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 → can hedge to reduce risk; C?
Who is exposed to longevity risk?

UK insurers, annuity liabilities:

<table>
<thead>
<tr>
<th>Company</th>
<th>Liabilities (GBP billions)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annuities</td>
<td>Total long term</td>
</tr>
<tr>
<td>Prudential</td>
<td>3.2</td>
<td>100.3</td>
</tr>
<tr>
<td>Legal and General</td>
<td>11.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Norwich Union</td>
<td>11.5</td>
<td>124.7 (Aviva)</td>
</tr>
</tbody>
</table>
## UK employers: salary/service-linked pension liabilities

<table>
<thead>
<tr>
<th>Company</th>
<th>D.B. Pension Liability</th>
<th>Market Cap (GBP Billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviva (incl. N.U.)</td>
<td>7.2</td>
<td>14.6</td>
</tr>
<tr>
<td>British Airways</td>
<td>11.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Lloyds TSB</td>
<td>13.7</td>
<td>25.6</td>
</tr>
<tr>
<td>British Aerospace</td>
<td>14.4</td>
<td>8.6</td>
</tr>
</tbody>
</table>
What is Stochastic mortality?

- **Unsystematic mortality risk:**
  - $\frac{N}{n} \to p$ as $n \to \infty$

- **Systematic mortality risk:**
  - $p$ is uncertain

$n$ lives, probability $p$ of survival, $N$ survivors
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?

![Frequency distribution graph]

- **Deterministic reserving**: ~12.6
- **95% VaR**: ~13.3

Stochastic reserving
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

\[ t = 1, 2, \ldots, 25 \]

\[ S(t) \times 50M \]

\[ t = 0: \]

Issue Price \( \sim \) $540M

\[ S(t) = \text{proportion still alive at } t \text{ out of} \]

males aged 65 in 2003
EIB

Interest-rate swap

Floating $S(t)$

Issue Price

Bond Holders

Issue Price

Mortality Swap

Partner Re

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:
  pharmaceutica 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 ⇒
mismatch between reference population and own risk

Examples:

• different population characteristics
• different age profile
• males/females
Traded securities: basis risk

Single, reliable reference population

⇒ high basis risk for many hedgers

⇒ security not worth holding

⇒ low demand

⇒ low liquidity
Traded securities: basis risk

Several reference populations
⇒ low basis risk for hedgers

BUT too many reference populations
⇒ poor transparency or reliability
⇒ 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*

⇒ 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 (⇒ no basis risk)

- OTC ⇒ 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)

<table>
<thead>
<tr>
<th>Force of mortality</th>
<th>Force of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_{x+t}$</td>
<td>$r(t)$</td>
</tr>
<tr>
<td>$tp_x = \exp \left( - \int_0^t \mu_{x+s} ds \right)$</td>
<td>$P(0, t) = \exp \left( - \int_0^t r(s) ds \right)$</td>
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**SCOR**
(Survivor Credit Offer Rate)

| $\frac{q_x}{p_x} = \frac{1-p_x}{p_x}$ | $\frac{1-P(0,1)}{P(0,1)}$ |

**LIBOR**
Analogy between mortality and interest rates

2: Stochastic interest and mortality

\( x = \text{age at time 0} \)

\[
\begin{array}{c|c}
\mu(t, x) & r(t) \\
\hline
p(0, t, x) = & P(0, t) = \\
E_? \left[ \exp \left( - \int_0^t \mu(s, x) \, ds \right) \right] & E_Q \left[ \exp \left( - \int_0^t r(s) \, ds \right) \right] \\
\text{Forward SCOR} & \text{Forward LIBOR} \\
\end{array}
\]

\( E_? \): 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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