LMU Ludwig-Maximilians-Universität München

Mortality-Indexed Annuities

Managing Longevity Risk via Product Design

Andreas Richter
Frederik Weber

LIFE Colloquium 2009
München

Agenda

- Introduction: Motivation and Related Research
- Mortality-Indexed Annuities as a Product Design Proposal
- Simulation Framework and Benchmark
- Selected Results
- Conclusion

Motivation – Background

- **Demographic Transition** worldwide phenomenon *(Oeppen/Vaupel, 2002)*
  - Decreasing birth rates *(Berkel et al., 2002)*
    - Reason: Changing societal and family structures
  - Decreasing mortality *(Willets, 1999; Kytir, 2003)*
    - Reason: "better" living, working, environmental conditions; medical advances; health consciousness
- Consequences:
  - Changing age structures (age pyramids) *(Sinn, 2004)*
    - burden for PAYGO social security systems
  - Globally increasing life expectancies *(Vaupel , 1986; Oeppen/Vaupel, 2002)*
    - Societal achievement, also holds **longevity risk**

- **Individual Longevity Risk**
  - Risk of individual deviations of lifetime from average. Sufficient financial means during retirement or post-working ages? *(MacMinn et al., 2006)*
  - Social security tends to provide lower benefits than initially expected *(Schmähl, 2001)*
  - Individuals challenged to adjust long-term saving/consumption to uncertain, longer lifetime *(Bloom et al. , 2001)*; possibly by transferring longevity risk to insurer (life annuity)
- **Aggregate Longevity Risk**
  - Uncertainty regarding correct projection of future average mortality *(Blake/Burrows, 2001)*
  - Strong, worldwide correlation *(Zahn/Henninger, 1942)*; potential for accumulative losses
  - Hardly diversifiable or (re)insurable *(Riemer-Hommel/Trauth, 2005)*

- **Annuity Puzzle**: empirically low demand for life annuities despite theoretical optimality *(Yaari, 1965)*
  - Several explanations exist in literature *(Davidoff et al., 2005; Brown/Orszag, 2006; Van de Wen/Weale, 2006; Schulze/Post, 2006; Milevsky/Young, 2007)*
  - Among others: prices could be too high or perceived to be excessive *(Mitchell et al., 1999; Murthi et al., 1999; Finkelstein/Poterba, 2002)* – partly justified due to strong correlation

- Conservative Pricing
  - Limited by competition, regulation
  - Limited marketability of excessively priced products *(e.g. Mitchell et al., 1999)*

    (⇔ tax advantages and other incentives designed to mitigate insufficient demand)
- Natural Hedging *(Cox/Lin, 2007; Wetzel/Zwiesler, 2008)*
- Securitization
- Leaving the annuity market (?)
- **Modification of actuarial product design**

- **Example:** private health insurance in Germany
  - Design similar to life annuities: recurring, constant premiums; lifelong coverage
  - Policyholders bear systematic risk of increasing health expenditures (**premium adjustments**)

- Also: Transfer of risk successful with respect to investment risk (e.g., unit-linked life insurance/life annuities)

- **Proposal: Mortality-Indexed Annuity (MIA)** as modification of a constant life annuity

  → **New:** adjustments of annuity payments based on **actual** mortality experience: higher/lower portfolio mortality → higher/lower benefits

- **Result**: limited risk for insurer; policyholders' perspective?

Assumptions – Indexed Product

- Immediate annuity sold against (actuarially fair) single premium; constitutes initial per-policy reserve
- Evolution of reserves due to **inheritance effect** and **interest**
- **Annual** adjustments of benefits according to equivalence principle (best estimate of mortality, based on actual **portfolio** experience)
- **Regulatory requirements** neglected
  (taxation, calculation requirements, model choices etc.)
- Further details
  - No period certain
  - Constant interest rate
  - Pure net perspective without costs or expenses; actuarially fair price

Simulation – Model

- **Monte-Carlo simulation** (*N*=10,000 paths)
  - Consider a large portfolio of homogeneous risks over *T* periods
- **General** mortality follows **Lee-Carter model** *(Lee/Carter, 1992; Brouhns et al., 2002)*
- Best estimate of mortality for remaining periods based on Lee-Carter, accounting for mortality **experience.**
- Mortality data of British annuitants, Source: CMI
- Males, initial age x=60, single premium π_0=100,000, contract term T=41 (last payment due on 100th birthday)

Benchmark

- Idea: constant life annuity with guaranteed benefits serves as a benchmark – identical single premium π_0
- Starting point: Initially (t=0), benchmark benefits equal to those from MIA, as calculation based on identical assumptions;

  but: benefits reduced by safety loading (see below)
- Mortality correctly projected **on average**, but subject to **uncertainty**
  - Calculation sufficient **on average**, but underlies **strong fluctuations**
  - Insurer charges **safety loading** to reduce deficit risk to α

Simulation – Benchmark

- Single premium assumed fixed (identical price π_0), **benefits reduced** from FV_0 to FV_0^α to incorporate safety loading
  - Difference accumulated over contract term in order to reduce deficit risk

- Large potential for surplus reserves; increased by safety loading
  - **Pro-rata** surplus share for policyholders
    e.g. ***X*=75%** (in Germany since 2008)

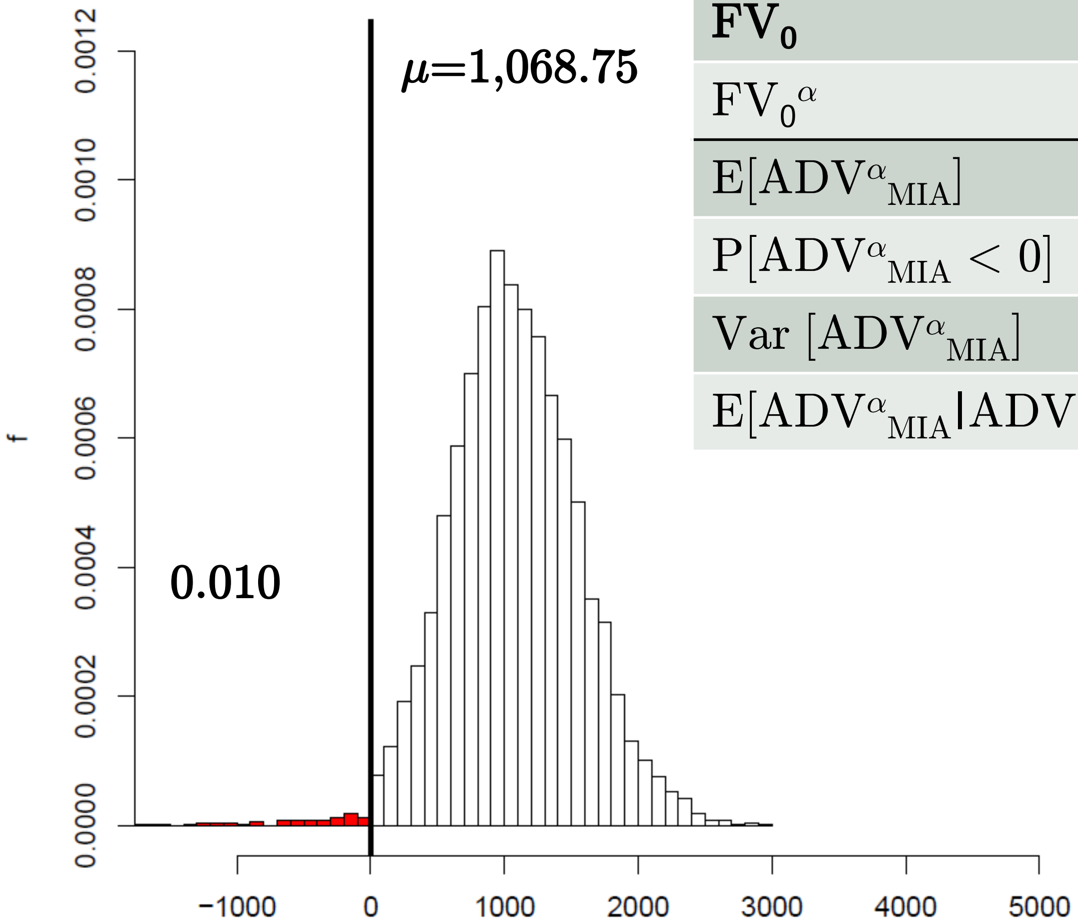
Simulation – MIA Advantageousness

- Measure of “advantageousness”: **actuarial present value** of differences of benefits from both products, subject to **actual** mortality:

$$
\begin{aligned}
ADV_{\mathrm{MIA}}^{\alpha} \;=\; & \sum_{k=0}^{T-1} \left\{ \left(FV_k - FV_0^{\alpha}\right) \cdot {}_k\tilde{p}_x \cdot v^k \right\} \\
& - X \cdot \max\{0; V_{T,\alpha}^{*,\mathrm{conv}}\} \cdot {}_{T-1}\tilde{p}_x \cdot v^{T-1}
\end{aligned}
$$

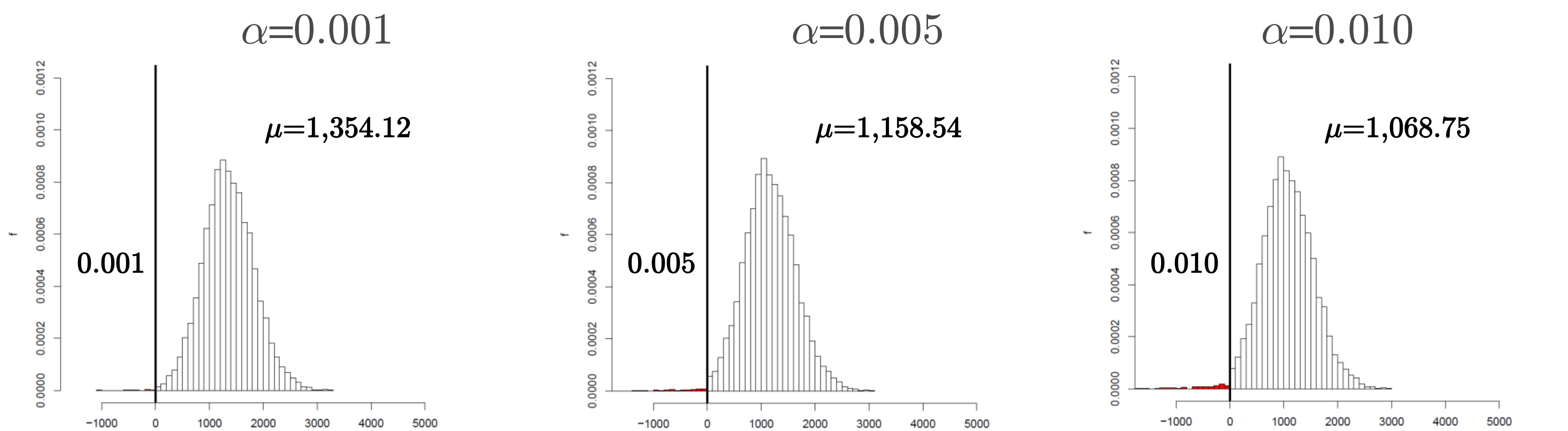
- Consider **empirical distribution/coefficients** of $\mathrm{ADV}^{\alpha}{}_{\mathrm{MIA}}$

Results – i=3%, l_{60}=100,000, α=0.010



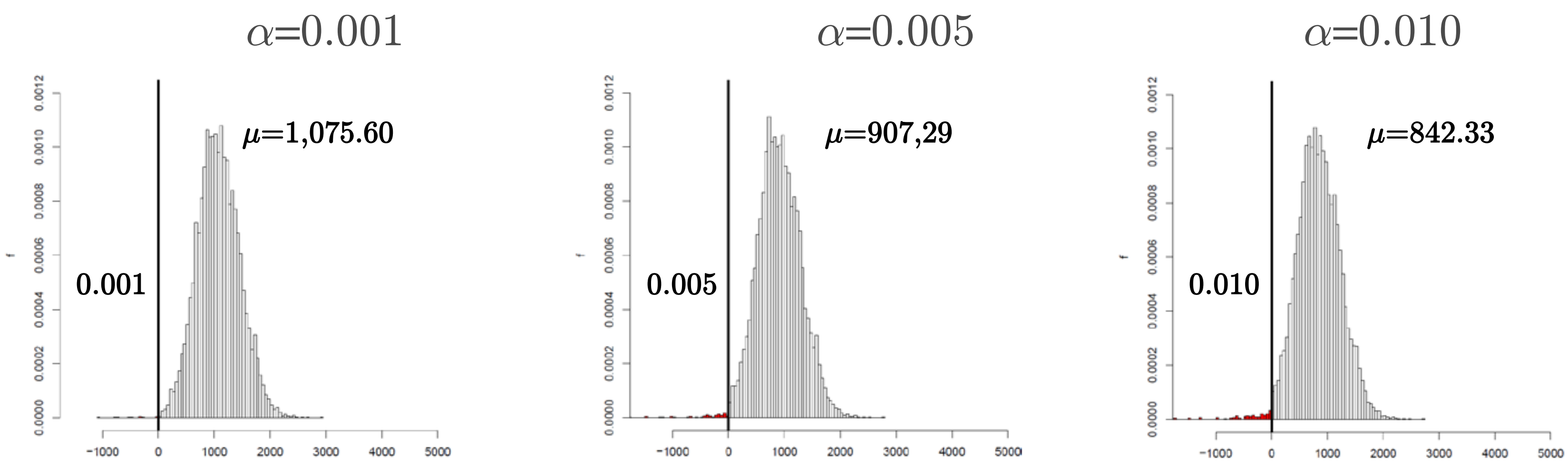
FV_0	**5,631.67**
FV_0^{α}	5,393.50
$E[ADV^{\alpha}_{MIA}]$	1,068.75
$P[ADV^{\alpha}_{MIA} < 0]$	0.010
$Var\ [ADV^{\alpha}_{MIA}]$	238,233.3
$E[ADV^{\alpha}_{MIA} \mid ADV^{\alpha}_{MIA} < 0]$	−520.37

Results – i=3%, l_{60}=100,000



	$\alpha = 0.001$	$\alpha = 0.005$	$\alpha = 0.010$
FV_0		**5,631.67**	
FV_0^{α}	5,330.00	5,373.50	5,393.50
$E[ADV^{\alpha}_{MIA}]$	1,354.12	1,159.54	1,068.75
$P[ADV^{\alpha}_{MIA} < 0]$	0.001	0.005	0.010
$Var\ [ADV^{\alpha}_{MIA}]$	220,915.5	229,915.0	238,233.3
$E[ADV^{\alpha}_{MIA} \mid ADV^{\alpha}_{MIA} < 0]$	−321.29	−492.31	−520.37

Results – i=5%, l_{60}=100,000



	$\alpha = 0.001$	$\alpha = 0.005$	$\alpha = 0.010$
$\mathbf{FV_0}$		**6,975.56**	
$FV_0{}^{\alpha}$	6,679.05	6,725.70	6,743.45
$E[ADV^{\alpha}{}_{MIA}]$	1,075.60	907.29	842.33
$P[ADV^{\alpha}{}_{MIA} < 0]$	0.001	0.005	0.010
$Var\ [ADV^{\alpha}{}_{MIA}]$	142,381.3	147,804.8	152,138.2
$E[ADV^{\alpha}{}_{MIA} \vert ADV^{\alpha}{}_{MIA} < 0]$	−448.61	−413.32	−391.25

Results – i=3%, l_{60}=100,000 vs. 1,000

i=3%, l_{60}=100,000

	$\alpha = 0.001$	$\alpha = 0.005$	$\alpha = 0.010$
FV_0		**5,631.67**	
FV_0^{α}	5,330.00	5,373.50	5,393.50
$E[ADV^{\alpha}_{MIA}]$	1,354.12	1,159.54	1,068.75
$P[ADV^{\alpha}_{MIA} < 0]$	0.001	0.005	0.010
$Var\ [ADV^{\alpha}_{MIA}]$	220,915.5	229,915.0	238,233.3
$E[ADV^{\alpha}_{MIA} \mid ADV^{\alpha}_{MIA} < 0]$	−321.29	−492.31	−520.37

i=3%, l_{60}=1,000

	$\alpha = 0.001$	$\alpha = 0.005$	$\alpha = 0.010$
FV_0		**5,631.67**	
FV_0^{α}	5,285.50	5,334.00	5,358.50
$E[ADV^{\alpha}_{MIA}]$	1,552.15	1,335.36	1,224.22
$P[ADV^{\alpha}_{MIA} < 0]$	0.001	0.005	0.010
$Var\ [ADV^{\alpha}_{MIA}]$	274,235.1	285,507.6	297,112.2
$E[ADV^{\alpha}_{MIA} \mid ADV^{\alpha}_{MIA} < 0]$	−329.35	−501.95	−577.94

Conclusion

- Longevity risk creates highly correlated long-term contractual obligations for insurance companies.
- If longevity risk is considered a severe threat to insurability, alternative product design and risk (re)transfer to policyholders should be considered.
- MIA transfer a significant amount of risk to policyholders, but in return ensure insurability and offer substantial upside potential.
  - Mostly greater annuity payments, expected advantages strictly positive.
  - The more expensive the benchmark, the more advantageous the MIA.
  - The lower the interest rate, the stronger the MIA advantage.
  - A smaller insured portfolio increases the safety loading required by the benchmark product.

Conclusion: Further Research

- Refined actuarial modeling:
  - **Stochastic investment returns** from diversified portfolio
  - **Model uncertainty**: insurer does not know "true nature"
  - Benefit only adjustments beyond certain **thresholds**
  - **Adjustments** to mortality **index** ($\rightarrow$ transparency vs. basis risk)
- Policyholders' **risk aversion**: (transferred) risk vs. (higher) benefits
  $\rightarrow$ more accurate analysis of **risk allocation** effects
- More explicit modeling of defaults

LUDWIG-
MAXIMILIANS-
UNIVERSITÄT
MÜNCHEN

Mortality-Indexed Annuities

Managing Longevity Risk via Product Design

Andreas Richter
Frederik Weber

LIFE Colloquium 2009
München