The management of long term mortality risk at Swiss Re

Presentation by Michael Eves
International Mortality and Longevity Symposium
Birmingham, 17 September 2014
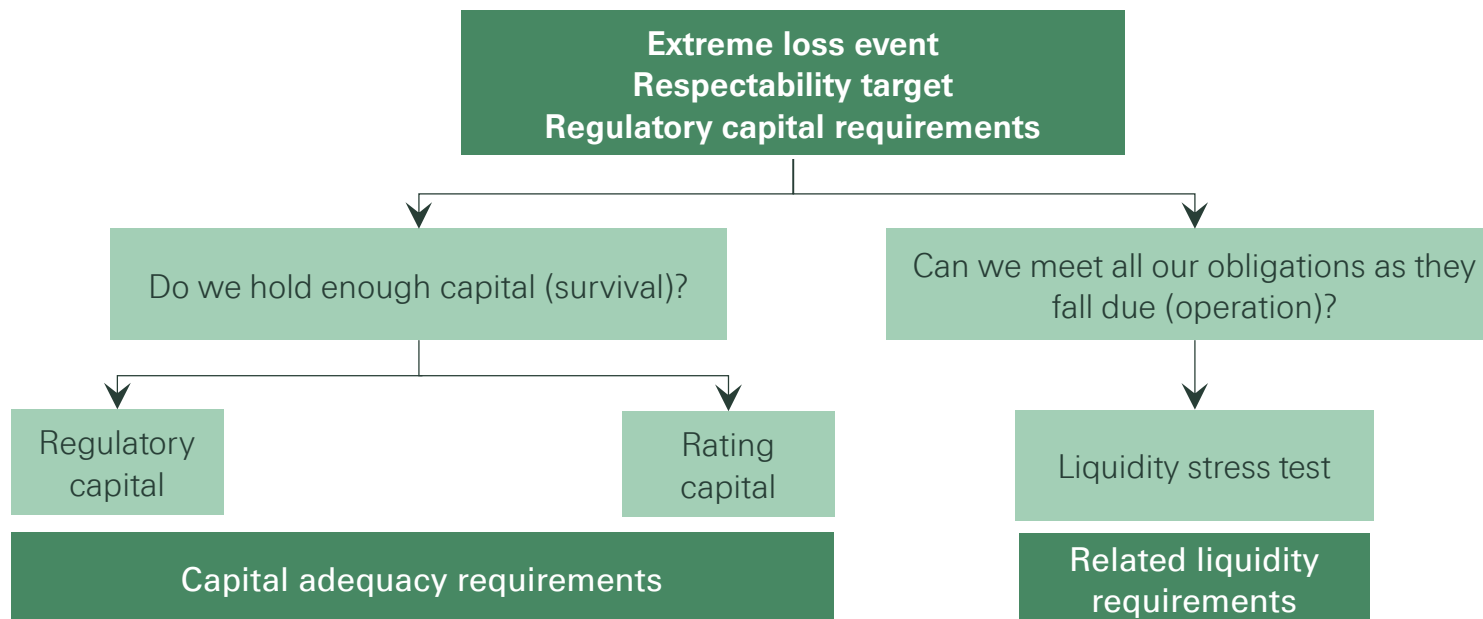
SWISS RE
150
YEARS

Agenda

- Risk Management Framework

- Modeling of Influenza Pandemic Risk

- Mortality Trend Model

- Managing mortality exposure

- Causal Mortality Model

Risk Management Framework

Acceptance of mortality risk starts by deciding on the Company's Risk tolerance. This then acts as a basis for risk steering and limit setting.

The risk tolerance represents the amount of risk (mortality, property, liability, asset etc) Swiss Re is willing to accept within the constraints imposed by its capital and liquidity resources, its strategy, its risk appetite, and the regulatory and rating agency environment. It is based on the following objectives:

- Maintain capital and liquidity that are sufficiently attractive from a client perspective, and that **meet regulatory requirements** and expectations ("respectability criteria")

- Be able to **continue to operate following an extreme loss event** ("extreme loss criteria"):

```
                    Extreme loss event
                   Respectability target
              Regulatory capital requirements

        Do we hold enough capital (survival)?          Can we meet all our obligations as they fall due (operation)?

   Regulatory                    Rating
   capital                       capital                Liquidity stress test

        Capital adequacy requirements                   Related liquidity requirements
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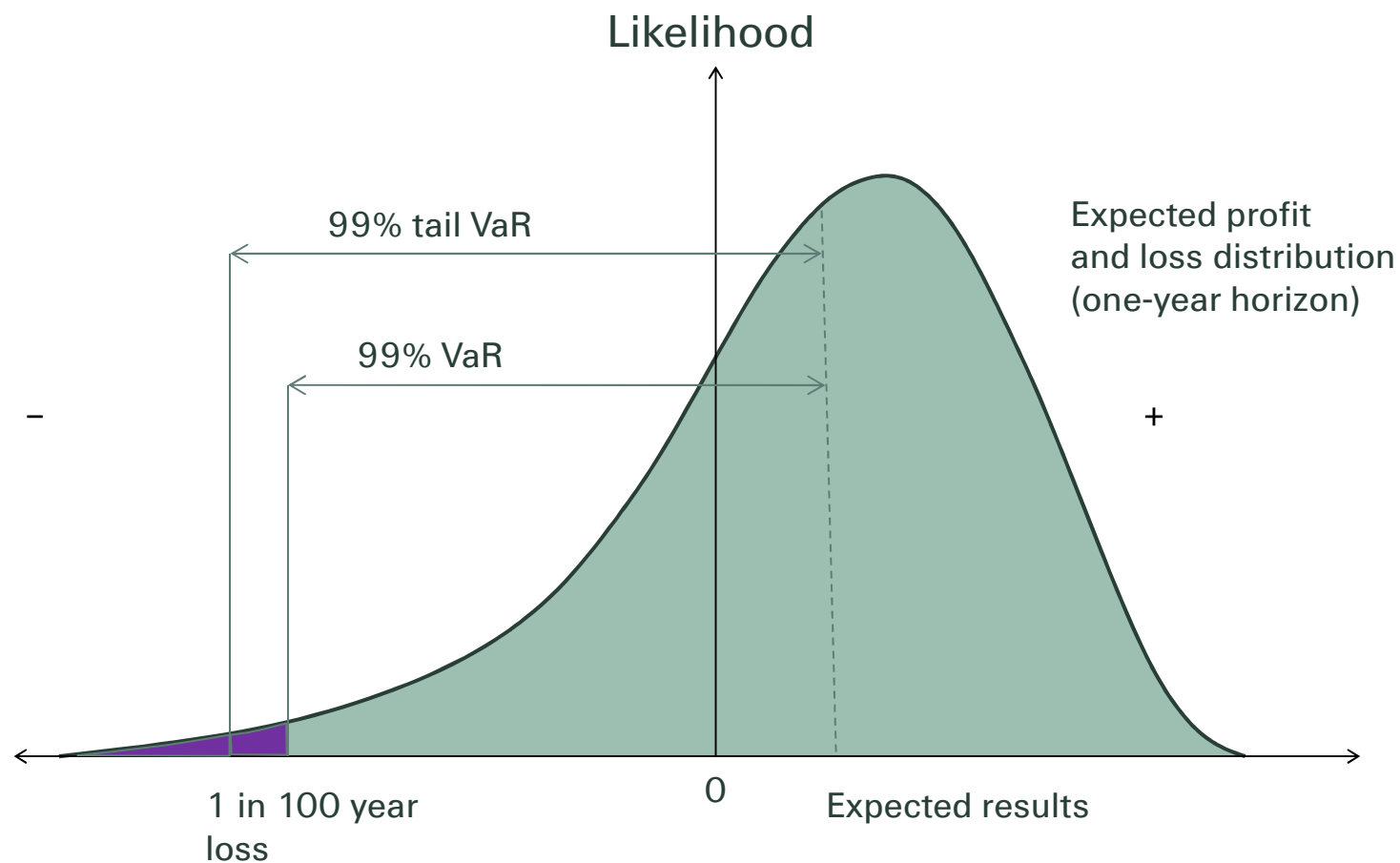
Life & Health Risks

- Life and Health Risk is defined as the unexpected economic impact from mortality, longevity or morbidity obligations as well as persistency rates deviating from the levels assumed at outset in costing or subsequently in reserving.

- For each risk factor, the underlying causes of uncertainty can be categorised into one of the following:

  - Shock Risk: an extreme, one-off fluctuation, e.g. mortality claims caused by a **lethal pandemic**.

  - **Trend Risk**: a permanent or cumulative deviation from the expected outcome, e.g. deviation in mortality/morbidity claims resulting from a medical advancement.

  - Parameter Risk: uncertainty related to pricing or reserving parameters, principally due to insufficient relevant information.

  - Volatility: a non-extreme, random fluctuation.

Pandemic risk and **trend risk** are the two major mortality related risks for Swiss Re and each will be discussed in detail later in the presentation.

Swiss Re asseses its risk tolerance using a 99% tail VaR with a one year time horizon as its risk measure

Likelihood

99% tail VaR

99% VaR

−

+

Expected profit
and loss distribution
(one-year horizon)

0

1 in 100 year
loss

Expected results

Risk Capacity Limits are set to keep the Company within its risk tolerance

- Risk capacity limits are established to control risk exposure accumulations at different levels.

- For Life and Health, three types of risk capacity limits are currently in place:

Type of limit	Description
Top-level risk capacity limits	Aggregate limits based on Tail-VaR which govern the acceptance of all life and health risks, with separate individual limits for mortality and longevity risk
Product capacity limits	To restrict risk-taking on certain non-core business lines. e.g. country level Catastrophe Excess of Loss and Stop Loss limits.
Concentration limits	To control concentration and volatility risk. e.g. per life retention limits for individual business; accumulation limits on buildings in densely populated areas.

- In addition, authority limits control risk origination by specifying the oversight required. All large, complex, or unusual transactions are reviewed and require approval from Risk Management.

Modeling of Influenza Pandemic Risk

Pandemic Risk

A major risk which can very quickly impact a mortality portfolio is an increase in mortality claims due to the influence of a pandemic. Significant pandemics are rare events of which the "1918 Spanish Flu" is the most well known. In today's world the particular features of such an event would be:

- fast human to human transmission spreading rapidly around the world due to air travel

- uncertainty with science's ability to quickly develop a cure / vaccine

- potential to impact infants, young or old adults or potentially all ages

- potential knock-on consequences such as fear of contact with other people, economic slowdown, asset falls etc.

Development of a Pandemic Model - Background

- 1918 was a unique event in 420 years with high mortality

  - 5.2 excess deaths per 1000 in the USA (vs. 0.4 in 1957 & 0.17 in 1968 when smaller pandemics occurred)

  - unusually, young adults were impacted most heavily

  - high incidence of viral pneumonia / cytokine storm

- 1957 / 1968 pandemics − return to typical mortality intensity and pattern: most excess deaths confined to infants and elderly; use of antibiotics; better knowledge; behavioural changes etc

- 2009 pandemic − infection risk highly skewed to young; low infectivity; low lethality; still uncertainty about serological attack rate by age

- Model

  - attempts to identify baseline variables and understand their importance and interaction (e.g. lethality, spread characteristics, age profile, proportion bacterial /viral, age-specific susceptibility)

  - incorporates most of these factors into an SIR model (susceptible, infected, recovered individuals, with defined rates of flow between groups)

  - uses 'event based' modelling which randomly selects certain key factors from a range of defined possibilities based on history and current conditions, e.g. basic reproduction number (R_0), lethality, antiviral success

Factors that complicate comparison of pandemics

	Under-standing of viruses	Social distancing (available, even if not used)	Anti-biotics	Pandemic Vaccines	Anti-virals	R_0 value (spread capability)	Lethality (death per infection)
1918	X	√	X	X	X	2.1	1.1%
1957	√	√	√	√ but too late	X	1.6	0.275%
1968	√	√	√	√ but too late	X	1.89	0.054%
2009	√	√	√	small effect	√	1.45??	unknown – very low
today	√	√	√	√ often too late	√	??	??

- Inferring current risk based on past total mortality is inappropriate

- Model must reliably imitate spread dynamics & changes that have occurred
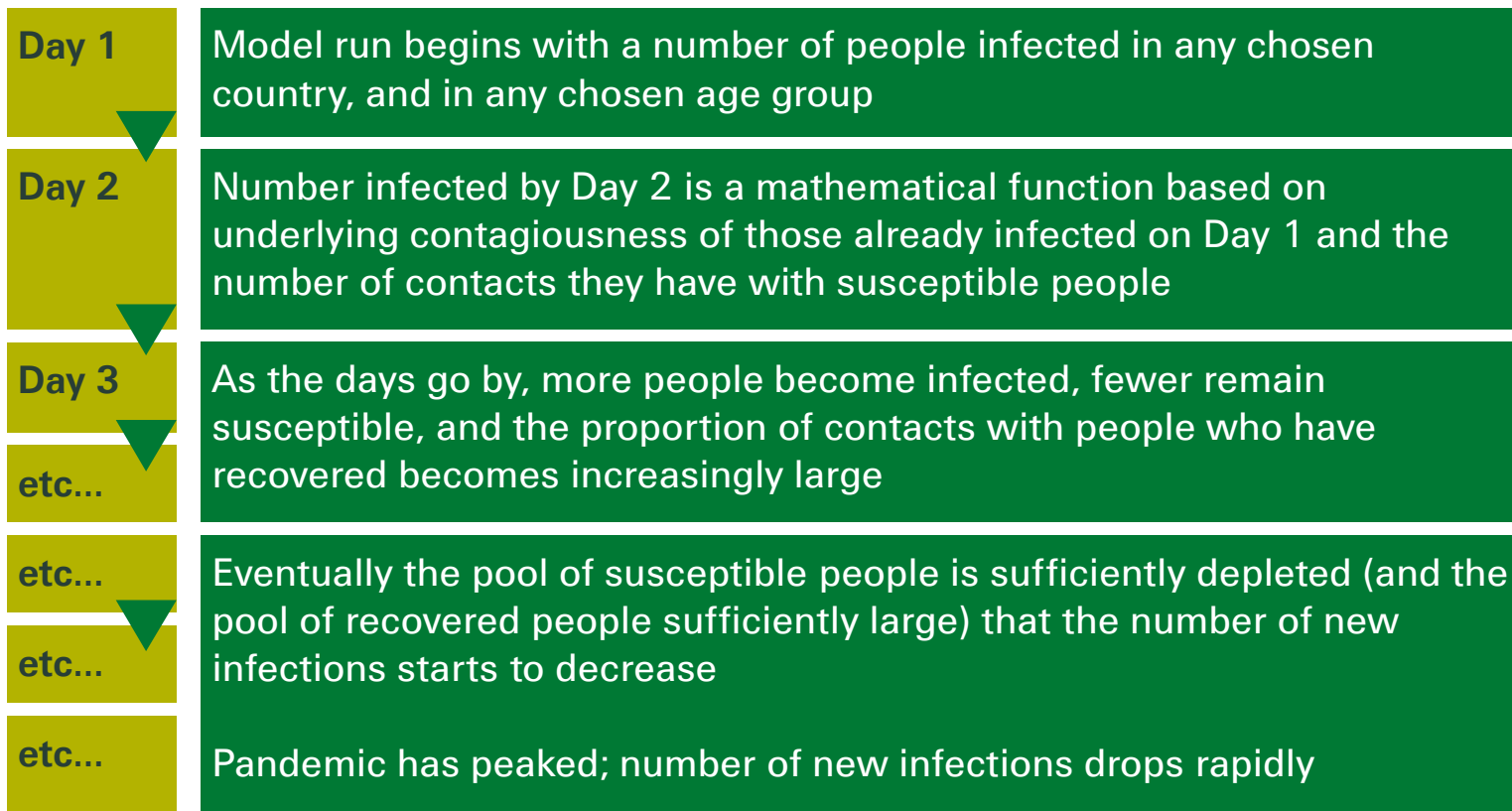
Spread model − calculation process

- Model begins with infected people in any one of the 37 territorial entities

- Population cells: 5yr age groups, 37 countries, disease state (susceptible, infected by duration, recovered, dead, vaccinated)

- Model is based on daily iterations: cells change incrementally on a daily basis (i.e. gradually changing new infections, deaths)

- Specified within each population cell:
  - mixing between ages, mixing rates, mortality per infection, viral /bacterial disease progression, travel propensity, share of meds

- At each time, number of infections in each cell dependent on previous day's:
  - susceptibles; no. contacts (of both uninfected and infected); number infected in groups with which contact occurs; transmission prob. (affected by stage, antivirals, vaccines)

- Intervention affects one/some of the above, slowing infection and/or reducing mortality
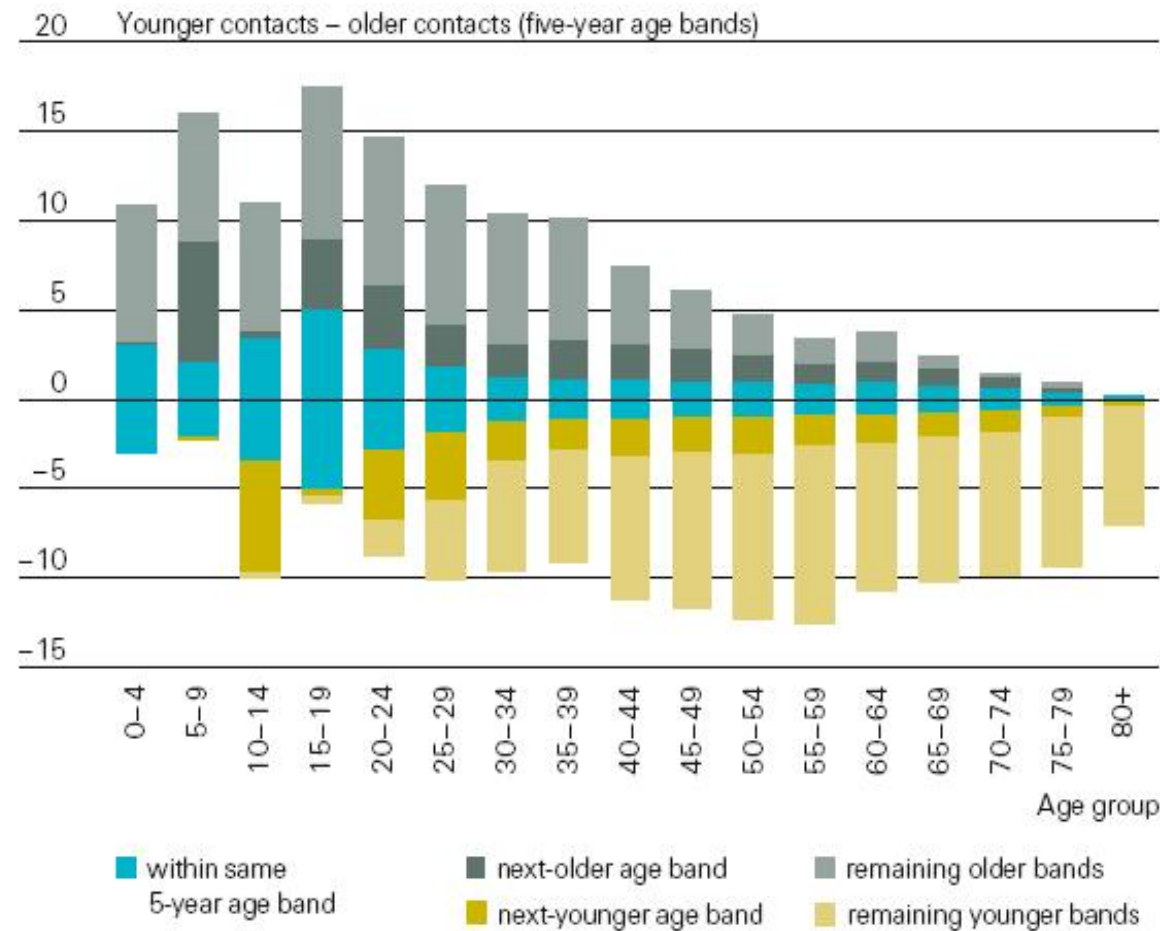
Calculating spread
(process day by day)

- Using Susceptible/Infected/Recovered (SIR) cells the model calculates spread at discrete time intervals, each lasting 24 hours
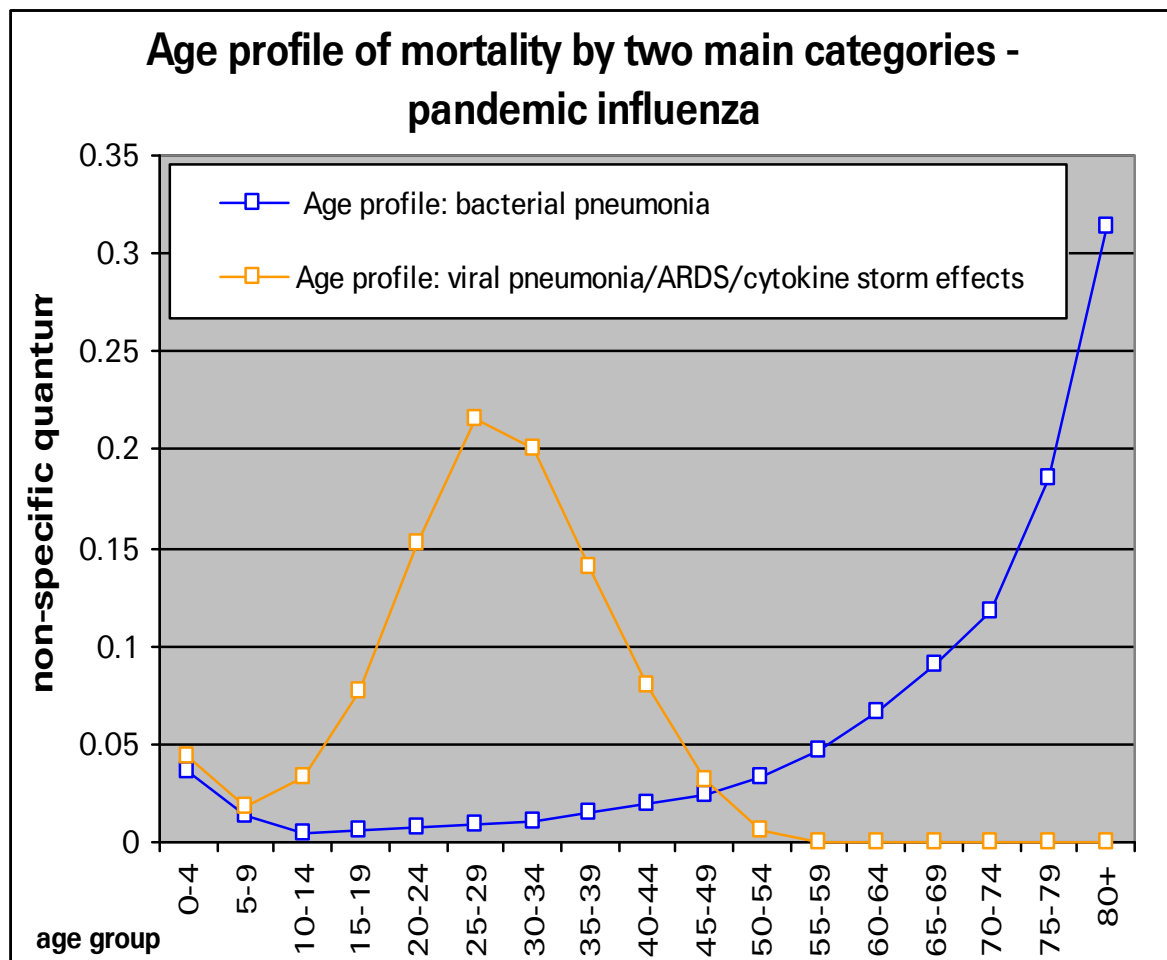
Day 1	Model run begins with a number of people infected in any chosen country, and in any chosen age group
Day 2	Number infected by Day 2 is a mathematical function based on underlying contagiousness of those already infected on Day 1 and the number of contacts they have with susceptible people
Day 3 / **etc...**	As the days go by, more people become infected, fewer remain susceptible, and the proportion of contacts with people who have recovered becomes increasingly large
etc... / **etc...**	Eventually the pool of susceptible people is sufficiently depleted (and the pool of recovered people sufficiently large) that the number of new infections starts to decrease
etc...	Pandemic has peaked; number of new infections drops rapidly

Number of contacts by age group and age profile of those contacts

Younger contacts – older contacts (five-year age bands)

- Young adults have more than 3x as many contacts with other people as the elderly

- Ageing populations tend to have lower spread values, especially as mixing rates peak among young adults

Legend:
- within same 5-year age band
- next-older age band
- remaining older bands
- next-younger age band
- remaining younger bands

Chart source: see Pandemic influenza: A 21st Century model for mortality shocks

Age profile of lethality − bacterial and viral

Age profile of mortality by two main categories - pandemic influenza

non-specific quantum (y-axis): 0, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35

- Age profile: bacterial pneumonia
- Age profile: viral pneumonia/ARDS/cytokine storm effects

age group (x-axis): 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80+

	% of mortality due to bacterial pneumonia	% of mortality other causes: viral pneumonia/ ARDS / cytokine storms
1918	57%	43%
1957	95%	5%
1968	100%	0%

Swiss Re

One key parameter, for example:
Age profile of lethality
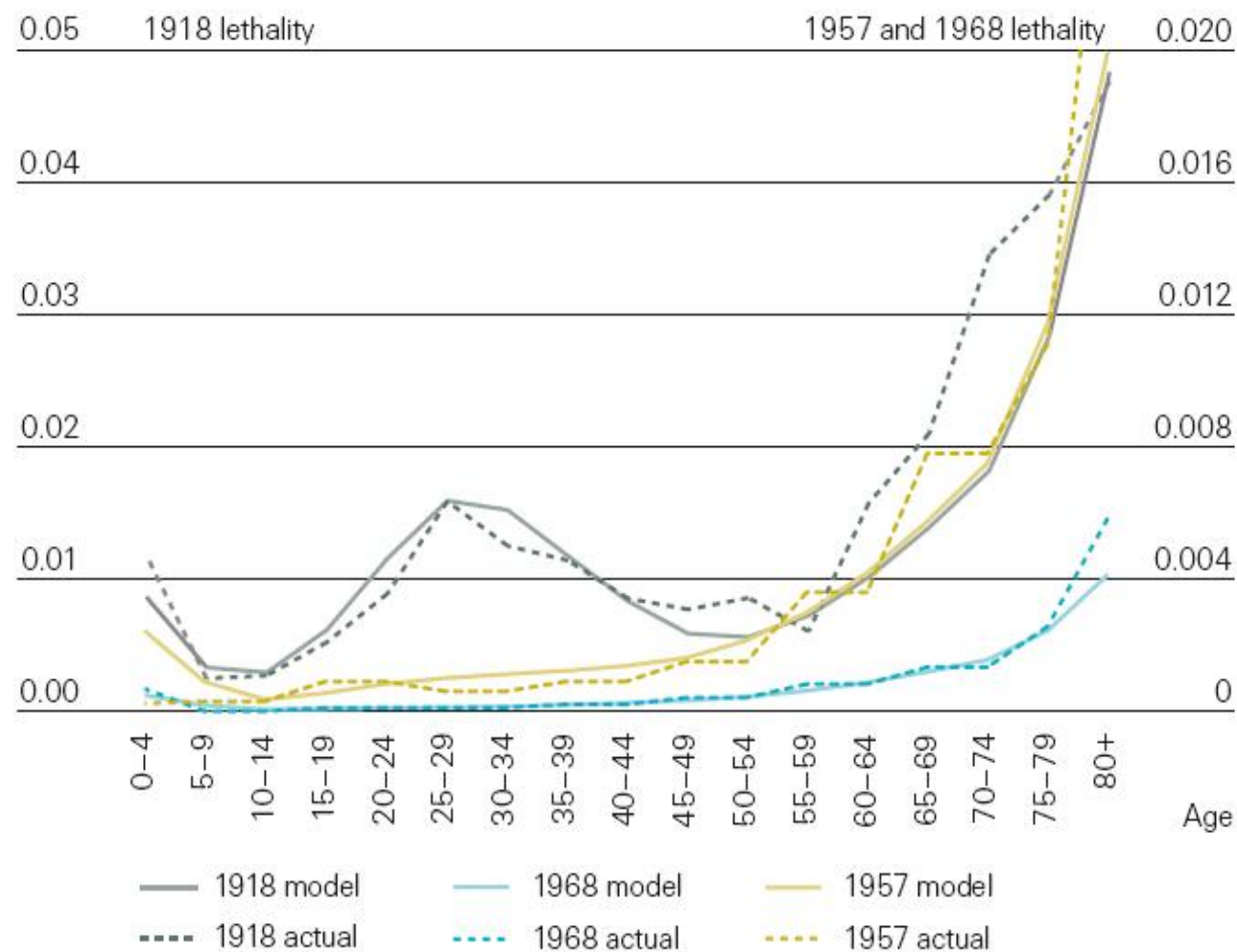
- Low lethality pandemics (1957 and 1968) are assumed to be entirely due to bacterial pneumonia (U-shaped)

- Mortality in high lethality pandemics (1918) is a combination of the two causes (W-shaped)

- Impact of each of the two causes changes proportionally as lethality increases

Chart sources: see Pandemic influenza: A 21st century model for mortality shocks

Other key parameters

- Age profile of lethality

- Contagiousness (by age & duration since infection)

- Behavioural factors (by age & clinical status)

- Susceptibility to infection (by age)

- Population age structure (for each geographical entity)

- Daily contacts (by age)

Fit to historic events

- Frequency of pandemics: approximately 1 / 30 years on average

- 1918 − using R_0 = 2.1, and death-per-infection of 0.011 for USA

  - Fit numbers of deaths, lethalities, date of peak, etc

- 1957/ 1968 − much less data, so tested lethality curves mainly, and used published data on R_0 values

- Algorithm developed to produce age profile of lethality:

  - model automatically produces age profile depending on lethality level

- In generating event set use 2009 demographic equivalent:

  - R_0 : 1918=2.1 ; 1957=1.6 ; 1968=1.89; (2009=1.45?)

  - Baseline lethality: 1889=0.00375; 1918=0.011; 1957=0.002753; 1968=0.00054

Moving 1918 to today

- Demographics:
  - Population age structure: rate of spread changes as populations age - older people mix less, children have higher viral shedding
  - Population density/ living conditions: tested effect of this on R_0

- Underlying health status
  - higher life expectancy = better underlying health status, especially in developing world
- Antibiotics:
  - approximately 57% of deaths in1918 assumed mainly due to bacterial pneumonia
  - bacterial pneumonia deaths predominantly in elderly and very young
  - antibiotics reduce bacterial pneumonia deaths by 60-80%
  - access varies by country

Moving 1918 to today

- Antivirals:
    - makes infected people less infectious to others: slower spread, reduced peak, lower serological attack rate
    - lower lethality: when effective and available assume 38% reduction in viral pneumonia mortality & 67% reduction in bacterial pneumonia mortality
    - potential usage varies by country
        - maximum access is 65% , accounting for need for rapid administration
        - further constrained by country stockpile and supply rates
    - antivirals assumed to be effective in 3/4 of pandemics

- Travel:
    - has been tested and has minimal impact
    - travel restrictions delay entry of the virus into countries, but given the growth patterns when it does eventually reach a country (which it almost always will) , the impact on final mortality outcomes is small

# Simulated 1918 pandemic, then & now...

24.0 Deaths/1000 (in the general population)

18.0

12.0

6.0

4.5

3.0

1.5

0.0

Base   1   2   3   4   5

1 2006 population structure (spread rate and age profile of mortality)
2 ... plus underlying health changes relative to US (US assumed unchanged)
3 ... plus antibiotics
4 ... plus antiviral treatment
5 ... plus vaccines
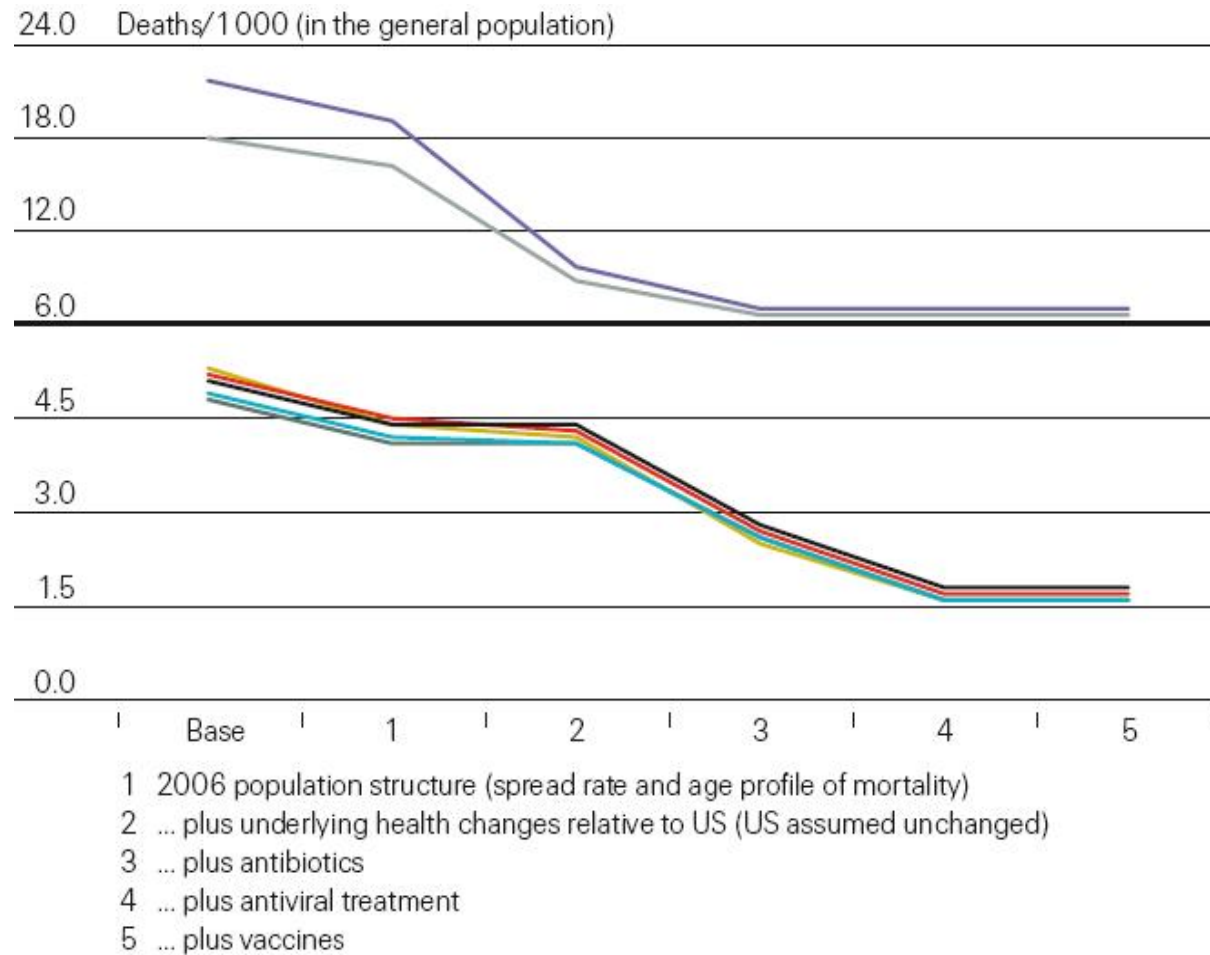
- The graph shows the cumulative effect on mortality rates of selected changes between 1918 (the "Base") and 2006

—— India
—— China

—— Germany
—— Switzerland
—— Canada
—— UK
—— US   —

Modelling results:
Selected developed countries

Insured-age excess mortality due to pandemic influenza, selected developed countries
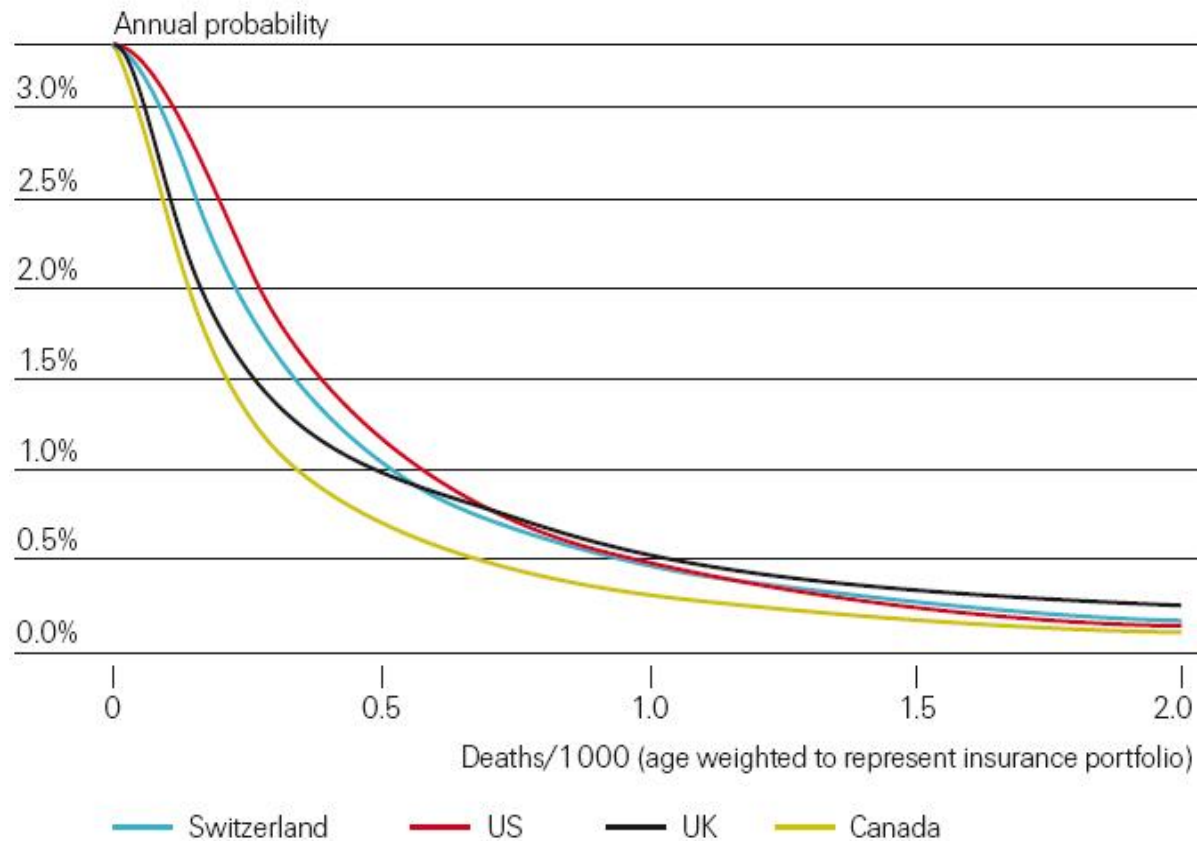
Canada is among the countries appearing to be least impacted, with estimated 1-in-200-year excess mortality at around 0.7‰ in an insurance-age population

Modelling results:
Selected developing countries

Insured-age excess mortality due to pandemic influenza, selected developing countries
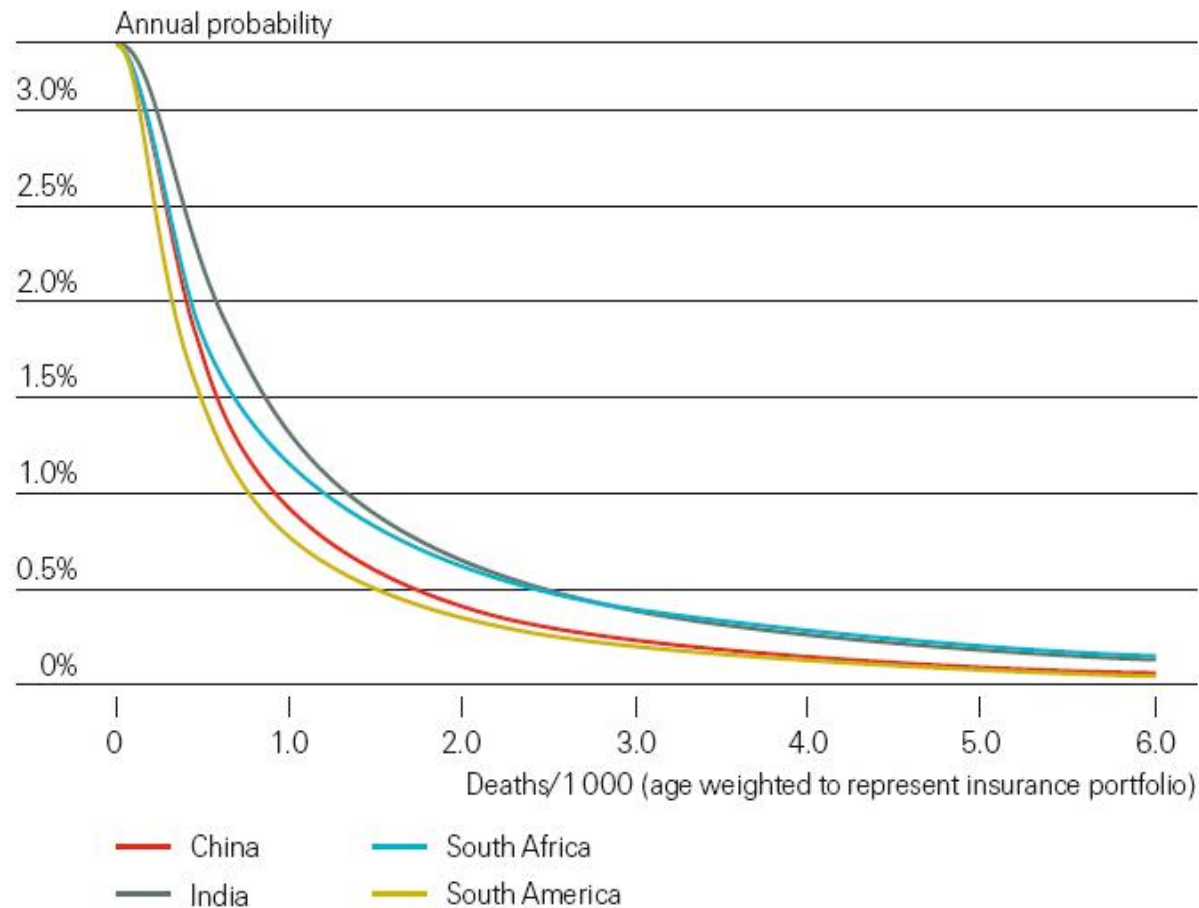
Countries expected to experience higher levels of mortality include India, Pakistan and Indonesia, due to high population density, along with a weak capacity to reduce contact rates (India shown)

The healthcare systems of these countries are also weaker than in developed countries, almost no antivirals are available

Mortality Trend Model

Mortality trend model is required for both internal use as well as to meet regulatory requirements such as Solvency II and Swiss Solvency Test

- All these measures define the capital required to meet the expected loss event as

$$\cdots\left(AC_{T+1} - AC_T \,\middle|\, F_T\right),\text{ where}$$

$AC_T = A_T - L_T$ denotes Available Capital (Assets minus Liabilities) today at time T,

F_T denotes a filtration representing today's information,

$\cdots$ denotes a risk measure (VaR at 99.5%, expected shortfall at 99%), and

$AC_{T+1} = A_{T+1} - L_{T+1}$ denotes Available Capital one year into the future

Historical and future life expectancy of UK males
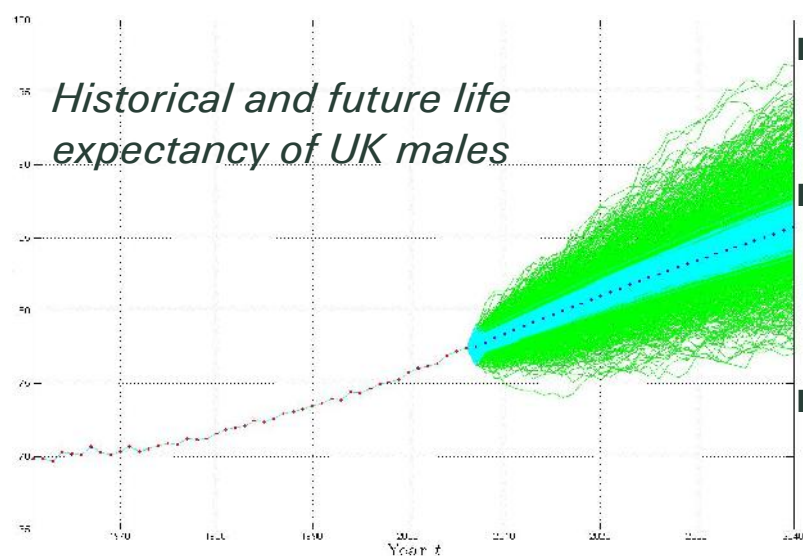
- Liabilities are affected by best estimate assumptions on future mortality rates $\hat{q}_{x,t}$

- **Mortality Trend Risk** in the **one-year view** of the above definition is the potential deviation of next year's best estimates from today's best estimates

- Focus on systematic Mortality Trend Risk of given populations, e.g. UK males, US females, etc.

Ultimate view

- Usually, mortality models simulate an **ultimate view** of future mortality rates, e.g.

  Lee-Carter model $\qquad\qquad \ln(m_{x,t}) = \Gamma_x + \kappa_t^{(1)} s_x$

  Age-Period-Cohort model $\qquad \ln(m_{x,t}) = \Gamma_x + \kappa_t^{(1)} + x_{t-x}$
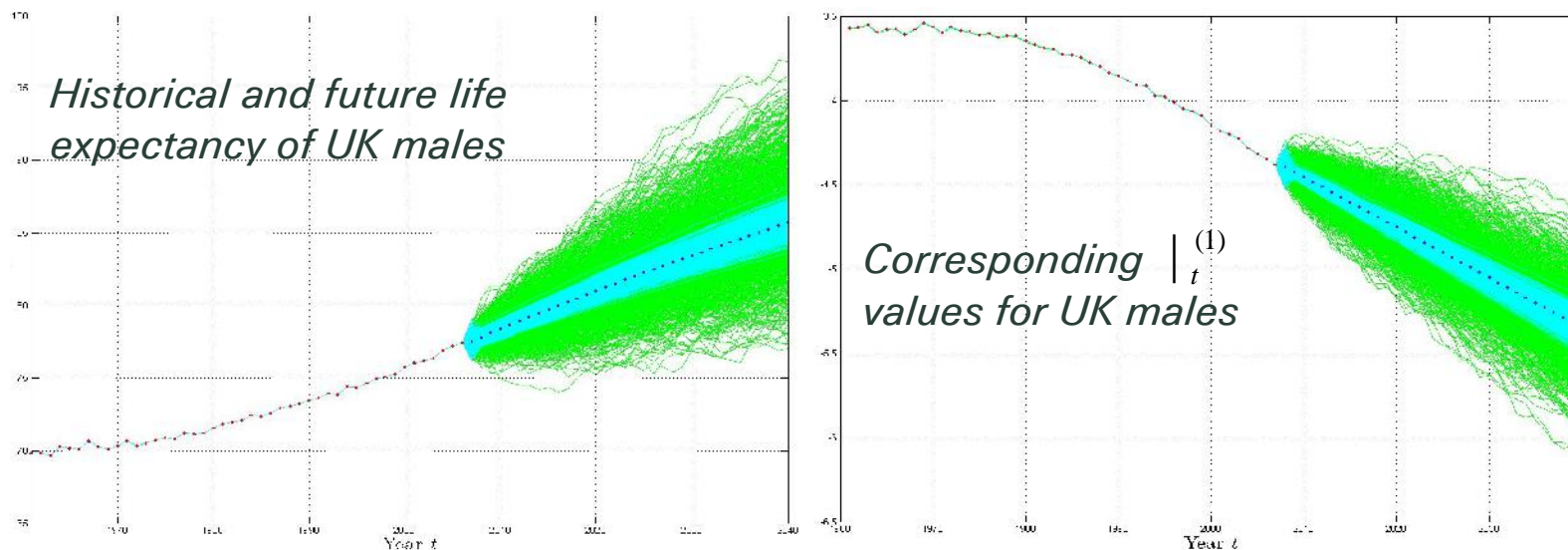
  Cairns-Blake-Dowd model $\quad \mathrm{logit}(q_{x,t}) = \Gamma_x + \kappa_t^{(1)} + |_t^{(2)}(\bar{x} - x) + x_{t-x}$

  Plat model $\qquad\qquad\qquad \ln(m_{x,t}) = \Gamma_x + \kappa_t^{(1)} + |_t^{(2)}(\bar{x} - x) + |_t^{(3)}(\bar{x} - x)^+ + x_{t-x}$

  Swiss Re's model $\qquad\quad \mathrm{logit}(q_{x,t}) = \Gamma_x + \kappa_t^{(1)} + |_t^{(2)}(x - x_{\text{center}}) + |_t^{(3)}(x_{\text{young}} - x)^+$
  $$+ |_t^{(4)}(x - x_{\text{old}})^+ + x_{t-x}$$

Historical and future life expectancy of UK males

Corresponding $|_t^{(1)}$ values for UK males

One-year view and ultimate view

- One-year view can be constructed by *(semi-)nested simulations* as follows

life expectancy

historical data

today's best estimates

ultimate view

one-year view

Illustrative example:

90

80

70

T-50   T   T+50   time
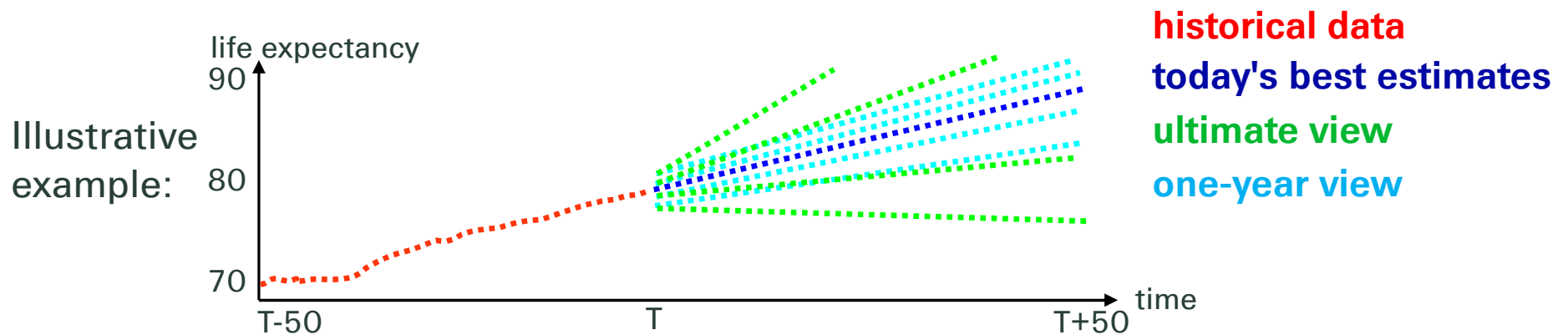
- Run model to determine today's best estimates based on historical mortality rates and to simulate future mortality rates, say, 10000 realizations

- Use each of the 10000 realizations of next year's mortality rates as additional historical data and re-run the model to get 10000 best-estimate mortality rates

- One-year view imposes new challenges, e.g. fast algorithms to estimate and re-estimate parameters, consistency between one-year and ultimate view required

Multi-population model

- Two step approach

  1. Model mortality trend of the total population (blue line)

  2. For each population the difference to the mortality trend of the total population is modeled (main ingredient is to model differences of $\big|_t^{(1)}$ as AR(1) process)
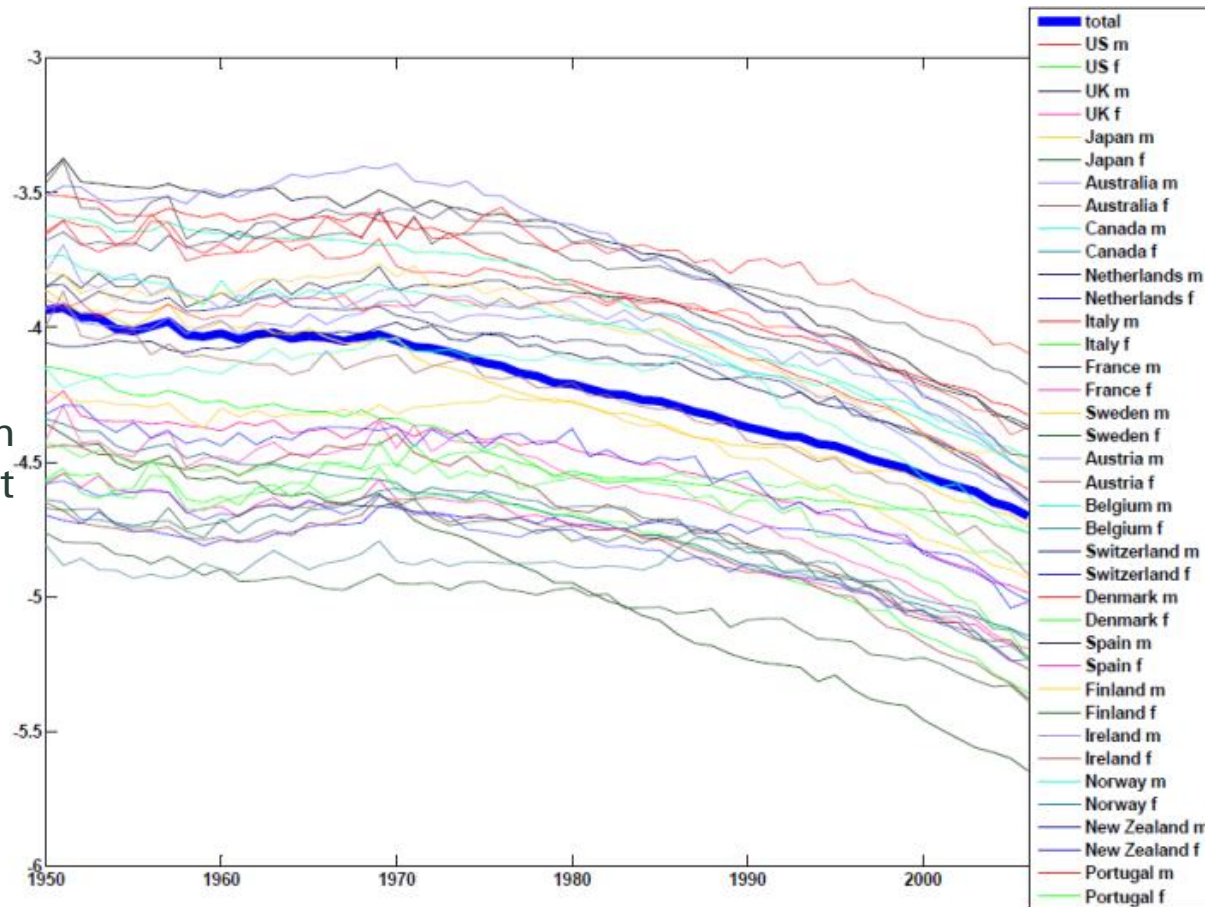
Summary

- Focus on one-year view

- Consistency between one-year and ultimate view

- Calibration of model's ultimate view to historical data

- Fast algorithms allow (semi-)nested simulations

- Multi-population model

- Details can be found in the article "Modeling the Mortality Trend under Modern Solvency Regimes", M. Börger, D. Fleischer, N. Kuksin, ASTIN Bulletin 2014

Deaths $d_{x,t}$ of UK males
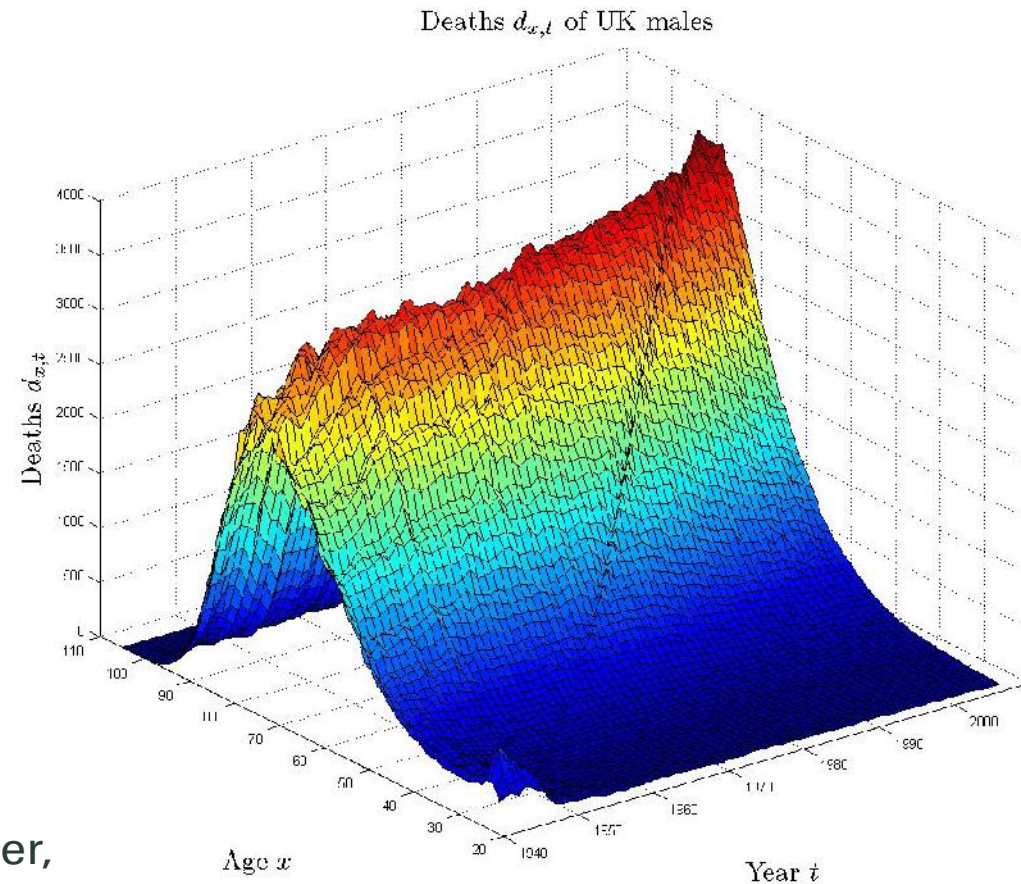
Managing
mortality exposure

Swiss Re

SWISS RE
150
YEARS

Risks are diversified across the Swiss Re Group

Credit 9%

Financial Market 42%

P&C 28%

L&H 21%

USD 20 bn
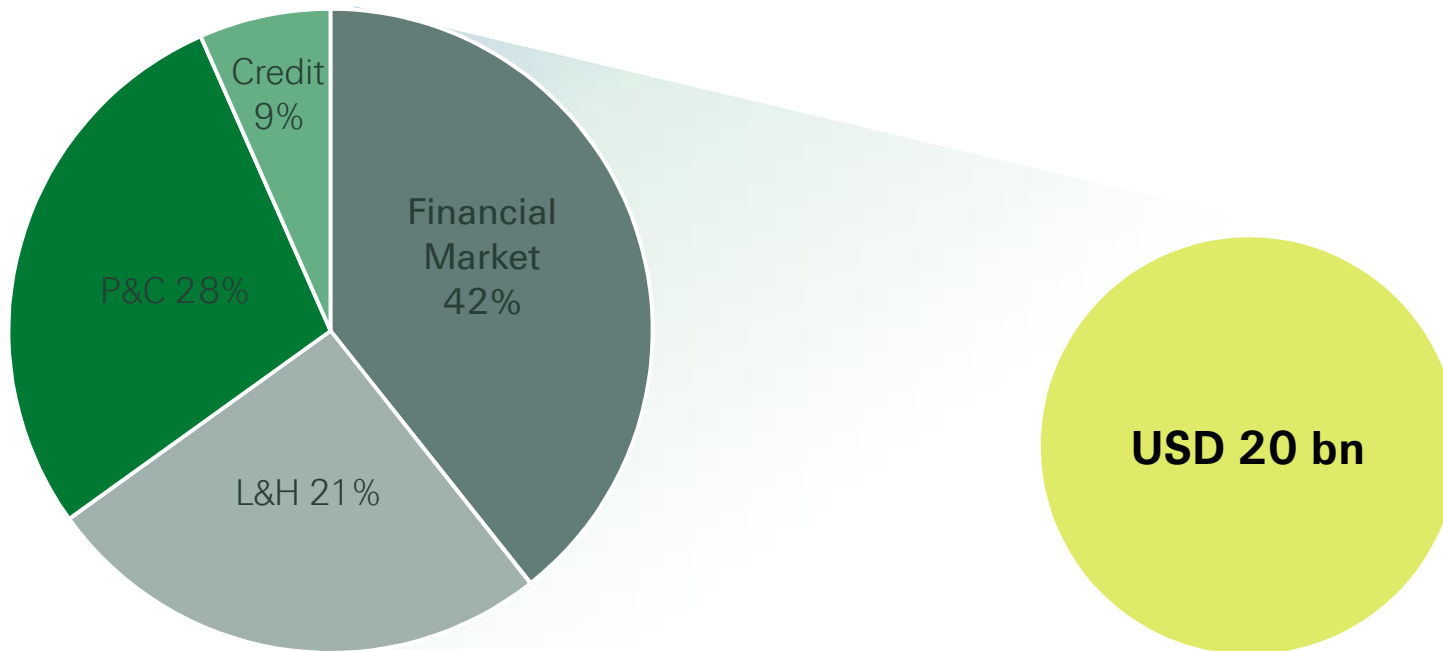
USD 31.9 billion[1]
Standalone 99% shortfall based on 1-year Tail VaR

Diversification

USD 20.0 billion
Group 99% shortfall after **diversification** between risk categories

[1] Simple sum, as of 31.12.2013, prior to diversification; both calculations are based on internal model figures, as disclosed in 2013 annual report

Longevity Risk

Longevity risk provides a hedge against Swiss Re's mortality business. Swiss Re also holds other risks which are not correlated with longevity risk. It is unlikely that several unrelated extreme events will occur at the same time. This reduces the capital that is required for a well diversified reinsurer.

Diversification	Global Reinsurers cover a wide range of non-correlated risks
Opposite Risk	Significant book of mortality business
Consolidation	Reduce risk through the consolidation of lots of portfolios

Large diversified global reinsurers have significant expertise and a strong rationale to write and hold longevity risks

External retrocession and ILS

- Swiss Re uses retrocession to other reinsurers to managed the risk exposure in the life and health book. (More generally insurance companies are reinsuring their own exposures to manage their mortality risks).

- In addition, Insurance-linked securities (ILS) are a key part of Swiss Re's overall strategy to reduce "peak" risk exposures.

- Extreme mortality events such as pandemic influenza and terrorism events in the U.S, Canada or Australia are some of Swiss Re's "peak" perils. Hedging these risks in the capital markets is an important tool for Swiss Re in managing its risk capital efficiently.

- We have developed capabilities in risk assessment, structuring, transformation, and distribution that enable us to transfer life insurance risks to the capital markets to complement our traditional retrocession instruments.

- Since pioneering the securitization of extreme mortality risk in 2003, Swiss Re has regularly issued ILS, such as VITA bonds, to transfer risk to the capital markets.

Causal Mortality Model

Visions of the future

GENES

INDIVIDUAL BEHAVIOUR

HEALTHCARE

CONNECTIVITY

Developing predictive models of longevity
Integrated Risk factors and Impairment Scenarios

- Complementary approach to
  - stochastic mortality models
  - blending between current mortality improvements and long-term assumptions over defined horizons

- Bringing together:
  - Swiss Re experience (data and expert knowledge)
  - Large patient medical databases in different countries
  - External networks capturing expert opinion

- Causal-based mortality predictions, evaluating factors such as:
  - Promotion and adoption of healthy lifestyle choices
  - Advances in screening and diagnostic technology
  - Pharmaceutical pipeline and its likely impact

Deep analysis of mortality experience
Patient medical data (GPRD) mortality split by duration and calendar year since heart attack (MI)

A/E against GAD (population table) by MI event year and duration

Swiss Re
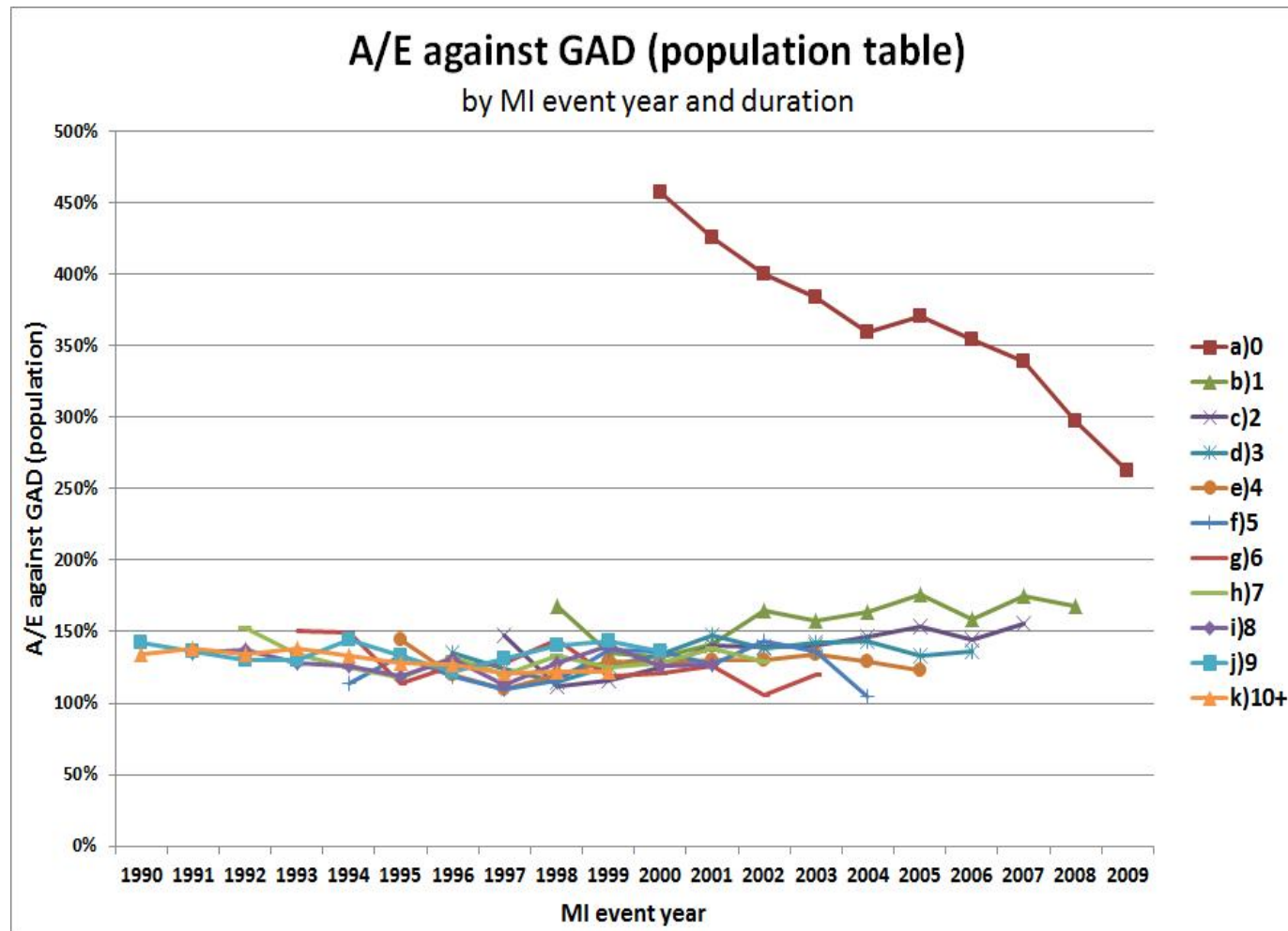
Advances in DNA sequencing

Sanger (capillary) sequencing

Next generation sequencing

Cancer Genomics

AML
Melanoma
Small-cell lung
Breast
Lung (NSCLC)
Hepatocellular
Myeloma
CLL
Mouse AML

2000	**2005**	**2008**	**2010**		**2015**
~10 years	~3 years	~4 months	~1month		? ~1day
~$ 3.5 billion	~$ 20million	~$ 1.5million	$9,500 (Illumina)		?? $100
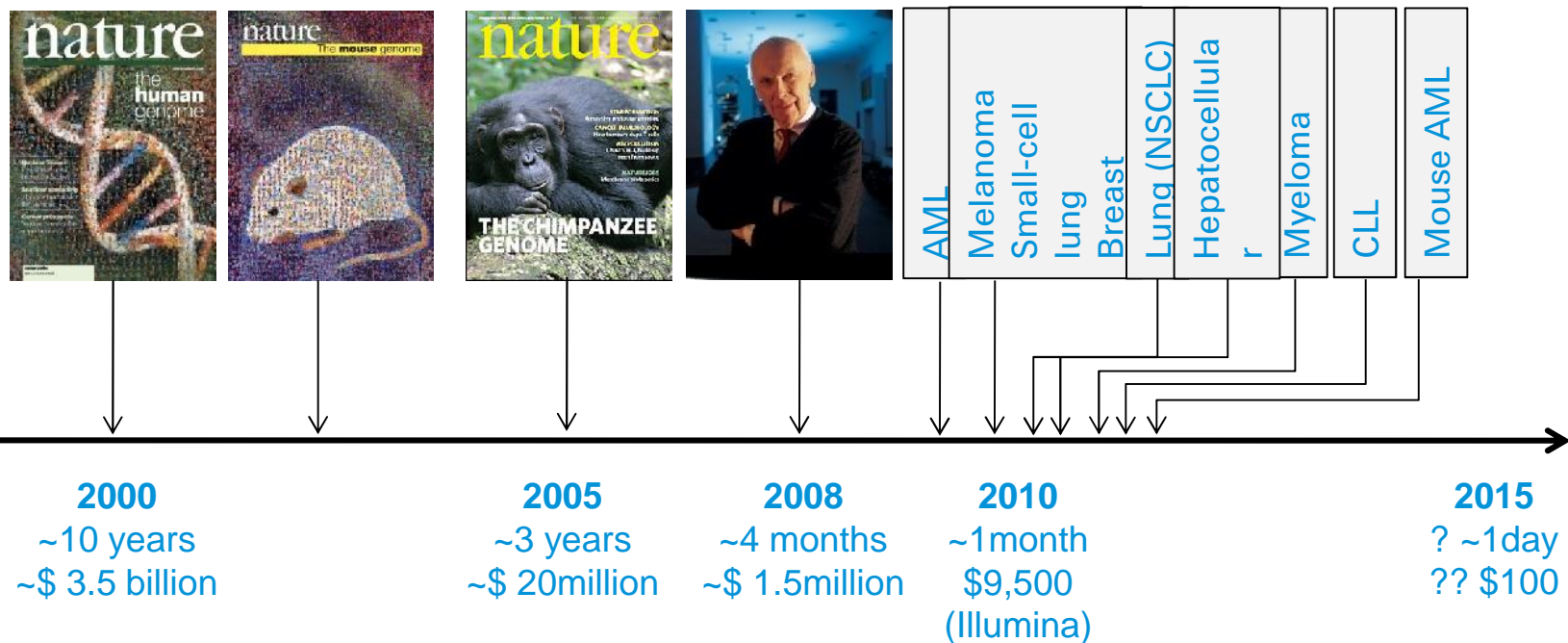
IRIS – multi-state model of mortality
Global and disease-specific factors to consider

General drivers to diagnosis and survival

Individual risk factors
Age, gender, diet, smoking – smoking considerations:
- Taxes and restrictions
- Current treatments (buproprion)
- Future treatments (vaccines)

Healthcare funding
- Public vs private funding
- Disease-based patient advocacy groups' influence
- Allocation of resources towards cure vs prevention

Patient interaction
- Health awareness
- Trust and confidence in advice given
- Use of clinical guidelines to improve quality of care

Research & development
- Public vs commercial sponsors
- Regulators' attitude to developments
- **Disease**-focused approach vs global impact of ageing

Disease types and disease progression

Circulatory
Stroke, angina, heart attack

Respiratory
Chronic obstructive pulmonary disease

Multiple diseases

Healthy

Death

Cancer
Lung, colorectal prostate breast

Neurological
Dementia, Alzheimer's, Parkinson's

Current approaches
- Targeting DCIS
- Surgery with node follow-up
- Adjuvant radiotherapy
- Herceptin, Tamoxifen

Factors involved in assessing specific example disease

Risk factors
- Family history
- Obesity
- Having children later in life
- Not breast feeding

Breast cancer

Early detection
- Digital mammography
- MRI for high-risk
- Gail algorithm (own factors)
- Klaus algorithm (family history)

Medical innovations
- Growth factor inhibition
- Future of personalised medicine (eg tumour profiling)

Clinical trials pipeline
- Phase II (230 trials*)
- Phase III (56)
- eg pertuzumab (limits cancer growth)

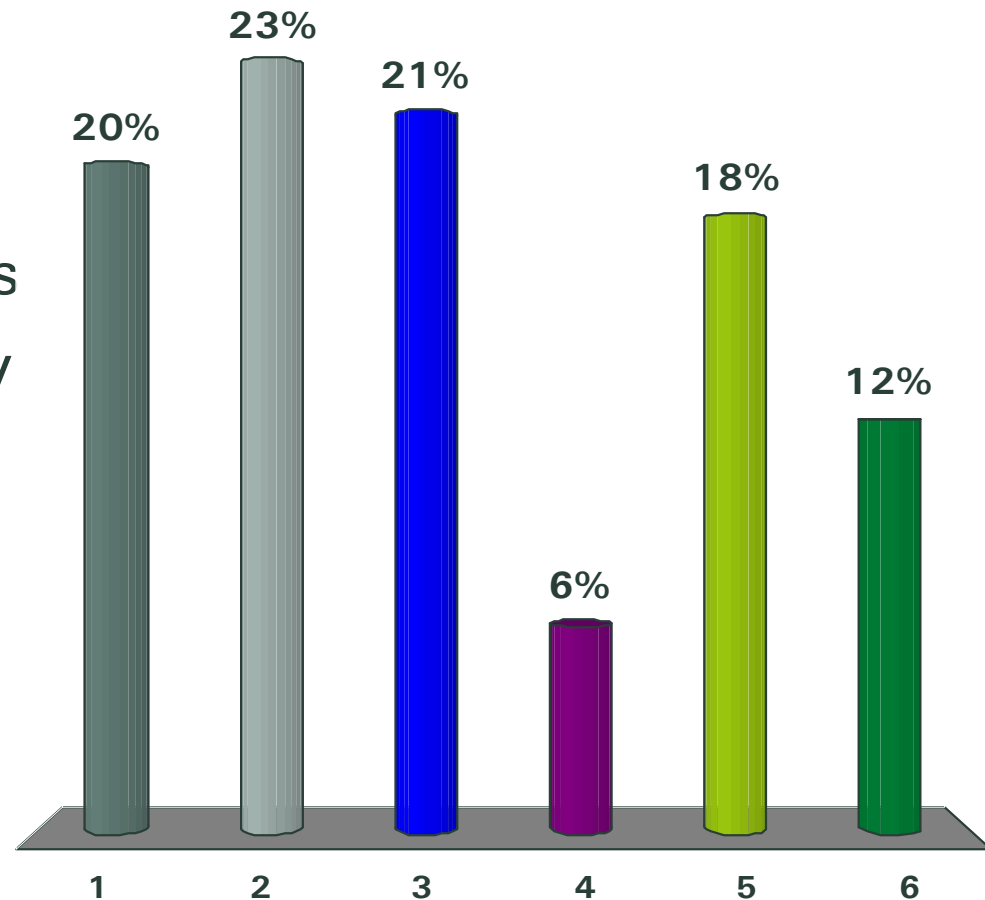# Output from scenario testing in IRIS
Distribution of health/disease across age groups in 20 years

LUCID

Expert opinion from Swiss Re conferences
Which will have the highest impact on future longevity?

1. Stem cell therapy

2. Genetic testing

3. Vaccines

4. Monoclonal antibodies

5. Monitoring technology

6. Nanomedicine

Legal notice

Thank you