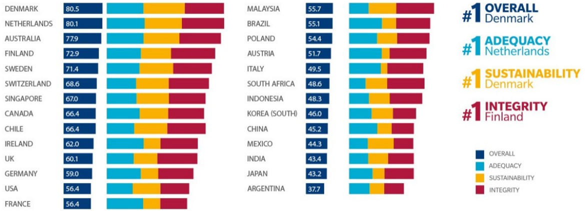
The impact of unforeseen longevity updates on guarantees: An analysis of choice and products

Anne Balter & Malene Kallestrup-Lamb & Jesper Rangvid

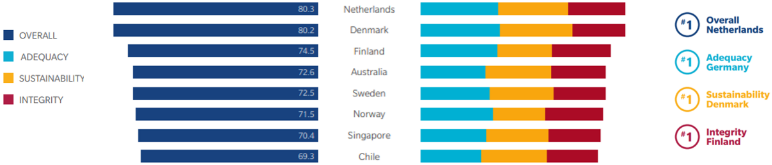
Longevity 15
Washington DC
September 12, 2019

Motivation

- The Dutch and the Danish pension systems are referred to as “the best in the world”
  - How can they maintain this position in the future?
  - Mercer 2017



  - Mercer 2018



Motivation

- Measured in relation to GDP, private pension savings in The Netherlands and Denmark are the largest in the world.
  - Despite large pension savings, both the Danish and the Dutch pension systems face challenges to honour promised (or guaranteed) pensions
    - Current low-interest rate environment
    - Increasing life-expectancy (in particular unexpected increases)
    - Fulfilment of Solvency II capital requirements.
- This paper focuses on the shift from "safe" to "risky" pension products in Denmark.
  - Moving from fixed annuities (guaranteed) to variable (unguaranteed) pension products.
  - Extension of variable annuity model by including longevity.

Denmark - 95% DC

- The majority of products in Denmark have historically included a guaranteed annual return based on a minimum guaranteed interest rate.
  - i.e. the contributions were guaranteed to increase by a certain minimum return.
  - Interest guarantees between 0% and 4.5%.
- When interest rates are low, pension guarantees force pension companies to invest mainly in safe assets, in order to fulfill guarantees in DC schemes.

Denmark

- Within the last 8 years the majority of the pension funds in Denmark have moved form from guaranteed fixed annuities to unguaranteed variable annuities.
  - Some pension funds made a collective decision to transfer all policyholders to zero interest guarantees.
  - Other funds (Danica, PFA and JØP) offered the policyholders the option to decide for themselves whether they wanted to give up their interest guarantees or not.
- Policyholders were financial compensated and thus their individual pension savings accounts increased significantly.
  - However certain conditions applied.

Outline and literature

- Outline
  - Empirical case study on choice
  - Theoretical model of products
- Literature
  - Survey or empirical data on pension choices on annuitization versus lump sum: Beshears et al. (2014); Brown (2001); Mottola and Utkus (2007); Bütler and Teppa (2007)
  - Guarantees and financial risk: extended literature (e.g. Bauer et al. (2008)), CPPI
  - Guarantees and micro: Chen et al. (2015) study expected utility comparison of guarantees with micro longevity risk
  - Pension and micro: Donnelly et al. (2013) measure implied costs of longevity hedge by pooled annuity funds without guarantees and with micro longevity risk
  - Macro longevity risk: Richards et al. (2014), De Waegenaere et al. (2018), Broeders et al. (2019) measure trend risk (and sharing) and Piggott et al. (2005) investigate differences between expected and actual payments in group self annuitizations, also model updates in annuity factors

JØP case study

- The Danish pension fund JØP, already offered their policyholder to relinquish their interest rate guarantees in 2007.
- The members have been offered different levels of guarantees depending on the date of admission.

Date of Admission	Level of Guarantee
Before 1st January 1990	3.70% or 4.25 %
1st January – 31st December 1996	3.70%
1st January 1997 – 30th June 1999	3.00%
1st July 1999 – 1st July 2005	2.00%
From 1st July 2005	0.00%

Summary statistics

Variable	Mean	Std. Dev.			
			Region		
Election Outcome	17.9%	38.3%	Copenhagen	50.6%	50.0%
			Greater Copenhagen	9.0%	28.6%
General			Zealand & Falster	8.5%	27.9%
Male	56.2%	49.6%	Funen & Islands	4.0%	19.6%
Married	65.4%	47.6%	South Jutland	3.5%	18.3%
Retired	5.7%	23.2%	West Jutland	3.0%	17.0%
			Central Jutland	11.2%	31.6%
Age			North Jutland	4.4%	20.6%
Between 20 and 29	3.7%	18.9%	Other Region	5.8%	23.5%
Between 30 and 39	38.4%	48.6%			
Between 40 and 49	27.5%	44.7%	**Level of Guarantee**		
Between 50 and 59	18.1%	38.5%	2%	31.9%	46.6%
Between 60 and 65	8.3%	27.7%	3%	11.8%	32.3%
Between 66 and 69	2.0%	14.0%	3.70%	25.8%	43.8%
Between 70 and 100	2.0%	14.0%	4.25%	30.5%	46.0%
Education			**Level of Pension Wealth**		
Economics	15.7%	36.4%	$<$ 100,000	16.4%	37.0%
Political Science	19.3%	39.5%	100,000-400,000	32.1%	46.7%
Law	33.8%	47.3%	400,001-800,000	22.1%	41.5%
Business Economics	12.9%	33.5%	800,001-2,000,000	21.2%	40.9%
Other Education	18.3%	38.6%	$>$ 2,000,000	8.1%	27.3%

Probit

- Let $Y = \begin{cases} 1 & \text{if switched to unguarantee} \\ 0 & \text{if kept guarantee} \end{cases}$ be the "Election Outcome" for an individual.
- The probability of an individual switching is described by the probit model

$$P(Y = 1|X) = \Phi(\beta_0 + \beta X)$$

where Φ is the standard normal CDF, X explanatory variables.

- Average marginal effects are given by

$$\frac{\partial P(Y = 1|X)}{\partial X_i} = \phi(\beta_0 + \beta X)\beta_i$$

where ϕ is the standard normal PDF.

Results from probit estimation

Number of obs	31,497						
Pseudo R2	16.96%						
	dy/dx	Std.Err.	$P > \|z\|$	**Region**			
				Greater Copenhagen	-1.73%	0.76%	2.2%
General				Zealand & Falster	-3.34%	0.78%	0.0%
Male	2.72%	0.41%	0.0%	Funen & Islands	-1.29%	1.06%	22.3%
Married	-0.87%	0.43%	4.2%	South Jutland	-3.29%	1.19%	0.6%
Retired	-11.35%	4.14%	0.0%	West Jutland	-4.41%	1.25%	0.0%
				Central Jutland	0.17%	0.65%	79.1%
Age				North Jutland	-3.80%	1.01%	0.0%
Between 30 and 39	-6.05%	0.91%	0.0%	Other Region	-6.33%	0.92%	0.0%
Between 40 and 49	-15.31%	1.02%	0.0%				
Between 50 and 59	-30.64%	1.33%	0.0%	**Level of Guarantee**			
Between 60 and 65	-39.21%	2.26%	0.0%	3%	-5.49%	0.64%	0.0%
Between 66 and 69	-33.26%	4.07%	0.0%	3.70%	-8.13%	0.68%	0.0%
Between 70 and 100	-38.50%	7.82%	0.0%	4.25%	-12.40%	1.15%	0.0%
Education				**Level of Pension Wealth**			
Political Science	-1.40%	0.64%	2.9%	100,000-400,000	6.27%	0.58%	0.0%
Law	-4.85%	0.63%	0.0%	400,001-800,000	8.35%	0.76%	0.0%
Business Economics	-5.79%	0.72%	0.0%	800,001-2,000,000	6.28%	1.05%	0.0%
Other Education	-4.75%	0.71%	0.0%	>2,000,000	0.69%	2.19%	75.2%

Results from a mid-sized pension fund

- Analysed which person specific characteristics would make it more likely to relinquish the guarantee.
  - If you are male, living in the city, or have moderate pension wealth it will increase the probability of giving up the interest rate guarantee.
  - Individuals with higher levels of guarantees, above the age of 50 or retired, significantly decreases the probability of relinquishing the guarantee.
  - We find no effect on the decision from Marital status.

Choice

- Between which two products did the pension holders actually have to choose?
  - Guaranteed pension product
    - No longevity risk
    - No complete freedom on investment strategy
  - Unguaranteed pension product
    - Longevity risk for pension holder
    - Complete freedom on investment strategy

Figure: Guarantee

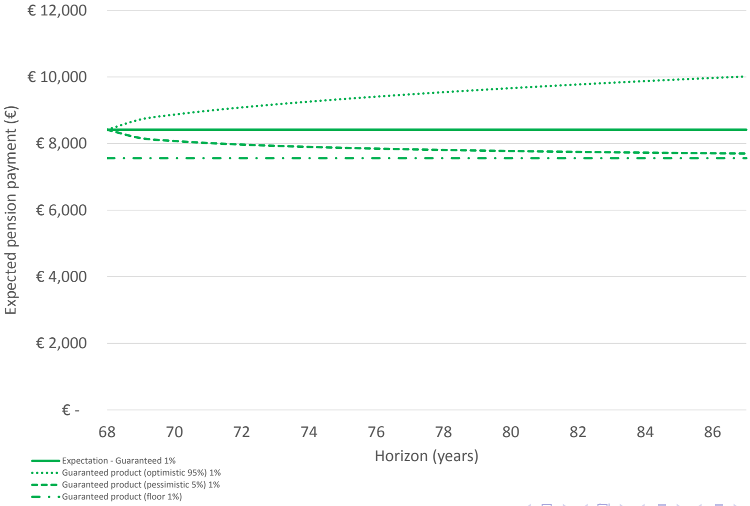


Figure: Non-guarantee

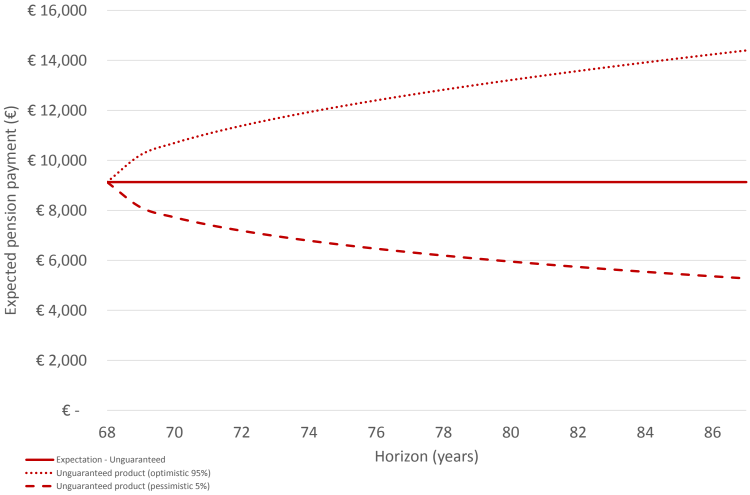
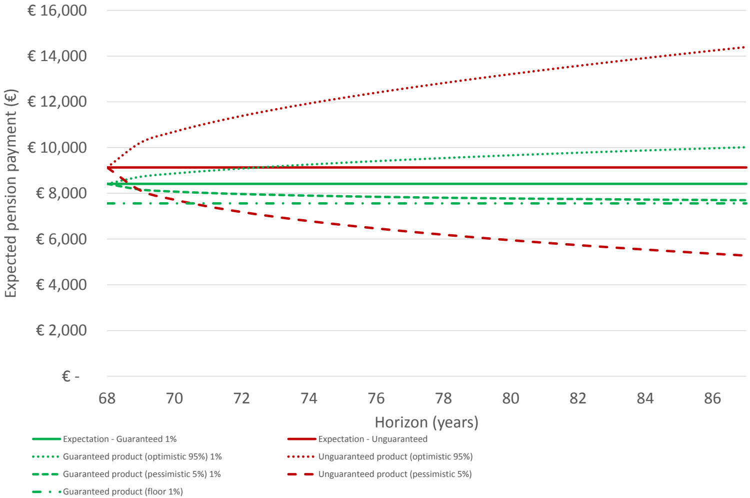


Figure: Non-guarantee and guarantee



Model

- Black-Scholes/Merton economy
- We consider a risk-free bank/money market account

$$\mathrm{d}M_t = r_f M_t \mathrm{d}t.$$

- And a risky asset that follows a Geometric Brownian Motion

$$\begin{aligned} \mathrm{d}S_t &= \mu S_t \mathrm{d}t + \sigma S_t \mathrm{d}Z_t \\ &= (r_f + \lambda\sigma) S_t \mathrm{d}t + \sigma S_t \mathrm{d}Z_t, \end{aligned}$$

- where μ stands for the expected return, σ is the stock volatility, $\lambda = (\mu - r_f)/\sigma$ is the Sharpe ratio, and Z is a standard Brownian motion on the probability space $(\Omega, \mathcal{F}, \mathbb{P})$.

Model

- Consider a pension holder who enters retirement with total wealth W_t at time t and needs to finance a lifelong stream of annual pension payments.
- We divide the total pension wealth W_t into separate buckets, where each bucket $(W_t(h))$ is used to finance the pension payment in one future year (h).
- The budget constraint implies

$$W_t = \sum_{h \geq t} W_t\left(h\right).$$

- We now consider what happens in case each of the buckets is partly invested in the risky asset S_t and the remainder on the risk-free bank account.

$$\mathrm{d}W_t\left(h\right) = \left(r_f + \overbrace{w_t}^{w} \lambda\sigma\right) W_t\left(h\right)\mathrm{d}t + \overbrace{w_t}^{w} \sigma W_t\left(h\right)\mathrm{d}Z_t.$$

Biometric return

- Biometric return, also called mortality credit or survivor credit, is the return due to the incorporation of mortality risk.

$$e^{(h-t)r^{b}_{x,t}(h)} = \frac{1}{{}_{h-t}p_{x,t}},$$

where ${}_{h-t}p_{x,t}$ is the probability that a person aged x in year t survives at least to the year h.

- The positive biometric return is received by the pension holders without any risk.
- Micro longevity risk is carried by the pension providers.
- Thus including survival probabilities implies that an individual can allocate less wealth to each bucket because there is a probability that he might not survive.

Expectation

Proposition (Expected return)

When reserving and investing $W_t(h)$ at time t to the pension payment for year h, its expectation with respect to stock market risk including the biometric return are given by

$$\mathbb{E}_t\left[W_h(h)\right] = \frac{W_t(h)\, e^{(h-t)(r_f+w\lambda\sigma)}}{{}_{h-t}p_{x,t}} = W_t(h)\, e^{(h-t)\left(r_f+w\lambda\sigma+r^b_{x,t}(h)\right)}.$$

- We allocate the pension wealth to each bucket in such a way (via the AIR) that the expected pension payments are all the same.

Expectation

Proposition (Variable annuity)

A life-long variable annuity with a investment exposure of w and a prevailing risk-free rate of r, pays out the following constant expected pension payments

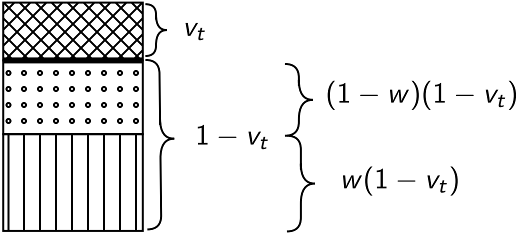
$$\mathbb{E}_t\left[W_h(h)\right] = W_t(t),$$

for all $h > t$, equal to

$$W_t^{r,w}(t) = \frac{W_t}{\sum_{k\geq t} e^{-(k-t)(r+w\lambda\sigma)}\,{}_{k-t}p_{x,t}} = \frac{W_t}{\sum_{k\geq t} e^{-(k-t)\left(r+w\lambda\sigma+r^b_{x,t}(k)\right)}}.$$

Guaranteed pension product

- Guaranteed rate is r_g
- Hedge demand v in invested on M to ensure the floor
- Speculative demand (remainder) $1 - v$ is risky, can be invested in M and S and is a bonus



The thick black line indicates that there is no continuous rebalancing between those sections.

Guaranteed pension product

Proposition (Guaranteed pension product)

If vW_t is invested in the money market and on a separate account $(1-v)W_t$ is invested in a rebalanced portfolio, then the pension payments are at least equal to the guaranteed payments based on r_g, when

$$v_t = \frac{W_t^{r_g,0}(t)}{W_t^{r_f,0}(t)} = \frac{\sum_{k\geq t} e^{-(k-t)r_f}\,{}_{k-t}p_{x,t}}{\sum_{k\geq t} e^{-(k-t)r_g}\,{}_{k-t}p_{x,t}} = \frac{\sum_{k\geq t} e^{-(k-t)\left(r_f+r^b_{x,t}(k)\right)}}{\sum_{k\geq t} e^{-(k-t)\left(r_g+r^b_{x,t}(k)\right)}}.$$

- Requirement $r_g < r_f$.

Unguaranteed pension product

- Macro longevity risk is borne by pension holder
- In expectation no unforeseen deviations in surival forecasts
- In practice, mortality tables are updated leading to unexpected shocks in the expected pension payments.
- We model the unforeseen deviations by ${}_{k-t}d_{x,t} = \ln\left(\frac{{}_{k-t}\tilde{p}_{x,t}}{{}_{k-t}p_{x,t}}\right)$

Unforeseen changes in life expectancies

Table: Unforeseen increases in life expectancy

data\conditional	2008	2011	2014	2017
2007	15y4m	12y5m	9y8m	7y3m
2010		13y8m	10y8m	8y2m
2013			12y3m	9y4m
2016				10y7m

Unguaranteed pension product

Proposition (Unguaranteed pension product)

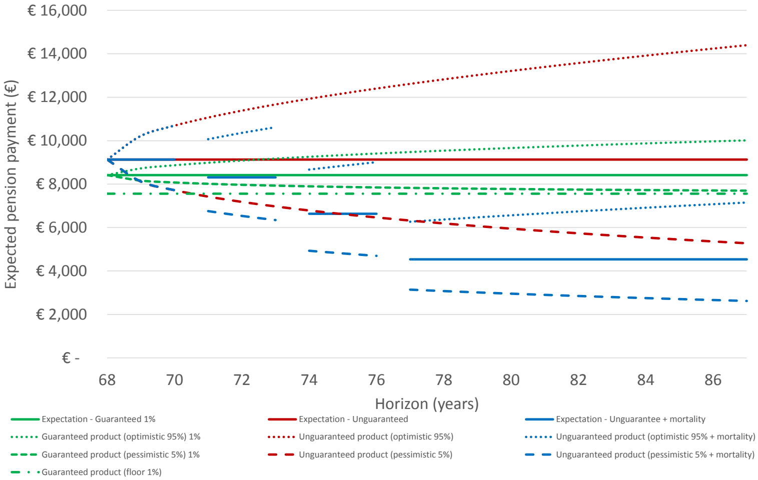
An update of survival forecasts from ${}_{k-t}p_{x,t}$ to ${}_{k-t}\tilde{p}_{x,t}$ for all $k \geq t$, x and t changes the expectations and quantiles of the pension payments by a shock equal to

$$\frac{\sum_{k\geq t} e^{-(k-t)(r_f+w\lambda\sigma)}\,{}_{k-t}p_{x,t}}{\sum_{k\geq t} e^{-(k-t)(r_f+w\lambda\sigma)}\,{}_{k-t}\tilde{p}_{x,t}} = \frac{\sum_{k\geq t} e^{-(k-t)(r_f+w\lambda\sigma)}\,{}_{k-t}p_{x,t}}{\sum_{k\geq t} e^{-(k-t)\left(r_f+w\lambda\sigma-\frac{{}_{k-t}d_{x,t}}{k-t}\right)}\,{}_{k-t}p_{x,t}} = \frac{\sum_{k\geq t} e^{-(k-t)\left(r_f+w\lambda\sigma+r^b_{x,t}(k)\right)}}{\sum_{k\geq t} e^{-(k-t)\left(r_f+w\lambda\sigma+\tilde{r}^b_{x,t}(k)\right)}}.$$

Parameters

- Risk-free rate $r_f = 2\%$, a guaranteed return $r_g = 1\%$, expected excess return $\mu - r_f = \lambda = 4\%$, volatility $\sigma = 20\%$, initial pension wealth $W_t = 100,000$, risk exposure (unguarantee) $w = 35\%$, risk exposure (guarantee) $w = 100\%$.
- The guarantee and first 3 years of the expected pension payments of the unguarantee are based on the mortality table forecasts (Lee-Carter) with data from 1978 to 2007, while the three updates are based on a rolling window of 3 years ahead each based on Danish data for males.

Figure


€ 16,000
€ 14,000
€ 12,000
€ 10,000
€ 8,000
€ 6,000
€ 4,000
€ 2,000
€ -
Expected pension payment (€)
68
70
72
74
76
78
80
82
84
86
Horizon (years)
Expectation - Guaranteed 1%
Expectation - Unguaranteed
Expectation - Unguarantee + mortality
Guaranteed product (optimistic 95%) 1%
Unguaranteed product (optimistic 95%)
Unguaranteed product (optimistic 95% + mortality)
Guaranteed product (pessimistic 5%) 1%
Unguaranteed product (pessimistic 5%)
Unguaranteed product (pessimistic 5% + mortality)
Guaranteed product (floor 1%)

Conclusion

- We find that the higher the guaranteed rate of return, the larger the fraction of pension savings that need to be invested in the risk-free asset.
- This causes expected pension payments to be lower when guarantees are higher.
- However, as there is no hedge against unforeseen increases in longevity in unguaranteed pension products, expected pension payments in unguaranteed pension products will be negatively affected by macro longevity improvements.
- Expected pensions might even be lower in unguaranteed products when there are frequent and large improvements to longevity.

Policy and future research

- The risk transfer of financial and longevity risk significantly adds to the complexity of the pension product. The leads to an increase in the required degree of financial literacy of the individual, if the individual should be able to optimally plan and prepare for retirement.
- Furthermore, as the longevity risk is transferred to the pension holder in the unguaranteed product, a natural demand for hedging this risk arises. This calls for the creation of a liquid and transparent market for individualistic longevity products.
- Future research: Quantification of the implied longevity hedge measured by the compensation.

Bauer, D., Kling, A., and Russ, J. (2008). A universal pricing framework for guaranteed minimum benefits in variable annuities. *ASTIN Bulletin*, 38(2):621–651.

Beshears, J., Choi, J. J., Laibson, D., Madrian, B. C., and Zeldes, S. P. (2014). What makes annuitization more appealing? *Journal of Public Economics*, 116:2–16.

Broeders, D., Mehlkopf, R., and van Ool, A. (2019). The economics of sharing macro-longevity risk. *De Nederlandsche Bank Working Paper No. 618*.

Brown, J. R. (2001). Private pensions, mortality risk, and the decision to annuitize. *Journal of Public Economics*, 82(1):29–62.

Bütler, M. and Teppa, F. (2007). The choice between an annuity and a lump sum: Results from Swiss pension funds. *Journal of Public Economics*, 91(10):1944–1966.

Chen, A., Hentschel, F., and Klein, J. K. (2015). A utility-and CPT-based comparison of life insurance contracts with guarantees. *Journal of Banking & Finance*, 61:327–339.

De Waegenaere, A., Joseph, A., Janssen, P., and Vellekoop, M. (2018). Het delen van langlevenrisico. *Netspar Industry Paper*.

Donnelly, C., Guillén, M., and Nielsen, J. P. (2013). Exchanging uncertain mortality for a cost. *Insurance: Mathematics and Economics*, 52(1):65–76.

Mottola, G. R. and Utkus, S. P. (2007). Lump sum or annuity? An analysis of choice in DB pension payouts. *Vanguard Center for Retirement Research*, 30(89):2.

Piggott, J., Valdez, E. A., and Detzel, B. (2005). The simple analytics of a pooled annuity fund. *Journal of Risk and Insurance*, 72(3):497–520.

Richards, S. J., Currie, I., and Ritchie, G. (2014). A Value-at-Risk framework for longevity trend risk. *British Actuarial Journal*, 19(1):116–139.