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ARTICLE

Redistributive effects of pension reforms: who are the winners and losers?

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Abstract
As the heterogeneity in life expectancy by socioeconomic status increases, many pension systems imply a wealth transfer from short- to long-lived individuals. Various pension reforms aim to reduce inequalities that are caused by ex-ante differences in life expectancy. However, these pension reforms may induce redistribution effects. We introduce a dynamic general equilibrium-overlapping generations model with heterogeneous individuals that differ in their education, labor supply, lifetime income, and life expectancy. Within this framework we study six different pension reforms that foster the sustainability of the pension system and aim to account for heterogeneous life expectancy. Our results highlight that pension reforms have to be evaluated at various dimensions. Reforms that may increase the sustainability of the pension system are not necessarily conducive to reduce the redistributive wealth transfers from short- to long-lived individuals. Our paper emphasizes the need for studying pension reforms in models with behavioral feedback and heterogeneous socioeconomic groups.

Keywords: educational decision; distributional effects; mortality and fertility differentials; overlapping generations; pensions reforms

JEL Codes: H55; J1; J11; J14; J18; J26

1. Introduction

Many studies have shown a negative and increasing correlation between mortality rates and higher socioeconomic status (SES) by occupation, education, income, and even wealth (Preston and Elo, 1995; Lleras-Muney, 2005; Waldron, 2007; Manchester and Topoleski, 2008; Luy *et al.*, 2011; Olshansky *et al.*, 2012; National Academies of Sciences, Engineering, and Medicine and Committee on Population and others, 2015; Chetty *et al.*, 2016). The results imply a widening of the difference in life expectancy between high- and low-SES groups in recent decades. One implication of this demographic trend is that pension systems become more regressive. Through risk pooling low-SES groups unexpectedly subsidize the pension benefits of high-SES groups since individuals who have on average a higher life expectancy receive their benefits for more years compared to those who have a low life expectancy.[1] Thus, besides the necessity of pension reforms to cope with the increasing life expectancy at retirement and the long-run sustainability of pension funding, policy makers also need to consider

[1]For a detailed review of the heterogeneity in life expectancy by SES and its implication on pension schemes see Ayuso *et al.* (2016), Auerbach *et al.* (2017), Lee and Sánchez-Romero (2020), Palmer and Gosson de Varennes (2019), Haan *et al.* (2020), Holzmann *et al.* (2019), Jijiie *et al.* (2022), and Sánchez-Romero and Prskawetz (2023).

that individual aging is heterogeneous across SES groups. Reforms need to counteract the increasing regressivity of pension systems.

In a pension system with a flat pension replacement rate, a reform to avoid the increasing regressivity across SES groups would imply that all SES groups receive the same return from their pension plans regardless their ex-ante life expectancy.[2] This reform can be implemented through changes in contributions or in benefits. Since different contribution rates by occupation may create unwanted labor incentives (Pestieau and Racionero, 2016), this option is generally not considered by pension systems. Instead, many proposals suggest modifying the benefit formula, given that once individuals claim their pension benefits, they cannot modify their working lives. However, it is still likely that individuals may react to changes in the benefit formula before retiring (Sánchez-Romero and Prskawetz, 2020; Sánchez-Romero *et al.*, 2020), which may also induce an unwanted redistribution of resources. Thus, in this paper we will study the redistributive properties of various pension reforms not just at the time of retirement but over the whole lifecycle. We will also consider how different birth cohorts are affected by the reforms.

For such reforms it is important to correctly choose the SES variable(s) used for differentiating across groups. In particular, the choice of the SES variables should be based on two main criteria. First, it should capture the strength of the increase in the longevity gap by SES and, second, it should not change over the lifecycle.[3] In the literature, the most frequently suggested SES measures, that satisfy both criteria, are education and lifetime labor income. However, neither lifetime labor income nor education can by itself account for the full variance in life expectancy by SES (Bosworth *et al.*, 2016). Consequently, any model aiming at analyzing the redistributive properties of reforms that aim to reduce the regressivity of pensions should consider a population that is at least heterogeneous with respect to life expectancy, education, and lifetime labor income. This implies the necessity of implementing a model with more than one degree of heterogeneity. The models of Fehr *et al.* (2013), Fehr and Uhde (2013), Fehr and Uhde (2014), Laun *et al.* (2019), and more recently Jones and Li (2023), in which agents face idiosyncratic income risk, disability risk, and mortality risk by the skill group, and the distribution of skill groups is the same across cohorts, are potential candidates. However, in reality, education is changing across birth cohorts, which may cause that the observed increasing gap in life expectancy by educational attainment is just driven by the fact that the low-educated group becomes more negatively selected over time (Goldring *et al.*, 2016; Hendi *et al.*, 2021).

To take into account the complexity of modeling the variance in life expectancy we setup a dynamic general equilibrium model with a heterogeneous population by education, life-time labor income, and life expectancy. More specifically our model allows individuals to (endogenously) choose their educational attainment, based on their initial endowments of their schooling effort and innate learning ability, two characteristics that represent the unobserved heterogeneities in our population. Similar to Pestieau *et al.* (2016), we link mortality and fertility to the education decision of individuals.[4] In addition, based on Chetty *et al.* (2016), Bosworth *et al.* (2016), and Murtin *et al.* (2022), we also link differences in longevity to income. Given a specific educational attainment, agents will choose their consumption and labor force participation at each age. The institutional setup in which agents make their decisions is given by the current Austrian pension system. Austria's pension system is an interesting case because, similar to many other non-progressive pension systems in The Organization for Economic Cooperation and Development countries, it has neither implemented any policy that corrects for the increasing life expectancy nor the diverging life expectancy by SES. However, like many other pension systems, to guarantee its long-run sustainability proposals are

[2]Ex-ante differences in life expectancy arise from differences in the probability of death, while the ex-post difference in the length of life arises from the random process of death.

[3]See Lee and Sánchez-Romero (2020) and Sánchez-Romero and Prskawetz (2023) for a discussion.

[4]Our model setup relies on studies that link differences in longevity between educational groups to education-specific individual behavior (Preston and Elo, 1995; Doblhammer *et al.*, 2005; Shkolnikov *et al.*, 2006; Manchester and Topoleski, 2008; Klotz, 2010; Luy *et al.*, 2011; Olshansky *et al.*, 2012).

indispensable and should also consider the diverging trends of life expectancy across different subgroups of the population.

We calibrate our model to fit the historical evolution of the Austrian educational distribution by applying the Bayesian melding method (Poole and Raftery, 2000). Within our model framework we then study how different pension reforms may induce a redistribution across a heterogeneous population that differs, among others, by income and longevity, taking the Austrian pension system as the benchmark. In each reform scenario we include a sustainability factor that guarantees that the contribution rate of the pension system will stabilize at 22 percent. In the first reform we assume that the Austrian pension system is augmented by the aforementioned sustainability factor (reform 1). We next implement a reform that accounts for a delay in the retirement age (reform 2) and a reform that aims at the same working length across the population (reform 3). In a further reform we implement the proposal by Ayuso *et al.* (2017) that recommends adjusting the pension replacement rate of each retiree according to the difference between the remaining years-lived of the population subgroup of the retiree and that of the average retiree (reform 4). With this proposal, it is expected that at the age of retirement all retirees will earn the same present value of benefits relative to the contributions paid. We continue with a reform by Sánchez-Romero and Prskawetz (2020) that suggests finding the level of progressivity in the replacement rate such that the pension program is ex-ante neither regressive nor progressive for any population subgroup (reform 5). The last reform we propose follows the recent literature, for example, Vandenberghe (2022), that implements a front-loading benefit scheme (reform 6).

To compare the various pension reforms we first present the effect of each reform on selected macro variables (output per capita, the pension cost-to-output ratio, and the total pension wealth-to-output ratio) for 2030, 2040, 2050, and 2060. To examine the redistributive properties of each pension reform, we utilize alternative indicators such as the lifetime labor supply (in years-worked), the internal rate of return (IRR) of the pension system,[5] and the change in welfare of each generation relative to the benchmark. We report all indicators for four distinct population groups that differ by educational attainment, labor income, and life expectancy and for two birth cohorts (1980, 2020). These two cohorts are selected to demonstrate the impact of pension reforms on the phase-out cohort (born in 1980), which bears the majority of the transition costs, as well as a cohort that experiences the fully matured new pension system (born in 2020).

Overall, our results indicate that a pension reform that implements a delay in the retirement age together with a sustainability factor (pension reform 2) is most favorable in terms of its macroeconomic outcome (compared to the benchmark of the current Austrian pension system, output per capita increases and the ratio of pension cost-to-output and the total pension wealth-to output decrease). However this reform increases the inequality among socioeconomic groups in terms of their labor supply, the IRR and welfare. All other pension reforms that we study are less favorable in terms of output per capita developments, but nevertheless they all manage to keep pension costs and pension wealth lower (or at least not higher) compared to the benchmark of the current Austrian pension system. In terms of the labor supply, pension reforms that aim to correct for the heterogeneity either in years-worked or in life expectancy (reforms 3–5) manage to reduce the inequality while the pension reform of a front-loading pension benefit scheme (reform 6) increases the inequality. In terms of the IRR the results are slightly different. Again, pension reforms 4 and 5, that take the heterogeneity of life expectancy into account, reduce the spread of the IRR between different groups in the population, while pension reform 3 that accounts for an equal working length, has a rather negligible effect on the spread of the IRR. Front loading of benefits (pension reform 6) on the other hand increases the spread of the IRR. In terms of welfare, our results indicate a loss of welfare for the 1980 cohort for all pension reforms except for reform 6 which implements a front loading of

[5]Previous empirical studies analyzing the progressivity of pension systems using the IRR are Aaron (1977), Hurd and Shoven (1985), Duggan *et al.* (1993), Gustman and Steinmeier (2001), and Liebman (2002) in the United States, and Schröder (2012) and Haan *et al.* (2020) in Germany, among others.

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benefits. In contrast, for cohort 2020 that is already confronted with a matured pension system, welfare improves for all reforms. In terms of the distributional effects, those reforms that account for the heterogeneity of life expectancy (reforms 4 and 5) also imply the lowest differences in welfare across social groups.

The paper is structured as follows. Section 2 introduces a general framework of modeling pension systems and illustrates the various components for the case of Austria. In Section 3 we present the dynamic general equilibrium-overlapping generations (OLG) model. In Section 4 we discuss the parametrization of the model and the calibration strategy using the Bayesian melding method. In Section 5 we introduce the six pension reforms which are compared with respect to their macroeconomic impact and distributional effects in Section 6. Section 7 concludes. We provide a detailed derivation of the economic model and further results on the calibration and simulation of the model in the online Appendix.

2. A general framework for modeling pension systems

Based on Sánchez-Romero *et al.* (2020) we introduce a general framework of pension systems which is applied to the Austrian case in Section 6. The Austrian pension system is an unfunded and defined benefit system. The general pension formula of the current Austrian pension system follows the rule that after forty-five years of contribution, retiring at age 65, workers will receive 80 percent of their average lifetime income (Knell *et al.*, 2006; Sánchez-Romero *et al.*, 2013). However, current workers are still subject to transition rules from older systems to the current pension regime, which have to be taken into account in a meaningful quantitative exercise. Our approach is flexible enough to not only capture these different historical changes in the Austrian pension system[6] that are still relevant for current living cohorts, but our framework is general enough to also capture the main characteristics of many different countries' pension systems.

The pension system will be embedded in a full-scale general equilibrium framework in the next section. For now, just take the series of age-specific labor supply l_a and gross labor income y_a as given, which will determine pension benefits b_a of a representative household head of age a. A representative household head consists of a mass of atomistic individuals of the same age and the same initial characteristics. A characteristic could be any form of heterogeneity (e.g., learning ability) as long as individuals do not switch characteristic during their active life time, which is why a corresponding index can be dropped in this section. Importantly, labor supply l_a can be thought of as the number of persons a representative household head sends to work at age a. Let $\alpha_J(l_a)$ be the fraction of individuals of age a with the same initial characteristics, represented by the household head, that are retired, which is inversely related to the labor supply, that is, $\alpha_J'(l_a) < 0$. Agents can retire after the minimum retirement age $\underline{J}$ and no later than a maximum retirement age $\bar{J}$. We denote the normal retirement age by J^N. The average pension benefit received at age a by a retired individual is given by

$$b_a = \max\{\lambda_a \cdot \varphi(\mathrm{pp}_a) \cdot \mathrm{pp}_a, b^{\min}\} \cdot \rho. \tag{1}$$

The amount of pension benefits claimed depends on four components: (i) pension points accumulated pp_a, (ii) a targeted pension replacement rate $\varphi(\cdot)$ (e.g., currently in Austria $\varphi = 0.8$), (iii) a replacement rate adjustment factor λ_a, which is a function of the average years contributed and the average retirement age (e.g., retiring at age 65 after 45 contribution years implies $\lambda_a = 1$ in Austria), and (iv) a minimum threshold $b^{\min}$ such that benefits are supplemented if they fall short of it. To be able to incorporate potential reforms, we further allow for a sustainability factor $\rho \leqslant 1$ (similar to a pension benefit specific tax), that guarantees a maximum social contribution rate. Thus, when the maximum

[6]See Section A.6 in the online Appendix for more information on the evolution of the parametric components of the Austrian pension system.

social security contribution rate is reached, the government will adjust the pension benefits downward by reducing ρ until the system is balanced.

The pension replacement rate adjustment factor λ_a consists of two components: λ_a^{ra} captures penalties and rewards for retiring earlier or later than the normal retirement age J^N and λ_a^{yc} corrects for fewer than the targeted contribution years (e.g., in Austria 45):

$$\lambda_a^{ra} = \begin{cases} 1 - \text{pen}(J^N - a) & \text{if } \underline{J} \leqslant a \leqslant J^N, \\ 1 + \text{rew}(a - J^N) & \text{if } J^N < a \leqslant \bar{J}. \end{cases} \tag{2}$$

For illustration, in the Austrian case every year retired before $J^N = 65$ implies a decrease in benefits by 5.1 percent and every year retired after J^N implies an increase in benefits by 4.2 percent, hence we would set pen = 0.051 and rew = 0.042. The factor λ_a^{yc} proportionally relates the number of years worked ly to the targeted years worked wy (e.g., 45 in Austria) and is defined as follows:

$$\lambda_a^{yc} = [ly_{\underline{J}} + (a - \underline{J})]/wy, \quad \text{for } a \geqslant \underline{J}, \tag{3}$$

where the number of working years for $a < \underline{J}$ is recursively defined as $ly_{a+1} = ly_a + (l_a/\bar{L})$.[7] Until minimum retirement age $\underline{J}$ persons have phases of work and phases of non-participation, for example, a maternity leave, with the latter not counting toward ly. This is captured on average by l_a falling short of the maximum number of possible working hours $\bar{L}$. However, after $\underline{J}$ each year a worker either continues to work for another full year or begins retirement which completes the working career. A worker retiring at age a therefore faces the joint adjustment factor $\lambda_a^{yc}\lambda_a^{ra}$. However, as not all members with the same and initial characteristics retire at the same time, we have to keep track of the fraction of workers retiring at each age to compute an average adjustment factor λ_a:

$$\lambda_a = \sum_{i=\underline{J}}^{a-1} (\lambda^{fl})^{a-1-i} \lambda_i^{yc} \lambda_i^{ra} \frac{\Delta l_{i-1}}{\bar{L} - l_a}, \quad \text{with } \lambda_{\underline{J}} = 0, \tag{4}$$

which is the sum from the earliest retirement age $\underline{J}$ to a–1 of the joint adjustment factors always weighted by the fraction of individuals of the same age and characteristics entering retirement. In addition, we allow for pension front-loading parameterized using λ^{fl}, which if smaller than 1 will reduce pension payouts for every additional year they are claimed by an agent. The dynamics of the pension points is given by

$$\text{pp}_{a+1} = [\alpha_J(l_a) + (1 - \alpha_J(l_a))\mathcal{R}_a]\text{pp}_a + \phi^p \text{PBI}(y_a), \tag{5}$$

where $\mathcal{R}_a = (1 + i_a)/\bar{\pi}_a$ is the capitalization factor of the pension system, which depends on a capitalization index (i_a) that is set by the social security system and the average conditional survival probability of the cohort ($\bar{\pi}_a$). Note that the average conditional survival probability of the cohort, $\bar{\pi}_a$, does not necessarily coincide with the conditional survival probability of the individual, π_a. Pension points are capitalized until all individuals of the cohort are retired or $\alpha_J(l) = 1$. Pension points of retired workers are inflation-indexed and therefore stay constant in real terms. ϕ^p is the conversion factor of labor income to pension points (e.g., in the Austrian case we currently have $\phi^p = 1/wy = 1/45 = 0.022$) and $\text{PBI}(y_a)$ is the pension base increment.

Although in the future all working years will serve as pensionable income base in Austria, the old systems that are still relevant in the transition are based on the n best income years which is explicitly modeled. We create an ordered vector $\mathbf{p}_a$ for each household head comprised of the n best

[7]The constant term $\bar{L}$ is set at 0.40, which is the fraction of time devoted by an individual who works full time, i.e., $\bar{L} = ((52–8) \text{ weeks} \times 40 \text{ hours})/(52 \text{ weeks} \times 7 \text{ days} \times (24–12) \text{ hours})$, where 8 corresponds to the correction for holidays and vacations.

earnings years in terms of capitalized income p_i until age a; that is $\mathbf{p}_a = \{(p_1, p_2, \ldots, p_n) \in \mathbb{R}^n_+ : p_1 > p_2 > \cdots > p_n\}$. Each year, after capitalizing all stored incomes, the vector is updated by inserting current income as long as it is larger than the smallest stored element p_n, which in turn will be eliminated from the vector. The effective pension base increment is therefore the improvement of using current income instead of the lowest past income still relevant for the pension base, that is, $\mathrm{PBI}(y_a) = \max(y_a - p_n, 0)$. Note that this formulation nests the case in which all life-time earnings are the pension base by setting n large enough which effectively implies $\mathrm{PBI}(y_a) = y_a, \;\; \forall a$. This way of explicitly modeling an n-best-years-system has a considerable advantage in terms of capturing the system's incentives over the commonly used short-cut of fixing the last n years as pensionable income years. This is true even if ex-post the last n years turn out to be the best n years. In the short-cut, household heads consider all incomes before the last n years as wasteful in terms of earning pension rights, resulting in a high effective participation tax rate during that period. However, this tax rate sharply drops once the last n years are included. In contrast, in our modeling approach, the evolution of the effective tax rate is much smoother over age, reflecting that an agent has already accumulated considerable pension rights by the time the last n years start.

Similarly, to account for the negative impact that the minimum pension benefit has on the labor supply, the minimum pension benefit is modeled assuming that individuals start with a minimum pension points; that is $b^{\min} = \boldsymbol{\varphi}(\mathrm{pp}^{\min}) \cdot \mathrm{pp}^{\min}$.

3. The model

To evaluate different pension reforms in heterogeneous aging populations we setup a discrete time dynamic general equilibrium-OLG model with heterogeneous households. Our model is populated by $\mathcal{Z} = \{1, 2, \ldots, 500\}$ generations, or birth cohorts. Each birth cohort is comprised of $\mathcal{N}$ heterogeneous representative agents. Each representative agent $n \in \{1, \ldots, \mathcal{N}\}$ is characterized by a set of initial endowments or permanent unobservable characteristics. We assume the set of permanent unobservable characteristics for agents of type n to be the same across all birth cohorts.[8] We denote the set of initial characteristics of all agents of type n by $\theta_n \in \Theta$, where Θ is the set of all possible combinations of characteristics. We distinguish between two components of characteristics, the effort of schooling η_n and the innate learning ability ξ_n; that is, $\theta_n = (\eta_n, \xi_n) \in \Theta$.

3.1 Households

Households are comprised of an adult agent (household head) and dependent children. Agents enter the model at age 0, face mortality risk, and may live up to a maximum of $\Omega = 100$ years (see agents' timeline in Figure 1). Agents give birth each year to a fraction of children according to age-, cohort-, and education-specific fertility rates and children can die according to age- and cohort-specific mortality rates.[9,10] Hence, our setup allows keeping track of changes in the family structure over time for each education and birth cohort. Let the household size in equivalent adult consumers units be denoted by H. Agents are raised by their parents from birth until the age of finishing primary schooling, denoted by $\underline{a}$. After age $\underline{a}$ agents leave their parents' home, settle their own household, and are randomly endowed with a set of initial characteristics $\theta_n = (\eta_n, \xi_n) \in \Theta$. After receiving the set of initial endowments, agents decide on whether they stay with primary school or to invest into additional

[8]Notice that by imposing an identical set of initial characteristics to a representative agent n, independent of the cohort she belongs to, we avoid that the good match of the model to the data is driven by having time-varying structural parameters.

[9]We assume the population growth rate to be equal across all educational groups within a cohort. Since higher educational groups have a lower mortality, this assumption implies that we need to also adjust fertility accordingly, i.e., agents with higher education have lower fertility rates. See the relationship between education, life expectancy, and fertility in Figure A.3 in the online Appendix.

[10]Similar to Wittgenstein Centre for Demography and Global Human Capital (2018), we assume children's mortality rates do not differ as long as they live with their parents.

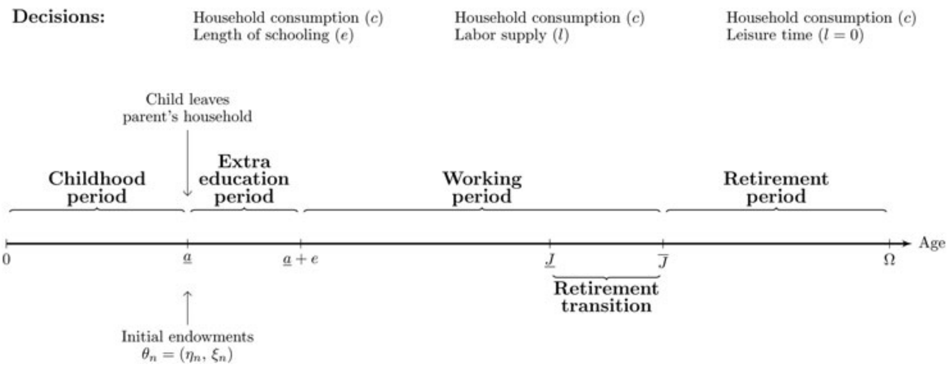

Figure 1. Agents' timeline.

schooling like secondary school or college. We therefore distinguish between three levels of education measured by additional years of schooling beyond primary school, $e \in E = \{0 \text{ years} := \text{primary}, 4 \text{ years} := \text{secondary}, 8 \text{ years} := \text{college}\}$.[11]

At each age agents choose the total consumption of the household and decide on the number of hours worked. From age $\underline{J}$ (i.e., minimum retirement age) until age $\bar{J}$ (i.e., maximum retirement age) each agent of type n will choose the fraction of time spent on the labor market and on retirement.[12] After age $\bar{J}$ all agents are assumed to be retired and only devote time to leisure.

For notational simplicity, we present in this section all control and state variables with the age subscript a, the educational attainment subscript e, the agent type with the subscript n, and suppress the birth cohort subscript $z \in \mathcal{Z}$.

3.1.1 Preferences

Given the years of schooling (e), agents have preferences over household consumption (c) and hours worked (l). Preferences are assumed to be separable and logarithmic in consumption. The period utility function of a representative agent of age a, with education e, of type n is given by

$$\begin{aligned} U(c_{a,e,n}, l_{a,e,n}) = &\, v_C(c_{a,e,n}) - v_E(a, e, n) \\ &- v_L(l_{a,e,n}) + v_J(\mathrm{LE}_{a,e,n})\alpha_J(l_{a,e,n}). \end{aligned} \tag{6}$$

Equation (6) implies that utility is increasing in household consumption ($v_C(c_{a,e,n}) = H_{a,e}\log(c_{a,e,n}/H_{a,e})$), where $H_{a,e}$ is the household size measured in equivalent adult consumption units. Utility decreases because agents incur a cost of attending schooling as measured by $v_E(a, e, n) = \eta_n 1_{\{a<\underline{a}+e\}}$ (Oreopoulos, 2007; Restuccia and Vandenbroucke, 2013; Le Garrec, 2015; Sánchez-Romero et al., 2016; Sánchez-Romero and Prskawetz, 2020), where $\eta_n > 0$ is the marginal cost of each additional year of schooling and $1_{\{a<\underline{a}+e\}}$ is an indicator function that takes the value of 1 if $a < \underline{a} + e$ and 0 otherwise. We consider η_n as a proxy for the socioeconomic background. Thus, higher (resp. lower) values η_n are associated with a lower (resp. higher) socioeconomic background. We assume a standard isoelastic disutility from working $v_L(l_{a,e,n})$, where the marginal disutility from working $l_{a,e,n}$ hours is

[11]The legal minimum working age in Austria is 15. However, there are a number of exceptions (codified in the 'Kinder- und Jugendlichen-Beschäftigungsgesetz, 1987') for working at lower ages (e.g., working in family businesses and most notably when starting an apprenticeship). This is why we set the first cut-off age to 14, although start working below the age of 15 is rather exceptional.

[12]This is equivalent to assuming that all households with similar permanent unobserved characteristics are part of a representative household and share their labor income and pension benefits. The same approach has been taken by Den Haan and Kaltenbrunner (2009) and de la Croix et al. (2013).

$v_L'(l_{a,e,n}) = \alpha_L(l_{a,e,n})^{1/\sigma_L}$, with $\alpha_L, \sigma_L > 0$. Utility also increases in the time spent in retirement as given by $\alpha_J(l_{a,e,n})$. Recall that $\alpha_J(l_{a,e,n})$ reflects the fraction of household members with similar characteristics (a, e, n) who are retired. The term $v_J(\mathrm{LE}_{a,e,n}) = v_0(\mathrm{LE}_{a,e,n})^{v_1}$ with $v_0 > 0$, $v_1 < 0$ implies that the utility from being retired is an increasing function with respect to the remaining life $\mathrm{LE}_{a,e,n}$ (Sánchez-Romero *et al.*, 2020).

3.1.2 Human capital

We denote the stock of human capital of an agent at age a with e years of education and of type n by $h_{a,e,n}$. All agent types are assumed to start at age $\underline{a}$ with the same initial stock of human capital, $h_{\underline{a},e,n}$, but different learning ability ξ_n. We assume individuals can increase their human capital by attending schooling. The accumulation of human capital is described by the following function that is based on the Ben-Porath mechanism:

$$h_{a+1,e,n} = \begin{cases} h_{a,e,n} + \xi_n(h_{a,e,n})^{\gamma_h} & \underline{a} \leqslant a < \underline{a} + e, \\ h_{a,e,n} & a \geqslant \underline{a} + e, \end{cases} \tag{7}$$

where the number of years of education, e, is a discrete choice variable. Specifically, agents choose whether to stay with compulsory education ($e = 0$), complete high school ($e = 4$), or complete college ($e = 8$).

3.1.3 Budget constraint

We assume the existence of a perfect annuity market in which agents can purchase life-insured loans, when they are in debt, and annuities in case of having positive financial wealth. Let us denote the conditional probability of surviving from age a to age $a + 1$ as $\pi_{a,e,n}$, the financial wealth at age a as $k_{a,e,n}$ and τ_a^k the tax rate on capital. There are three sources of income after survival: (1) the interests gained from the initial financial wealth annuitized $(R_{a,e,n}-1)k_{a,e,n}$, where $R_{a,e,n} = (1 + r_a(1-\tau_a^k))/\pi_{a,e,n}$ is the capitalization factor of the annuity, (2) the labor income earned net of contributions τ_a^s and taxes τ_a^l, that is, $(1-\tau_a^l)(1-\tau_a^s)y_{a,e,n}$, and (3) the pension benefits (net of taxes) $(1-\tau_a^l)b_{a,e,n}\alpha_J(l_{a,e,n})$. The term $\alpha_J(l_{a,e,n})$ represents the fraction of agents with similar endowments that are already retired. Recall that we assume $\alpha_J(l)$ is inversely related to the labor supply. See Section 2 for the pension benefit formula.

The income is used for savings $k_{a+1,e,n}-k_{a,e,n}$ and consuming market goods $(1 + \tau_a^c)c_{a,e,n}$ where τ_a^c is the consumption tax. We assume agents start with zero financial wealth $k_{\underline{a},0,n} = 0$. The budget constraint at age a of an agent with e additional years of education and of type n is

$$\begin{aligned} & k_{a+1,e,n} - k_{a,e,n} + (1 + \tau_a^c)c_{a,e,n} \\ & \quad = (R_{a,e,n} - 1)k_{a,e,n} + (1 - \tau_a^l)[(1 - \tau_a^s)y_{a,e,n} + b_{a,e,n}\alpha_J(l_{a,e,n})]. \end{aligned} \tag{8}$$

Labor income $y_{a,e,n}$ is given by the product of the wage rate $w_{a,e,n}$ and the labor supply $l_{a,e,n}$, which is normalized between 0 and 1. The wage rate $w_{a,e,n}$ consists of three components: (1) the effective wage rate w, (2) the efficiency of an individual with $a-\underline{a}-e$ years of experience after e years of schooling, and (3) the human capital stock $h_{a,e,n}$, $w_{a,e,n} = w_a\epsilon_a(e)h_{a,e,n}$. Per capita pension benefits are denoted by $b_{a,e,n}\alpha_J(l_{a,e,n})$.

3.1.4 Recursive household problem

Given a set of initial characteristics $\theta_n = (\eta_n, \xi_n) \in \Theta$, households choose the optimal consumption path (c), labor supply (l), and education (e) in two steps. First, given an educational level $e \in E$, and the set of state variables $\mathbf{x}_{a,e,n} = \{k_{a,e,n}, \mathrm{pp}_{a,e,n}, h_{a,e,n}\}$, agents choose consumption (c) and labor (l) that maximizes in backward manner (from $a = \Omega$ to $a = \underline{a}$) the following Bellman equation:

$$V(\mathbf{x}_{a,e,n}) = \max_{c_{a,e,n}, l_{a,e,n}} \{U(c_{a,e,n}, l_{a,e,n}) + \beta\pi_{a+1,e,n} V(\mathbf{x}_{a+1,e,n})\} \tag{9}$$

subject to equations (1)–(8) and the boundary conditions $k_{\underline{a},0,n} = 0$, $h_{\underline{a},0,n} = h_{\underline{a}}$. (The derivation of the optimality conditions can be found in the online Appendix in Section A.1.)

Second, given the optimal paths of consumption, labor supply, and the vector of state variables $x^*_{\underline{a},e,n}$ for each educational attainment $e \in \mathbf{E}$, the agent chooses the optimal level of education according to

$$\mathbf{e}_n = \arg\max_{e \in \mathbf{E}} V(\mathbf{x}^*_{\underline{a},e,n}). \tag{10}$$

Notice that given the stream of prices and demographic information each representative agent is uniquely characterized according to her initial endowments. The solution of the household problem and the equilibrium path can be found in online Appendices A.1 and A.2.

3.2 Production

We assume one representative firm that produces a final good by combining capital (K) and effective labor (L). Final goods can either be saved or consumed. The production function, that exhibits constant returns to scale, takes the following form:

$$Y_t = (K_t)^{\alpha_Y}(A_t L_t)^{1-\alpha_Y}, \tag{11}$$

where Y_t is output, α_Y is the capital share, and A_t is labor-augmenting technology, whose law of motion is $A_{t+1} = (1 + g_t^A)A_t$ with g_t^A being the productivity growth rate. Aggregate capital stock evolves according to the law of motion $K_{t+1} = K_t(1-\delta_K) + I_t$, where δ_K is the depreciation rate of capital and I_t is aggregate gross investment. See the determinants of K_t and L_t in online Appendix A.3.

We assume our representative firm maximizes the net cash flow by renting capital and hiring labor from households in competitive markets at the rates r_t and w_t, respectively. Capital and labor inputs are chosen by firms according to the first-order conditions:

$$r_t + \delta_K = \alpha_Y(Y_t/K_t), \tag{12}$$

$$w_t = (1 - \alpha_Y)(Y_t/L_t). \tag{13}$$

3.3 Government

The government provides public goods and services, denoted by G_t, and transfers all retirement pension benefits claimed, which are denoted by $\mathcal{S}_t$. The total amount of pension benefits claimed is

$$\mathcal{S}_t = \sum_{a=0}^{\Omega} N_{t-a,a+1}\left[\sum_{n=1}^{\mathcal{N}} \int_{\Theta} b_{t-a,a,n}\,\alpha_J(l_{t-a,a,n})\,\mathrm{d}P(\theta_n)\right]. \tag{14}$$

$N_{t-a,a}$ is the population size for cohort t–a at age a, $\mathcal{N}$ is the number of heterogeneous agents, $b_{t-a,a,n}$ is the pension benefit for cohort t–a at age a of type n, and $P(\theta_n)$ is the probability of having the initial endowments $\theta_n \in \Theta$. For simplicity, we assume the government does not hold debt and hence adjusts each year the social contribution rate. Following the Austrian pension system, social security contributions finance 70 percent of all retirement benefits claimed. Thus,

$$0.70\mathcal{S}_t = \tau_t^s w_t L_t, \tag{15}$$

where τ_t^s is the social security contribution rate in year t. To finance G_t and the remaining 30 percent of $\mathcal{S}_t$, the government levies taxes on labor income (τ^l), on capital income (τ^k), and on consumption (τ^c). The budget of the government in period t is[13]

$$G_t + 0.30\mathcal{S}_t = \tau_t^l(w_t L_t + 0.30\mathcal{S}_t) + \tau_t^k r_t K_t + \tau_t^c C_t, \tag{16}$$

where C_t is the total final goods consumed. Notice that the total tax base of labor income has to be augmented by the fraction of total pension benefits that are not financed by social contributions.

4. Parametrization

We calibrate our model to historical economic and demographic data of Austria for the period 1890–2010. Before introducing the calibration of our model in Section 4.5 we briefly summarize the reconstruction of education-specific demographic parameters, the age profiles of labor income and taxes, and the required social contributions to finance the pension system.

4.1 Demographics by education

To our knowledge there are no historical demographic rates by educational attainment for the XIX and XX centuries in Austria. Thus, following Lutz *et al.* (2007); Lutz *et al.* (2014); and Goujon *et al.* (2016), we assume a constant difference in life expectancy at age 15 across educational groups ($\text{LE}_{15,e}$). We consider three educational groups: primary, secondary, and college. We set the length of schooling, $e \in E$, at zero years for primary education, at four years for secondary education, and at eight years for college. Agents with primary or less education are assumed to have an average life expectancy, $\text{LE}_{15,0}$, five years lower than those with college, while agents with secondary education have an average life expectancy, $\text{LE}_{15,4}$, one year and a half lower than those with college (see section 5.2 in Goujon *et al.*, 2016). In addition, following Murtin *et al.* (2022) we assume that the variance in mortality is to a large extent driven by differences in income rather than in education. Hence, for each educational group we set the maximum difference in $\text{LE}_{15,e}$ at ten years of age. The income level for each educational group is proxied by the learning ability level. Table 1 summarizes the maximum differences in life expectancy within and across educational groups.

Note in Table 1 that the assumed maximum difference in life expectancy can be as large as fifteen years (adding up the maximum difference across educational groups and income), which is close to the maximum difference in life expectancy observed in the United States (Chetty *et al.*, 2016). Finally, age-specific fertility rates by birth cohort and educational group are calculated considering that the population growth rate is the same across our three education groups. The derivation of the age-specific mortality rates and age-specific fertility rates are provided in Section A.5 in the online Appendix.

4.2 Life-cycle earnings by education

As shown in Section 3.1.3, the wage rate per hour worked of our agents depends on (i) the wage rate per efficient unit of labor, on (ii) the age-specific labor productivity $\epsilon_a(e)$, which is a function of the experience, and on (iii) the stock of human capital $h_{a,e}$; that is, $w_{a,e,n} = w\epsilon_a(e)h_{a,e,n}$. The age-specific productivity of an agent with e additional years of education and $a{-}\underline{a}{-}e$ years of experience is assumed to follow a standard Mincerian equation $\log \epsilon_a(e) = \beta_1(a{-}\underline{a}{-}e) + \beta_2(a{-}\underline{a}{-}e)^2$, where $\underline{a}$ is the age at finishing primary education and the parameters (β_1, β_2) reflect the importance of experience on the wage rate, which are set to match EU-SILC 2011 data.

[13] Section A.2 in the online Appendix shows how equation (16) allows satisfying the goods market clearing condition.

Table 1. Fixed differences in life expectancy at age 15 by educational attainment and learning ability level

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

4.3 Private sector

Our choices for capital share and depreciation of capital are $\alpha_Y = 0.375$ and $\delta_K = 0.05$, respectively. The values of these two parameters imply an interest rate of 3.3 percent for an average capital-to-output ratio of 4.5. We assume no productivity growth before 1800. From 1800 to 2070 the exogenous productivity growth rate is taken from two main sources. For the period 1890–2018 we take Austrian historical productivity estimates from Bergeaud *et al.* (2016). For the period 2018–70 we rely on the productivity assumptions from the European Commission (2018). After 2070 we take the last productivity growth rate assumed by the European Commission (2018) and assume that it stays constant until the end of the simulation period. For the intermediate period 1800–90 we linearly extrapolate the productivity growth rate. See the productivity growth rate in panel B, Figure A.4 in the online Appendix.

4.4 Public sector

We collected historical information on the public consumption spending for the period 1913–2018 from Statistisches Handbuch Österreichs (1966, 1991). 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 and the General Pensions Act.[14] The historical evolution of the parametric components of the Austrian pension system can be found in Section A.6 in the online Appendix. Finally, we set the minimum pension points $\mathrm{pp}^{\min}$ to match the minimum pension benefits $b^{\min}$, which in Austria is close to 1/3 of the average income ($\bar{y}$) at the age of retirement.[15]

4.5 Calibration

We follow a two-stage process to replicate the evolution of the Austrian economy. In the first stage, we assign, based on the literature, values to the parameters governing the human capital accumulation and preferences. In a second stage, we estimate, using the Bayesian melding method, the permanent unobserved heterogeneity – initial characteristics – for each agent of type $n \in \{1, \ldots, \mathcal{N}\}$ by fitting the model to the observed educational distribution for Austria. We set $\mathcal{N}$ at 25 heterogeneous agents.[16]

We assume the same initial stock of human capital ($h_{\mathrm{a},e,n}$) for all agents and normalize it to one. The returns-to-education is set at $\gamma_h = 0.65$, similar to Cervellati and Sunde (2013, p. 2075). The parameters governing the behavior of agents are set to replicate specific features of the labor supply. We assume an intertemporal elasticity of substitution (IES) of consumption (σ_c) of one, which coincides with the upper range values for σ_c suggested by Chetty (2006) and guarantees a steady-state

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

[15] In 2010, the minimum yearly pension ('Ausgleichszulage') was 10,976 euros, which was 35 percent of the average income of the age group 56–60 (31,673 euros) in Austria, see §293 ASVG in 2010.

[16] We also applied the Bayesian melding for $\mathcal{N}$ equal to 5, 15, 25, 35, 50, and 100. We found that $\mathcal{N} = 25$ is the minimum number of heterogeneous agents per cohort that allowed us to replicate well the evolution of the educational distribution in Figure 3, panel A.

equilibrium. We assume an IES of labor supply, σ_l, equal to 0.40. Notice from equation (6) that σ_l coincides with the Frisch elasticity, which is between the lower bound of 0.1 and upper bound of 2.0 (Keane and Rogerson, 2012). The value of the weight of the disutility of labor ($\alpha_L = 866.28$) is chosen so as to obtain that prime aged agents work 33.0 percent of their available time in 2010. This is equivalent to an average of 37 hours of work per week and year. The preferences for retirement ν_0 and ν_1 are set at 77.06 and −1.94, respectively, to guarantee an average retirement age between 57 and 58 for the cohort born in 1950. The subjective discount factor β is calibrated to have a (real) interest rate between 3 percent and 4 percent along the XXI century. This interest rate can be interpreted as the opportunity cost of contributing to the pension system. Table 2 summarizes the set of model parameters.

The last set of parameters corresponds to the initial characteristics of our heterogeneous individuals $\theta_n = (\eta_n, \ \xi_n) \in \Theta = ([\bar{\eta}, \ \underline{\eta}] \times [\bar{\xi}, \ \underline{\xi}])$: the effort of attending schooling, η_n, and the innate learning ability, ξ_n. These two parameters are estimated using the Bayesian melding method (Poole and Raftery, 2000; Raftery and Bao, 2010), which provides an inferential framework that takes into account both model's inputs and outputs. We apply the Bayesian melding method to obtain the distribution of the set of initial characteristics that can best replicate the educational distribution among Austrian cohorts born between 1890 and 1980. Recall from Section 3 that the set of initial characteristics θ_n for agents of type n remains the same for all cohorts. However since the choice of educational length will be endogenous and depend on demographic and economic variables across the life course, our model implies that agents within the same educational group may have different characteristics over time. Not only will the unobserved characteristics be different across educational groups over time, but also economic and demographic characteristics such as for example income and life expectancy. Our model implies that agents with primary education become more negatively selected over time as indicated by an increase in schooling effort and a reduction in innate learning ability. Our model therefore controls for the influence of changes in the characteristics across educational groups on the evolution in life expectancy (Goldring *et al.*, 2016; Hendi *et al.*, 2021).

In Figure 2, we can observe the evolution of the average initial characteristics θ_n of each educational group generated by the model. Panel A displays the schooling effort, while panel B presents the learning ability, both plotted across cohorts. In panel A, agents with high-schooling effort are more likely to stay with primary education, while agents with low-schooling effort are more likely to attain college. Moreover, agents with primary and secondary education born after 2000 have, on average, a higher schooling effort than those born before 2000. Hence, younger cohorts with less than college are becoming more negatively selected (i.e., their schooling effort is higher).[17] Panel B shows a decline in the average learning ability of primary and college-educated agents, while the average learning ability of those with secondary education increases, for cohorts born until 1970. Thus, we obtain that agents with primary education are also becoming more negatively selected in terms of their learning ability (i.e., lower learning ability). For younger cohorts, the learning ability level of those with college education becomes more heterogeneous (as indicated by the increase in the width of the confidence interval [CI]), since a higher proportion of agents attain college.

Figure 3, panel A shows the fit of our model (colored areas) to the educational distribution data (dots), from Wittgenstein Centre for Demography and Global Human Capital (2018). Panels B–D, on the other hand, serve as an external validation of our calibration procedure. In particular, panel B shows that our model reproduces the time series of the pension spending-to-output ratio from 1950 to 2010. Panel C demonstrates that our model can replicate the evolution of per capita income, while panel D presents the average labor income and pension benefits profiles in 2010, obtained from the AGENTA database. These four panels confirm that our model can match key variables required to replicate the cost of the evolution of the Austrian pension system. At the aggregate level, our model

[17]Sánchez-Romero *et al.* (2016) show that schooling effort is considered by our agents as a fixed cost to education. Hence, as the lifetime income increases due to productivity growth, the marginal cost of education decreases and the marginal benefit of schooling increases. As a result, only those with very high schooling effort do not attain higher education.

Table 2. Model parameters

Parameter	Symbol	Value	Parameter	Symbol	Value
Preferences			Human capital		
Marginal schooling cost*	$[\bar{\eta},\ \underline{\eta}]$	[0, 40]	Learning ability*	$[\bar{\xi},\ \underline{\xi}]$	[0.00, 0.30]
Labor elasticity	σ_L	0.40	Initial human capital	$h_{\underline{a}}$	1.00
Labor weight	α_L	866.28	Returns to education	γ_h	0.65
Max. labor supply before retirement	$\bar{L}$	0.4	Experience		
Leisure in retirement	ν_0	77.0552	Age	β_1	0.070
	ν_1	−1.9425	Age^2	β_2	0.00092
Subjective discount factor	β	1.02			
			Production		
			Capital depreciation rate	δ_K	0.05
			Capital share	α_Y	0.375
			Productivity growth rate	g_t^A	See Figure A.4

*Parameter calibrated using the Bayesian melding method.

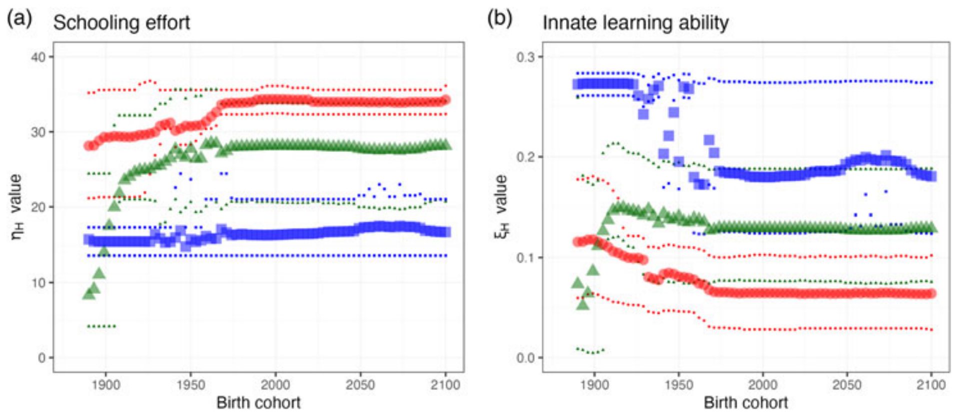

Figure 2. Evolution across cohorts of the initial endowments of each educational group, birth cohorts 1880–2100.
Source: Authors' calculations.
Notes: Each panel shows for each education group (primary – red circles, secondary – green triangles, and college – blue squares) the evolution of the mean (shapes) and the 50% CI (dots) of each initial endowment: schooling effort (A) and innate learning ability (B).

captures the evolution of total pension spending and per capita income. At the micro level, it matches the profiles of labor income and pension benefits.

In summary, by calibrating our model to historical time series of important macroeconomic and pension related variables, with a focus on the heterogeneity of agents by educational attainment, we can apply our framework for studying the redistributional effects of alternative pension reforms in Section 6.

5. Pension reforms

The increasing regressivity of pensions caused by the difference in life expectancy across socio-economic groups has initiated research on scrutinizing current pension reforms and their distributional effects and to suggest alternative pension reforms that may counteract these redistributive trends. In this section we discuss six alternative pension reforms. To guarantee the future sustainability of all pension reforms, we implement a sustainability factor in each proposed reform. To understand the impact of each reform proposal compared to the status quo of the current Austrian pension system we proceed as follows. First, we present results of a pension reform that only takes into account a sustainability factor (first pension reform) and compare them to the results in the status quo. Next, we introduce the various pension reforms on top of the sustainability factor and compare them to our first

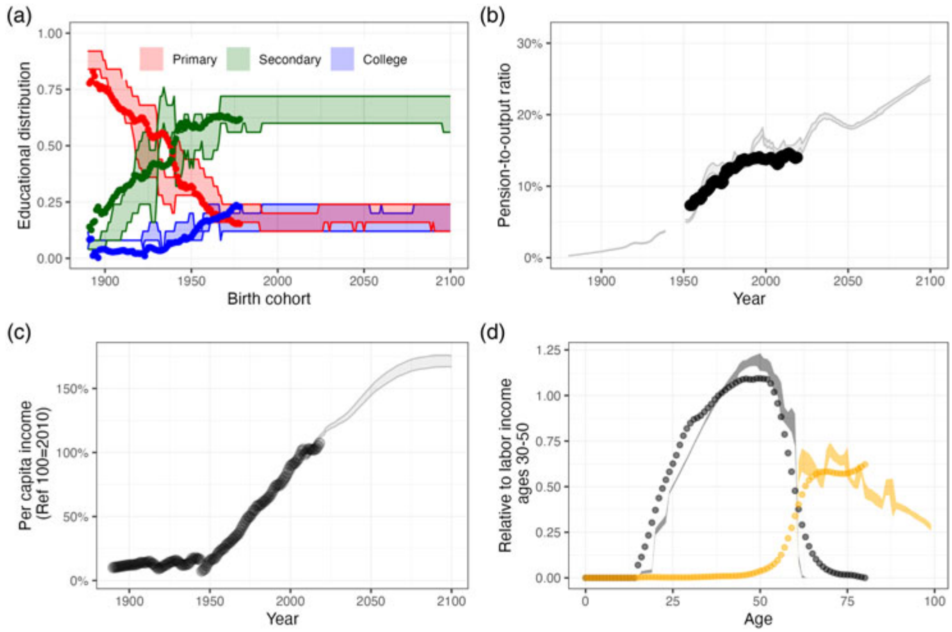

Figure 3. Model fit, 1880–2100.

Notes and sources: Panel A shows the fit of the model (colored areas) to the educational distribution data (colored circles) from Wittgenstein Centre for Demography and Global Human Capital (2018). Panel B shows the fit of the model (gray area) to the total pension spending to output ratio (black circles), excluding the period of World War II. Panel C shows the model fit (gray area) to the per capita income (black circles) taken from Bergeaud *et al*. (2016). Panel D shows the model fit of labor income (gray area) and pension benefits profiles (orange area) in 2010 to AGENTA data (orange circles) (see http://dataexplorer.wittgensteincentre.org/nta/). The width of the areas contains all the results (i.e., CI = 100%) from the 200 randomly drawn model simulations.

pension reform. This provides a comprehensive comparison of the proposed reforms against both the status quo and the first pension reform. For the sake of comparability across pension reforms, we assume all pension reforms have a similar phase-in/out period of twenty years, which starts for the 1961 birth cohort and ends for the 1980 birth cohort. The changes of the parametric components of the pension system associated with each pension reform are summarized in Table 3.

Reform 1. Sustainability factor: 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 downward the pension replacement rate by reducing the pension sustainability factor, denoted by ρ_t, until the system is balanced:

$$\begin{cases} \rho_t = 1 \text{ and } 0.70\mathcal{S}_t = \tau_t^s w_t L_t & \text{if } \tau_t^s < \overline{\tau_t^s}, \\ \rho_t < 1 \text{ and } 0.70\mathcal{S}_t = \overline{\tau_t^s} w_t L_t & \text{if } \tau_t^s \geqslant \overline{\tau_t^s}, \end{cases} \tag{17}$$

where $\mathcal{S}_t$ is the total cost of the pension system in year t, $w_t L_t$ is the total wage bill in year t, and τ_t^s is the social contribution rate in year t. This policy will transform the defined benefit (DB) system to a defined contribution (DC) system once that the maximum social security contribution rate is reached (Sánchez-Romero and Prskawetz, 2019).

The social security rate in 2010 is 19.1 percent, which is below $\overline{\tau_t^s}$. We obtain that the sustainability factor (i.e., ρ_t) will be triggered from 2060 onward and will decline linearly up to a value of 0.75 in 2100. Therefore, this policy reform will affect retirees and workers living beyond 2060 through a reduction in their pension benefits and by keeping the social contributions at $\overline{\tau_t^s}$.

Table 3. Parametric reforms of the pension system

Parameter	Symbol	Benchmark (status quo)	Pension reform: (1) Sustainability factor	(2) Delayed retirement	(3) Same work length	(4) ABH proposal	(5) SP proposal	(6) Front loading
Pension benefits	b_a	$\max(\lambda_a\varphi(\mathrm{pp}_a)\mathrm{pp}_a,\ b^{\min})\rho$						
Working years (full pension)	wy	45	–	50	–	–	–	–
Pension points	pp_a	$\mathrm{pp}_{a+1} = [\alpha_J(l_a) + (1-\alpha_J(l_a))\mathcal{R}_a]\mathrm{pp}_a + \phi^p \mathrm{PBI}(y_a)$						
Capitalization index	$\mathcal{R}_a$	Growth rate of the total wage bill						
Pensionable income years	n	wy						
Accrual rate	ϕ^p	$1/n$						
Pensionable income	p_a	$p_a = \{(p_1, \ldots, p_n) \in \mathbb{R}^n_+ : p_1 \geqslant \cdots \geqslant p_n\}$ (with $p_{a+1} = [\alpha_J(l_a) + (1-\alpha_J(l_a))\mathcal{R}_a]p_a$)						
Pension base increase	$\mathrm{PBI}(y_a)$	$\max(y_a - p_n, 0)$ (if $y_a > p_n$ replace p_n for y_a in p_a)						
Proportion of people retired	$\alpha_J(l_a)$	$\begin{cases} 1 - l_a/\bar{L} & \text{if } a \geqslant \underline{J} \\ 0 & \text{otherwise} \end{cases}$						
Minimum retirement age	$\underline{J}$	62	–	67	59	–	–	–
Normal retirement age	J^N	65	–	70	NA	–	–	–
Late retirement age	$\bar{J}$	68	–	73	NA	–	–	–
Replacement rate	$\varphi(\mathrm{pp}_a)$	0.80	–	–	–	$0.80\,\frac{\overline{\mathrm{LE}}}{\mathrm{LE}(\mathrm{pp}_a)}$	$0.80 + \nu\,\frac{\overline{\mathrm{pp}_a} - \mathrm{pp}_a}{\mathrm{pp}_a}$	1.0
Pension adjustment factor	λ_a	$\sum_{i=\underline{J}}^{a-1} (\lambda^{fl})^{a-1-i} \lambda_i^{yc} \lambda_i^{ra} \frac{\Delta l_{i-1}}{\bar{L}-l_a}$ with $\lambda_{\underline{J}} = 0$						
Years contributed	$\lambda_i^{yc} = 1 + \phi^{yc} f(yc_{\underline{J}} + (i - \underline{J}) - wy)$ with $yc_{i+1} = yc_i + (l_i/\bar{L})$	$\phi^{yc} = 1/wy$ $f(x) = x$.	–	–	$\phi^{yc} = 3.3/wy$ $\min(0, x)$	–	–	–
Retirement age	$\lambda_i^{ra} = \begin{cases} 1 - \mathrm{pen}(J^N - i) & \text{if } \underline{J} \leqslant i \leqslant J^N \\ 1 + \mathrm{rew}(i - J^N) & \text{if } j^N < i \leqslant \bar{J} \end{cases}$	$\mathrm{pen} = 0.051$ $\mathrm{rew} = 0.042$	–	–	$\mathrm{pen} = 0.0$ $\mathrm{rew} = 0.0$	–	–	–
Front loading	$\lambda^{fl} = (1 - r_b)$	$r_b = 0\%$	–	–	–	–	–	$r_b = 1\%$
Minimum pension	$b^{\min}$	$\mathrm{pp}^{\min} = \frac{1}{0.8}\frac{\bar{y}}{3}$	–	–	–	–	–	–
Sustainability factor	ρ	1.0	$\leqslant 1.0$	$\leqslant 1.0$	$\leqslant 1.0$	$\leqslant 1.0$	$\leqslant 1.0$	$\leqslant 1.0$

Notes: – Same value as in the benchmark.

Reform 2. Delayed retirement: In this reform the pension formula is transformed from the existing rule 45–65–80 to the rule 50–70–80. That is, workers who have contributed during fifty years and retire at age 70 receive 80 percent of their average labor income. For consistency reasons, the minimum, normal, and maximum retirement ages are increased by five years with respect to the benchmark (i.e., $\underline{J} = 67,\ J^N = 70,\ \bar{J} = 73$). In addition, the working years (wy) and the pensionable income years (n) are increased by five additional years in order to guarantee the consistency between the pension points accumulated and the pension benefits' formula. In this reform the social contribution rate will decline from 17.8 (2020) to 14.8 percent by 2050 and then increase back to 17.8 percent by 2100. Hence, the sustainability factor will not be triggered before 2100. Since 30 percent of the Austrian pension spending is financed by taxes, this pension reform will also reduce future tax rates.

Reform 3. Same work length: Individuals who started working at age 18 could have contributed forty-five years to the system at the age of 63. However, if these workers retire at age 63, the current pension system in Austria will penalize them since they retire before the normal retirement age of 65. In this pension reform, we cancel the adjustment factor related to the retirement age (i.e., $\lambda_i^{ra} = 1 \forall i \in [\underline{J},\ \bar{J}]$), which penalizes retiring before a specific fixed age, and strengthen the adjustment factor related to the years contributed. The new rule is 45–80; that is, a worker who contributes for forty-five years receives 80 percent of their average labor income. The new adjustment factor formula becomes

$$\lambda_i^{yc} = 1 + \frac{3.3}{wy} \min\left(0, yc_{\underline{J}} + (i - \underline{J}) - wy\right) \quad \text{for } i \in [\underline{J},\ \bar{J}], \tag{18}$$

where yc reflects the years contributed, with $yc_{i+1} = yc_i + (l_i/\bar{L})$ and $yc_0 = 0$. We impose a penalty equal to $3.3/wy$ for every year contributed below the target working years (wy) in order to have the same penalty for early retirement as in the benchmark case. In addition, we also modify the minimum retirement age in order to allow workers who started working after finishing primary education claiming their pension benefits once that they have contributed for forty-five years (i.e., $\underline{J} = 59$). Furthermore, we eliminate both the normal retirement age and the late retirement age since individuals have no incentive to retire after having contributed to the system wy years. The suggested reform implies that an earlier labor market entry allows also an earlier entry into retirement keeping the replacement rate unchanged. However, individuals with a late labor market entry face a higher penalty than in the status quo. Given that workers with a later labor market entry generally also have acquired a higher level of education leading to higher earning potentials and hence higher pension benefits, the suggested reform implies that the pension system becomes less expensive and the social contribution rate declines.

Reform 4. ABH proposal: Following Ayuso *et al.* (2017) the ABH proposal suggests adjusting the replacement rate of the pension system for an agent of age a taking into account the difference between the average life expectancy of the cohort at age a ($\overline{\text{LE}}$) and the life expectancy of the agent at age a. Since it is assumed that the life expectancy of each agent is unknown to the government, we consider that such a policy can be implemented similar as in Holzmann *et al.* (2019) where the remaining years of life are related to the log of the number of pension points (see Section A.7 in the online Appendix).

Assuming that the ABH proposal is fully implemented (i.e., $\zeta = 1$), the pension replacement rate becomes

$$\varphi(\text{pp}) = \varphi \frac{\overline{\text{LE}}}{\text{LE}(\text{pp})}, \tag{19}$$

where LE(pp) denotes the estimated life expectancy as a function of the number of pension points pp. The estimation of the life expectancy by pension points, LE(pp), is shown in Section A.7 in the online Appendix. The pension replacement rate will be equal to φ (i.e., the same as the benchmark) for agents with pension points equal to the average pension points ($\overline{\text{LE}} = \text{LE}(\overline{\text{pp}})$) and lower (resp. higher) than φ for those agents with pension points higher (resp. lower) than the average pension points. Notice that since life expectancy is positively related to the number of pension points, agents with higher (resp. lower) life expectancy would receive a lower (resp. higher) replacement rate than agents with lower (resp. higher) life expectancy, ceteris paribus the retirement age. Based on the estimated LE (pp) we obtain a maximum replacement rate of 92 percent for $\text{pp} = \text{pp}^{\text{min}}$ and a minimum replacement rate of 67 percent for $\text{pp} = \text{pp}^{\text{max}}$.

Reform 5. SP proposal: Sánchez-Romero and Prskawetz (2020) implement a pension reform (denoted as SP proposal in the following) such that the poorest workers – who have accumulated the least pension points and have on average the lowest life expectancy – receive the same return from the pension system as the richest workers – who have accumulated the most pension points and have on average the highest life expectancy. According to Sánchez-Romero and Prskawetz (2020) this can be implemented by calculating the ratio ν of the relative mortality advantage to the relative lifetime income advantage (where always the wealthiest workers are compared to the poorest workers):

$$\nu = \frac{(\text{LE}(\text{pp}^{\text{max}}) - \text{LE}(\text{pp}^{\text{min}}))/\text{LE}(\text{pp}^{\text{max}})}{(\text{pp}^{\text{max}} - \text{pp}^{\text{min}})/\text{pp}^{\text{max}}}. \tag{20}$$

Assuming that the SP proposal is fully implemented (i.e., $\zeta = 1$), the pension replacement rate in the SP proposal becomes

$$\varphi(\text{pp}) = \varphi + \nu\frac{\overline{\text{pp}} - \text{pp}}{\text{pp}}. \tag{21}$$

Equation (21) implies that those agents with pension points equal to the average number of pension points ($\text{pp} = \overline{\text{pp}}$) will also receive a replacement rate equal to φ (as in the ABH proposal and the status quo). While agents with pension points lower (resp. higher) than $\overline{\text{pp}}$ will have a replacement rate higher (resp. lower) than φ. The estimated relationship between life expectancy and the number of pension points is summarized in Section A.7 in the online Appendix. We obtain that the value of ν is 0.345, which leads to a maximum replacement rate of 114.5 percent for $\text{pp} = \text{pp}^{\text{min}}$ and a minimum replacement rate of 58 percent for $\text{pp} = \text{pp}^{\text{max}}$. Therefore, the SP proposal is more progressive than the ABH proposal.

While comparing the results of pension reforms 4 and 5 to the status quo, it is worth keeping in mind that long-lived retirees are more costly to the pension system than short-lived retirees, since the former receive their pension benefits over a longer period of time, keeping other things equal. Therefore, a progressive replacement rate as in reforms 4 and 5 makes the pension system less expensive. Thus, the social contribution rate and the tax rates paid are lower in pension reforms 4 and 5 relative to the status quo.

Reform 6. Front loading: Individuals who are short-lived can benefit from having a pension benefit higher at the beginning of their retirement period and lower at the end of their retirement period (Vandenberghe, 2022). To have this possibility, in this pension reform we consider that pension benefits are front-loaded. In particular, the replacement rate at the normal retirement age is 100 percent (i.e., $\varphi(\text{pp}) = 1.0$) and it will decline at a rate $r_b = 1\%$ for each additional year receiving pension benefits. Thus, the pension replacement rate will be close to 80 percent after twenty-three years receiving pension benefits, which coincides with the average life expectancy at age 65 for the 1980 birth cohort.

Table 3 summarizes the parametric components for each of the suggested pension systems. Each row of Table 3 corresponds to a specific parametric component. Cells in column 3 show the value as well as the formula of the parametric components in the benchmark model, while columns 4–10 show the corresponding expressions for each pension reform. The symbol '–' in Table 3 indicates that the parametric component is the same as in the benchmark.

6. Comparison of pension reforms

We structure the comparison of the pension reforms by first presenting the effect of each reform on selected macroeconomic variables. In a second step we present the redistributive properties of each of the six pension reforms on the labor supply (behavioral reactions), the IRR, and alternatively the welfare effect across our heterogeneous agents. The results for the first pension reform, that only introduces a sustainability factor, are reported relative to the current Austrian pension system (the benchmark/status quo). The results for the remaining five pension reforms are reported relative to the first pension reform. In this way we highlight the specific effect for reforms 2–6 over and above the sustainability factor in reform 1.

6.1 Macroeconomic impact

Table 4 shows the impact of each pension reform, up to 2060, on the growth rate of output per capita (columns 1–4), on the annual costs of financing the pension system as measured by the total pension cost-to-output ratio (columns 5–8), and on the future obligations of the pension system as measured by the total pension wealth-to-output ratio (columns 9–12). We define the total pension wealth-to-output ratio in year t as the discounted value of the future flow of the total cost of the pension system from year t onward divided by the output in year t.[18]

Under the status quo, per capita output is expected to grow annually by 1.72 percent (=(1/50)log (236/100)) between 2010 and 2060 (columns 1–4, line 0, in Table 4). Only by delaying the retirement age (reform 2) (hence increasing labor supply), per capita output growth can be fostered, while all other pension reforms have either negligible or a negative effect on per capita output growth. As it will be explained in more detail in the next subsection the negative effect on per capita output growth is caused by a reduction in the labor supply associated with these other pension reforms.

Columns 5–8 show that for the current Austrian pension system (status quo) expenditures will range between 18 percent and 20 percent of total output over the period 2030–60 and will peak around 2040 (as indicated in panel B, Figure 3). With the exception of pension reform 6, all other reforms will decrease the costs of the pension system and these reductions will be most obvious when delaying the retirement age (reform 2).

The value of the total pension wealth-to-output ratio for the status quo (columns 9–12) in 2040 is equivalent to 10.0 times the output. Two pension reforms are interesting when compared to the status quo. First, delaying retirement age (reform 2) implies a reduction in the cost of financing the pension system of 2.5 (=−2.4−0.1) times the output in 2040, which is consistent with the reduction in the total cost of the pension system and the increase in output per capita. Second, introducing front loading (reform 6) leads to an increase in the cost of the pension system of 0.6 (=0.7−0.1) times the output in 2040. All other reforms reduce the costs of financing the pension system by less than half of the output.

6.2 Distributional effects

At the macro level, we have seen in Section 6.1 that reform 2 is the most favorable for promoting economic growth and reducing pension spending. However, the macroeconomic impact of each pension reform hides important distributional effects that may disadvantage specific population subgroups. In this section, we discuss the impact of the six alternative pension reforms on the labor supply (i.e., behavioral effects), the IRR, and on welfare for the birth cohorts 1980 and 2020. We selected these

[18]The discount factor used for this calculation is the market interest rate from each simulation scenario.

Table 4. Macroeconomic impact of pension reforms (mean values)

	Output per capita (year 2010 = 100)				Pension cost-to-output (in %)				Total pension wealth-to-output (in output years)			
Year Pension reform	2030 (1)	2040 (2)	2050 (3)	2060 (4)	2030 (5)	2040 (6)	2050 (7)	2060 (8)	2030 (9)	2040 (10)	2050 (11)	2060 (12)
0. Benchmark (status quo)	149	176	208	236	18	20	18	19	10.3	10.0	9.7	9.8
1. Sustainability factor (SF)	149	176	208	235	18	20	18	19	10.2	9.9	9.6	9.6
Absolute difference with respect to status quo												
1. Sustainability factor (SF)	0	0	0	−1	0	−1	0	0	−0.1	−0.1	−0.2	−0.2
Absolute difference with respect to sustainability factor												
2. SF + delayed retirement	2	7	11	20	−2	−4	−5	−7	−2.2	−2.4	−2.5	−2.5
3. SF + same work length	−2	0	1	3	0	−1	−2	−2	−0.2	−0.3	−0.2	−0.1
4. SF + ABH proposal	−1	−1	−2	−1	0	0	0	−1	0.0	−0.1	−0.1	−0.1
5. SF + SP proposal	−2	−3	−4	−3	0	0	0	−1	0.0	0.0	0.0	0.0
6. SF + front loading	−1	0	−3	−3	1	0	2	1	0.7	0.7	0.7	0.7

two cohorts to illustrate the impact of the pension reforms on the phase-out cohort (born in 1980), which faces most of the transition costs, and a cohort that experiences the fully matured new pension system (born in 2020). For expositional purposes, we divide each cohort in four population subgroups that differ according to their permanent unobservable characteristics (i.e., learning ability and schooling effort). Comparing these four population subgroups allows us to study which groups are the winners and losers of each pension reform. These four groups have the following characteristics:

- *Group a:* Low-learning ability and high-schooling effort. This group reflects individuals with less than a secondary education, early entrance into the labor market, early retirement age, but on average, longer working lives. Their life expectancy is close to five years lower than the average, and their lifetime consumption is close to 50 percent of the average consumer.
- *Groups b and c:* Low-learning ability and low-schooling effort (group b) and high-learning ability and high-schooling effort (group c). These groups represent the average individual. They are characterized by having close to a secondary education, an average age at entrance into the labor market, and an average retirement age. Their life expectancy varies by two years with respect to the average, and their lifetime consumption varies between 60 percent and 110 percent with respect to the average consumer.
- *Group d:* High-learning ability and low-schooling effort. This group represents individuals with college education, late entry into the labor market, later exit from the labor market, but a working life that is close to one year shorter than the average. Their life expectancy is close to three years higher than the average, and their lifetime consumption is two times higher than the average consumer.

Note that the distribution of these characteristics is constant across all cohorts, ensuring that they are not influenced by selectivity within the group, as can occur with education or income. In the online Appendix, Section A.9, we also provide the distributional effects by educational group.

6.2.1 Behavioral effects

To study the behavioral effects of pension reforms, we record the number of years worked, which includes changes in the labor supply at the intensive and extensive margins. To calculate the number of years worked, we divide the sum of lifetime hours worked of an agent by the yearly maximum number of hours worked before retirement ($\bar{L}$).

We structure the results by birth cohort and population subgroup (columns 1 and 2, Table 5) and report the absolute values for the Austrian pension system (Bench.) and the first pension reform (SF)

Table 5. Impact of pension reforms on the labor supply by unobservable characteristics (in years worked)

					Absolute difference with respect to reform 1 (the sustainability factor, SF)				
					Pension reform				
Cohort	Learning ability and schooling effort ξ–η	Bench. (0)	SF (1)	(1) − (0)	(2)	(3)	(4)	(5)	(6)
1980	a. Low-high	41.07	41.10	0.03	2.42	−0.26	−0.51	−1.05	−0.18
	b. Low-low	39.77	39.92	0.15	2.37	0.23	−0.68	−1.32	−0.43
	c. High-high	40.60	40.78	0.18	2.28	0.01	−0.51	−0.72	−0.39
	d. High-low	39.53	39.57	0.04	2.04	0.23	−0.07	0.15	−0.53
2020	a. Low-high	41.67	41.96	0.29	2.26	−0.45	−0.71	−1.43	−0.38
	b. Low-low	40.50	40.98	0.48	1.92	−0.04	−0.92	−1.78	−0.59
	c. High-high	41.52	41.93	0.41	1.90	−0.20	−0.51	−0.91	−0.46
	d. High-low	40.51	40.99	0.48	1.69	−0.27	−0.14	0.03	−0.55
Difference between groups d and a									
1980	Marginal			0.01	−0.38	0.49	0.44	1.20	−0.35
	Total	−1.54	−1.53	−1.53	−1.91	−1.04	−1.09	−0.33	−1.88
2020	Marginal			0.19	−0.57	0.18	0.57	1.46	−0.17
	Total	−1.16	−0.97	−0.78	−1.54	−0.79	−0.40	0.49	−1.14

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.

in columns 3 and 4. We continue by presenting the absolute difference in the labor supply between the benchmark and reform 1 in column 5. In columns 6 through 10 we report the absolute difference in labor supply of all other reforms in comparison to the first reform. In the lower panel we also report, for each pension system, the absolute difference of the labor supply between the highest educated, wealthiest, and long-lived (group d) and the less educated, poorest, and short-lived group (group a) for birth cohorts 1980 and 2020. We report the total difference together with the marginal differences.

In the benchmark, the bottom panel shows that individuals who are more educated and wealthier (group d) work, on average, 1.54 years less than those who are less educated and poorer (group a) for the 1980 birth cohort and 1.16 years less for the 2020 birth cohort. Comparing reform 1 to the status quo, Table 5 shows the following findings. First, the bottom panel demonstrates that reform 1 reduces this difference (i.e., the disparity in years worked across population subgroups) by 0.01 years for the 1980 birth cohort and by 0.19 years for the 2020 birth cohort. This indicates a decrease in inequality in terms of years worked. Second, the upper panel reveals that for cohort 2020 reform 1 leads to an increase in the number of years worked by almost half a year for the population subgroups b–d, and by 0.29 years for group a. The implementation of the sustainability factor, which reduces pension benefits, motivates individuals to supply more labor in order to compensate for the income loss during retirement. Overall, these results highlight that reform 1 not only diminishes the disparity in years worked among different population subgroups but also encourages increased labor supply to offset the reduced retirement benefits resulting from the application of the sustainability factor.

Comparing reforms 2–6 to reform 1 in Table 5 reveals the following results. First, reform 2 leads to an overall increase in the retirement age by approximately two years (see upper panel). However, this increase is not uniform across all population subgroups. The bottom panel highlights a widening disparity in the number of years worked between individuals who are more educated and wealthier (group d) and those who are less educated and poorer (group a). The marginal increase in this difference amounts to 0.38 years for the 1980 birth cohort and to 0.57 years for the 2020 birth cohort. This result can be explained by the fact that reform 2 imposes a stricter effective penalty on benefits for individuals who retire early and have a shorter life expectancy, compared to those who live longer. Second, reform 3 (same work length) reduces the disparity in the number of years worked between individuals in groups d and a by 0.49 years for the 1980 birth cohort and by 0.18 years for the 2020 birth cohort (see the bottom panel). In the case of the 1980 birth cohort, individuals with shorter lifespans and lower incomes (group a) decrease their labor supply by 0.26 years, while more educated and wealthier workers (group d) increase it by 0.23 years. For the 2020 birth cohort, the absence of retirement age penalties results in a reduction in the number of years worked compared to reform 1. Third, reforms 4 and 5, which implement a progressive replacement rate, lead to more equitable working lives among different population groups. In particular, for the 1980 birth cohort, the difference in years worked between groups d and a decreases to (0.44–1.53=)−1.09 years in reform 4 and to (1.20–1.53=)−0.33 years in reform 5. However, this outcome leads to a reduction in labor supply, and this effect becomes more pronounced as the difference in years-worked across socioeconomic groups decreases. The progressive pension replacement rate increases the effective tax on labor, thereby discouraging labor supply (see Figure A.7 in Section A.8 in the online Appendix). Finally, reform 6 (front loading) leads to an increase in the difference in the labor supply between individuals in groups d and a of 0.35 years for the 1980 birth cohort and of 0.17 for the 2020 birth cohort. Moreover, our simulation findings indicate that reform 6 decreases labor supply by advancing the retirement age of individuals. This result is the consequence of the increased effective tax on labor at the extensive margin caused by the front-loading factor.

6.2.2 Internal rate of return

Besides the behavioral effect induced by pension reforms, pension systems may redistributive resources across different socioeconomic groups over the lifecycle. To study these redistributive properties, Table 6 shows the average IRR for the 1980 and 2020 birth cohorts across four socioeconomic groups (i.e., groups a–d).[19]

Table 6 presents several key findings. First, for the Austrian pension system (Bench.), we obtain a decline from the 1980 to the 2020 cohort in the IRR for all population groups, which is driven by the slowdown in the population growth rate (Aaron, 1977).[20] In addition, we observe that wealthier and longer-lived individuals (group d) from the 1980 (resp. 2020) birth cohort earn an IRR that is 1.71 (resp. 1.14) percent higher compared to poorer and shorter-lived individuals. This difference arises because individuals with above-average (resp. below-average) life expectancy receive their benefits over a longer (resp. shorter) period. Consequently, smaller disparities in life expectancy among socioeconomic groups would result in smaller differences among their IRRs. See Sánchez-Romero and Prskawetz (2023) for a survey analyzing the impact of heterogeneous life expectancy on the IRR.

Second, reform 1 shows that compared to the benchmark the IRR declines for the 2020 birth cohort (see column 5 of the upper panel) due to the activation of the sustainability factor from 2060 onward. The bottom panel reveals that the difference in the IRR between groups d and a, both born in 2020, decreases by 0.12 percent. This is because lower pension benefits imply lower transfers from short-lived to long-lived, thereby reducing inequality in the IRR.

Third, reform 2 leads to a reduction in the IRR for the 1980 birth cohort, while it maintains the average IRR nearly unchanged for the 2020 birth cohort. The decline in the IRR for the 1980 birth cohort is due to this cohort bearing the majority of the transition costs associated with the reform. However, for future cohorts, this reform does not have a significant impact since the Austrian pension system is close to actuarially fair. Hence, changes in the retirement age should not substantially influence the IRR. An important drawback of reform 2 (delaying the retirement age) is the widening of the difference in the IRR between groups d and a. Specifically, for the 1980 birth cohort, the disparity in the IRR increases by 0.40 percent, while for the 2020 birth cohort, it expands by 0.51 percent. Another drawback of this reform is that differences of five years in life expectancy between group a and the average individual imply for the 2020 birth cohort that the IRR of the retirement pension system is negative (=−0.25%) in the benchmark and it decreases further for this group when the sustainability factor is implemented (=−0.38%), due to the cut in benefits. The lowest IRR for group a is reached in reform 2 with an average value of −0.63 percent (=−0.38%–0.25%). Given the correction for the

[19]The IRR of the retirement pension system is the discount factor that equates the actuarial present value of the stream of contributions paid to the actuarial present value of the stream of pension benefits received.

[20]Recall that the overall IRR of a mature pension system is the sum of the population growth rate and the productivity.

Table 6. Impact of pension reforms on the IRR by unobservable characteristics (mean values, in %)

					Absolute difference with respect to reform 1 (the sustainability factor, SF)				
					Pension reform				
Cohort	Learning ability and schooling effort ξ–η	Bench. (0)	SF (1).	(1) − (0)	(2)	(3).	(4)	(5)	(6)
1980	a. Low-high	0.32	0.35	0.03	−1.47	−0.24	0.32	0.59	0.25
	b. Low-low	1.26	1.29	0.03	−1.19	−0.40	0.16	0.26	0.23
	c. High-high	1.55	1.57	0.02	−1.16	−0.24	−0.12	−0.23	0.22
	d. High-low	2.03	2.05	0.02	−1.07	−0.40	−0.54	−0.80	0.28
2020	a. Low-high	−0.25	−0.38	−0.13	−0.25	0.07	0.46	0.77	0.06
	b. Low-low	0.54	0.39	−0.15	0.04	−0.03	0.36	0.53	0.12
	c. High-high	0.74	0.58	−0.16	0.02	0.07	0.07	0.03	0.10
	d. High-low	1.01	0.76	−0.25	0.26	0.12	−0.27	−0.48	0.26
Difference between groups d and a									
1980	Marginal			−0.01	0.40	−0.16	−0.86	−1.39	0.03
	Total	1.71	1.70	1.69	2.10	1.54	0.84	0.31	1.73
2020	Marginal			−0.12	0.51	0.05	−0.73	−1.25	0.20
2020	Total	1.26	1.14	1.02	1.65	1.19	0.41	−0.11	1.34

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.

difference in life expectancy in reforms 4 and 5, the IRR only becomes positive for group a under these two pension reforms.

Fourth, reform 3 (same work length) causes a decrease in the IRR for all groups born in 1980. This decline is attributed to the higher social contributions paid under reform 3 compared to reform 1 during the period 2015–25 (see Figure A.6, panel A, in the online Appendix). Fifth, reforms 4 and 5 result in more equal IRRs across the socioeconomic groups by raising the IRR of those with shorter lifespans at the expense of reducing the IRR of those with longer lifespans. It is important to note that this outcome aligns with the intended goal of both reforms, as they aim to equalize the IRR among individuals with different life expectancy. Specifically, in reform 4 (resp. reform 5) the difference in the IRR between groups d and a is reduced by 0.86 (resp. 1.39) percent for the 1980 birth cohort and by 0.73 (resp. 1.25) percent for the 2020 birth cohort. Sixth, reform 6 increases the IRR for both birth cohorts due to the anticipation of the pension benefits that results from the front loading. However, this reform also amplifies the difference in the IRR across socioeconomic groups for the 2020 birth cohort. This is because individuals with longer lifespans disproportionately benefit from higher pension benefits over a longer period of time, when the front-loading factor is not properly aligned with increases in life expectancy.

6.2.3 Welfare effects

The behavioral reactions caused by pension reforms and their financial impact are reflected on the welfare, leaving some agents better off and others worse off. To compare the welfare gains or losses across different reforms, we report in the upper panel of Table 7 the veil of ignorance in consumption; that is, the percentage change in the baseline consumption path that makes the expected lifetime utility in the status quo equal to the expected lifetime utility in the pension reform (Nishiyama and Smetters, 2014). In the bottom panel of Table 7 we show the relative change in welfare for the average individual in each cohort (benchmark = 100). It is important to note in Table 7 that a positive (resp. negative) value is associated with welfare gains (resp. losses) relative either to the status quo or to reform 1.

Comparing the welfare effect of reform 1 (i.e., sustainability factor) relative to the status quo we obtain small welfare gains for the 1980 birth cohort. These gains are caused by the additional savings, necessary for compensating the expected reduction in pension benefits, which lead to a small increase in capital per worker and to a higher consumption level relative to the status quo. For the 2020 birth cohort, we obtain welfare gains for individuals with shorter lifespans (groups a and b) and welfare

Table 7. Impact of pension reforms on welfare by unobservable characteristics (veil of ignorance, in %)

					Absolute difference with respect to reform 1 (the sustainability factor, SF)				
					Pension reform				
Cohort	Learning ability and schooling effort ξ–η	Bench. (0)	SF (1)	(1) – (0)	(2)	(3)	(4)	(5)	(6)
1980	a. Low-high	–	0.18	0.18	−9.11	−3.00	2.77	5.92	2.58
	b. Low-low	–	0.53	0.53	−7.69	−4.00	1.49	2.51	2.13
	c. High-high	–	0.65	0.65	−8.52	−3.16	−2.38	−3.86	2.31
	d. High-low	–	0.00	0.00	−8.62	−5.82	−7.03	−9.76	2.54
2020	a. Low-high	–	0.31	0.31	11.28	2.11	5.71	9.89	−0.26
	b. Low-low	–	0.38	0.38	13.20	1.63	4.69	6.76	0.04
	c. High-high	–	−0.23	−0.23	12.06	2.22	0.97	0.06	0.26
	d. High-low	–	−1.22	−1.22	15.85	3.92	−3.76	−6.09	2.91
1980	Average welfare	100	100.06	0.06	−1.15	−0.49	−0.10	−0.12	0.38
2020	Average welfare	100	99.99	−0.01	1.46	0.26	0.24	0.31	0.05

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.

losses for individuals with longer lifespans (groups c and d). The reduction in welfare disparities across socioeconomic groups is caused by the reduction in transfers from short-lived individuals to long-lived individuals due to the lower future generosity of the pension system.

When comparing the welfare obtained from the remaining five pension reforms to reform 1, several key results emerge. First, reform 2 leads to significant welfare losses for the 1980 birth cohort. The negative values in the upper panel indicate a decline in welfare, and in the bottom panel, the welfare decreases by 1.15 percent for the average individual compared to the benchmark. This is because individuals are required to contribute more years to the pension system and receive lower pension benefits. However, it generates substantial welfare gains for the 2020 birth cohort due to lower social contributions paid. Importantly, this reform exacerbates welfare disparities across socioeconomic groups. Specifically, the welfare losses are more pronounced for group a compared to group d (i.e., −9.11% vs. −8.62%), while the welfare gains are stronger for group d compared to group a (i.e., 15.85% vs. 11.28%).

Second, reform 3 (same work length) also leads to overall welfare losses for the 1980 birth cohort and welfare gains for the 2020 birth cohort. However, in contrast to reform 2, welfare losses are more pronounced for individuals with less years worked (group d) than for individuals with longer years worked (group a). The welfare gains are produced by enjoying more years in retirement and the higher consumption that results from the increase in lifetime income due to the lower social contribution rates (see panel A in Figure A.6 in the online Appendix).

Third, reforms 4 and 5 also result in an overall reduction in welfare for the 1980 birth cohort and to an overall increase in welfare for the 2020 birth cohort (see bottom panel). However, these two pension reforms significantly reduce the disparity in welfare across socioeconomic groups a–d, indicating a more equal redistribution of income across socioeconomic groups.

Fourth, reform 6 (front loading) raises welfare for both generations, although to a greater extent for the 1980 birth cohort. This is because individuals are better off by anticipating their pension benefits. For the 2020 birth cohort, fixing the front-loading factor at the level corresponding to the 1980 birth cohort creates an imbalance in the system for future generations. This increases the cost of the pension system and favors long-lived and wealthier individuals, while leaving short-lived and poorer individuals worse off.

7. Conclusion

Population aging, as caused by low-fertility levels and increasing life expectancy, challenges any social security system that is based on the redistribution of resources from the employed toward the dependent older population. The persistent population aging observed in most developed countries prompts governments to introduce pension reforms that guarantee the long-run sustainability of their social security systems. Such proposals are delaying the effective retirement age, introducing penalties and rewards for early and late retirement, and linking the pension replacement rate to the remaining life expectancy, among others. However, in many countries, the difference in life expectancy between the high- and low-socioeconomic groups have widened in recent decades. Ignoring this heterogeneity might jeopardize any proposal, as pension schemes become highly regressive. The introduction of any pension proposal needs to take into account that individual aging is heterogeneous across socioeconomic groups. Therefore, it is necessary to investigate how pension proposals that correct for ex-ante differences in life expectancy impact on the decisions of heterogeneous individuals by SES and on the degree of regressivity of the system across socioeconomic groups. This task implies developing models that account for the behavioral response of heterogeneous individuals with different life expectancies to changes in the pension system.

To account for potential behavioral responses and to control for the implications of changes in the educational distribution on the life expectancy gradient, this paper builds a dynamic general equilibrium-OLG model in which agents optimally choose their consumption, length of schooling, and their labor supply. Agents are heterogeneous by their learning ability and their effort of attending schooling, characteristics that represent permanent unobserved heterogeneity. Life expectancy differs across individuals related to innate heterogeneities and the educational level.

We calibrate our model to the historical evolution of the educational distribution in Austria and implement the historical changes of the non-progressive pension system of Austria into our model. To account for the disparity in life expectancy among our heterogeneous individuals, we assume an extreme scenario where the maximum difference in life expectancy at age 15 within each cohort can be as high as fifteen years, which is similar to the maximum difference observed in the United States (Chetty *et al.*, 2016). Within this framework we then study six alternative pension reforms. We have selected the first two reforms that mainly aim to increase the sustainability of pension costs and four additional reforms that are targeted to reduce the regressivity of pension systems. For our simulations we assume that pension reforms are first implemented for the 1961 cohort and are phased in over twenty years, such that the 1980 cohort represents the phase-out cohort. We structure our results by first showing the macroeconomic implications of each reform over time (with a specific focus on the pension costs) and then continue to present three indicators to measure the distributional effects of each pension reform for the birth cohort 1980 (when pension reforms are phased out) and the 2020 birth cohort (which is subject to the mature new pension system).

Our simulations show the following results. First, in the current Austrian pension system (benchmark) individuals who are more educated, wealthier, and have longer life expectancy work on average 1.54 years less than those who are less educated and have lower income and lower life expectancy. Similarly, the IRR for the socioeconomically more advantaged group is higher compared to the lower socioeconomic group. Second, a reform that mainly targets the sustainability of the pension system, by implementing a cap on the sustainability factor for the contribution rate together with a delay in retirement (pension reform 2), will increase output per capita and reduce pension costs, compared to the benchmark (the current Austrian pension system). However this reform will increase the disparity among low- and high-socioeconomic groups at all three dimensions we considered (labor supply, IRR, and welfare). Third, with the exception of the last reform we implemented (pension front loading), all other pension reforms result in a reduction of pension costs, but too a much smaller extent compared to reform 2 that delays the retirement age. Fourth, reforms that control for the heterogeneity across individuals succeed in reducing the disparity across socioeconomic groups in labor supply, the IRR, and welfare. The strongest reductions are achieved for pension reforms 4 and 5 that control for heterogeneous life expectancy. Comparing the effects of both proposals, we find that the Sánchez-Romero and Prskawetz (2020) proposal (SP proposal or reform 4) provides a more equal IRR across population subgroups than the Ayuso *et al.* (2017) proposal (ABH proposal or reform 5). The main advantage of the SP proposal is to provide the highest IRR to individuals who are less educated and have lower income and lower life expectancy. Its main disadvantage compared to the ABH proposal is that the SP proposal also yields the highest effective tax on labor due to its higher degree of progressivity, which discourages labor supply to a greater extent than the ABH proposal. This result can be explained by the fact that the degree of progressivity of the ABH proposal only compensates for differences in life expectancy at retirement, whereas the degree of progressivity in the SP proposal compensates for differences in both, life expectancy and pension points. Fifth, a reform that implements a front loading of pension benefits not only increases the costs of pensions but also has quite detrimental effects on the disparity of labor supply and the IRR. Sixth, a comparison across cohorts highlights that the 1980 cohort bears the burden of pension reforms by having a lower IRR and a decrease in welfare.

Overall, our results highlight that pension reforms have (a) to be evaluated from a life-cycle perspective that accounts for heterogeneity across individuals and (b) have to be evaluated at various dimensions (such as the sustainability of pension costs but also focusing on the redistributive effects across socioeconomic groups). These redistributive effects can again be measured at various dimensions and should take into account a life-cycle perspective such as the life-time labor supply, IRR, and welfare measure we have introduced. Most importantly these distributional effects of pension reforms will be triggered by behavioral effects in relation to the changing macroeconomic and demographic environment.

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