A Online Appendix for "Redistributive effects of pension reforms: Who are the winners and losers?"

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A.1 Solution: Household problem

Given the set of endowments $\theta_n \in \Theta$ we solve the household problem of maximizing the lifetime utility (9) and the educational decision (10) subject to eqs. (1)–(8) and the boundary conditions $k_{\underline{a},e,n} = 0$ and $h_{\underline{a},e,n} = h_{\underline{a}}$. For notational convenience, let us define the marginal rate of substitution between pension points and assets for an agent of age a, with education e, of type n as

$$\mathcal{P}_{a,e,n} = \frac{\partial V(\mathbf{x}_{a,e,n})}{\partial \text{pp}_{a,e,n}} \Big/ \frac{\partial V(\mathbf{x}_{a,e,n})}{\partial k_{a,e,n}}$$

and the marginal rate of substitution between human capital and assets for an agent of age a, with education e, of type n as

$$\mathcal{H}_{a,e,n} = \frac{\partial V(\mathbf{x}_{a,e,n})}{\partial h_{a,e,n}} \Big/ \frac{\partial V(\mathbf{x}_{a,e,n})}{\partial k_{a,e,n}} .$$

Each marginal rate of substitution measures the value, assigned by an agent with endowments θ_n, of investing in each state (pension points and human capital) relative to investing in assets.

The first-order conditions (FOCs) of this problem are:

$$U_c(c_{a,e,n}, l_{a,e,n}) = \beta \pi_{a+1,e,n} \frac{\partial V(\mathbf{x}_{a+1,e,n})}{\partial k_{a+1,e,n}} (1 + \tau_a^c), \tag{A.1}$$

$$-U_l(c_{a,e,n}, l_{a,e,n}) = U_c(c_{a,e,n}, l_{a,e,n}) \left(1 - \tau_{a,e,n}^L\right) w_{a,e,n}, \tag{A.2}$$

where $\tau_{a,e,n}^L = \frac{\tau_a^c + \tau_a^l + \tau_{a,e,n}^S + \tau_{a,e}^J(-\alpha_J'(l_{a,e,n}))}{1+\tau_a^c}$ is the effective labor income tax. Notice that the effective labor income tax includes the effective social security tax rate at the intensive margin, denoted by $\tau_{a,e,n}^S$, and the retirement tax/subsidy rate, denoted by $\tau_{a,e,n}^J$, which are given by

$$\tau_{a,e,n}^S = \tau_a^s(1 - \tau_a^l) - \mathcal{P}_{a+1,e,n} \phi^p \text{PBI}'(y_{a,e,n}), \tag{A.3}$$

$$\tau_{a,e,n}^J = (1 - \tau_a^l)\left(1 + \varepsilon_{b,\alpha_J,e,n}\right) \frac{b_{a,e,n}}{w_{a,e,n}} - (\mathcal{R}_a - 1) \frac{\text{pp}_{a,e,n} \mathcal{P}_{a+1,e}}{w_{a,e,n}}. \tag{A.4}$$

The term $\varepsilon_{b,\alpha_J,e,n}$ is the retirement-elasticity of pension benefit; i.e. $\frac{1}{b_{a,e,n}} \frac{\partial b_{a,e,n}}{\partial l_{a,e,n}} \frac{\alpha_J(l_{a,e,n})}{\alpha_J'(l_{a,e,n})}$. Eqs. (A.3)-(A.4) coincide with the effective social security tax rate and the retirement tax/subsidy rate in Sánchez-Romero et al. 2020.

The envelope conditions (ECs) imply that:

$$U_c(c_{a,e,n}, l_{a,e,n}) = R_{a+1,e,n} \beta \pi_{a+1,e,n} \frac{1 + \tau_a^c}{1 + \tau_{a+1}^c} U_c(c_{a+1,e,n}, l_{a+1,e,n}), \tag{A.5}$$

$$R_{a,e,n} \mathcal{P}_{a,e,n} = (1 - \tau_a^l) \frac{\partial b_{a,e,n}}{\partial \text{pp}_{a,e,n}} \alpha_J(l_{a,e,n}) + \mathcal{P}_{a+1,e,n} \frac{\partial \text{pp}_{a+1,e,n}}{\partial \text{pp}_{a,e,n}}, \tag{A.6}$$

$$R_{a,e,n} \mathcal{H}_{a,e,n} = \left(1 - \tau_a^l - \tau_{a,e,n}^S\right) \frac{y_{a,e,n}}{h_{a,e,n}} + \mathcal{H}_{a+1,e,n} \frac{\partial h_{a+1,e,n}}{\partial h_{a,e,n}}, \tag{A.7}$$

Combining FOCs and ECs we have that the total expenditure on final goods not only changes with age because of the difference between the market and the subjective time discount factors, but also because of changes in the household size

$$\frac{(1 + \tau_{a+1}^c) c_{a+1,e,n}}{(1 + \tau_a^c) c_{a,e,n}} = \beta(1 + r_a(1 - \tau_a^k)) \frac{H_{a+1,e}}{H_{a,e}}. \tag{A.8}$$

The labor supply of our representative agents is given by

$$l_{a,e,n} = \begin{cases} \left(\frac{1}{\alpha_L} \frac{\left(1 - \tau_{a,e,n}^L\right) w_{a,e,n}}{c_{a,e,n}/H_{a,e}} \right)^{\sigma_L} & \text{if } a < J, \\ \left(\frac{1}{\alpha_L} \frac{\left(1 - \tau_{a,e,n}^L\right) w_{a,e,n}}{c_{a,e,n}/H_{a,e}} - \frac{1}{\alpha_L} \frac{v_0 (LE_{a,e,n})^{-v_1}}{\overline{L}} \right)^{\sigma_L} & \text{if } a \geq J. \end{cases} \tag{A.9}$$

Eq. (A.9) implies that agents who have lower effective labor income tax and higher wage rates, relative to the average consumption of the household, supply more labor. Once that retirement is allowed, those agents with longer life expectancy, lower effective labor income tax, and lower wage rates, relative to the average consumption of the household, will retire later, ceteris paribus the initial endowments.

The value of $\mathcal{H}_{a,e,n}$, which is also calculated backwards, gives

$$\mathcal{H}_{a,e,n} h_{a-1,e,n} = \sum_{s=a}^{\Omega-1} \left(\prod_{z=a}^{s} \frac{1}{R_{z,e,n}} \right) \left(1 - \tau_s^l - \tau_{s,e,n}^S\right) y_{s,e,n}. \tag{A.10}$$

The value of human capital times the stock of human capital is the present value of the remaining lifetime income, which includes the present value of future pension benefits through the stream of $\{\tau_{a,e,n}^S y_{a,e,n}\}_{a=\underline{a}}^{\overline{J}}$ values.

A.2 Aggregation

To prove that the market of final goods clears, we apply the following aggregation rules

$$K_t \equiv \sum\nolimits_{a=0}^{\Omega} \sum\nolimits_{n=1}^{\mathcal{N}} N_{t-a,a} \int_{\Theta} \mathbf{k}_{t-a,a,n} \mathrm{d}P(\theta_n), \tag{A.11}$$

$$C_t \equiv \sum\nolimits_{a=0}^{\Omega} \sum\nolimits_{n=1}^{\mathcal{N}} N_{t-a,a+1} \int_{\Theta} \mathbf{c}_{t-a,a,n} \mathrm{d}P(\theta_n), \tag{A.12}$$

$$L_t \equiv \sum\nolimits_{a=0}^{\Omega} \sum\nolimits_{n=1}^{\mathcal{N}} N_{t-a,a+1} \int_{\Theta} \epsilon_a(\mathbf{e}_{t-a,n}) \mathbf{h}_{t-a,a,n} \mathbf{l}_{t-a,a,n} \mathrm{d}P(\theta_n), \tag{A.13}$$

$$\mathcal{S}_t \equiv \sum\nolimits_{a=0}^{\Omega} \sum\nolimits_{n=1}^{\mathcal{N}} N_{t-a,a+1} \int_{\Theta} \mathbf{b}_{t-a,a,n}\, \alpha_J(\mathbf{l}_{t-a,a,n})\, \mathrm{d}P(\theta_n), \tag{A.14}$$

where K_t is aggregate capital stock, C_t is aggregate private consumption, L_t is aggregate labor, $\mathcal{S}_t$ is the total social security spending. The term $N_{t-a,a}$ is the total population size of a cohort born in year $t-a$ at age a. All the terms in bold are household policy functions, and $P(\theta_n)$ is the probability of having the initial endowments $\theta_n \in \Theta$.

First, we sum all the flow budget constraints of households at time t across all ages and group types. This implies that the flow budget constraint of a household born in year $t-a$ at age a is multiplied by the population size surviving to the end of the period $N_{t-a,a+1}$ or, equivalently, $\sum_{n=1}^{\mathcal{N}} N_{t-a,a} \int_{\Theta} \boldsymbol{\pi}_{t-a,a,n}\, \mathrm{d}P(\theta_n)$. After aggregation we have

$$K_{t+1} + (1+\tau_t^c)C_t = K_t + r_t(1-\tau_t^k)K_t + (1-\tau_t^l)[(1-\tau_t^s)w_t L_t + \mathcal{S}_t]. \tag{A.15}$$

Subtracting K_t and $\tau_t^c C_t$ in both sides of the equation gives

$$K_{t+1} - K_t + C_t = r_t(1-\tau_t^k)K_t + (1-\tau_t^l)[(1-\tau_t^s)w_t L_t + \mathcal{S}_t] - \tau_t^c C_t. \tag{A.16}$$

Since in the Austrian pension system, social contributions only finance seventy percent of all pension benefits claimed $\tau_t^s w_t L_t = 0.7\mathcal{S}_t$, the term inside brackets can be rewritten as

$$K_{t+1} - K_t + C_t = r_t(1-\tau_t^k)K_t + (1-\tau_t^l)[w_t L_t + 0.3\mathcal{S}_t] - \tau_t^c C_t. \tag{A.17}$$

Splitting the right-hand side of the equation into the gross income generated and the net cash transfers received gives

$$K_{t+1} - K_t + C_t = r_t K_t + w_t L_t + 0.3\mathcal{S}_t - \tau_t^k r_t K_t - \tau_t^l [w_t L_t + 0.3\mathcal{S}_t] - \tau_t^c C_t. \tag{A.18}$$

After adding public consumption G_t in both sides of the equation we have

$$K_{t+1} - K_t + C_t + G_t = r_t K_t + w_t L_t + G_t + 0.3\mathcal{S}_t - \tau_t^k r_t K_t - \tau_t^l [w_t L_t + 0.3\mathcal{S}_t] - \tau_t^c C_t. \tag{A.19}$$

Using the budget of the government, Eq. (17), we obtain the net income generated in the economy or value added in year t

$$K_{t+1} - K_t + C_t + G_t = r_t K_t + w_t L_t. \tag{A.20}$$

Finally, adding in both sides of the equation the depreciation of capital $\delta_K K_t$, using (13)-(14) and the fact that $K_{t+1} = (1-\delta_K)K_t + I_t$, we obtain that the total output of the economy equals the income generated and the uses in each year t

$$Y_t \equiv I_t + C_t + G_t = (r_t + \delta_K)K_t + w_t L_t. \tag{A.21}$$

A.3 Equilibrium conditions

Given initial time, cohort, and age sets $\{\mathcal{T}, \mathcal{Z}, \mathcal{A}\}$, the set of education levels $\mathbf{E}$, the probability space of initial endowments $(\Theta, \boldsymbol{\theta}, \mathrm{P})$, the number of heterogeneous agents $\mathcal{N}$ in each birth cohort, the model parameters (see Table 2), exogenous economic data $\{A_t\}_{t\in\mathcal{T}}$, and demographic data $\{N_{z,a}, \pi_{z,a,e,n}, \mathrm{fer}_{z,a,e},\ H_{z,a,e}, \Delta_e\}_{t\in\mathcal{T},z\in\mathcal{Z},a\in\mathcal{I},e\in\mathbf{E},\theta_n\in\Theta}$, a recursive competitive equilibrium is a sequence of a set of household policy functions $\{\mathbf{c}_{z,a,n}, \mathbf{l}_{z,a,n}, \mathbf{e}_{z,n}, \mathbf{k}_{z,a,n}, \mathbf{pp}_{z,a,n}, \mathbf{h}_{z,a,n}\}_{z\in\mathcal{Z},a\in\mathcal{A},\theta_n\in\Theta,n\in 1,\ldots,\mathcal{N}}$, government policy functions $\{G_t,\ \tau_t^c,\ \tau_t^l, \tau_t^k,\ \tau_t^s\}_{t\in\mathcal{T}}$ and factor prices $\{w_t, r_t\}_{t\in\mathcal{T}}$ such that

(i) Given the factor prices and government policy functions, household policy functions satisfy (7)-(11).

(ii) Factor prices w_t, r_t equal their marginal productivities.

(iii) The government's budget constraints (15)–(17) are satisfied.

(iv) The stock of capital and the effective labor input are given by:

$$K_t = \sum\nolimits_{a=0}^{\Omega} \sum\nolimits_{n=1}^{\mathcal{N}} N_{t-a,a} \int_{\Theta} \mathbf{k}_{t-a,a,n} \mathrm{d}P(\theta_n), \tag{A.22}$$

$$L_t = \sum\nolimits_{a=0}^{\Omega} \sum\nolimits_{n=1}^{\mathcal{N}} N_{t-a,a+1} \int_{\Theta} \epsilon_a(\mathbf{e}_{t-a,n}) \mathbf{h}_{t-a,a,n} \mathbf{l}_{t-a,a,n} \mathrm{d}P(\theta_n). \tag{A.23}$$

(v) The market of final goods clears

$$Y_t = I_t + C_t + G_t, \tag{A.24}$$

where I_t is the investment in year t, C_t is aggregate consumption of final goods, and G_t is the aggregate consumption of publicly financed goods.

A.4 Bayesian melding method

We use the Bayesian melding method to derive in our dynamic general equilibrium-overlapping generations model the unobserved initial heterogeneity of our heterogeneous agents, while keeping consistency between the micro- and the macroeconomic information. To implement the Bayesian melding we initially used the sampling importance resampling (SIR) algorithm (Poole and Raftery 2000). However, after running the algorithm thousands of times the number of unique points was very low, which is a signal of poor performance and suggests that the algorithm is not suitable for finding the most likely parameters. To cope with this problem, Raftery and Bao 2010 suggest to use a more sophisticated algorithm such as the incremental mixture importance sampling (IMIS) algorithm, which outperforms the Markov chain Monte Carlo (MCMC) algorithm. We modify the IMIS algorithm of Raftery and Bao 2010 in order to allow for heterogeneous agents.

Let our large scale dynamic general equilibrium-overlapping generations model be $M(\cdot)$. Let us assume each cohort is represented by a set of $\mathcal{N}$ heterogeneous agents whose endowments are randomly assigned at birth. Let the set of endowments characterizing the n-th agent in all cohorts be $\theta_n = (\xi_n, \eta_n)$ or permanent unobserved heterogeneity. Let Θ be the the product set of $\Theta_1, \ldots, \Theta_{\mathcal{N}}$ that consists of all $\mathcal{N}$-tuples $(\theta_1, \theta_2, \ldots, \theta_n, \ldots, \theta_{\mathcal{N}})$ where $\theta_n \in \Theta_n$ for each n. Let a realization of Θ be $\boldsymbol{\theta}$. The initial endowments $\boldsymbol{\theta}$ are random variables with a joint prior distribution denoted by $q_1(\Theta)$. We assume independent uniform priors for the distribution on the inputs

$$q_1(\Theta) = \mathcal{U}\left([0, 0.3] \times [0, 40]\right).$$

Let $\Phi = (\mathbf{e}_{z_0}(\boldsymbol{\theta}), \ldots, \mathbf{e}_{z_T}(\boldsymbol{\theta}))$ be the set of outputs of the dynamic general equilibrium-overlapping generations model given the model inputs $\boldsymbol{\theta}$; i.e., $M(\boldsymbol{\theta}) = \Phi$. We assume the likelihood of the model's output is given by

$$\mathcal{L}(\Phi|\text{data}) \propto \exp\left\{-\frac{1}{2}\sum_{z=z_0}^{z_T} (\mathbf{m}_z(\boldsymbol{\theta}) - \widehat{\mathbf{m}}_z)'\widehat{W}^{-1}(\mathbf{m}_z(\boldsymbol{\theta}) - \widehat{\mathbf{m}}_z)\right\} \tag{A.25}$$

where $\mathbf{m}_z(\boldsymbol{\theta}) = (\mathrm{E}[\mathbf{e}_z(\boldsymbol{\theta})]; \sigma[\mathbf{e}_z(\boldsymbol{\theta})])$ is the vector with the model mean and standard deviation of the additional years of education for cohort z, $\widehat{\mathbf{m}}_z$ is the vector with the estimated mean and standard deviation of the additional years of education for cohort z, and $\widehat{W} = \text{diag}\left(\sigma[\boldsymbol{\mu}^e], \sigma[\boldsymbol{\sigma}^e]\right)$ is the weighting matrix with the standard deviations of the estimated mean and standard deviation of the additional years of education across all cohorts.

IMIS algorithm (Raftery and Bao, 2010)

1. Initial Stage:
   (a) Run B_0 samples of $\boldsymbol{\theta} \in \Theta$ realizations from the joint prior distribution on inputs $q_1(\Theta)$ obtained with the SIR algorithm
   (b) For each $\boldsymbol{\theta}_i$ sampled, run the model to obtain the set of output $M(\boldsymbol{\theta}_i) = \Phi_i$,
   (c) Calculate the likelihood of each model output
   $$\mathcal{L}(\Phi_i|\text{data}) \text{ for } i = \{1, \ldots, B_0\}$$
   (d) Construct the importance sampling weights (ISW)
   $$w_0(\boldsymbol{\theta}_i) \propto \frac{\mathcal{L}(\Phi_i|\text{data})}{\sum_{i=1}^{B_0} \mathcal{L}(\Phi_i|\text{data})}$$
2. Importance Sampling Stage: for $k = 1, 2, \ldots,$ until a stopping criteria is satisfied
   (a) Compute $\mathcal{N}$ multivariate Gaussian distribution $H_n^{(k)}$ with center $\mu_n^{(k)}$ and covariance $\Sigma_n^{(k)}$ for $n \in \{1, \ldots, \mathcal{N}\}$. Choose the input set $\boldsymbol{\theta}_i = (\theta_{i1}, \ldots, \theta_{i\mathcal{N}})$ with maximum weight $w_{k-1}(\boldsymbol{\theta}_i)$. Choose as the center $\mu_n^{(k)}$ the set of parameters $\theta_{in}^{(k)}$. Calculate the weighted covariance matrix $\Sigma_n^{(k)}$ with the (B) agents, one for each sampled ϑ, with the smallest Mahalanobis distance to $\theta_{in}^{(k)}$ and the weights are the average between the importance weight and $1/B_k$.
   (b) Sample B new inputs θ_{jn}, with $j \in \{1, \ldots, B\}$, from $H_n^{(k)}$ for each n-th agent and form inputs $\boldsymbol{\theta}_j$ and combine them with the previous realizations.
   (c) Compute steps 1(b)–(c) and calculate the new importance sampling weights as follows
   $$w_k(\boldsymbol{\theta}_i) \propto \mathcal{L}(M(\boldsymbol{\theta}_i)|\text{data}) \times \prod_{n=1}^{\mathcal{N}} \frac{q_1(\theta_{in})}{q_n^{(k)}(\theta_{in})},$$
   where $q_n^{(k)}(\theta_{in})$ is the mixture sampling distribution for the n-th agent, with $q_n^{(k)}(\theta_{in}) = \frac{B_0}{B_k} q_1(\theta_{in}) + \frac{B}{B_k} \sum_{s=1}^{k} H_n^{(s)}(\theta_{in})$ and $B_k = B_0 + Bk$ is the total number of inputs up to iteration k.
3. Resample Stage: For J equal to 200, if the expected fraction of unique points after resampling $\hat{Q}(w) = \frac{1}{J} \sum_{i=1}^{B_k} (1 - (1 - w_i)^J)$ is less than 63%, go to Step 2.; otherwise, resample (J) 200 inputs with replacement from $\boldsymbol{\theta}_1, \ldots, \boldsymbol{\theta}_{B_K}$ with weights $w_1, \ldots, w_{B_K}$, where K is the number of iterations at step 2.

After running the IMIS algorithm we have obtained the 200 most likely inputs (i.e., initial endowments). Figure 4 shows how the two initial endowments (learning ability and schooling effort) are positively correlated. Table A.1 reports the mean and standard deviation across the 200 initial endowments for each of the $\mathcal{N}$ clusters.

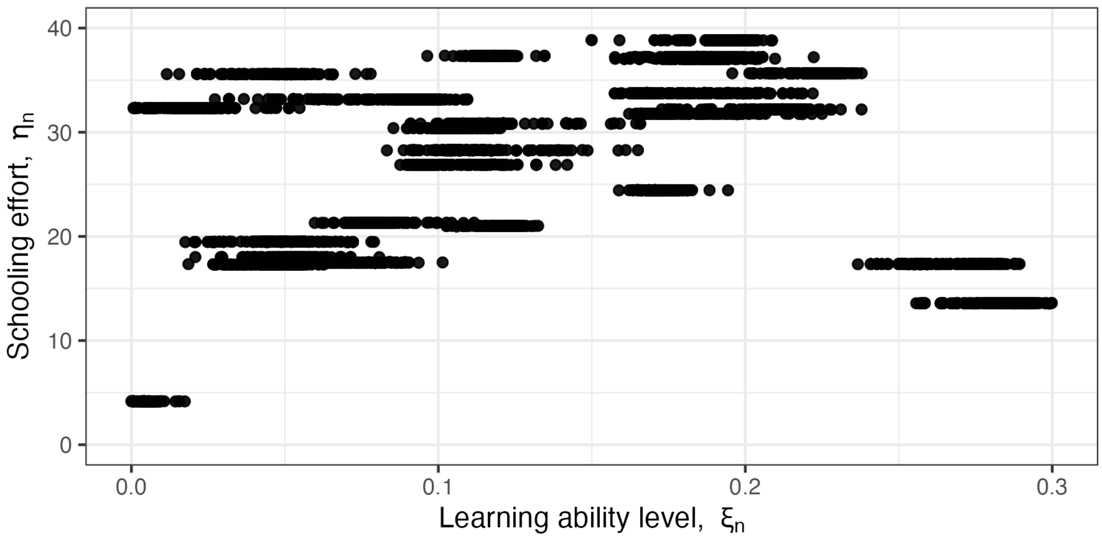

Figure A.1: Correlation matrix of the initial endowments ϑ for the $\mathcal{N} = 25$ agents of each cohort. *Notes*: Dots represent the initial endowments of the most likely set of parameters obtained from the posterior distribution.

Table A.1: Mean and standard deviation of the initial endowments across the 200 parameter sets withdrawn from the posterior distribution

Cluster	Learning ability, ξ_n		Schooling effort, η_n	
$\mathcal{N}$	$E[\xi_n]$	$sd[\xi_n]$	$E[\eta_n]$	$sd[\eta_n]$
1	0.185	0.009	37.219	0.012
2	0.047	0.012	19.488	0.015
3	0.082	0.018	33.147	0.014
4	0.183	0.016	33.732	0.013
5	0.265	0.012	17.348	0.010
6	0.193	0.009	38.821	0.008
7	0.208	0.013	32.192	0.010
8	0.185	0.012	31.780	0.015
9	0.046	0.008	17.298	0.011
10	0.172	0.005	24.435	0.006
11	0.121	0.006	21.003	0.009
12	0.282	0.009	13.591	0.010
13	0.018	0.011	32.320	0.009
14	0.105	0.006	30.387	0.005
15	0.185	0.010	37.042	0.014
16	0.045	0.011	35.576	0.012
17	0.052	0.008	18.009	0.011
18	0.117	0.005	37.318	0.012
19	0.111	0.014	28.273	0.015
20	0.104	0.011	26.876	0.008
21	0.079	0.008	21.301	0.008
22	0.222	0.007	35.660	0.006
23	0.118	0.012	30.824	0.013
24	0.005	0.003	4.171	0.005
25	0.071	0.011	17.487	0.018

A.5 Introducing differential fertility and mortality in the model

We extend the historically reconstructed population estimates for Austria by introducing differential fertility and mortality by educational attainment (see A.2). Demographic data before 2010 is taken from historical records (Rivic 2019), while the demographic data after 2010 is based on Eurostat's projections.

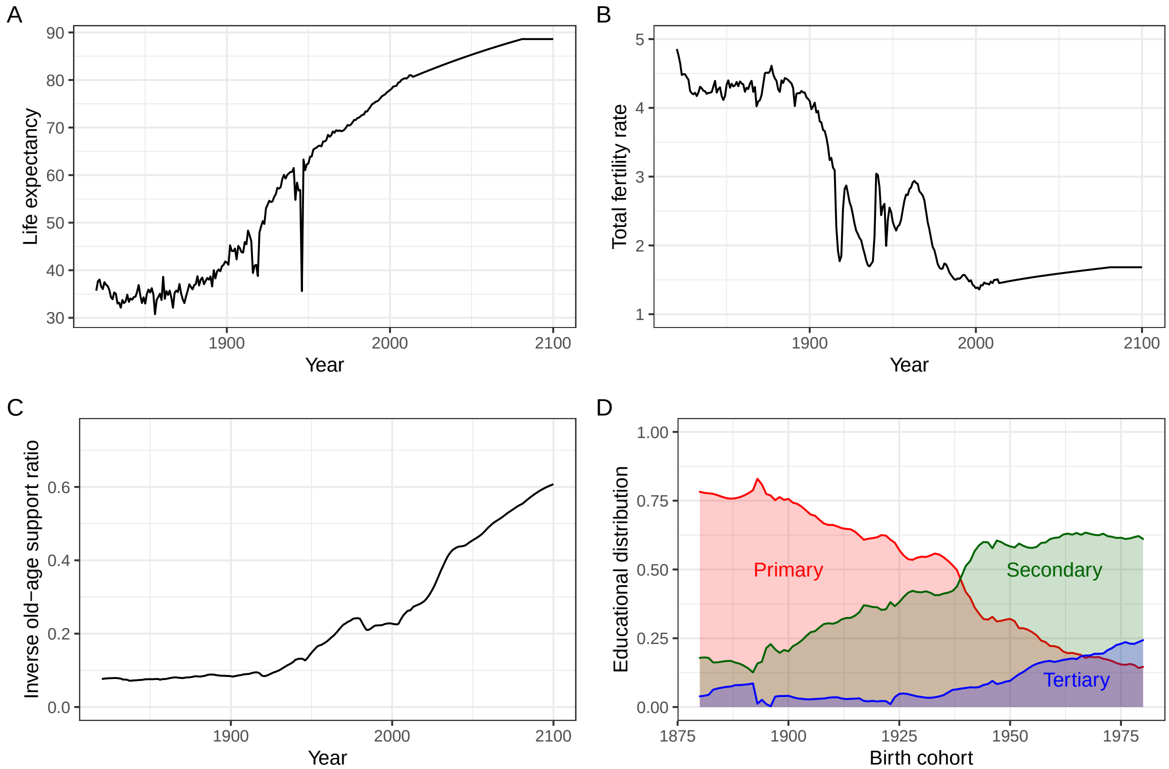

Figure A.2: Austrian demographics, 1880–2100. *Source*: Data taken from Rivic 2019. *Notes*: Panel A shows the life expectancy at birth, Panel B shows the total fertility rate, Panel C shows the inverse of the old-age support ratio, and Panel D is the educational distribution by birth cohort. The inverse of the old-age support rate is the ratio of the population aged 65+ to the economically active population (ages 15-64).

Next, we detail the assumptions and the calculations for consistently introducing differences in mortality and fertility rates by educational attainment.

Mortality We use standard mortality differentials by education based on existing literature (Lutz et al. 2007; Lutz et al. 2014; Goujon et al. 2016). Moreover, following Murtin et al. 2022 we include mortality differential by income level. The next table shows the difference in life expectancy at age 15 by learning ability level between agents with education e and those with college (reference group).

Table A.2: Differences in life expectancy at age 15 by educational attainment and learning ability level

Education level, e	Primary	Secondary	College (Ref.)
Highest learning ability	0	+3.5	+5
Average learning ability	-5	-1.5	0
Lowest learning ability	-10	-6.5	-5

To include the differential mortality by educational group across cohorts, we first calculate the life expectancy of the reference group (=college). Let us denote by Δ_e the difference in life expectancy at age 15 between agents with education $e \in \mathbf{E}$ and those with college. Thus, the life expectancy at age 15 of an agent born in year $z \in \mathcal{Z}$ with educational attainment e can be written as $\mathrm{LE}_{z,15,e} = \mathrm{LE}_{z,15,8} - \Delta_e$. Let the average life expectancy at age 15 of the cohort born in year z be denoted by $\overline{\mathrm{LE}}_{z,15}$, which can be expressed as

$$\overline{\mathrm{LE}}_{z,15}=\sum\nolimits_{e\in\mathbf{E}}\frac{N_{z,15,e}\mathrm{LE}_{z,15,e}}{N_{z,15}}=\sum\nolimits_{e\in\mathbf{E}}\frac{N_{z,15,e}}{N_{z,15}}(\mathrm{LE}_{z,15,8}-\Delta_e)=\mathrm{LE}_{z,15,8}-\sum\nolimits_{e\in\mathbf{E}}\frac{N_{z,15,e}\Delta_e}{N_{z,15}}, \tag{A.26}$$

where $\frac{N_{z,15,e}}{N_{z,15}}$ is the fraction of people of cohort z with education e. Rearranging terms in (A.26) we have that the life expectancy of cohort z at age 15 with education e is given by

$$\mathrm{LE}_{z,15,e}=\overline{\mathrm{LE}}_{z,15}+\sum\nolimits_{e\in\mathbf{E}}\left(\frac{N_{z,15,e}}{N_{z,15}}-1\right)\Delta_e. \tag{A.27}$$

The simulated evolution across cohorts of the average life expectancy (at birth) for the three educational groups is presented in Fig. A.3, panel A. Second, assuming that the conditional survival probability of cohort z, at age a, with education e is given by $\pi_{z,a,e}=(\pi_{z,a})^{\kappa^m_{z,e}}$, where $\kappa^m_{z,e}$ reflects the differential mortality of having education e for cohort z relative to the average individual within the same cohort, we calculate the value of $\kappa^m_{z,e}$ as follows

$$\min_{\kappa^m_{z,e}\in\mathbb{R}}\left(\mathrm{LE}_{z,15,e}-\sum\nolimits_{a=15}^{\Omega}\left[\Pi^a_{s=15}\left(\pi_{z,s}\right)^{\kappa^m_{z,e}}\right]\right)\text{ for all } e\in\mathbf{E}\text{ and } z\in\mathcal{Z}. \tag{A.28}$$

Third, we introduce the differences by learning ability level in the conditional survival probability of each cohort and level of education. To do so, we assume for each educational group that the difference between the highest (resp. lowest) possible learning ability level $\overline{\xi}$ (resp. $\underline{\xi}$) and the mean learning ability level is 5 years of age (see Table A.2). Hence, the life expectancy at age 15 for the cohort z, with education e, and learning ability ξ is

$$\mathrm{LE}_{z,15,e}(\xi)=\mathrm{LE}_{z,15,e}+5\left(\xi-\frac{\overline{\xi}+\underline{\xi}}{2}\right). \tag{A.29}$$

Following the same strategy as we used for introducing the difference in life expectancy at age 15 across educational groups, we assume the conditional survival probability of cohort z, at age a, with education e, and learning ability ξ is given by $\pi_{z,a,e}(\xi)=(\pi_{z,a,e})^{\kappa^l_{z,e}(\xi)}$, where $\kappa^l_{z,e}(\xi)$ accounts for the differential mortality of having a learning ability level ξ for agents belonging to cohort z, who have education e. Then, function $\kappa^l_{z,e}(\xi)$ is constructed via interpolation after estimating $\kappa^l_{z,e}(\cdot)$ via (A.28) for a grid of values of $\xi\in[\overline{\xi},\underline{\xi}]$.

Fertility We introduce the fertility differential by education assuming that the net reproduction rate (NRR) is the same across educational group; i.e. $\mathrm{NRR}_{z,e}=\mathrm{NRR}_z$ for all $e\in\mathbf{E}$. The total number of daughters born from the birth cohort z, or net reproduction rate, is

$$\mathrm{NRR}_z=\sum\nolimits_{a=0}^{\Omega}\left[\Pi^a_{s=0}\pi_{z,s}\right]\mathrm{fer}_{z,a}f_{\mathrm{fab}}, \tag{A.30}$$

where $\mathrm{fer}_{z,a}$ is the age-specific fertility rates for the cohort z and f_{fab} is the fraction of females at birth. Let us now consider that the birth cohort is comprised of individual with different educational attainment. Thus, we can rewrite the previous equation as

$$\mathrm{NRR}_z=\sum\nolimits_{e\in\mathbf{E}}\frac{N_{z,e}}{N_z}\underbrace{\left(\sum\nolimits_{a=0}^{\Omega}\left[\Pi^a_{s=0}\pi_{z,s,e}\right]\mathrm{fer}_{z,a,e}f_{\mathrm{fab}}\right)}_{\mathrm{NRR}_{z,e}}, \tag{A.31}$$

where $\mathrm{fer}_{z,a,e}$ is the age-specific fertility rate for agents that belong to cohort z with education e.

To minimize the change in the age distribution of the population caused by the introduction of heterogeneity by education, we assume that fertility profiles across the different education groups are given by $\mathrm{fer}_{z,a,e}=\kappa^f_e\mathrm{fer}_{z,a}$, where κ^f_e is calculated as

$$\kappa^f_e=\mathrm{NRR}_z\Big/\left(\sum\nolimits_{a=0}^{\Omega}\left[\Pi^a_{s=0}\pi_{z,s,e}\right]\mathrm{fer}_{z,a}f_{\mathrm{fab}}\right). \tag{A.32}$$

Note that since we have assumed the same population growth rate across educational groups, the fertility for lower educated is slightly higher than for more educated agents to overcome the higher mortality of lower educated as shown in the evolution across cohorts of the total fertility rate for the three educational groups in Fig. A.3, panel B. As a result, agents with different educational attainment will also face a different household size consistent with their mortality and fertility profiles

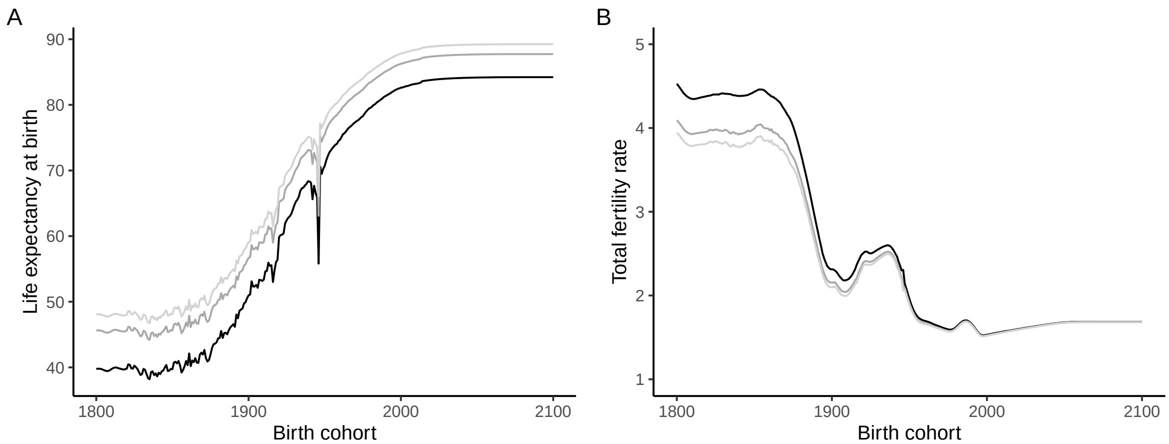

Figure A.3: Simulated average vital rates by educational attainment for birth cohorts born between 1800 and 2100 in Austria: Primary or less (black), secondary (dark gray), and college (light gray). *Source*: Differences in life expectancy and in total fertility rate across the educational groups are based on assumptions taken from Goujon et al. 2016. The average life expectancy and the total fertility rate across educational groups are based on historical reconstructions of the Austrian population done by the authors using data from Rivic 2019. *Notes*: Panel A shows the life expectancy at birth by educational attainment. Panel B shows the total fertility rate (TFR) by educational attainment.

A.6 Private and public sectors

We collected historical information from Statistisches Handbuch Österreichs (1966, 1991) on the public consumption spending from 1913 to 2018. Before 1913 and after 2018 we assume that public consumption represents 8 percent and 20 percent of the total output, respectively, which coincides with the first and the last public consumption to output ratio from the time series taken from Statistisches Handbuch Österreichs (1966, 1991). See the ratio of public consumption to output in panel A Figure A.4.

Based on National Accounts data from Statistics Austria for the period 1995–2018 we consider that labor income taxes finance 55 percent, consumption taxes finance 35 percent, and capital income taxes finances the remaining 10 percent of the total budget. The implementation of the evolution of all the historical parametric components of the Austrian pension system is taken from the General Law on Social Security (ASVG) and the General Pensions Act (APG).[1] We detail the values of the parametric components in the Online Appendix, Section A5.

Under the current law of the Austrian pension system, we estimate that pension spending will represent more than 20% of the total output by year 2100, which is 5 percent higher than the current pension spending. The social contribution rate is expected to reach 25 percent by year 2100, as compared to 19.1% in 2010.[2] To reduce the expected increasing cost of the pension system due to population aging and the longer life expectancy of retirees, we introduce a pension sustainability factor, which guarantees a maximum social security contribution rate, denoted by $\overline{\tau_t^s}$, of 22 percent. When the maximum social security contribution rate is reached, the government will adjust downwards the pension replacement rate by reducing the pension sustainability factor, denoted by ρ_t (see Eq. (**??**)),

[1] All the historical proposals can be found in the historic law database www.sozdok.at.

[2] The social contribution rate is calculated as the ratio between the total pension spending and the total wage bill of the economy.

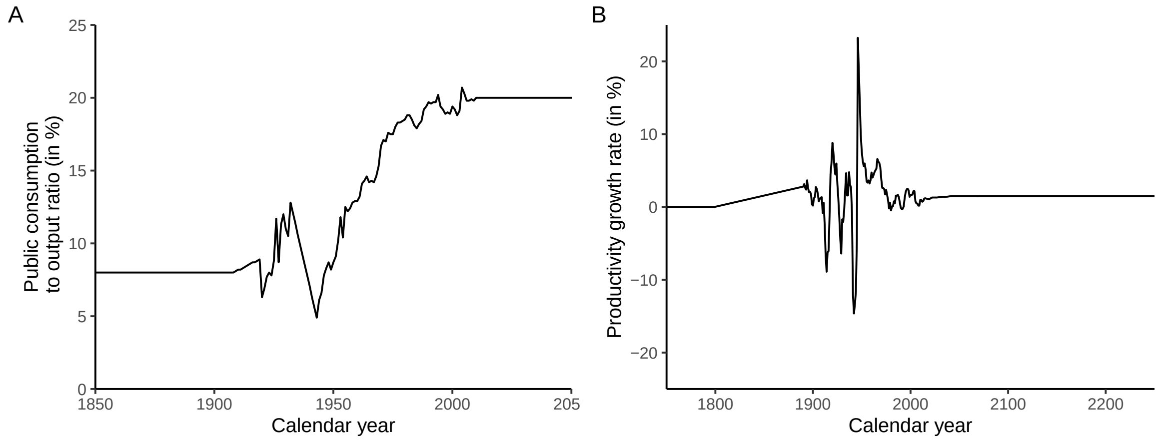

Figure A.4: Public consumption to output ratio (**A**) and exogenous productivity growth rate (**B**). *Source*: Data on public consumption to output ratio comes from Statistisches Handbuch Österreichs (1966, 1991) and the National Accounts from Statistics Austria. The exogenous productivity growth rate is taken from Bergeaud et al. 2016 and European Commission 2018.

until the system is balanced. In addition to the sustainability factor, in this paper, we analyze several pension proposals, many of which aim at correcting the regressivity of the pension system when there is an ex-ante difference in life expectancy by socio-economic status. We assume that each pension proposal is introduced for the cohort born in year 1961 and has a similar phase-in/out period of 20 years

$$\zeta_z = \begin{cases} 0 & \text{for } z \leq 1960, \\ \frac{z-1960}{20} & \text{for } 1960 < z \leq 1980, \\ 1 & \text{for } z > 1980, \end{cases} \tag{A.33}$$

where $z \in \mathcal{Z}$ denotes the birth cohort. Eq. (A.33) implies that the cohort $z = 1960$ is the last cohort without any correction ($\zeta_z = 0$) and that the reform is fully implemented ($\zeta_z = 1$) for all cohorts born after year 1980.

A.6.1 Parametric components of the Austrian Pension System

The model has been designed to reflect at each age the average pension points accumulated and the average pension benefit of the members of a cohort and not of a single individual. Table A.3 shows the historical evolution of the main parametric components of the Austrian pension system by birth cohort.

A.7 Life expectancy by pension point level

Pension reforms 4 (ABH proposal) and 5 (SP proposals) suggest modifying the replacement rate considering that individuals have ex-ante a different life expectancy.

Given that we assume, yet realistically, that the social security system has no information on the life expectancy of each individual, we cannot use the individual's life expectancy. To calculate the difference in life expectancy across individuals, most scholars use lifetime labor income as a good proxy see, for instance, Chetty et al. 2016 and Holzmann et al. 2019. Thus, we consider that the social security system uses the information on the number of pension points, which is known by the social security, to estimate the average remaining years of life at age 65. We follow the literature and regress the relative average remaining years of life at age 65 to the logarithm of the relative number of pension points

$$le_{zni} = a + b\log(p_{zni}) + u_{zni}, \tag{A.34}$$

Table A.3: Parametric components of the Austrian pension system by birth cohort

Birth cohort z	Pensionable income years n_z	Working years wy_z	Early retirement $\underline{J}_z$	Normal retirement J_z^N	Late retirement $\overline{J}_z$	Replacement rate φ_z
⋮	⋮	⋮	⋮	⋮	⋮	⋮
1875	5	45	57.0	63.0	68	0.00
1880	5	45	57.0	63.0	68	0.01
1885	5	45	57.0	63.0	68	0.06
1890	5	45	57.0	63.0	68	0.40
1895	5	45	57.0	63.0	68	0.74
1900	5	45	57.0	63.0	68	0.79
1905	5	45	57.0	63.0	68	0.80
1910	5	45	57.0	63.0	68	0.80
1915	5	45	57.0	63.0	68	0.80
1920	5	45	57.0	63.0	68	0.80
1925	5	45	57.0	63.0	68	0.80
1930	12	45	57.0	63.0	68	0.80
1935	15	45	57.0	63.0	68	0.80
1940	15	45	57.0	63.0	68	0.80
1945	15	45	59.0	63.0	68	0.80
1950	15	45	60.4	63.0	68	0.80
1955	15	45	60.9	63.0	68	0.80
1960	20	45	61.4	63.0	68	0.80
1965	25	45	61.9	63.8	68	0.80
1970	30	45	62.0	65.0	68	0.80
1975	35	45	62.0	65.0	68	0.80
1980	40	45	62.0	65.0	68	0.80
1985	45	45	62.0	65.0	68	0.80
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Notes: Men and women combined.

where $le_{zni} \in [0,1]$ is the relative remaining year of life at age 65 for an individual born in year z of type n in model i with respect to the highest life expectancy at age 65 observed for individuals born in year z and model i (i.e., $le_{zni} = \text{LE}_{65,zni}/\max(\text{LE}_{65,zi})$), $p_{zni} \in [0,1]$ is the relative number of pension points at age 65 for an individual belonging to cohort z of type n in model i with respect to the maximum number of pension points at age 65 observed for individuals born in year z in model i (i.e., $p_{zni} = \text{pp}_{65,zni}/\max(\text{pp}_{65,zi})$) and u_{zni} is the error term.

Table A.4 shows the estimated parameters ($\hat{a}$, $\hat{b}$) for a group of selected cohorts (1980, 2000, 2020, and 2100). We obtain that an increase of 1% in the relative number of pension points is associated with an increase between 16.7% (cohort 1980) and 14.6% (cohort 2100) in the remaining years of life at age 65 relative to the highest life expectancy at age 65. Since the phase-out cohort for all pension reforms is that born in year 1980, we assume that the social security system uses the parameters of the 1980 birth cohort ($\hat{a} = 1.044$, $\hat{b} = 0.167$) to calculate the replacement rate for each individual.

Figure A.5 shows the relationship between the relative remaining years of life at age 65 and the relative number of pension points at age 65 for the 1980 birth cohort. The red line represents the fit of Eq. (A.34) to the simulated data, where the value of $\hat{b}$ is the slope of the red curve.

Pension replacement rate progressivity ABH and SP proposals imply that the pension replacement rate varies according to the life expectancy. Thus, given Eq. (A.34) the pension replacement rate becomes a function of the number of pension points accumulated. In particular, given that in the SP proposal $\nu = \frac{\text{LE}(\text{pp}^{\max})-\text{LE}(\text{pp}^{\min})}{\text{LE}(\text{pp}^{\max})} \Big/ \frac{\text{pp}^{\max}-\text{pp}^{\min}}{\text{pp}^{\max}}$, Eq. (A.34) yields that $\text{LE}(\text{pp}^{\max}) = \hat{a}$ and $\text{LE}(\text{pp}^{\min}) = \hat{a} + \hat{b}\log \text{p}^{\min}$, with $\text{p}^{\min} = \frac{\text{pp}^{\min}}{\text{pp}^{\max}}$. Thus,

$$\nu = -\frac{\hat{b}}{\hat{a}} \frac{\log \text{p}^{\min}}{1-\text{p}^{\min}}. \tag{A.35}$$

Table A.4: OLS regression of the relative remaining years of life at age 65 by the relative number of pension points

	Dependent variable:			
	Cohort: LE/max(LE)			
	1980	2000	2020	2100
	(1)	(2)	(3)	(4)
log(p)	0.167***	0.155***	0.151***	0.146***
	(0.001)	(0.001)	(0.001)	(0.001)
a	1.044***	1.040***	1.039***	1.041***
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	5,000	5,000	5,000	5,000
R^2	0.815	0.786	0.775	0.760
Adjusted R^2	0.815	0.786	0.775	0.760
Residual Std. Error (df = 4998)	0.036	0.035	0.036	0.036
F Statistic (df = 1; 4998)	22,072.480***	18,360.380***	17,188.580***	15,823.330***
Note:				*p<0.1; **p<0.05; ***p<0.01

Since the minimum possible pension points are 0.33 relative to the average (due to the minimum pension benefits) or 0.165 relative to the maximum, we set ν at 0.345. As a consequence, we obtain that an individual with the highest (resp. lowest) pension points has a replacement rate of 0.58 (resp. 1.145). In the ABH proposal, the pension replacement rate of those with the highest (resp. lowest) number of pension points is 0.67 (resp. 0.92).

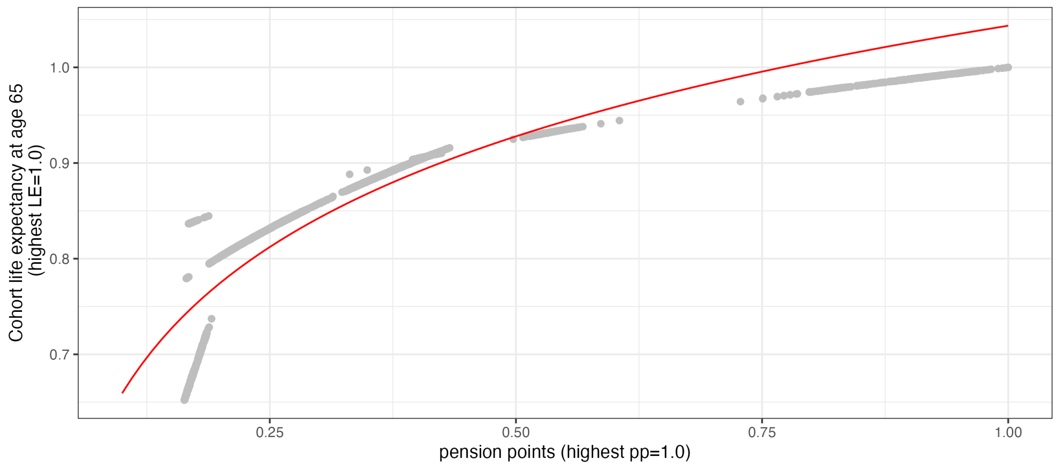

Figure A.5: Relationship between the cohort life expectancy and the relative number of pension points at age 65 for the 1980 birth cohort. *Source*: Authors' calculations using the results of the benchmark model.

A.8 Comparison of the reforms

A.8.1 Macroeconomic effects

Fig. A.6 shows the evolution of the social contribution rate and the taxes on consumption, labor income, and capital income for the period 1950–2100 for seven alternative simulations.

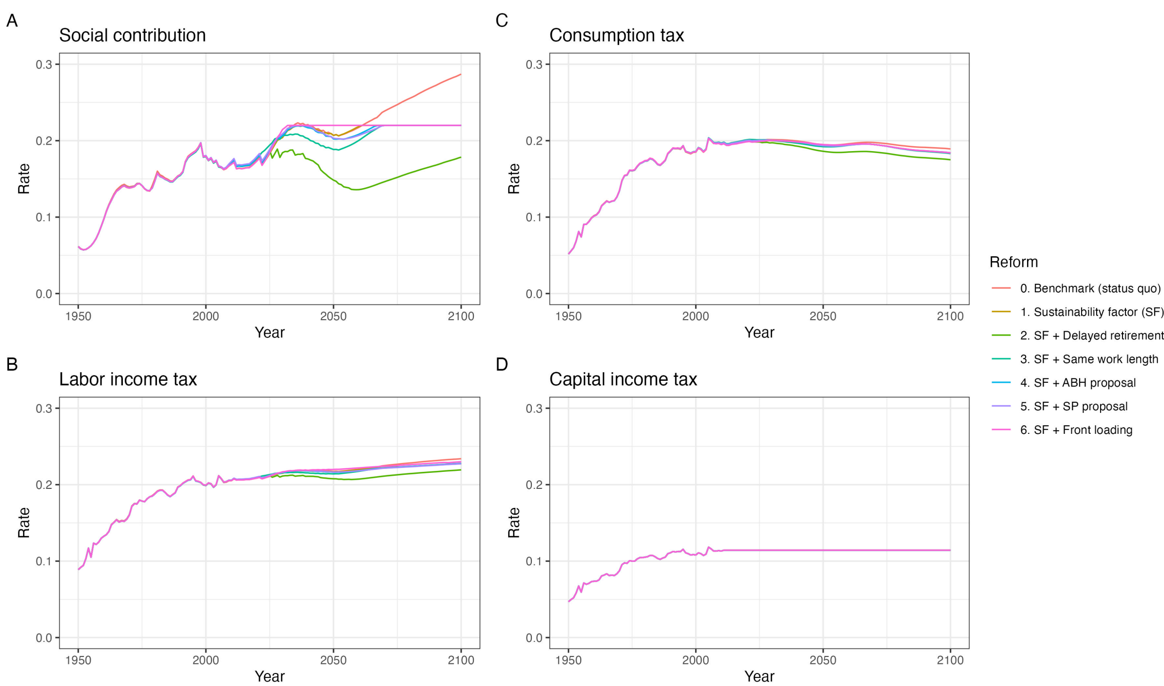

Figure A.6: Evolution of the social contribution rate (panel **A**) and general taxes on consumption (panel **B**), labor income (panel **C**), and capital income (panel **D**) from 1950 to 2100 across pension reforms. *Source: Authors' calculations using the model. Notes: Each panel shows the average value for each simulation across the 200 models.*

Fig. A.7 shows the age profile of the effective tax on labor in each pension reform (measured as the difference to the effective tax on labor on the status quo). Our simulation results show that reforms 4 and 5 generate an average increase in the effective tax on labor of 1.25% and 2.5% in reforms 4 and 5, respectively. Instead, reforms 2 and 3 yield a reduction in the effective tax on labor relative to that in the status quo, which is more pronounced in reform 2.

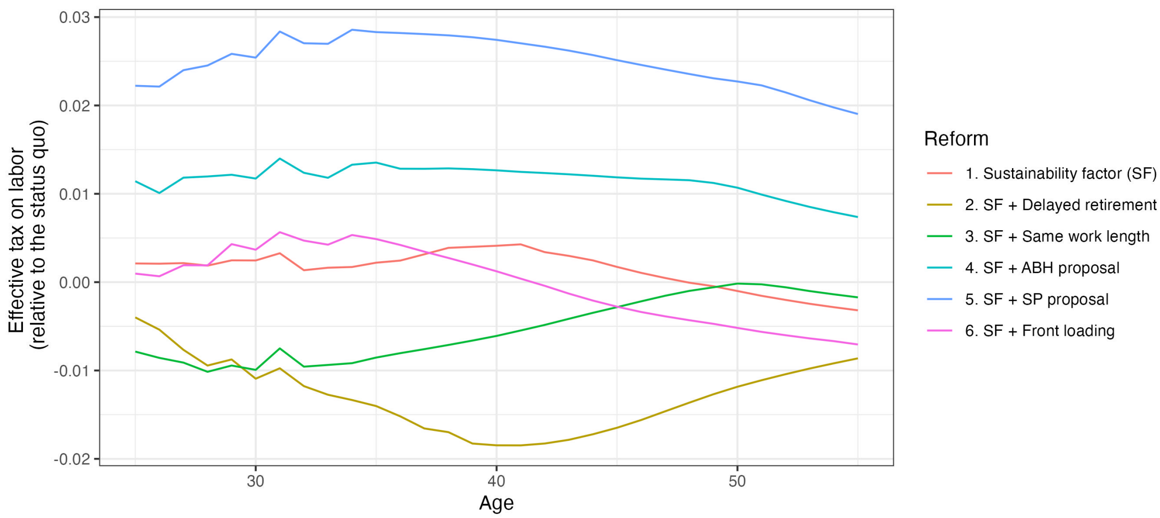

Figure A.7: Age profile of the difference in the effective tax on labor between the pension reforms and the status quo. Birth cohort 2020. *Source: Authors' calculations using the model. Notes: Each panel shows the average value for each simulation across the 200 models.*

A.8.2 Distributional effects of pension reforms by educational group and unobservable characteristics

By educational group

Table A.5: Impact of pension reforms on labor supply by education (in years-worked)

		Cohort 1980		Cohort 2020	
		Mean	Max-Min	Mean	Max-Min
Pension reform	Education	(1)	(2)	(3)	(4)
0. Benchmark (status quo)	Primary	41.23	0.52	41.77	0.46
	Secondary	40.21	1.09	41.10	1.44
	College	39.17	1.56	40.03	2.07
1. Sustainability factor (SF)	Primary	41.25	0.53	42.04	0.45
	Secondary	40.39	1.17	41.54	1.35
	College	39.18	1.52	40.57	1.84
Absolute difference with respect to status quo					
1. Sustainability factor (SF)	Primary	0.02	0.01	0.27	-0.01
	Secondary	0.18	0.08	0.44	-0.09
	College	0.01	-0.04	0.54	-0.23
Absolute difference with respect to sustainability factor					
2. SF + Delayed retirement	Primary	2.43	0.04	2.32	0.04
	Secondary	2.32	-0.23	1.93	-0.30
	College	2.06	-0.26	1.70	-0.10
3. SF + Same work length	Primary	-0.31	-0.06	-0.50	-0.08
	Secondary	0.07	-0.14	-0.16	-0.06
	College	0.35	-0.96	-0.08	-0.87
4. SF + ABH proposal	Primary	-0.50	0.02	-0.70	0.03
	Secondary	-0.59	0.32	-0.69	0.44
	College	-0.24	0.87	-0.37	1.44
5. SF + SP proposal	Primary	-1.05	0.02	-1.42	0.02
	Secondary	-1.04	1.16	-1.30	1.18
	College	0.00	1.88	-0.30	3.08
6. SF + Front loading	Primary	-0.14	0.05	-0.37	-0.05
	Secondary	-0.42	0.08	-0.50	0.11
	College	-0.55	0.08	-0.62	0.34

Table A.6: Impact of pension reforms on the IRR by education (mean values, in %)

		Cohort 1980		Cohort 2020	
		Mean	Max-Min	Mean	Max-Min
Pension reform	Education	(1)	(2)	(3)	(4)
0. Benchmark (status quo)	Primary	0.19	0.42	-0.36	0.28
	Secondary	1.43	0.56	0.65	0.40
	College	2.02	0.61	1.02	0.31
1. Sustainability factor (SF)	Primary	0.22	0.42	-0.49	0.28
	Secondary	1.45	0.55	0.49	0.38
	College	2.04	0.61	0.76	0.29
Absolute difference with respect to status quo					
1. Sustainability factor (SF)	Primary	0.03	0.00	-0.13	0.00
	Secondary	0.02	-0.01	-0.16	-0.02
	College	0.02	0.00	-0.26	-0.02
Absolute difference with respect to sustainability factor					
2. SF + Delayed retirement	Primary	-1.51	0.06	-0.30	0.05
	Secondary	-1.17	0.07	0.02	0.03
	College	-1.07	0.08	0.25	0.10
3. SF + Same work length	Primary	-0.22	0.06	0.07	0.07
	Secondary	-0.31	0.26	0.04	0.16
	College	-0.36	-0.01	0.09	0.23
4. SF + ABH proposal	Primary	0.35	-0.09	0.50	-0.08
	Secondary	0.01	-0.47	0.19	-0.31
	College	-0.43	-0.22	-0.17	0.49
5. SF + SP proposal	Primary	0.68	-0.19	0.84	-0.17
	Secondary	-0.01	-0.22	0.25	0.05
	College	-0.69	0.15	-0.32	1.06
6. SF + Front loading	Primary	0.26	-0.01	0.05	-0.02
	Secondary	0.23	-0.01	0.10	0.01
	College	0.29	-0.05	0.25	0.04

Table A.7: Impact of pension reforms on welfare by education (mean values, in %)

		Cohort 1980		Cohort 2020	
		Veil of ignorance	$\frac{\text{Max-Min}}{\text{Mean}}$	Veil of ignorance	$\frac{\text{Max-Min}}{\text{Mean}}$
Pension reform	Education	(3)	(4)	(7)	(8)
0. Benchmark (status quo)	Primary	-	11.32	-	8.58
	Secondary	-	27.73	-	23.19
	College	-	55.61	-	48.02
1. Sustainability factor (SF)	Primary	-	11.32	-	8.53
	Secondary	-	27.76	-	23.07
	College	-	55.59	-	47.55
Absolute difference with respect to status quo					
1. Sustainability factor (SF)	Primary	0.13	0.00	0.33	-0.05
	Secondary	0.62	0.03	0.06	-0.12
	College	-0.04	-0.02	-1.03	-0.47
Absolute difference with respect to status quo					
2. SF + Delayed retirement	Primary	-9.32	0.06	11.05	-0.12
	Secondary	-8.07	0.11	12.52	-0.40
	College	-8.40	-0.18	16.03	0.85
3. SF + Same work length	Primary	-2.92	0.04	2.07	0.03
	Secondary	-3.60	0.34	2.02	-0.34
	College	-6.24	-10.49	3.55	-3.80
4. SF + ABH proposal	Primary	3.17	-0.10	6.11	-0.02
	Secondary	-0.70	-0.81	2.60	-0.70
	College	-6.25	-3.47	-2.36	-0.92
5. SF + SP proposal	Primary	6.40	-0.26	10.79	-0.15
	Secondary	-1.18	-1.39	2.87	-1.62
	College	-9.35	-7.73	-3.99	-2.87
6. SF + Front loading	Primary	2.64	0.02	-0.36	-0.03
	Secondary	2.23	-0.04	0.11	0.05
	College	2.41	-1.48	2.75	1.38

Extra tables by unobservable characteristics

Table A.8: Impact of pension reforms on the additional years of schooling by unobservable characteristics (in years)

Cohort	Learning ability & schooling effort $\boldsymbol{\xi} - \boldsymbol{\eta}$	Bench. **0.** (1)	SF **1.** (2)	(2)-(1)	Absolute difference with respect to the sustainability factor (SF) — Pension reform (P.R.) **2.** (4)	**3.** (5)	**4.** (6)	**5.** (7)	**6.** (8)
1980	1. low-high	0.50	0.50	0.00	0.00	0.00	-0.01	-0.09	0.00
	2. low-low	4.21	4.22	0.01	0.00	-0.20	-0.05	-0.26	-0.04
	3. high-high	3.79	3.79	0.00	0.00	0.00	0.00	-0.01	0.00
	4. high-low	7.54	7.51	-0.03	0.00	-0.36	-0.42	-0.60	0.02
2020	1. low-high	0.53	0.53	0.00	0.01	0.00	-0.02	-0.02	0.00
	2. low-low	4.32	4.31	-0.01	0.12	-0.15	0.01	-0.06	0.08
	3. high-high	3.80	3.80	0.00	0.02	0.01	-0.02	-0.02	0.01
	4. high-low	7.57	7.56	-0.01	0.06	0.02	-0.19	-0.40	0.04

Notes: '**low**' means lower than the median and '**high**' means higher than the median. **0.** Benchmark (status quo), **1.** Sustainability factor (SF), **2.** SF+Delayed retirement, **3.** SF+Same work length, **4.** SF+ABH proposal, **5.** SF+SP proposal, **6.** SF+Front loading.

Table A.9: Impact of pension reforms on the life expectancy at age 14 by unobservable characteristics (in years)

Cohort	Learning ability & schooling effort $\boldsymbol{\xi} - \boldsymbol{\eta}$	Bench. **0.** (1)	SF **1.** (2)	(2)-(1)	Absolute difference with respect to the sustainability factor (SF) — Pension reform (P.R.) **2.** (4)	**3.** (5)	**4.** (6)	**5.** (7)	**6.** (8)
1980	1. low-high	64.45	64.45	0.00	0.00	0.00	-0.01	-0.11	0.00
	2. low-low	69.14	69.15	0.01	0.01	-0.12	-0.06	-0.29	-0.03
	3. high-high	71.47	71.47	0.00	0.00	0.00	0.00	0.00	0.00
	4. high-low	73.88	73.87	-0.01	0.00	-0.18	-0.22	-0.31	0.01
2020	1. low-high	68.15	68.15	0.00	0.01	0.00	-0.02	-0.02	0.00
	2. low-low	72.54	72.54	0.00	0.07	-0.10	0.01	-0.08	0.04
	3. high-high	74.22	74.22	0.00	0.01	0.00	-0.01	-0.02	0.00
	4. high-low	76.35	76.35	0.00	0.03	0.01	-0.09	-0.18	0.02

Notes: '**low**' means lower than the median and '**high**' means higher than the median. **0.** Benchmark (status quo), **1.** Sustainability factor (SF), **2.** SF+Delayed retirement, **3.** SF+Same work length, **4.** SF+ABH proposal, **5.** SF+SP proposal, **6.** SF+Front loading.

Table A.10: Impact of pension reforms on lifetime consumption relative to the average lifetime consumption in the same birth cohort in the status quo (Average=100)

Cohort	Learning ability & schooling effort $\boldsymbol{\xi}-\boldsymbol{\eta}$	Bench. **0.** (1)	SF **1.** (2)	(2)-(1)	Absolute difference with respect to the sustainability factor (SF) Pension reform (P.R.) **2.** (4)	**3.** (5)	**4.** (6)	**5.** (7)	**6.** (8)
1980	1. low-high	54.07	54.15	0.08	-0.97	-1.12	-0.41	-1.88	0.45
	2. low-low	64.68	64.81	0.13	-1.03	-1.35	-0.65	-1.79	0.44
	3. high-high	107.56	107.74	0.18	-2.35	-2.04	-2.34	-3.86	0.84
	4. high-low	200.13	199.70	-0.43	-4.46	-8.25	-11.59	-15.59	1.83
2020	1. low-high	55.24	55.06	-0.18	3.03	-0.01	0.30	0.03	-0.07
	2. low-low	65.59	65.36	-0.23	4.07	0.02	0.12	-0.60	0.20
	3. high-high	107.77	107.06	-0.71	5.63	0.27	-1.19	-2.54	0.24
	4. high-low	196.79	194.68	-2.11	12.44	2.04	-6.95	-10.72	2.27

Notes: '**low**' means lower than the median and '**high**' means higher than the median. **0.** Benchmark (status quo), **1.** Sustainability factor (SF), **2.** SF+Delayed retirement, **3.** SF+Same work length, **4.** SF+ABH proposal, **5.** SF+SP proposal, **6.** SF+Front loading.

Table A.11: Impact of pension reforms on the retirement age (in years)

Cohort	Learning ability & schooling effort $\boldsymbol{\xi}-\boldsymbol{\eta}$	Bench. **0.** (1)	SF **1.** (2)	(2)-(1)	Absolute difference with respect to the sustainability factor (SF) Pension reform (P.R.) **2.** (4)	**3.** (5)	**4.** (6)	**5.** (7)	**6.** (8)
1980	1. low-high	58.12	58.12	0.00	2.40	-0.25	-0.07	-0.10	-0.11
	2. low-low	58.66	58.68	0.02	2.11	0.12	-0.19	-0.43	-0.40
	3. high-high	58.59	58.59	0.00	2.11	0.07	0.04	0.06	-0.35
	4. high-low	59.70	59.71	0.01	1.73	0.43	0.12	0.32	-0.46
2020	1. low-high	58.15	58.36	0.21	2.25	-0.38	-0.20	-0.28	-0.25
	2. low-low	58.81	59.25	0.44	1.76	-0.02	-0.36	-0.65	-0.41
	3. high-high	58.90	59.28	0.38	1.74	-0.05	-0.07	-0.12	-0.38
	4. high-low	60.31	60.78	0.47	1.36	-0.17	0.07	0.20	-0.44

Notes: '**low**' means lower than the median and '**high**' means higher than the median. **0.** Benchmark (status quo), **1.** Sustainability factor (SF), **2.** SF+Delayed retirement, **3.** SF+Same work length, **4.** SF+ABH proposal, **5.** SF+SP proposal, **6.** SF+Front loading.

References

Bergeaud, Antonin, Gilbert Cette, and Rémy Lecat (2016). "Productivity trends in advanced countries between 1890 and 2012". In: *Review of Income and Wealth* 62.3, pp. 420–444.

Chetty, Raj, Michael Stepner, Sarah Abraham, Shelby Lin, Benjamin Scuderi, Nicholas Turner, Augustin Bergeron, and David Cutler (2016). "The association between income and life expectancy in the United States, 2001-2014". In: *Jama* 315.16, pp. 1750–1766.

European Commission (2018). *The 2018 ageing report: underlying assumptions & projections.*

Goujon, Anne, Samir Kc, Markus Speringer, Bilal Barakat, Michaela Potančoková, Jakob Eder, Erich Striessnig, Ramon Bauer, and Wolfgang Lutz (2016). "A harmonized dataset on global educational attainment between 1970 and 2060–An analytical window into recent trends and future prospects in human capital development". In: *Journal of Demographic Economics* 82.03, pp. 315–363.

Holzmann, Robert, Jennifer Alonso-Garcıa, Heloise Labit-Hardy, and Andrés M Villegas (2019). *NDC schemes and heterogeneity in longevity: proposals for redesign.* World Bank.

Lutz, Wolfgang, William P Butz, and KC ed Samir (2014). *World population and human capital in the twenty-first century.* OUP Oxford.

Lutz, Wolfgang, Anne Goujon, Samir KC, and Warren Sanderson (2007). "Reconstruction of populations by age, sex and level of educational attainment for 120 countries for 1970-2000". In: *Vienna Yearbook of Population Research*, pp. 193–235.

Murtin, Fabrice, Johan P Mackenbach, Domantas Jasilionis, and Marco Mira d'Ercole (2022). "Educational inequalities in longevity in 18 OECD countries". In: *Journal of Demographic Economics* 88.1, pp. 1–29.

Poole, David and Adrian E Raftery (2000). "Inference for deterministic simulation models: the Bayesian melding approach". In: *Journal of the American Statistical Association* 95.452, pp. 1244–1255.

Raftery, Adrian E and Le Bao (2010). "Estimating and projecting trends in HIV/AIDS generalized epidemics using incremental mixture importance sampling". In: *Biometrics* 66.4, pp. 1162–1173.

Rivic, Stefani (2019). "Konstruktion einer demographischen und ökonomischen Datenbank für Österreich zwischen 1820 und 2010". MA thesis. TU Wien.

Sánchez-Romero, Miguel, Ronald D Lee, and Alexia Prskawetz (2020). "Redistributive effects of different pension systems when longevity varies by socioeconomic status". In: *The Journal of the Economics of Ageing* 17, p. 100259.