The Impact of Longevity Risk Hedging on Economic Capital

Andrew J.G. Cairns

Heriot-Watt University, Edinburgh

and

Director, Actuarial Research Centre,

Institute and Faculty of Actuaries

IAA Life Colloquium, Barcelona, October 2017

Actuarial Research Centre

Institute and Faculty of Actuaries

The Actuarial Research Centre (ARC)

A gateway to global actuarial research

The Actuarial Research Centre (ARC) is the Institute and Faculty of Actuaries' (IFoA) network of actuarial researchers around the world.

The ARC seeks to deliver cutting-edge research programmes that address some of the significant, global challenges in actuarial science, through a partnership of the actuarial profession, the academic community and practitioners.

The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the ARC, the SoA and the CIA.

www.actuaries.org.uk/arc

ARC Research Programmes

Actuarial Research Centre (ARC):
funded research arm of the Institute and Faculty of Actuaries

Three major programmes started in 2016, including

Modelling, Measurement and Management of Longevity and Morbidity Risk

- New/improved models for modelling longevity
- Management of longevity risk
- Underlying drivers of mortality
- Modelling morbidity risk for critical illness insurance

Outline

- Introduction and motivation
- Hedging longevity risk with an index-based call-spread option contract
- Anatomy of a hedging calculation in 22 easy steps!
- Numerical example
- Discussion

Motivation

- Longevity risk
- Measurement
  - e.g. Capital Requirement
  - Best estimate + extra for risk
- Longevity risk management
  - customised hedges
  - index-based hedges

Motivation

- Why use General Population Longevity Index based risk transfer instruments?
  → Capacity and **Price**
- Pros/cons
  - Transferred risk is efficiently priced
  - But hedger left with basis risk
- Thus we need
  - a clear and rigorous approach to quantify basis risk
  - hedger and regulator agreement on approach
  - to quantify properly the Capital Relief

Introduction

- Underlying problem:
  - Life insurer
  - Aim 1: measure mortality/longevity risk
  - Aim 2: manage mortality/longevity risk
  - e.g. to *reduce* regulatory capital
  - e.g. to *reduce* economic capital
  - e.g. to *increase* economic value

Regulatory Capital Requirements: Annuity Portfolio

- Solvency II options:
  - Solvency Capital Requirement, SCR= difference between Best estimate of annuity liabilities (BE) and Annuity liabilities following an immediate 20% reduction in mortality
  - or SCR= extra capital required at time 0 to ensure solvency at time 1 with 99.5% probability
  - or *SCR= extra capital at time 0 to ensure solvency at time T with $x\%$ probability*

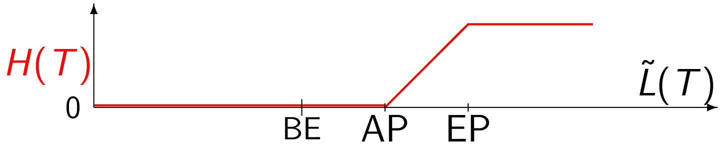
Liability to be Hedged

- L = random PV at time 0 of liabilities
- $L(0)$ = point estimate of L based on time 0 info
- $L(T)$ = point estimate of L based on info at T
  = PV of actual cashflows up to T
  + PV of estimated cashflows after T
- Risk $\Rightarrow$ capital requirements

What type of hedge to modify capital requirements and manage risk?

- Index-based hedge
  - Synthetic $\tilde{L}(T) \approx$ true $L(T)$
  - Call spread derived from underlying $\tilde{L}(T)$
    Payoff at T, *per unit*

$$H(T) = \begin{cases} 0 & \text{if } \tilde{L}(T) < AP \text{ (Attachment Point)} \\ \tilde{L}(T) - AP & \text{if } AP \le \tilde{L}(T) < EP \text{ (Exhaustion Point)} \\ EP - AP & \text{if } EP \le \tilde{L}(T) \end{cases}$$



The Synthetic $\tilde{L}(T)$

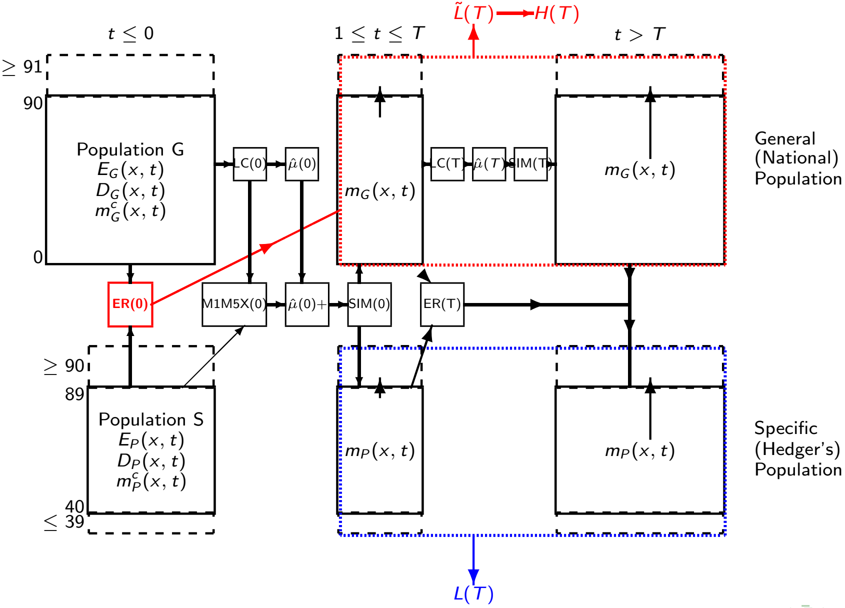
- $\tilde{L}$ = random PV at time 0 of a portfolio of synthetic liabilities
- Synthetic mortality experience
  - based on general population mortality
  - adjusted using experience ratios

- $\tilde{L}(T)$ = point estimate of $\tilde{L}$ based on info at T
  = PV of actual *synthetic* cashflows up to T
  + PV of estimated *synthetic* cashflows after T

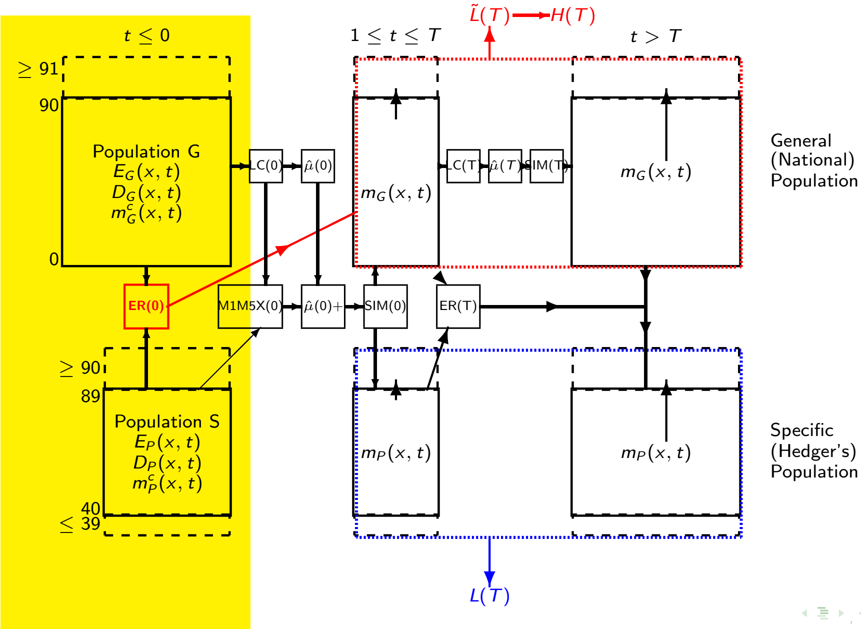
Questions and Observations

- What impact $L(T) \quad \longrightarrow \quad L(T) - H(T)$?
- Need a two population mortality model
- Practical reality: calculation is more complex than academic 'ideal world'
- What are good choices of AP, EP, T?

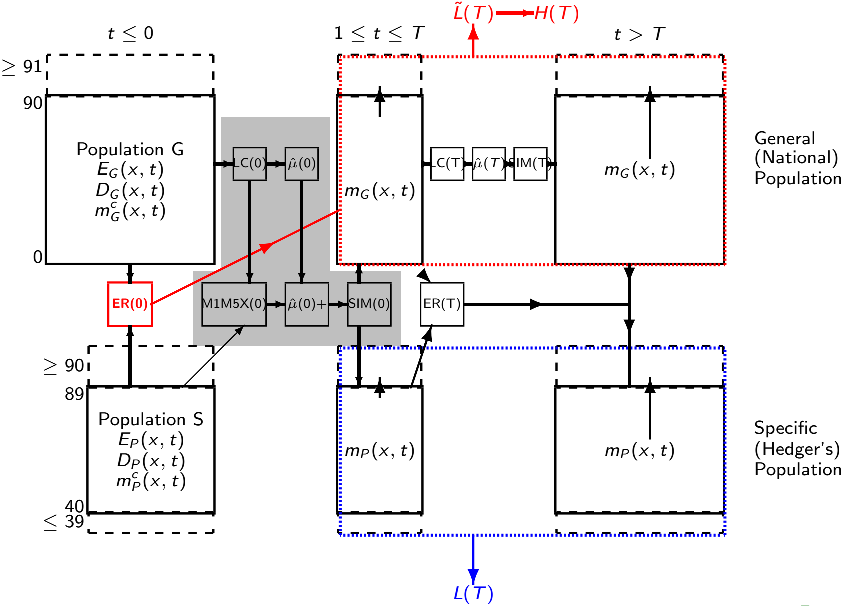
Anatomy of a Hedging Calculation in 22 Easy Steps!



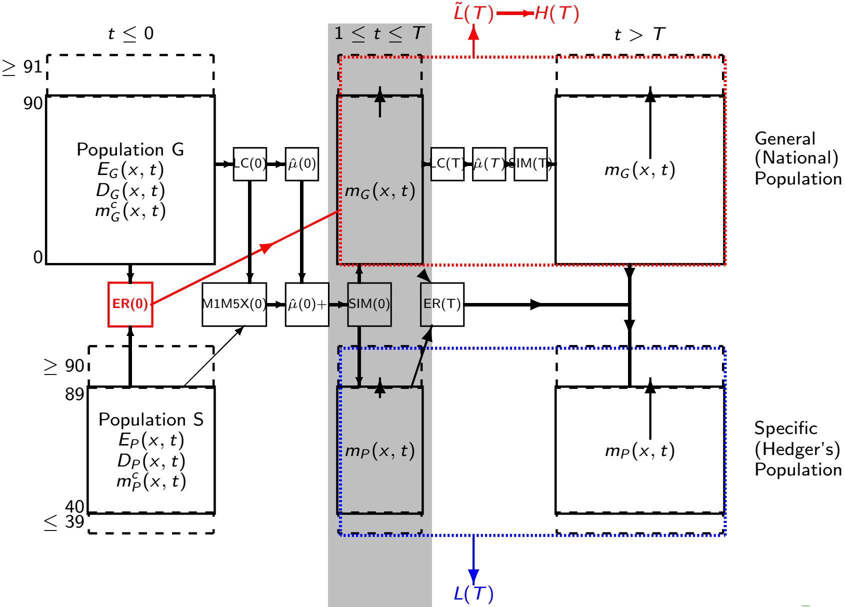
Anatomy of a Hedging Calculation: Steps 1, 2



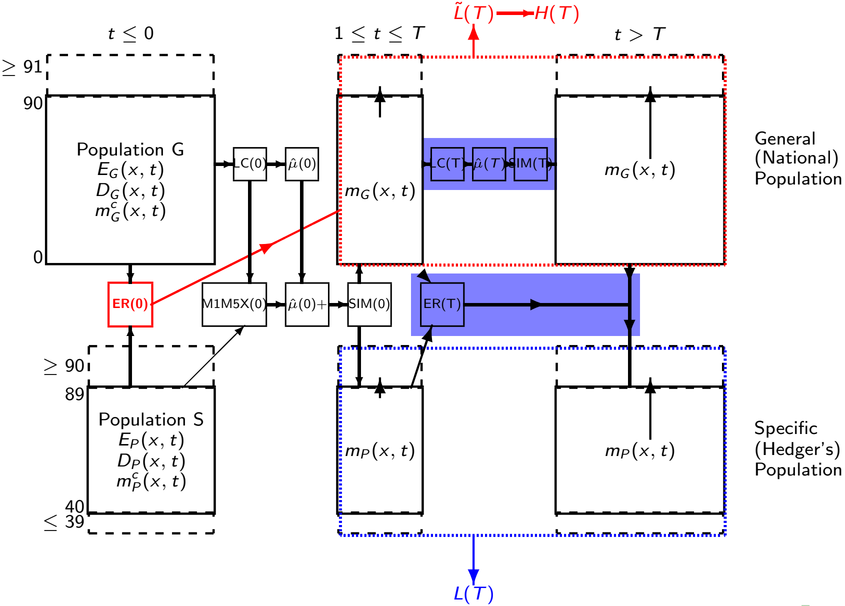
Anatomy of a Hedging Calculation: Steps 3-5



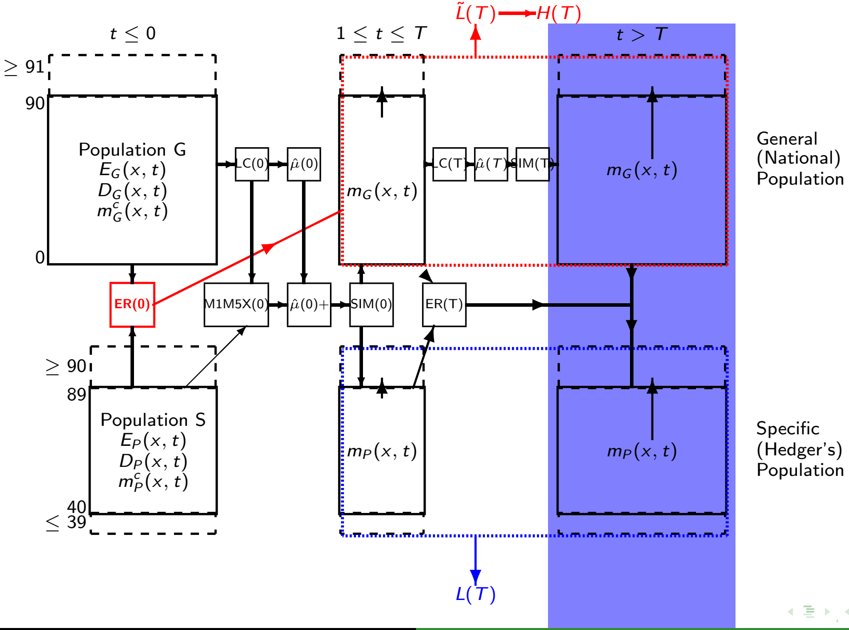
Anatomy of a Hedging Calculation: Steps 6, 7, 14, 15, 17



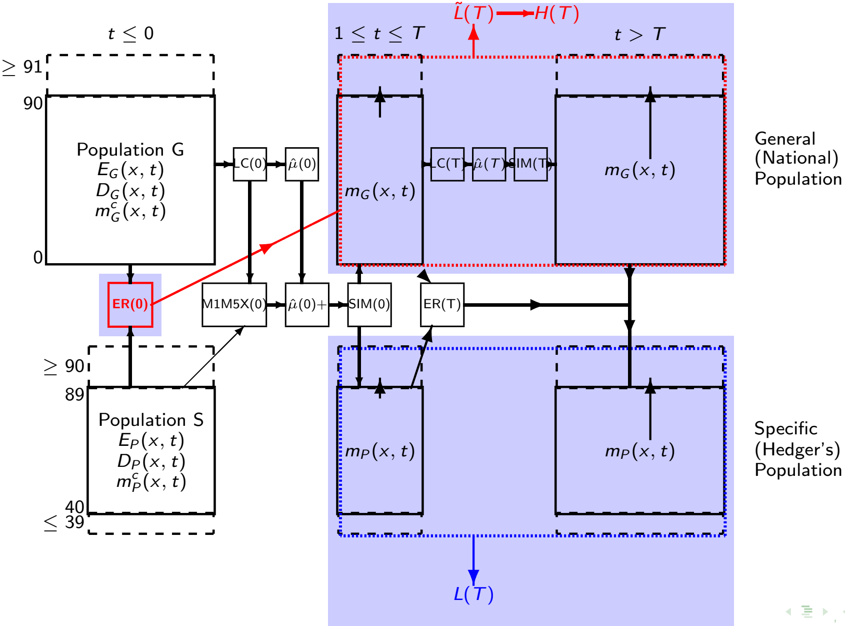
Anatomy of a Hedging Calculation: Steps 8, 9, 12



Anatomy of a Hedging Calculation: Steps 10,11,13,14,16,18



Anatomy of a Hedging Calculation: Steps 19-22



How many models do you need?

Academic 'ideal': One model

In practice:

- Time 0:
  - Liability valuation model (BE + SCR)
  - Simulation model ($0 \rightarrow T$)
- Time T:
  - Hedge instrument valuation model
  - Liability valuation model
- 'Models' for extrapolating to high (and low) ages

- Unhedged Liabilitiies:
  Deterministic BE + 20% stress

- Simulation: (by way of example)
  - General population: (Lee-Carter/M1)

$$\ln m_{gen}(x,t) = A(x) + B(x)K(t) \quad \text{(Lee-Carter/M1)}$$

  - Hedger's own population: (M1-M5X)

$$\ln m_{pop}(x,t) = \ln m_{gen}(x,t) + a(x) + k_1(t) + k_2(t)(x - \bar{x})$$

Time T models

- Hedge instrument:
  - Lee-Carter (M1) for general population
  - Recalibration: *on basis specified at time 0*

$$q^H_{pop}(x,t) = q^H_{gen}(x,t) \times ER(x,0) \rightarrow \tilde{L}(T) \rightarrow H(T)$$

- Liability: specific (hedger's) population
  - Lee-Carter (M1) for general population
  - Possibly different calibration from the hedge instrument
  - $q^L_{pop}(x,t) = q^L_{gen}(x,t) \times ER(x,T) \rightarrow L(T)$
  - Approach must mimic local practice

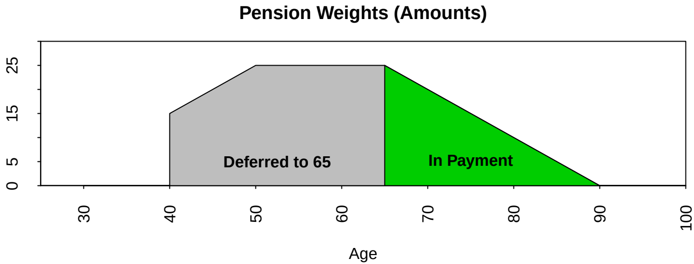
Hedging Example

- Data: Netherlands
  - CBS national data
  - CVS insurance data (Dutch aggregated industry experience data)

- Hedge instrument maturity: $T = 10$
- Attachment and exhaustion points at 60% and 95% quantiles of $\tilde{L}(T)$
- Key point: EP " << " 99.5% quantile of $\tilde{L}(T)$

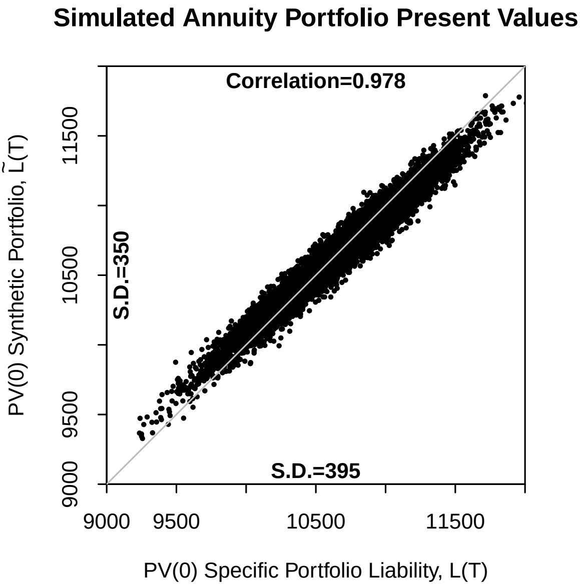
Hedging Example

- Portfolio of deferred and immediate annuities
- Current ages 40 to 89
- Weights (≡ pension amounts):

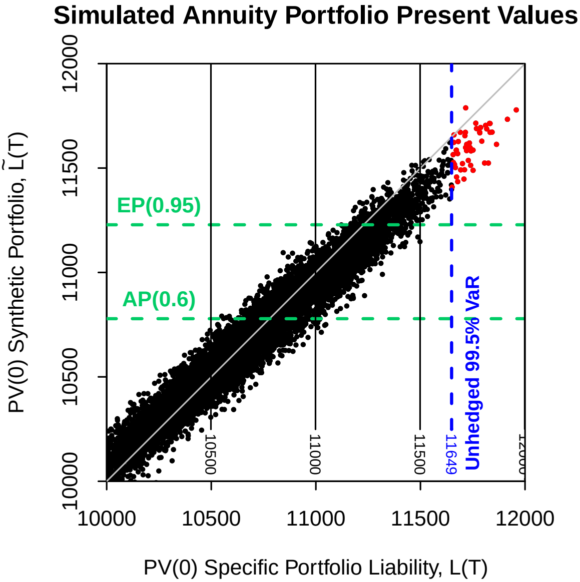


- Before and after: Compare $L(T)$ with $L(T) - H(T)$
- SCR = 99.5% quantile − mean

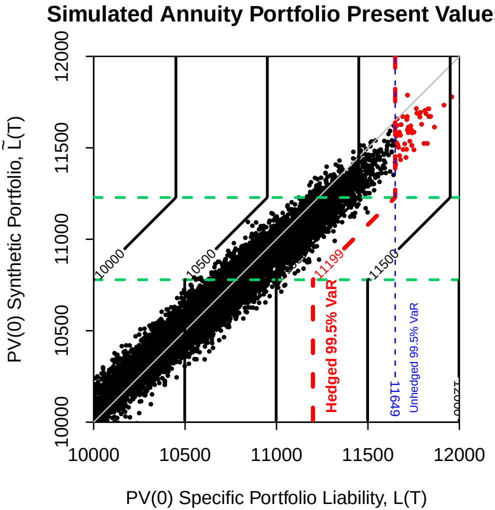
Hedging Example ($n = 10,000$ scenarios)



Hedging Example: Unhedged VaR $= 11,649$

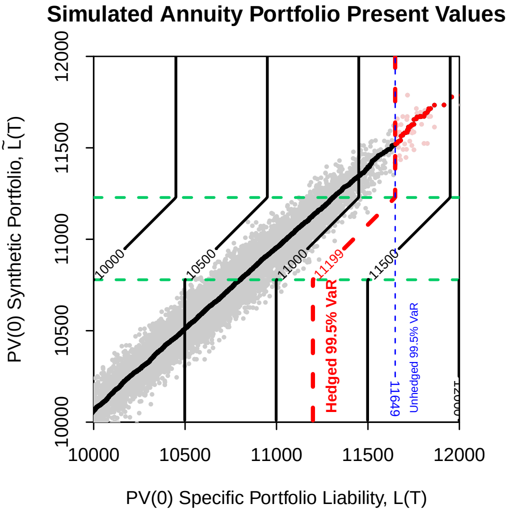


Hedging Example: Hedged VaR $= 11,199$



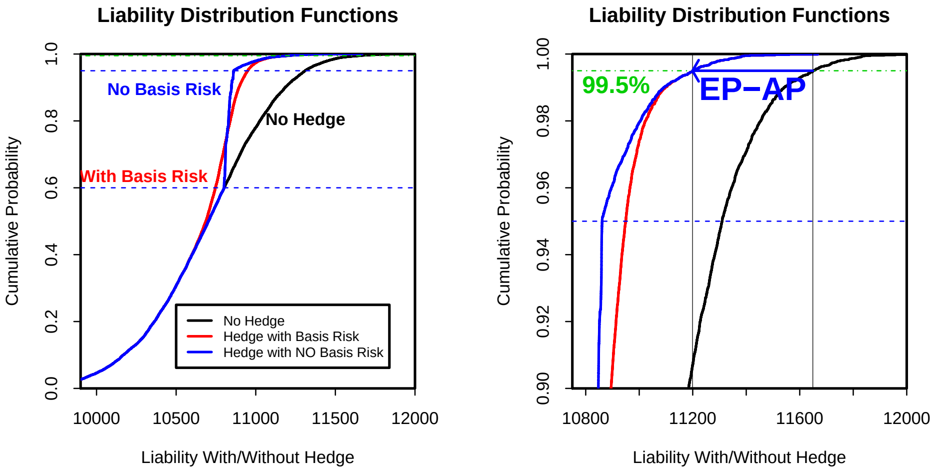
Plot shows kinked contours of $L(T) - H(T)$.

Hedged VaR $= 11,119$ with no Pop. Basis Risk



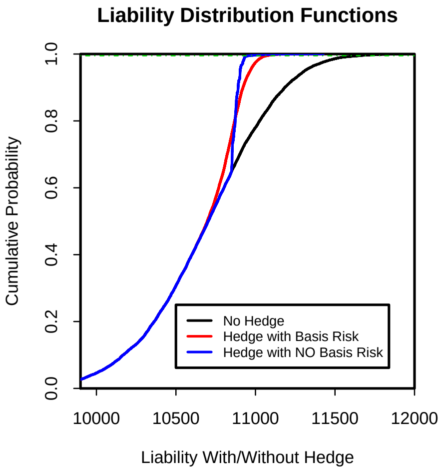
Plot shows kinked contours of $L(T) - H(T)$.

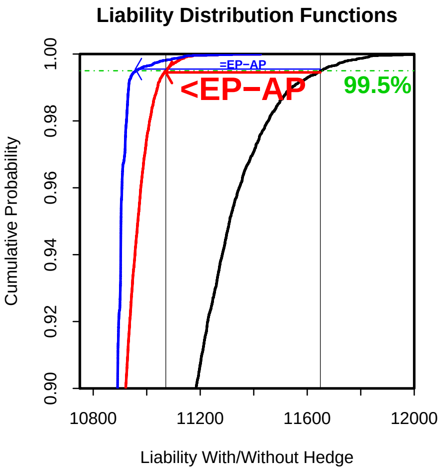
Hedging Example: VaR Calculations



Note: CDF makes no allowance for the price of the hedge.

Hedging Example: Higher AP (0.65) and EP (0.995)





Numerical Example: AP, EP $=$ 60% and 95% quantiles

$L(0)$:	$SCR_{20\% stress}$	840	
$\tilde{L}(T)$:	SCR_{10}	840	(Pop 1; no hedge)
$\tilde{L}(T) - H(T)$:	SCR_{11}	478	(Pop 1; with $\tilde{L}(T)$ hedge)
$L(T)$:	SCR_{20}	960	(Pop 2; no hedge)
$L(T) - H(T)$:	SCR_{21}	598	(Pop 2; with $\tilde{L}(T)$ hedge)

Table: SCR values in excess of the mean liability. For the hedging instrument $AP = 10779$ (60% quantile) and $EP = 11228$ (95% quantile). Pop 1: synthetic $\tilde{L}(T)$. Pop 2: true $L(T)$.

How good is the hedge?

- “Good” $\Rightarrow$ price and risk reduction
- “Good” $\leftrightarrow$ Types of basis risk
  - Structural (e.g. non-linear payoff)
  - Population basis risk
    - Within population (e.g.linkage to different cohort)
    - Different population
- Hedge effectiveness $\Rightarrow$ % reduction in required capital
- Haircut $\Rightarrow$ impact on capital relief as a result of population basis risk
- EIOPA Solvency II guidelines $\Rightarrow$ regulatory approval should focus on the haircut

Numerical Example: AP, EP = 60% and 95% quantiles

$L(0)$:	$SCR_{20\%stress}$	840	
$\tilde{L}(T)$:	SCR_{10}	840	(Pop 1; no hedge)
$\tilde{L}(T) - H(T)$:	SCR_{11}	478	(Pop 1; with $\tilde{L}(T)$ hedge)
$L(T)$:	SCR_{20}	960	(Pop 2; no hedge)
$L(T) - H(T)$:	SCR_{21}	598	(Pop 2; with $\tilde{L}(T)$ hedge)

Table: SCR values in excess of the mean liability. For the hedging instrument $AP = 10779$ (60% quantile) and $EP = 11228$ (95% quantile). Pop 1: synthetic $\tilde{L}(T)$. Pop 2: true $L(T)$.

What is the impact of Population basis risk on hedge effectiveness?

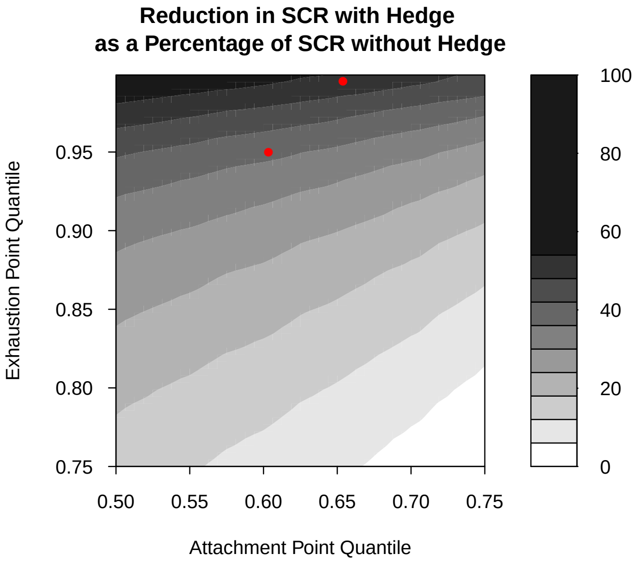
$$\text{Haircut} \quad HC = 1 - \frac{SCR_{20} - SCR_{21}}{SCR_{10} - SCR_{11}} = 0.000.$$

Haircut ≈ 0: Interpretation

- Here EP "$<<$" 99.5% quantile
- Above the 99.5% quantile the call spread (almost) always pays off in full
- So population basis risk $\Rightarrow$ little impact
- Structural basis risk prevails

- More detailed analysis $\Rightarrow$
  Haircut is *worst* (highest) when EP is close to the 99.5% quantile.

Reduction in SCR: Dependence on AP and EP



Discussion

- Rigorous approach: practical assessment of the impact of a longevity hedge
- Call spread: choice of EP $\Rightarrow$ impact on haircut $\Rightarrow$ impact on regulatory approval
- Choice of AP and EP $\Rightarrow$ impact on SCR reduction
- Interaction: SCR reduction $\leftrightarrow$ price
  $\Rightarrow$ tradeoff
- Applies equally well to economic capital
- Index option $\longrightarrow$ Cat Bond for receivers

HERIOT WATT UNIVERSITY

Actuarial Research Centre
Institute and Faculty of Actuaries

Thank You!

Questions?

Paper online at:

www.macs.hw.ac.uk/∼andrewc/ARCresources

HERIOT WATT UNIVERSITY

Actuarial Research Centre
Institute and Faculty of Actuaries

Bonus Slides

Tradeoffs and Other Considerations

How to choose Maturity, AP and EP?

- Reduction in SCR $\nearrow$
- Cat Bond nominal $\searrow$
- Bull spread price $\searrow$
- Shareholder value added $\nearrow$
- Insurer risk appetite, hedging objectives etc.

Theory vs Practice: Bridging the Gap

OR

Try to avoid this:

Actuarial Research Centre
Institute and Faculty of Actuaries

Theory vs Practice: Bridging the Gap

Where we are now?

Actuarial Research Centre
Institute and Faculty of Actuaries

Sensitivity to Hedge Maturity, T

- e.g. $T = 20$

- % reduction in SCR is *slightly* higher
- Haircut is *slightly* worse
- Haircut is still ≈ 0 for $EP \leq 99.5\%$ quantile

- The longer the maturity:
  - less liquid market
  - less confidence in future reserving method
  - more future capital relief (everything else held constant)