Institut für Finanz- und Aktuarwissenschaften ifa

On the economics of the longevity risk transfer market

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On the economics of the longevity risk transfer market

Agenda

Introduction

The longevity risk transfer market: status quo

Longevity swaps totalling £250bn forecast for next decade: Hymans

16TH FEBRUARY 2021 - AUTHOR: STEVE EVANS   Share:

Hymans Robertson LLP, the pensions and financial services consultants, expects that longevity risk transfer activity will remain high in the United Kingdom across the coming decade, with as much as UK £250 billion of longevity swaps likely to be transacted by 2031.

That's on top of a forecast £450 billion of pension buy-in and buy-out deals, taking the expected total UK pension risk transfer activity for the next ten years to £750 billion.

This suggests the need for significant longevity reinsurance capacity to support the needs of pension funds looking to offload their longevity risk and provide greater funding certainty to their beneficiaries.

Since the pension risk transfer and longevity risk transfer market came into being in around 2007, some UK £300 billion of risk has been transferred.

https://www.artemis.bm/news/longevity-swaps-totalling-250bn-forecast-for-next-decade-hymans/

Taken in the context of the $60–80 trillion aggregate retirement obligations (using current estimates of mortality), we see that liabilities could balloon by a further $5–8 trillion.

To put this into context, the total assets held by the global insurance industry (for all classes of insurance business) were estimated to be $3.66 trillion as of the end of 2013 (AON Benfield [2014]). Add to that an estimated $540 billion of capital in the reinsurance and insurance-linked securities industries, and we see that the combined capital of the insurance and reinsurance industries is barely 80% of the existing global potential for longevity risk, at the low end of the range. This drastic shortfall presents a substantial problem, as the longevity risk inherent in the world's aggregate retirement obligations is far in excess of the amount of risk capital the global insurance industry could realistically bring to bear against this risk.

Michaelson & Mulholland (2014), p. 2

Without question, reinsurance capacity for the global longevity and annuity sector is paramount, and demand is almost certain to exceed supply. Today, reinsurance capacity remains sufficient for current levels of activity but a capital market solution will be needed as demand increases. Kessler (2019), p. 15

Introduction

The longevity risk transfer market: market participants

Which hedging solution offers
- A high risk reduction?
- A cost-efficient cost of capital reduction?

Primary hedger(s)

- **Annuity provider (e.g., a life insurer)**
- First writer of longevity risk
- Special socioeconomic book structure

- Which hedge structure?
- Which hedge horizon?
- Which index population? Customized or index-based?

For which risk premium is it economically attractive to
- Take on longevity risk?
- Transfer longevity risk to the capital markets?

Reinsurer(s)

- **Economic cost of capital perspective**
- Exploits diversification effects between
  - 1) Longevity business
  - 2) Mortality business
  - 3) Other uncorrelated risks

- Which hedge structure?
- Which hedge horizon?

Which risk-adjusted returns can be earned in this market?
- Where to enter the market? (deal with reinsurers or with primary hedgers?)
- How to enter the market? (which instruments?)

Capital market investor(s)

- Low correlation of longevity with other asset classes
- Interested in **attractive risk-adjusted returns**
- Prefers index-based deals over short terms

Introduction
Structure of the talk

Model of a longevity risk transfer market with these three types of market participants

- **First step**: We analyze transactions between **primary hedgers** and **reinsurers**
  - How do reinsurance prices depend on the available diversification opportunities?
  - We consider different "stages of the market" that are characterized by the amount of longevity risk that has already been transferred to the reinsurance sector and show that
    - Different instruments might be suitable in different stages of the market
    - The market might eventually face a capacity constraint in the reinsurance sector
- **Second step**: We discuss the potential market entry of **capital market investors**
  - We show that the market risk premium depends on the free capacity in the reinsurance sector
  - We derive risk-adjusted returns that can be earned in different stages of the market when offering index-based capital market instruments to
    - **Primary hedgers**
    - **Reinsurers**
  - Which components of longevity risk should be transferred to the capital market?
  - Which instruments are suitable to reconcile capital market investors�much and hedgers‵ interests?

Market participants
Primary hedger: hedging objectives

- **Liability to be hedged**
  - Simplified closed book of immediate life annuities with starting age of $x_0 = x_R$ (retirement age)
    - Limited portfolio size N_{Book}, special socioeconomic structure η
    - Time-t random present value of unhedged liabilities: $L(t)$; hedged: $L_H(t) := L(t) - H(t)$
    - Time-zero random present value of all cost of capital [with hedge H]: $CoC_{L_{[H]}} := \sum_{t\geq 0} \frac{r_{CoC}\, SCR_{L_{[H]}}(t)}{(1+r)^{t+1}}$
- **Two simultaneous hedging objectives** (cf. Börger et al. (2021a))
  - High **capital efficiency** (CoC relief net of hedging costs relative to unhedged CoC)

$$\boldsymbol{CE}(\boldsymbol{H}) := \frac{E(\text{"}CoC\ relief\text{"} - \text{"}hedging\ costs\text{"})}{E(\text{"}unhedged\ CoC\text{"})} = \frac{E\left(CoC_L - CoC_{L_H} + H(0)\right)}{E(CoC_L)} = 1 - \frac{E\left(CoC_{L_H} - H(0)\right)}{E(CoC_L)}$$

  - High **hedge effectiveness** (relative risk reduction under a centralized risk measure ρ)

$$\boldsymbol{HE}(\boldsymbol{H}) := 1 - \frac{\rho\left(L_H(0) + CoC_{L_H}\right)}{\rho\left(L(0) + CoC_L\right)}$$

- Fully customized hedges naturally dominate in terms of hedge effectiveness
- Cost-efficient partial or index-based instruments might be more capital efficient

➡ **HE/CE-frontier of "efficient" instruments**

Market participants

Reinsurer: economic capital model

- **Economic capital model**
  - Rolling one-year perspective (in the spirit of Solvency II)

    $$EC(t) := VaR_{99,5\%}(\text{"}portfoliowide\ loss\ in\ year\ t\text{"}) := VaR_{99,5\%}(L^L(t) + L^M(t) + L^O(t))$$

  - Three lines of business
    - **Longevity** business: $L^L(t) := loss\ in\ year\ t\ from\ longevity\ business$
      - Book of immediate life annuities that consists of different cohorts of age $x \geq x_R$
      - Face value F^L: cumulative annual annuity payments for which the reinsurer is liable
    - **Mortality** business: $L^M(t) := loss\ in\ year\ t\ from\ mortality\ business$
      - Book of term life insurance policies that consists of different cohorts of age $x \in [x_M, x_R]$
      - Face value F^M: sum of all annual death benefits for which the reinsurer is liable
    - **Other** business: $L^O(t) := loss\ in\ year\ t\ from\ other\ business$
      - Lognormally distributed with face value F^O (mean) and coefficient of variation CoV^O
      - Uncorrelated with biometric risks
  - Path-dependent projection for future years $t > 0$
    - Constant new business to obtain a stable business mix over time

Market participants

Reinsurer: pricing longevity transactions

- **Expected return on risk-adjusted capital (RORAC) pricing approach**

$$RORAC(H) := \frac{E(\text{"PV of cash flows from the hedge contract"})}{E(\text{"PV of required economic capital"})} := \frac{E(\sum_t (1+r)^{-t}(-h(t)))}{E(\sum_t (1+r)^{-(t+1)} \widetilde{EC^H}(t))} \overset{!}{=} roe$$

  - Reinsurer is invariant with respect to all longevity transactions that satisfy this RORAC-criterion
  - Hedging instrument cash flows in year t of the form: $h(t) := \text{"floating"} - \text{"fixed"}$
  - Pricing at inception: determine fixed lags based on anticipated target return on equity rate roe
  - Absolute risk premium $E(\sum_t (1+r)^{-t} h(t))$ is interpreted as hedging costs for the hedger

- **The impact of longevity transactions on economic capital**

$$EC^{+H}(t) := VaR_{99,5\%}\left(L^L(t) + L^M(t) + L^O(t) + L^H(t)\right), \qquad t \geq 0$$

  - Interdependencies between different lines of business are implicitly taken into account
  - **Euler allocation principle** yields the following additive decomposition

$$EC^{+H}(t) = \widetilde{EC^L}(t) + \widetilde{EC^M}(t) + \widetilde{EC^O}(t) + \widetilde{EC^H}(t), \qquad t \geq 0$$

The marginal economic capital $\widetilde{EC^H}(t)$ for supporting the transaction depends on

- The available diversification effects within the reinsurer‘s business mix
- The structure of the hedging instrument

Stochastic mortality modeling framework

Multi-population actual/estimated mortality trend (AMT/EMT) model of Börger et al. (2021a/b)

- **AMT simulation model** captures the following risk drivers
  - Long-term mortality trend risk for a reference population
    - Stochastic trend process of Börger & Schupp (2018)
  - Mortality differentials of several subpopulations of different socioeconomic status
    - Common relative modeling approach, random walk with drift (cf. Villegas et al. (2017))
    - Characterization approach (cf. Haberman et al. (2014); Villegas & Haberman (2014))
  - Small sample risk by sampling survivors from a binomial distribution (only for primary hedger)
- **EMT valuation model** for the derivation of best estimate liabilities (BEL)
  - Reference population (cf. Börger et al. (2021b))
    - Estimating the prevailing mortality level and trend based on observed mortality
  - Subpopulations (in the spirit of Cairns and El Boukfaoui (2021))
    - Adjustment for differing mortality levels and trends relative to the reference populalation

This AMT/EMT setup is used for the computation of SCRs and economic capital:

- The AMT simulation model is used to project mortality over a 1-year horizon
- The accompanying change in the BEL is assessed with the EMT valuation model

Hedging instruments

Overview

- **Different index population (IP)s**
  - ○ **IP=*B*** (fully customized, linked to the ***B***ook population)
    - Linked directly to realized survivors and to realized mortality in the book population
  - □ **IP=*S*** (index-based, linked to the ***S***ubpopulations)
    - Hedger bears small sample risk
  - △ **IP=*R*** (index-based, linked to the ***R***eference population)
    - Hedge exclusively covers the randomness originating from the reference population
- **Hedge payout structures**
  - **Longevity swaps** $h(t) \coloneqq SI_{x_0+t,t} - K(t),\ 0 < t \leq \tau$
    - Exchange the realizations of a survivor index $SI_{x_0+t,t}$ against a set of fixed payments $K(t)$
  - **Annuity forwards** $h(\tau) \coloneqq LI(\tau) - K(\tau)$
    - Exchange the realization of a liability index $LI(\tau)$ against a single pre-defined payment $K(\tau)$
  - **Q-forwards** $h(\tau) \coloneqq n\left(K(\tau) - q_{x_0+\tau,\tau}\right)$
    - Exchange realized mortality probabilities $q_{x_0+\tau,\tau}$ against a fixed forward rate $K(\tau)$
    - Simple portfolio of a single q-forward with reference age $x_0 + \tau$

Numerical results

Model calibration

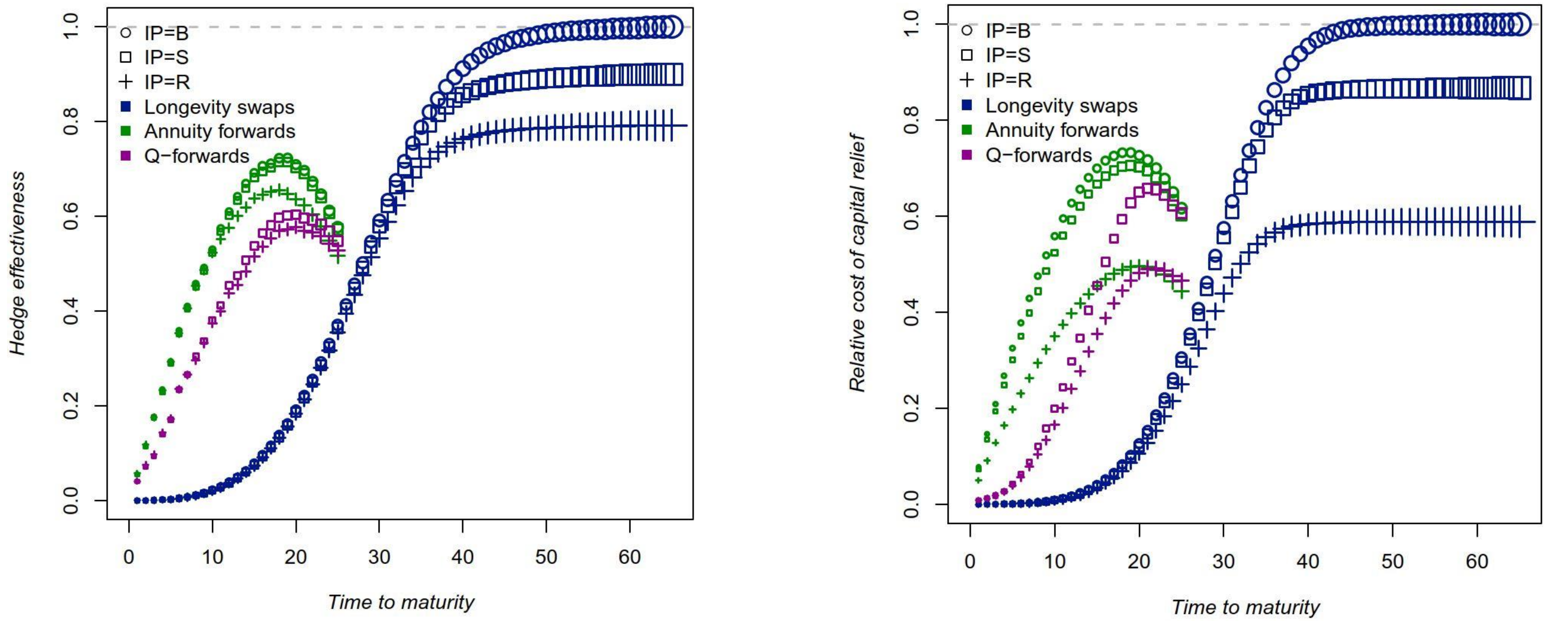
Model calibrated to the historical mortality experience of English and Welsh males

- National population serves as the reference population
- 5 socioeconomic subpopulations based on the Index of Multiple Deprivation (IMD) for England

	Description	Parameter
General model parameters	Risk-free interest rate	$r = 2\%$
	Retirement age	$x_R = 65$
	Socioeconomic book composition	$\eta = (10\%, 15\%, 20\%, 25\%, 30\%)$
Primary hedger	Book size	$N_{Book} = 10{,}000$
	Cost of capital rate	$r_{CoC} = 6\%$
	Risk measure for assessment of *HE*	$\rho \ = TVaR_{90\%}$
Reinsurer	Face value of initial longevity exposure	$F^L = S * 100{,}000$
	Face value of initial mortality exposure	$F^M = 100{,}000{,}000$
	Starting age of mortality business	$x_M = 50$
	Face value of initial other business	$F^O = 300{,}000$
	Coefficient of variation of other business	$CoV^O = 0.20$
	Target return on equity rate	$roe = 9\%$

Numerical results: individual perspective of the primary hedger

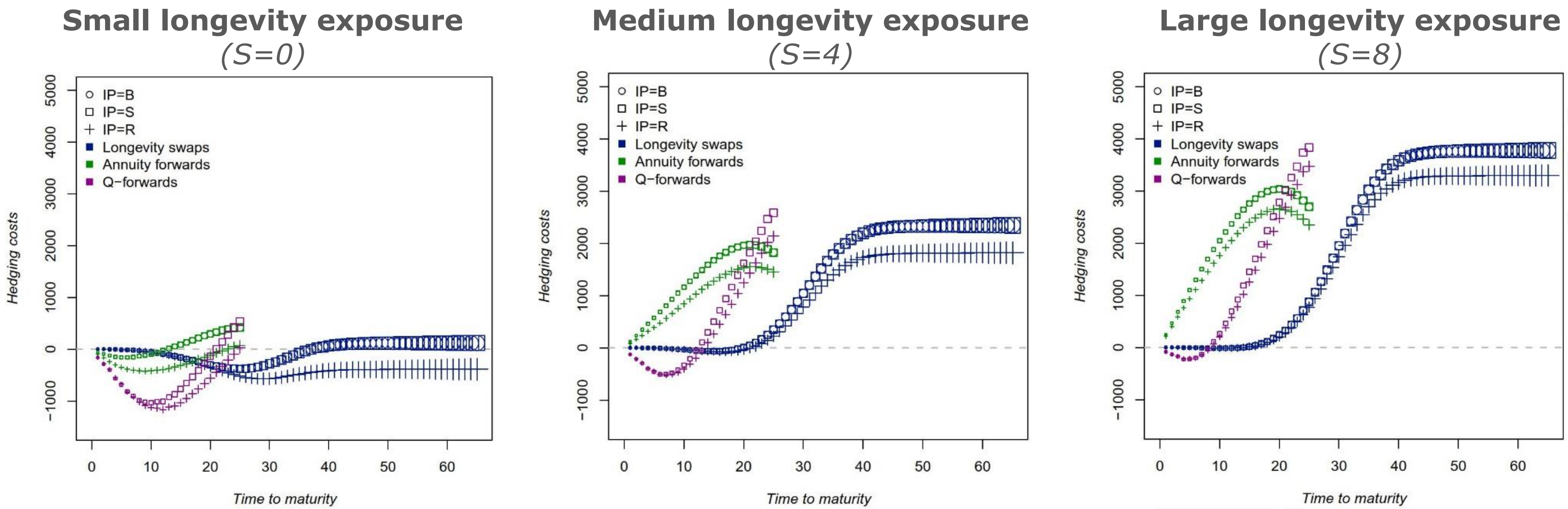
The effects of hedging when disregarding the costs of hedging



- Structurally similar picture for *HE* (left panel) and for CE (right panel)
  - Unlimited fully customized (IP=B) **longevity swap** provides the perfect hedge (i.e., *HE=CE=1*)
  - Intuitive ranking among the IPs
    - *HE* and *CE* declines with each component of longevity risk that is not covered
    - Significant haircuts for population basis risk when using index-based instruments (IP=S,R)
  - With **q-forwards** & **annuity forwards**, medium to high values between 50% and 75% can be reached over much shorter times to maturity of less than 20 years

Numerical results: individual perspective of the reinsurer

Pricing longevity transactions



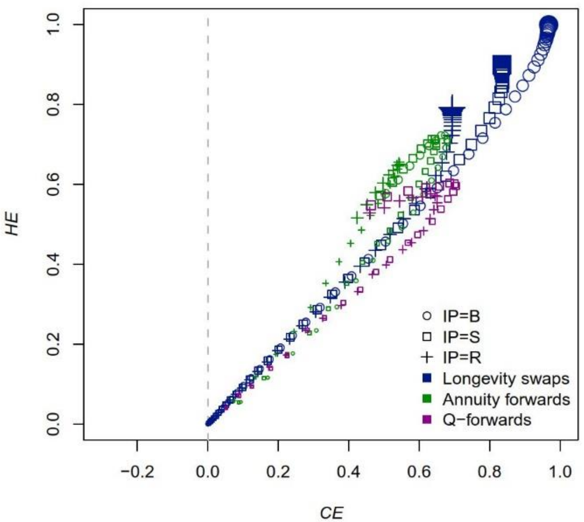
- Some short-term contracts are even offered at a negative risk premium due to strong diversification effects with the reinsurer‘s mortality exposure
- Prices are slightly higher if socioeconomic mortality differentials are covered (IP=B,S)
- Risk premium increases in the reinsurer‘s initial longevity exposure (from the left to the right panel)

- Reinsurance prices for longevity protection significantly depend on the amount of longevity risk that is already being held by the reinsurer
- Market might be monopolistic in early stages, become competitive in later stages

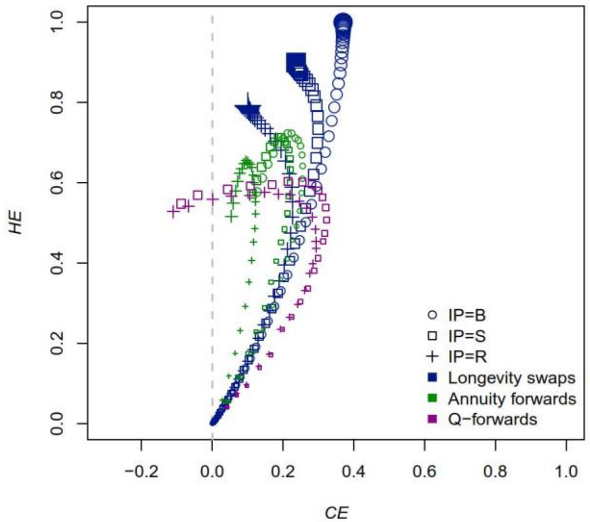
Numerical results: transactions between primary hedger and reinsurer

HE/CE-efficient frontier in different stages of the market

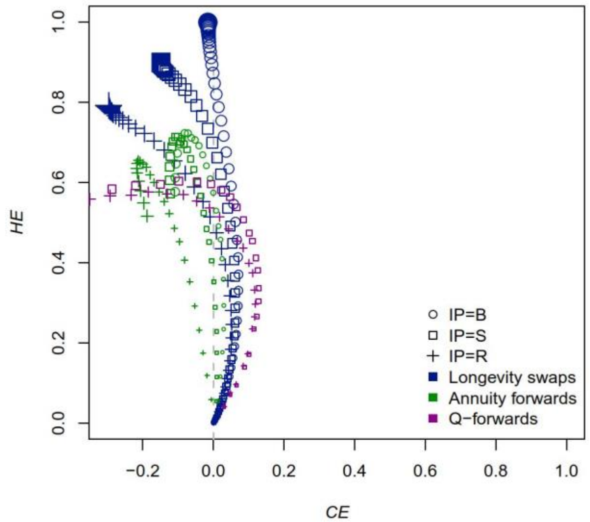
Early stage *(S=0)*



Advanced stage *(S=4)*



Saturated stage *(S=8)*



- Early and advanced stage: unlimited fully customized **longevity swap** dominates
- Saturated stage: **longevity swaps** & **q-forwards** over limited terms are reasonable alternatives
- Eventually: longevity hedging becomes capital-inefficient (i.e., economically unattractive)
- For any instrument: index-based designs (IP=R) are dominated by their customized counterparts

- In early stages of the market, it is economically attractive to both parties to fully transfer longevity risk to the reinsurer (via customized **longevity swaps**)
- With increasing saturation, the market might face a **capacity constraint**

Numerical results: involvement of the capital market investor

Objectives and potential market entry points

- **Investing objective**
  - Attractive risk-adjusted returns in terms of high annualized **Sharpe ratios**

$$Sharpe\ ratio\ (H) := \frac{1}{\sqrt{\tau}} \frac{E(-H(0))}{SD(-H(0))}$$

  - Exclusively interested in index-based deals (IP=R)
  - Short contract duration τ (at most 20 years, preferably much shorter)
- What is the **maximum risk premium** a hedger is willing to pay for an index-based hedge?
  - **Primary hedger**
    - Consider the prevailing HE/CE-frontier in a given stage of the market: Determine maximum risk premium so that an index-based deal constitutes an economically viable alternative
  - **Reinsurer**
    - Expected present value of the cost of economic capital relief (net of diversification effects)

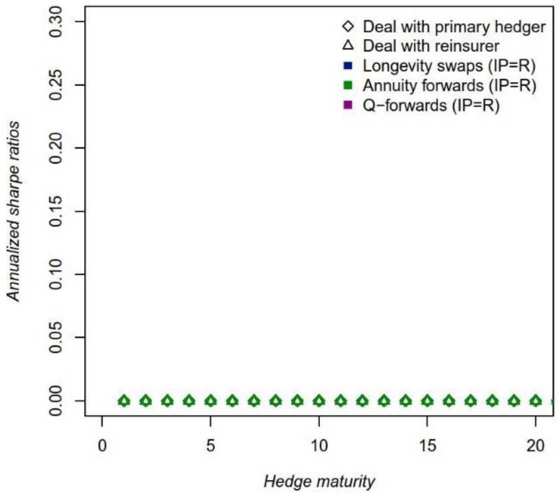
Maximum Sharpe ratios that an investor can earn in the market depends on the

- Stage of the market (i.e., the free capacity of the reinsurance sector)
- Hedging instrument (i.e., hedge payout structure, time to maturity)

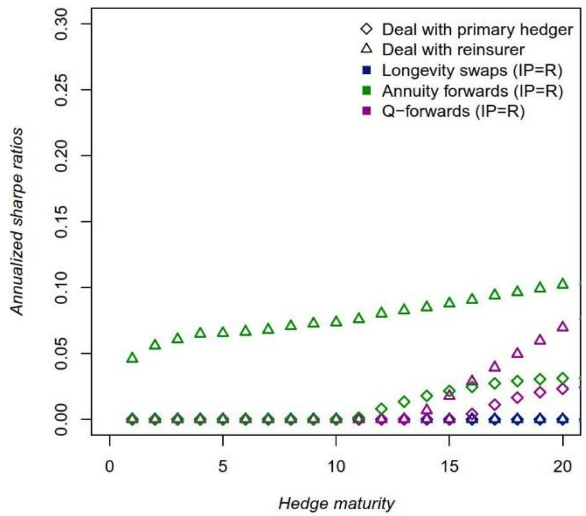
Numerical results: involvement of the capital market investor

Sharpe ratios for index-based capital market instruments in different stages of the market

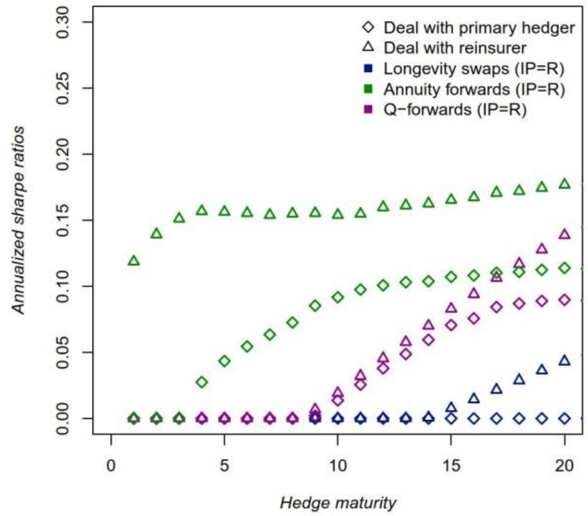
Early stage *(S=0)*



Advanced stage *(S=4)*



Saturated stage *(S=8)*



- Sharpe ratios increase with increasing market saturation (from the left to the right panel)
- **Short-term value hedges** vs. **long-term cash flow hedges**
  - For **longevity swaps**, a rather long contract duration is required to obtain positive Sharpe ratios
  - For **q-forwards** & **annuity forwards**, higher Sharpe ratios with shorter durations
    - Allow the reinsurer to optimize diversification effects with mortality business
- For any instrument: reinsurer △ is willing to pay a higher risk premium than the primary hedger ◇
  - Population basis risk is of less relevance to the reinsurer than to the primary hedger

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Summary

- **Framework for the analysis of the economics of the longevity risk transfer market**
  - Different market participants
  - With different hedging/investment objectives
- **Main findings**
  - Role of the **reinsurance sector**
    - Customized hedges are more suitable reinsurance instruments than index-based designs
    - Prices increase with shrinking capacity in the reinsurance sector
    - Market might be monopolistic in the early stage and become competitive in later stages
    - Eventually, the market might face a capacity constraint in the reinsurance sector
  - Potential market entry of **capital market investors**
    - Market risk premium for longevity risk depends on the free capacity of the reinsurance sector
    - Optimal market entry point
      - Results suggest that index-based transactions with reinsurers (e.g., via sidecars) are more promising than transactions directly with primary hedgers
      - Short-term index-based value hedge agreements seem to be suitable to reconcile reinsurers�much and capital market investors‘ interests

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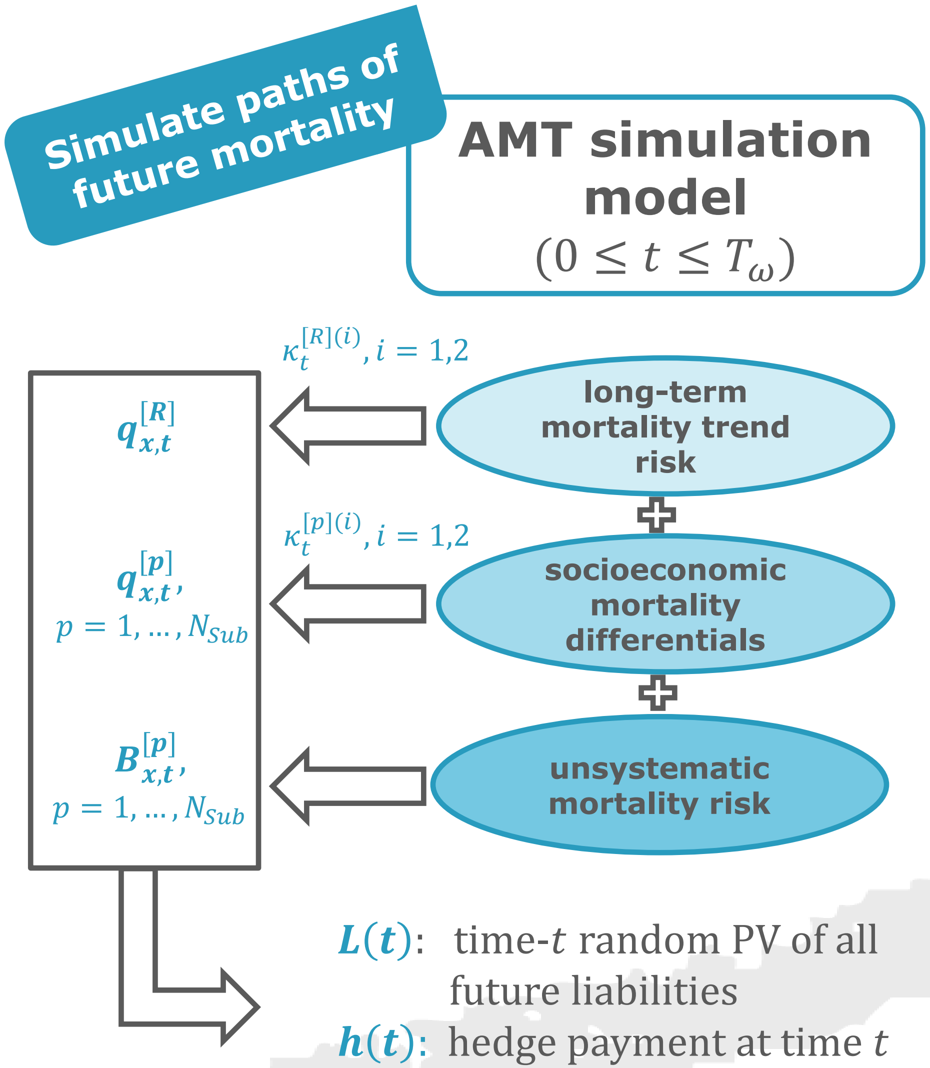
Appendix

Multi-population AMT simulation model



$L(t)$: time-t random PV of all future liabilities

$h(t)$: hedge payment at time t

$H(t)$: time-t random PV of all future hedge payments

CBD model structure (Cairns et al. (2006))

- Reference population *R*

$$logit\left(q_{x,t}^{[R]}\right) := log\left(\frac{q_{x,t}^{[R]}}{1 - q_{x,t}^{[R]}}\right) = k_t^{(1)[R]} + (x - \bar{x})k_t^{(2)[R]}$$

- Socioeconomic subpopulations $p = 1, \dots, N_{Sub}$

$$logit\left(q_{x,t}^{[p]}\right) - logit\left(q_{x,t}^{[R]}\right) = k_t^{(1)[p]} + (x - \bar{x})k_t^{(2)[p]}$$

Stochastic trend process (Börger & Schupp (2018))

- $k_t^{(i)[R]} = \bar{k}_t^{(i)[R]} + \varepsilon_t^{(i)[R]}, \quad i = 1,2$
  - **Random noise** around piecewise linear trend
- $\bar{k}_{t+1}^{(i)[R]} = \bar{k}_t^{(i)[R]} + AMT_t^{(i)}, \quad i = 1,2$
  - Actual mortality trend $AMT_t^{(i)} = AMT_{t-1}^{(i)} + O_t^{(i)} S_t^{(i)} M_t^{(i)}$
    - $O_t^{(i)} \in \{0,1\}$ did a trend change **occur**?
    - $S_t^{(i)} \in \{-1,1\}$ **sign** of trend change
    - $M_t^{(i)} > 0$ absolute trend change **magnitude**

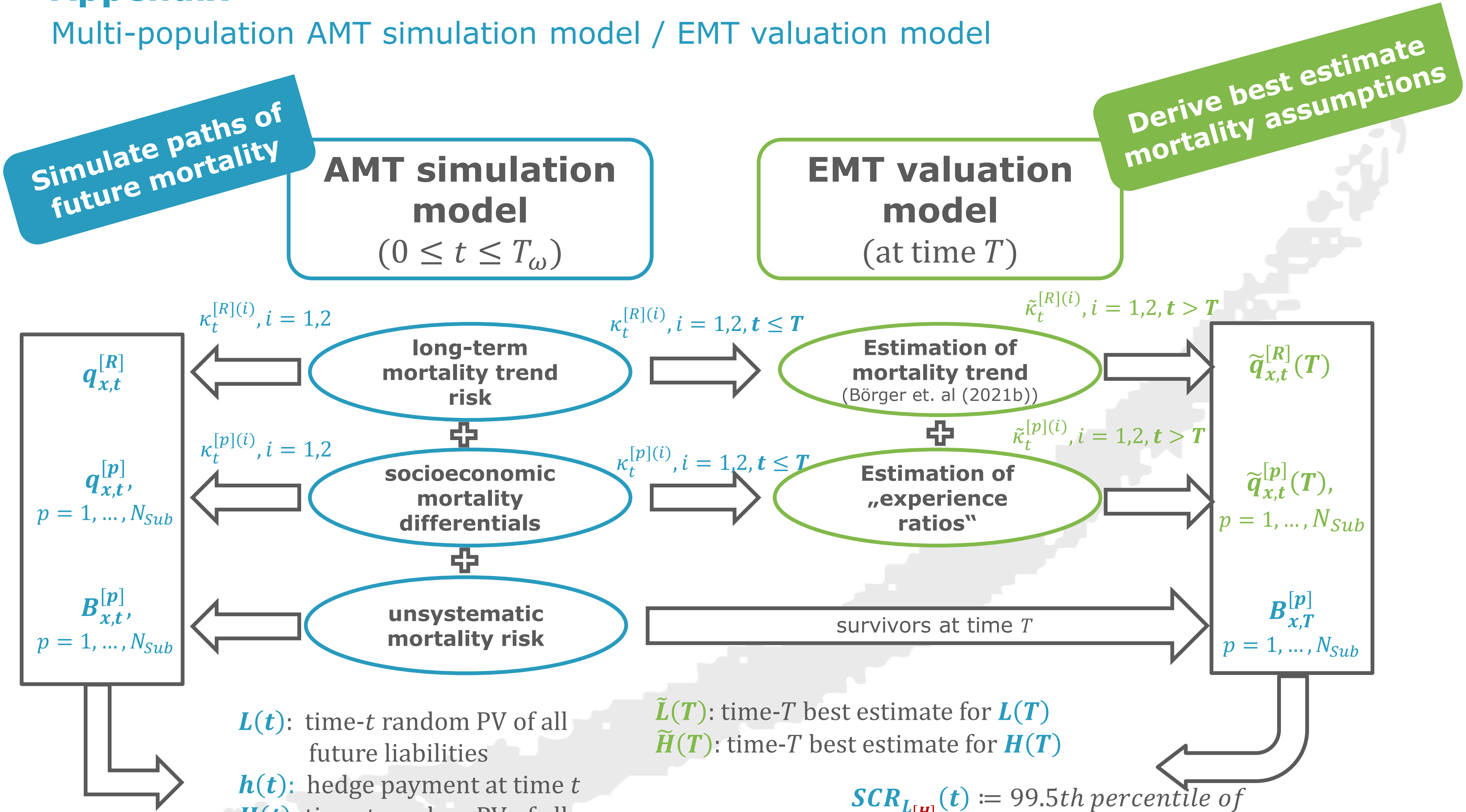
Random walk with drift

$\varepsilon_t^{(i)[p]}$ annual random innovations for subpopulation p

For primary hedger:
Sampling survivors from a **Binomial distribution**

Appendix

Multi-population AMT simulation model / EMT valuation model



$L(t)$: time-t random PV of all future liabilities

$h(t)$: hedge payment at time t

$H(t)$: time-t random PV of all future hedge payments

$\tilde L(T)$: time-T best estimate for $L(T)$

$\tilde H(T)$: time-T best estimate for $H(T)$

$$SCR_{L_{[H]}}(t) := 99.5th\ percentile\ of\ \frac{\tilde L(T+1) + CF(T+1) - [\tilde H(T+1) + h(T+1)]}{1+r} - (\tilde L(T) - [\tilde H(T)])$$

Appendix

Euler allocation & proportionate risk contribution of each individual line of business

- **Marginal Euler allocation principle** (cf. e.g. Rosen & Saunders (2010))

$$EC(t) \coloneqq VaR_{99,5\%}\left(L^L(t) + L^M(t) + L^O(t)\right)$$

$$= \sum_{B \in \{L,M,O\}} a_B \frac{\partial \rho(a_L L^L(t) + a_M L^M(t) + a_O L^O(t))}{\partial a_B}\Big|_{a_L = a_M = a_O = 1} \eqqcolon \widetilde{EC}^L(t) + \widetilde{EC}^M(t) + \widetilde{EC}^O(t)$$

  - Positive homogeneous risk measure $\rho \coloneqq VaR_{99,5\%}$
  - Numerical finite difference approximation

- **Proportionate risk contribution (PRC) of each individual line of business**

$$PRC(B) \coloneqq \frac{E\left(\sum_t (1+r)^{-(t+1)} \widetilde{EC}^B(t)\right)}{E\left(\sum_t (1+r)^{-(t+1)} EC\ (t)\right)}, \qquad B \in \{L, M, O\}$$

- **Resulting PRCs for the three considered reinsurers (aka. stages of the market)**

Size of longevity business	Stage of the market	*PRC(L)*	*PRC(M)*	*PRC(O)*
Small *(S=0)*	Early	0%	38.5%	61.5%
Medium *(S=4)*	Advanced	28.5%	29.0%	42.5%
Large *(S=8)*	Saturated	60.8%	16.9%	22.3%

What we do

Overview

Life

product development
biometric risks
life settlements/TEPs

Non-Life

product design ▪ pricing
reserving ▪ DFA
risk management

Health

actuarial modeling
claims management
portfolio analyses

Actuarial Consulting

Solvency II ▪ embedded value ▪ asset liability management
ERM ▪ value- and risk-based management ▪ data analytics

project management ▪ market entries ▪ inforce management ▪ strategic consulting

Actuarial Services

large-scale actuarial projects ▪ actuarial tests
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Research

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