Modern design of life annuities in view of longevity and pandemics

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Introduction & Motivation – I

Shift from DB to DC schemes

- In many countries (Pillar I and Pillar II)
- Most of the individual longevity and financial risks remain with individuals
- Individuals need to take decisions regarding their post-retirement income

Introduction & Motivation – II

A number of post-retirement income products/arrangements

With different types and levels of guarantees

- Traditional, immediate life annuities
  - Longevity guarantee (lifelong payment) & financial guarantee (fixed or minimum annual amount)
- Variable annuities
  - Several guarantees available, typically financial
- Delayed and contingent life annuities (e.g., ALDA, RCLA)
  - Longevity guarantee at older ages only, possibly contingent on adverse scenarios
- *Mortality/longevity-linked life annuities*
  - Longevity risk sharing within an annuity, with partial guarantees
- Group Self-Annuitization (GSA), pooled annuities and tontine arrangements
  - Longevity risk sharing within a pool, without guarantees
- Self-annuitization (Income drawdown)
  - No guarantee

Introduction & Motivation – III

The annuity puzzle

- Under given assumptions, standard annuities represent the optimal post-retirement income solution ([Yaari, 1965])
- However: The annuity market is little (all over the world)

There is room for innovative solutions

In particular: Trade-off between cons & pros of annuities, in particular in view of the mortality/longevity dynamics

The standard longevity guarantee – I

Lifelong payment (fixed or minimum annual amount)

- Independent of: Individual's lifetime & average lifetime of the population (& returns on investments)
- Relying on mortality credits, whose amount is guaranteed

From the point of view of the provider

- $\underbrace{\text{Idiosyncratic}}_{\text{✌ } minor}$ & $\underbrace{\text{aggregate}}_{\text{📢 } major}$ longevity risk
- Long-term exposure to risk
- Pricing assumptions, and other aspects of the annuity design, chosen at issue, without following updates

➔ Loadings

➔ Inflexible benefits (apart from participation to extra-returns)

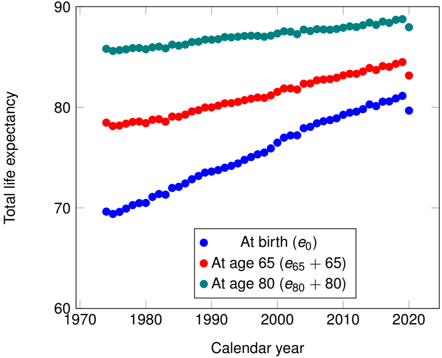
The standard longevity guarantee – II

From the point of view of the individual

- 👍 Lifelong protection, guaranteed annual (minimum) amount
- 👎 No bequest (mortality credits)
- 👎 Irreversible decision
- 👎 Illiquid asset for the individual
- 👎 Perceived to be expensive
- 👎 Further downside: Possible mortality shocks

The mortality/longevity dynamics

The (total) life expectancy (Italy, males. Source: ISTAT)



What's next?

A possible solution reconciling the (different) requirements of individuals and providers – I

Relax guarantees on mortality credits

☞ *Mortality/longevity-linked annuity benefits*

- The benefit amount is allowed to fluctuate (down or up), depending on a given mortality/longevity experience
- Guarantees are not (necessarily) excluded (for example: a minimum benefit amount)

A possible solution reconciling the (different) requirements of individuals and providers – II

Benefit at time t

$$b_t = b_{t-1} \cdot \text{adj}_{(t-1,t)} \qquad \text{every year}$$

or

$$b_t = b_0 \cdot \text{adj}_{(0,t)} \qquad \text{every year}$$

or

$$b_t = b_{t-k} \cdot \text{adj}_{(t-k,t)} \qquad \text{every } k \text{ years}$$

- $\text{adj}_{(t-1,t)}$, $\text{adj}_{(0,t)}$, $\text{adj}_{(t-k,t)}$: Adjustment coefficients at time t, expressing a mortality/longevity experience, respectively in $(t-1, t)$, $(0, t)$ or $(t-k, t)$

State of the art – I

Self-insured arrangements

- Group Self-Annuitization (GSA), pooled annuities and tontine arrangements
- They rely on mortality credits, which are not guaranteed
- Literature
  GSA: [Piggott et al., 2005], [Valdez et al., 2006], [Bravo et al., 2009], [Qiao and Sherris, 2013], [Boyle et al., 2015]
  Pooled annuities: [Stamos, 2008], [Donnelly et al., 2013], [Donnelly et al., 2014], [Donnelly, 2015]
  Tontine arrangements: [McKeever, 2009], [Baker and Peter Siegelman, 2010], [Sabin, 2010], [Milevsky, 2014], [Milevsky and Salisbury, 2015], [Milevsky and Salisbury, 2016], [Chen et al., 2019], [Weinert and Gründl, 2020]

State of the art – II

Insurance-based arrangements

- Mortality/longevity-linked life annuities
- Partially guaranteed mortality credits
- Literature
  [Lüthy et al., 2001], [de Melo, 2008], [Denuit et al., 2011], [Richter and Weber, 2011], [Maurer et al., 2013], [Denuit et al., 2015], [Weale and van de Ven, 2016], [Bravo and de Freitas, 2018], [Olivieri and Pitacco, 2020a], [Olivieri and Pitacco, 2020b]

To define the adjustment coefficient

We need

1. A mortality/longevity experience/index
2. Quantities recording the longevity experience

Alternatives

	Portfolio/Indemnity-based	*Index-based*
Number of survivors or Survival rates (observed vs expected)	In the portfolio	In a reference population
Actuarial quantities	Required portfolio reserve vs Available assets	Actuarial value of the annuity with updated life tables

Indemnity vs index-based solutions

- Portfolio/pool experience
  - Indemnity-based solution
  - No basis risk for the provider
  - Subject to random fluctuations
  - Possibly subject to manipulations (or perceived as such)
  - Natural choice in self-insured arrangements
- Experience of a reference population
  - Index-based solution
  - Basis risk for the provider
  - Less subject to random fluctuations
  - Perhaps more trusted, as it is measured by an independent institution
  - Appropriate choice in insured arrangements
- (Projected) Life table
  - Index-based solution
  - Less subject to random fluctuations

Mortality/Longevity-linked annuity benefits

A general definition

$$b_t = b_{t-1} \cdot \underbrace{\frac{1+g_t}{1+i(\tau)}}_{\substack{\text{Return} \\ \text{on investments}}} \cdot \underbrace{\frac{p_{x+t-1}(\tau)}{\tilde{p}_{x+t-1}}}_{\text{Survival rate}} \cdot \underbrace{\frac{1+a_{x+t}(\tau)}{1+a_{x+t}(\tau')}}_{\substack{\text{Actuarial value} \\ \text{of the annuity}}}$$

- A life annuity immediate. One cohort. Entry time: 0. Entry age: x
- Technical basis (benchmark) chosen/revised at time τ, $0 \le \tau \le t-1$
- g_t: Realized financial return in year $(t-1, t)$
- $i(\tau)$: Interest rate based on best-estimate assumptions at time τ
- $p_{x+t-1}(\tau)$: Survival rate based on the best-estimate assumptions at time τ

  ➔ *benchmark survival rate*
- $\tilde{p}_{x+t-1}$: Realised survival rate in year $(t-1, t)$, in a given population
- $a_{x+t}(\tau)$, $a_{x+t}(\tau')$: Actuarial value at time t of a unitary annuity, based on the best-estimate assumptions at time τ (τ'), $0 \le \tau \le t-1$, $0 \le \tau' \le t$)

  ➔ $a_{x+t}(\tau)$: *benchmark annuity value*

How to get there – I

Recursion for the reserve in year $(t-1, t)$ ... (One policy, in-force at time $t-1$)

... According to the reserving basis at time $t-1$

$$\overbrace{b_{t-1} \cdot a_{x+t-1}(\tau)}^{\text{Reserve at time } t-1} \cdot (1 + i(\tau)) = \underbrace{b_{t-1} \cdot (1 + a_{x+t}(\tau)) \cdot p_{x+t-1}(\tau)}_{\text{Payment + Reserve at time } t \text{, if alive}}$$

- Reserving basis chosen at time τ, $0 \leq \tau \leq t-1$

How to get there – II

However

- If there is a financial linking: the return assigned to the reserve in year $(t-1, t)$ is g_t (hopefully, higher than $i(\tau)$)
- If there is a longevity linking:
  - The survival rate is measured in a chosen population (either the portfolio or a reference population) $\Rightarrow \tilde{p}_{x+t-1}$ instead of $p_{x+t-1}(\tau)$

  or
  - The reserving basis in the actuarial value of the annuity at time t is updated to a later time $\tau' \Rightarrow a_{x+t}(\tau')$ instead of $a_{x+t}(\tau)$, $\tau \leq \tau' \leq t$

Then

The actuarial balance is kept by adjusting the benefit amount to b_t

How to get there – III

Actuarial balance in year $(t-1, t)$ ... (One policy, in-force at time $t-1$)

... in terms of the conditions applied to the annuitant

$$\underbrace{\overbrace{b_{t-1} \cdot a_{x+t-1}(\tau)}^{\text{Reserve invested at time } t-1} \cdot (1+g_t)}_{\text{"Assets" at time } t} = \underbrace{b_t \cdot (1 + a_{x+t}(\tau')) \cdot \tilde{p}_{x+t-1}}_{\text{Payment + Reserve at time } t \text{, if alive}}$$

☞ $b_t \gtreqless b_{t-1}$

How to get there – IV

Benefit at time t

$$b_t = b_{t-1} \cdot \frac{\overbrace{a_{x+t-1}(\tau) \cdot (1+g_t)}^{\text{Available assets}}}{\underbrace{(1 + a_{x+t}(\tau')) \cdot \tilde{p}_{x+t-1}}_{\text{(Payment +) Required reserve}}}$$

- Typical structure in self-insured arrangements or when no guarantee is provided (e.g., GSA)

How to get there – V

Equivalently: Benefit at time t

$$b_t = b_{t-1} \cdot \underbrace{\frac{1+g_t}{1+i(\tau)}}_{\substack{\text{Return} \\ \text{on investments}}} \cdot \underbrace{\frac{p_{x+t-1}(\tau)}{\tilde{p}_{x+t-1}}}_{\text{Survival rate}} \cdot \underbrace{\frac{1+a_{x+t}(\tau)}{1+a_{x+t}(\tau')}}_{\substack{\text{Actuarial value} \\ \text{of the annuity}}}$$

- Appropriate structure in insured arrangements
- In this case, it is also appropriate to link the adjustment only to the survival rate or only to the actuarial value of the annuity $\Rightarrow$ Some risk is retained by the provider
- Guarantees can be introduced by setting minimum / maximum values for the benefit amount the adjustment coefficients, the items of the adjustment coefficient, . . .

Targets of a mortality/longevity-linking arrangement

For the provider

- Default probability
- Business value
- Deviations in annual payouts and annual profits wrt a target
- Portfolio reserve vs available assets
- ...

For the individual

- Fees
- Longevity guarantee
  - Duration of the annuity
  - Stability of the path of the benefit amounts
- Flexibility
- ...

Some results – I

Basic parameters

- One cohort
- Initial age: $x = 65$. Maximum attainable age: $\omega = 100$
- No financial return, no financial risk (and no financial linking)
- Annuity immediate
- Stochastic mortality rate
- Premium loading charged at issue only

Some results – II

Arrangements

- Fixed benefit
- GSA arrangement
- Linking based on the survival rates
  - Mortality experience measured in a reference population (index-based linking)
  - Benchmark survival rate: either the best-estimate at time 0 or the latest best-estimate (time $t-1$)
  - Maximum age for benefit adjustment: $x_{\max} = 95$
  - Maximum reduction of the benefit amount (in respect of the initial amount): 25%
  - No uplift in respect of the initial benefit
- Linking based on the actuarial value of the annuity
  - Benchmark actuarial value: either the best-estimate at time 0 or the latest best-estimate (time $t-1$)
  - Other conditions as above
- Adjustment every $k = 1, 3, 5$ years

Some results – III

Premium loading

- Assessed such that the provider's probability of loss is 10%, excluding basis risk

  (the premium loading is then expressed as a % of the actuarial value of a unitary annuity, based on the best-estimate assumption at time 0)

Benefit type		Moderate longevity risk	Major longevity risk
FB	Fixed benefit	1.731%	5.647%
L-SP$(t-k), k=1$	Survival rate (Benchmark: BE k years before)	1.654%	5.472%
L-SP$(t-k), k=3$	Adjustment every k years	1.572%	5.158%
L-SP$(t-k), k=5$		1.481%	4.848%
L-AV$(t-k, t), k=1$	Actuarial value (Benchmark: BE k years before)	0.092%	0.219%
L-AV$(t-k, t), k=3$	Adjustment every k years	0.185%	0.539%
L-AV$(t-k, t), k=5$		0.293%	0.892%
L-SP$(0), k=1$	Survival rate (Benchmark: BE at time 0)	0.052%	0.169%
L-SP$(0), k=3$	Adjustment every k years	0.227%	0.714%
L-SP$(0), k=5$		0.384%	1.208%
L-AV$(0, t), k=1$	Actuarial value (Benchmark: BE at time 0)	-0.034%	-0.136%
L-AV$(0, t), k=1$	Adjustment every k years	0.017%	-0.027%
L-AV$(0, t), k=1$		0.144%	0.404%
GSA	Group Self-Annuitization	0.000%	0.000%

Some results – IV

Present Value of Future Profits and Business Value

- Annual profits are discounted in a market-consistent manner (in practice, in this implementation no discounting, as the interest rate is set to 0)
- $\mathrm{PVFP}_0^{[\mathrm{ben}]}$: from the benefit adjustment
- $\mathrm{PVFP}_0^{[\mathrm{res}]}$: from the need to update the reserve (including the reserving basis)
- $\mathrm{PVFP}_0^{[\mathrm{load}]}$: from the premium loading
- BV_0: PVFP net of the cost of capital (assessed in a market-consistent logic $\rightsquigarrow$ frictional costs)

Some results – V

- Moderate longevity risk, no basis risk

Arrangement	$PVFP_0$	$PVFP_0^{[ben]}$	$PVFP_0^{[res]}$	$PVFP_0^{[load]}$	BV_0
		(as a % of the expected value of $PVFP_0$)			
FB	1.677	– 0.198%	– 1.288%	101.486%	75.787%
L-SP$(t-k)$, $k=1$	1.656	0.071%	1.659%	98.270%	76.281%
L-SP$(t-k)$, $k=3$	1.595	0.123%	2.850%	97.028%	76.841%
L-SP$(t-k)$, $k=5$	1.529	0.224%	4.399%	95.376%	77.285%
L-AV$(t-k,t)$, $k=1$	0.674	4.216%	82.258%	13.526%	96.542%
L-AV$(t-k,t)$, $k=3$	0.683	3.841%	69.297%	26.862%	93.697%
L-AV$(t-k,t)$, $k=5$	0.737	3.450%	57.164%	39.385%	90.945%
L-SP(0), $k=1$	0.553	9.634%	80.957%	9.409%	97.766%
L-SP(0), $k=3$	0.672	7.330%	59.129%	33.541%	92.243%
L-SP(0), $k=5$	0.779	5.841%	45.184%	48.974%	88.717%
L-AV$(0,t)$, $k=1$	0.557	5.098%	100.996%	– 6.094%	96.151%
L-AV$(0,t)$, $k=3$	0.551	5.036%	91.878%	3.085%	96.733%
L-AV$(0,t)$, $k=5$	0.620	4.325%	72.532%	23.143%	94.392%

Some results – VI

- Major longevity risk, no basis risk

Arrangement	$PVFP_0$	$PVFP_0^{[ben]}$	$PVFP_0^{[res]}$	$PVFP_0^{[load]}$	BV_0
		(as a % of the expected value of $PVFP_0$)			
FB	5.131	– 0.149%	– 4.251%	104.400%	74.507%
L-SP$(t-k)$, $k=1$	5.052	– 0.044%	– 2.809%	102.853%	74.824%
L-SP$(t-k)$, $k=3$	4.856	0.046%	– 1.126%	101.080%	75.269%
L-SP$(t-k)$, $k=5$	4.663	0.171%	0.707%	99.122%	75.776%
L-AV$(t-k,t)$, $k=1$	1.794	4.551%	83.475%	11.973%	97.046%
L-AV$(t-k,t)$, $k=3$	1.951	4.102%	68.780%	27.118%	93.708%
L-AV$(t-k,t)$, $k=5$	2.166	3.675%	55.988%	40.337%	90.924%
L-SP(0), $k=1$	1.645	10.021%	79.858%	10.121%	83.096%
L-SP(0), $k=3$	2.010	7.612%	57.524%	34.864%	82.373%
L-SP(0), $k=5$	2.336	6.071%	43.368%	50.561%	82.571%
L-AV$(0,t)$, $k=1$	1.661	5.492%	102.543%	– 8.035%	97.669%
L-AV$(0,t)$, $k=3$	1.585	5.638%	96.018%	– 1.656%	98.549%
L-AV$(0,t)$, $k=5$	1.827	4.738%	73.512%	21.750%	94.537%

Summary

- We address annuity designs in which the benefit is updated to the mortality/longevity experience
- A general framework provides several particular cases
- Experiences available in self-insured arrangements (GSA, tontines) support this kind of solutions
- Empirical investigations suggest that individuals might accept the chance of a benefit reduction in the future, if rewarded with a higher initial annuity rate (i.e., lower premium loading)
- Possible profit sharing, in case of a mortality shock
- Critical issues:
    - Individual preferences and demand issues
    - Cost of capital and value created for the provider
    - Pricing of the guarantees
    - Timing of the fees: Upfront vs periodic fees
    - Choice of the mortality model
    - Solidarity effects, in case of a heterogeneous population
    - . . .

Many thanks for your kind attention!

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