Longevity risk

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Cologne, 22nd September 2010

redefining / standards

Introduction

- **Significant advancement in longevity over the last few decades around the world**
- **No agreement among experts as to what the future holds in terms of longevity**
- **The current trend creates a lot of challenges for stakeholders concerned by longevity (governments, insurers, pension funds, individuals)**
- **This presentation will focus on the trends and issues in developed countries**

Agenda

1 Actuarial definitions and techniques

Mortality rate and other related statistics

Mortality rate

- q(x,t): the rate of mortality at age x in year t, i.e. the probability of dying during the year t for individuals who were aged *x* last birthday (annual mortality rate)
- μ(x,t): the instantaneous death rate exactly at time t for lives aged x (also called "force of mortality ")
- Relation: $q(x,t) = 1- e^{-\mu(x,t)}$

Improvement rate

- r(x,t): the rate of decrease of the mortality rate at age x between year t-1 and year t (annual improvement rate)
- Relation $r(x,t) = [q(x,t)-q(x,t-1)]/q(x,t-1)$

Life expectancy at a given age

- Average future lifetime of an individual at a given age. Synonymous to "life expectation" or "expectation of life".
- Algebraically life expectancy at age x can be written as: $e_x = \sum_{t=1}^{120-x} {}_t p_x$
  - where we assume 120 is the ultimate age and ${}_t p_x$ is the relevant survival rate defined as the probability that a person aged x survives t more years: ${}_t p_x = \prod_{i=0}^{t-1} (1-q_{x+i})$

Life expectancy (1/2)

Relationship between life expectancies at different ages

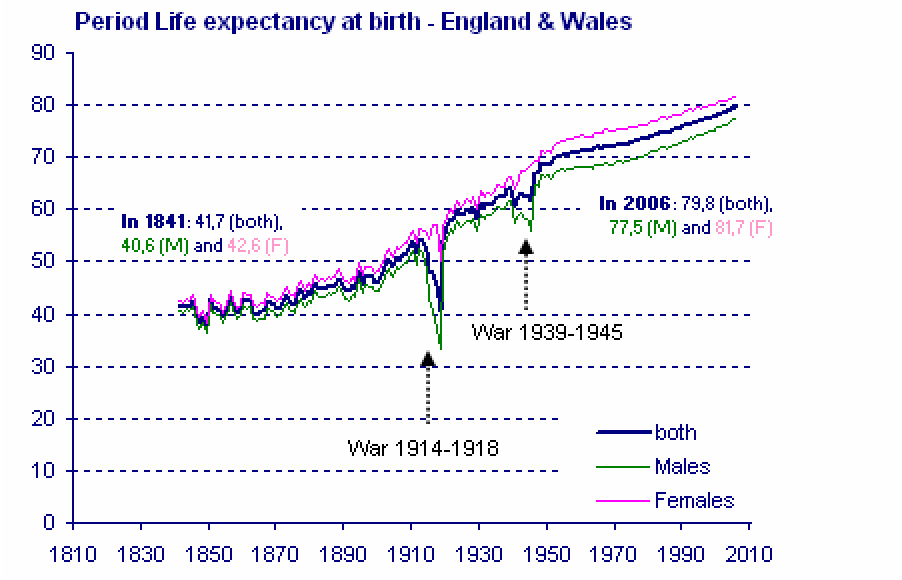
- Considering the total life expectancy of a person aged 60 (60 years + additional life expectancy at age 60) would generally be greater than the life expectancy at birth…
  - If you're 60 (or any age), you avoided all the hazards to reach that age
  - It is a conditional expectancy: conditional on the fact that you are alive at the age 60
- … unless there has been a deterioration in the outlook for mortality at higher ages since your birth

Life expectancy: two main types depending on the statistics used

- **Period life expectancy:** the most commonly used and based on current mortality rates (by default used in this presentation)
  - for a given calendar year, this represents the average number of years of life remaining if a group of persons at that age were to experience the mortality rates for that year over the course of their remaining lives
- **Cohort life expectancy:** more relevant, albeit more subjective because it requires some assumptions of trends in mortality
  - This represents the average number of years of life remaining for a group of persons having a given year of birth

Life expectancy (2/2)

- **Evolution of the (period) life expectancy**



Source: Human Mortality Database (HMD)

- **Did the UK experience a strong decrease followed by a strong recovery in life expectancy during the 40s?**
  - Limit of the (period) life expectancy concept

Mortality table

Mortality tables: two types (depending on the usage)

- Period Life table: the most basic table; it is a snapshot of mortality rates for a specific period, the period typically being a calendar year. No assumption of a future trend of mortality.

- Generational Life table: 2-dimensional tables which take into account future improvements in mortality.

Transversal mortality : mortality rates for a age and a year.
Example: French statutory tables TH/F00-02

Age/ Calendar Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
60	1,26%	1,25%	1,24%	1,23%	1,20%	1,16%	1,14%	1,12%	1,13%	1,14%	1,15%
61	1,37%	1,36%	1,35%	1,34%	1,32%	1,28%	1,25%	1,22%	1,21%	1,21%	1,22%
62	1,52%	1,49%	1,47%	1,45%	1,43%	1,41%	1,38%	1,35%	1,32%	1,31%	1,31%
63	1,67%	1,63%	1,60%	1,57%	1,54%	1,52%	1,50%	1,48%	1,45%	1,43%	1,42%
64	1,81%	1,77%	1,74%	1,70%	1,67%	1,64%	1,62%	1,60%	1,58%	1,57%	1,55%
65	1,96%	1,92%	1,88%	1,84%	1,79%	1,76%	1,73%	1,72%	1,71%	1,70%	1,69%
66	2,15%	2,09%	2,04%	2,00%	1,95%	1,90%	1,86%	1,84%	1,83%	1,82%	1,82%
67	2,35%	2,29%	2,23%	2,17%	2,11%	2,06%	2,02%	1,98%	1,96%	1,95%	1,95%
68	2,54%	2,49%	2,43%	2,36%	2,30%	2,24%	2,19%	2,15%	2,12%	2,10%	2,10%
69	2,77%	2,72%	2,65%	2,58%	2,50%	2,43%	2,38%	2,34%	2,31%	2,28%	2,27%
70	3,01%	2,96%	2,89%	2,82%	2,73%	2,66%	2,59%	2,54%	2,51%	2,48%	2,46%

observed mortality (2000–2006) · prospective mortality (2007–2010)

Mortality rates from US Males (HMD data), smoothed and projected

Longitudinal mortality : mortality rates for a generation.
Example: French statutory tables TGH/F05

Annuity value

- **Represents the present value of the expected annuity payments**
  - $\sum \frac{1}{(1+i)^t} {}_t p_x$
- **Very sensitive to the anticipated future mortality**
  - An underestimation of 1 year of life expectancy at age 65 ~ 5% underestimation in the annuity value (1bn <-> 50m)

⇨ **Correctly managing longevity risk is crucial**

- **Very sensitive to interest rates**
  - A variation of 1% in interest rate ~ 10% / 15% difference in annuity value
  - Interest rate environment at date of the annuity conversion / purchase date has a significant impact –more and more risk born by policyholders
  - Ongoing investment risk managed by insurers and pension funds (depending on the ALM strategies)

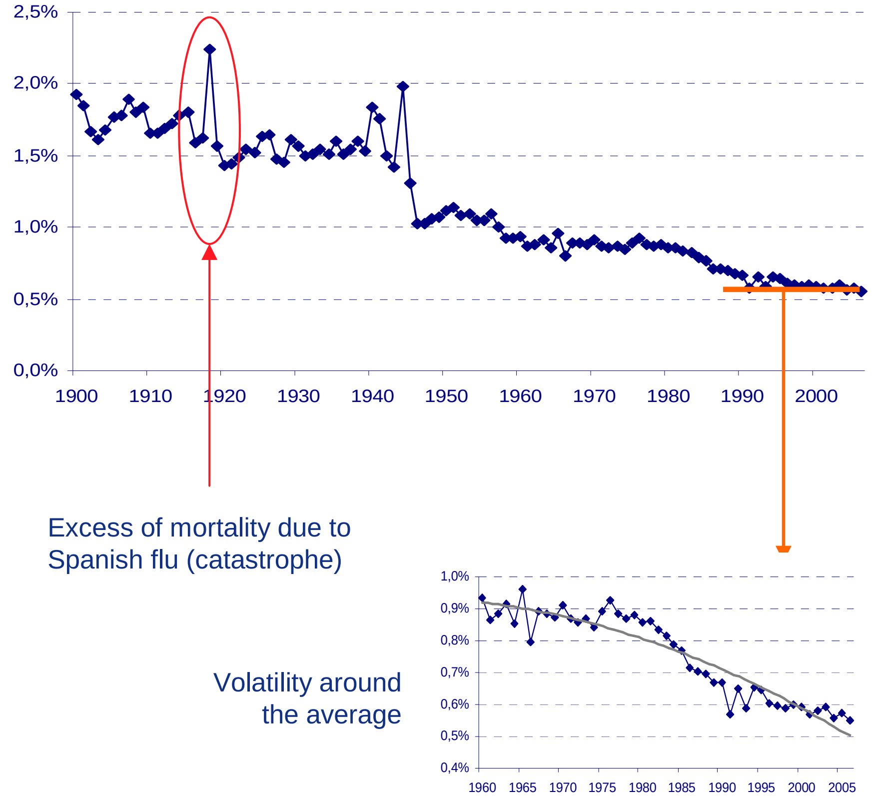
Components of longevity risk

- **Longevity risk: the risk that a portfolio lose value from mortality being lower than expected**

  - **Major component: Trend, which is the uncertainty around the future rate of change in mortality**

  - Other components
    - Level: uncertainty around the current average rate of mortality,
    - Volatility: the risk of statistical fluctuation around the central expectation
    - Catastrophe: the risk of mortality being significantly different from the average because of a concentration of risk.

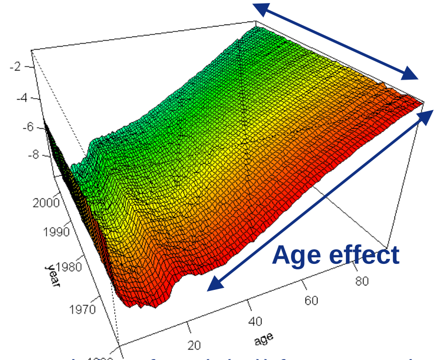
Mortality rates – FR Males aged 50yo (HMD data)



Evolution of Log(q(x,t)) for E&W Males

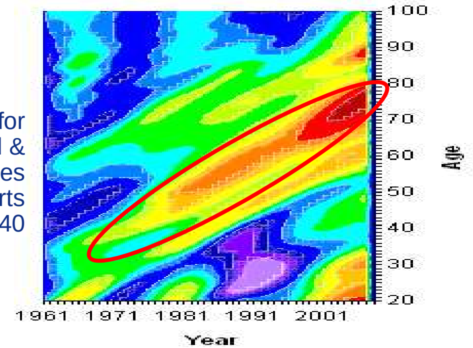
Approaches for modeling longevity

- **Cause-specific extrapolation**
  - Models trends in causes of death
  - Difficult to predict and project
- **Epidemiological models**
  - Causal forecasting using the relationship between economic or environmental risk factors and mortality
  - For example, trends in obesity, smoking, or socio-demographic changes
- **Extrapolative models**
  - Projects mortality trends into the future assuming the historical trends continue
  - Approach typically used by the insurance industry
  - Two main views
    - Mortality surface (p-splines)
    - Time-series (stochastic)
  - Three main factors
    - Period effect (decrease in mortality over time)
    - Age effect (increased mortality with age)
    - Cohort effect (specific patterns by birth year)



Evolution of Log(q(x,t)) for E&W Males

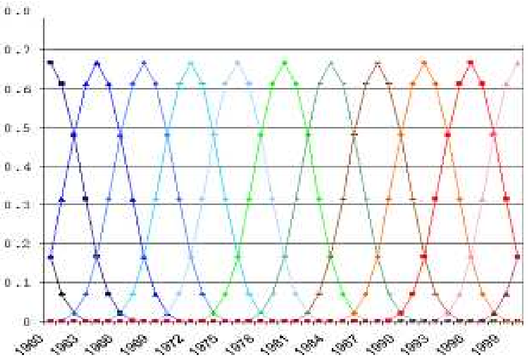
Cohort effect for England & Wales cohorts 1920-1940



P-spline models

- **P-splines model**
  - Penalized fitting process using basis splines
  - A basis of splines (B-spines) is a set of cubic spline basis functions
  - A penalty is added to balance the fit and smoothness resulting in a smooth mortality surface
  - Models the instantaneous mortality rate

$$\ln \mu(t, x) = \sum_{i,j} \theta_{i,j} B_{i,j}(x,t)$$



  - Where
    - θ is the regression coefficient
    - B is the B-spline function

- **Flexibility around:**
  - The order of B-splines
  - The number of splines
    - The more splines, the more smoothing required
  - The order of differencing in the penalty (*d*)
    - A large order of differencing means a tendency to over-smooth and a small d means a tendency to over-fit
  - Period effect vs. Cohort effect
  - Years of historical data used
    - 20 year minimum
  - Ages used
    - Minimum range of 40 years

Stochastic models

Lee-Carter family

- Models instantaneous mortality rate
  - **Lee Carter** – no cohort effect
  - **Renshaw-Haberman** – LC extention with cohort effect
  - **Age Period Cohort** – simplified RH model

Age effect

Period effect

Cohort effect

$$\ln \mu(t,x) = \beta_x^{(1)} + \beta_x^{(2)} \kappa_t$$

$$\ln \mu(t,x) = \beta_x^{(1)} + \beta_x^{(2)} \kappa_t + \beta_x^{(3)} \gamma_{t-x}$$

$$\ln \mu(t,x) = \beta_x + \frac{1}{n_a} \kappa_t + \frac{1}{n_a} \gamma_{t-x}$$

Cairns Blake Dowd (CBD) family

- Models initial mortality rate
- Basic model plus 3 extentions
- Includes cohort effect

$$\text{logit } q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x})$$

$$\text{logit } q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \gamma_{t-x}$$

$$\text{logit } q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \kappa_t^{(3)} ((x - \bar{x})^2 - \hat{\sigma}_x^2) + \gamma_{t-x}$$

$$\text{logit } q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \gamma_{t-x}^{(3)} (x_c - x)$$

Model developed internally by AXA in 2010

- Lee-Carter model with cohort effect

$$\ln m(t,x) = \beta_x^{(1)} + \beta_x^{(2)} \kappa_t^{(2)} + \gamma_{t-x}^{(3)}$$

P-Splines vs stochastic models

P-spline models

- **Advantages**
  - National population data can be used and is available for most developed countries (HMD database)
  - Reflects historical trends
  - Generates mortality rates by age, cohort and gender
  - Studied by the CMI (UK) – models and literature available
  - Generates standard errors so percentiles can be produced
- **Limits**
  - Requires large amount of data to calibrate
  - Can be sensitive to the choice of assumptions and data
  - Does not generate scenarios
  - Long run-time to fit model

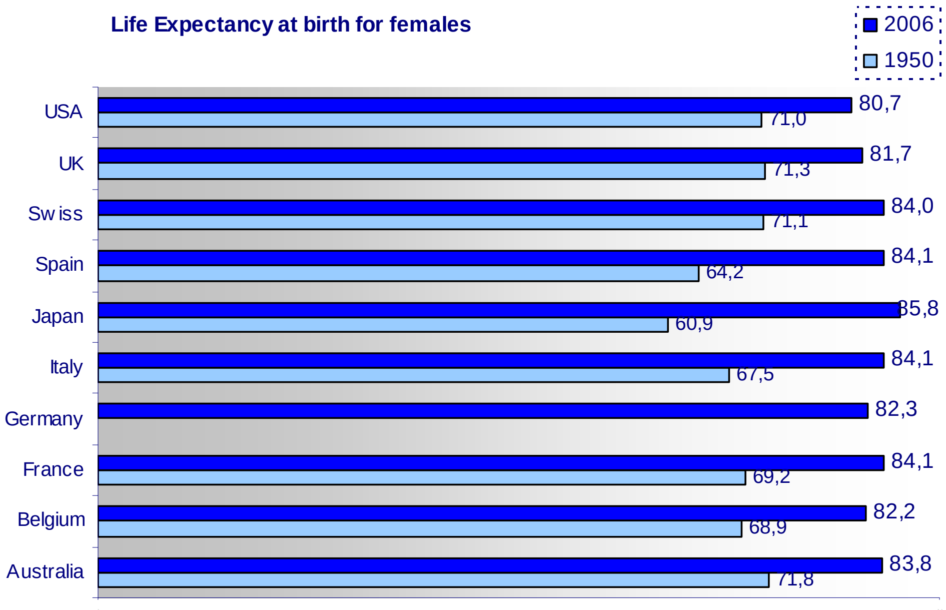
Stochastic models

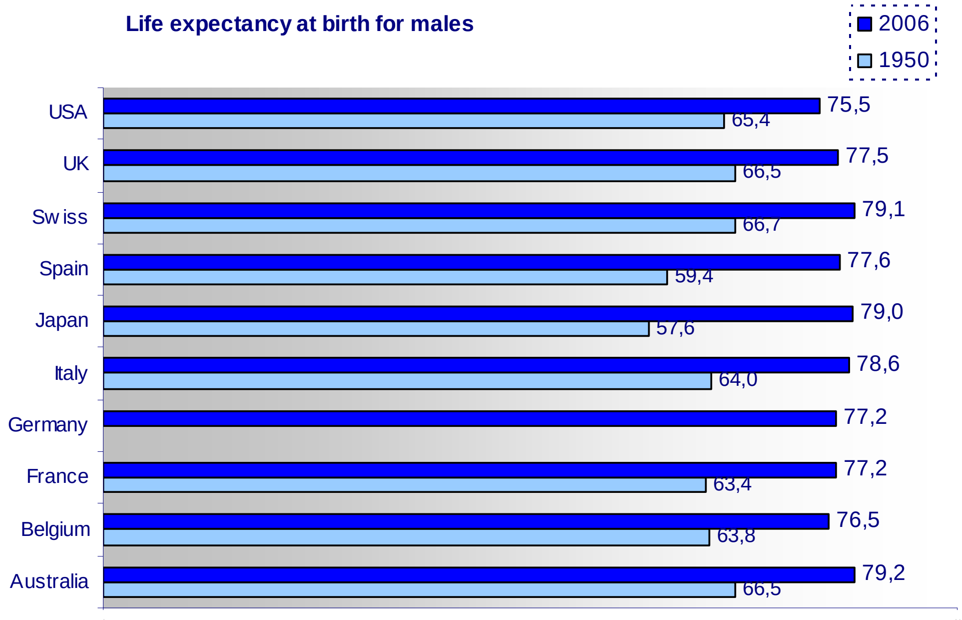
- **Advantages**
  - National population data can be used and is available for most developed countries (HMD database)
  - Reflects historical trends
  - Most models incorporate cohort effect
  - Researched and documented by the Pensions Institute (UK)
  - Generates sample paths by simulation
- **Limits**
  - Requires large amount of data to calibrate
  - Projections very dependent on choice of model, and difficult to select "best" model
  - Can be sensitive to choice of assumptions and data

2 Longevity, past trends and future evolution

Evolution of Life Expectancy

- **Impressive increases in life expectancy over the last 50 years – around 2 years per decade**





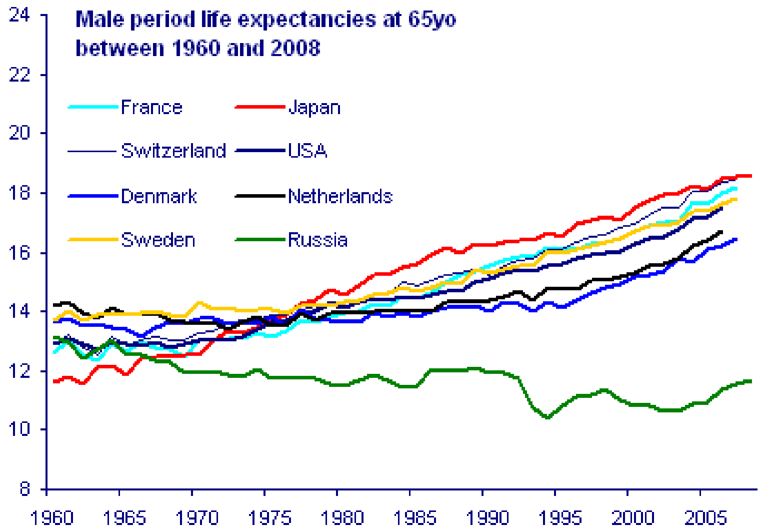
Source: Human Mortality Database (HMD)

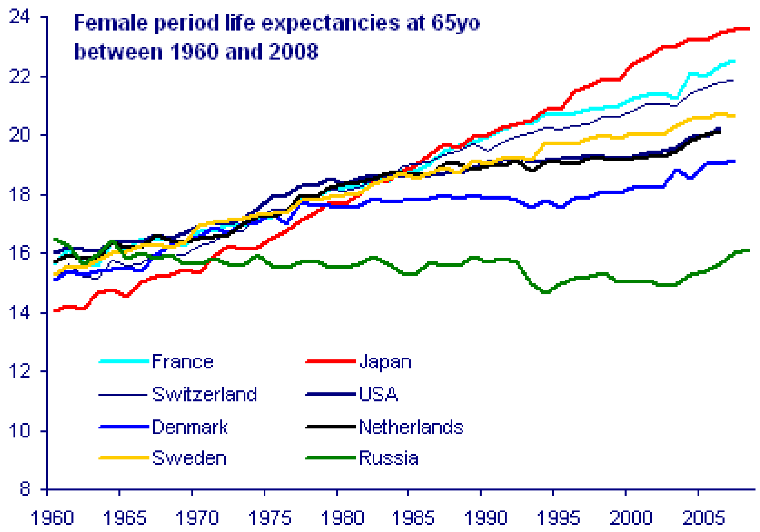
> **Members of OCED countries can expect to live over 10 years longer on average than they could 50 years ago**

Evolution of life expectancy: differences between countries

- Life expectancy steadily increasing for nearly all countries
- Convergence between countries until 1980, then divergence

Life expectancy at age 65





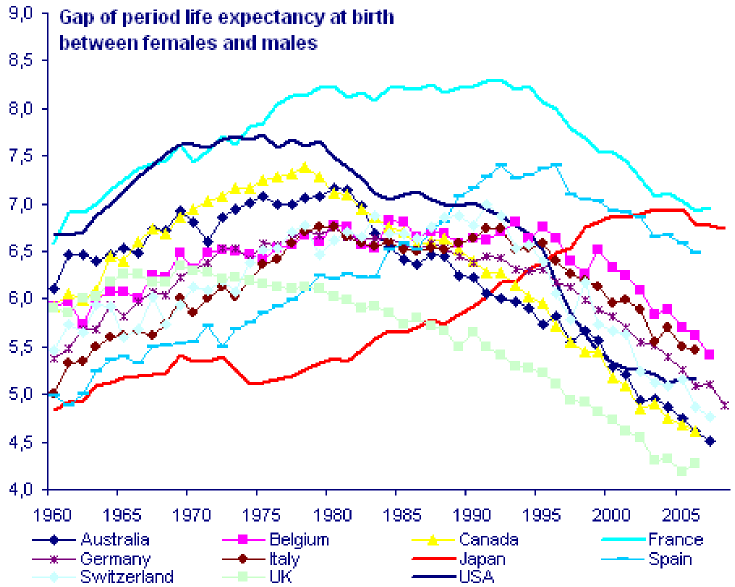
Source: HMD Database www.mortality.org (downloaded in June 2010)

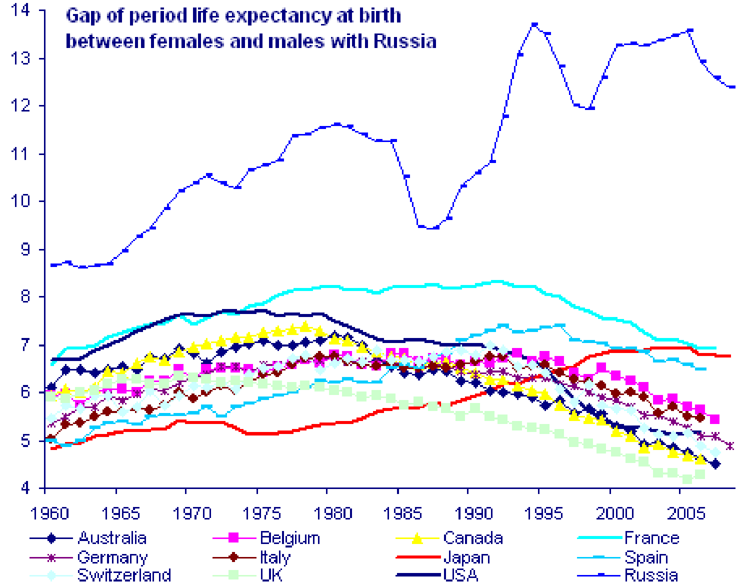
Evolution of life expectancy: differences between genders

- Female mortality consistently lower than males'

- Significant differences remain between countries

Difference of period life expectancy at birth





Source: HMD Database www.mortality.org (downloaded in June 2010)

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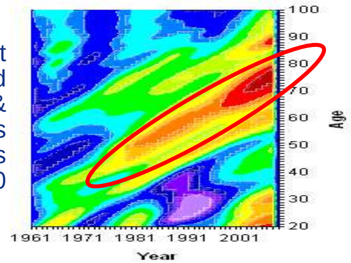
Evolution of life expectancy: differences within countries

Discrepancies between generations: the cohort effect

- Higher mortality improvement than the previous and the following generations

Cohort effect for England & Wales cohorts 1920-1940



Annual improvement rate
[q(x,t)-q(x,t-1)]/q(x,t-1)

Socio-economic inequalities

- Life expectancy at birth in certain suburbs of Glasgow, Scotland, can be 28 years lower than for someone born just 13 km away… (WHO study)

UK insurers have developed segmented annuity pricing

- Enhanced annuities – higher annuity rate depending on risk factors (e.g. smoking, post code pricing as a proxy for socio-economic status)
- Impaired annuities – higher annuity rate depending on specific medical conditions

Evolution of improvements in mortality

- Higher improvements at younger ages during first half of century
- Recently older ages have experienced higher improvements

Age-specific contributions to the increase of LE in women from 1850 to 2007

	1850-1900	1900-25	1925-50	1950-75	1975-90	1990-2007
0-14 years	62·13%	54·75%	30·99%	29·72%	11·20%	5·93%
15-49 years	29·09%	31·55%	37·64%	17·70%	6·47%	4·67%
50-64 years	5·34%	9·32%	18·67%	16·27%	24·29%	10·67%
65-79 years	3·17%	4·44%	12·72%	28·24%	40·57%	37·22%
>80 years	0·27%	-0·06%	-0·03%	8·07%	17·47%	41·51%

Data derived from reference 12 and the Human Mortality Database.

- The average annual improvements in mortality have accelerated in the last 10 years compared to the previous decade
- Acceleration has been more marked at older ages

Males

Country	Available data	IR ages 60-69yo	IR ages 70-79yo	IR ages 80-89yo	IR ages 90-99yo
Australia	2007				
	1998-2007	3,7%	3,3%	2,3%	1,6%
	1988-1997	2,9%	2,4%	1,3%	-0,8%
France	2006				
	1997-2006	3,0%	2,4%	2,1%	1,4%
	1987-1996	1,8%	2,2%	1,7%	0,3%
W Germany	2006				
	1997-2006	3,4%	2,7%	2,4%	0,7%
	1987-1996	1,4%	2,0%	1,1%	-0,2%
UK	2006				
	1997-2006	3,4%	3,4%	2,5%	1,6%
	1987-1996	2,7%	2,1%	1,3%	-0,1%
USA	2006				
	1997-2006	2,3%	2,1%	1,9%	2,3%
	1987-1996	1,7%	1,7%	0,9%	-0,2%

Source: Human Mortality Database (HMD)

Longevity drivers

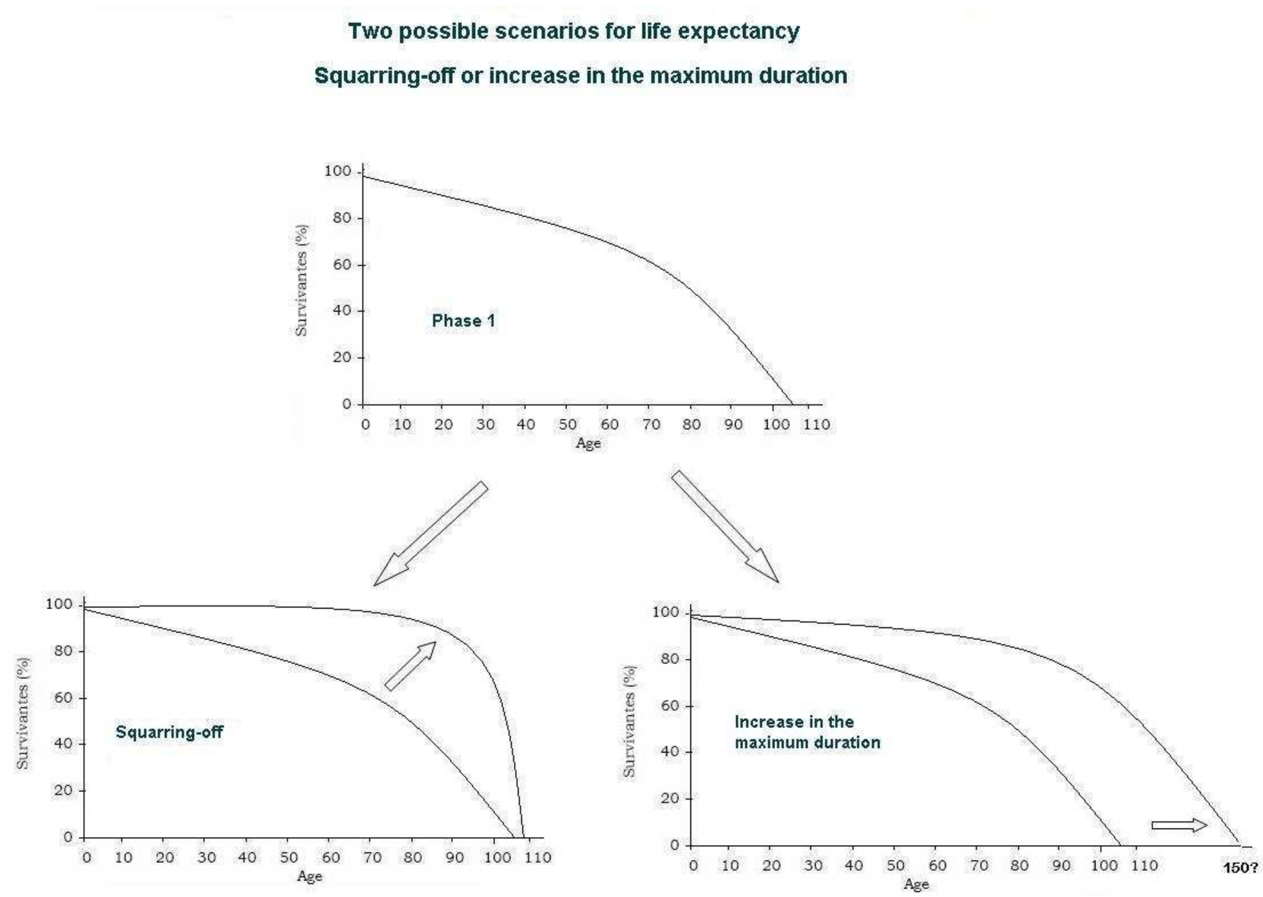
- **First half of the 20th century: substantial reductions in mortality for younger ages (below 60)**
  - Improved hygiene and public sanitation
  - Introduction of new health measures
  - Adoption of widespread vaccination programs and development of antibiotics

- **Since the second half of the 20th century: significant improvements in mortality rates at older ages (above 60)**
  - Socio-behavioral factors
    - Healthier diet and more regular exercise
  - Improved medical care
    - Reduction of mortality linked to cardio-vascular diseases and medical advances

- **What will be the trend for the future?**

Key questions regarding the future

- **Is there a limit to life expectancy (does the Hayflick limit exist)?**



Key questions regarding the future

- **The impact of emerging risks?**
  - Cell phones: no clear conclusions regarding a link between the usage of cell phones and a higher frequency of cancer
  - Pollution: established evidence of higher mortality rates in polluted zones
  - Climate change: what will be the impact?

- **The impact of potential accelerators to improvement?**
  - Fewer and fewer smokers
  - Increasing focus on accident prevention (speed limits, etc) and on disease detection
  - Medical breakthroughs on cancer and other disease
  - …

- **The impact of some countervailing trends?**
  - Obesity epidemic
  - New diseases
  - More stress and less physical activity
  - …

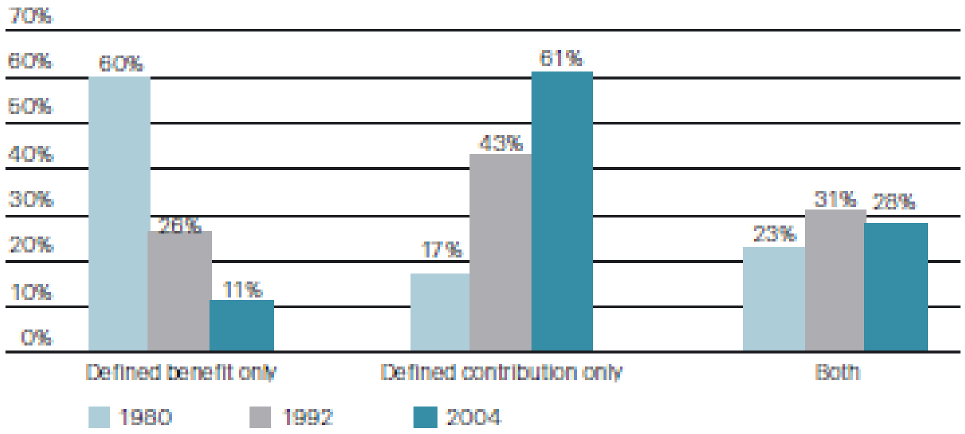
⇨ **The currently observed trend could change**

3 Challenges linked to longevity

The switch from DB plans to DC plans

- **Pension funds have started closing defined benefit plans**

Figure 4
US private sector workers with pension coverage, by pension type, selected years

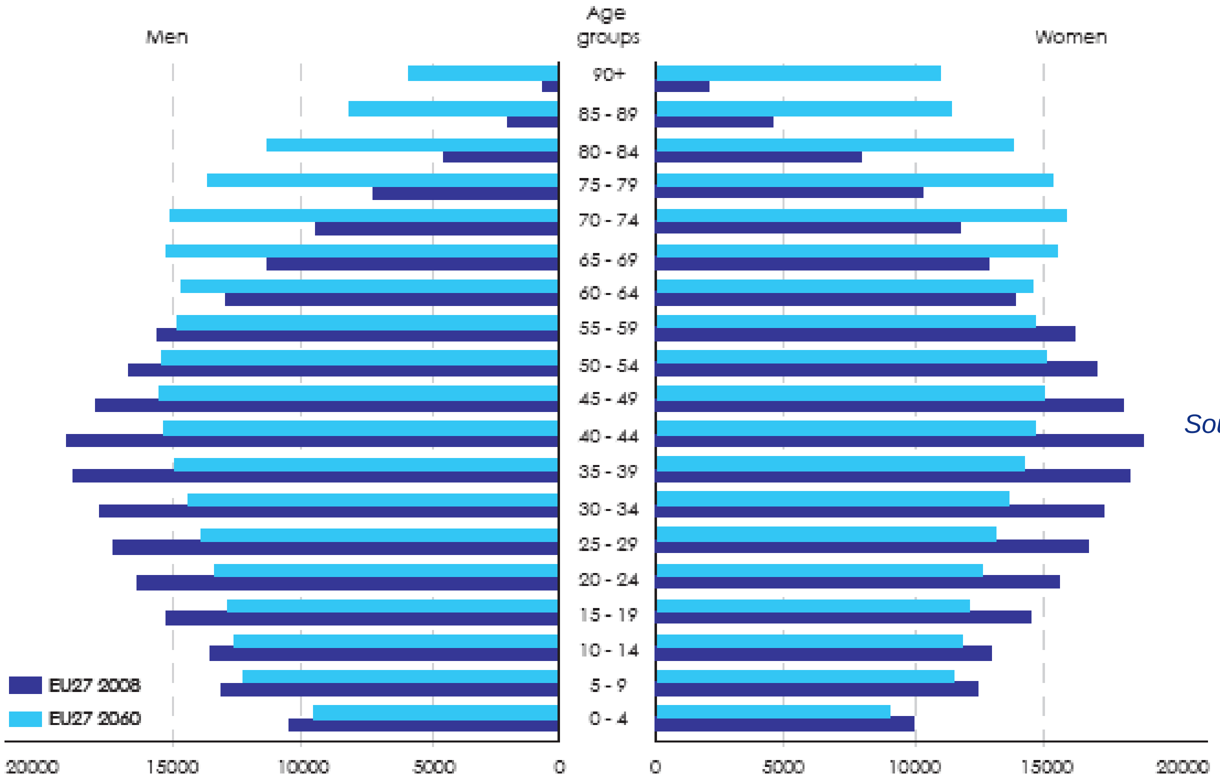


Source: Center for Retirement Research at Boston College
Available at: http://crr.bc.edu/frequently_requested_data/frequently_requested_data.html

- **Longevity risk is being shifted from employers to employees… as well as investment risk**
  - Pensions will be likely to be lower

An ageing phenomenon

- **An increasing number of older ages and a decreasing number of younger ages**

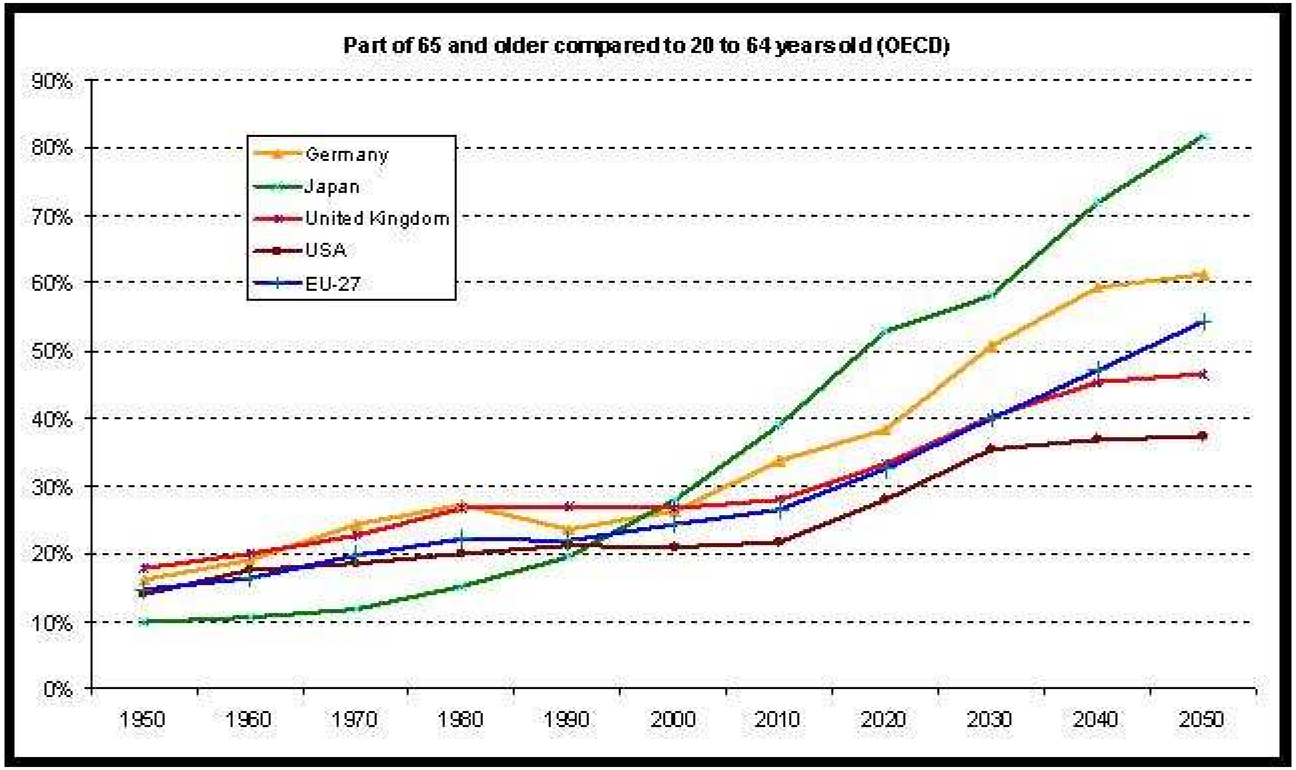


Source: European Commission

- **NB: worldwide phenomenon not limited to developed countries**

An ageing phenomenon: the consequences

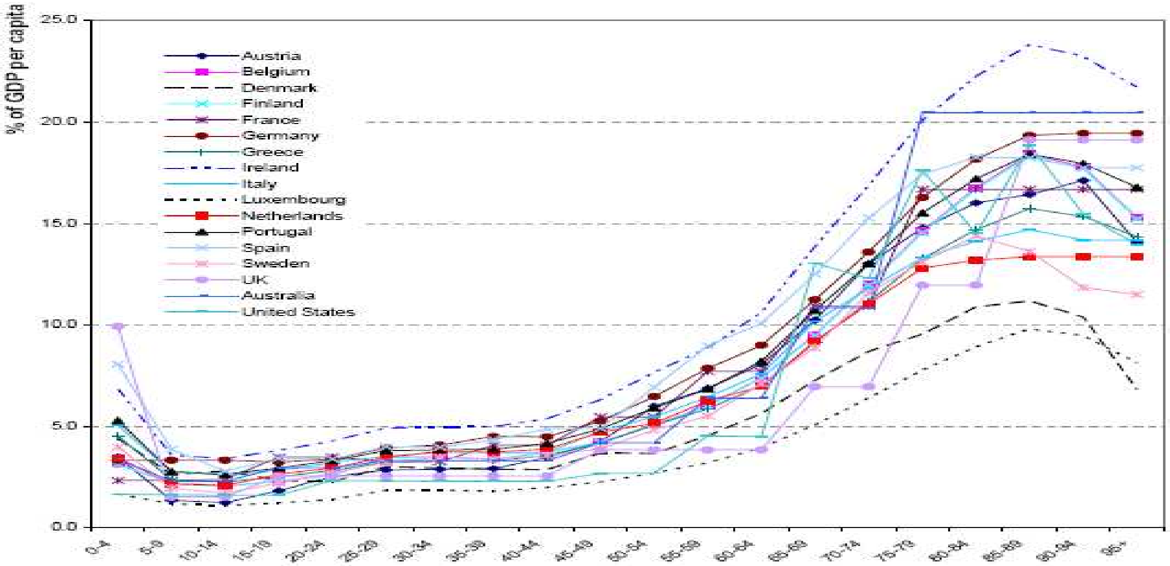
■ An increasing old age dependency ratio



Source: OECD

⇨ Increasing pension funding problem for social protection systems… among other challenges.

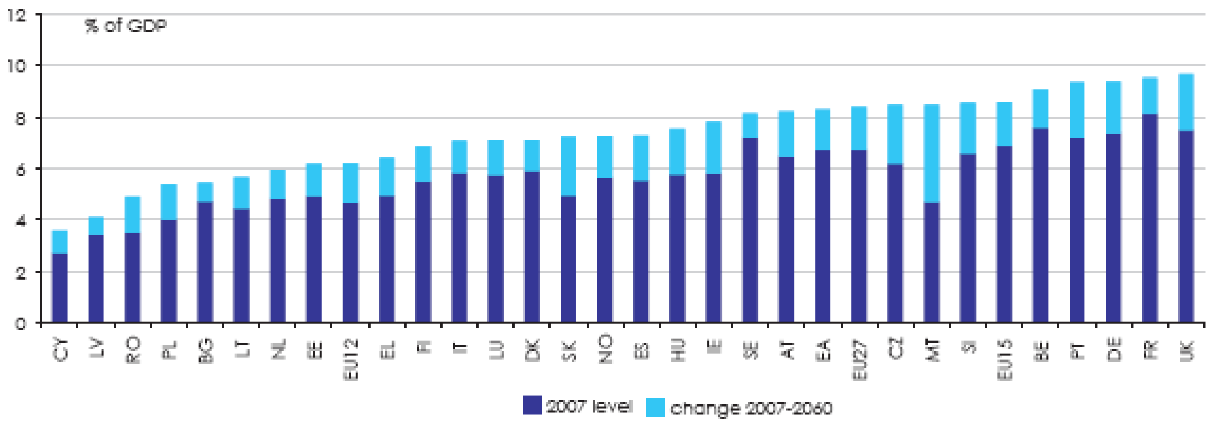
Significant differences between ages: health care costs



Public health expenditure by age group in 2005 as % of GDP per capita

Source: OECD

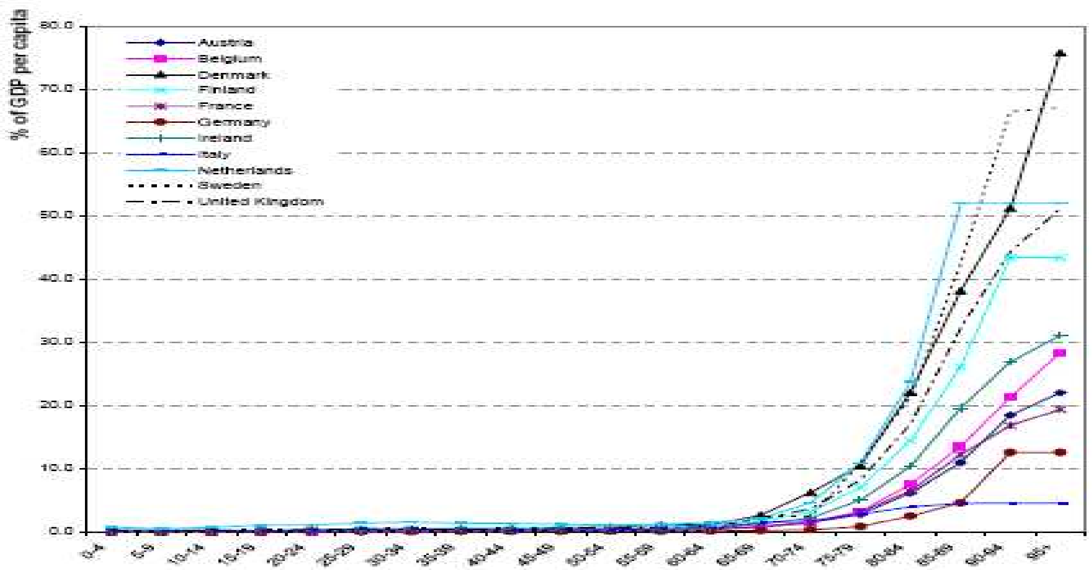
Projected demographic impact



Public health expenditure in % of GDP in EU

Source: EC

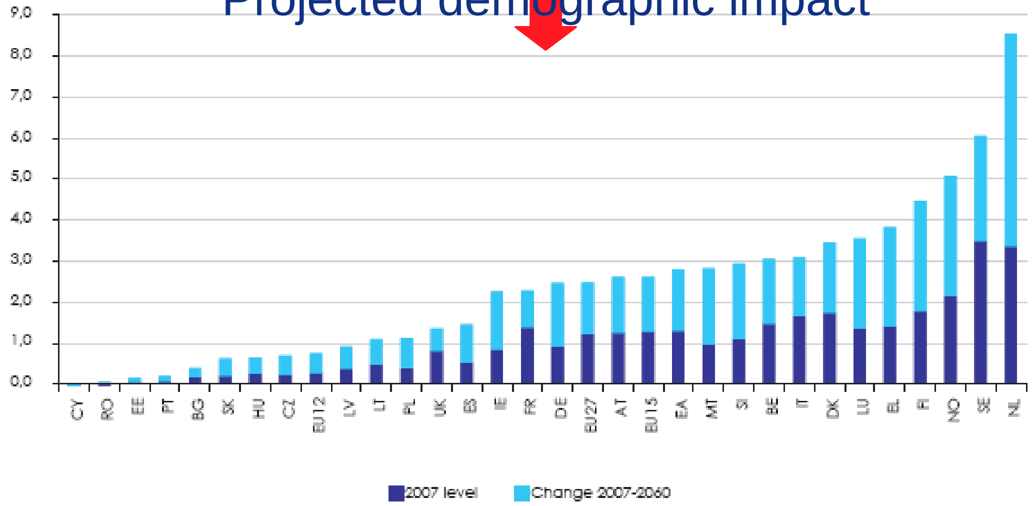
Significant differences between ages: long-term care costs



Public LTC expenditure by age group in 2005 in % of GDP per capita

Source: OECD

Projected demographic impact



Public LTC expenditure in % of GDP in EU

Source: EC

A lot of uncertainties in these projections

- **Other factors can influence the overall trend of expenditures**
  - Prevention programs as well as the diffusion of technology

- **An additional question: will the gain of life expectancy be spent in good or bad health?**
  - Several studies but no clear conclusions yet
  - There may be a difference between men and women
  - Medical advances may significantly extend healthy life

Critical consequences of the increase in life expectancy

- **Solutions for social protection systems like in continental Europe?**
  - Increasing tax pressure?
  - More and more delegate / transfer to private insurance coverage?
- **Solutions for places with weak social safety nets, like in the US?**
  - Must people save more to face all these contingencies? Or must they buy more insurance solutions to pool the risk with others?
  - Can people really save/spend more? And do they understand personal risk management well enough to buy protection?
- **Meanwhile insurers and private pension funds will offer lower and lower annuities due to the rise in life expectancy (all else being equal)**
  - Current aggravating factor: low interest rate situation

4 Managing longevity risk

The insurance industry

- **A natural buyer of longevity risk**
  - Sales of annuities to individuals (or groups of people)

- **With experience in managing this risk using several levers**
  - Product design
  - Annuity portfolio diversification
  - Business diversification – natural hedge between mortality and longevity exposures
  - Risk exposure monitoring
  - Reinsurance of portfolios
  - Securitization

The regulation of the insurance industry

- **An industry highly regulated…**

- **…but subject to a regulation poorly aligned with the underlying risk in the European Union**
  - Reserves are often based on mandatory mortality tables for annuities
  - Capital requirements are equal to 4% of reserves

- **A new solvency regime in 2013 (Solvency II)**
  - Will introduce economic reserves (BEL)
  - Will introduce capital requirements in line with the underlying risk

- **In parallel, large insurance groups are developing internal models**
  - To measure correctly their risk exposures and
  - To capture adequately their risk profile and their solvency capital requirement coverage

- **These will be implemented for Solvency II**

Longevity risk in Solvency II

- **Most companies will use the Solvency II standard formula**
  - Based on a uniform decrease in best-estimate mortality rates (20% reduction in QIS5)

- **Large insurance groups will use their internal models**
  - Based on more sophisticated approaches:
    - Example: stress of mortality improvement rates (e.g. 4% improvement rates instead of 2%)

- **Different views on longevity risk?**
  - The insurance industry is critical of the standard formula proposed by CEIOPS and the European Commission
  - Exposure should vary by age and by product term (whole life for annuities), which may not be the case with the standard formula
  - The standard formula does not correctly capture the main systematic component of this risk - the trend

AXA's experience in managing longevity risk

- **Harmonized risk management processes and governance spread across the AXA Group**
- **Regular measurement of the risk exposures and solvency assessment at a local and group level with the internal model**
- **Local and Group decisions taken using this monitoring**
- **Management of longevity risk:**
  - Risk modeling centrally performed using P-spline or stochastic models -> calibration of the 99.5th percentile
  - Regular measurement at local and group level
  - If locally the exposure is considered as too risky (too high), externalization project in coordination with the Group
  - Example: Longevity swap in the UK (before the sale!)

5 Capital markets and longevity risk

Existing options to externalize longevity risk (1/3)

Bulk annuities

- Transfer of the risk from a pension fund to an insurer, or from an insurer to a reinsurer
- Payment by a single premium
- Full transfer of all risks including financial risks to the buyer (e.g. pension fund obligations transferred to the insurer)

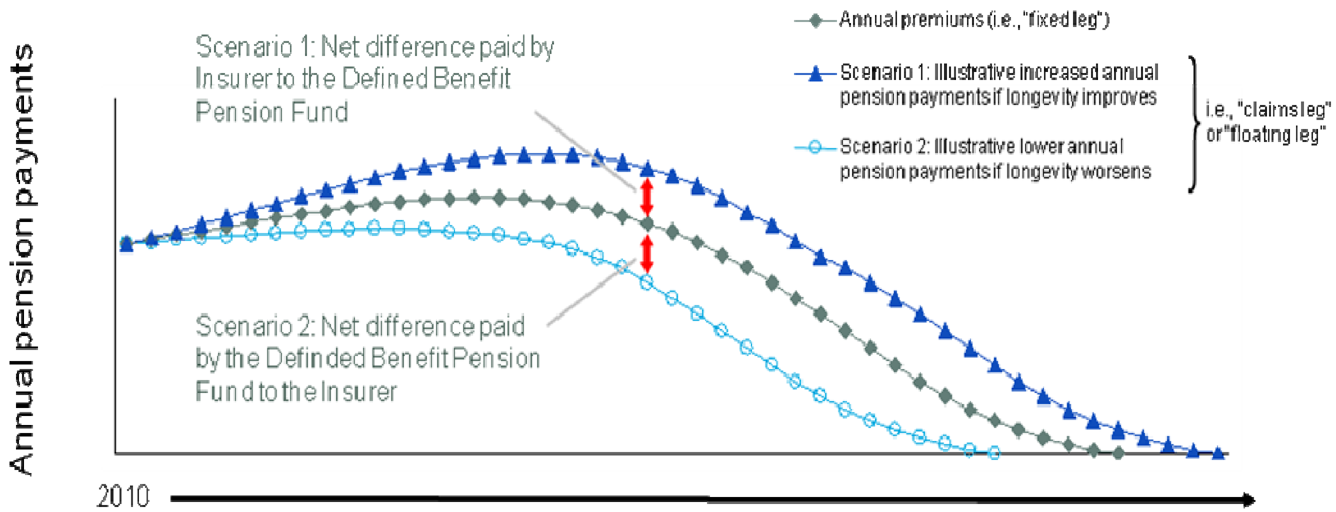
- Two types in the UK:
  - "Buy-out": the purchase of individual annuities for members of the pension scheme where each annuity forms a single policy between the member and the insurance company
  - "Buy-in": the purchase of a bulk annuity held by the trustee of the pension scheme as an investment of the scheme. The relationship between the member and the scheme does not change

- Widespread solution used in the UK by pension funds in termination
  - Seen as expensive

Existing options to externalize longevity risk (2/3)

Longevity swaps

- Transfer of the risk from a pension fund to an insurer, or from an insurer to a reinsurer
- Payment by annual premiums, corresponding to the net position (like a swap)
- Only transfer of the longevity risk: the assets remain with the seller
- New risk externalization solution recently used by pension funds in the UK



Existing options to externalize longevity risk (3/3)

Longevity swaps publicly announced

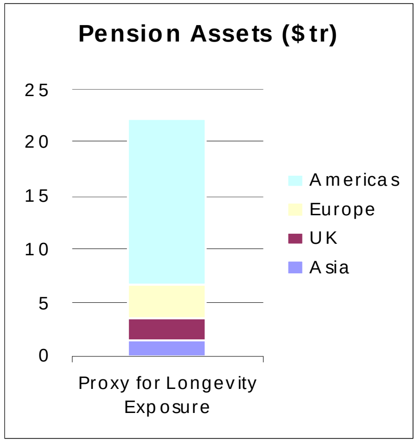
Longevity Risk Cedant (Date of Transaction)	Value of Liabilities Transferred	Longevity Risk Transferred to	
RSA (July 2009)	£1.9 bn	Goldman Sachs / Rothesay Life	Pacific Life Re
Babcock International (June/Sep/Dec 2009)	£1.2 bn	Credit Suisse	Pacific Life Re / RBC / RGA
Royal County of Berkshire (Dec 2009)	£1.0 bn	Swiss Re	
BMW (February 2010)	£3.0 bn	Deutsche Bank / Abbey Life	Hannover Re / Pacific Life Re / Partner Re
BA (July 2010)	£1.3 bn	Goldman Sachs / Rothesay Life	Pacific Life Re

Ultimate Longevity Risk Carrier

Source: Swiss Re

The current problem of funding longevity

- **An estimated $20tr in private longevity exposure across the world…**
  - 90% from pension funds and 10% from insurers



Source: OECD

- **… and the insurance industry solvency capital is limited**

The current problem of funding longevity

- **Given the current situation**
  - The increasing demand for annuities due to the ageing population,
  - The development of the deferred annuities purchased from insurers as an alternative to the public pension system provided by the governments,
  - The existing deficit or the underestimation of liability for pension funds

- **The insurance industry may not be able to absorb the demand**

- **The development of an active market on longevity could be a solution**

Conditions to create an active capital market on longevity (1/2)

- **The existence of a risk appetite for longevity**
  - Already an existing risk appetite for mortality
  - Advantage of longevity: a risk independent from financial markets
- **An increase in market transparency regarding longevity risk**
  - Improved data at population level
  - More reliable and standardized longevity indices
- **Convergence of views on how to assess the mortality improvement trend risk**
  - Raising investor awareness on longevity trends
  - Better consideration of the risk by the regulation and more disclosure
  - Improved and diffused modeling techniques of the longevity risk

Conditions to create an active capital market on longevity (2/2)

- **A liquid secondary market for investors**
  - Standardized contract specifications
  - Innovative short-term financial instruments: swaps over a limited number of years

- **Government longevity linked bonds?**
  - Coupons payable are linked to population survivorship
  - Would introduce alternative longevity risk buyers to the capital market: governments
  - Could play the same role as inflation linked securities

Life and Longevity Market Association (LLMA)

- **An association of stakeholders concerned by longevity risk**
  - Insurers (AXA, Prudential, L&G, Pension Corporation),
  - Reinsurers (SwissRe)
  - Banks (JP Morgan, Morgan Stanley, RBS, Deutsche Bank, UBS)

- **Which aims at developing liquidity for the trading of financial instruments for longevity and mortality risks**

- **By promoting**
  - Templates for standardized longevity products
  - A longevity trading index
  - Standardized valuation model for longevity

LLMA **www.llma.org**

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