New Developments in Longevity Risk Transfer Market – Assessing Basis Risk for Longevity Transactions

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Assessing Basis Risk for Longevity Transactions – Phase 2

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The Impact of Model Uncertainty on Index-based Longevity Hedging

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Longevity Risk

- continual decline in mortality is a global phenomenon
- improved nutrition, hygiene, medical technology, health care, lifestyle are contributing factors
- there exists longevity risk that pension funds / annuity portfolios may pay out more than expected
- systematic longevity risk cannot be diversified by pooling
- insurance companies / governments are cautious about taking too much longevity risk
Managing Longevity Risk

- *traditional reinsurance* allows insurers to transfer longevity risk to reinsurers, but reinsurers often have limited appetite.
- *natural hedging* exploits the opposite movements between the values of annuities and life insurances, but it is feasible only for certain large insurance companies.
- *capital market solutions* are recently proposed and tested, such as insurance securitisation, longevity-linked / mortality-linked securities / derivatives.
- Market investors may be interested to diversify across an arguably uncorrelated market sector.
Life Market

- Life and Longevity Markets Association (LLMA) was established in 2010 in UK
- members include several global insurers, investment banks
- LLMA promotes the development of a liquid ‘life market’
- longevity-linked / mortality-linked securities / liabilities could readily be traded amongst insurers, reinsurers, investors
- it is still in its infancy stage, far from reaching its full potential in providing diversification opportunities, enhancing market efficiency
Trading Volumes from 2007 to 2015 in UK
Capital Market Solutions

- *bespoke transactions* are tailored to individual circumstances, such as pension buy-ins, buy-outs, longevity swaps.
- *index-based solutions* are constructed such that cashflows are linked to selected mortality indices.
- *standardised products* based on well-specified mortality indices could draw investors’ interest and develop market liquidity.
- One notable example is €12bn longevity swap offered by Deutsche Bank to Dutch insurer Aegon in 2012, in which Dutch population was taken as an index and entire trade was targeted at capital market investors.
Index-based Longevity Hedging

• index-based hedges have considerable potential to provide effective risk / capital management
• e.g. longevity bond, \( q \)-forward, longevity swap, mortality option, which are linked to the mortality of a reference population
• there is mismatch between the reference population and the portfolio to be hedged (book population)
• longevity basis risk includes demographic basis risk, sampling basis risk, structural basis risk
• difficulty in quantifying this risk is perceived to be one major obstacle to more widespread use of index-based hedges
Longevity Basis Risk

Pension Fund

Hedging Instrument

Book Population

Reference Population
Modelling Demographic Basis Risk

- Demographic risk
  - Lee-Carter family
  - Li and Lee family
  - CBD family
- Process error
  - Time series modelling
- Parameter error
  - Residuals / semi-parametric bootstrapping
- Model error
  - Comparison between models; modified bootstrapping
CAE+Cohorts Model

\[
\text{logit } q_{x,t}^R = \alpha_x^R + \beta_x^R \kappa_t^R + \gamma_{t-x}^R
\]

\[
\text{logit } q_{x,t}^B - \text{logit } q_{x,t}^R = \alpha_x^B + \beta_x^B \kappa_t^B
\]
Li-Lee Model

\[
\text{logit } m_{x,t}^R = \alpha_x^R + \beta_x^c \kappa_t^c + \sum_j \beta_{x,j}^R \kappa_{t,j}^R + \gamma_{t-x}^R
\]

\[
\text{logit } m_{x,t}^B = \alpha_x^B + \beta_x^c \kappa_t^c + \sum_j \beta_{x,j}^B \kappa_{t,j}^B + \gamma_{t-x}^B
\]
M7-M5 Model

\[ \logit q^R_{x,t} = \kappa^R_{t,1} + (x - \bar{x}) \kappa^R_{t,2} + ((x - \bar{x})^2 - \sigma_x^2) \kappa^R_{t,3} + \gamma^R_{t-x} \]

\[ \logit q^B_{x,t} - \logit q^R_{x,t} = \kappa^B_{t,1} + (x - \bar{x}) \kappa^B_{t,2} \]
Characterisation Approach

Book Data

- B1
- B2
- B3

- Proxy Group 1
- Proxy Group 2
- Proxy Group 3
Modelling Longevity Basis Risk

- Longevity basis risk
  - Demographic basis risk
  - Sampling basis risk
  - Structural basis risk
  - Process error
  - Parameter error
  - Model error

- M7-M5 model / CAE+Cohorts
  - Model / characterisation approach
  - + time series processes
  - + residuals bootstrapping

- Comparison between different models and assumptions

- Binomial distribution for different portfolio sizes

- Numerical optimisation / mortality duration matching for risk minimisation
Data Sources

Continuous Mortality Investigation

The Human Mortality Database

Vladimir Shkolnikov, Director
Magali Barbieri, Associate Director
John Wilmoth, Founding Director

Max Planck Institute for Demographic Research
University of California, Berkeley and INED, Paris
United Nations and formerly University of California, Berkeley
Index-based Hedging – Hypothetical Example

- all pensioners / annuitants aged 65 now
- $1 p.a. on survival from 66 to 90
- pension plan / annuity portfolio closed
- hedged by 25-year index-based longevity swap
- calibration based on simulated scenarios
- flat interest rate 1% p.a.
Index-Based Longevity Swap

how significantly are these two sets of cash flows related?

book experience

reference experience

Pensioners / Annuitants

Pension Fund / Annuity Portfolio

counterparty

fixed payments

index-based swap
Future Book vs Reference Mortality Rates

black – book cohort aged 65 now
grey – reference cohort aged 65 now

[solid lines : best estimates
dashed lines : simulated values]
Hedge Effectiveness

CMI Dataset
- unhedged
- hedged

total present value

ONS Dataset
- unhedged
- hedged

Mercer Australia Dataset
- unhedged
- hedged

total present value
Risk Metric

$$\text{longevity risk reduction} = \left(1 - \frac{\text{risk(hedged)}}{\text{risk(unhedged)}}\right) \times 100\%$$
Maximum Longevity Risk Reduction

risk reduction = 50% - 80%

We have some sampling basis risk...

risk reduction < 50%

We have a lot of sampling basis risk!
Sensitivity Analysis (Settings & Assumptions)

- size of pension plan or annuity portfolio
- assumed coherence property
- data characteristics
- type of hedging instrument
- simulation method
- structural mortality changes
Sensitivity Analysis (Time Series Processes)

- Limited book data length
- Bounded future variability of ‘book minus reference’ component
- Assumed pace of reaching coherence
- Other correlation assumptions
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the plan have 20,000+ members?</td>
<td>Yes! Got 50 points.</td>
</tr>
<tr>
<td>Are book and reference very related?</td>
<td>Quite...6 out of 10 I think.</td>
</tr>
<tr>
<td>Is it fast to reach coherence?</td>
<td>Average, say, 5 points.</td>
</tr>
<tr>
<td>Would potential structural changes affect both book and reference the same way?</td>
<td>Maybe...I would give 4.</td>
</tr>
<tr>
<td>It looks like 65% of risk is hedged!</td>
<td></td>
</tr>
</tbody>
</table>
Summary (Rule-of-Thumb)

longevity risk reduction

\[ y = -0.0303 + 0.0644x_1 + 0.0553x_2 - 0.0784x_3 - 0.8120x_4 - 0.1662x_5 \\
+ 0.0006x_6 + 0.0219x_7 + 0.1204x_8 + 0.1217x_9 - 0.0762x_{10} \]

- \( x_1 \): log size
- \( x_2 \): book vs reference
- \( x_3 \): hedging scheme
- \( x_4 \): interest rate
- \( x_5 \): swaps or q-forwards
- \( x_6 \): M7-M5
- \( x_7 \): CAE+Cohorts
- \( x_8 \): simulation method
- \( x_9 \): structural changes
- \( x_{10} \): AR order
Natural Hedging – Hypothetical Example
Li and Haberman (2015)

- life annuity at age 65 vs life insurance at age 35
- $1,400 p.a. on survival vs $100,000 on death
- 100,000 policies between annuity and life insurance
- weight of life policies from 0%, 1%, 2%, ... to 100%
- analysis based on simulated scenarios
- flat interest rate 3% p.a.
Hedge Effectiveness
Maximum Longevity Risk Reduction

We have some sampling basis risk...

risk reduction = 40% - 70%

We have a lot of sampling basis risk!

risk reduction < 40%
Next Step

- further test more data, models, scenarios for potential capital savings
- communicate results with insurers, banks, regulators, clients
- standardise key factors that drive longevity basis risk
- investigate dynamic hedging and market pricing of longevity risk
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