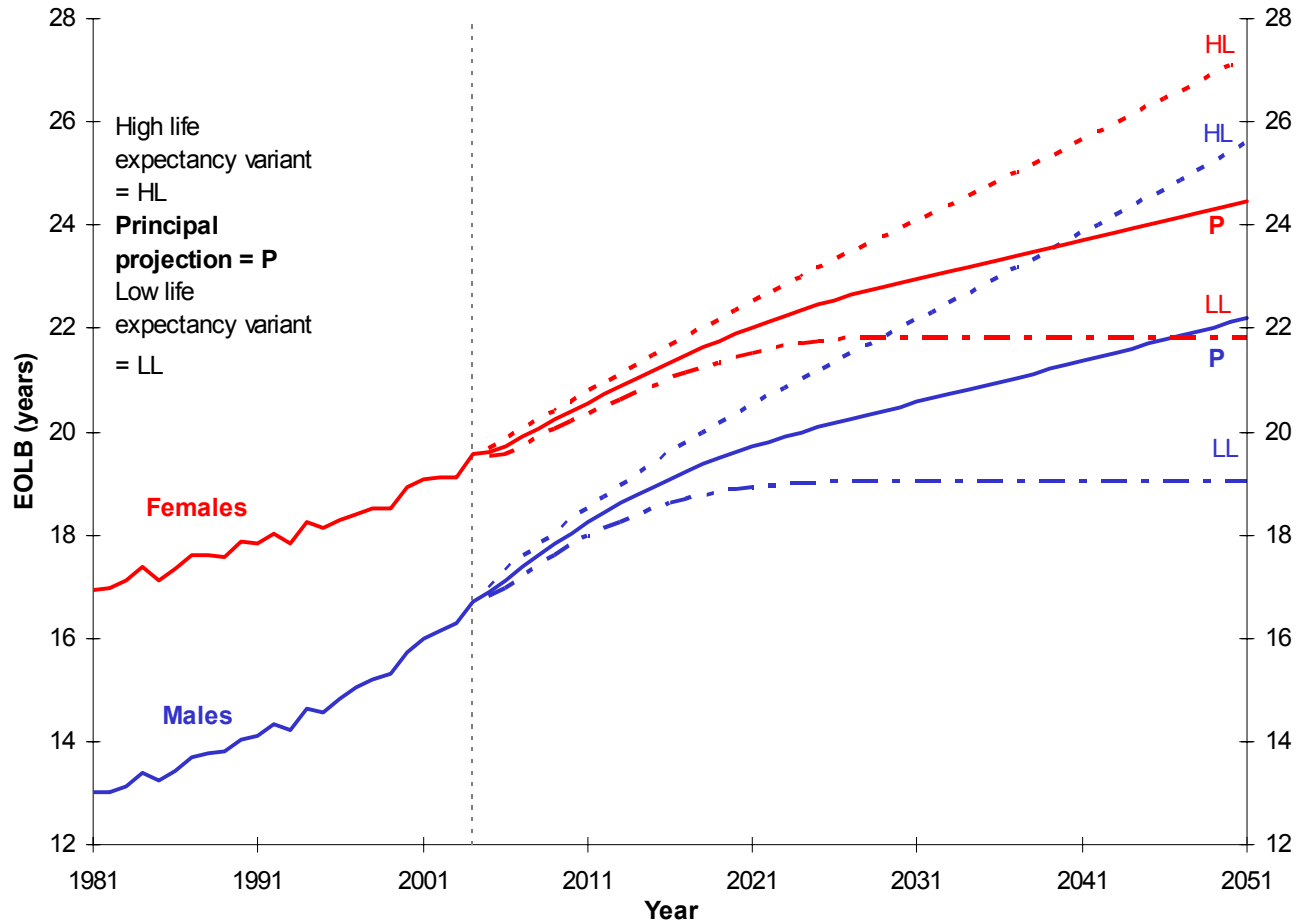
# UK Population Mortality Projections

- Estimate current rates of mortality improvement by age and gender
- Set rates of mortality improvement for some future year (the target year)
- Make assumptions on method and speed of convergence from current improvement rates to target rates and how improvement rates change after target year

# UK Population Mortality Projections

- Target year is 25<sup>th</sup> year of projection (ie 2029 for 2004-based projections)
- Improvements in 2029 assumed to be 1% pa for all ages for both males and females
- Convergence not linear; more rapidly at first for males, less rapidly for females
- For those born before 1960, convergence assumed along cohort
- After 2029 rates of improvement assumed to remain constant at 1% pa
- Variants – HLE target rate 2%, LLE target rate 0%
- Applies to UK and constituent countries

# Period expectation of life at age 65, UK



Source: Adrian Gallop, Mortality seminar, 26 April 2007

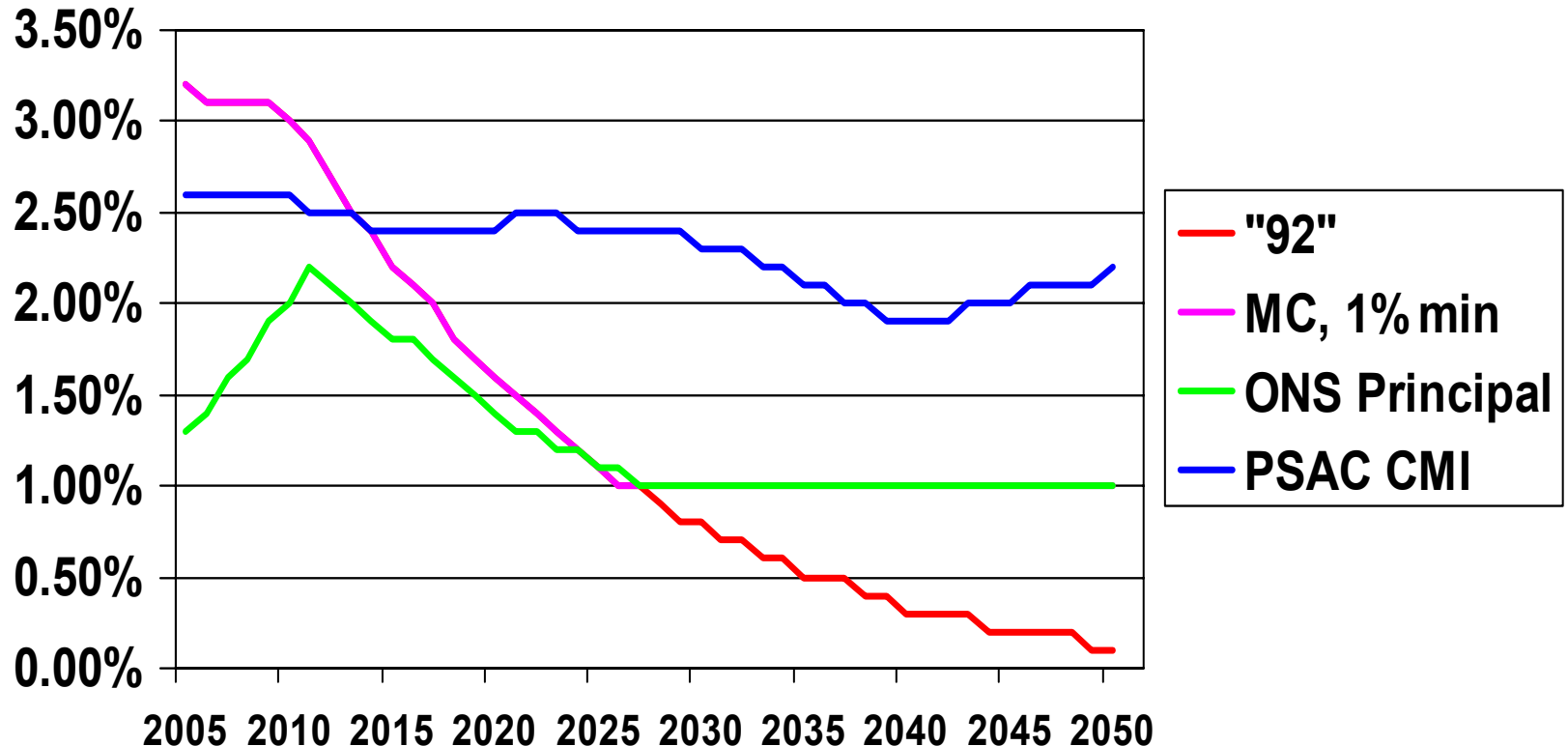
# Actual and assumed overall annual rates of mortality improvement

|                    | Males            |                     | Females          |                     |
|--------------------|------------------|---------------------|------------------|---------------------|
|                    | Past<br>(Actual) | Future<br>(assumed) | Past<br>(Actual) | Future<br>(assumed) |
| Last/next 22 years | 2.0%             | 1.9%                | 1.3%             | 1.8%                |
| Last/next 42 years | 1.5%             | 1.5%                | 1.3%             | 1.4%                |
| Last/next 72 years | 1.2%             | 1.3%                | 1.2%             | 1.3%                |

Note: Analysis relates to England & Wales. Historic estimates are based on comparison of 2002-04 Interim Life Tables with English Life Tables for 1930-32, 1960-62 and 1980-82

# Comparison of projections

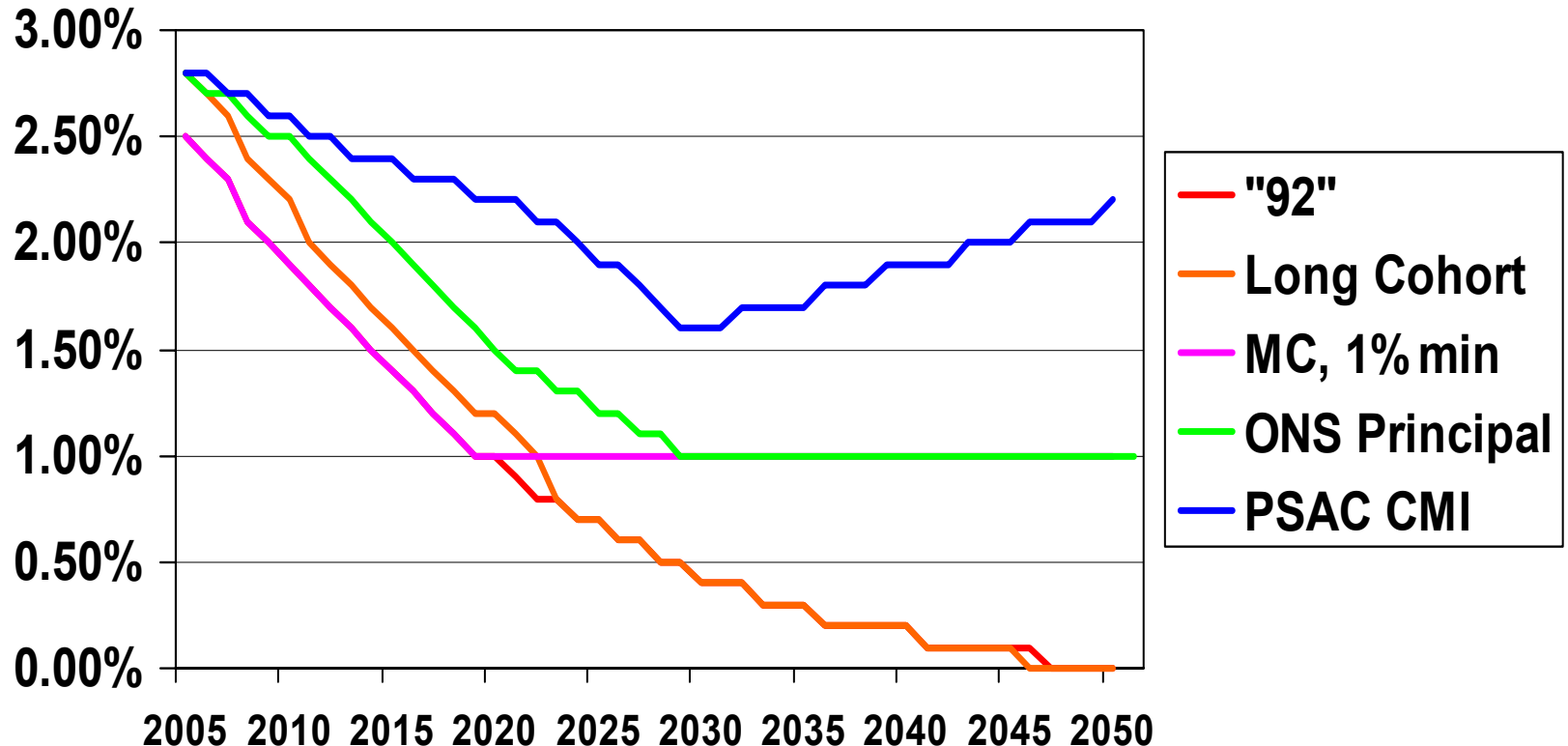
Male age 55 in 2005



Source: own calculations

# Comparison of projections

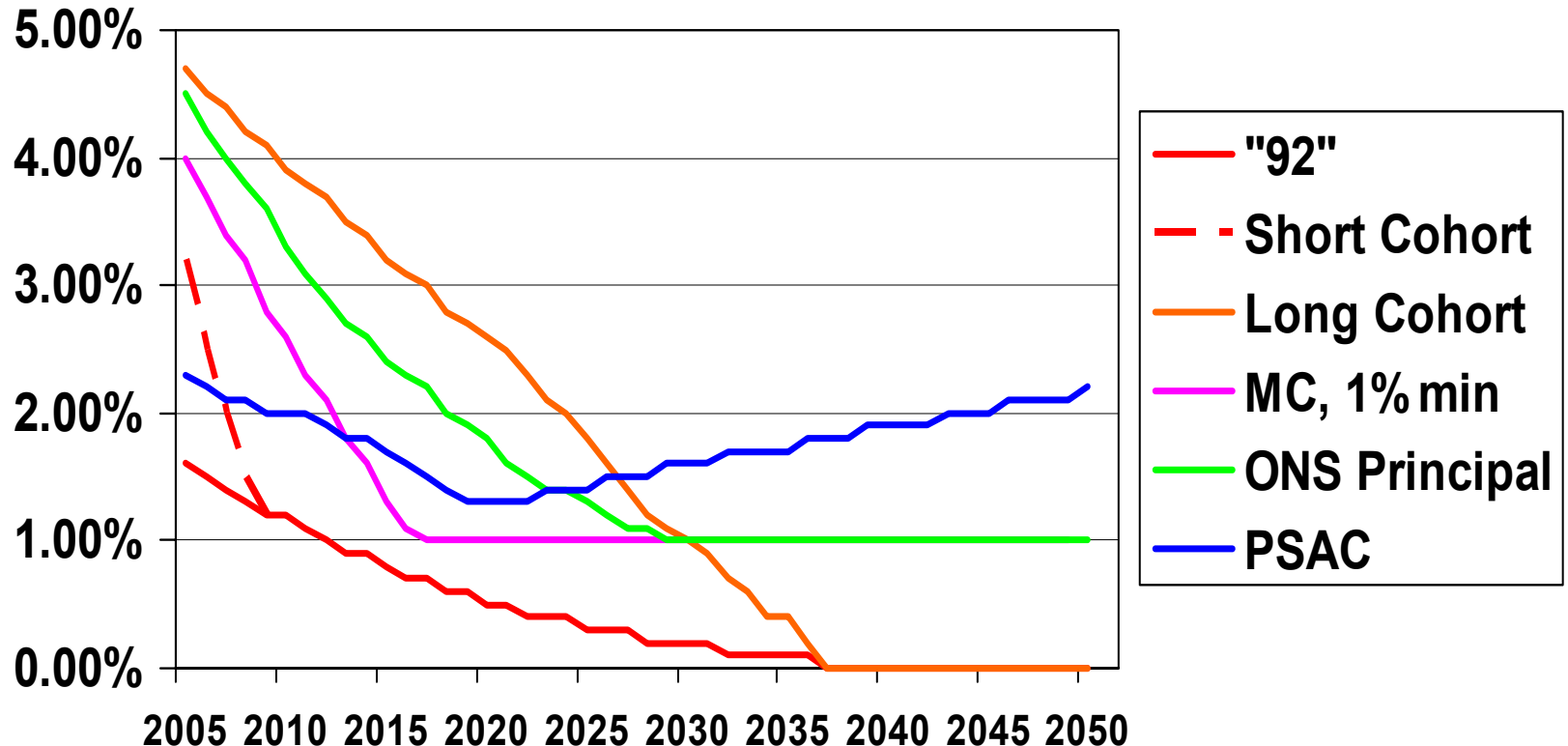
Male age 65 in 2005



Source: own calculations

# Comparison of projections

Male age 75 in 2005



Source: own calculations



# Comparison of projections

|               | ${}_{20 }\ddot{a}_{45}$ | ${}_{10 }\ddot{a}_{55}$ | $\ddot{a}_{65}$ | $\ddot{a}_{80}$ |
|---------------|-------------------------|-------------------------|-----------------|-----------------|
| PMA92         | 4.539                   | 7.462                   | 12.542          | 7.054           |
| PMA92sc       | 4.624                   | 7.613                   | 12.816          | 7.303           |
| PMA92mc       | 4.698                   | 7.738                   | 13.034          | 7.531           |
| PMA92lc       | 4.862                   | 8.015                   | 13.508          | 7.869           |
| PMA92mc/1%    | 4.781                   | 7.823                   | 13.109          | 7.581           |
| PSac CMI 2004 | 5.164                   | 8.167                   | 13.206          | 7.397           |
| PSac ONS 2004 | 5.873                   | 9.060                   | 14.212          | 7.944           |

Annuity values @ 5%, base mortality = 100% PCMA00 for a life aged x in 2005. Source: own calculations

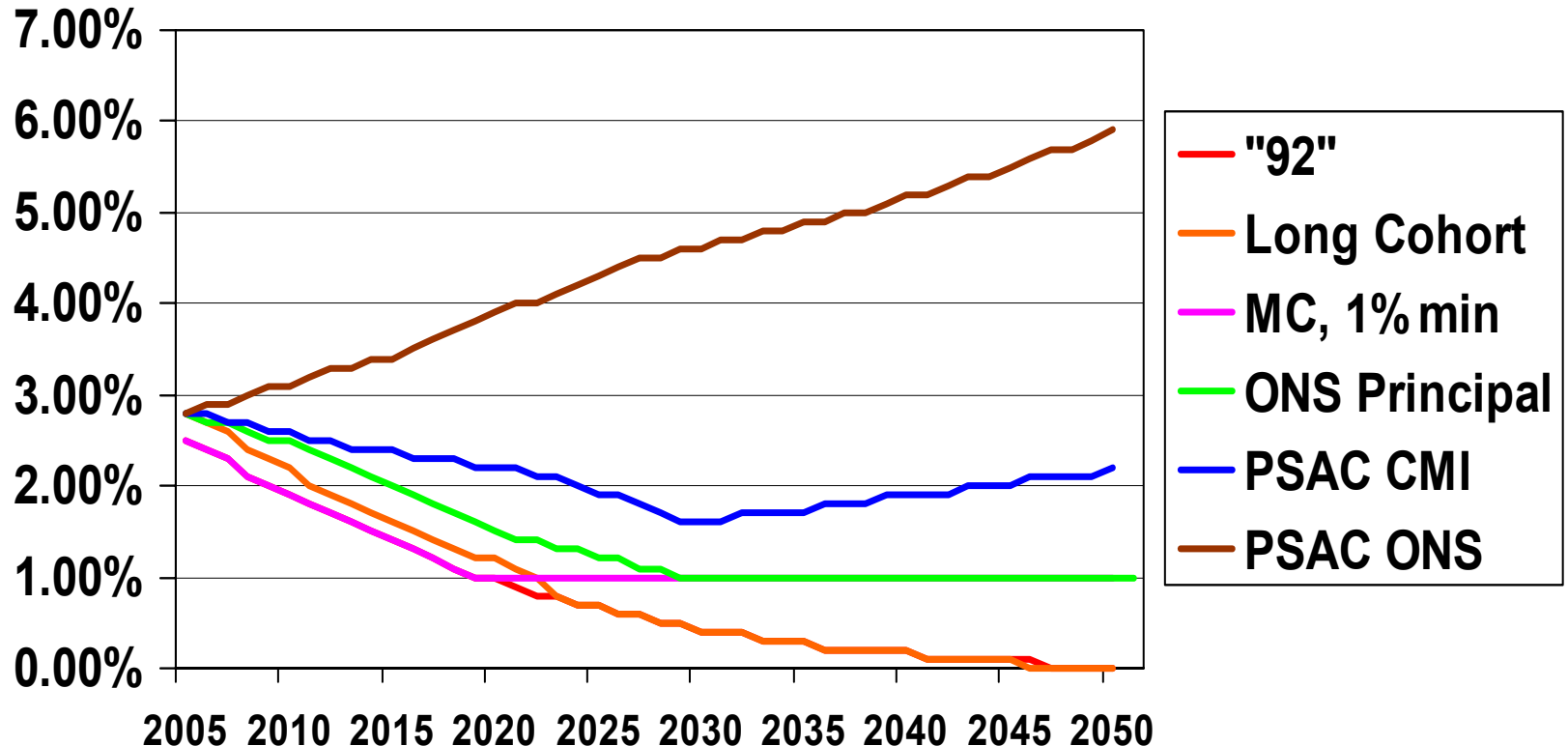
# Comparison of projections

|               | $20 \ddot{a}_{45}$ | $10 \ddot{a}_{55}$ | $\ddot{a}_{65}$ | $\ddot{a}_{80}$ |
|---------------|--------------------|--------------------|-----------------|-----------------|
| PMA92         | 100%               | 100%               | 100%            | 100%            |
| PMA92sc       | 102%               | 102%               | 102%            | 104%            |
| PMA92mc       | 104%               | 104%               | 104%            | 107%            |
| PMA92lc       | 107%               | 107%               | 108%            | 112%            |
| PMA92mc/1%    | 105%               | 105%               | 105%            | 107%            |
| PSac CMI 2004 | 114%               | 109%               | 105%            | 105%            |
| PSac ONS 2004 | 129%               | 121%               | 113%            | 113%            |

Annuity values @ 5%, base mortality = 100% PCMA00 for a life aged x in 2005. Source: own calculations

# Comparison of projections

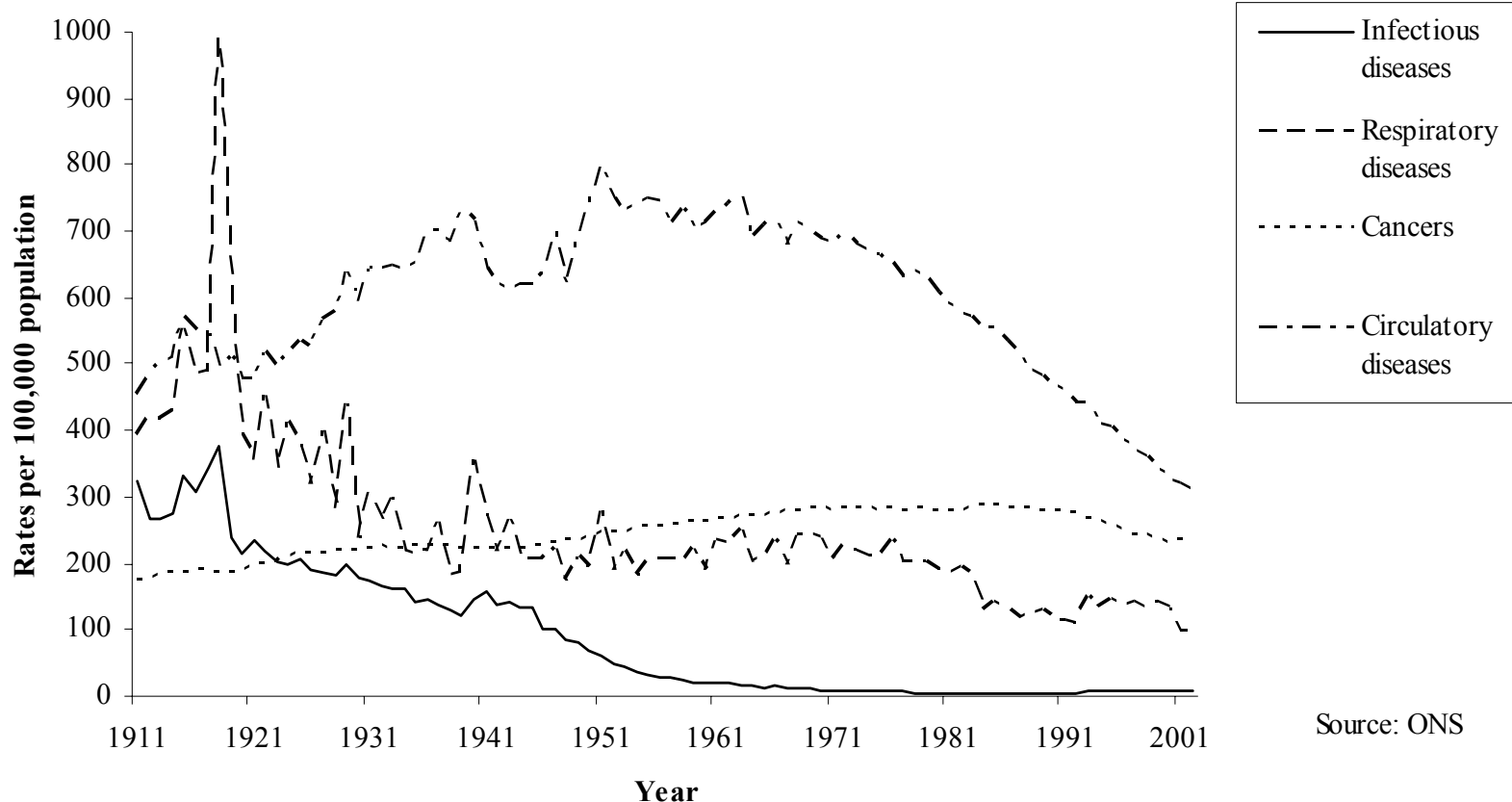
Male age 65 in 2005



Source: own calculations

# Male mortality by major cause, England & Wales, 1911-2002

Age standardised mortality rates for selected broad disease groups



Source: ONS

Source: ONS

# Mortality improvements – where next?

## Conclusions:

- There is no “right” answer
- P-spline and Lee-Carter project continued high rates of improvement (at most ages) – is it prudent to assume lower?
- But they are not extreme, e.g. compared to a continued acceleration in rate of improvement
- Medium Cohort now implies a very rapid fall in improvements – cannot be considered prudent
- Long Cohort plus a minimum represents a more gradual reversion to longer-term trends in improvements...
- ... and not dissimilar from adapting ONS principles for social mix
- Appropriateness will depend on age-profile

# Mortality improvements – where next?

## Conclusions:

- There is no “right” answer
- Need to explain uncertainty in ways that Boards or trustees can comprehend
- Need to consider trends by cause
- Need for more research –
  - Life Research Committee proposing working party into modeling mortality by cause – volunteers to [dave.grimshaw@barnett-waddingham.co.uk](mailto:dave.grimshaw@barnett-waddingham.co.uk)
- Can we do more on (new) projection methodologies?

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making financial sense of the future

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