LONGEVITY BONDS AND MORTALITY-LINKED SECURITIES

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The Problem

Nothing is certain in life except death and taxes.

(1789: Franklin)

2005: What we know as the facts:

- Death is still a certainty!
- Life expectancy is increasing.
- Future development of life expectancy is uncertain.

"Longevity risk"

The Problem

Pension Plans:

- Before 2000:
  - High equity returns masked impact of longevity improvements
- After 2000:
  - Poor equity returns, low interest rates
  - Decades of longevity improvements now a problem

The Problem

Life Insurers:

- Annuity providers:
  - Risk due to *unanticipated* changes in mortality.
- Equitable Life (and others): GAO's

  Guaranteed Annuity Option: becomes valuable if
  - interest rates fall
  - mortality rates fall

The Problem

Life insurers and pension plans can either:

A: bear the longevity risk; or

B: OTC transfer of longevity risk to alternative agencies;

or

C: transfer longevity risk to financial markets.

PLAN FOR TALK

- The problem
- Background:
  - Who?
  - How much money?
  - How much risk?
- Longevity bonds and mortality-linked securities
- Design issues

BACKGROUND

Life insurers and pension funds exposed to many risks

A: investment risk

B: interest-rate risk

C: longevity risk

D: others

A, B $\longrightarrow$ can hedge to reduce risk; C?

Who is exposed to longevity risk?

UK insurers, annuity liabilities:

Company	Liabilities (GBP billions)		
	Annuities	Total long term	
Prudential	3.2	100.3	
Legal and General	11.0	33.0	
Norwich Union	11.5	124.7	(Aviva)

UK employers: salary/service-linked pension liabilities

Company	D.B. Pension Liability	Market Cap (GBP Billions)
Aviva (incl. N.U.)	7.2	14.6
British Airways	11.4	3.0
Lloyds TSB	13.7	25.6
British Aerospace	14.4	8.6

What is Stochastic mortality?

n lives, probability p of survival, N survivors

- Unsystematic mortality risk:

  $\Rightarrow N|p \sim$ Binomial(n, p)

  $\Rightarrow$ risk is diversifiable, $N/n \longrightarrow p$ as $n \to \infty$

- Systematic mortality risk:

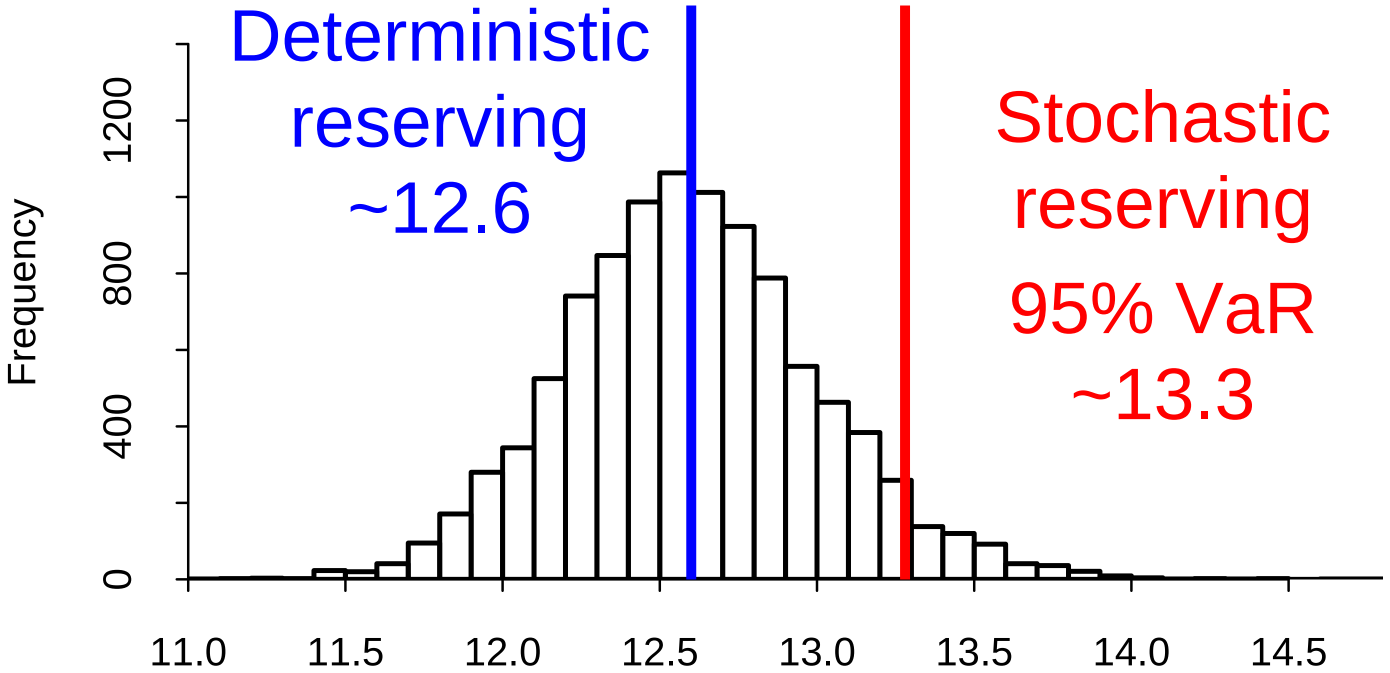
  $\Rightarrow p$ is uncertain

  $\Rightarrow$ risk associated with p is not diversifiable

Statistically: how significant is systematic mortality risk?

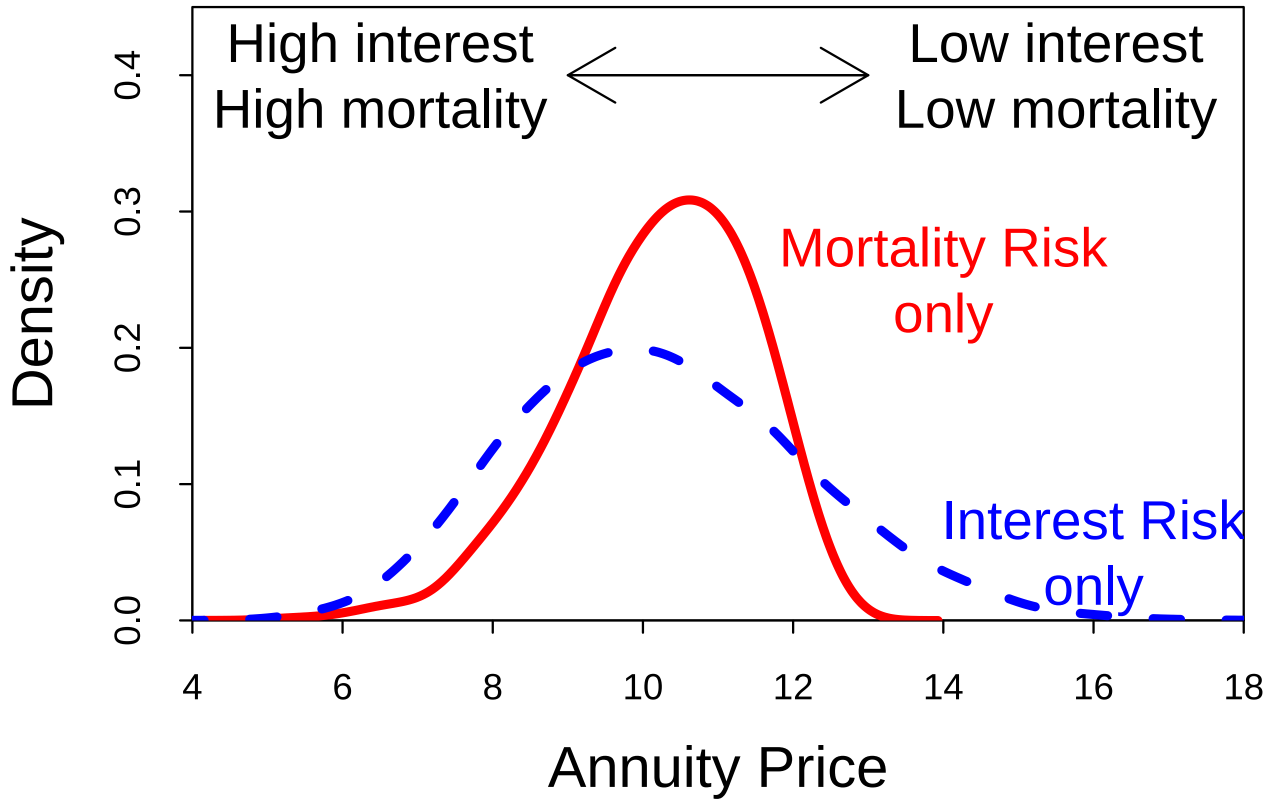
Risk to annuity provider:

How much systematic risk is there in a portfolio of annuities to a cohort now age 65?



Risk to individuals and pension plans

Male – Now age 35 – Annuity purchase in 30 years



Mortality accounts for $\sim$ 25% of total risk

HEDGING LONGEVITY RISK

How to reduce risk:

A: balanced portfolio of term assurance and annuity business

B: change design of policies to reduce risk

C: mortality-linked securities

MORTALITY-LINKED SECURITIES

- Long-term longevity bonds (EIB/BNP, Nov. 2004)

  cashflows linked to survivorship index

- Short-term catastrophe bonds (Swiss Re, Dec. 2003)

- Survivor swaps (some OTC contracts)

  swap fixed for floating mortality-linked cashflows

- Annuity futures

  traded contract; underlying=market annuity rates; many exercise dates

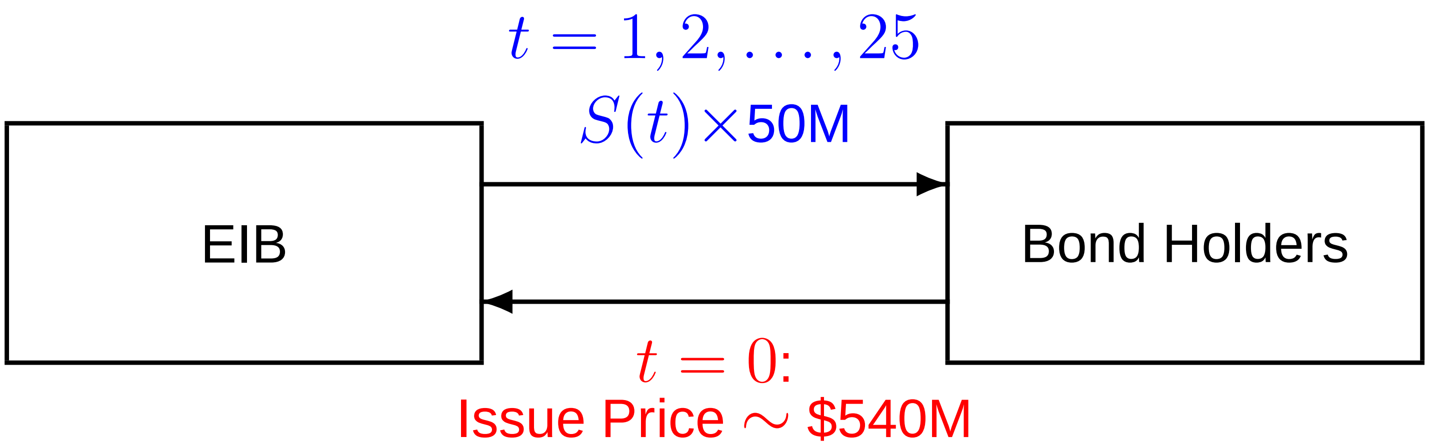
November 2004: EIB/BNP Paribas longevity bond

- Payments linked to survivor index $S(t)$
- $S(t) =$ proportion of cohort age 65 at time 0 surviving to time t.
- Bond pays 50M$\times S(t)$ at time t
- Reference population: England and Wales, males
- Issuer$=$European Investment Bank
- Structurer and Manager$=$BNP Paribas

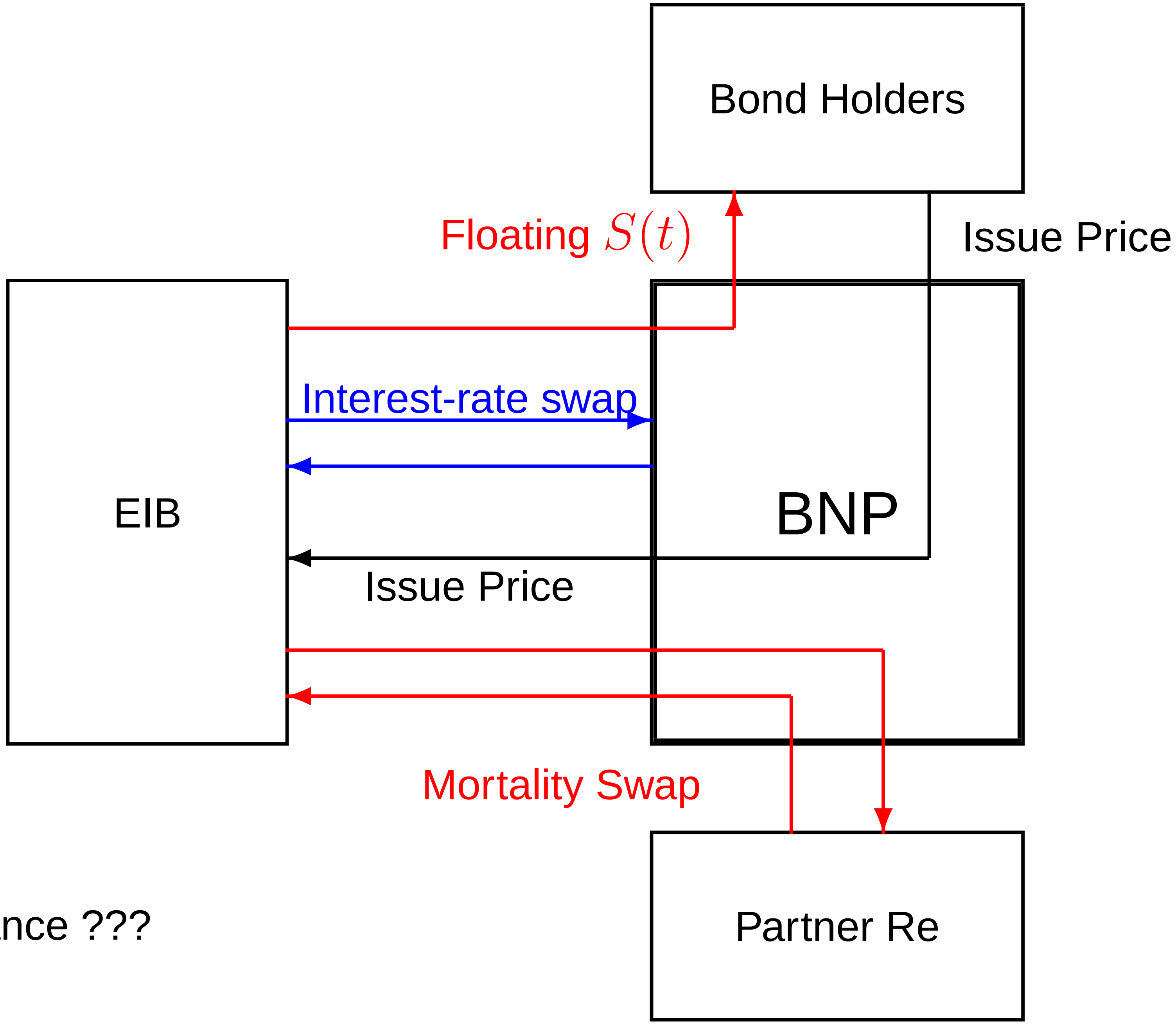
BNP Paribas / EIB Bond

European Investment Bank $=$ Issuer

BNP Paribas $=$ Manager and Structurer

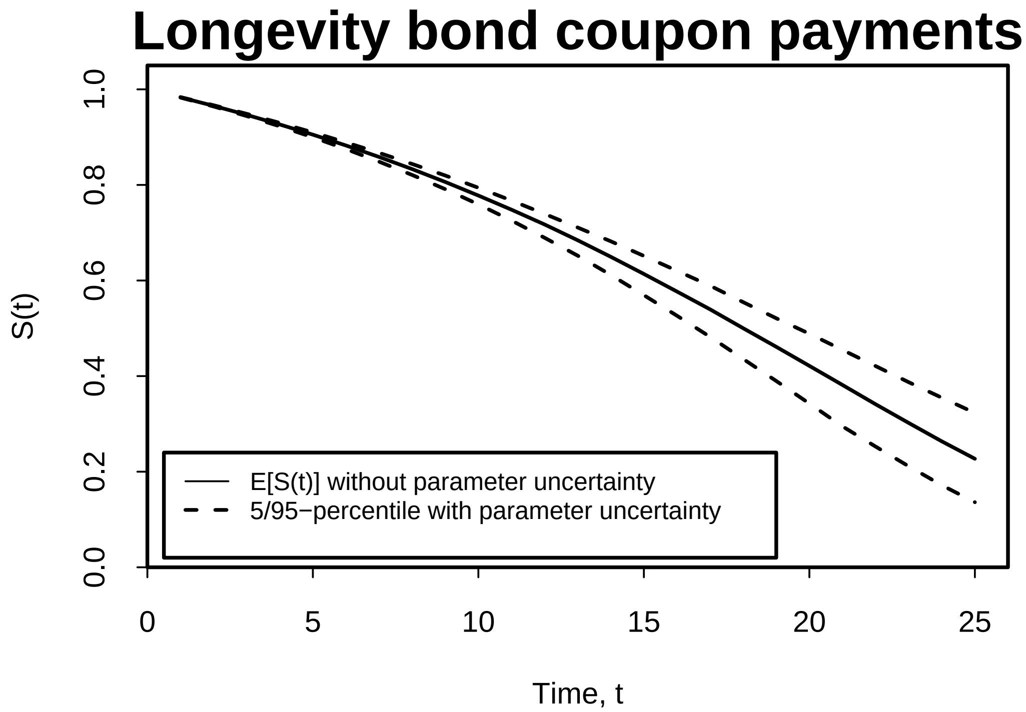


$$S(t) \;=\; \text{proportion still alive at } t \text{ out of males aged 65 in 2003}$$



+ Credit Insurance ???

Aims:



- How do we price the EIB/BNP longevity bond?
- How can we price future longevity bonds in a consistent fashion? (i.e. arbitrage-free)

Basic idea

$$\text{price} = P(0,1)E_Q[S(1)] + P(0,2)E_Q[S(2)] + \ldots$$
$$\ldots + P(0,25)E_Q[S(25)]$$
$$P(0,T) = \text{EIB discount factor}$$
$$E_Q[S(T)] = \text{risk-adjusted expected cashflow}$$

We need:

- A stochastic mortality model
- A method for determining Q

Possible criteria for stochastic mortality models

- Positive mortality rates at *all times* and *all ages*
- Model consistent with historical data
- Future dynamics should be *biologically* reasonable
- Complexity of model appropriate for task in hand
- Model allows fast numerical computation
- Avoid mean reversion

Mortality-linked securities: Issues

- Buyers and sellers
- Reference population
- Liquidity
- Basis risk
- Credit risk

Traded securities

- Examples:

  Swiss-Re mortality bond; EIB/BNP longevity bond

- Liquidity is essential

- Low credit risk is essential for hedgers

Traded securities: investors

- Hedgers: life offices, pension funds
- Counterparties:
  - Speculators: e.g. hedge funds

    low correlation with financial markets
- Government: could issue longevity bonds to help reduce pension fund longevity risk
- Private issuers naturally short on longevity risk: pharamaceutical companies; long-term care homes

Traded securities: liquidity

- Reference population:
  - Reliable, public source
  - Low moral hazard
- Attractive contract design
  - Useful for hedging
  - Pure insurance risk
  - Transparent
  - Easy to assess the risks and potential returns

Traded securities: basis risk

Basis Risk $\Rightarrow$

mismatch between reference population and own risk

Examples:

- different population characteristics
- different age profile
- males/females

Traded securities: basis risk

Single, reliable reference population

$\Rightarrow$ high basis risk for many hedgers

$\Rightarrow$ security not worth holding

$\Rightarrow$ low demand

$\Rightarrow$ low liquidity

Traded securities: basis risk

Several reference populations

$\Rightarrow$ low basis risk for hedgers

BUT too many reference populations

$\Rightarrow$ poor transparancy or reliability

$\Rightarrow$ low liquidity

Tradeoff required to get the right balance

Traded securities: basis risk

How to achieve low basis risk and liquidity?

e.g. Swiss Re mortality bond, December 2003

- 3-year Catastrophe bond
- Transparent reference populations
- Reference index tailored to Swiss Re portfolio of risk
- Low moral hazard
- Low basis risk for Swiss Re
- generous risk premium!

Conclusions

- Life insurers and pension plans are exposed to significant systematic longevity risk
- Options:
  - bear the risk internally
  - transfer the risk to the financial markets
- Life Insurance and Pensions liabilities are huge

  ($ Trillions)
- Potential huge demand for mortality-linked securities

Conclusions

- Challenge for the future:

  to develop a substantial, liquid market in mortality-linked securities

  $\Rightarrow$ need to design products that are attractive for both buyers and sellers

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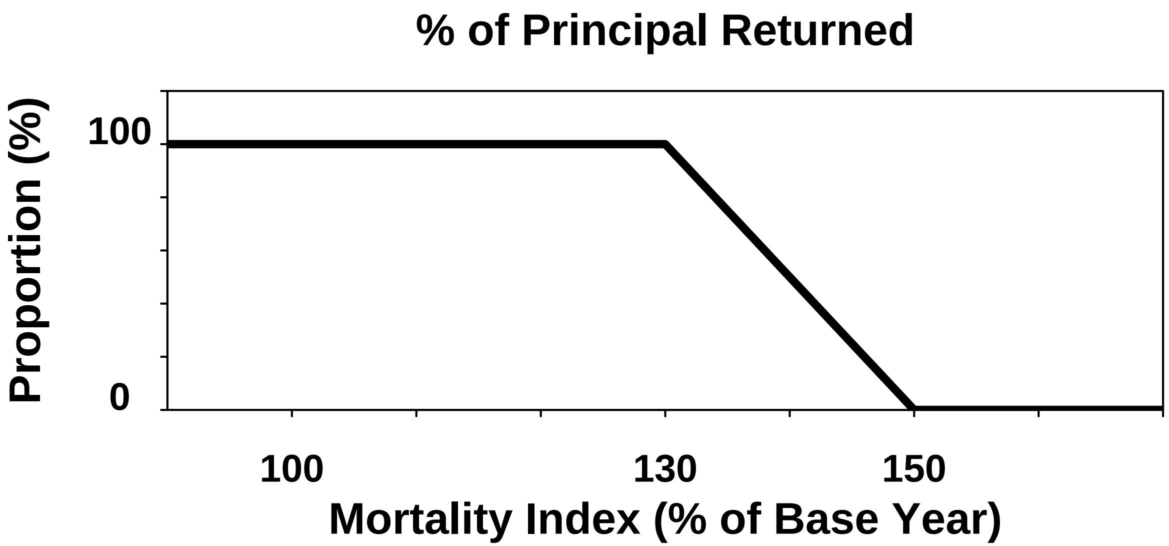
OTC contracts

- e.g. Mortality Swap:
  - e.g. life office pays fixed rate, receives floating to hedge longevity risk
- Tailored to mortality risk of hedger ($\Rightarrow$ no basis risk)
- OTC $\Rightarrow$ could be expensive for life office
- No need for liquidity
- counterparty credit risk

Swiss Re Mortality Bond

- Catastrophe bond
- 3-years duration to 1 January 2007
- Hedges exposure to catastrophic mortality events
  - severe outbreak of influenza
  - major terrorist attack (WMD)
  - natural disaster
- Principal $= \$400M$
- Quarterly coupon: 3-M USD LIBOR + 135bp

- Mortality index weighted by: Country; Age; Sex
- Index tailored to Swiss Re exposure
- Principal at risk if mortality index $> 130\%$ of base
- Principal exhausted if mortality index $> 150\%$ of base



Analogy between mortality and interest rates

1: Deterministic interest and mortality (no improvements)

Force of mortality	Force of interest
μ_{x+t}	$r(t)$
${}_tp_x = \exp\left(-\int_0^t \mu_{x+s}ds\right)$	$P(0,t) = \exp\left(-\int_0^t r(s)ds\right)$
SCOR (Survivor Credit Offer Rate) $\frac{q_x}{p_x} = \frac{1-p_x}{p_x}$	LIBOR $\frac{1-P(0,1)}{P(0,1)}$

Analogy between mortality and interest rates

2: Stochastic interest and mortality

$x =$ age at time 0

$\mu(t,x)$	$r(t)$
$p(0,t,x) = E_{?}\left[\exp\left(-\int_0^t \mu(s,x)ds\right)\right]$	$P(0,t) = E_{Q}\left[\exp\left(-\int_0^t r(s)ds\right)\right]$
Forward SCOR	Forward LIBOR

$E_{?}$: Choice of measure depends on application.

Alternative form of securitization

Special Purpose Vehicle

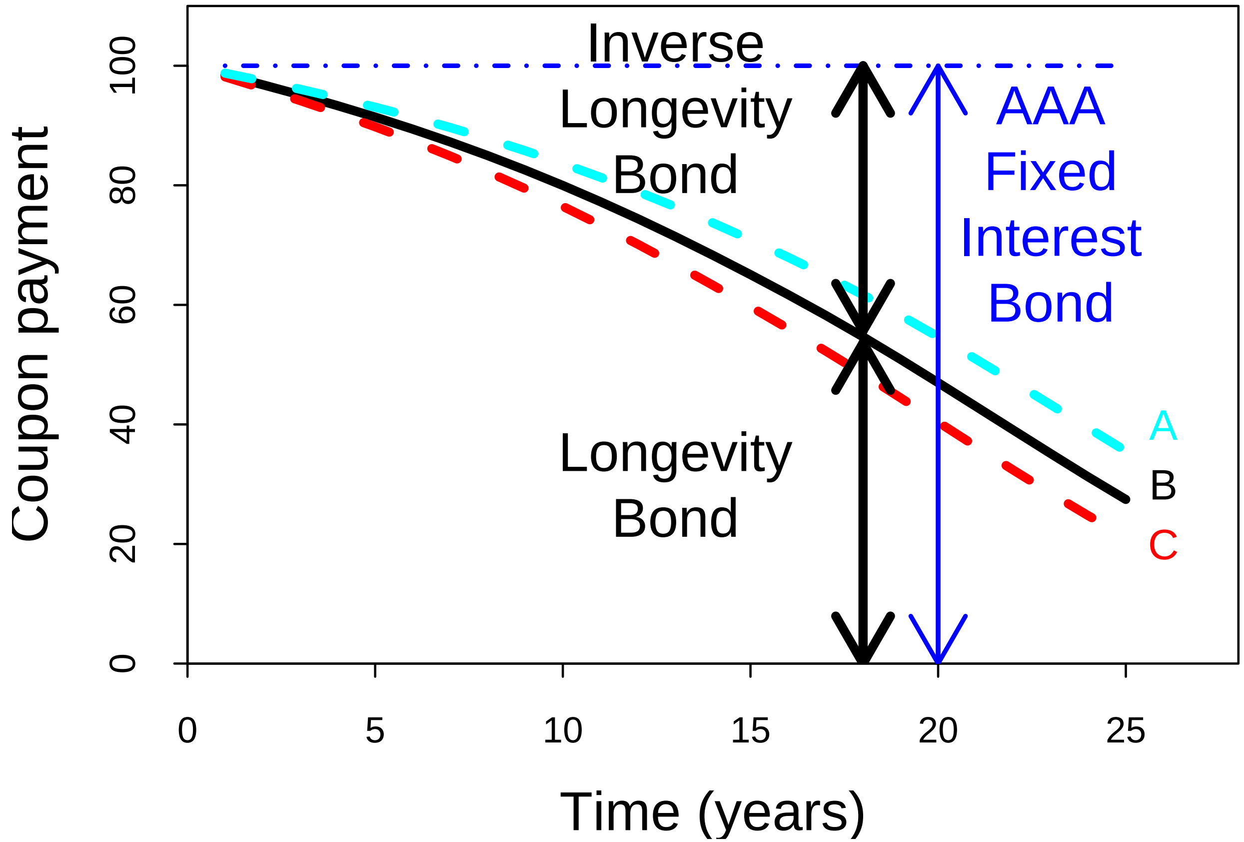
- invests in AAA bonds
- like a CDO:

"senior debt" = longevity bond (LB)

"equity" = inverse longevity bond (ILB)

- fixed cashflow to SPV: C at $t = 1, 2, \ldots, 25$

C split between LB and ILB holders



A, B, C = different outcomes

Challenge: make the long-term ILB appeal to short-term speculators

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