Longevity 5:
Fifth International Longevity Risk and Capital Markets Solutions Conference
New York City

POPULATION BASIS RISK AND HEDGE EFFECTIVENESS

Hedging Longevity Risk

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"Buy an annuity cheap, and make your life interesting to yourself and everybody else that watches the speculation."

- Charles Dickens (1812 - 1870)

Overview

- **Hedging longevity risk with index-based hedges**
  - Can be beneficial because
    - The only practical alternative for deferred pensions/annuities
    - Some pension plans are too large to fully hedge any other way
    - Cost and liquidity
  - Basis risk must be measured
- **Framework for basis risk analysis**
  - Focus on Data and Context
- **Empirical analysis of UK and US case studies**
  - Widely available data
  - Evidence of stable relationships between them
  - Risk reduction using national population longevity index-based hedges can be significant if hedge optimally calibrated

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What is basis risk?

- **Basis risk** refers to the mismatch associated with a hedging relationship
  - Present in most financial hedges
  - Differences between underlying exposure and hedging instrument
  - Leads to residual risks because the hedge is imperfect

- **Longevity basis risk** refers to mismatch in demographics between the beneficiaries of a pension plan or annuity portfolio and the population associated with the longevity hedging instrument
  - Gender basis
  - Age basis
  - Socioeconomic basis
  - Geography basis

Framework for analyzing basis risk and hedge effectiveness

- Framework must be aligned to the objective of longevity hedging
  - Focus on the implications for hedge effectiveness

- Key elements:

  1. Data:
     - Metric
     - Time horizon
     - Analytical method
  2. Context

- Framework must recognize that data is likely to be insufficient
  - Most pension plans and annuity portfolios don't have enough historical data to draw rigorous statistical conclusions
  - Careful analysis using available data but also taking account of demographic, social and economic context

Conclusions based on judgment not statistical proofs

Metrics for analyzing basis risk

1. Mortality rates ← *Underlying observable data*
2. Mortality improvements
3. Survival rates
4. Life expectancy
5. Liability cash flows
6. Liability values

Derived data

- Simple comparison of mortality rates can be misleading
  - Mortality rates do not directly relate to hedge effectiveness
  - Annual mortality rates contain a lot of "noise"

Time horizon for basis risk analysis should be long

- Longevity risk is a slowly-building cumulative trend risk that should be evaluated over long horizons
  - Metrics should be compared over multi-year horizons
  - This better reflects the nature of the risk
  - Helps reduce the impact of noise that can give misleading results

- But long horizons mean fewer independent observations available from historical data.

Selecting an appropriate time horizon involves a trade-off

Analytical methods

- Analytical approaches to explore relationship between populations:
  - **Correlation**
    - E.g. correlation in improvements in mortality rates
  - **Regression**
    - E.g., regression of life expectancies through time
  - **Graphical assessment**
    - E.g., stability of ratio of survival rates through time
  - **Risk reduction**
    - E.g., reduction in volatility of liability value after hedging

- Techniques to reduce noise:
  - Graduation of mortality rates
  - Age bucketing
  - Long-term horizon

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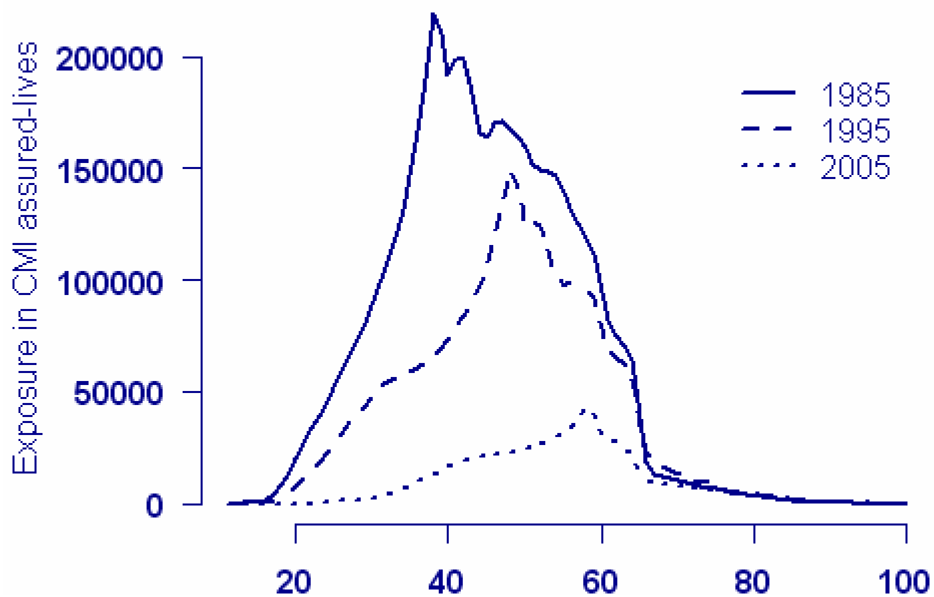
UK males who own life assurance: "CMI Assured Lives"

- Assured population is an affluent subset of the national population
  - Data collected by the CMI (Continuous Mortality Investigation)
  - Contributors are UK Life offices

- Characterized by:
  - Lower mortality rates
  - Higher mortality improvements
  - Higher life expectancy
  - Fewer lives at high ages
  - Number of lives variable
  - Contributors vary

Male assured lives (CMI)



Source: Longevitas (www.longevitas.co.uk)

At face value basis risk relative to national population is "high"

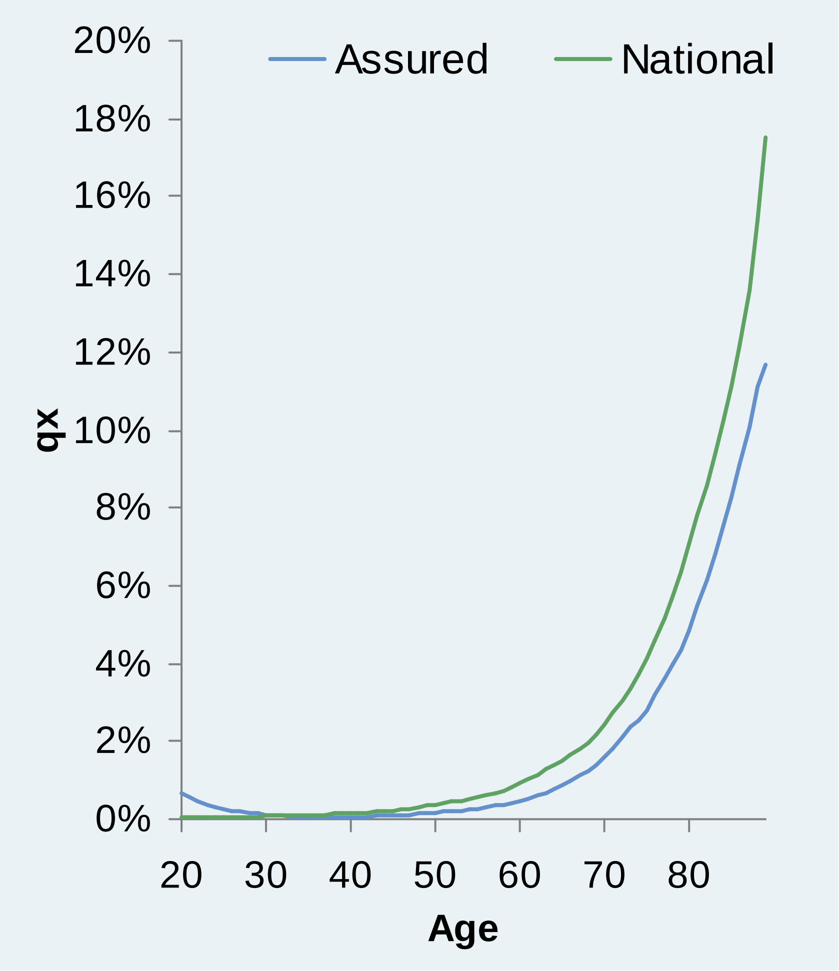
Setting the context

- CMI assured lives:
  - A subpopulation of the UK national population
    ➔ Influenced by the same trends that impact national population
  - Affluent, high income
    ➔ Lower mortality rates, higher life expectancy, faster improvements
  - Data very noisy
    ➔ Changing contributors, changing numbers of lives and small numbers at high ages

- Implications
  - The socioeconomic fabric of the UK means that mortality rates and life expectancies should not diverge without bound over the long run
  - This doesn't mean that they converge, rather they shouldn't get too far apart over the long run
  - Noise may mask underlying relationships, particularly at high ages

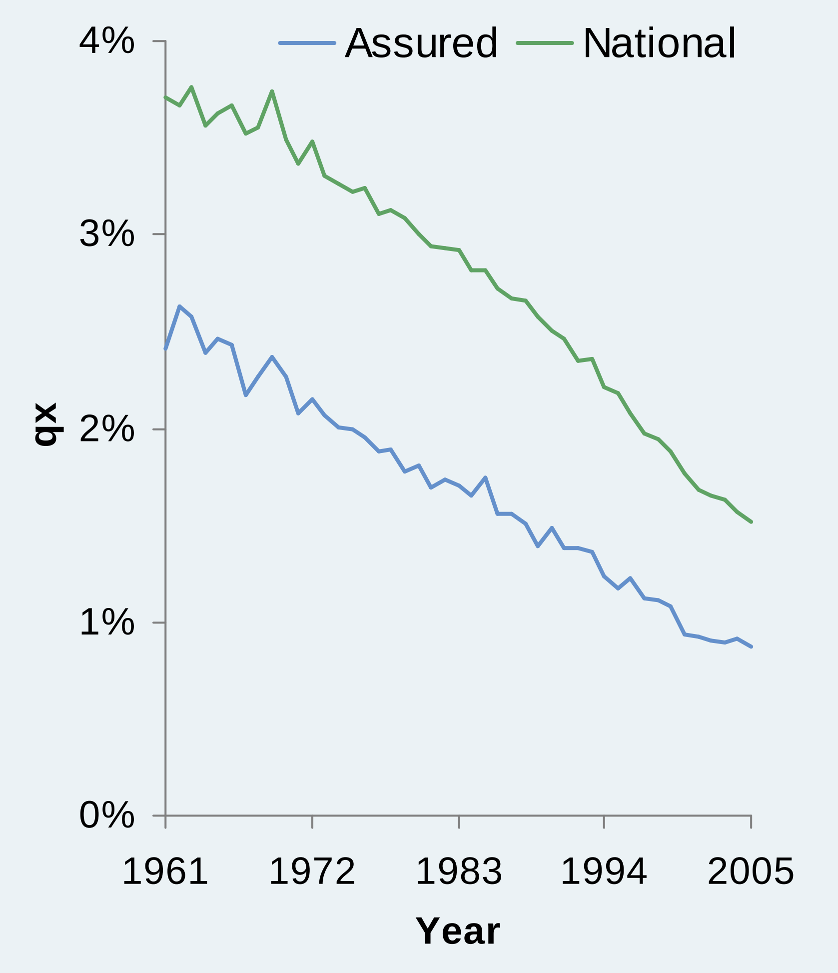
Metric 1: Graduated mortality rates: Assured lives vs. national population

2005 mortality rates



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Historical mortality rates age 65



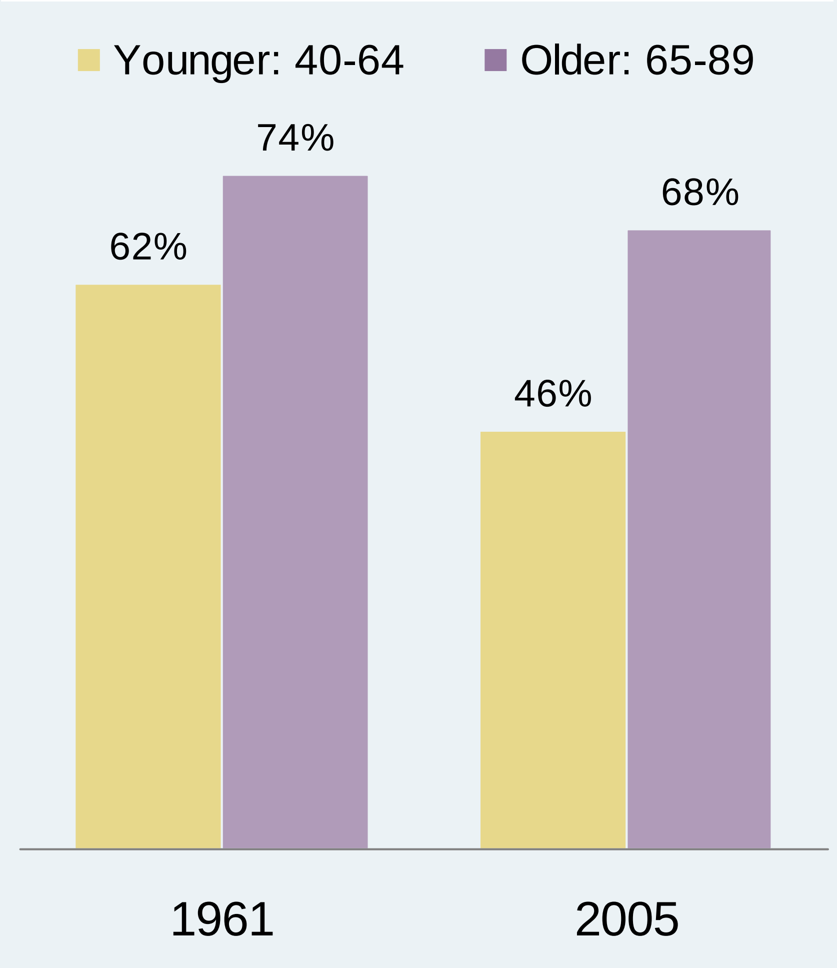
Source: J.P. Morgan, LifeMetrics Index and CMI publications

At face value experience has been very different

EXAMPLE FROM THE UK

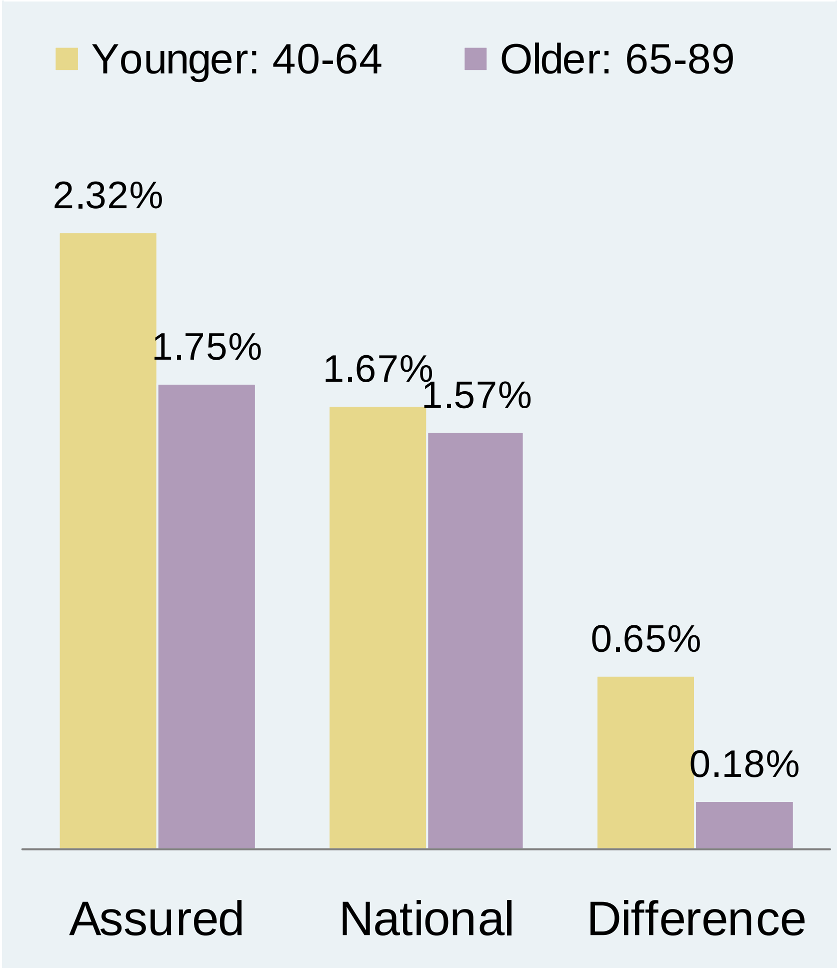
Comparing graduated mortality rates 1961-2005

Ratio of mortality rates [assured / national]



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Annualized improvements 1961-2005



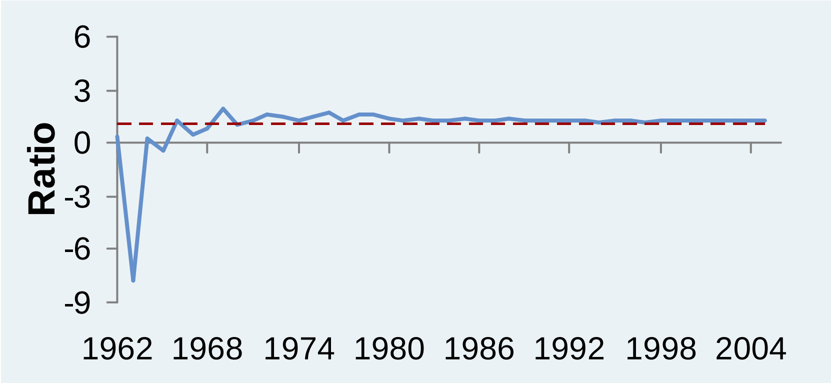
Source: J.P. Morgan, LifeMetrics Index and CMI publications

Assured population has lower mortality and higher improvements

Metric 2: Mortality improvements converge over the long run

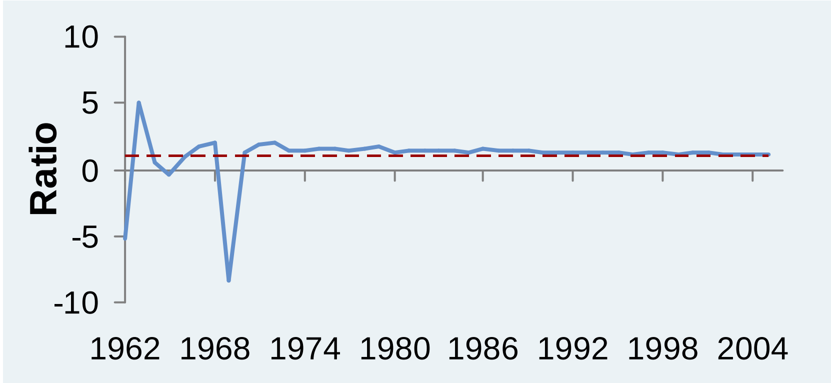
Ratio of cumulative mortality improvements*: [assured / national]

Age group 50-59



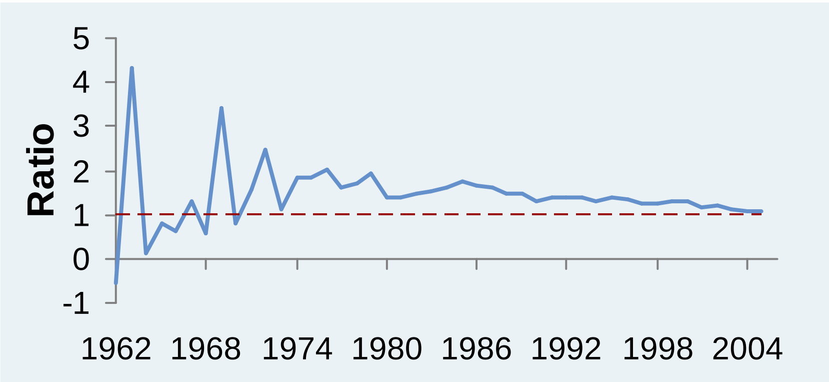
Source: J.P. Morgan, LifeMetrics Index and CMI publications

Age group 60-69



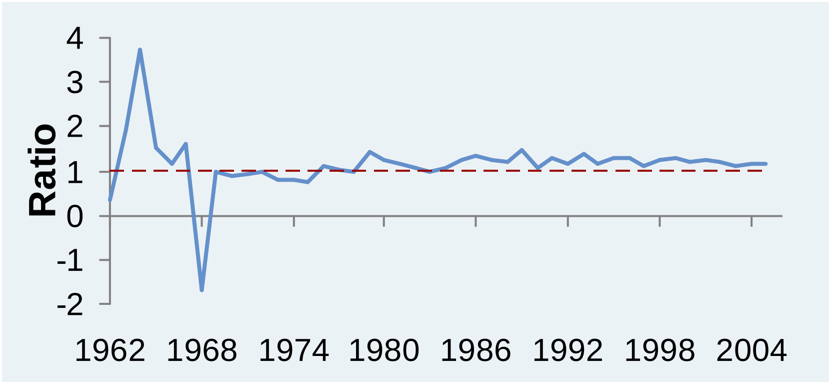
Source: J.P. Morgan, LifeMetrics Index and CMI publications

Age group 70-79



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Age group 80-89



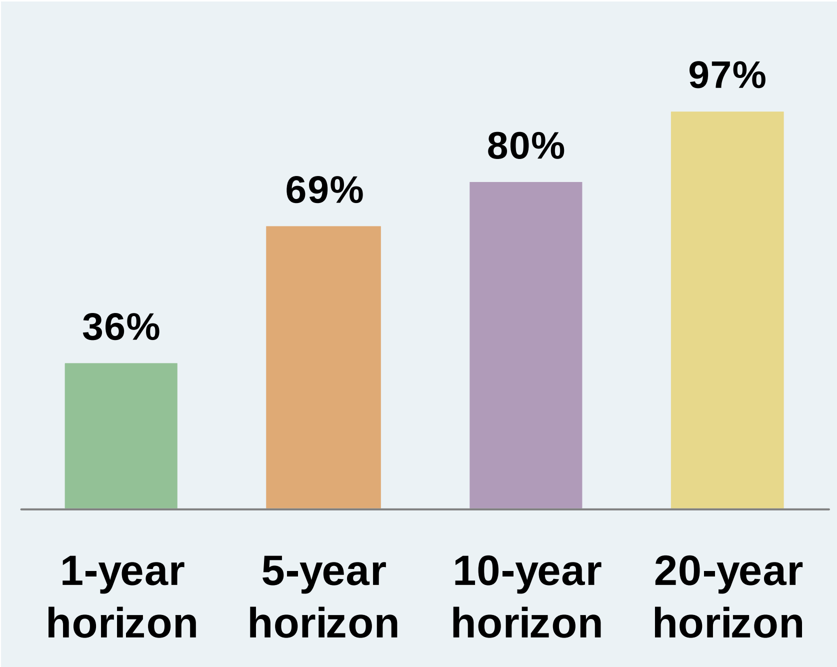
Source: J.P. Morgan, LifeMetrics Index and CMI publications

* Ratio of annualized improvements since 1961

EXAMPLE FROM THE UK

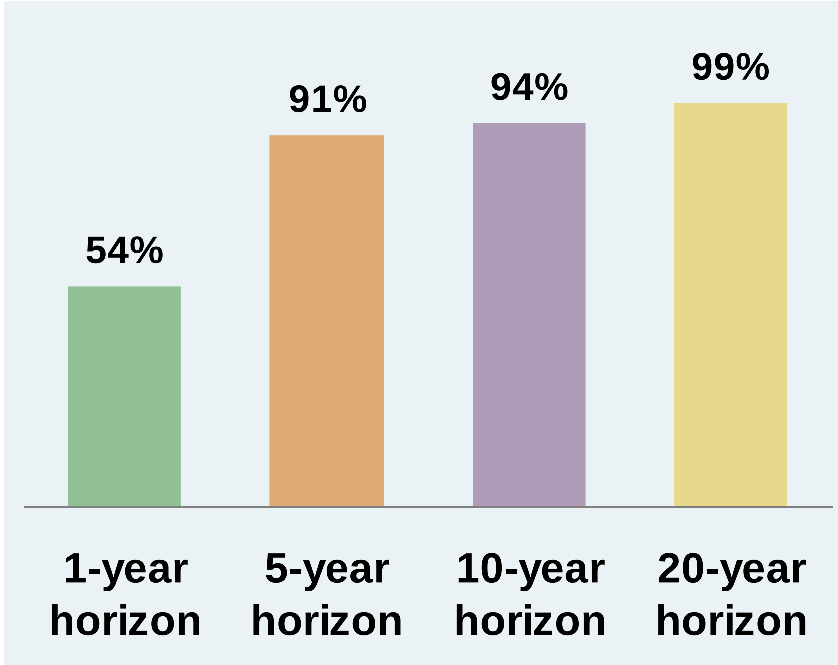
Aggregate correlations of changes in mortality rates

Aggregate correlation for individual ages



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Aggregate correlation for 10-yr age buckets

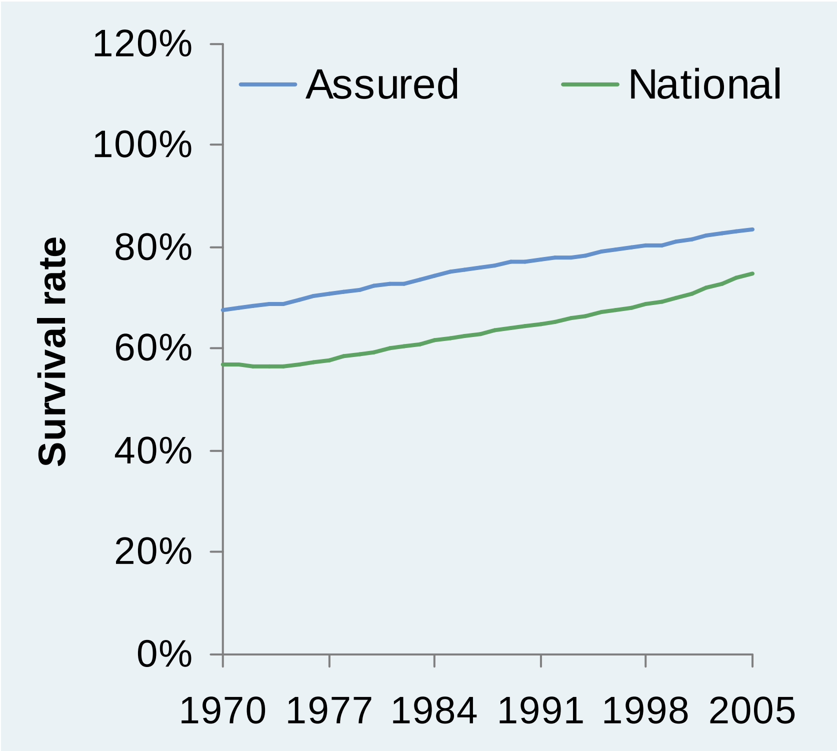


Source: J.P. Morgan, LifeMetrics Index and CMI publications

- Aggregate correlations between assured lives and national population
  - Calculated as one correlation across time and age
  - Graduated mortality rates, non-overlapping time periods
- Correlations increase with the time horizon
  - But long horizons have few data points

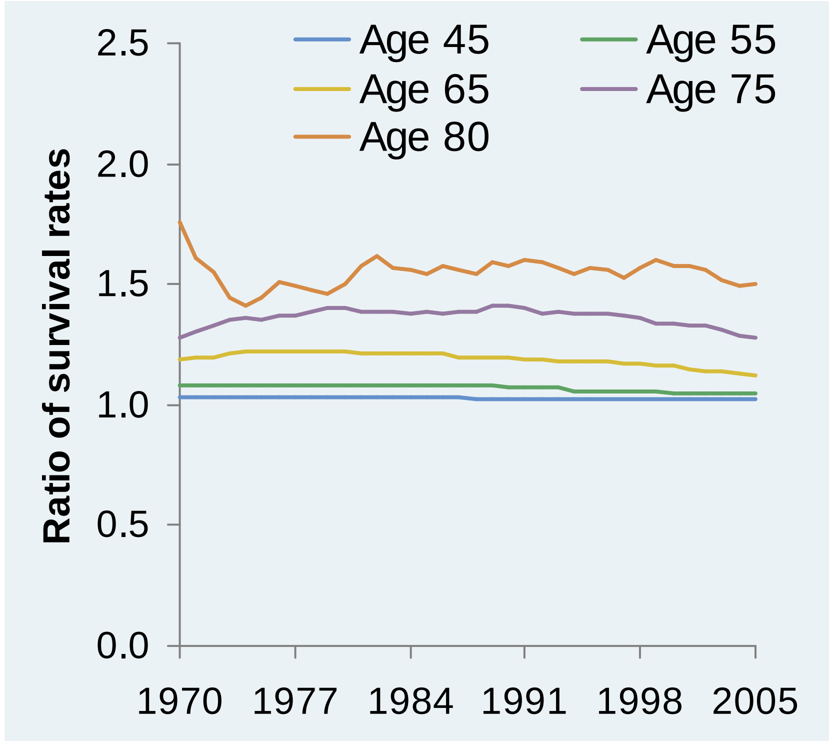
Metric 3: Survival rates historically have differed, but increased broadly in unison

10-yr survival rates for age 65



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Ratio of 10-yr survival rates



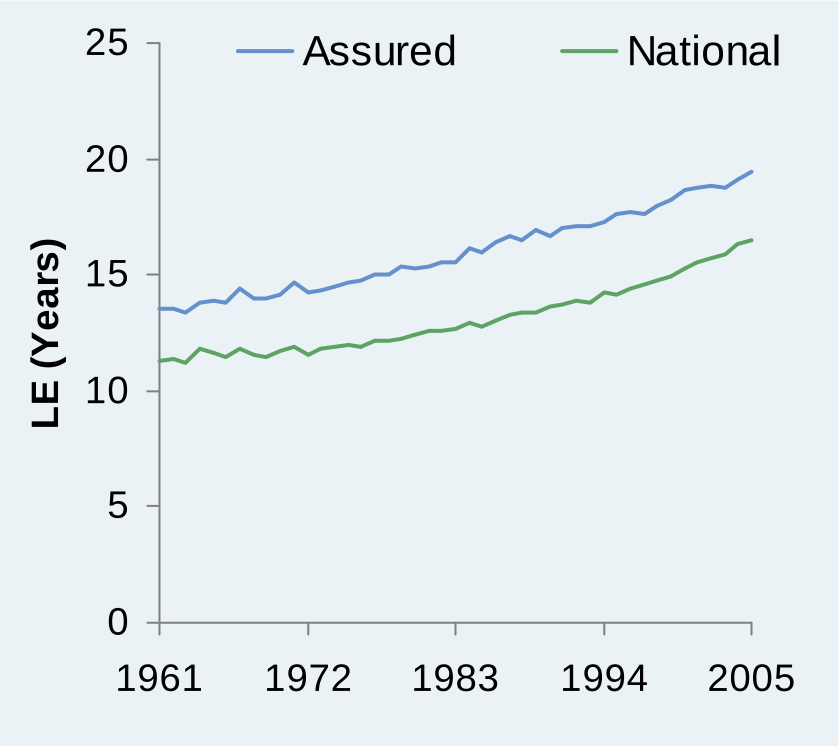
Source: J.P. Morgan, LifeMetrics Index and CMI publications

- Ratio of survival rates [assured / national]
  - Relatively constant through time
  - Increases with age
  - 1.03 (age 45); 1.19 (age 65); 1.36 (age 75); 1.55 (age 80)

EXAMPLE FROM THE UK

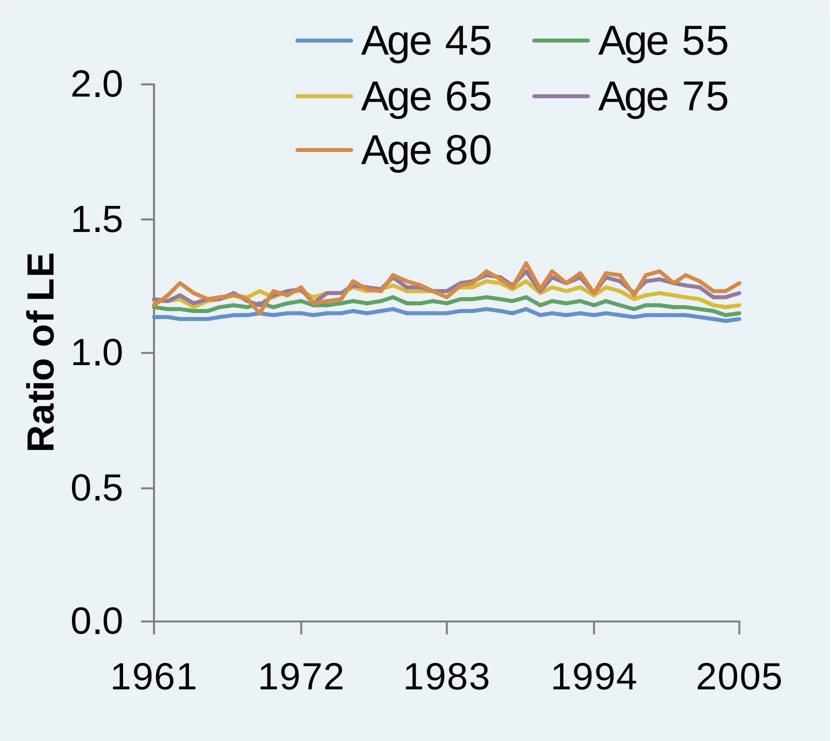
Metric 4: Period life expectancy has increased broadly in step

Period life expectancy for age 65



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Ratio of period life expectancy

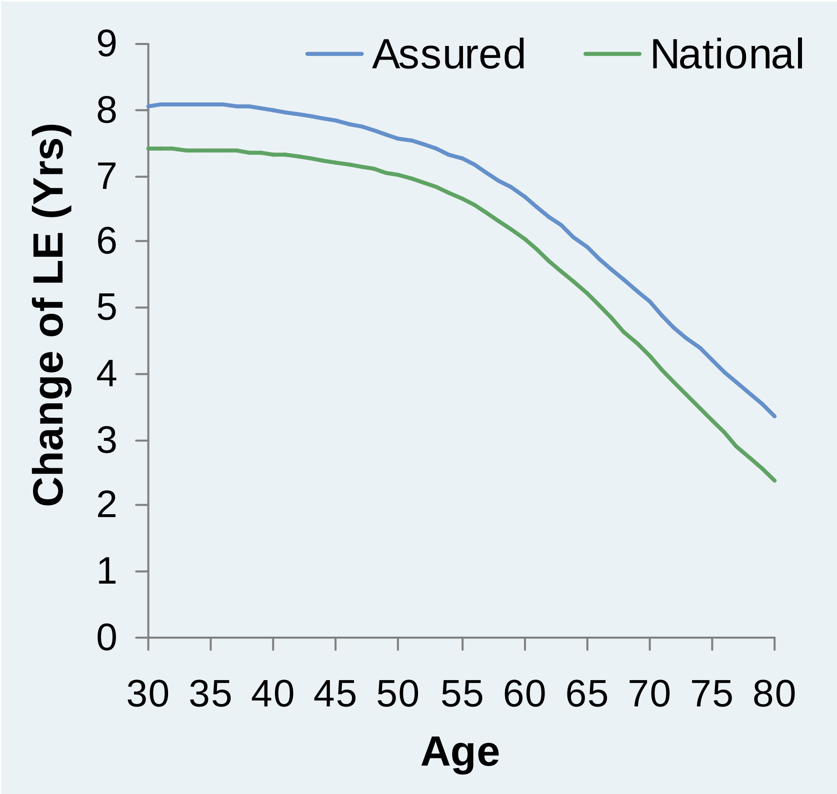


Source: J.P. Morgan, LifeMetrics Index and CMI publications

- Ratio of life expectancy [assured / national]
  - Relatively constant through time
  - Increases with age
  - 1.14 (age 45); 1.22 (age 65); 1.24 (age 75); 1.24 (age 80)

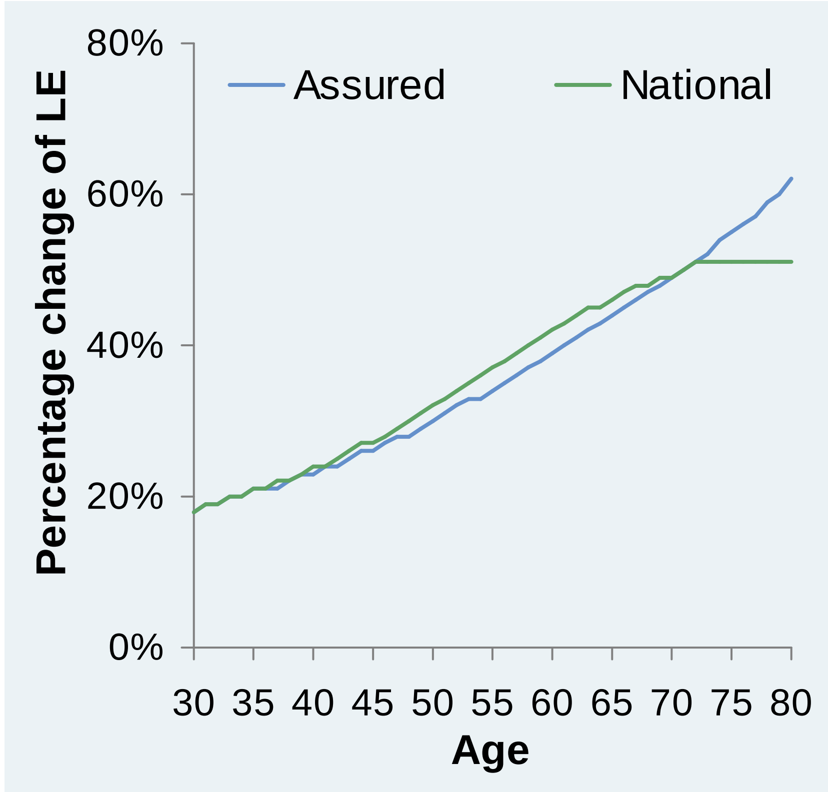
45-year change in period life expectancy has been approximately the same for all ages

Increase of life expectancy 1961-2005 (years)



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Increase of life expectancy 1961-2005 (%)



Source: J.P. Morgan, LifeMetrics Index and CMI publications

- Period life expectancy over 1961-2005
  - Similar percentage increases between the two populations
  - Greatest percentage increases for higher ages

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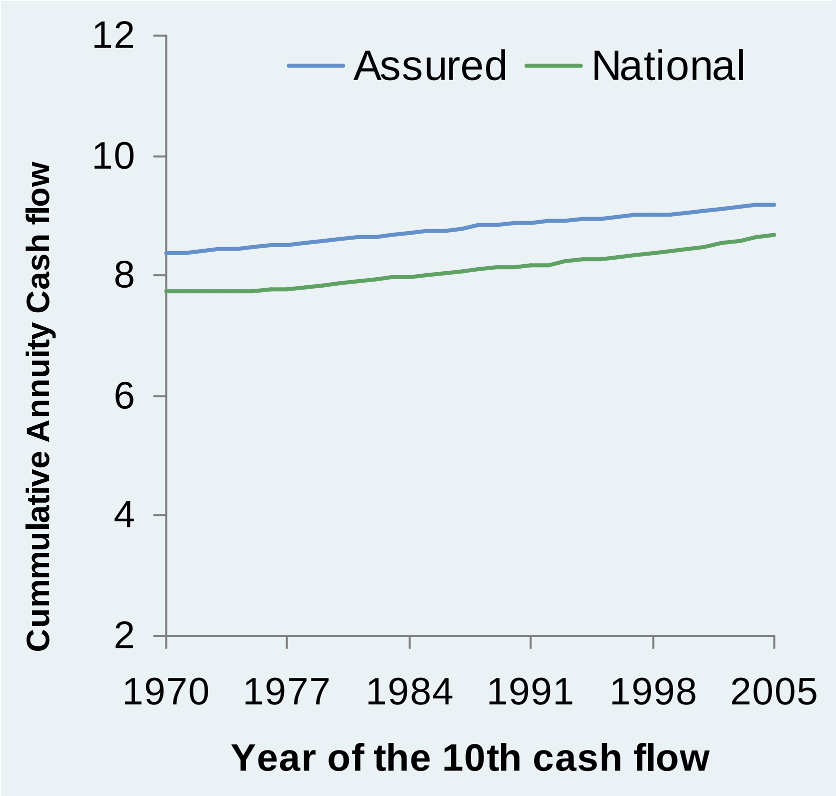
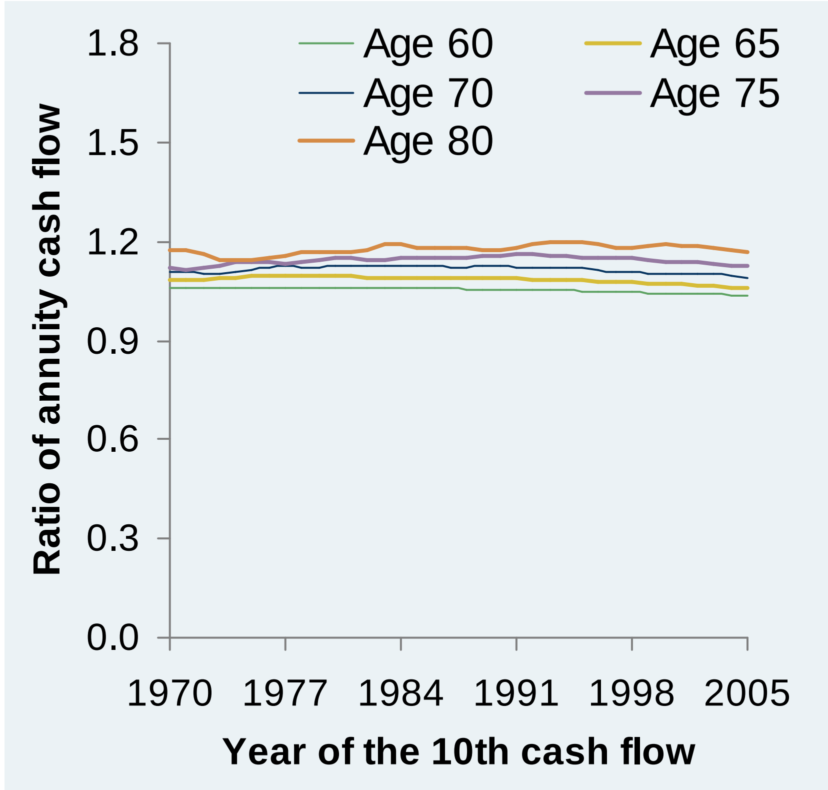
Metric 5: Liability cash flows realized over 10-year historical periods

Cumulative 10-yr cash flow age 65



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Ratio of 10-yr cash flow



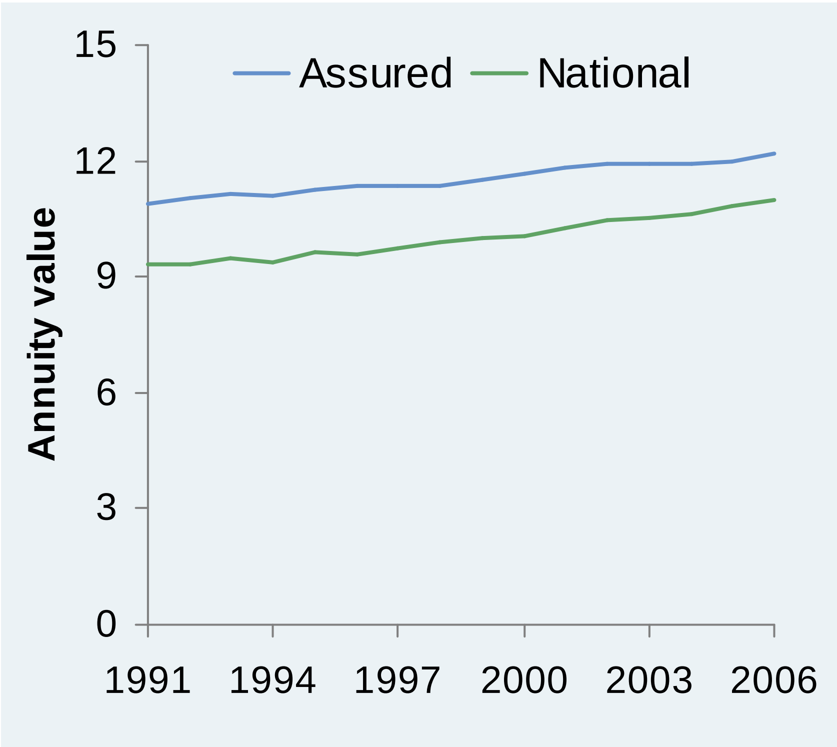
Source: J.P. Morgan, LifeMetrics Index and CMI publications

- Lifetime annuity paying GBP1 annually to survivors of a cohort
  - Calculate sum of cash flows over 10 years
  - Ratio relatively constant through time
  - Ratio increases with age

EXAMPLE FROM THE UK

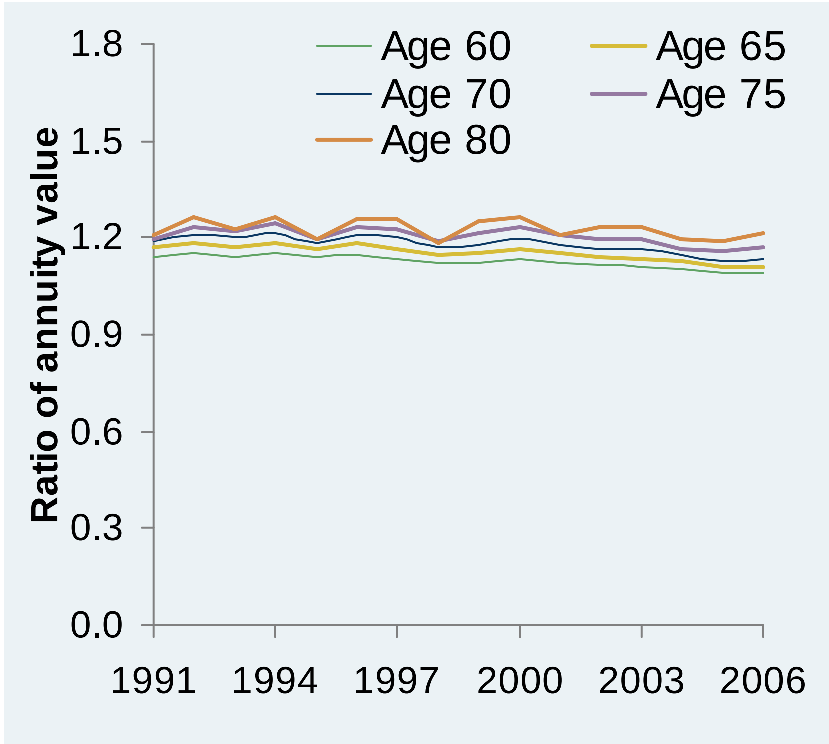
Metric 6: Theoretical liability value: Fixed age perspective

Liability value for age 65



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Ratio of liability values



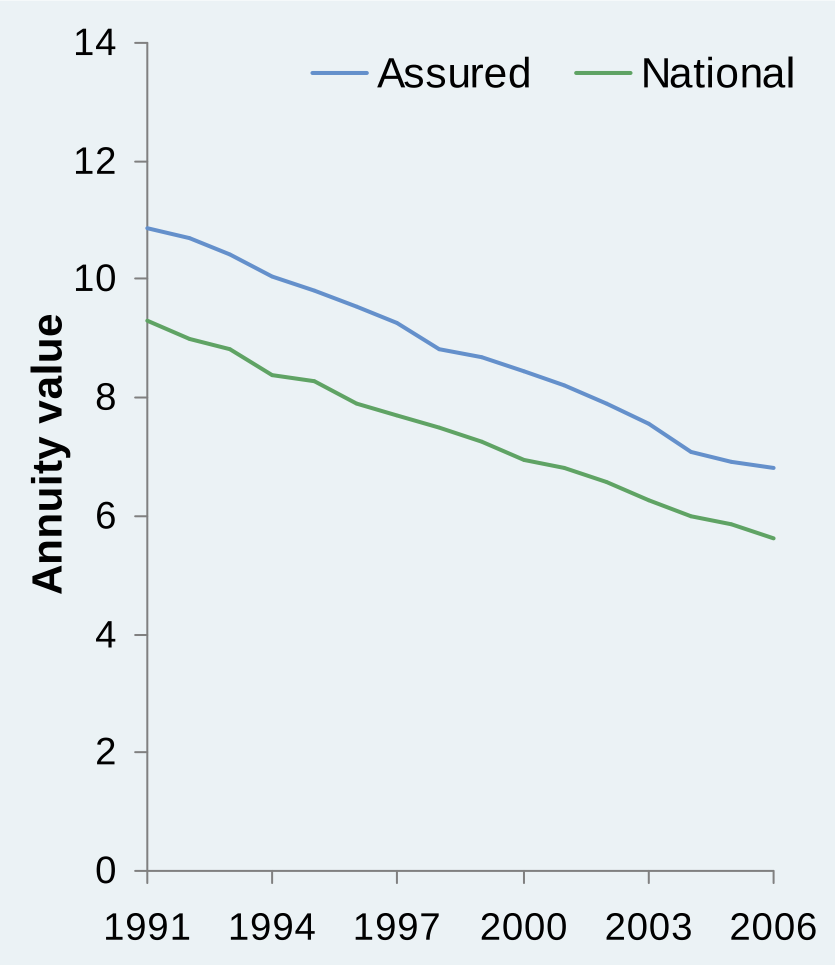
Source: J.P. Morgan, LifeMetrics Index and CMI publications

- Lifetime annuity paying GBP1 annually to survivors of a cohort
  - Calculate theoretical annuity price, using mortality projection model
  - Ratio relatively constant through time
  - Ratio increases with age

Note: The calibration look-back period for mortality projection is 30 years and discount rate is assumed to be 5%

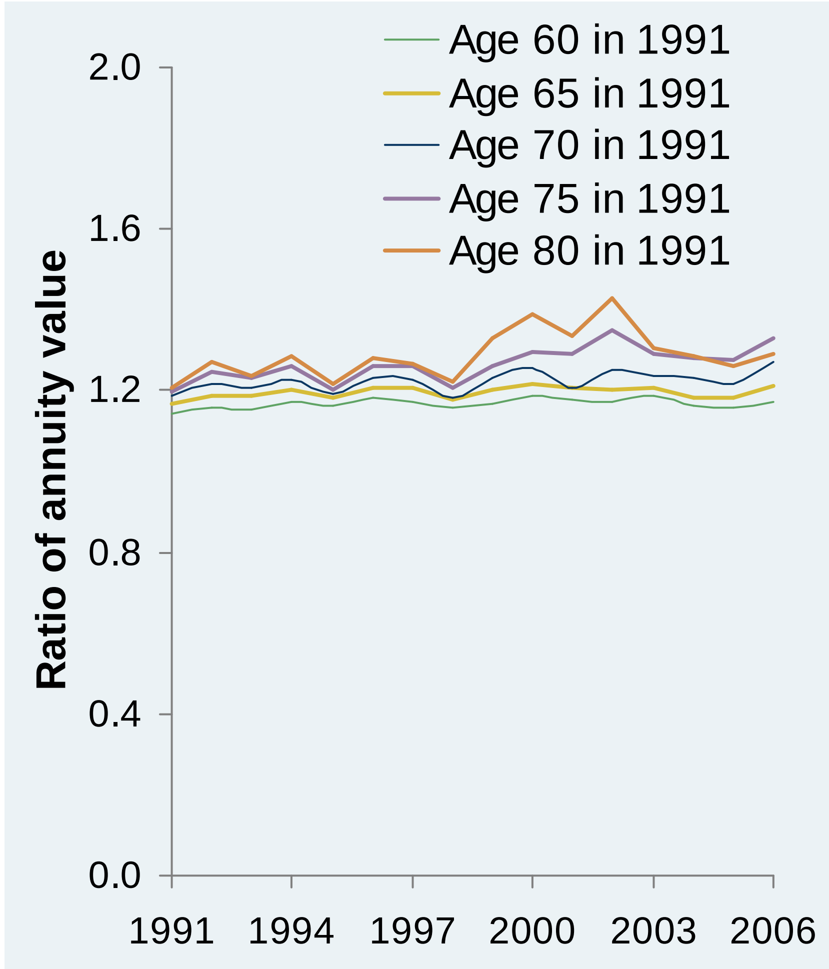
Theoretical liability value: Cohort perspective

Liability values for cohort aged 65 in 1991



Source: J.P. Morgan, LifeMetrics Index and CMI publications

Ratio of liability values for different cohorts in 1991



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California vs US national population: males

- California population is a affluent subset of the national population
  - Data collected by same process for both

- Characterized by:
  - Lower mortality rates
  - Higher mortality improvements
  - Higher life expectancy
  - Large subpopulation
  - Shorter history

US vs California population statistics

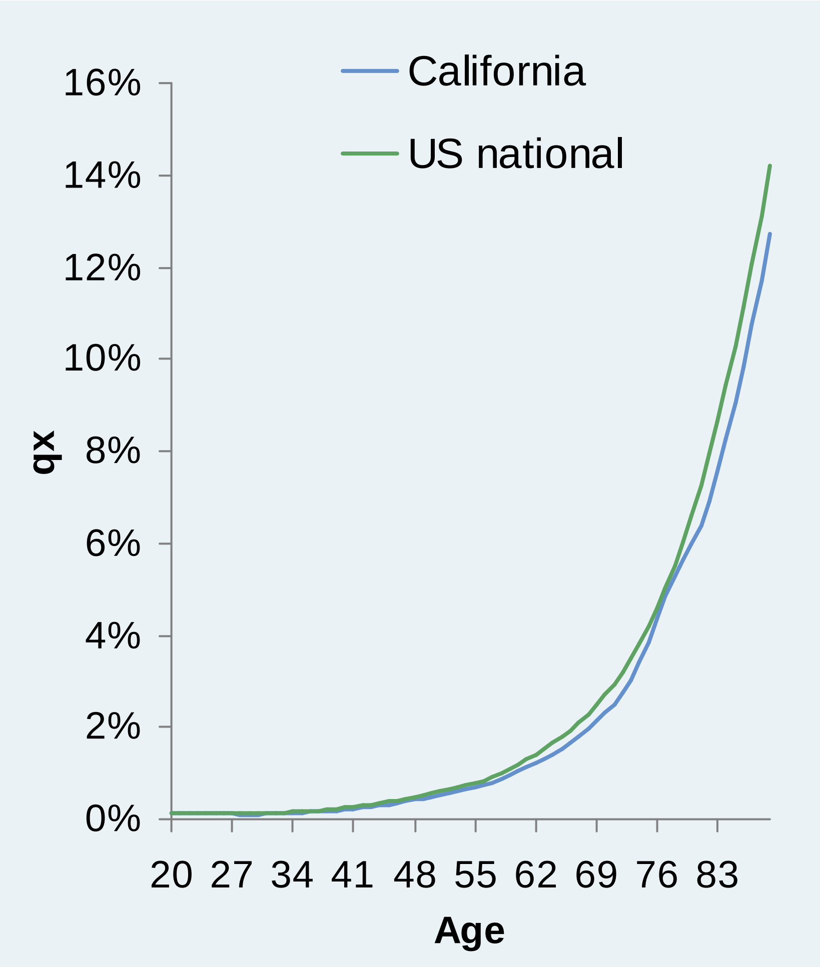
	National	California	%
Total (mm)	304.1	36.8	12%
Over 65 (mm)	38.9	4.1	11%
GDP per capita	$37,899	$42,064	111%

Source: U.S. Census Bureau and Bureau of Economic Analysis, 2008 figures

Similar relationship to national population as in UK example, but closer match in terms of size and profile

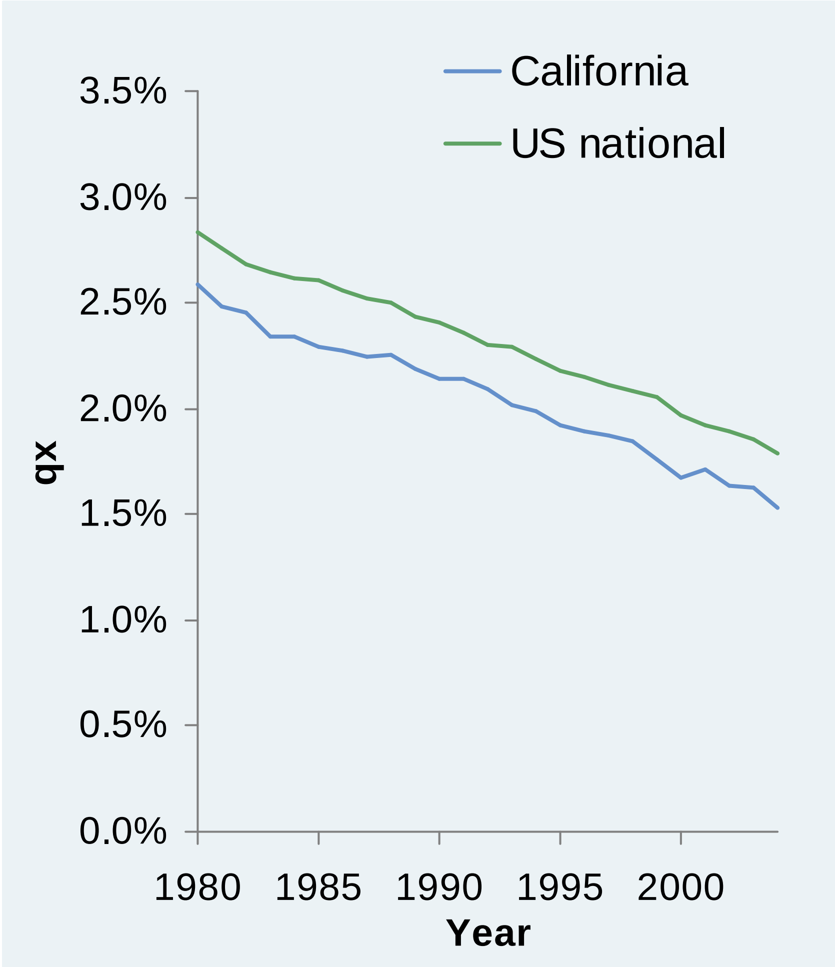
Metric 1: Graduated mortality rates:
California state population vs. US national population

2004 mortality rates



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Historical mortality rates age 65



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

At face value experience looks comparable

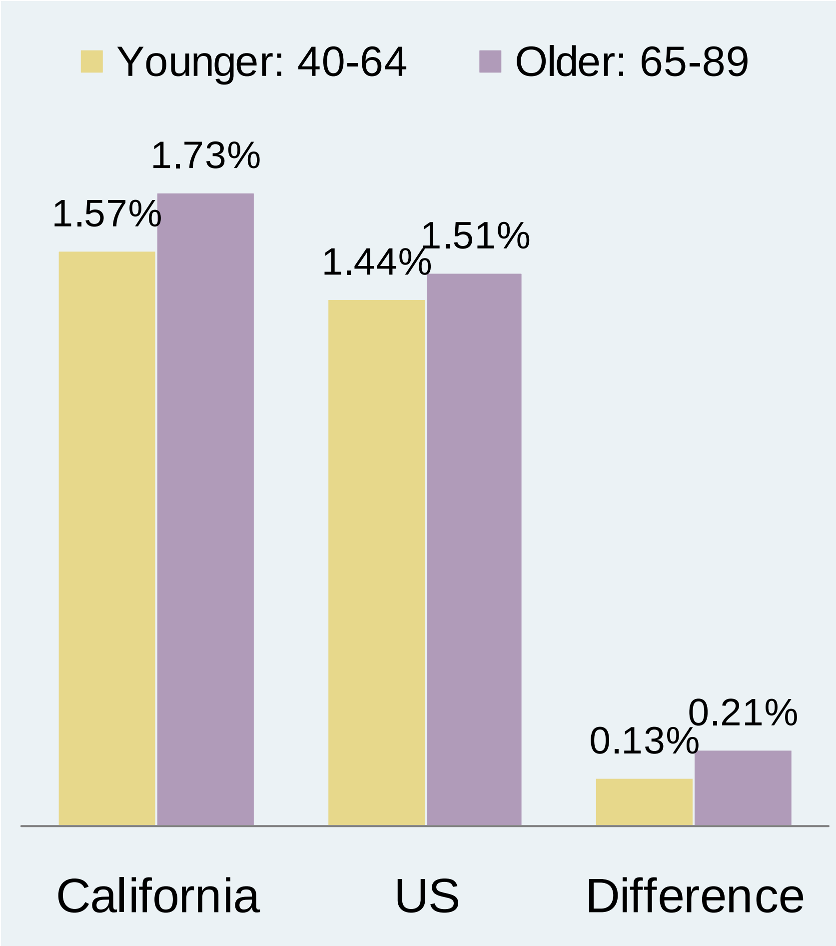
EXAMPLE FROM THE US

Comparing graduated mortality rates 1980-2004

Ratio of mortality rates [assured / national]

Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Annualized improvements 1980-2004



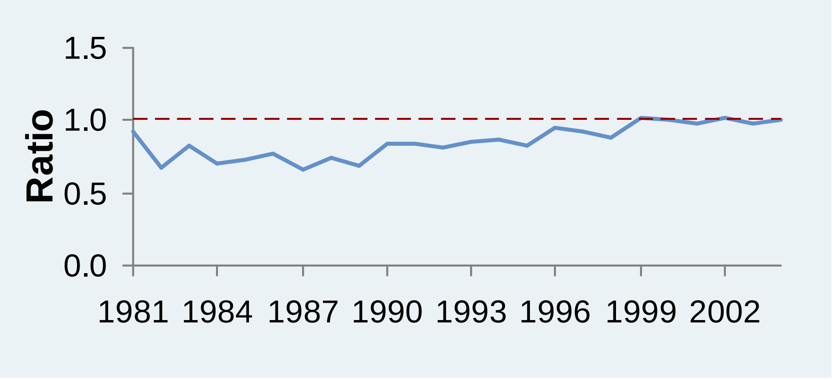
Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

California has lower mortality and higher improvements

Metric 2: Mortality improvements converge over the long run

Ratio of cumulative mortality improvements*: [California / national]

Age group 50-59



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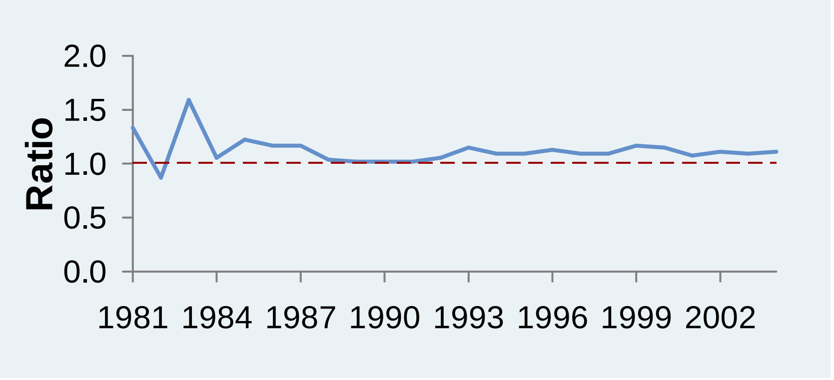
Age group 60-69



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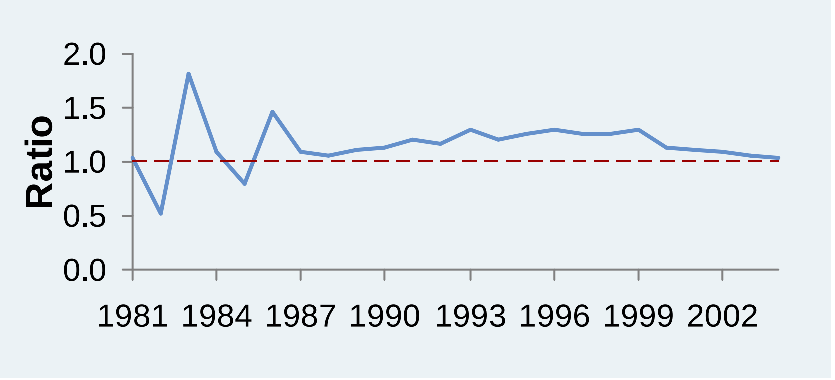
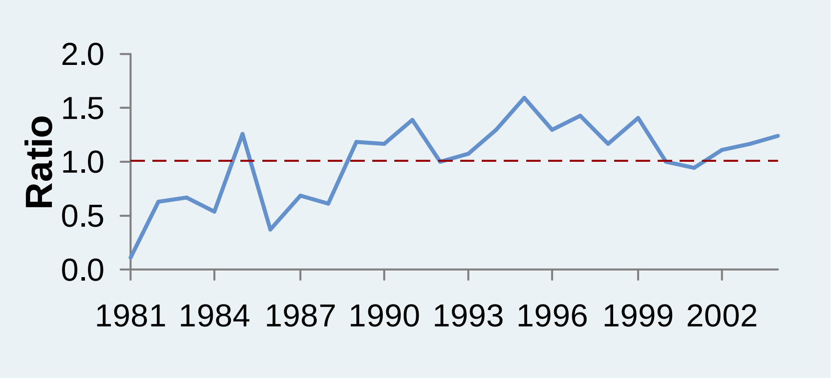
Age group 70-79



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Age group 80-89



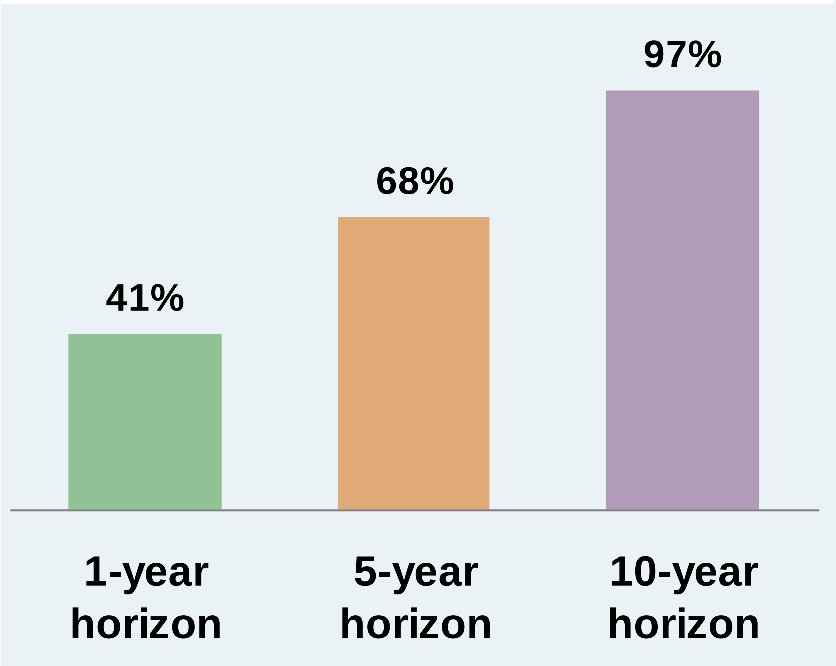
Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

* Ratio of annualized improvements

Aggregate correlations of changes in mortality rates

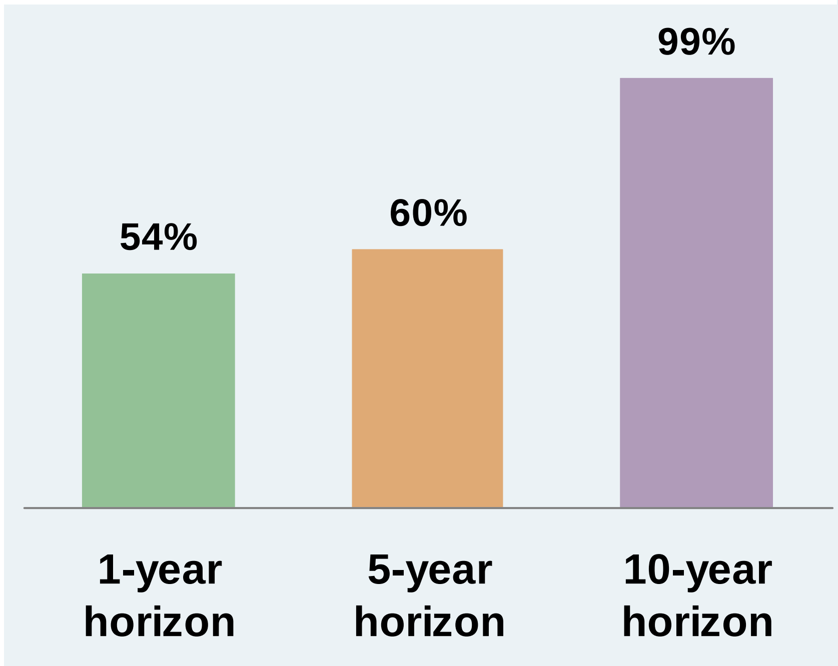
EXAMPLE FROM THE US

Aggregate correlation for individual ages



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Aggregate correlation for 10-yr age buckets

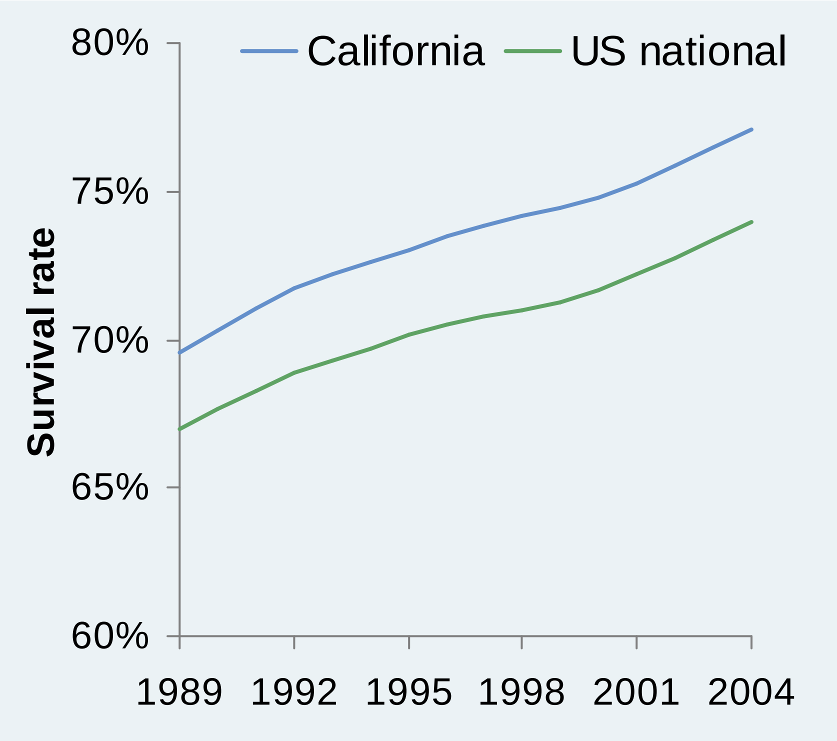


Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

- Aggregate correlations between California and national population
  - Calculated as one correlation across time and age
  - Graduated mortality rates, non-overlapping time periods
- Correlations increase with the time horizon
  - But long horizons have few data points

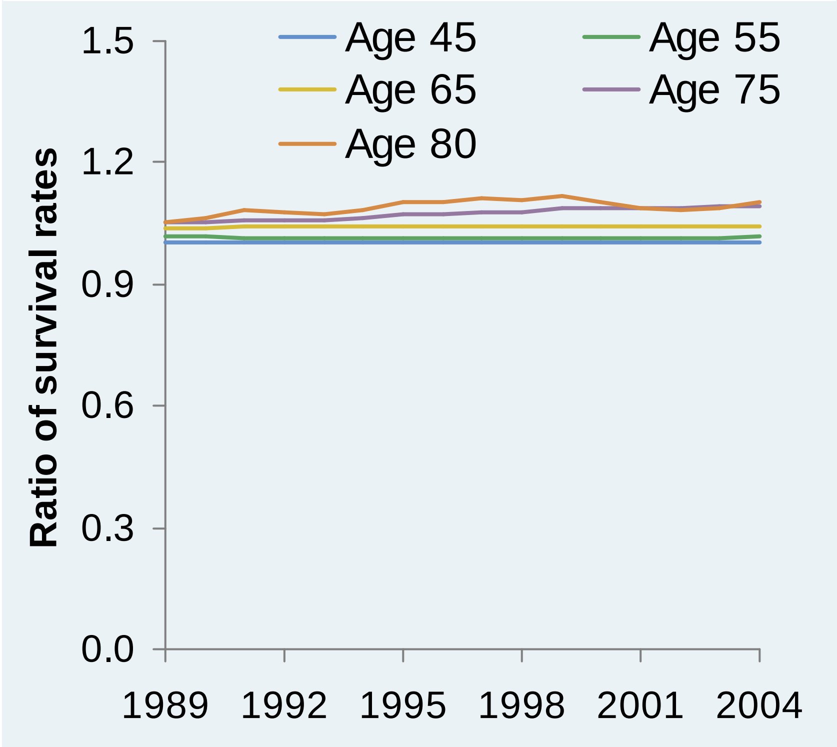
Metric 3: Survival rates historically increased broadly in unison

10-yr survival rates for age 65



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Ratio of 10-yr survival rates

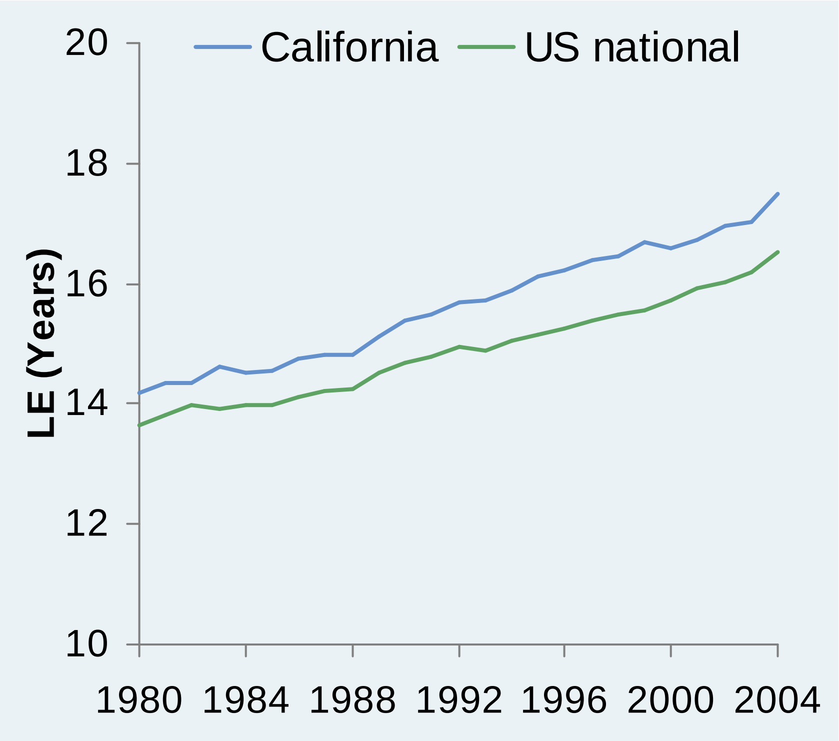


Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

- Ratio of survival rates [California / national]
  - Relatively constant through time
  - Increases with age
  - 1.00 (age 45); 1.04 (age 65); 1.07 (age 75); 1.09 (age 80)

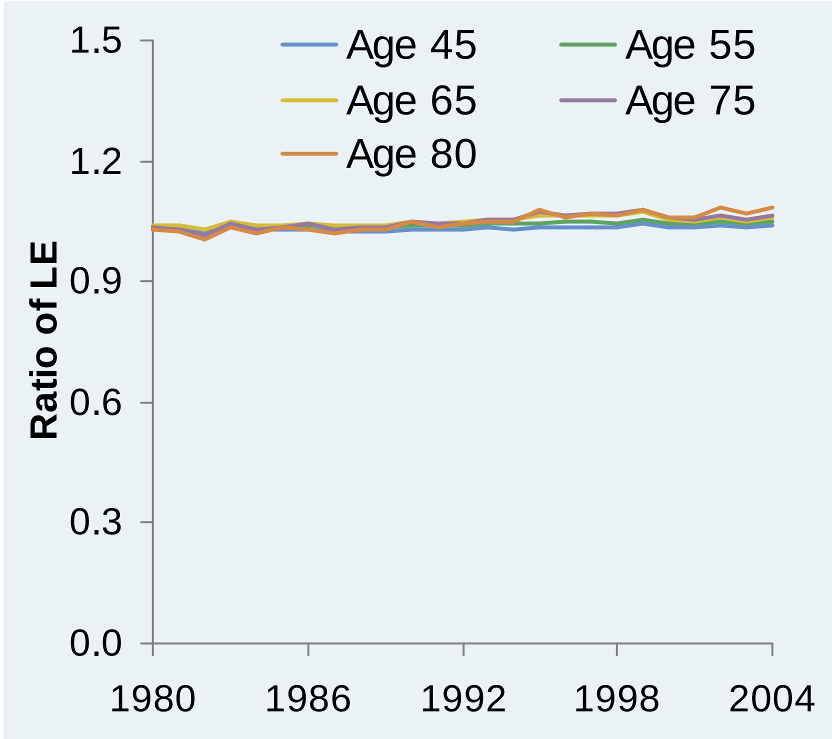
Metric 4: Period life expectancy has increased broadly in step

Period life expectancy for age 65



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Ratio of period life expectancy



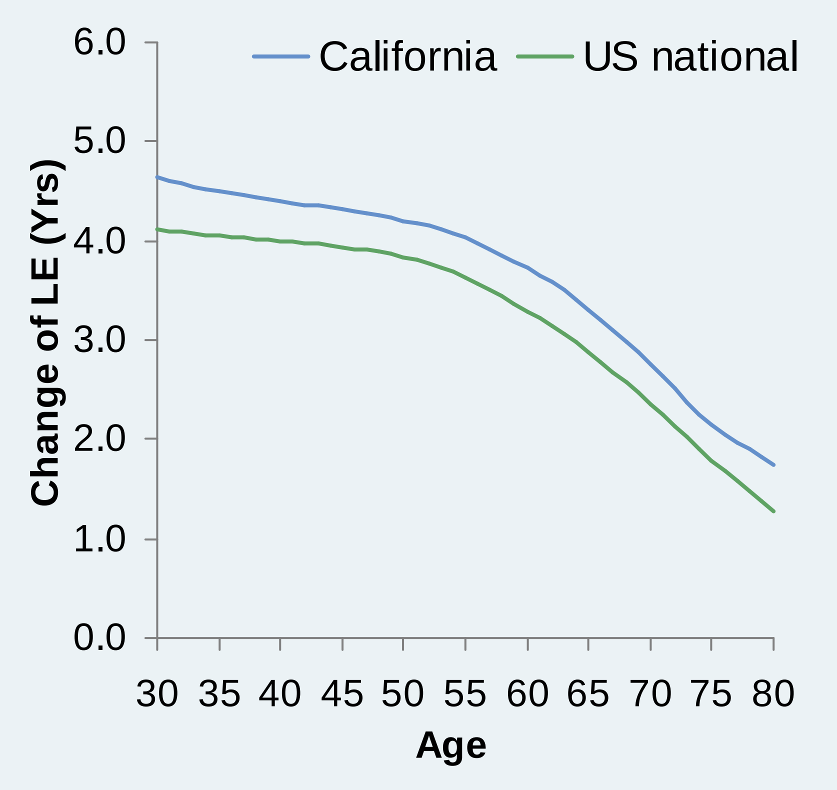
Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

- Ratio of life expectancy [California / US national]
  - Relatively constant through time
  - 1.03(age 45); 1.05 (age 65); 1.05 (age 75); 1.05 (age 80)

EXAMPLE FROM THE US

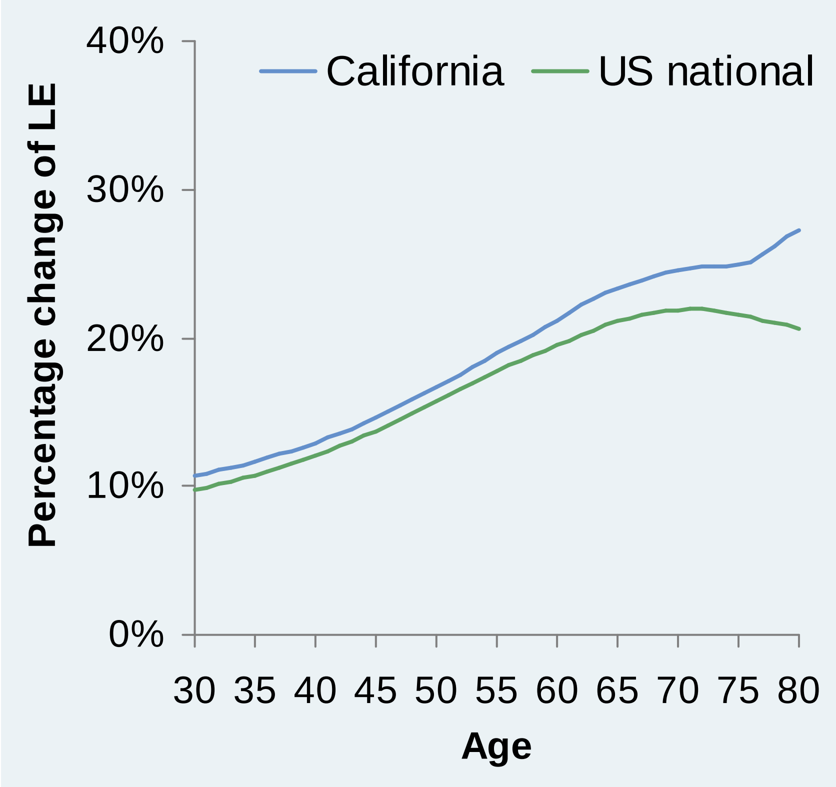
25-year change in period life expectancy has been approximately the same for all ages

Increase of life expectancy 1980-2004 (years)



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Increase of life expectancy 1980-2004 (%)

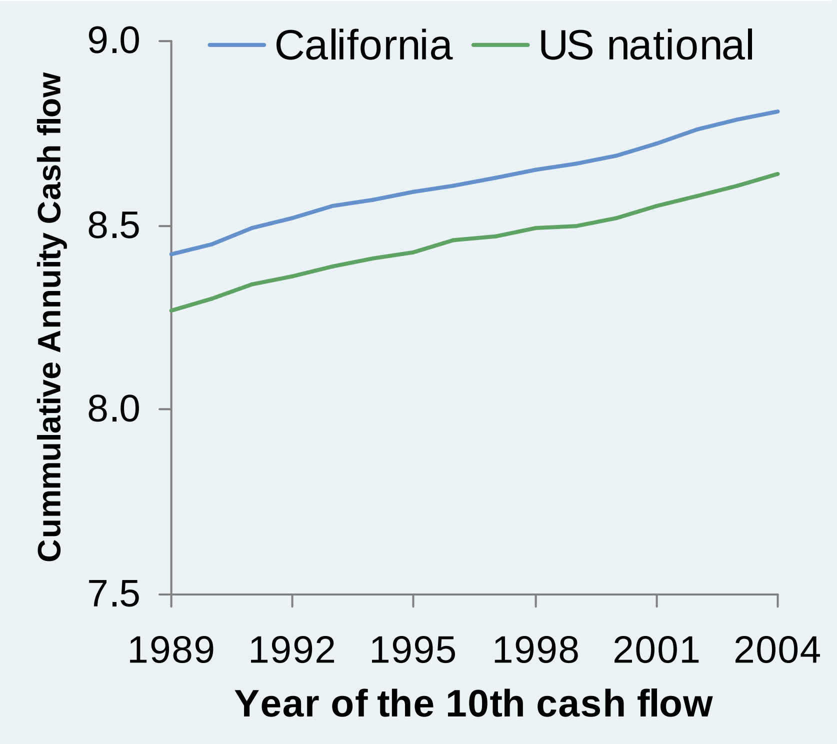


Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

- Period life expectancy over 1980-2004
  - Similar percentage increases between the two populations
  - Greatest percentage increases for higher ages

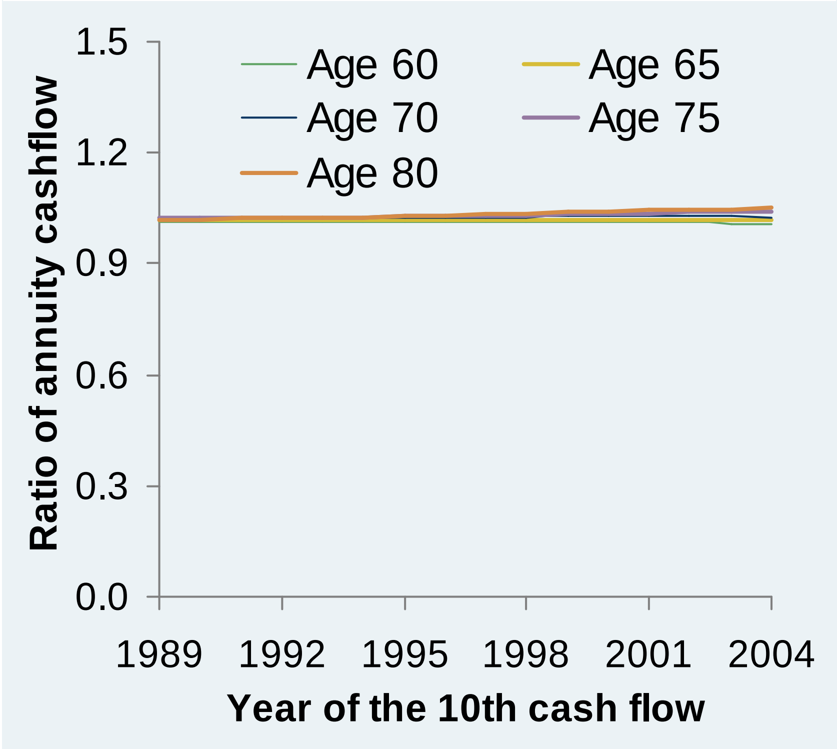
Metric 5: Liability cash flows realized over 10-year historical periods

Cumulative 10-yr cash flow age 65



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

Ratio of 10-yr cash flow



Source: J.P. Morgan, LifeMetrics Index, U.S. Census Bureau and CDC publications

- Lifetime annuity paying $1 annually to survivors of a cohort
  - Calculate sum of cash flows over 10 years
  - Ratio relatively constant through time
  - Ratio increases with age

EXAMPLE FROM THE US

Agenda

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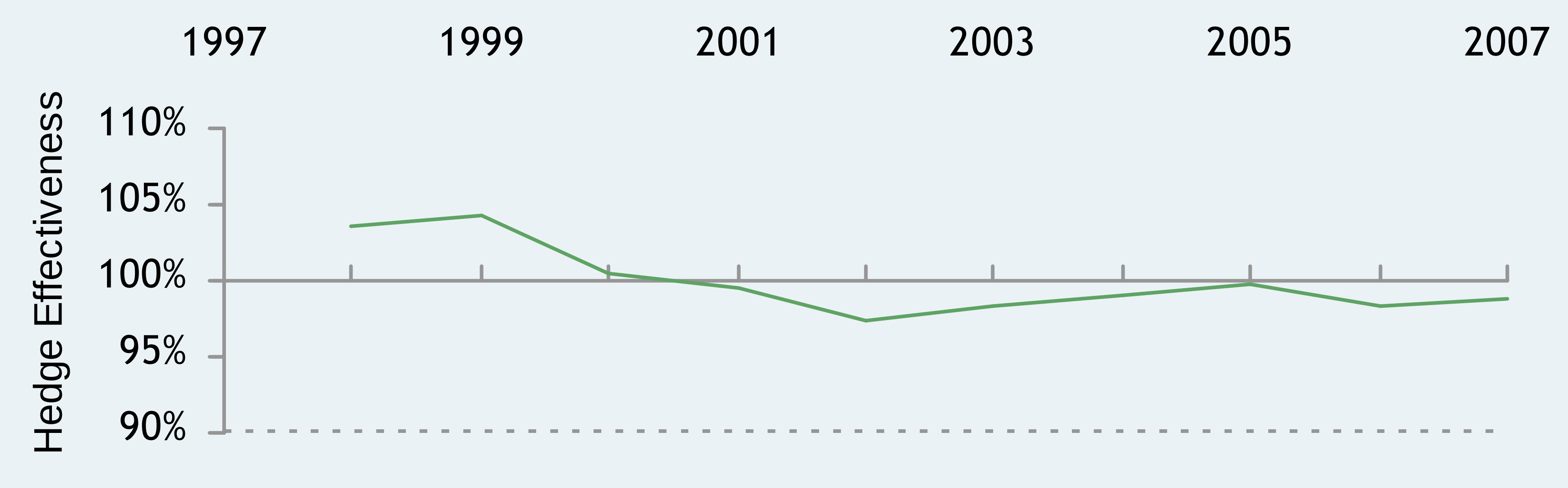
Conclusions from the US and UK examples

- **UK Assured Lives**
  - Smallish subgroup of national population
  - Noise in data
  - Age profile centered around people in their 40s, with few lives 65+
  - Basis risk likely to be higher than for a large pension plan / annuity portfolio
- **California**
  - Large subgroup of national population
  - Same process for data collection as national population, so less noise
- **Both**
  - Affluent subpopulations, with lower mortality and higher life expectancy than respective national populations
  - Have larger numbers of lives and longer history than typical insurer annuity portfolios or pension plans

Implications for hedge effectiveness calculations: Case study 1 – Retrospective effectiveness test (backtesting)

- **Case study:** Longevity hedge based on national population index
  - Hedge variability of <u>cash flow</u>
  - Retrospective hedge effectiveness test

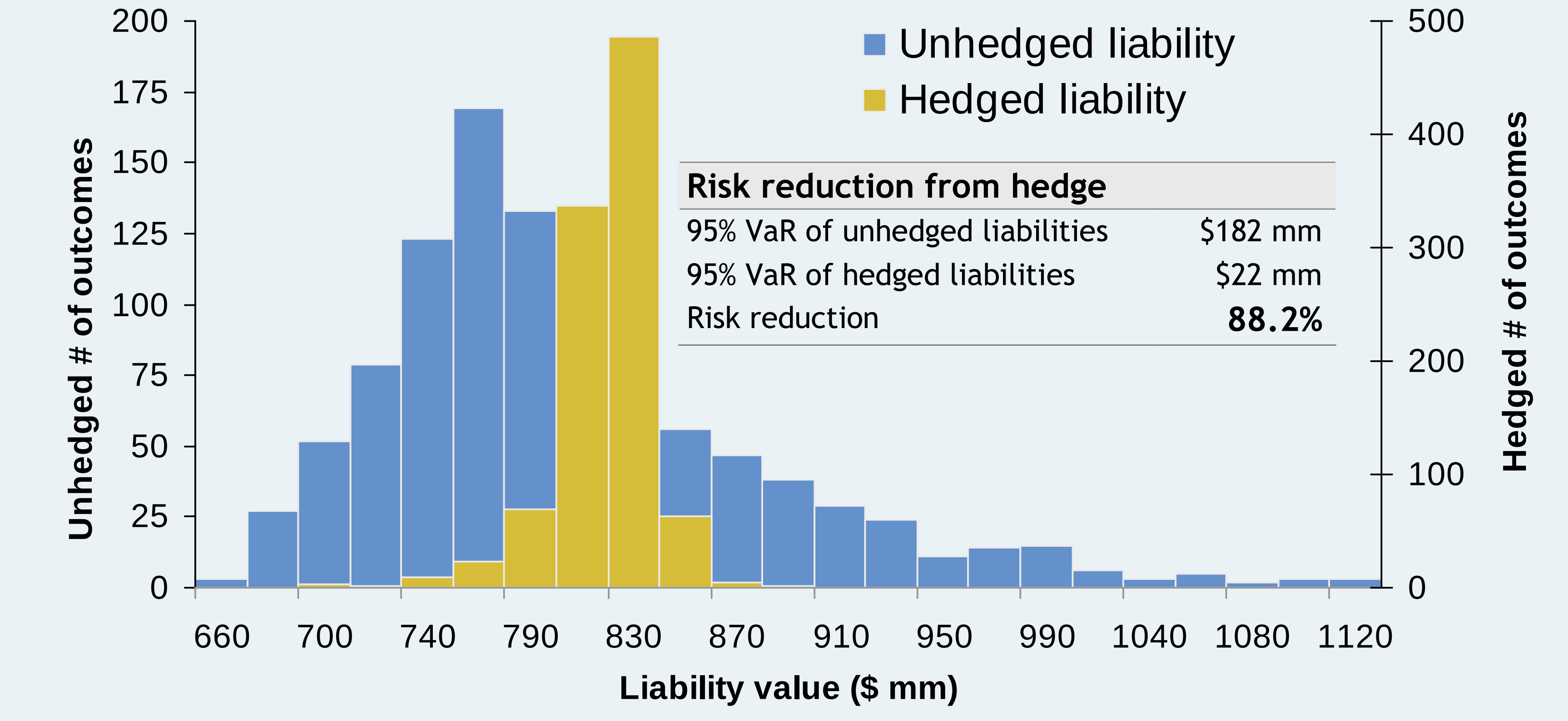
Hedge effectiveness for an index hedge: Historical case study



Case Study2: Prospective hedge effectiveness test

- **Case study:** Longevity hedge based on national population index
  - Hedge variability of liability value
  - 94% correlation between 10-year improvements for pension plan and LifeMetrics hedge

Distribution of liability value in 10 years: Before and after hedging



Summary

- **Framework for basis risk analysis**:
  - Focus on
    - Data (metric, long horizon, analytical method)
    - Context
- **Empirical analysis of UK and US case studies:**
  - Significant evidence of stable relationships historically
    - Correlations high when measured appropriately over long horizons
    - Survivor rates, life expectancies, liability cash flows and value have moved proportionately over time
    - Ratios are stable over the medium-to-long term
  - Risk reduction using national population longevity index-based hedges can be significant if hedge optimally calibrated