Macro Longevity Risk and the Choice between Annuity Products: Evidence from Denmark

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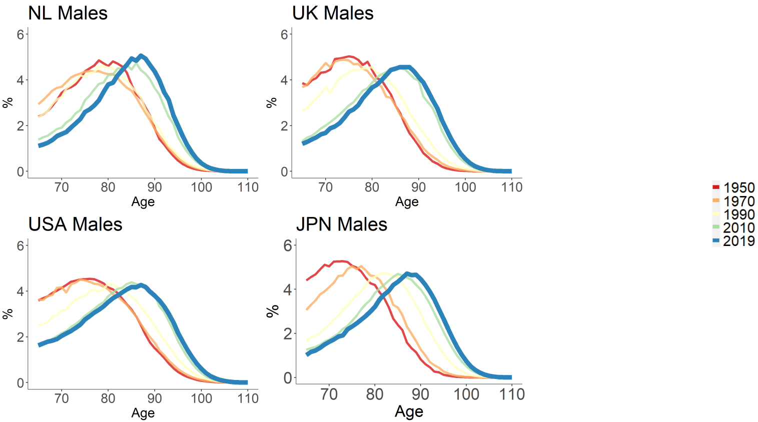
Introduction

- Pension systems worldwide are challenged by:
    - Historical low interest levels
    - Systematic increases in life expectancy
    - Fulfillment of Solvency II capital requirements
- Additionally, a global transition/ shift is observed
    - As we go from defined-benefit schemes (DB)
    - To defined-contribution schemes (DC)

Motivation

- All conditional death distributions point towards increased median age of death

Figure: Distribution of deaths conditional on reaching age 65 for males



Longevity risk definition

- The literature separates longevity risk into:
  1) Idiosyncratic (micro) longevity risk
     - Risk of individual living longer (or shorter) than forecast
     - Diversifiable for large pools (seen from pension provider)
  2) Systematic (macro) longevity risk
     - Risk that the life expectancy of the population as a whole increases (or decreases) unexpectedly → Non-diversifiable risk
     - Present when updating mortality tables

Motivation

- We focus on the decision between two pension products that differ in their exposure to systematic (macro) longevity risk.
  - Resembles the decision between a DB-type and a DC-type product
  - Denmark as a case study with a unique data set
- The question, therefore, is: How can we best estimate the market value of the pension products, taking into account systematic (macro) longevity risk?

Table: Unforeseen increases in remaining life expectancy

	NL Males					USA Males	UK Males	JPN Males
Fitting Period / Conditional	2008	2011	2014	2017	2020	2020	2020	2020
2007	16y1m	13y4m	10y7m	7y10m	5y1m	6y1m	5y9m	7y4m
2010		14y5m	11y8m	9y0m	6y3m	7y1m	6y7m	7y8m
2013			12y8m	9y11m	7y2m	7y9m	7y5m	8y3m
2016				10y9m	8y0m	8y6m	8y5m	9y2m
2019					9y1m	9y6m	9y6m	10y2m

Note: Individuals are 65 years old in 2007.

- Biffis and Blake (2009) find that an additional year of life expectancy at age 65 increases the PV of UK pension liabilities by, at least, 3%.
- How can we measure unexpected increases?

Aim

- To quantify the compensation needed to be indifferent between:
  1) Going from a DB-type product with
     - No longevity risk (borne by provider)
     - Guaranteed payments in retirement
     - Limited financial risk
  2) To a DC-type product with
     - Longevity risk (borne by pension holder)
     - Variable payments in retirement
     - Financial risk
  - Extend the DC-type product to include the modelling of macro longevity risk

Literature

- Managing macro-longevity risk
  - Richards, Currie and Ritchie (2014) disentangle many types of risk (model risk, basis risk, trend risk, volatility, idiosyncratic risk, mis-estimation risk) and model the one-year ahead risk
  - De Waegenaere, Melenberg and Markwat (2017) re-estimate best estimates based on one-year forecasts of LC and show that the impact on value of pension annuities is age dependent.
  - Broeders, Mehlkopf and van Ool (2021) combine stochastic variation, parameter risk (re-estimation) and model risk and focus on intergenerational risk-sharing.
- Uncertainty within LC
  - Dees, de Jong and Nijman (2021) look at quantiles within LC and argues the risk is negligible compared to financial risk.

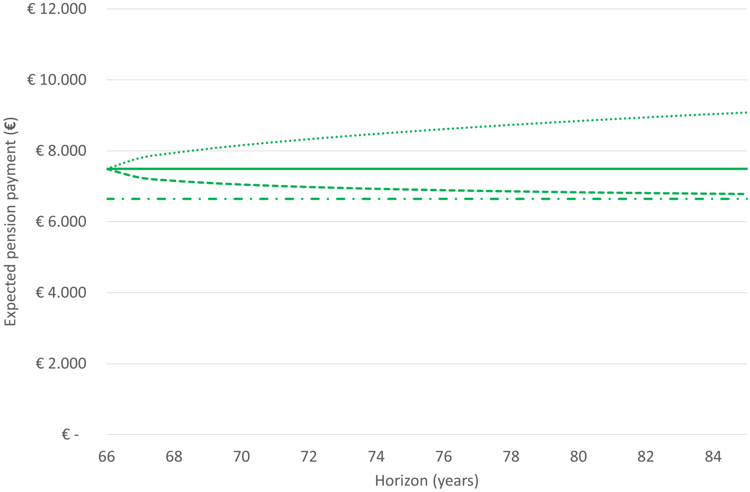
Literature

- Collective sharing of macro longevity risk
  - Piggott, Valdez and Detzel (2005) investigate group self-annuitization (GSA) in which the annuitants bear their systematic risk, but the pool shares idiosyncratic risk. CEA_t is the changed expectation adjustment factor measuring the change in mortality expectations
  - Boon, Brière and Werker (2020) find that individuals prefer to bear the risk under a collective arrangement than to insure it with a life insurers' annuity contract subject to insolvency risk.
- No consensus on how to quantify the macro longevity risk

Ex post

- Before we address the ex ante longevity risk, we take a closer look at the ex post risk, by
    - Examining the unforeseen increases in life expectancy (recall Table)
- Still leaves us with the question of how to model future macro longevity risk

Figure: DB-type product



$r_f = 2\%, r_g = 1\%, \mu - r_f = \lambda = 4\%, \sigma = 20\%, W_t = 100,000, w_u = 35\%, w_g = 100\%$

Figure: DC-type product

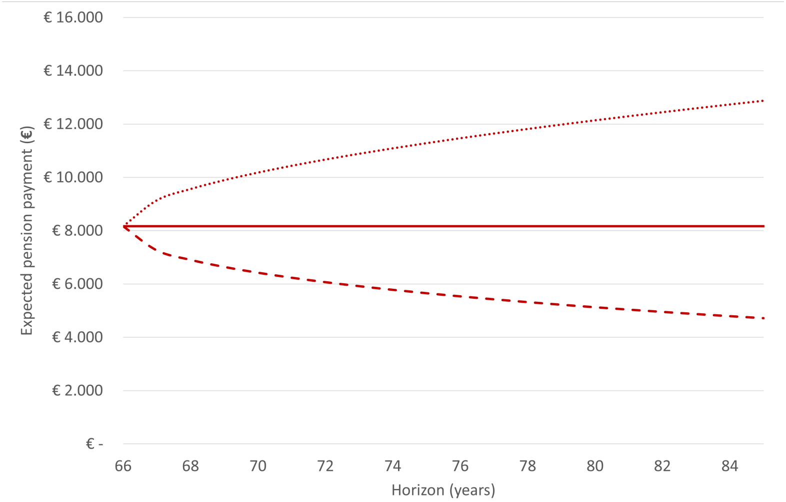
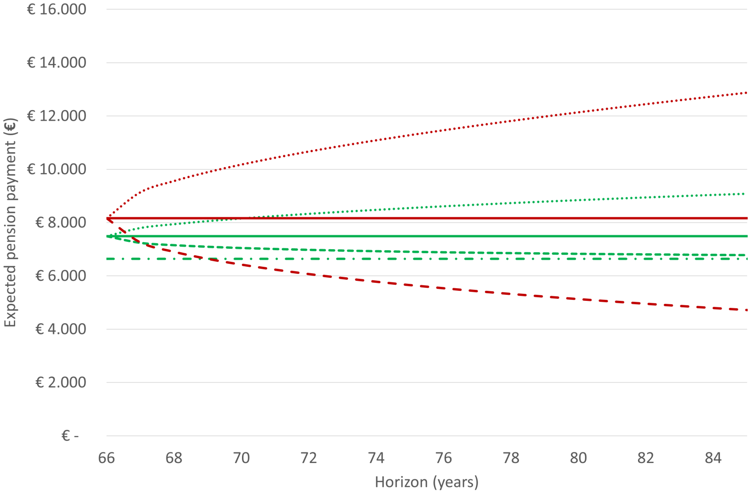


Figure: Both products



Unforeseen increase in remaining life expectancy

Table: Unforeseen increases in remaining life expectancy

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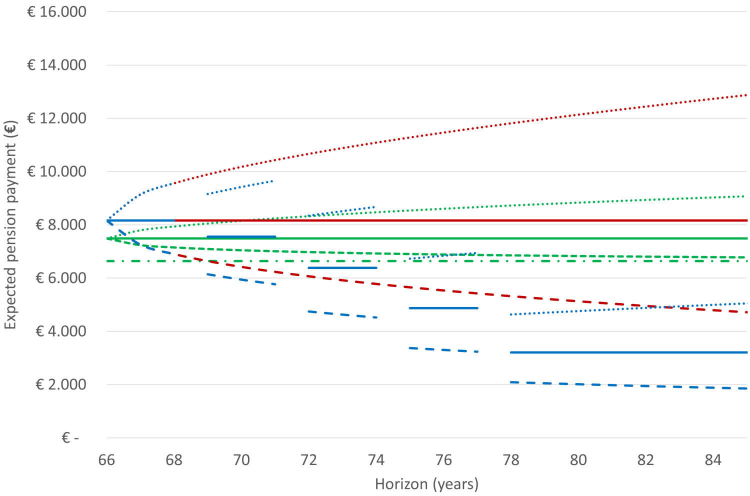
2016				10y9m	8y0m
2019					9y1m

$\}$ 4y0m

Figure: Both products including longevity risk



Ex ante

- Ex post longevity risk is shown to affect pension payments in retirement
- We want to quantify the ex ante macro longevity risk and propose to
    - Examine historical deviation rates in forecasts as new data become available
    - The future is highly uncertain - Utilize the ex post risk in combination with simulated mortality rates, to address the paths and risk of future updates
- Our work is most similar to Boon, Brière and Werker (2020), but differs by:
    - Type of products (Longevity risk, Financial Risk, Equityholders)
    - Modelling of macro longevity risk (Historical deviations, Simulation)

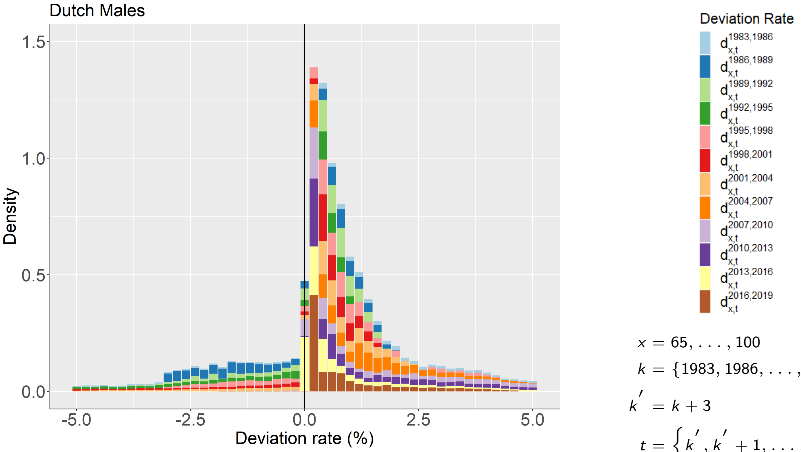
Historical deviation rates in forecasts

- Let ${}_{h-t}p_{x,t}^{k}$ be the probability forecast that an individual of age x in year t survives further $h-t$ years according to some mortality model (e.g. standard Lee-Carter)
  - Based on data between $[k-R,k]$, with R being the rolling estimation window
- Let ${}_{h-t}p_{x,t}^{k'}$ be the same but based on data between $\left[k'-R,k'\right]$
- The deviation rate is then defined as

$$ {}_{h-t}d_{x,t}^{k,k'} = log\left(\frac{{}_{h-t}p_{x,t}^{k'}}{{}_{h-t}p_{x,t}^{k}}\right) \tag{1}$$

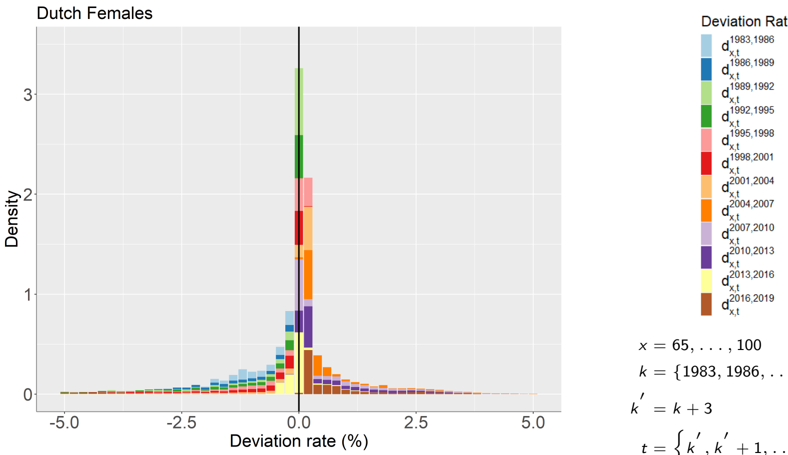
$\rightarrow {}_{h-t}d_{x,t}^{k,k'} > 0$ tells us that the new survival probability forecast has increased

Empirical distribution of historical deviation rates



$$
\begin{aligned}
x &= 65, \ldots, 100 \\
k &= \{1983, 1986, \ldots, 2016\} \\
k' &= k + 3 \\
t &= \left\{k', k' + 1, \ldots, k' + T\right\} \\
T &= 100,\ h - t = 1,\ R = 30
\end{aligned}
$$

Empirical distribution of historical deviation rates



$$x = 65, \ldots, 100$$

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$$t = \left\{k', k' + 1, \ldots, k' + T\right\}$$

$$T = 100,\ h - t = 1,\ R = 30$$

Simulating future mortality rates

- Use the LC model

$$ln(m_{x,t}) = \alpha_x + \beta_x \kappa_t + \epsilon_{x,t} \tag{2}$$

- Model κ_t as a random walk with a drift

$$\kappa_t = c + \kappa_{t-1} + \delta_t \tag{3}$$
$$\delta \sim \mathbb{N}(0, \hat{\sigma}_\delta^2)$$

- Simulate I paths of future mortality rates by first

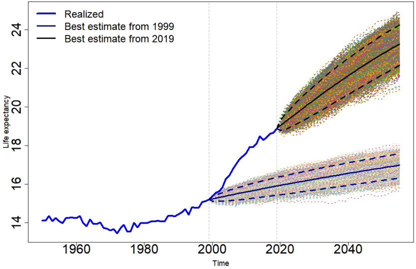
$$\hat{\kappa}_{t+h} = (h-t)\hat{c} + \kappa_t + \sum_{i=1}^{h} \delta_{t+i} \tag{4}$$

- As a last step, plug equation (4) in (2) to get future mortality rates

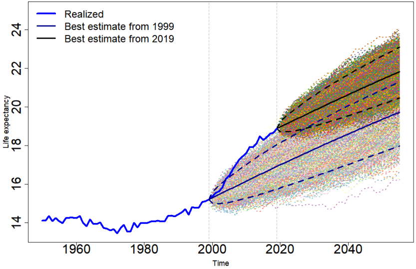
Illustration of simulation

- What happens when we simulate the future based on different data periods?

NL Males



NL Females



Case study - Denmark

- We have access to a unique data set on Danish individuals
    - Individuals were offered to switch products and be compensated
        - Between 20-50% of pension wealth in compensation
        - Value of hedge against macro longevity risk not included
    - Balter, Kallestrup-Lamb and Rangvid (2021) examine the decision of individuals
        - Being a male, living in the city, or having a moderate pension wealth increased the probability of switching products
        - High levels of guarantees (up to 4.25%), above the age of 50, or retired decreases the probability

Conclusion

- Ex post impact of macro longevity risk has shown to be large compared to financial risk.
- Importance increasing because of trend towards individual contracts in which longevity risk is explicitly borne by the individual - communication purposes.
  - Chile's transition from DB-type product to DC-type product.
- Future research:
  - Quantify risk in utility framework
  - Examine the difference between theoretical compensation and the empirical using our unique data set

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