Addressing Life Expectancy Gap in Pension Policy

Jorge M. Bravo[1] Mercedes Ayuso [2] Robert Holzmann[3]

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[1]Universidade Nova de Lisboa & BBVA Pensions Institute (jbravo@novaims.unl.pt)
[2]University of Barcelona
[3]Academy of Sciences (Vienna), CEPAR & IZA & CESifo.

Outline

1. Introduction & Motivation
2. Life expectancy gap concept
3. Ensemble methods
4. Research Design
5. Results
6. Final remarks

Introduction & Motivation

- Increased longevity is one of the biggest challenges to both public and private DC or DB pension schemes
- In recent decades most OECD countries have implemented pension reforms in which a common denominator is to create an automatic link of future pensions to changes in life expectancy
- The link between life expectancy and pension benefits has been accomplished by (Ayuso, Bravo & Holzmann, 2018):
  - introducing an automatic link between life expectancy and pension benefits, e.g., through demographic sustainability factors (FIN, POR, ESP)
  - by linking the normal retirement age to life expectancy (e.g., Denmark, Italy, the Netherlands, Portugal)
  - by connecting years of contributions needed for a full pension to life expectancy (Portugal and Spain)
  - by linking penalties (bonuses) for early (late) retirement to years of contributions and normal retirement age
  - by substituting traditional NDB public schemes by NDC schemes (e.g.

Introduction & Motivation

- In almost all cases and countries, period and not cohort life expectancy measures have been used to link longevity and pension benefits, which results in
  - underestimating remaining lifetime at retirement,
  - incorrectly signalling solvency and delaying pension reforms,
  - sizable implicit subsidy rates between current and future generations
  - an unfair actuarial link between contributions and benefits, which distorts labor supply and saving decisions
- Reference longevity measures tipically correspond to life expectancies as published by national statistical offices or on the basis of the records of the Social Security Agencies

Introduction & Motivation

- For pension schemes the issue of the correct estimation of the future life expectancy is further complicated by empirical evidence showing that longevity improvements are not homogenous across socioeconomic groups (disaggregated by age, gender, education, income, marital status) and that the mortality gradient is even expanding (e.g., Ayuso, Bravo & Holzmann, 2017a,b; National Academies of Sciences, Engineering, and Medicine, 2015; Alonso-García et al., 2019; Palmer & Zhao de Gosson de Varenes, 2019; Jijiie et al., 2019; Alaminos & Ayuso, 2019)

- ...translating into an implicit tax/subsidy that risks perverting the redistributive objectives of pension schemes and invalidating the closer contribution-benefit link of current reform approaches

Welfare-enhancing Redistributive Mechanisms in pension schemes

- Three main mechanisms of mandated pension schemes are typically considered to redistribute income in a welfare-enhancing manner: redistribution of income
  - Redistribution across Lifecycles and Generations, optimizing consumption across the lifecycle
  - Redistribution from the Lifetime Rich to the Lifetime Poor (e.g., through differentiated accrual rates, uprating mechanisms, replacement rates)
  - Redistribution through Risk Pooling, offering a mechanism that addresses the uncertainty of death; i.e., the provision of a lifetime annuity
    - If all individuals have the same life expectancy across the lifecycle, an annuity has no ex-ante distribution if actuarially fair annuities are provided

Life expectancy gap

- Ayuso, Bravo and Holzmann (2019), defined the concept of life expectancy gap, $\dot{e}_x^{Gap}(t)$, as the difference between cohort $\dot{e}_x^{C}(t)$ and period $\dot{e}_x^{P}(t)$ life expectancy at age x in year t,

$$\dot{e}_x^{Gap}(t) = \dot{e}_x^{C}(t) - \dot{e}_x^{P}(t) \quad (1)$$

  and expressed it in terms of the Lee-Carter (LC) stochastic mortality model
- The authors empirically show that period life expectancies at retirement age can be up to two years lower when compared to those derived from cohort tables in countries such as Spain and Portugal (and even higher in other countries), but methodological differences require further research to have a comprehensive measure of the implicit tax/subsidies
- To quantify the magnitude of $\dot{e}_x^{Gap}(t)$, period and cohort life expectancy must be estimated using stochastic mortality models

Ensemble methods

- In this paper we use ensemble methods combining Generalised Age-Period-Cohort Stochastic Mortality Models to forecast future mortality rates of all 42 HMD countries
- Ensemble learning methods train several baseline models and use rules to combine them together to make predictions
- The performance of a particular learner depends on how effective its searching strategy is in approximating the optimal predictor defined by the true data generating distribution (van der Laan et al., 2007)
- When compared to a single model, ensemble learning has demonstrated to improve traditional and machine learning forecasting results in multiple areas
- Offers a common basis for studying all countries and allows us to account for both model risk and forecasting uncertainty.
- Mortality forecasts are then used to quantify the magnitude of $\dot{e}_x^{Gap}(t)$ by age, gender and across years, and to measure the implicit intergenerational subsidy rates

Stochastic mortality models

- Lee-Carter model under a Poisson setting (Brouhns et al., 2002)

$$\eta_{x,t} = \alpha_x + \beta_x^{(1)} \kappa_t^{(1)} \tag{2}$$

- Age-Period-Cohort (APC) model (Currie, 2006)

$$\eta_{x,t} = \alpha_x + \kappa_t^{(1)} + \gamma_{t-x} \tag{3}$$

- Renshaw and Haberman (2003) model

$$\eta_{x,t} = \alpha_x + \beta_x^{(1)} \kappa_t^{(1)} + \beta_x^{(0)} \gamma_{t-x} \tag{4}$$

- Two factor CBD model (Cairns et al., 2006)

$$\eta_{x,t} = \kappa_t^{(1)} + (x - \bar{x}) \kappa_t^{(2)} \tag{5}$$

Stochastic mortality models

- Quadratic CBD model with cohort effects (Cairns et al., 2009)

$$\eta_{x,t} = \kappa_t^{(1)} + (x - \bar{x})\,\kappa_t^{(2)} + \left((x - \bar{x})^2 - \sigma\right)\kappa_t^{(3)} + \gamma_{t-x} \qquad (6)$$

- Plat (2009) model

$$\eta_{x,t} = \alpha_x + \kappa_t^{(1)} + (x - \bar{x})\,\kappa_t^{(2)} + (\bar{x} - x)^+\,\kappa_t^{(3)} + \gamma_{t-x} \qquad (7)$$

- We adopted the usual assumptions regarding the distribution of $D_{x,t}$ (Poisson, Binomial), the linear predictor, the link function (log, logit), the set of parameter constraints and the time series methods for forecasting model parameters
- All models were fitted in the age range 60-95 and the Denuit & Goderniaux (2005) closing method with $\omega = 125$ was used to complete life tables

Accuracy of forecasting prediction

- We determine which models received a greater or lesser weight in the final projections based on performance in projecting holding data in the following steps
- In step 1, we measured the performance of projections from individual models for each country and subpopulation (male, female, total)
- We carry out a back testing exercise in the spirit of Dowd et al. (2010) and Haberman et al. (2014) and used the projection bias in mortality rates as the metric to measure projection error

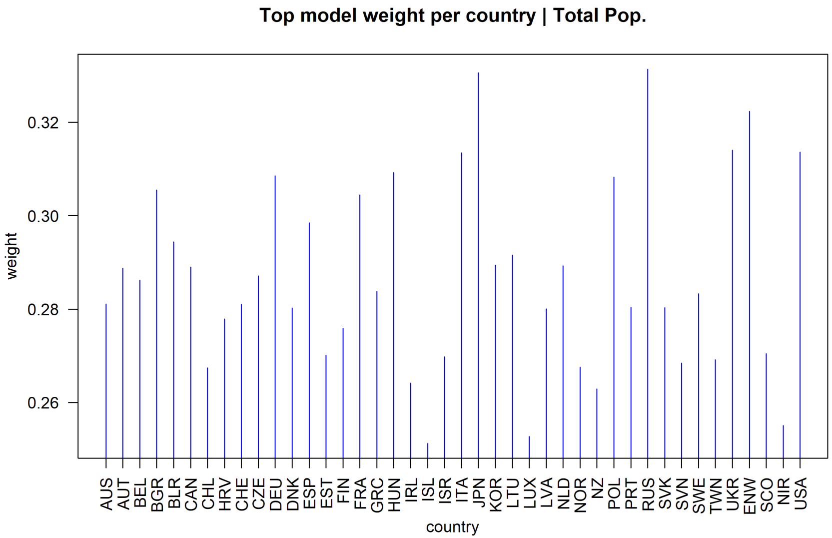
Accuracy of forecasting prediction

- In step 2, we calculated model weights such that models with smaller bias were assigned larger weights, with the weights decaying exponentially as the magnitude of the projection bias increased

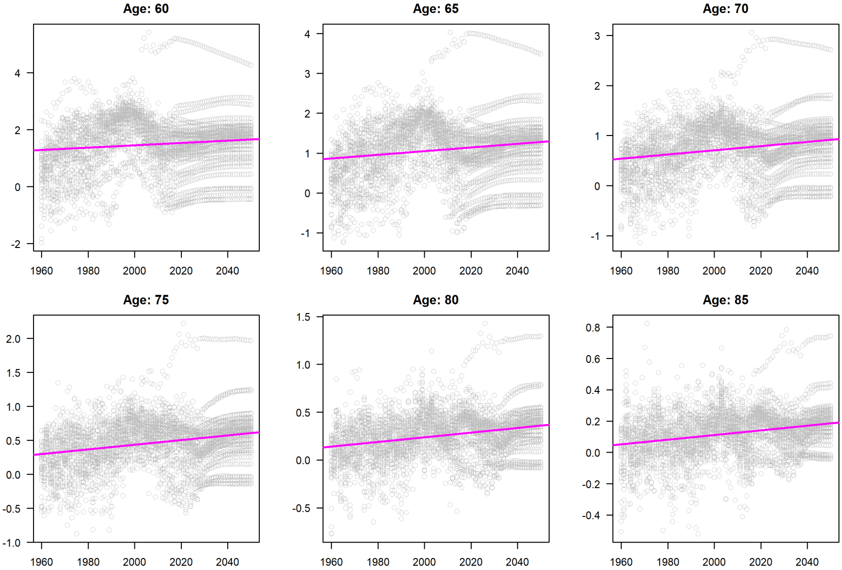
$$w_i = \frac{\exp\left(-\left|\text{Projection bias}\right|_{\text{model } i}\right)}{\sum_{i=1}^{n} \exp\left(-\left|\text{Projection bias}\right|_{\text{model } i}\right)}$$

- In step 3, we calculated the final projections
- We used HMD data from 1960 (or later if unavailable) for each country and sex to estimate model parameters

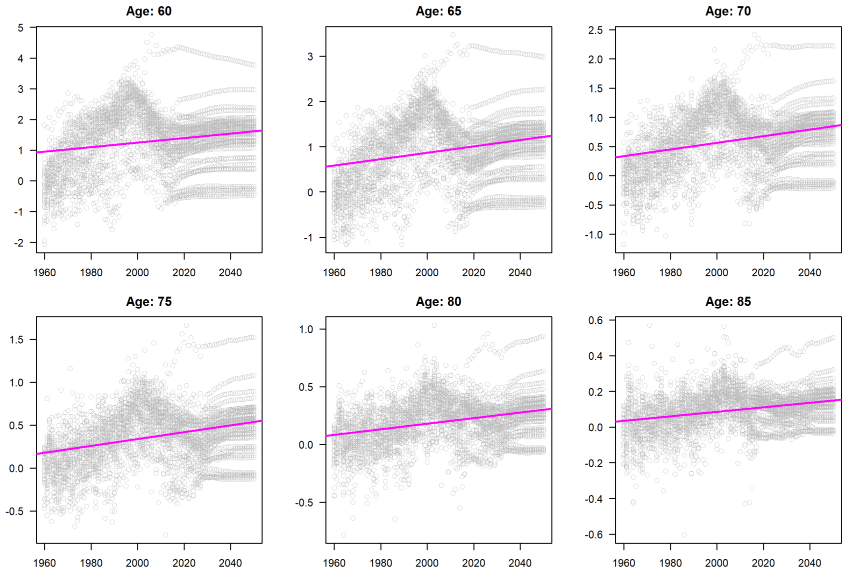
Top model weight per country



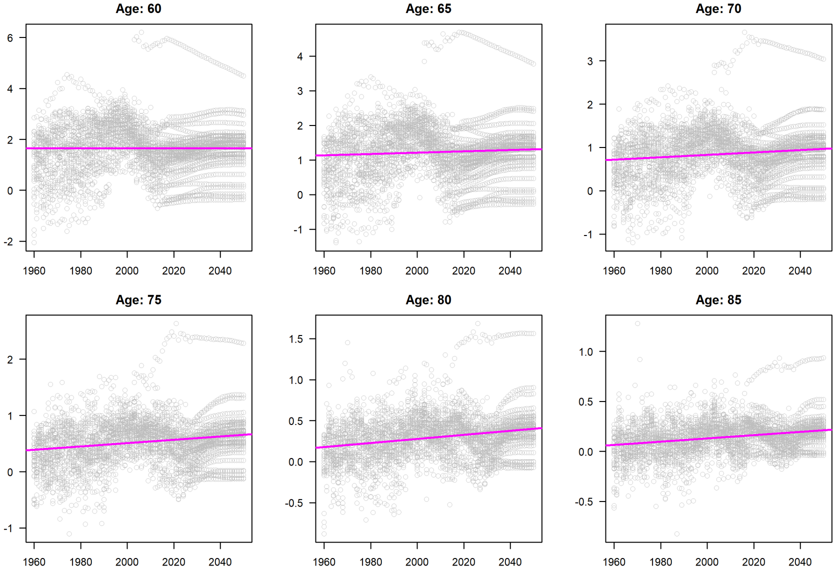
Aggregate life expectancy gap by age and year (Total)



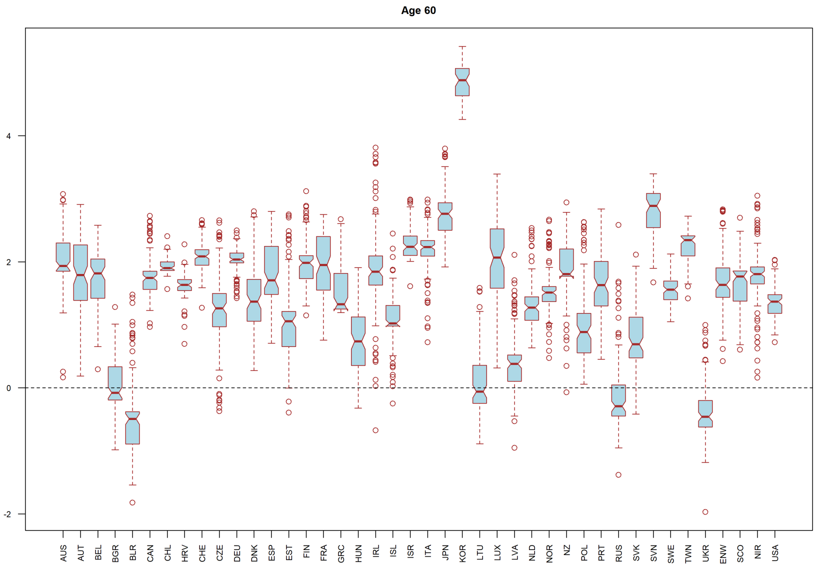
Aggregate life expectancy gap by age and year (Male)



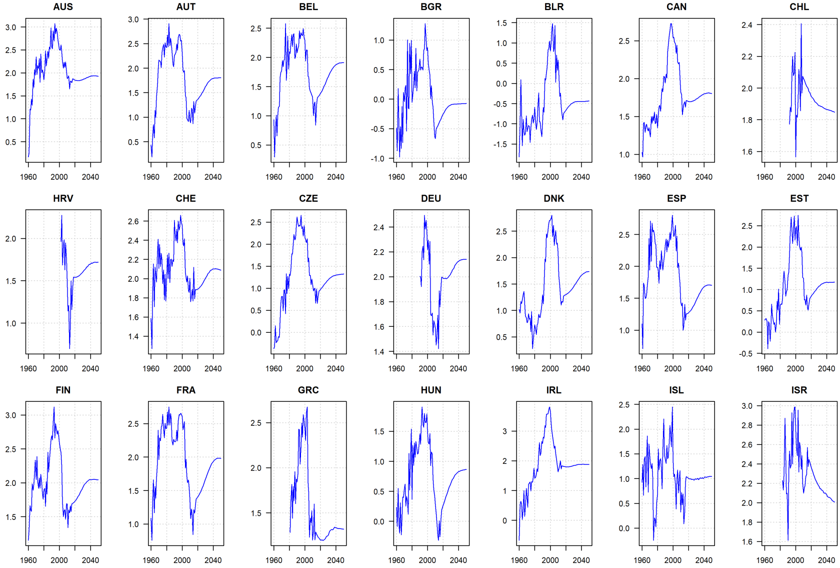
Aggregate life expectancy gap by age and year (Female)



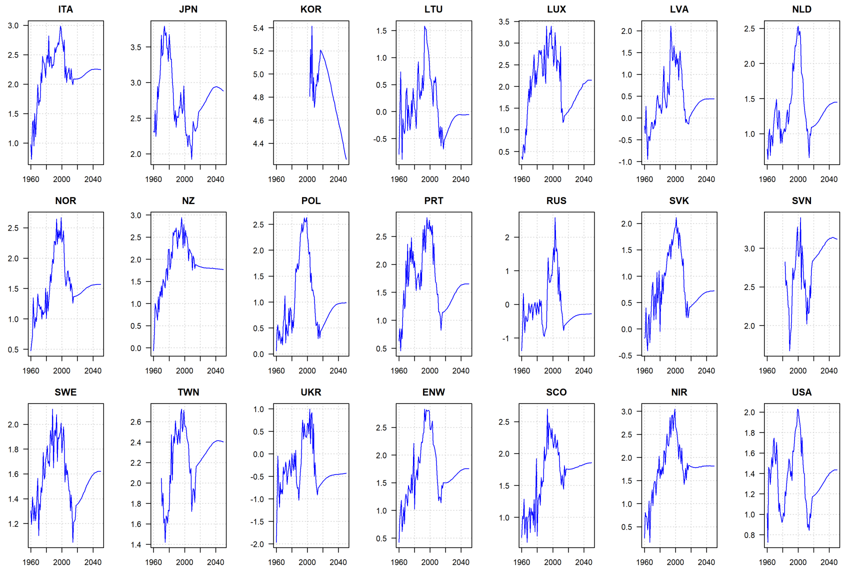
LE Gap at age 60: boxplot (Total)



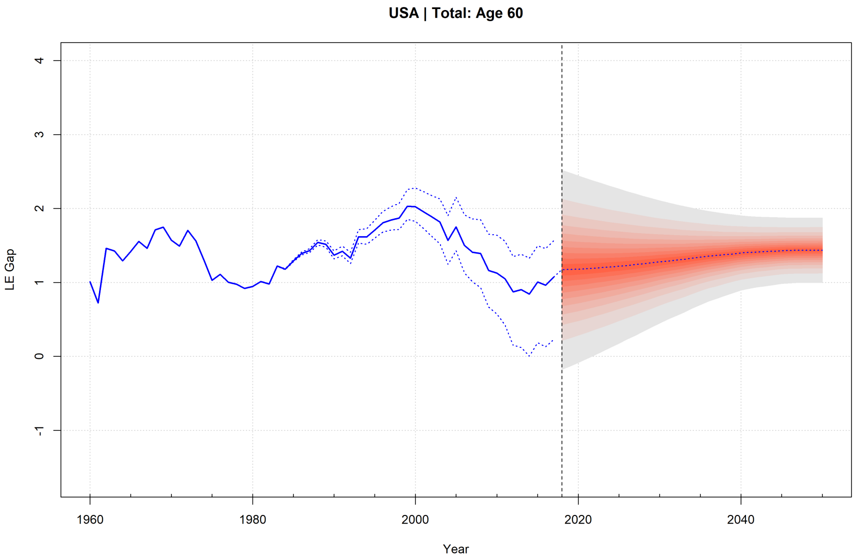
LE Gap at age 60 per country (1): Total

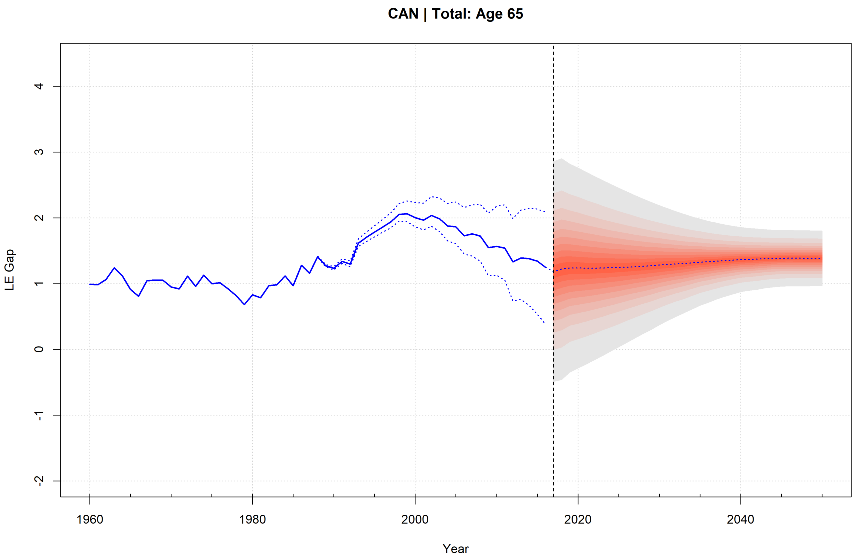


LE Gap at age 60 per country (2): Total

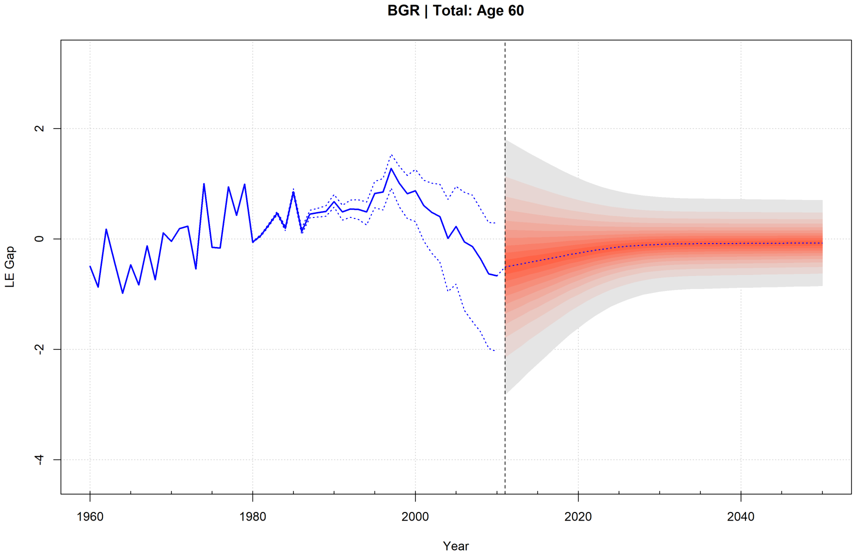


Fanplot of observed and forecasted LE gap (1)




CAN | Total: Age 65
LE Gap
Year
4
3
2
1
0
-1
-2
1960
1980
2000
2020
2040

Fanplot of observed and forecasted LE gap (3)



Tax/subsidy implied by LE Gap

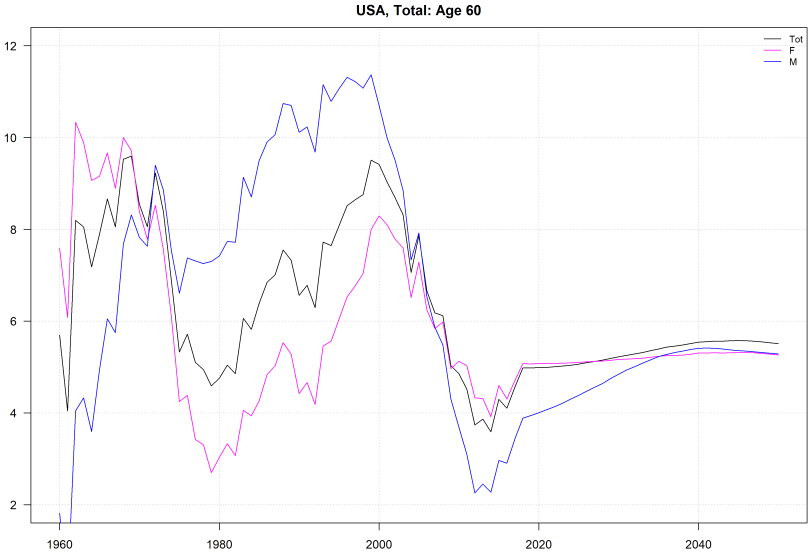
- Define the tax/subsidy implied by the existence of a difference between period and cohort life expectancy at age x and year t for gender g as

$$TS_{x,g}(t) = \left(\frac{\dot{e}^{C}_{x,g}(t)}{\dot{e}^{P}_{x,g}(t)} - 1 \right) \times 100 \quad (8)$$

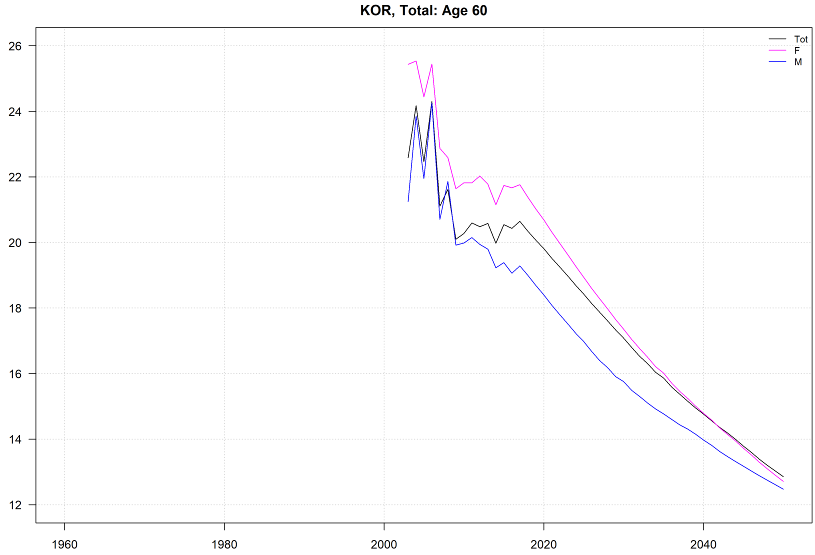
$$= \frac{\dot{e}^{Gap}_{x,g}(t)}{\dot{e}^{P}_{x,g}(t)} \times 100 \quad (9)$$

- Interpretation
  - if $\dot{e}^{Gap}_{x,g}(t) > 0,\ TS_{x,g}(t) > 0 \Longrightarrow$ tax for future generations
  - if $\dot{e}^{Gap}_{x,g}(t) < 0,\ TS_{x,g}(t) < 0 \Longrightarrow$ subsidy for future generations

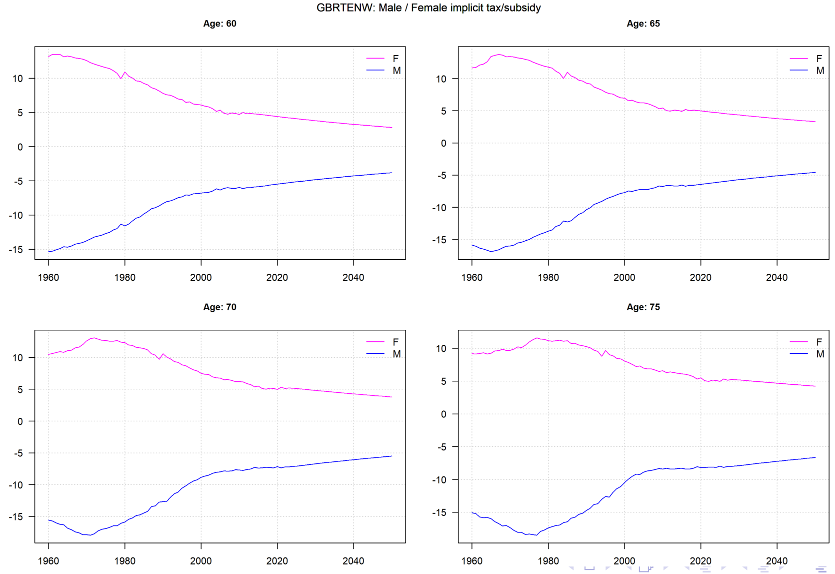
Tax/subsidy implied by LE Gap



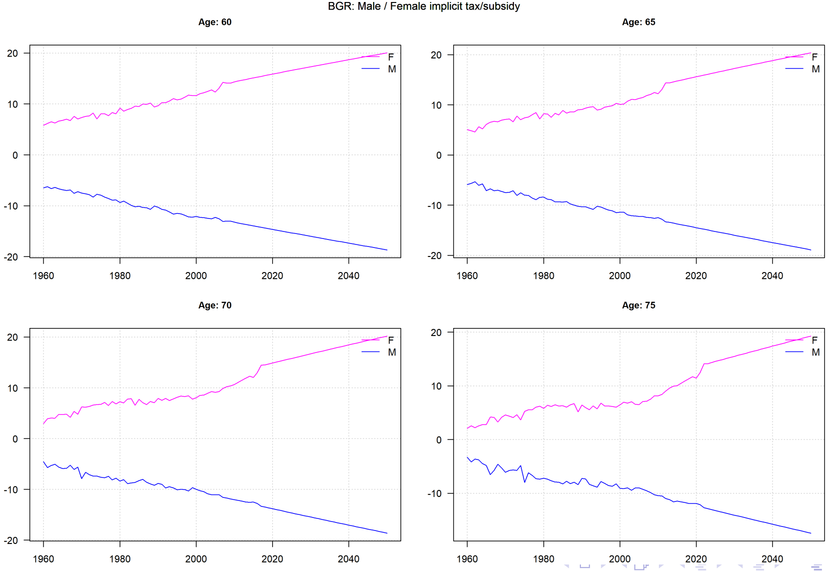
Tax/subsidy implied by LE Gap



Male/Female Tax/subsidy using cohort LE



Male/Female Tax/subsidy using cohort LE



Policy Options for Pension Design

- There are a number of policy options to redesign the pension scheme to address the effects of heterogeneity in longevity on pension schemes' objectives and outcomes (see Ayuso, Bravo & Holzmann, 2017a,b, 2018) for a detailed discussion)
- The starting position is a pension scheme with no redistributive objectives. This is best approximated by an underlying (financial or non-financial) DC scheme
- The scope of the tax/subsidy effects of LE Gap and LE heterogeneity in the pension scheme before and after the redesign is suggested as a measure of improvement
- A successful redesign should be able to reduce (eliminate) the aggregate tax/subsidy effect and, conceptually, may include ex-ante or ex post redistribution
- By definition, an ex-ante zero-close tax/subsidy effect will emerge if the annuity is calculated based on the actual or best estimate of individual cohort life expectancy

Policy Options for Pension Design: Accumulation stage

- Alternative stages at which interventions/scheme redesign to counteract life expectancy gap and heterogeneity in longevity can occur: (i) Accumulation; (ii) Annuitization, (iii) Decumulation

- 1. Interventions at contribution payment stage:
    - Differential social contribution rates by socioeconomic group: high (low) taxes for high- (low-) income groups
    - Application of a two-tier contribution scheme of individual and flat-rate allocation to individual accounts (in dc schemes)
    - Differential accrual rates by socioeconomic group: high (low) accruals for low- (high-) income groups
    - Application of different revalorization indexes (of contribution or benefits accounts) across income groups
    - Matching contributions for short-lived income groups

Policy Options for Pension Design: Annuitization stage

- 2. Interventions at benefit calculation stage:
  - Linkage of statutory retirement age x_r with socioeconomic group-specific life expectancy or to $\dot{e}^{C}_{x_r}(t)$
  - Apply demographic sustainability factors (e.g., Portugal, Spain, Finland) based on the relationship between $\dot{e}^{P}_{x_r}(t)$ and $\dot{e}^{C}_{x_r}(t)$
  - Use of differential demographic sustainability factors by socioeconomic group
  - Eligibility for retirement benefits based on additional/reduced years of contributions
  - Early (late) pension claiming bonus-malus adjustments indexed to $\dot{e}^{C}_{x_r}(t)$
  - Calculation of annuity factors for substandard mortality groups using an age-rating or age-shifting model
  - Calculation of annuity factors for substandard mortality groups, e.g., lifetime deciles
  - Two-tier benefit schemes: lump sum plus earnings-related payments (in DB schemes)

Policy Options for Pension Design: Decumulation stage

- 3. Interventions at benefit disbursement stage
  - Longevity-linked life annuities (Bravo & El Mekkaoui, 2018)

$$b_{t_0+k} = b_{t_0} \times \mathcal{I}_{t_0+k} \times \mathcal{R}_{t_0+k}, \quad k = 1, ..., \omega - x_0 \tag{10}$$

with

$$\mathcal{I}_{t_0+k} = \frac{{}_k p_{x_0}^{[\mathcal{F}_0]}(t_0)}{{}_k p_{x_0}^{[\mathcal{F}_k]}(t_k)} \text{ and } \mathcal{R}_{t_0+k} = \frac{\prod_{t=1}^{k} (1+R_t)}{(1+i_{t_0})^k} \tag{11}$$

  - Indexation of annual benefits to cohort-specific life expectancy
  - Use of differential pension indexation rules by socioeconomic group
  - Deferred annuities with a sharing of common and asymmetric longevity development between annuity calculation and disbursement
  - Mixed interventions that combine elements of all three stages.

Policy Options for Pension Design: Sustainability factors

- Let $B_{x_r}(t)$ denote the annual pension benefit computed at the retirement age x_r in year t based on the DB/DC rules and assume the annuity factor uprating and discounting rates are equal
- Assuming the uprating and discounting rates are equal, the pension wealth at the retirement age x_r in year t, computed using the period and cohort life expectancy, is

$$PW^P_{x_r}(t) = B_{x_r}(t) \times \dot{e}^P_{x_r}(t) \quad (12)$$

$$PW^C_{x_r}(t) = B_{x_r}(t) \times \dot{e}^C_{x_r}(t) \quad (13)$$

- Assume the pension scheme is in equilibrium for a benefit disbursement period of $\dot{e}^P_{x_r}(t)$ years
- The pension scheme estimate of the unfunded liabilities is

$$\Delta PW_{x_r}(t) = B_{x_r}(t) \times \left(\dot{e}^C_{x_r}(t) - \dot{e}^P_{x_r}(t)\right) = B_{x_r}(t) \times \dot{e}^{Gap}_{x,g}(t) \quad (14)$$

Policy Options for Pension Design: Sustainability factors

- For a positive $\dot{e}_{x,g}^{Gap}(t)$, one way to eliminate the implied tax is to reduce the initial pension benefit by a sustainability factor $S_{x_r}(t)$ such that $\Delta PW_{x_r}(t) = 0$; Equation (14) becomes

$$\Delta PW_{x_r}(t) = B_{x_r}(t) \times \left(S_{x_r}(t)\, \dot{e}_{x_r}^{C}(t) - \dot{e}_{x_r}^{P}(t) \right) \qquad (15)$$

- Achieving $\Delta PW_{x_r}(t) = 0$ is equivalent to

$$S_{x_r}(t)\, \dot{e}_{x_r}^{C}(t) - \dot{e}_{x_r}^{P}(t) = 0$$

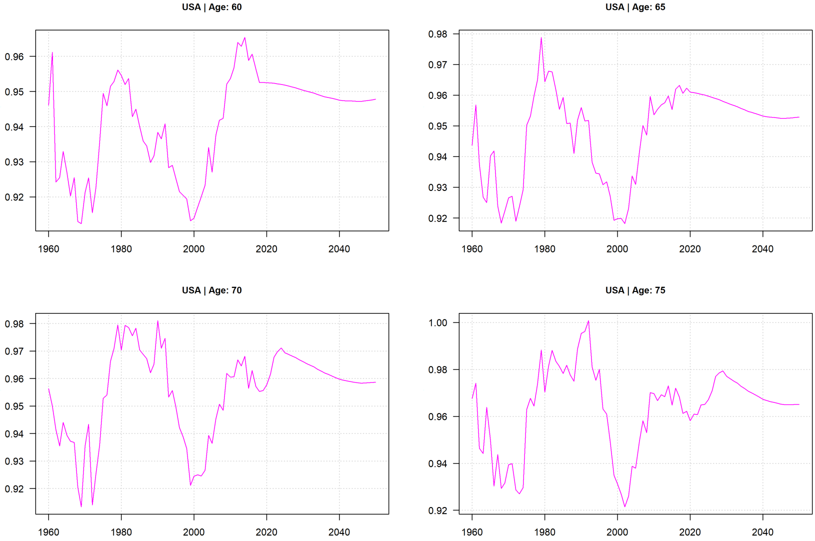
i.e.,

$$S_{x_r}(t) = \frac{\dot{e}_{x_r}^{P}(t)}{\dot{e}_{x_r}^{C}(t)}$$

- Currently, countries use period life expectancy at a unique common age to compute sustainability factors, e.g., Portugal uses

$$S_{x_r}(t) = \frac{\dot{e}_{65}^{P}(t-1)}{\dot{e}_{65}^{P}(2000)}$$

Sustainability factor estimates



Policy Options for Pension Design: benefit uprating rate

- More geneally, define the pension wealth as

$$PW_{x_r}(t) = B_{x_r}(t) \times \left[\sum_{t=0}^{\omega - x_r} \left(\frac{1+\beta_t}{1+i_t} \right)^t {}_t p_{x_r}(t) \right] \quad (16)$$

  where β and i denote, respectively, the uprating and discounting rates
- Assume that, for a given discount rate i, policy-makers consider to adjust the annual pension benefit uprating rate in order to eliminate the tax/subsidy implied by a non-zero $\dot{e}_{x,g}^{Gap}(t)$
- The estimate of the unfunded pension liabilities can be written as

$$\Delta PW_{x_r}(t) = B_{x_r}(t) \left[\sum_{t=0}^{\omega - x_r} \upsilon^t \left({}_t p_{x_r}^{[C]}(t) \left(1+\beta_t^C\right)^t - {}_t p_{x_r}^{[P]}(t) \left(1+\beta_t^P\right) \right. \right. \quad (17)$$

  where β_t^C (β_t^P) are the time t cohort (period) uprating rates

Policy Options for Pension Design: benefit uprating rate

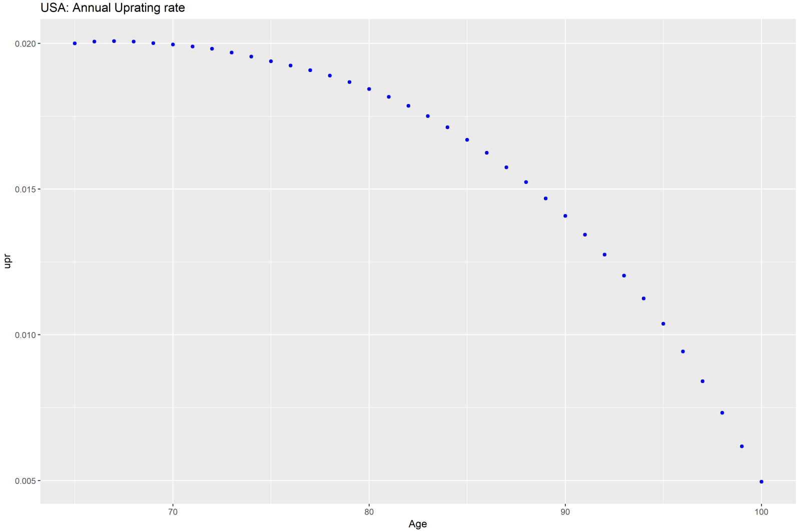
- Setting $\Delta PW_{x_r}(t)$ to zero is equivalent to uprate annual pension $t-$years ahead according to

$$\beta_t^C = \left[\left(1+\beta_t^P\right)^t \times \frac{{}_t p_{x_r}^{[P]}(t)}{{}_t p_{x_r}^{[C]}(t)} \right]^{\frac{1}{t}} - 1 \tag{18}$$

- Possible cases:
  - if ${}_t p_{x_r}^{[P]}(t) = {}_t p_{x_r}^{[C]}(t) \Longrightarrow \beta_t^C = \beta_t^P$
  - if ${}_t p_{x_r}^{[P]}(t) < {}_t p_{x_r}^{[C]}(t) \Longrightarrow \beta_t^C < \beta_t^P$
  - if ${}_t p_{x_r}^{[P]}(t) > {}_t p_{x_r}^{[C]}(t) \Longrightarrow \beta_t^C > \beta_t^P$

Policy Options for Pension Design: benefit uprating rate

Example: $i = \beta_t^P = 2\%$; $x = 65$, USA Total Pop.



Policy Options for Pension Design: benefit uprating rate

Example: $i = \beta_t^P = 2\%$; $x = 65$, Australia Total Pop.