Hedging using longevity-linked securities: Costs, benefits and systemic risks

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Motivation

- Annuity providers may incur significant losses if mortality improves by more than expected
- This is driving the development of new markets of assets with cash-flows linked to the longevity of an underlying population
- In 1970s Black-Scholes option pricing model enabled the growth of new markets in derivative assets
- Over time the market price of options adjusted to reflect volatility of underlying assets and systemic constraints
- E.g. Since 1987, market implied volatility for options of low strike prices are higher than high strike prices
- Similarly market price of longevity derivatives should reflect
  - Volatility of underlying mortality rates
  - Systemic constraints e.g. Solvency Capital Requirements

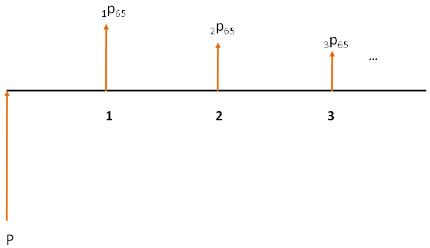
Research Issues

- SCR affect companies' willingness to pay for securitization
- Similarly, capital relief under SCR will affect insurers' willingness to pay for longevity bonds
- Profit-maximizing insurer will only buy a longevity bond for hedging if this is cost-effective
- It is unclear **which hedging strategies are cost-effective under Solvency II framework**
- It is unclear **how cost-effective hedging strategies differ from risk-reducing hedging strategies**

Research questions

- How will a profit-maximizing insurer use LBs?
  - Trade off between the cost of the LB and benefit from holding the LB, which is cost of capital saving
  - Assume decision is made based on PV of all future costs vs. benefits at $t = 0$
- How does the profit-maximizing hedging strategy influence financial and systemic risks?
  - Expected shortfall of reserves to meet annuity payments
  - Insurer's probability of default

The annuity book



- At time $t = 0$ the insurer receives a single premium $P = BEL$
- Each year the insurer must pay out $_tp_{65}$
- Insurer must also maintain SCR under Solvency II

Solvency Capital Reserve

- Insurer holds technical provisions and SCR
- Technical provision = BE Liabilities + Risk Margin i.e. amount insurer needs to immediately transfer its obligations
- SCR is the capital required to ensure 99.5% VaR over 1 year

Model set-up:

- Each year the insurer tops up the technical provisions and holds the SCR
- So the annual cost of maintaining the technical provision is = (Cost of Capital)*(Loss + SCR)
- SCR is ΔNAV from permanent reduction to BE mortality of 20% for all ages

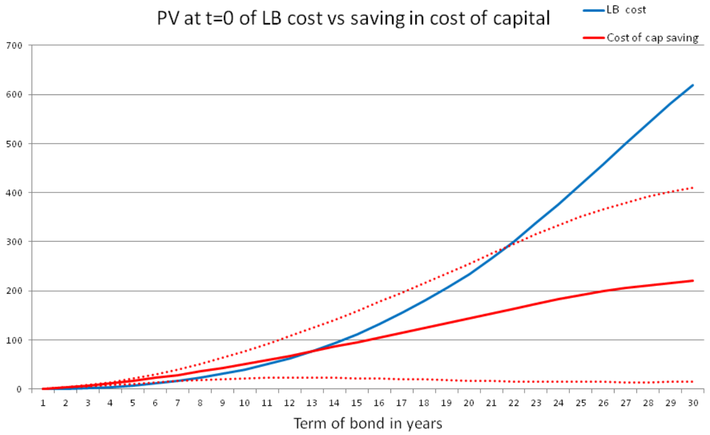
SCR with hedging

- Buying a T year longevity bond changes cash flow

	No hedge	Buy a T year longevity bond
Payments	${}_tp_x$	$E({}_tp_x)$ in years 1 to T ${}_tp_x$ year T+1 on
Loss	${}_tp_x - E({}_tp_x)$	0 in years 1 to T ${}_tp_x - E({}_tp_x)$ from T+1 on
Capital required	$K(t) +_t p_x - E({}_tp_x)$	0 in years 1 to T $K(t) +_t p_x - E({}_tp_x)$ from T+1 on

- Benefit of hedging = cost of capital saving for the T years over which longevity risk is hedged
  - E.g. $6\%(K(t) +_t p_x - E({}_tp_x))$ in years 1 to T
- Minimise cost of capital + cost of hedging (i.e. cost of LB)

Cost-benefit analysis



Pricing the LB

- q-forward exchanges realized mortality rate at some future date, for a fixed mortality rate agreed at inception
- the fixed mortality rate agreed at inception will be forecast mortality rate adjusted for risk premium
- the risk premium and price of longevity derivatives is driven by volatility of the underlying mortality rates σ_x

Pricing the LB

q-forward can be priced using a Sharpe Ratio:

$$q^F_{x,t} = (1 - SR\sigma_x t)E(q_{x,t})$$

Coupon paying LB can be priced using approximation:

$$S_{x,t} = \prod_{i=0}^{t-1}(1 - q^F_{x,i}) - (q_{x,i} - q^F_{x,i})$$

$$\approx \prod_{i=0}^{t-1}(1 - q^F_{x,i}) - \sum_{i=0}^{t-1}(q_{x,i} - q^F_{x,i}) \prod_{j=0,j\neq i}^{t-1}(1 - q^F_{x,j})$$

So hedge $S_{x,t}$ by holding:
$-v^{t-1}\prod_{j=0,j\neq 0}^{t-1}(1 - q^F_{x,j})$ units of the 1-yr q-forward
$-v^{t-2}\prod_{j=0,j\neq 1}^{t-1}(1 - q^F_{x,j})$ units of the 2-yr q-forward
...
$\prod_{j=0,j\neq t-1}^{t-1}(1 - q^F_{x,j})$ units of the t-yr q-forward

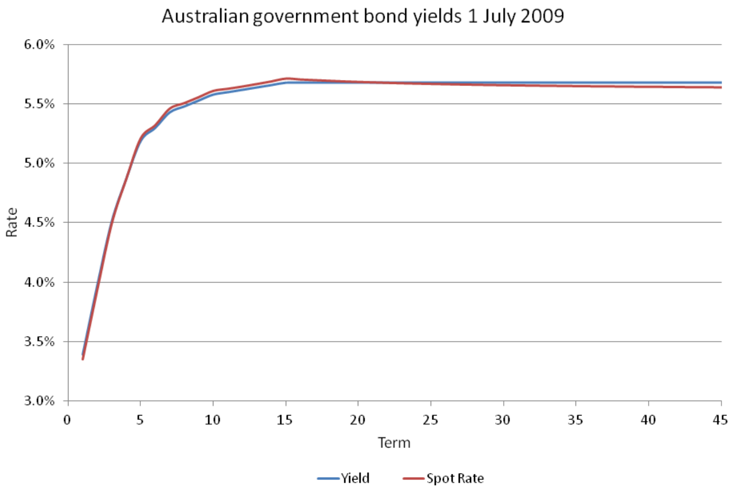
Data and assumptions

- Australian male age 65 purchases life annuity for \$100,000
- Insurer BE basis is 2009 rates rolled forward using improvement factor based on last 25 years
- Annual payment of $\approx \$8,900$ not indexed from EOY 1
- Analysis does not allow for investment risk, basis risk, Solvency IIs counterparty risk requirements or loss of diversification benefits

Other assumptions for pricing:

- Insurer's annual cost of capital is 6% (+)
- No profit loading, tax or frictional costs (+)
- Sharpe ratio of 0.20 (+/-)
- Assume 100% capital relief for hedged position (-)

Discounting



Mortality assumptions

For forecasting insurer's experience:

- Lee-Carter model was fit to Australian mortality rates 1970 to 2009 and used to forecast mortality
- Assume actual experience follows LC forecast

For pricing the LB and hedge:

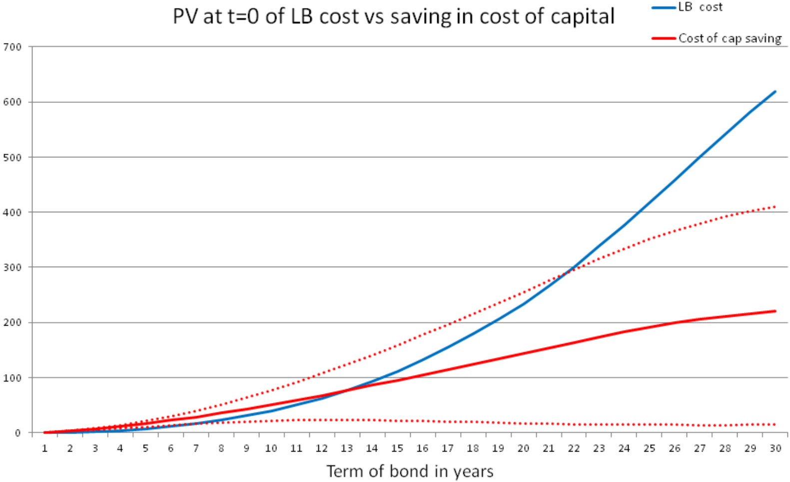
- σ_x calculated as standard deviation of smoothed (5 year rolling average) annual percentage change in $q_{x,t}$
- Also use LLMA (2012) smoothing method to smooth crude rates (cubic spline with 5 year age knots) then calculate σ_x

Sensitivity tests

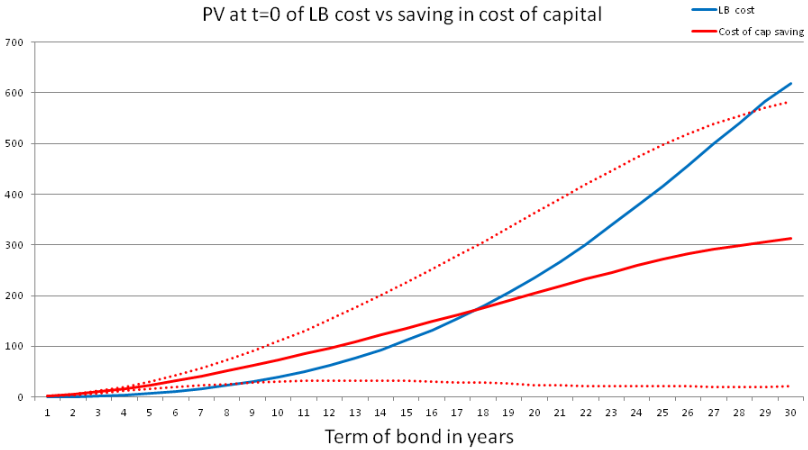
Scenario	1	2	3	4	5	6
Cost of capital	6.0%	**8.5%**	6.0%	6.0%	6.0%	6.0%
Sharpe ratio	0.2	0.2	**0.15**	**0.25**	0.2	0.2
Capital relief	100%	100%	100%	100%	**50%**	100%
Smoothing	5-yr avg	5-yr avg	5-yr avg	5-yr avg	5-yr avg	**Spline**

- Sharpe ratios for LB used in past studies: 0.20 Ngai and Sherris (2010), 0.25 Loeys et al. (2007), ≈0.12 Bauer et al. (2009)
- For smoothing mortality rates, LLMA (2012) uses cubic splines with knots at every 5 years from 0-100+

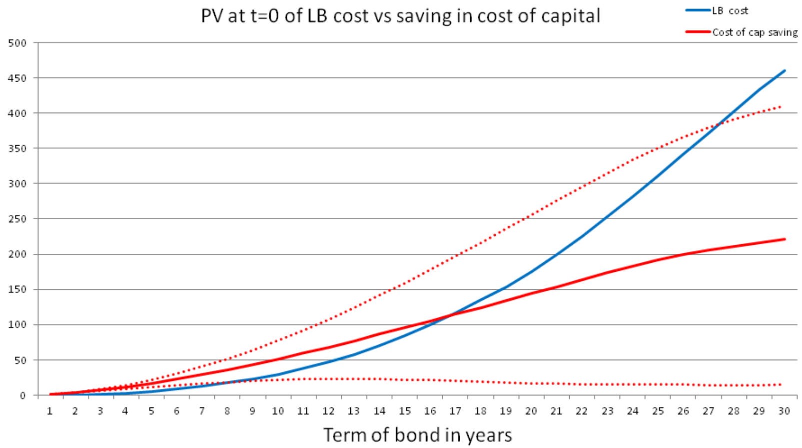
Results: Base case



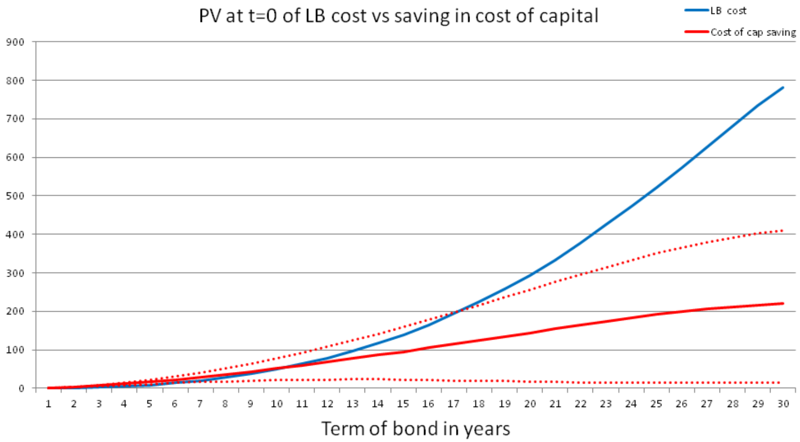
Results: Frictional costs



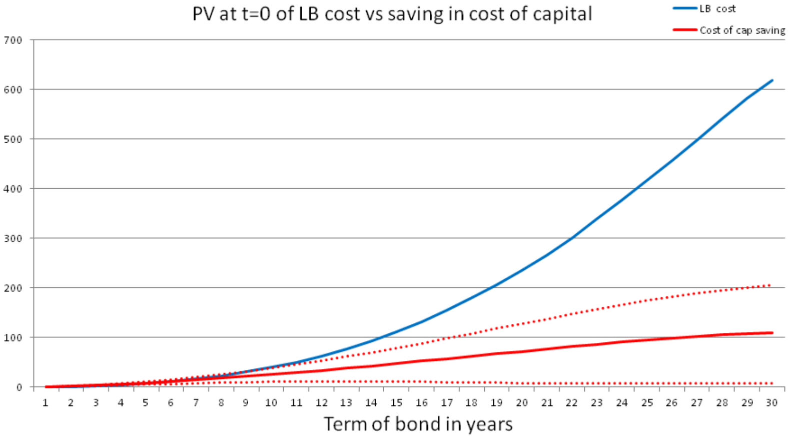
Results: Low Sharpe Ratio



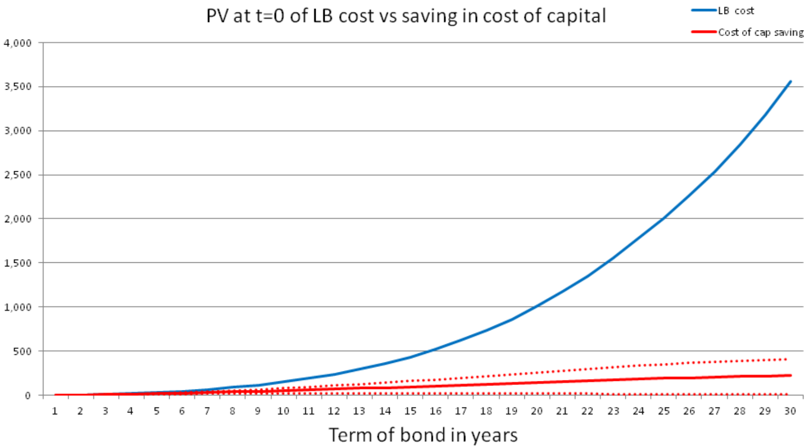
Results: High Sharpe Ratio



Results: 50% Capital relief



Results: Smoothing of q_x



Summary of results

Scenario	**1**	**2**	**3**	**4**	**5**	**6**
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LB T	6	8	7	6	≈5	≈5
Avg T	13	17	16	10	≈5	≈5
UB T	21	28	27	17	≈5	≈5

Contributions:

- Framework to quantify the trade-off between the cost of buying a longevity bond and the benefit from holding it in terms of reduced SCR
- LBs with term over 25 years are not cost-effective
- Market-based risk transfer mechanisms for oldest ages likely to be expensive
- Insurers should consider in-house risk management e.g. diversifying across cohorts

Limitations and further directions:

- Sharpe ratio is an approximation to the market price of LB, as market evolves other pricing models should be used
- Sensitivity analysis for volatility of q_x

Questions?

References

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