Addressing the Life Expectancy Gap in Pension Policy

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2. Period & cohort life expectancy and Life expectancy gap
3. Life expectancy gap & Intergenerational actuarial fairness and neutrality
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Background & Motivation

- Increased longevity and population ageing are some of the most important challenges to both funded/unfunded pension schemes
- Countries have responded to longevity improvements with systemic or parametric pension reforms in which a common denominator has been to create an automatic link of future pensions to life expectancy
- The link has been tightened in at least seven different ways (Ayuso, Bravo & Holzmann, 2019):
  - through initial pension benefits (GER, FIN, POR, ESP, JPN)
  - via the normal retirement (10 countries)
  - via qualifying conditions (e.g., FRA)
  - adjusting the penalties (bonuses) for early (late) retirement to years of contributions and the normal retirement age (e.g., POR)
  - replacing traditional NDB public PAYG schemes with NDC schemes (e.g., SWE, ITA, POL, LAT, NOR)
  - introducing funded defined-contribution plans (e.g., MEX, POL, SWE)
  - conditioning pension indexation (e.g., Netherlands) or modifying the annual account indexation rate in NDC schemes.

Background & Motivation

- The way these automatic longevity risk sharing mechanisms have been introduced in pension schemes suffers from various weaknesses:
  - they have been designed and implemented in a uniform way to all individual participants and considering the average mortality experience in a population ⇒ heterogeneity problem (see, e.g., Ayuso, Bravo and Holzmann, 2017a,b; Sánchez-Romero, Lee and Prskawetz, 2019)
  - Unisex life expectancy measures computed from period and not cohort life tables have been used ⇒ wrong measure of longevity
- In a scenario of continuous decline in age-specific mortality rates, the use of period life expectancy
  - systematically underestimates the remaining lifetime at retirement, incorrectly signalling solvency prospects and delaying pension reforms
  - generates unintended and potentially sizable subsides between current and future generations, and an unfair actuarial link between contributions and pension entitlements
  - distorts labour supply and saving decisions

Background & Motivation

- The concept of life expectancy gap measures the systematic difference between cohort and period life expectancy at a given age and time
- The gap represents, when positive, an estimate of the extra years of life a given cohort will enjoy as a result of expected future mortality improvements
- For pension policy, the gap is a proxy of
  - the amount of unfunded pension liabilities due to the use of an incorrect measure of remaining lifetime,
  - the amount by which pension wealth exceeds the value of the accumulation
  - the implicit debt transferred to future generations unless corrective actions are undertaken
  - the implicit tax/subsidy between current and future generations

The paper goals

- Estimate the life expectancy gap at adult ages for 42 homogeneous national populations, disaggregated by sex, from 1960 to 2050
- Quantify the size (and the trend) of the unfunded pension liabilities and of the implicit subsidies between current and future generations
- Contrary to previous studies that use a single model to forecast mortality rates or life expectancy, we adopt a new projection approach based on a Bayesian Model Ensemble of six well-known single population Generalised Age-Period-Cohort (GAPC) stochastic mortality models
- Explore potential policy interventions to address the consequences of the life expectancy gap – spanning over adjustments in the accumulation, benefit determination, and payout stages
- Comprehensive numerical results are provided for two policy options: (i) introducing a sustainability factor; and (ii) through pension indexation.

Period and cohort life expectancy

Let ${}_{\tau}p_x\left(t\right)$ denote the τ-year survival rate of a cohort aged x at time t:

$$ {}_{\tau}p_x\left(t\right) := \exp\left(-\int_0^{\tau}\mu_{x+s}\left(s\right)ds\right). \qquad (1) $$

Assume that the age-specific forces of mortality are constant within each square of the Lexis diagram, i.e. $\mu_{x+\xi}\left(t+\epsilon\right)=\mu_x\left(t\right)=m_x\left(t\right)$ for any $0\leq\xi,\epsilon<1$

The complete cohort life expectancy for an x-year old individual belonging to population g in year t is

$$ \dot{e}^{C}_{x,g}(t) := \frac{1}{2}+\sum_{k=1}^{\omega-x}\exp\left(-\sum_{j=0}^{k-1}m_{x+j,g}\left(t+j\right)\right), \qquad (2) $$

whereas the corresponding complete period life expectancy is

$$ \dot{e}^{P}_{x,g}(t) := \frac{1}{2}+\sum_{k=1}^{\omega-x}\exp\left(-\sum_{j=0}^{k-1}m_{x+j,g}\left(t\right)\right). \qquad (3) $$

Life expectancy gap

- The life expectancy gap, $\dot{e}_{x,g}^{Gap}(t)$, measures the systematic difference between the cohort and period life expectancy measures for a given population at age x in year t, i.e.,

$$\dot{e}_{x,g}^{Gap}(t) := \dot{e}_{x,g}^{C}(t) - \dot{e}_{x,g}^{P}(t), \tag{4}$$

- The gap can be interpreted as a sort of leading indicator of future trends in longevity and of the existence of maximum lifespans, informing also on the debate on lifespan inequality
- A positive but declining (increasing) gap signals a deceleration (acceleration) in expected mortality improvements
- A zero gap at very old ages suggests that a given population may be reaching the frontier of human survival

Actuarial fairness and the life expectancy gap

- For an actuarially fair pension scheme, the accumulation at the retirement age $x_r(t)$ equals the pension wealth

$$PW_t^{x_r(t)} = B_t^{x_r(t)} a_{x_r(t)}^{\pi,y}, \tag{5}$$

where $B_t^{x_r(t)}$ denotes the initial annual pension benefit and $a_{x_r(t)}^{\pi,y}$ is the life annuity factor, computed using the (period or cohort) survival probabilities, the uprating rate for pensions (π) and the discount rate (y), i.e.,

$$a_{x_r(t)}^{\pi,y} = \sum_{t=1}^{\omega - x_r} \left(\frac{1+\pi_t}{1+y_t} \right)^t \ {}_t p_{x_r}(t). \tag{6}$$

Life expectancy gap and implied tax/subsidies

- Assuming that $\pi_t = y_t \ \forall t$, an assumption that broadly holds for wage-indexed pensions, the pension wealth at retirement can be estimated multiplying the initial pension benefit by life expectancy
- The actual pension wealth exceeds the value of the accumulation by

$$\Delta^d PW_{x_r,g}(t) = B_t^{x_r(t)} \left[\dot{e}^C_{x_r,g}(t) - \dot{e}^P_{x_r,g}(t) \right] = B_t^{x_r(t)} \dot{e}^{Gap}_{x_r,g}(t) \qquad (7)$$

- The life expectancy gap amounts to a ex-ante tax/subsidy, $S_{x_r,g}(t)$, that a given generation would pay/receive unless benefit adjustments are undertaken to make the system actuarially fairer

$$S_{x_r,g}(t) := \frac{\dot{e}^{Gap}_{x_r,g}(t)}{\dot{e}^P_{x_r,g}(t)} \times 100 = \left(\frac{\dot{e}^C_{x,g}(t)}{\dot{e}^P_{x_r,g}(t)} - 1 \right) \times 100, \qquad (8)$$

- In equation (8) negative (positive) values represent a tax (subsidy) rate to current generations

Mortality forecasting: Bayesian Model Ensemble approach

- We use a novel approach based on a Bayesian Model Ensemble (BME) of six well known single population discrete-time GAPC stochastic mortality models to forecast age and sex-specific mortality rates of 42 HMD countries
- These models are then probabilistically combined to project period and cohort life expectancy and the life expectancy gap
- We carry out a backtesting exercise in the spirit of Dowd et al. (2010) and use the projection bias in mortality rates as the metric to assess the forecasting error
- The final forecast assigns larger weights to models with smaller forecasting error
- The BME approach offers a common basis for studying all countries and reduces the inherent uncertainty in the choice of the appropriate projection model (model risk)

GAPC Stochastic mortality models

Model	Linear Predictor	Original reference
M1	$\eta_{x,t} = \alpha_x + \beta_x^{(1)}\kappa_t^{(1)}$	Brouhns et al. (2002)
M2	$\eta_{x,t} = \alpha_x + \kappa_t^{(1)} + \gamma_{t-x}$	Currie (2006)
M3	$\eta_{x,t} = \alpha_x + \beta_x^{(1)}\kappa_t^{(1)} + \beta_x^{(0)}\gamma_{t-x}$	Renshaw and Haberman (2006)
M4	$\eta_{x,t} = \kappa_t^{(1)} + (x-\bar{x})\,\kappa_t^{(2)}$	Cairns et al. (2006)
M5	$\eta_{x,t} = \kappa_t^{(1)} + (x-\bar{x})\,\kappa_t^{(2)} + \left((x-\bar{x})^2 - \sigma\right)\kappa_t^{(3)} + \gamma_{t-x}$	Cairns et al. (2009)
M6	$\eta_{x,t} = \alpha_x + \kappa_t^{(1)} + (x-\bar{x})\,\kappa_t^{(2)} + (\bar{x}-x)^{+}\,\kappa_t^{(3)} + \gamma_{t-x}$	Plat (2009)

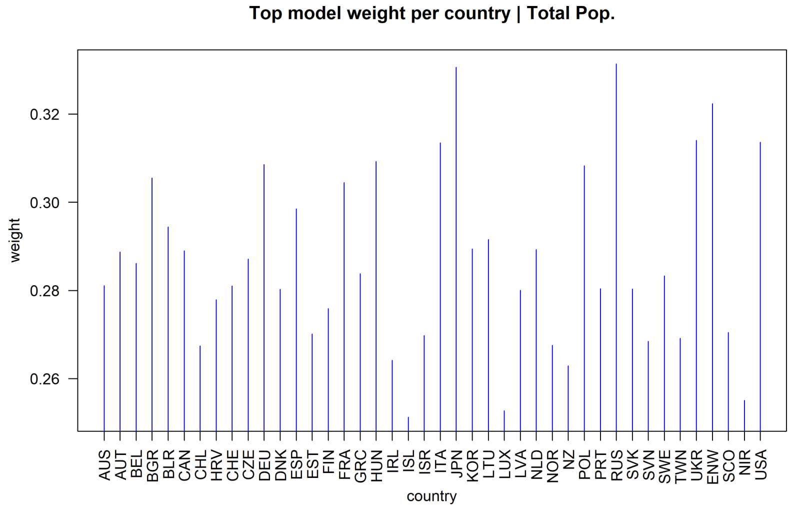
We adopted the usual assumptions regarding the distribution of $D_{x,t}$ (Poisson, Binomial), the linear predictor, the link function (log, logit), the set of parameter constraints and the time series methods for forecasting model parameters

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

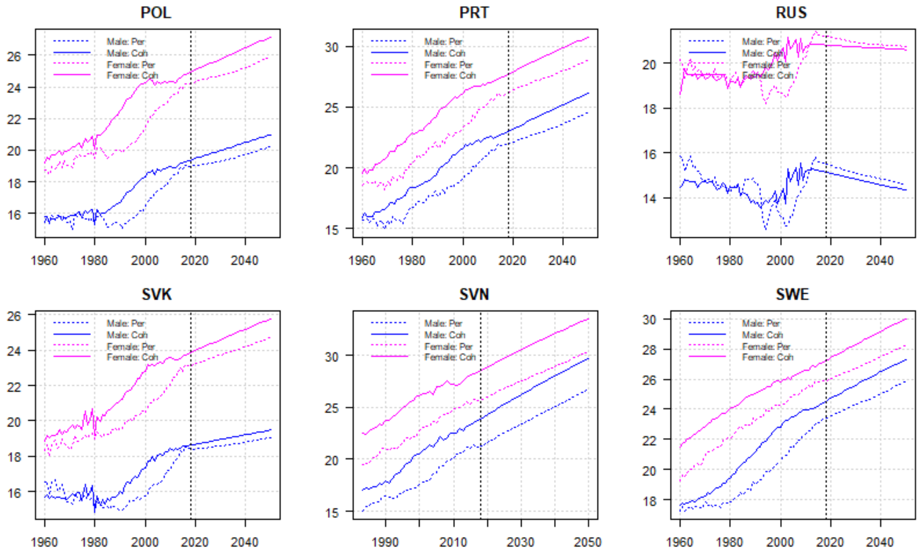
HMD Data op model weight per country

Available data	Countries and Regions
1960 – 2016	Australia (AUS), Belarus (BLR), Canada (CAN), Denmark (DNK), Iceland (ISL), Netherlands (NDL), Poland (POL),Spain (ESP), England & Wales (ENW), Scotland (SCO), Northern Ireland (NIR)
1960 – 2017	Austria (AUT), Bulgaria (BGR), Czech Republic (CZE), Estonia (EST), France (FRA), Hungary (HUN), Ireland (IRL), Japan (JPN), Latvia (LVA), Lithuania (LTU), Slovakia (SVK), Luxembourg (LUX), Sweden (SWE), Switzerland (CHE), U.S.A. (USA)
1960 – 2018	Belgium (BEL), Finland (FIN), Norway (NOR)
1992 – 2008	Chile (CHL)
2002 – 2017	Croatia (HRV)
1990 – 2017	Germany (DEU)
1981 – 2013	Greece (GRC)
1983 – 2016	Israel (ISR)
1960 – 2014	Italy (ITA), Russia (RUS)
1960 – 2013	New Zealand (NZL), Ukraine (UKR)
1960 – 2015	Portugal (PRT)
2003 – 2018	Republic of Korea / South Korea (KOR)
1983 – 2017	Slovenia (SLV)
[illegible]	[illegible]

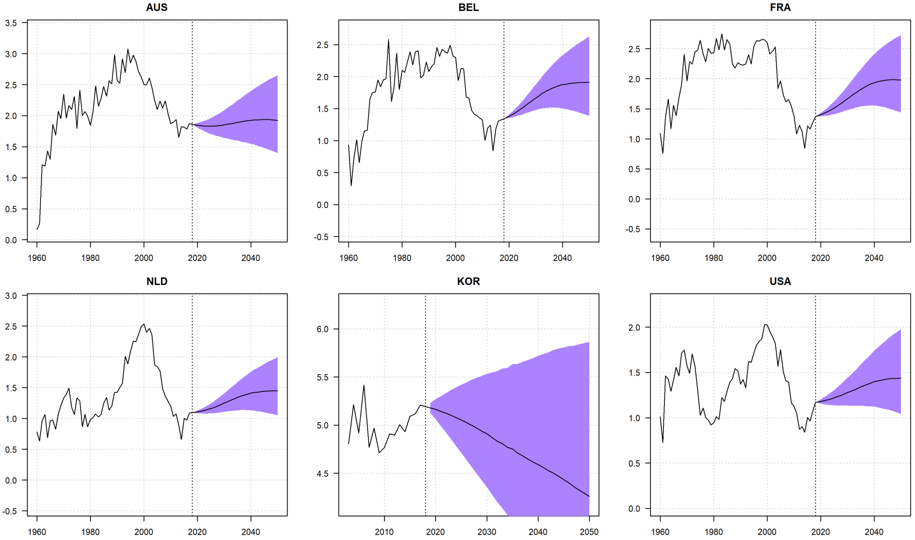
Top model weight per country



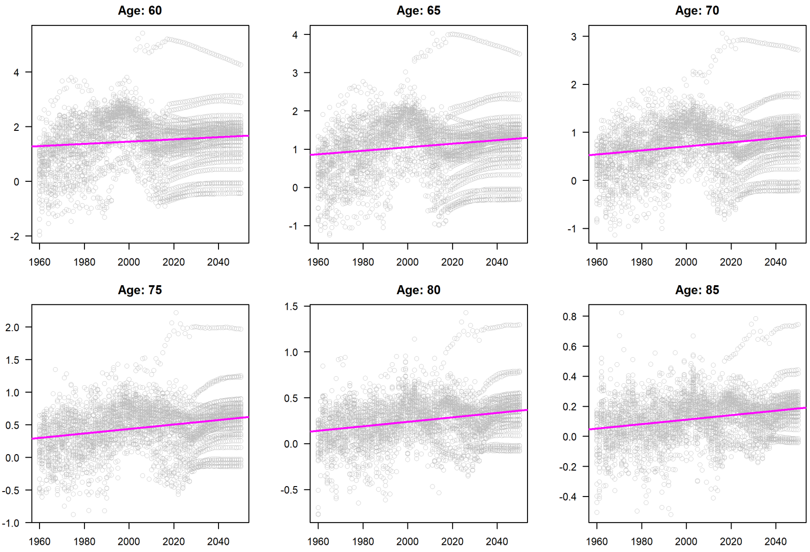
Period and cohort life expectancy at age 60



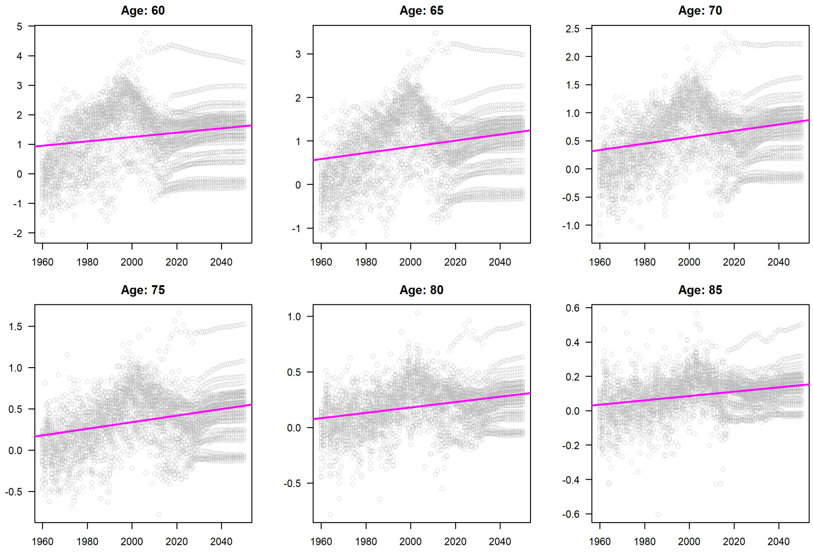
Life expectancy gap at 60



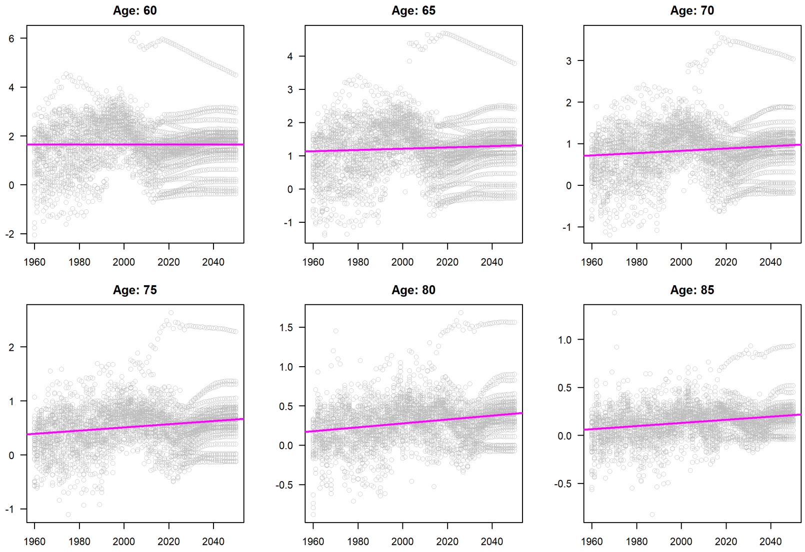
Aggregate life expectancy gap by age and year (Total)



Aggregate life expectancy gap by age and year (Male)



Aggregate life expectancy gap by age and year (Female)

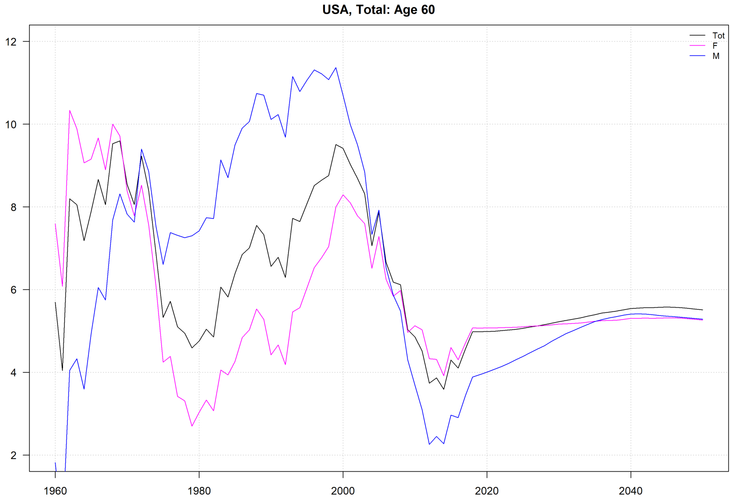


LE Gap at age 60: boxplot (Total)

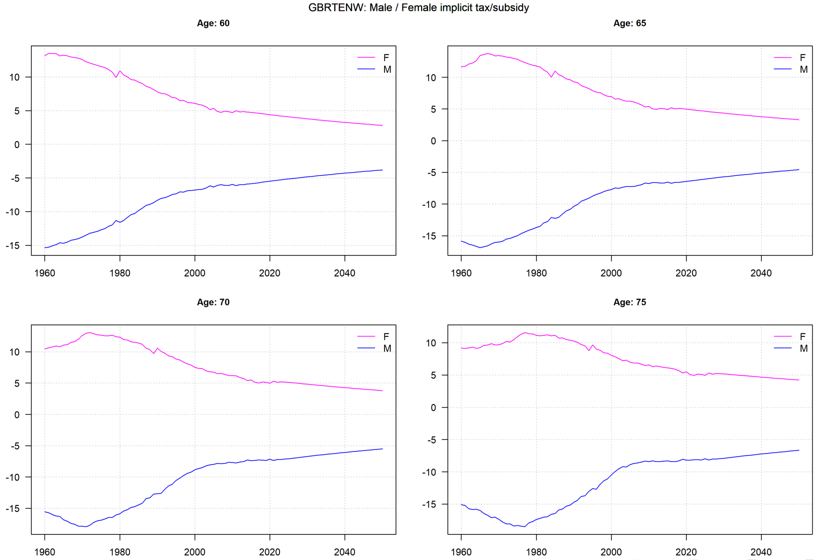
Implicit Tax/subsidies at age 65

Country	Year					Country	Year				
	1960	1980	2000	2019	2050		1960	1980	2000	2019	2050
AUS	2.5	7.1	10.3	6.3	6.1	ITA	3.9	12.8	10.7	7.2	7.2
AUT	2.5	12.1	10.0	4.2	6.1	JPN	10.4	17.0	8.6	8.3	8.8
BEL	4.3	12.1	10.5	4.3	6.5	KOR	-	-	-	18.7	12.3
BGR	-3.7	-1.1	6.0	-1.9	-0.4	LTU	-3.4	0.7	3.4	-3.4	-0.3
BLR	-5.0	-2.8	3.2	-3.7	-2.2	LUX	2.5	12.5	13.4	4.2	7.2
CAN	6.7	5.0	10.8	5.8	5.8	LVA	-1.9	1.4	4.9	-0.6	1.9
CHL	-	-	6.7	7.4	6.1	NLD	4.0	3.6	10.4	3.6	5.0
HRV	-	-	NA	6.0	6.2	NOR	2.4	4.5	9.8	4.8	5.3
CHE	7.5	9.4	10.4	6.3	6.7	NZL	2.3	10.5	8.6	6.6	5.7
CZE	-1.6	6.2	11.4	3.2	4.9	POL	0.9	4.2	11.8	1.2	3.9
GER	-	-	7.5	7.2	7.1	PRT	1.9	8.5	11.7	3.6	5.6
DNK	6.6	4.1	9.7	4.4	6.1	RUS	-5.4	-0.2	6.1	-3.0	-1.4
ESP	5.7	9.1	10.4	3.8	5.6	SVK	0.2	3.2	9.4	1.0	3.0
EST	1.5	3.1	12.1	2.7	4.5	SVN	-	-	12.0	10.5	10.1
FIN	5.1	8.4	12.0	5.8	6.8	SWE	6.4	7.4	7.2	4.4	5.5
FRA	6.7	11.5	10.6	3.9	6.4	TWN	-	6.0	10.2	8.0	7.9
GRC	-	-	10.5	4.2	4.5	UKR	-5.5	-0.8	1.4	-3.5	-2.3
HUN	2.9	3.4	6.6	-0.3	3.9	ENW	3.1	6.4	11.3	5.2	5.9
IRL	0.1	6.7	17.2	6.6	6.2	SCO	4.1	4.6	10.6	6.8	6.4
ISL	1.6	-0.9	3.7	3.7	3.6	NIR	2.0	9.2	12.5	6.8	6.1
ISR	-	-	11.7	8.8	6.3	USA	6.0	3.7	8.7	3.9	4.9

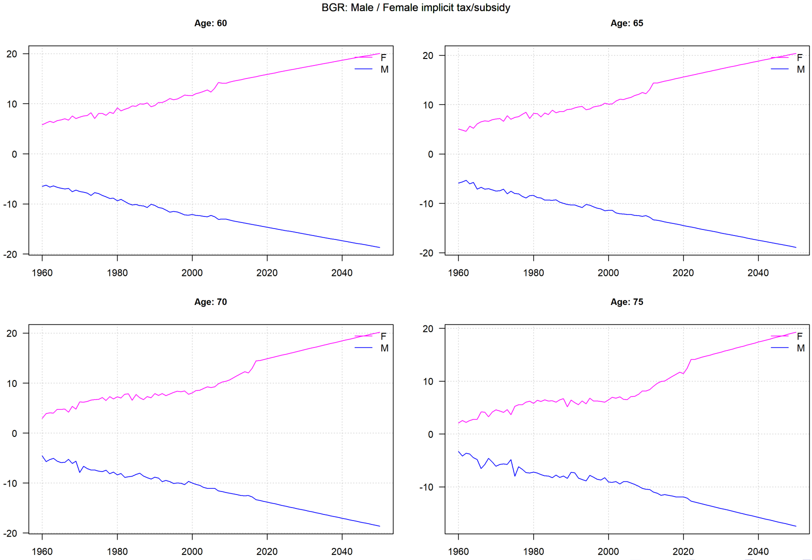
Implicit Tax/subsidies at age 60: USA



Male/Female tax/subsidy at age 60: England & Wales



Male/Female tax/subsidy at age 60: Bulgaria



Policy Options

- We adopt an intergenerational actuarial fairness and neutrality principle to pension design and reform for policy evaluation
- The starting position is a pension scheme with no ex-ante redistributive objectives
- The suggested interventions aim to eliminate the wealth redistribution effects and the distortions created by the life expectancy gap
- The scope of the unfunded pension liabilities before and after the policy intervention are suggested as a performance measure
- A zero ex-ante distortion takes place if an actual or virtual accumulation at retirement translates into an annuity based on cohort survival probabilities at retirement
- Conceptually, the policy interventions can take place at the accumulation, annuitization and decumulation phases
- Given the nature of the distortion addressed in this paper, we believe that redesign is best approached if implemented at the annuitization and/or decumulation phases

Policy options at the Annuitization Stage

- Policy options at this stage include.
  - Adjusting the initial pension benefit through an actuarially designed sustainability/reduction factor based on the relationship between period and cohort life expectancy at the retirement age
  - Adjusting the statutory retirement age and the contribution period along with cohort life expectancy (maintaining the accrual rate per year constant or keeping constant the total replacement rate by reducing the accrual rate per year)
  - Updating the early (late) retirement bonus-malus coefficients to restore actuarial fairness and neutrality
  - Modifying the eligibility conditions for retirement, namely by requiring additional (reduced) contributions years if the gap is positive (negative)
  - Adjusting the valorisation (pre-retirement indexation) of past earnings when calculating the initial benefit
  - Linking the minimum pension age to cohort life expectancy

Policy interventions at benefit disbursement stage

- Policy interventions at this stage include:
  - Linking annual pension indexation to actual cohort-specific life expectancy developments
  - Using longevity-linked life annuities, i.e., updating benefits periodically based on the dynamics of both a longevity index and an interest rate factor (see, e.g., Bravo and El Mekkaoui de Freitas (2018))
  - a change in the annual account indexation rate (in NDC schemes);
  - a reduction in the nominal benefit level.

Policy interventions at benefit disbursement stage

- Longevity-linked life annuities (Bravo & El Mekkaoui, 2018)

$$b_{t_0+k} = b_{t_0} \times \mathcal{I}_{t_0+k} \times \mathcal{R}_{t_0+k}, \qquad k = 1, \ldots, \omega - x_0 \tag{9}$$

  - with

$$\mathcal{I}_{t_0+k} = \frac{{}_k p_{x_0}^{[\mathcal{F}_0]}(t_0)}{{}_k p_{x_0}^{[\mathcal{F}_k]}(t_k)} \text{ and } \mathcal{R}_{t_0+k} = \frac{\prod_{t=1}^{k}(1+R_t)}{(1+i_{t_0})^k} \tag{10}$$

  - 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.

Introducing a Sustainability factor

Recap the scope of the unfunded pension liabilities

$$\Delta^d PW_{x_r,g}(t) = B_t^{x_r(t)} \left[\dot{e}^C_{x_r,g}(t) - \dot{e}^P_{x_r,g}(t) \right] = B_t^{x_r(t)} \dot{e}^{Gap}_{x_r,g}(t) \qquad (11)$$

One way to eliminate $\Delta^d PW_{x_r,g}(t)$ is to introduce an age-specific correction factor $RF_t^{x_r(t)}$ for each birth cohort such that $\Delta^d PW_{x_r,g}(t)$ is zero

$$\Delta^d PW_{x_r,g}(t) = B_t^{x_r(t)} \left[\dot{e}^C_{x_r,g}(t) \times RF_t^{x_r(t)} - \dot{e}^P_{x_r,g}(t) \right] = 0, \qquad (12)$$

from which we obtain

$$RF_t^{x_r(t)} = \frac{\dot{e}^P_{x_r,g}(t)}{\dot{e}^C_{x_r,g}(t)}, \qquad (13)$$

for all x_r or, equivalently,

$$RF_t^{x_r(t)} = 1 - \frac{\dot{e}^{Gap}_{x_r,g}(t)}{\dot{e}^C_{x_r,g}(t)}. \qquad (14)$$

Reduction factor estimates for selected ages, 2019

Country	Age			
	60	62	64	66
AUS	0.9330	0.9360	0.9393	0.9435
AUT	0.9474	0.9514	0.9557	0.9578
BEL	0.9465	0.9510	0.9559	0.9614
BGR	1.0152	1.0166	1.0183	1.0204
BLR	1.0377	1.0380	1.0384	1.0418
CAN	0.9371	0.9400	0.9431	0.9473
CHL	0.9237	0.9266	0.9296	0.9327
HRV	0.9324	0.9363	0.9408	0.9571
CHE	0.9320	0.9351	0.9385	0.9439
CZE	0.9584	0.9619	0.9657	0.9720
GER	0.9227	0.9259	0.9294	0.9337
DNK	0.9482	0.9517	0.9556	0.9602
ESP	0.9529	0.9566	0.9608	0.9680
EST	0.9643	0.9672	0.9706	0.9872
FIN	0.9346	0.9384	0.9426	0.9473
FRA	0.9485	0.9528	0.9576	0.9623
GRC	0.9528	0.9555	0.9583	0.9614
HUN	0.9888	0.9929	0.9979	1.0049
IRL	0.9312	0.9339	0.9369	0.9401
ISL	0.9598	0.9614	0.9633	0.9654
ISR	0.9134	0.9154	0.9175	0.9222

Country	Age			
	60	62	64	66
ITA	0.9247	0.9277	0.9310	0.9346
JPN	0.9111	0.9150	0.9194	0.9262
KOR	0.8329	0.8363	0.8402	0.8452
LTU	1.0248	1.0270	1.0297	1.0338
LUX	0.9463	0.9513	0.9570	0.9636
LVA	0.9975	1.0002	1.0034	1.0164
NLD	0.9563	0.9595	0.9630	0.9674
NOR	0.9473	0.9499	0.9528	0.9559
NZL	0.9320	0.9343	0.9368	0.9395
POL	0.9780	0.9815	0.9854	0.9931
PRT	0.9542	0.9583	0.9629	0.9679
RUS	1.0292	1.0299	1.0308	1.0320
SVK	0.9803	0.9826	0.9854	0.9931
SVN	0.8931	0.8975	0.9024	0.9155
SWE	0.9483	0.9512	0.9545	0.9558
TWN	0.9157	0.9197	0.9240	0.9288
UKR	1.0369	1.0365	1.0363	1.0363
ENW	0.9419	0.9453	0.9490	0.9538
SCO	0.9290	0.9319	0.9350	0.9383
NIR	0.9298	0.9324	0.9351	0.9389
USA	0.9526	0.9558	0.9593	0.9625

Conditional pension indexation

- Denote by π_t^P the promised (exogenous or endogenous) pension indexation rate at time t and by π_t^C the intergenerationally fair and neutral indexation rate
- The the scope of the unfunded pension liabilities in (7) can be written as

$$\Delta^d PW_{x_r,g} = B_t^{x_r(t)} \left[\sum_{t=1}^{\omega - x_r} \left({}_t p_{x_r}^{[C]} \left(1 + \pi_t^C \right)^t - {}_t p_{x_r}^{[P]} \left(1 + \pi_t^P \right)^t \right) v^t \right]$$

where ${}_t p_{x_r}^{[P]}$ and ${}_t p_{x_r}^{[C]}$ denote the t-year survival probability computed using a period and cohort approach respectively, and $v^t = (1 + y_t)^{-t}$

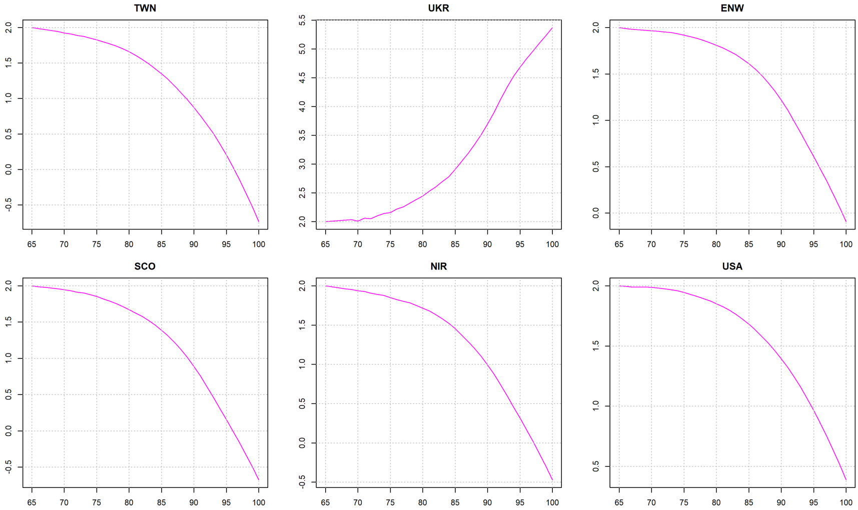
Conditional pension indexation

- Eliminating the implicit tax/subsidies generated by the life expectancy gap would require adopting the following cohort-specific pension indexation rule

$$\pi_t^C = \left[\left(1 + \pi_t^P\right)^t \times \frac{{}_t p_{x_r}^{[P]}(t)}{{}_t p_{x_r}^{[C]}(t)} \right]^{\frac{1}{t}} - 1. \tag{15}$$

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

Conditional pension indexation



Conclusions and policy implications

- The paper confirms very affirmatively the deficiency of period estimates of life expectancy compared to cohort life expectancy
- If mortality across ages improves, period life expectancy substantially underestimates the cohort life expectancy that differs for each birth cohort and over ages
- The life expectancy gap serves proxies the gap on the pension scheme financial position
- For most countries (37 out of 42) and years, the life expectancy gap is positive confirming that period life expectancy measures typically and systematically tend to underestimate human remaining lifetime
- The exceptions are ulgaria, Belarus, Lithuania, Russia and Ukraine
- In 22 of the 42 investigated countries, the retirees in 2019 received a subsidy beyond 10 percent of the cohort's accumulated pension wealth

Conclusions and policy implications

- In order to reduce or neutralize the tax/subsidy effects of underestimated life expectancy the paper presents multiple policy actions and explores empirically two policy options
- In order to reduce or neutralize the tax/subsidy effects of underestimated life expectancy the paper presents multiple policy actions and explores empirically two of them: (i) introducing a sustainability factor; and (ii) through pension indexation
- Ideally both interventions should be differentiated not only with respect to the retirement age but also by the birth cohort. However, applying differentiated correction factors are likely to meet with political resistance
- The combined analysis of the life expectancy gap and longevity heterogeneity creates a more complicated technical hurdle. But this is a topic of a different paper.