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Public pension policy and the equity–efficiency trade-off*

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Abstract

This paper illustrates that the equity–efficiency trade-off between a redistributive, Beveridgean, pension system and an earnings-based, Bismarckian, scheme can collapse when accounting for labor supply effects on the extensive margins. I introduce a general equilibrium overlapping generations model with endogenous savings, human capital formation, and labor supply. The model is calibrated to an average OECD economy. The results suggest that allocating funds towards a Bismarckian pension system always reduces earnings inequality – and, in some cases, lifetime inequality – when compared with a Beveridgean scheme. However, the Bismarckian scheme crowds out more human capital in the economy following a higher steady-state interest rate.

Keywords: Dynamic general equilibrium; income inequality; pension reform

JEL classification: D58; H55; J22

1. Introduction

Should a public pension system prioritize redistribution from young to old age or from high- to low-income individuals? Views on this matter typically revolve around an equity–efficiency trade-off. A system designed to redistribute income intragenerationally is expected to introduce labor supply distortions, while a system designed to supplement only private savings will lack explicit mechanisms for alleviating economic inequality (see, e.g., Cremer and Pestieau, 2003; Jensen et al., 2004; Buyse et al., 2017). This trade-off is relevant when comparing recent trends in public pension reform. Since the 1990s, several developed economies have reformed their pension systems by strengthening the link between individual contributions and realized

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pension benefits.[1] Meanwhile, many developing economies have instead opted for schemes with a dominating basic-income component (Kemmerling and Neugart, 2019). The former approach is expected to promote efficiency, and the latter equity.

The present study argues against the importance, or even existence, of this trade-off in the context of pension design. In a neoclassical framework, I show that a reform from a basic-income pension system towards an earnings-based scheme can both increase aggregate labor supply and reduce life-cycle income inequality. The key to this result is that a redistributive public pension system may allow low-income (high-income) households to secure a sufficient retirement income with less (more) labor supplied relative to the amount supplied under an earnings-based system of comparable size. This effect increases the earnings dispersion between high- and low-income individuals and, in some cases, increases lifetime inequality.

I introduce a dynamic overlapping generations (OLG) model in continuous time to study the equity–efficiency trade-off from a life-cycle perspective. The microfoundations encompass the model presented by Jacobs (2009) in which a representative individual makes decisions regarding human capital formation, including on the timing of labor market entry, the intensity of labor supply during one's working life, and when to retire. This paper adds skill heterogeneity and a pension system to account for the different behavioral incentives implicit in the retirement benefit formula. In consonance with much of the theoretical literature on pension reform (see, e.g., Casamatta et al., 2000; Sommacal, 2006; Hachon, 2008), the model studies the responses to a combined earnings-based, Bismarckian, and basic-income, Beveridgean, pension scheme.

The analysis relies on a method of solving for the labor supply behavior of individuals integrated into an earnings-based pension system via the maximum principle. To account for the link between an individual's earnings history and their realized pension benefits, which any rational, forward-looking individual will acknowledge, the model is solved as a "delayed response" optimal control problem (see, e.g., Kamien and Schwartz, 2012). This approach is, to the best of my knowledge, novel, and results in a highly coherent and tractable framework for studying pension reforms when savings and labor supply on both the intensive and extensive margins are endogenous. The model is calibrated to replicate key statistics of an average OECD economy. Any effects of pension reform are analyzed in both partial and general equilibrium

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[1] For example, countries such as Sweden, Italy, Latvia, and Poland have introduced individual notional accounts in which contributions are appreciated by a fictitious interest rate to mimic the capitalization of funds without abandoning the pay-as-you-go (PAYG) transfer mechanism.

to illustrate both the direct policy effects on individual behavior as well as any feedback effects through changes in factor prices.

The findings of this paper contribute to the literature in several important ways. First, I expand on the research of Sommacal (2006), who shows in a two-period Diamond model that a redistributive and an earnings-based scheme, for a given contribution rate, can generate the same life-cycle inequality in a competitive equilibrium. Sommacal's findings rely on the assumption that the utility function is linear in leisure, and thereby a dominating substitution effect, where the wage elasticity of labor supply is higher for high-income individuals than for low-income individuals. The current paper shows, in a more general model, that a redistributive scheme can generate higher life-cycle inequality relative to an earnings-based scheme when allowing adjustments on the extensive margins while assuming utility to be concave in intensive margin leisure time.[2]

Second, the paper adds to a growing literature on the effects of public pension reform on skill formation and human capital investments. Alongside, for example, Jacobs (2009), Ludwig et al. (2012), Kindermann (2015), Vogel et al. (2017), and Caliendo and Findley (2020), this paper recognizes that pension policy will affect the incentives underlying human capital formation. If the pension system promotes an early retirement, thus lowering the financial returns to education, the incentives for human capital investments early in life are weakened. This complementarity can have at least two important implications for intragenerational inequality: (i) if the effects of pension policy on human capital formation differ across skill groups, then the policy will affect earnings inequality through changes in labor market participation among individuals; (ii) if human capital inequality increases (decreases), the policy will increase (reduce) wage inequality. In partial equilibrium, this paper, consistent with Kindermann (2015), finds that if the earnings-based pension system is return-dominated by private savings, labor supply becomes relatively more attractive later in life as the foregone compound interest by investing in the pension system decreases over the life cycle. The implicit tax treatment thus lowers the opportunity cost of tertiary education, and promotes a delayed entry into the labor market. The introduction of a Bismarckian system introduces direct behavioral effects, which promote an increase in educational attainment, while a Beveridgean system has the opposite effect.

Third, challenging the above partial equilibrium results, the paper shows that a switch from a Beveridgean system to a Bismarckian system reduces the

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[2] It also provides an alternative explanation to the political economy literature in which Ignacio Conde-Ruiz and Profeta (2007) illustrates that redistributive pension schemes are likely to prevail in economies with a large share of low-income households who are expected to benefit financially from a Beveridgean structure.

average educational attainment in general equilibrium. Specifically, increasing the earnings dependence of pension benefits is found to increase both aggregate labor supply and aggregate capital in the economy, while the change is disproportionally smaller for the latter. Under the assumption that capital and labor are imperfect substitutes in production, which is standard in the literature, the steady-state interest rate increases. This both promotes an earlier retirement and lowers the financial prospects of skill formation. The Beveridgean system is ultimately found to yield a larger human capital stock relative to a Bismarckian scheme, which stands in stark contrast to the findings of Docquier and Paddison (2003).

The rest of the paper is organized as follows. Section 2 reviews the literature. The model is outlined in Section 3. Section 4 presents the numerical results. Section 5 concludes.

2. Literature review

An important strand of research focuses on how public pension systems affect labor supply incentives (see, e.g., Browning, 1975; French and Jones, 2012; Frassi et al., 2019). In particular, the contribution rate, defined as the net of the present value of incremental pension benefits realized from such transfer, effectively works as an income tax (see, e.g., Beckmann, 2000; Fenge and Werding, 2004; Goda et al., 2011). The magnitude of such implicit taxation is then determined by the relationship between individual contributions and benefit entitlements. If this link is strong, as with a Bismarckian system, then the implicit tax rate is low. On the contrary, if the system is characterized by a large degree of within-cohort redistribution, as with a Beveridgean system, then the implicit tax rate is high.

Consistent with the equity–efficiency trade-off, in a two-period model, Cigno (2008) concludes that reducing the size of a Beveridgean system has positive effects on labor supply while resulting in an increased income inequality. Meanwhile, in a two-period Diamond model, Wen et al. (2015) show that reforming a pension structure from Beveridgean to Bismarckian substantially reduces labor supply disincentives. Focusing on the extensive margin response, Gruber and Wise (1999) find a systematic relationship between implicit taxation of social security systems and retirement behavior, which can explain early retirement behavior in the developed world.

Following the implicit income taxation induced by public pension systems, this study also builds on the insights of researchers who study how labor income taxation, both related to social security and in general, affects aggregate labor supply. For example, in a highly influential paper, Prescott (2004) finds that differences in labor income taxation can explain much of the variation in aggregate labor supply between Europe and the United States. Jacobs (2009) and Wallenius (2013) also make notable contributions by quantifying the labor supply response to variations in labor income tax rates. Plus, while Prescott (2004) and Wallenius (2013) focus on adjustments on the retirement margin in general equilibrium, Jacobs (2009) considers entry and exit, as well as the intensive margin response in partial equilibrium. He finds that the uncompensated labor supply elasticity increases by almost 50 percent when accounting for decisions regarding education and retirement. This suggests that labor income taxation is much more distortionary when the labor market entry and exit margins are taken into account.

Meanwhile, Sommacal (2006) studies the intragenerational redistributive effect of reforming a pension system from Bismarckian to Beveridgean. In a two-period Diamond-type model with endogenous intensive margin labor supply, when the labor market is competitive, he finds that an increase in the flat-rate pillar does not reduce economic inequality. This is because as funds are allocated toward the Beveridgean pillar, the low-skilled reduce their labor supply more than the high-skilled. As a result, the reform increases earnings inequality, which offsets the direct effects of the reduced pension income inequality. However, this result is not robust to the inclusion of a minimum wage, which suggests that labor market institutions play an important role in determining the redistributive outcome of pension system reform.

The structure and funding of public pensions will also directly and indirectly affect incentives for human capital investments through changes in the labor income returns to education. Caliendo and Findley (2020) examine the relationship between social security taxation and human capital formation under both Beveridgean and Bismarckian contribution–benefit formulas, thus keeping the retirement age fixed. Their model can replicate the negative correlation between public pension contribution rates and average educational attainment among OECD economies. It should be noted, though, that this result is not consistent with the findings of Kindermann (2015), who shows that return-dominated notional defined contribution (NDC) pension systems subsidize human capital formation. The intuitive explanation for this finding is that the NDC system introduces a higher implicit marginal tax on younger workers because of the foregone compound interest when returns to the pension system perform less well than returns to private savings. Both Caliendo and Findley (2020) and Kindermann (2015) model labor market entry as endogenous while keeping the retirement margin fixed.

A growing body of literature focuses on the impact of retirement policies on physical and human capital accumulation. Docquier and Paddison (2003) and Le Garrec (2012) study the impact of retirement policies on human capital formation in endogenous growth OLG models. Generally, they find that PAYG systems crowd out both physical and human capital in the economy. Investment in physical capital is crowded out by the forced savings of the pension system. This finding is well established following the ground-breaking work of Feldstein (1974). Furthermore, the imposed scarcity of physical capital increases market interest, which makes human capital investments less attractive, while Docquier and Paddison (2003) show that the more a pension system is redistributive, the larger are the disincentives for human capital investments.

In a model with physical capital-driven growth and heterogeneous longevity, Hachon (2010) illustrates that a Beveridgean system increases savings dispersion between high- and low-income individuals. In his model, more-productive individuals compensate for the reduced replacement income by saving more privately. On the contrary, the higher replacement income faced by agents of below-average productivity will reduce private savings further. When acknowledging that life expectancy is positively correlated with income, the net effect on overall capital accumulation and economic growth is found to be positive.

Within the political economy literature, Pestieau (1999) describes a paradox in that Beveridgean systems are often smaller than Bismarckian pension systems, even though they should enjoy more support among low-income groups. Ignacio Conde-Ruiz and Profeta (2007) rationalize this phenomenon in a bi-dimensional voting model concerning the size and the design of public pensions. They propose an explanation in which a coalition of low- and high-income individuals are likely to vote in support of a small redistributive system, while economies with a large middle class will favor a more extensive Bismarckian system.

3. The model

Consider a continuous-time OLG framework in which individuals of all ages are represented at each instant in time.[3] The economy consists of two types of rational individuals varying only in human capital production and indexed $i = 1, 2$, where $i = 1$ $(= 2)$ corresponds to low (high) ability. Unless explicitly needed, this indexation will be suppressed to avoid notational clutter. Individuals are non-altruists and thus have no bequest motive. All generations are identical, and birth-cohort size is kept constant such that the population growth is zero. These assumptions allow me to model the behavior of one representative generation. For convenience, the population is normalized to unity.

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[3] While several papers analyze the implications of pension design and funding in two- or three-period Diamond model frameworks (e.g., Sommacal, 2006; Wen et al., 2015; Frassi et al., 2019), it is difficult to augment the discrete-time OLG models with additional periods to study the extensive margins of labor supply without compromising on tractability.

3.1. Individuals

I assume that the economic life of an individual starts with the completion of secondary education and ends with certainty at time $t = T$.[4] The economic life of any individual can be decomposed into three distinct phases: tertiary education $t \in [0, S)$, working life $t \in [S, R)$, and retirement $t \in [R, T]$. At each instant t, individuals are endowed with one unit of time. Individuals discount the future at a constant rate θ.

When undertaking tertiary education, individuals devote all their available time to productivity-enhancing training.[5] The human capital decision is then reduced to a choice of timing for labor market entry. Let $F(S)$ denote the human capital production function, which will be specified later. During their working life, individuals separate their available time between leisure activities $l(t)$ and working $1 - l(t)$. For each unit of effective labor supply $(1 - l(t))F(S)$, individuals earn the wage rate w, net of a pension contribution rate τ. Retirement is assumed to be an absorbing state, which implies a permanent full-time withdrawal from the labor market. Retirement leisure, meanwhile, is considered to be a completely separate good compared with leisure time during one's working life, and the utility of being retired depends on the time spent in retirement $(T - R)$. Individuals derive felicity from the consumption of non-durable goods $c(t)$ throughout their economic life. Any net-of-tax income not used for contemporaneous consumption flows into the individual's asset account $k(t)$, which grows at the constant risk-free interest rate r. Because students are natural borrowers, and debt is a commonly observed feature of one's economic life, I allow for $k(t) < 0$ at any interior point in time.[6]

3.2. Human capital production

The production of human capital is stylized according to the following functional form:

$$F_i(S_i) = A_i S_i^{\rho_i}. \tag{1}$$

Here, A is the overall propensity for converting time spent in tertiary education into labor productivity units, and ρ is the elasticity of human capital with respect to education. Let $\rho \in [0, 1)$ such that the production function exhibits

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[4] While the original model proposed by Jacobs (2009) assumes individuals enter the model at age 6, I follow the modeling assumption of Caliendo and Findley (2020) in this regard.

[5] This assumption is consistent with the model specification in Jacobs (2009).

[6] This assumption is not problematic as long as the aggregate capital stock is positive. In a two-period Diamond model, it is natural to impose credit constraints to avoid solutions in which individuals finance debt in the first period by borrowing against future pension benefits.

diminishing marginal returns. In this specification, time spent in education has a pure multiplicative scaling effect on the individual's labor efficiency profile. This specification allows for heterogeneity in productivity between individuals without affecting the intertemporal trade-off between labor and leisure.

3.3. Pension system

To make the results applicable to the OECD in general, and in consonance with much of the theoretical work on public pension design, this paper considers a pension system that is stylized to resemble three key mechanisms (pillars) of most modern public pension systems following the recommendations of World Bank (1994). Two pillars are mandatory: the earnings-based, Bismarckian pillar; and the flat-rate, Beveridgean pillar. I assume the third pillar to be composed entirely of voluntary private savings on the capital market. The transfer mechanism is PAYG, implying that contributions are contemporaneously realized as pension benefits of the retired.[7]

Some OECD economies, including Sweden, Latvia, and Italy, have introduced so-called "notional defined contribution" pillars to their pension systems. These pillars are Bismarckian in the sense that realized pension benefits are a function of past contributions. The main difference is that contributions are registered in notional accounts and appreciate at a government-determined fictitious interest rate. In the theoretical analysis, I will include a notional interest parameter to illustrate how the implicit taxation of a Bismarckian pension system varies with the foregone compound interest of contributing to the pension system instead of investing in the capital market. In the equilibrium analysis, this rate should be equal to an Aaron–Samuelson return for the pension system to remain solvent at all times. That is, the notional interest rate should be equal to the sum of population growth and output growth per worker. Both population growth and technological growth are equal to zero in this model, and, in the numerical simulations, this parameter will subsequently be zero. As Beveridgean pillars traditionally do not earn notional interest, I assume that this is strictly PAYG also in both the theoretical and numerical analyses.

The benefit $b(t)$ received by individual i at any time $t \in [R, T]$ is the weighted sum of the Bismarckian and the Beveridgean pillars, annuitized over the time spent in retirement:

$$b(t) = \frac{1}{T-R}\left[\kappa B^{E}(R)e^{\gamma(t-R)} + (1-\kappa)B^{C}\right]. \tag{2}$$

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[7] This type of specification encompasses the general contribution-transfer mechanism of many OECD economies (Bovenberg et al., 2012).

In this specification, B^E is the Bismarckian pillar, where γ is the hypothetical notional interest on the fraction of contributions allocated to this pillar. B^C is the Beveridgean pillar. $\kappa \in [0, 1]$ is a policy parameter that governs the relative size of the two pillars, with $\kappa = 1$ implying a completely earnings-based benefit formula, and $\kappa = 0$ a completely redistributive system. κ thereby determines the correlation between individual earnings and pension entitlements.[8]

The redistributive pillar is specified as

$$B^C = \tau w H, \tag{3}$$

where

$$H = \Lambda F_1(S_1)\int_{S_1}^{R_1}(1 - l_1(t))dt + (1 - \Lambda)F_2(S_2)\int_{S_2}^{R_2}(1 - l_2(t))dt$$

and Λ is the population weight of low-ability individuals.

While B^C is treated as exogenous by these individuals, they do, however, rationalize how their labor supply decisions affect their pension benefits through the earnings-based component. The accumulation of individual pension entitlements during their working life satisfies the following differential equation:

$$\dot{B}^E = \frac{dB^E(t)}{dt} = (1 - l(t))wF(S)\tau + \gamma B^E(t). \tag{4}$$

Solving the differential equation, and assuming that the individual begins their working life with zero benefit entitlements (i.e., $B(S) = 0$), I obtain the following expression for the total amount of accumulated benefit entitlements through the Bismarckian pillar at retirement age:

$$B^E(R) = w\tau F(S)e^{\gamma R}\int_S^R (1 - l(t))e^{-\gamma t}dt. \tag{5}$$

Substituting equations (3) and (5) into equation (2) yields the fully specified retirement benefit system:

$$b(t) = \frac{w\tau[\kappa F(S)e^{\gamma t}\int_S^R(1 - l(t))e^{-\gamma t}dt + (1 - \kappa)H]}{T - R}. \tag{6}$$

It is important to note that this structural representation abstracts from non-linear features of the contribution–benefit formula common to real-world

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[8] This is sometimes referred to as the Bismarckian factor (see, e.g., Hassler and Lindbeck, 1997).

systems.[9] While such properties undoubtedly have an influence on the performance of public pension systems, these rules vary substantially between countries.[10]

3.4. The individual's maximization problem

As population size and composition are held constant, we can focus on the economic behavior of one single generation. I consider a stylized model to obtain closed-form expressions for consumption and intensive margin leisure. Following Jacobs (2009), suppose that lifetime utility takes the following additive separable form:

$$V = \int_0^T \frac{c(t)^{1-(1/\sigma)} - 1}{1-(1/\sigma)} e^{-\theta t} dt + \beta \int_S^R \frac{l(t)^{1-(1/\nu)} - 1}{1-(1/\nu)} e^{-\theta t} dt + \eta \frac{[T-R]^{1-(1/\phi)} - 1}{1-(1/\phi)}. \tag{7}$$

Here, β is the weight attached to leisure during one's working life, η is the weight on retirement leisure preferences, and $\{\sigma, \nu, \phi\}$ are elasticity parameters that make utility non-linear in its arguments.[11]

The individual maximizes equation (7) subject to the asset accumulation equation:

$$\dot{k} = \begin{cases} rk(t) - c(t) & \text{for } t \in [0, S), \\ (1 - l(t))wF(S)(1-\tau) + rk(t) - c(t) & \text{for } t \in [S, R), \\ b(t) + rk(t) - c(t) & \text{for } t \in [R, T]. \end{cases} \tag{8}$$

The discrete changes in the state function as specified in equation (8) allow for the specification of the optimal control problem as a multiple-stage control problem.[12]

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[9] These include, among others, benefit penalties or subsidies related to eligibility age and upper or lower boundaries to contributions or realized benefits.

[10] In addition, incorporating such non-linear features of the contribution–benefit formula in an optimal control framework introduces substantial modeling challenges (see, e.g., Wang and Li, 2017). Later, as a sensitivity analysis, I will introduce a minimum retirement age to the numerical analysis.

[11] Note that the retirement good is not explicitly discounted into present value, which is consistent with the model specification in Jacobs (2009). If an explicit discounting term were to be included, it would be difficult to determine which age should be used as a reference for discounting such a good, as it is a function of the years in retirement but not specified as a flow variable. Instead, any discounting is implicit to η.

[12] This is essentially a generalization of a two-stage control problem as outlined in Kamien and Schwartz (2012). A three-stage optimal control problem is also illustrated and solved as a generalized salvage value problem in Gustafsson (2021).

I begin by deriving the optimal dynamics of savings, consumption, and intensive margin leisure behavior conditional on labor market entry and exit. After that, I solve for optimal labor market entry and exit. The optimization problem of maximizing equation (7) subject to equation (8) allows me to define the Hamiltonian functions corresponding to the optimal control problems of each stage of the multiple-stage control problem. I introduce superscript $j = [1, 2, 3]$ to distinguish the different life-cycle phases, where 1 denotes the tertiary education phase $t \in [0, S)$, 2 denotes the working life phase $t \in [S, R)$, and 3 denotes the retirement phase $t \in [R, T]$. These Hamiltonians can be written in present value terms, discounted to time $t = 0$, as follows:

for phase 1,

$$\mathcal{H}^1(t) = \frac{c(t)^{1-(1/\sigma)} - 1}{1 - (1/\sigma)} e^{-\theta t} + \mu^1(t)[rk(t) - c(t)]; \tag{9}$$

for phase 2,

$$\begin{aligned}\mathcal{H}^2(t) = &\left[\frac{c(t)^{1-(1/\sigma)} - 1}{1 - (1/\sigma)} + \beta \frac{l(t)^{1-(1/\nu)} - 1}{1 - (1/\nu)}\right] e^{-\theta t} \\ &+ \mu^2(t)[(1 - l(t))wAS^{\rho}(1 - \tau) + rk(t) - c(t)];\end{aligned} \tag{10}$$

and finally for phase 3,

$$\mathcal{H}^3(t) = \frac{c(t)^{1-(1/\sigma)} - 1}{1 - (1/\sigma)} e^{-\theta t} + \mu^3(t)[b(t) + rk(t) - c(t)]. \tag{11}$$

Note that the utility of retirement leisure does not affect the optimal decisions of consumption, savings, and intensive margin leisure within each phase, and therefore does enter any of the Hamiltonian functions.

The consumer maximization problem specified in this section will be identical to the model presented by Jacobs (2009) if one assumes exogenous pension benefits and abstracts from skill heterogeneity. Jacob's model also includes a non-zero tuition fee.

3.4.1. Optimal saving dynamics. Because the model framework consist of three control horizons, it is convenient to begin by determining the law of motion that governs the optimal savings over the entire life-cycle domain. From equations (9)–(11), it can be seen that

$$\dot{\mu}^j = -\frac{\partial \mathcal{H}^j}{\partial k(t)} = -r\mu^j(t). \tag{12}$$

Solving the differential equation in equation (12) for $j = [1, 2, 3]$, the dynamics of the marginal utility of wealth are defined as

$$\mu(t) = \begin{cases} \mu_0 e^{-rt} & \text{for } \; t \in [0, S), \\ \mu^2(S) e^{-r(t-S)} & \text{for } \; t \in [S, R), \\ \mu^3(R) e^{-r(t-R)} & \text{for } \; t \in [R, T], \end{cases} \tag{13}$$

where μ_0 is an unknown parameter to be solved for. Following the principle for optimality of a multiple-stage control problem, the following transversality conditions ensure continuity of the co-state variable over the entire control domain:

$$\mu^1(S) = \mu^2(S), \tag{14}$$

$$\mu^2(R) = \mu^3(R). \tag{15}$$

The cases described in equation (13) then simplify to the following expression,

$$\mu(t) = \mu_0 e^{-rt}, \tag{16}$$

which is consistent with smoothing the marginal utility of wealth and, in the context of additive separable utility between consumption and leisure, the smoothing of consumption.

3.4.2. Optimal consumption.

As specified in equation (7), the agent makes an intertemporal choice regarding the consumption–savings margin at all times. The condition characterizing the optimal consumption at each instant therefore becomes

$$\frac{\partial \mathcal{H}^j}{\partial c(t)} = \frac{e^{-\theta t}}{c(t)^{(1/\sigma)}} - \mu^j(t) = 0. \tag{17}$$

Substituting the law of motion in equation (16) into equation (17) and solving for consumption, we obtain the following expression:

$$c^*(t) = \left[\frac{e^{(r-\theta)t}}{\mu_0} \right]^{\sigma}. \tag{18}$$

Equation (18) implies that the optimal consumption evolves monotonically over the entire life-cycle domain. If $r > \theta$ ($r < \theta$), consumption increases (decreases) over the life cycle, and if $r = \theta$, it remains constant.

As utility is specified as additively separable between consumption and leisure, any changes to the pension system will not affect optimal consumption behavior directly. Rather, any impact caused by a change in the contribution rate or the degree of redistributiveness is realized indirectly by modifying the marginal utility of wealth through changes in the income stream.

3.4.3. Optimal intensive margin leisure. Conditional on the fact that $\kappa > 0$, the total effect on utility of a small change in leisure time is partially realized contemporaneously through the conventional trade-off between leisure utility and foregone labor income. However, it is also partially realized through the accumulation of pension income via the Bismarckian pillar. The first-order condition must therefore reflect that the leisure choice made at *any* instant $t \in [S, R)$ will affect the annuitized benefits at *every* instant $t \in [R, T]$. This resembles a delayed response problem as described in Kamien and Schwartz (2012), with the difference that the lagged response in this model takes place over a continuum of future time periods as opposed to one future instant in time. The first-order condition ensuring optimality of the intensive margin leisure trajectory then becomes[13]

$$\frac{\partial \mathcal{H}^2(t)}{\partial l(t)} + \int_R^T \frac{\partial \mathcal{H}^3(u)}{\partial l(t)} du = \frac{\beta e^{-\theta t}}{l(t)^{(1/\nu)}} - \mu^2(t) w F(S)(1-\tau) + \int_R^T \mu^3(u) \frac{\partial b_i(u)}{\partial l(t)} du = 0, \tag{19}$$

for $u \in [R, T]$. From equation (19), using the transversality condition in equation (15) and the law of motion as expressed in equation (16), the following explicit solution for the optimal intensive margin leisure is obtained:

$$l^*(t) = \left[\frac{\beta e^{-\theta t}}{\mu_0 w A S^{\rho} [(1-\tau)e^{-rt} + (\kappa \tau e^{-\gamma t} / T - R) \int_R^T e^{(\gamma - r)t} dt]} \right]^{\nu}. \tag{20}$$

Equation (20) shows that the opportunity cost of leisure consists of the contemporaneous loss of earnings and any future loss in terms of foregone pension income. Moreover, the opportunity cost is reduced by the fraction of contributions that is allocated to the Beveridgean pillar $1 - \kappa$, and any foregone compound interest of contributing to the Bismarckian pillar conditional on $\gamma < r$.

Some special cases of equation (20) are of analytical interest regarding the direct effects of changes in the contribution rate. If $\kappa = 0$, the condition for optimal intensive margin leisure collapses to the following expression:

$$l^*(t) = \left[\frac{\beta e^{(r-\theta)t}}{\mu_0 w A S^{\rho} (1-\tau)} \right]^{\nu}. \tag{21}$$

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[13] It is possible to obtain the same condition when using a Lagrangian function instead of the Hamiltonian. These calculations are available upon request.

This implies that the contribution rate becomes a pure implicit labor income tax rate as the returns to contributions are not recognized by the individual following the flat benefit-design of the transfer mechanism. If we instead consider $\kappa > 0$ (i.e., that benefits bear some explicit relationship to contributions) and contributions earn market return, $\gamma = r$, then the expression in equation (20) simplifies to the following expression:

$$l^*(t) = \left[\frac{\beta e^{(r-\theta)t}}{\mu_0 w A S^{\rho}[(1-\tau)+\kappa\tau]}\right]^{\nu}. \tag{22}$$

The expression in equation (22) implies that in an actuarially fair system, the contributions to the earnings-based pillar, $\kappa\tau$, are rationalized as a perfect substitute for private savings. If the system is fully Bismarckian (i.e., $\kappa = 1$), then the contemporaneous decrease in labor income from an increase in the contribution rate is perfectly offset by the increase in pension income. That is, an actuarially fair Bismarckian system does not introduce any direct disincentives for the intensive margin labor supply.

3.4.4. Special case: logarithmic utility. When $\sigma = \nu = 1$ (i.e., the preferences are specified as logarithmic in consumption and intensive margin leisure), it is possible to obtain a closed-form solution for μ_0. Following the calculations outlined in Online Appendix A, μ_0 then takes the following expression:

$$\mu_0 = \left(\int_0^T e^{-\theta t}dt + \beta\int_S^R e^{-\theta t}dt\right)\left[w\left\{F(S)\left[(1-\tau)\int_S^R e^{-rt}dt\right.\right.\right.$$
$$\left.\left.\left. + \frac{\kappa\tau}{T-R}\int_R^T e^{(\gamma-r)t}dt\int_S^R e^{-\gamma t}dt\right] - \frac{(1-\kappa)\tau H}{T-R}\int_R^T e^{-rt}dt\right\}\right]^{-1}. \tag{23}$$

For an actuarially fair pension system (i.e., $\kappa = 1$ and $\gamma = r$), the expression in equation (23) for μ_0 simplifies to

$$\mu_0 = \frac{\int_0^T e^{-\theta t}dt + \beta\int_S^R e^{-\theta t}dt}{wF(S)\int_S^R e^{-rt}dt}. \tag{24}$$

Equation (24) implies that an increase in the contribution rate does not have any direct effect on the marginal utility of wealth, meaning that there is no indirect effect on consumption–savings or the intensive margin labor–leisure trade-off.

3.4.5. Optimal labor market entry and exit. The final step is to determine the optimal timing for labor market entry and exit $\{S^*, R^*\}$. Conditional on this, the consumption/savings and leisure are chosen optimally given any values for $\{S, R\}$, and so equation (7) can be rewritten as

$$\begin{aligned}V = &\int_0^S \left\{\mathcal{H}^1(t, c^*(t), k^*(t), \mu^1(t)) - \mu^1(t)\dot{k}\right\} dt\\ &+ \int_S^R \left\{\mathcal{H}^2(t, S, c^*(t), l^*(t), k^*(t), \mu^2(t)) - \mu^2(t)\dot{k}\right\} dt\\ &+ \int_R^T \left\{\mathcal{H}^3(u, S, R, c^*(u), l^*(t), k^*(u), \mu^3(u)) - \mu^3(u)\dot{k}\right\} du\\ &+ \frac{\eta[T-R]^{1-(1/\phi)}}{1-(1/\phi)}. \end{aligned} \tag{25}$$

Integrating the final term in each curly bracket by parts, and using equations (14) and (15), and the initial and terminal conditions on individual wealth, $k(0) = k(T) = 0$, we obtain the following expression:

$$\begin{aligned}V = &\int_0^S \left\{\mathcal{H}^1(t, c^*(t), k^*(t), \mu^1(t)) - \dot{\mu}^1 k^*(t)\right\} dt\\ &+ \int_S^R \left\{\mathcal{H}^2(t, S, c^*(t), l^*(t), k^*(t), \mu^2(t)) - \dot{\mu}^2 k^*(t)\right\} dt\\ &+ \int_R^T \left\{\mathcal{H}^3(u, S, R, c^*(u), l^*(t), k^*(u), \mu^3(u)) - \dot{\mu}^3 k^*(u)\right\} du\\ &+ \frac{\eta[T-R]^{1-(1/\phi)}}{1-(1/\phi)}. \end{aligned} \tag{26}$$

The first switching point that corresponds to the age of labor market entry, S^*, must satisfy the following first-order condition:

$$\begin{aligned}\frac{\partial V}{\partial S^*} = &-\beta\frac{l(S^*)^{1-(1/\nu)}-1}{1-(1/\nu)}e^{-\theta S^*} - \mu_0 wA\Big[(1-l(S^*))S^{*\rho}(1-\tau)e^{-rS^*}\\ &- \rho S^{*\rho-1}(1-\tau)\int_{S^*}^R (1-l(t))e^{-rt}dt - \frac{\kappa\tau}{T-R}\\ &\times\left(\rho S^{*\rho-1}\int_{S^*}^R (1-l(t))e^{-\gamma t}dt - S^{*\rho}(1-l(S^*))e^{-\gamma S^*}\right)\int_R^T e^{(\gamma-r)t}dt\Big]\\ = &\ 0. \end{aligned} \tag{27}$$

The condition characterized in equation (27) can be interpreted as a modified Mincer condition for optimal human capital formation. In addition to the conventional Mincer trade-off between foregone initial labor income and wage prospects, the individual also accounts for the foregone utility associated with leisure activities when employed. Building on the condition derived in Jacobs (2009), equation (27) also includes the effect of additional time spent in education on pension income via the Bismarckian pillar. On the one hand, the individual forgoes labor income, and therefore pension contributions, for the time spent in education. On the other hand, additional time in education enhances productivity and thus raises labor and pension income prospects. This effect is only realized via the Bismarckian pillar as the individual does not directly account for contributions to the Beveridgean pillar. Assuming an actuarially fair system, $\gamma = r$ and $\kappa = 1$, the first-order condition for optimal education simplifies to

$$\frac{\partial V}{\partial S^*} = -\beta \frac{l(S^*)^{1-(1/\nu)} - 1}{1-(1/\nu)} e^{-\theta S^*} - \mu_0 w A \left[(1 - l(S^*)) S^* \rho e^{-rS^*} - \rho S^{*\rho-1} \int_{S^*}^{R} (1 - l(t)) e^{-rt}\, dt \right] = 0. \tag{28}$$

Equation (28) suggests that the optimality condition that determines labor market entry becomes independent of the contribution rate. We find this result because the actuarially fair system does not induce any leakage from the life-cycle labor income stream following perfect substitutability between saving privately and saving through the pension system. Thus, the returns to life-cycle human capital formation are unchanged.

The second switching point that corresponds to the age of retirement, R^*, must, in turn, satisfy the following first-order condition:

$$\begin{aligned}\frac{\partial V}{\partial R^*} &= \beta \frac{l(R^*)^{1-(1/\nu)} - 1}{1-(1/\nu)} e^{-\theta R^*} - \eta [T - R^*]^{-(1/\phi)} \\ &\quad + \mu_0 \Bigg[(1 - l(R^*)) w A S^\rho (1-\tau) e^{-rR^*} - b(R^*) e^{-rR^*} \\ &\quad + \frac{w\tau}{(T-R^*)^2} \Bigg(\kappa A S^\rho \Bigg((T - R^*)(1 - l(R^*)) e^{-\gamma R^*} \\ &\quad + \int_S^{R^*} (1 - l(t)) e^{-\gamma t}\, dt \Bigg) \int_{R^*}^{T} e^{(\gamma - r)t}\, dt + (1-\kappa) H \int_{R^*}^{T} e^{-rt}\, dt \Bigg) \Bigg] \\ &= 0. \end{aligned} \tag{29}$$

The interpretation of the retirement condition is straightforward. The costs of entering retirement are the explicit loss of earnings, the implicit loss of prospects for pension income, and utility loss of foregone intensive margin leisure. These costs are partially offset by the withdrawal of pension benefits and the utility of retirement leisure. Similar to the condition for optimal education, it is interesting to examine the optimality condition for retirement when one considers the pension system to be actuarially fair. Setting $\gamma = r$ and $\kappa = 1$, equation (29) simplifies to

$$\frac{\partial V}{\partial R^*} = \beta \frac{l(R^*)^{1-(1/\nu)} - 1}{1 - (1/\nu)} e^{-\theta R^*} - \eta [T - R^*]^{-(1/\phi)} + \mu_0 (1 - l(R^*)) w A S^\rho e^{-r R^*} = 0. \tag{30}$$

Analogous to the entry condition, the exit condition becomes neutral to changes in the contribution rate because contributions are effectively realized as pension income plus interest.

As a result, the cost of entering retirement in terms of foregone earnings is not affected by the forced contributions to the pension system. Ultimately, an increase in the contribution rate when the pension system is actuarially fair affects behavior only through the budget constraint. That is, to smooth consumption over the life cycle,[14] the individual compensates for the foregone instantaneous labor income when they are young by borrowing more and saving less throughout their working life.

3.5. General equilibrium

3.5.1. Aggregation. The economic aggregates are, by construction, equal to the weighted average of each corresponding individual quantity. Because population is held constant and identical, these aggregates will be constant. For aggregate capital, labor supply, and consumption, respectively, we have

$$K = \Lambda \int_0^T k_1(t) dt + (1 - \Lambda) \int_0^T k_2(t) dt, \tag{31}$$

$$H = \Lambda F_1(S_1) \int_{S_1}^{R_1} (1 - l_1(t)) dt + (1 - \Lambda) F_2(S_2) \int_{S_2}^{R_2} (1 - l_2(t)) dt, \tag{32}$$

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[14] To clarify, the individual has a preference for smoothing the marginal utility of wealth over the life cycle. Because the utility is specified as additive separable between consumption and leisure, this directly translates to a preference for consumption smoothing.

$$C = \Lambda \int_0^T c_1(t)dt + (1 - \Lambda) \int_0^T c_2(t)dt. \tag{33}$$

The government operates on a balanced budget. Because all payroll tax revenues are allocated to the pension system, which must balance at each instant, government consumption is zero.

The aggregate output function is specified as Cobb–Douglas,

$$Y = K^{\alpha} H^{1-\alpha}, \tag{34}$$

where α is the share of the national income attributable to physical capital.

3.5.2. Steady state.

The economy is in a competitive steady state when both individual types behave according to equations (18), (20), (27), and (29), conditional on factor prices $\{w^*, r^*\}$, which close the labor and capital markets, respectively,

$$w^*(K, H) \equiv \frac{\partial Y}{\partial H} = (1 - \alpha)\left(\frac{K}{H}\right)^{\alpha}, \tag{35}$$

$$r^*(K, H) \equiv \frac{\partial Y}{\partial K} - \delta = \alpha\left(\frac{K}{H}\right)^{\alpha-1} - \delta, \tag{36}$$

where δ is the capital depreciation rate. What is not consumed is invested, which in a steady state equals the depreciated capital:

$$K^{\alpha} H^{1-\alpha} = C + \delta K. \tag{37}$$

Equation (37) implies that the GDP identity is satisfied and the model is closed in general equilibrium.[15]

3.6. Inequality measures

Following Sommacal (2006), I give equal weight to labor and pension income in the inequality measures. The index for earnings inequality (EI) is

$$\mathrm{EI} = \frac{(1 - \Lambda)F_2(S_2)\int_{S_2}^{R^2}(1 - l_2(t))dt}{\Lambda F_1(S_1)\int_{S_1}^{R^1}(1 - l_1(t))dt}, \tag{38}$$

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[15] The numerical procedure to solve for the competitive steady state is explained in Online Appendix B.

and for lifetime inequality (LI) it is

$$\mathrm{LI} = \frac{(1-\Lambda)\left[w(1-\tau)F_2(S_2)\int_{S_2}^{R^2}(1-l_2(t))dt + \int_{R_2}^{T} b_2 dt\right]}{\Lambda\left[w(1-\tau)F_1(S_1)\int_{S_1}^{R^1}(1-l_1(t))dt + \int_{R_1}^{T} b_1 dt\right]}. \tag{39}$$

Given the absence of effective social discounting, these measurements could also be interpreted in terms of intergenerational inequality at any time t. I let human capital inequality be measured by the human capital premium measure.

4. Calibration and numerical analysis

The model is first calibrated in general equilibrium to reproduce some key statistics of an average OECD economy. To isolate the direct effects of pension policy on the life-cycle behavior of each individual, I fix the equilibrium factor prices obtained from the calibration and simulate the different policy scenarios. After documenting these effects on labor supply and savings, I endogenize the factor markets again and simulate different policy scenarios by varying κ.

4.1. Parametrization and calibration targets

I assume that the economic life starts upon completion of secondary education at age 18 (i.e., model age $t = 0$). The average life-length in the OECD is 79 years, which corresponds to model age $T = 61$. I assume that half of the population is of low ability, $\Lambda = 0.5$ (e.g., Golosov et al., 2013; Heer and Rohrbacher, 2021). The effects of changing the population composition are examined in Section 4.4.

The pension contribution rate is set to $\tau = 15.4$ percent, which equals the OECD average rate for public pension schemes in 2017 (OECD, 2017). I set $\kappa = 0.5$, which implies that equal weight is given to the Bismarckian and Beveridgean pillars in the pension benefit formula. Because population and technology growth are both zero by assumption, and the pension scheme should balance at each instant in time in general equilibrium, $\gamma = 0$.

It is important to note that changing a parameter value in general equilibrium can affect many aggregate outcomes simultaneously, making it difficult to discipline a specific parameter based on one particular moment (Conesa et al., 2009). Hereafter, I associate a parameter with the equilibrium object it affects the most quantitatively.

A capital–output ratio within the interval of 2.9 and 3.1 is standard (Gahramanov and Tang, 2013), and will be targeted likewise. By setting $\alpha = 0.34$, which is also standard, the model output is intermediate to this interval. Equally standard is a capital depreciation rate of 7 or 8 percent. I therefore set $\delta = 0.07$.

The target interval for the equilibrium interest rate is wide. Gahramanov and Tang (2013) considers the Feldstein (1995) estimate of pre-tax rate of return on corporate capital investment of 10 percent as an upper limit. Meanwhile, Barro et al. (1995) targets 6 percent, and Caliendo and Findley (2020) targets 2 percent. This paper targets an interest rate closer to 4 percent, which is similar to Wallenius (2013).[16]

In a similar vein to Caliendo and Findley (2020), I discipline ρ_1 and ρ_2 such that the model reproduces an average time spent in tertiary education close to 2.5 years, which is consistent with OECD data. While there exist several combinations of ρ_1 and ρ_2 that can reproduce this target, I set $\rho_1 = 0.0185$ and $\rho_2 = 0.085$. I argue that these values also deliver reasonable individual educational lengths. The equilibrium length for the high-skilled individuals is equal to 4.1, which is approximately a one-year Master's degree, while it equals 0.9 for the low-skilled individuals.[17]

Next, I normalize $A_1 = 1$ and then set $A_2 = 1.5$ such that the human capital (wage) premium, $F_2(S_2)/F_1(S_1)$, after completed tertiary education is close to 1.7. This value is consistent with, for example, Acemoglu (2002), Sommacal (2006), and Hachon (2010).

I set $\sigma = 1$ such that the intertemporal elasticity of substitution in consumption is equal to unity. This is reasonable given the empirical evidence as reviewed by Thimme (2017), and also a standard in real business-cycle models as it is consistent with balanced growth. As discussed by Jacobs (2009), a value of σ below unity results in backwards-bending labor supply curves.

In the benchmark simulation, I also set $\nu = 1$, which is consistent with the empirical evidence as reviewed by Blundell and MaCurdy (1999). For lower values of ν, the willingness to substitute labor supply over the course of the life cycle is lower. Relative to the calibrated profile, the labor supply profile then becomes flatter. This, in turn, increases the cost of retirement as the individual chooses to work more hours later in life, which results in retirement being postponed. Ultimately, the individual's labor supply responds less to

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[16] As consumption has been found to be essentially constant across the life cycle, once family size is controlled for (Browning and Ejrnæs, 2009), it is natural in the context of single individuals to aim for a net of interest rate and discount rate close to 0.

[17] These values are lower compared with Caliendo and Gahramanov (2013), who set $\rho_1 = 0.08$ and $\rho_2 = 0.3$. It should, however, be noted that they assume that 20 percent of the population live hand-to-mouth and do not receive any education. Therefore, educational attainment needs to be higher among rational individuals to generate an average of 2.5 years in tertiary education. Note, too, that their model abstracts from endogenous retirement and intensive margin labor supply, which could imply non-trivial feedback effects of modifying parameters of the human capital production function. Jacobs (2009) assumes that $\rho = 0.55$ for a representative individual. Because he models the economic life cycle as starting at age 6, his analysis requires a substantially higher value for ρ to generate a reasonable length of time spent in education. He then assumes a non-zero monetary cost of education, which increases its cost.

changes in the contribution rate and entitled pension benefits. The effects of changing ν are presented in Section 4.4.

Following Duval (2004), Jacobs (2009), and Gruber and Wise (2019), I set $\phi = 0.99$. The retirement elasticity predominantly has important effects for the timing of retirement, but also indirectly influences the timing of labor market entry. Lower values of ϕ are associated with later retirement and labor market entry dates.

Lastly, the average hours of work per week and retirement age in the OECD are 37 and 63.5 ($R = 44.5$), respectively. I assume that the time endowment corresponds to 16 waking hours per day and five days per week to allocate between labor supply and leisure activities during individuals' working lives. This corresponds to an average leisure intensity of 0.54. These targets tightly restrict β and η. By setting $\beta = 1.3$ and $\eta = 0.05$, the intensive margin and average retirement age targets are considered to be met. Table 1 provides an overview of the parametrization, while Table 2 compares the targeted and calibrated equilibrium objects.

4.2. Partial equilibrium analysis

As shown in Section 3, no labor supply distortions are caused by increasing the contribution rate to an actuarially fair pension scheme, which means the labor supply profiles for both individual types will be identical to a scenario without a pension system. As such, all inequality measures will be independent of the

Table 1. Parametrization for calibration

Parameter	Value	Source
Time horizon	$T = 61$	Lifespan concern ages 18–79
Low ability share of population	$\Lambda = 0.5$	Golosov et al. (2013)
Subjective discount rate	$\theta = 0.035$	Caliendo and Gahramanov (2013)
Intertemporal elasticity consumption	$\sigma = 1$	Chetty (2006)
Intertemporal elasticity leisure	$\nu = 1$	Blundell and MaCurdy (1999)
Leisure preference	$\beta = 1.3$	Average working hours per week = 37
Retirement preference	$\eta = 0.05$	Average retirement age = 63.5
Retirement elasticity	$\phi = 0.99$	Gruber and Wise (2019)
Contribution rate	$\tau = 0.154$	OECD data
Bismarckian factor	$\kappa = 0.5$	Equal weight to pillars
Capital share of output	$\alpha = 0.34$	Caliendo and Findley (2020)
Capital depreciation rate	$\delta = 0.07$	Caliendo and Findley (2020)
Human capital productivity ($i = 1$)	$A_1 = 1$	Normalized
Human capital productivity ($i = 2$)	$A_2 = 1.5$	Human capital premium = 1.7
Human capital elasticity ($i = 1$)	$\rho_1 = 0.0185$	Average tertiary education = 2.5
Human capital elasticity ($i = 2$)	$\rho_2 = 0.085$	–

Table 2. Equilibrium objects for calibration

Object	Target	Calibrated	Source
Interest rate	4%	4.47%	Wallenius (2013)
Capital–output ratio	2.9–3.1	2.96	Gourinchas and Parker (2002)
Average tertiary education	2.5	2.51	OECD data
Average retirement	63.5	63.38	OECD data
Average leisure intensity	0.54	0.55	OECD data
Human capital premium	1.7	1.69	Acemoglu (2002)

size of the contribution rate. Therefore, the focus of the numerical simulations will instead be to compare the outcomes of the calibrated scenario $\kappa = 0.5$ to a purely Beveridgean system $\kappa = 0$ and a purely Bismarckian system $\kappa = 1$ for $\gamma = 0$ such that the difference in actuarial fairness between the schemes is entirely defined in terms of κ. These scenarios, in turn, encompass the qualitative insights related to any intermediate value of κ. The individual labor supply and private savings profiles under the different pension scenarios in partial equilibrium are illustrated in Figure 1. The inequality measures, meanwhile, are illustrated in Figure 2.

4.2.1. Labor supply and savings. I begin by comparing the effects of an increase in the contribution rate on individuals' life-cycle labor supply behavior for the three public pension scenarios. I compare the profiles of the model calibrated to $\tau = 0.154$ with a scenario that has self-financing agents $\tau = 0$. Some general results are worth mentioning. Because the equilibrium interest rate is higher than the utility discount rate, optimal labor supply decreases over the life cycle (equations (20)–(22)). On aggregate, this can be interpreted as decreasing labor market participation over the life cycle.[18]

For the Bismarckian scenario, returns to contributions will fall short of the risk-free returns on the capital market. This opportunity cost is larger for younger workers, following a compound interest effect. As such, the implicit tax treatment of a return-dominated Bismarckian system is asymmetric over the life cycle. Furthermore, there is a higher implicit marginal tax on younger workers relative to older workers. This mechanism explains why an increase in the contribution rate increases optimal labor supply intensity among older individuals. The magnitude of the asymmetric tax treatment is, in turn, determined by the difference between the notional and market

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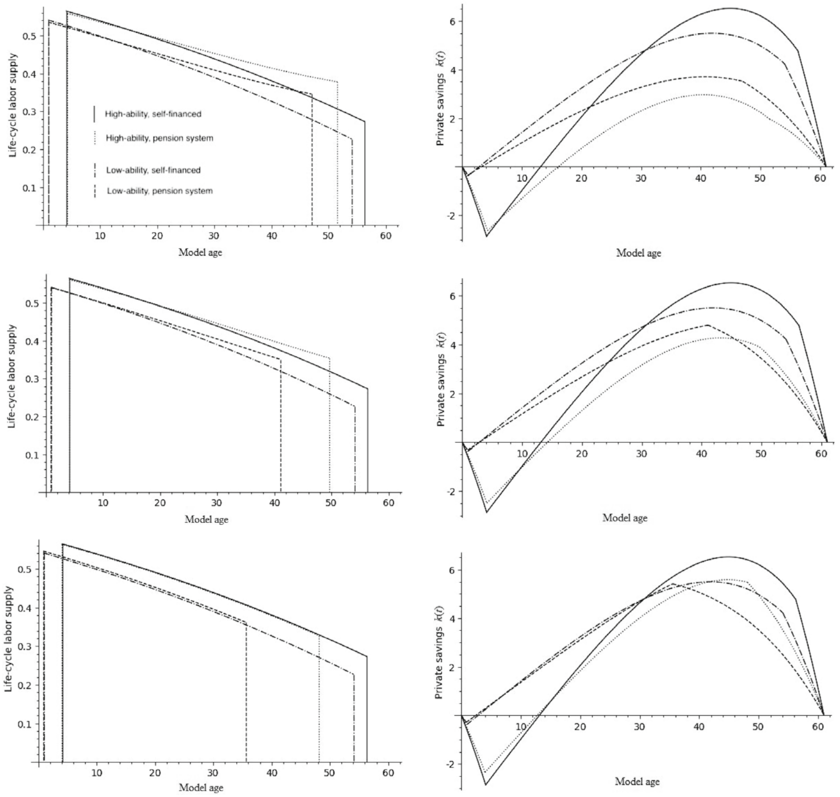
[18] This is partially consistent with OECD data, as the age-participation profile is generally found to increase until age 25–29, to remain stable until age 50–54, and then to decline (OECD, 2021).

Figure 1. Partial equilibrium life-cycle effects: top panels, pure Bismarckian $\kappa = 1$; middle panels, 50/50 Bismarckian and Beveridgean $\kappa = 0.5$; bottom panels, pure Beveridgean $\kappa = 0$

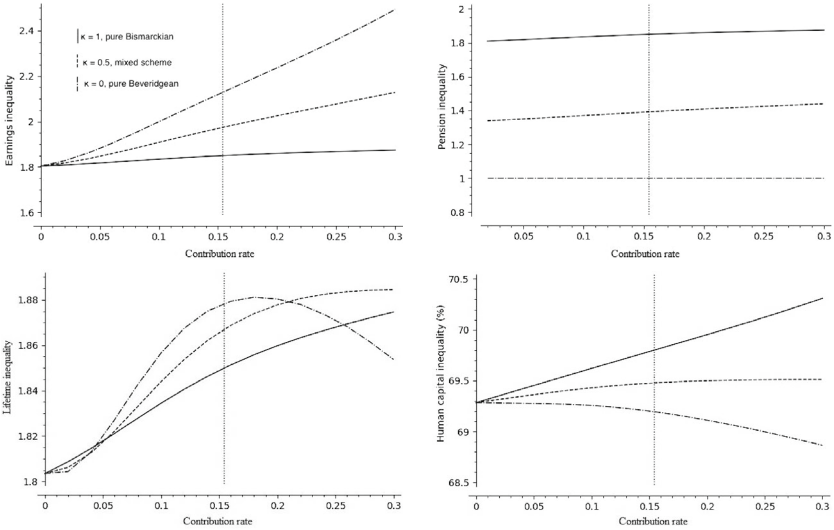


Notes: See the top-left panel for the key to the plotted lines. The OECD average contribution rate is $\tau = 0.154$.

interest rate, as expressed in equation (20). This corresponds to the findings of Kindermann (2015), who found that an earnings-based pension system makes work relatively less attractive early in life. The larger the difference, the greater the implicit tax imposed on younger individuals because of the foregone compound interest.

Regarding entry and exit responses, participation in the actuarially unfair Bismarckian system introduces two effects. Retirement becomes cheaper as the net payoff to labor supply decreases. As a result, both types of individuals retire earlier than in the benchmark. The decision to retire earlier, in turn, shortens the horizon over which returns to human capital accrue. Hence, this serves as a disincentive for acquiring more education. However, this effect is found to be dominated by the reduced opportunity cost of education, which

Figure 2. Partial equilibrium inequality effects



Notes: See the top-left panel for the key to the plotted lines. The vertical dashed lines mark the OECD average contribution rate $\tau = 0.154$.

is expressed in terms of foregone earnings as the contribution rate increases. The net effect is that both types of individuals spend more time in education, which challenges the result of Caliendo and Findley (2020) that an increase in the contribution rate leads to lower educational attainment in the economy for both Beveridgean and Bismarckian specifications of the public pension system. The results in Kindermann (2015), which indicate that an actuarially unfair NDC pension system promotes more time being spent in education, are thus robust to the inclusion of endogenous retirement. However, the implicit education subsidy imposed by the foregone compound interest is found to be partially offset by the compound returns to human capital following an earlier retirement.

As individual-specific benefits are not linked to their contributions under a Beveridgean system, the contribution rate perfectly mimics a labor income tax (equation (21)). As such, contributions are not recognized as an alternative savings technology, implying that the implicit tax treatment is symmetric over the life cycle. As preferences are specified in logarithmic terms, the income and substitution effect perfectly offset each other such that the contribution rate has no direct effect on the intensive margin labor supply. However, individuals face a modification of the active–retired trade-off through the taxation of earnings and changes in replacement income. First, as the contribution rate imposes a tax only on earnings and does not directly affect retirement utility, an increase in the contribution rate lowers the cost of retiring. Second, as a result of a redistributive benefit formula, low-skilled individuals will experience an increase in replacement income. This further lowers the cost of retirement as low-skilled households can achieve a sufficient retirement buffer with less labor supplied. The opposite effect applies to high-skilled individuals, who will face a lower replacement income relative to that under a Bismarckian system. The labor supply of low-skilled individuals drops disproportionally more than the labor supply of high-skilled individuals. Ultimately, this finding is consistent with the findings produced by Sommacal (2006) that a redistributive pension system increases earnings inequality through an increased dispersion in labor supply. Because individuals decrease their total labor supply, the pension system also implicitly introduces a disincentive for human capital formation, and this crowds out human capital in the economy, as both high- and low-skilled individuals decide to enter the labor market earlier.

A study of savings behavior provides an insight into the different crowding-out effects induced by the forced savings mechanism of the Bismarckian system and the tax-transfer mechanism of the Beveridgean system. In general, both types of individuals accumulate debt during their time in tertiary education in order to finance consumption in the absence of labor income. As the high-income individuals spend more years in school, their debt will be higher. Being forced to contribute to the pension system will tighten the budget constraint for the allocation between consumption and private savings. The closer the link between contributions and private savings, the larger the crowding-out effect will be. The individuals do not rationalize the Beveridgean scheme as a less beneficial savings mechanism, but rather as a leakage from the labor payoff stream. Therefore, the Beveridgean scheme does not crowd out as much private savings as the Bismarckian system. In addition, as less time is spent in education in the Beveridgean scenarios, the individuals involved do not accumulate as much private debt and therefore return to solvency earlier in their lifetime. Finally, as individuals retire earlier, they also reach a peak in private savings earlier in their lifetime from which they dis-save to finance retirement consumption.

4.2.2. Inequality. The effects of increasing the contribution rate on the different inequality measures, conditional on pension design, are illustrated in Figure 2.

Because a Beveridgean scheme introduces stronger incentives for low-skilled individuals to retire earlier, the scheme promotes a larger difference in labor market participation compared with any other scheme where $\kappa > 0$. It is clear from Figure 2 that the Beveridgean scheme, for any $\tau > 0$, will generate the highest earnings inequality. A higher τ generates a higher earnings inequality.

For very low contribution rates ($\tau \lessapprox 5$ percent), the reduced pension inequality of the Beveridgean scheme dominates the increase in earnings inequality. However, when τ goes beyond 5 percent, the increased earnings inequality begins to dominate and lifetime inequality increases. Then, as the contribution rate continues to increase, labor market participation among both types of individuals will continue to decrease. As such, earnings will constitute a smaller share of life-cycle income for both individual types. When the scheme becomes extensive enough ($\tau \gtrapprox 18$ percent), the reduced pension inequality begins to dominate again, and lifetime inequality begins to decrease. However, for any $\tau \in [5\%, 25\%]$, the Bismarckian scheme results in lower lifetime inequality. This implies that, for the average OECD contribution rate of $\tau = 15.4$ percent, a reform from the combined Bismarckian–Beveridgean to a pure Bismarckian scheme would in fact reduce lifetime inequality, while a reform towards a pure Beveridgean scheme would increase lifetime inequality. Perhaps most interesting to note is that the lowest inequality is achieved by the scenario with self-financing agents. As such, a goal of lifetime income equality fails to rationalize the need for a public pension system in this model framework.

As previously discussed, the Bismarckian and Beveridgean systems have opposite total effects on human capital formation in partial equilibrium. Both systems impose a disincentive for human capital formation by promoting early retirement, conditional on the fact that $\gamma < r$. For the actuarially unfair Bismarckian system, labor supply becomes more lucrative when a person is old because the opportunity cost of foregone investment opportunities grows smaller over the course of the life cycle. As a result, it becomes more costly – in terms of foregone earnings – to retire earlier for both sets of individuals. Given the wage premium of the high-skilled, the decrease in retirement age is smaller than that of the low-skilled, which implies that the disincentives for human capital formation following an increase in the contribution rate are larger for low-skilled individuals. Because the Bismarckian system also lowers the opportunity cost of foregone labor earnings when individuals are young, an opposite effect arises following the conventional Mincer trade-off. This effect ultimately promotes more time being invested in education, and is found to dominate the disincentives induced by lower lifetime returns to human capital. The total effect is that high-skilled individuals increase their educational attainment more than low-skilled individuals.

While the implicit labor income taxation of the Beveridgean system reduces the opportunity cost of education in terms of foregone labor income, this effect is dominated by the reduced lifetime financial returns to human capital. As the human capital production function is a concave function of the duration of education, and $\rho_2 > \rho_1$, a proportional reduction in the educational attainment of both types of individuals will reduce human capital inequality. When comparing the different pension systems, the Beveridgean

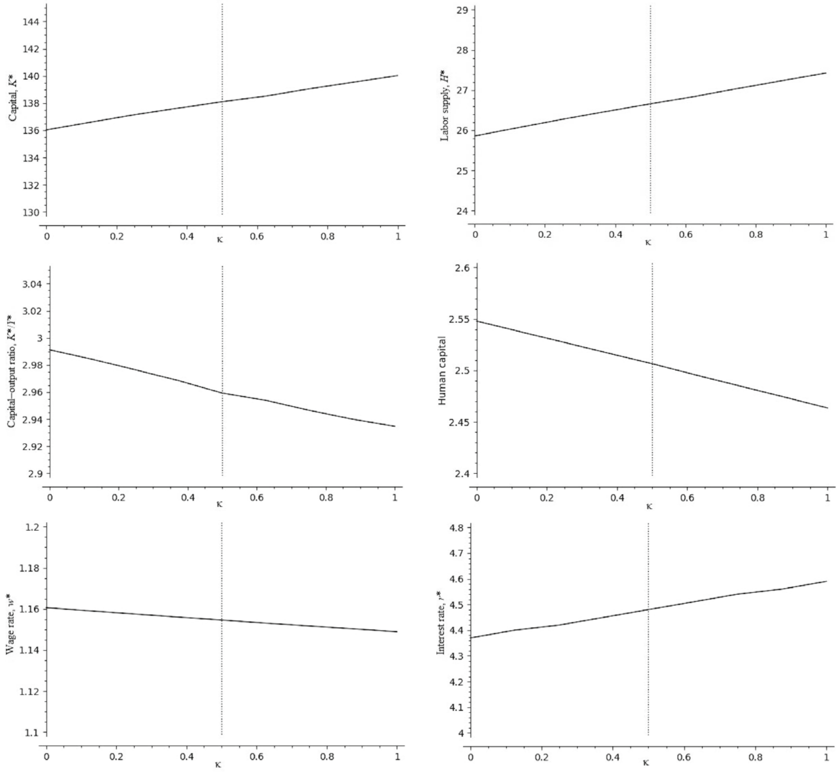
(Bismarckian) system ultimately reduces (increases) human capital inequality. As is evident from Figure 2, however, the change in human capital inequality following an increase in the contribution rate is small, irrespective of the design of the pension system.

The main takeaway from these simulations is that the Beveridgean scheme delivers a higher lifetime inequality compared with the Bismarckian scheme for the OECD average contribution rate of 15.4 percent. This suggests that a reform towards a Bismarckian scheme will promote lower lifetime inequality. The next stage is to determine whether this result is robust when factor prices are allowed to vary with the different policy scenarios.

4.3. General equilibrium analysis

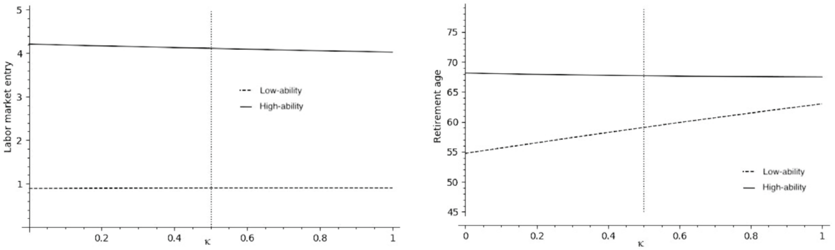
Figure 3 illustrates the effects of changing κ on the economic aggregates relative to the calibrated benchmark scenario in which $\kappa = 0.5$. Figure 4

Figure 3. General equilibrium aggregate effects



Notes: Vertical dashed lines illustrate the calibrated scenario.

Figure 4. General equilibrium effects on extensive margin decisions



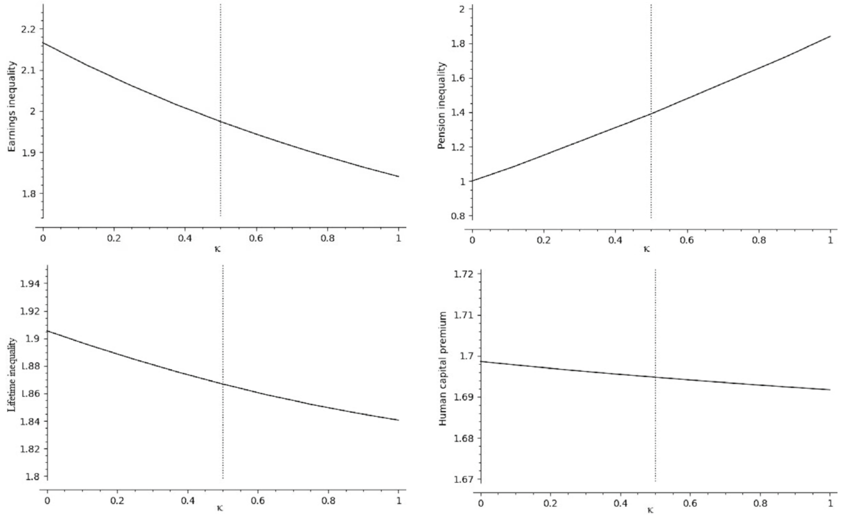
Notes: Vertical dashed lines illustrate the calibrated scenario.

illustrates how the labor market entry and exit ages change for the different individual types.

Moving towards a Beveridgean scheme is shown to reduce labor supply and physical capital in the economy, which leads to a reduction in output. Contrary to, for example, Sommacal (2006), who shows that such a reform leads to a proportional decrease in the input factors, this analysis suggests that labor supply decreases disproportionately more than capital. As a result, the capital–labor and capital–output ratios increase. In a steady state, the interest rate decreases while the wage rate increases, but the opposite holds true for a reform towards a Bismarckian pension scheme.

In the partial equilibrium scenario, it was shown that the Bismarckian scheme, given fixed factor prices, crowds out more capital relative to the Beveridgean scheme. Because this leads to an increased interest rate in general equilibrium, there will be a positive effect on capital accumulation. As previously discussed, an increase in the interest rate has two primary effects on labor supply behavior in this framework. First, an increase in the interest rate promotes an early retirement. However, this effect is found to not be sufficiently large to offset the incentives for a delayed retirement induced by increasing the earnings dependence of benefits, at least not for the low-skilled. From Figure 4, it can be seen that the retirement age of the high-ability type is essentially unchanged, while the retirement age of the low-skilled individual type decreases with κ. For the high-skilled individual type, the increased interest rate and the lower implicit tax on earnings offsets the effects of a higher replacement income such that any change in retirement age is negligible. Second, an increase in the interest rate reduces the financial prospects of skill formation. As such, the incentives for tertiary education are weakened. Interestingly, the simulations suggest that this effect dominates the incentives for human capital formation arising from a delayed retirement when increasing κ. This is likely explained by the discounting of the incremental earnings. From Figure 4, it can be seen that any change in the optimal labor market entry age is barely visible for the high-skilled individual type

Figure 5. General equilibrium inequality effects



Notes: Vertical dashed lines illustrate the calibrated scenario.

only, while it remains unchanged for the low-skilled type. Ultimately, this result challenges the findings in Kindermann (2015), as it suggests that a Beveridgean scheme can lead to a higher average educational attainment in the economy when compared with a scenario with a Bismarckian scheme of the same size.

Figure 5 illustrates how the change in κ affects the inequality measures. A stand-out result is that a reform towards a Bismarckian scheme now reduces the human capital premium in the economy. This follows from the dominating interest rate effect on the decision to enroll in tertiary education. While the Bismarckian scheme lowers the opportunity cost of delaying labor market entry, the disincentives introduced by the increase in the interest rate are found to dominate this effect for high-income individuals. As a result, the Bismarckian system reduces human capital inequality in general equilibrium. The results of a reform with regards to earnings, pension, and lifetime inequality are qualitatively the same as for the partial equilibrium analysis.

Thus far, I have shown that a Bismarckian pension system can achieve lower income inequality and lower labor supply distortions relative to a Beveridgean pension system. However, whether one pension system is preferable over another does not only reflect performances in terms of aggregate labor supply and overall economic inequality. If the purpose of the pension system is to improve the economic welfare according to some reasonable metric, the question of optimal pension design remains an open, non-trivial, quantitative question. Presumably, the low-skilled individuals will favor a pension system that grants them more resources. If the utility of the low-skilled is paramount, then any issue of income inequality might be secondary, or even non-important, to the policymaker. Therefore, I conclude the main analysis of the paper by performing a welfare analysis.

Following Caliendo and Findley (2020), let welfare be computed by

$$\mathbb{W}(\kappa, \tau) = \Gamma_1 \Lambda \mathbb{V}_1 + \Gamma_2 (1 - \Lambda) \mathbb{V}_2, \tag{40}$$

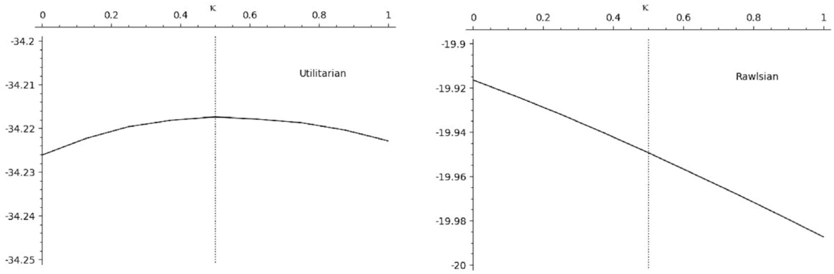
where

$$\mathbb{V}_i = \max_{\{c(t), l(t), S, R\}} V_i \ \text{ s.t. equation (8),} \tag{41}$$

and Γ_1 and Γ_2 are welfare weights attached to the life-cycle utility of low- and high-skilled individuals, respectively. I focus on two special cases of equation (40). The first case is where $\Gamma_1 = \Gamma_2 = 1$, implying that the welfare function is utilitarian, and attributes the same weight to the different individual types. The second case is obtained by setting $\Gamma_2 = 0$, such that the welfare function is Rawlsian. The welfare effects of reforming κ are presented in Figure 6.

For a utilitarian welfare criterion, a mixed pension system ($\kappa = 0.5$) is optimal for the given contribution rate of 15.4 percent. If using the Rawlsian criterion instead, which only concerns the welfare of those worst off, a fully Beveridgean pension system ($\kappa = 0$) is optimal. To summarize, a Bismarckian scheme is shown to outperform a Beveridgean scheme in terms of output, labor supply, and equity, and to lead to a larger aggregate physical capital stock but a smaller aggregate human capital stock. Aggregate utility is maximized for a pension system where equal weights are attributed to the different pillars. For a Rawlsian welfare criterion, the pure Beveridgean system is preferable.

Figure 6. General equilibrium welfare effects



Notes: Vertical dashed lines illustrate the calibrated scenario.

4.4. Sensitivity

The key mechanism that explains how the Beveridgean pension system can generate higher lifetime income inequality than a Bismarckian scheme refers to responses on the retirement margin to changes in the contribution–benefit formula. This, in turn, rests on the assumption of retirement flexibility, which so far has been assumed to be unconstrained. One reason for this assumption is that it keeps the model sufficiently general to be consistent with the wide array of retirement ages observed among the OECD economies. For example, the normal retirement age in the OECD at the time of writing covers a wide span of 51 in Turkey up to 67 in Norway. Imposing institutional features of one specific pension system, such as a particular eligibility age, might restrict the model from being able to reproduce this span. Another reason is modeling convenience. Vertical constraints on free-switching time optimal control problems are not trivial to integrate in the theoretical model in a tractable fashion. Despite these arguments, both the qualitative and quantitative results are presumably sensitive to the assumption of retirement age flexibility. Therefore, as a numerical sensitivity analysis, I introduce a minimum retirement age to the model. This exercise is described in detail in Online Appendix C.1.

The main takeaway is that when the minimum retirement age binds for the low-ability type, reducing κ succeeds in lowering lifetime inequality. If the minimum age is set to 59, which is intermediate to the eligibility rules in the OECD which spans from [55, 63], the equity–efficiency trade-off holds for pension reform within the span of $\kappa \in [0, 0.5)$. This is not a surprising result as the minimum retirement age prevents an increased difference in life-cycle labor supply between the high- and low-skilled, which would generate an increased earnings inequality. Nevertheless, the equity–efficiency trade-off still collapses whenever $\kappa \in (0.5, 1]$, which implies that there are both efficiency and equity gains when increasing the earnings dependence of pension benefits compared with the benchmark case. If the minimum retirement age is set to a higher age, then the span of κ for which the main results hold shrinks.

Another assumption that can have important implications for the redistributive outcomes concerns the proportion of low- and high-ability types. Thus far, I have assumed that the population is split evenly in half between the two skill groups. As a second sensitivity analysis, I recalibrate the model under two alternative assumptions on population structure: one where the high-ability individuals make up 40 percent of the population, and a second where they make up 60 percent. This exercise is also presented in detail in Online Appendix C.2. The qualitative results are found to be robust to these variations in population structure.

As a third and final sensitivity analysis, I recalibrate the model for different values of the intertemporal elasticity of leisure. I use the interval of $\nu \in [0.5, 1]$, which follows from the review of Blundell and MaCurdy (1999) as a reference for this exercise. The results are presented in Online Appendix C.3.

For $\nu = 0.9$ and $\nu = 0.8$, the latter being used in Auerbach and Kotlikoff (1987), the qualitative results of the main analysis remain. For $\nu = 0.7$, any pension reform away from the benchmark has essentially zero effect on lifetime inequality. While the lowest lifetime inequality is seemingly achieved when $\kappa = 0.375$, this requires that a distinction based on the fourth decimal is made when comparing the inequality measures. For $\nu = 0.6$ and $\nu = 0.5$, the Beveridgean pension system successfully achieves redistribution of lifetime income, although increased earnings inequality still offsets a large part of the redistributive effect through equal pension benefits. If instead increasing ν above unity, the results found in the main analysis that a Beveridgean scheme increases lifetime inequality are further supported.

5. Concluding remarks

This paper studies the implications of the design of public pension systems for labor supply behavior and redistribution in a continuous-time OLG model. The model includes the entry and exit and the intensive margin of labor supply to capture a rich set of adjustable margins for the individual. The microfoundations follow Jacobs (2009), who integrates human capital formation, labor supply, and retirement in a coherent framework. This paper augments Jacobs' framework in two ways. It uses heterogeneous agents in terms of earnings ability, and it endogenizes retirement benefits by using a stylized combined earnings-based/redistributive pension system, which is at best actuarially fair. The model is then solved as a multi-stage, delayed-response optimal control problem to account for the inclusion of schooling, working life, retirement, and the link between labor supply and realized pension benefits. This novel approach provides an analytically coherent framework for studying pension policies. The model is analyzed in both partial and general equilibrium.

The results suggest that scenarios with a redistributive pension system display higher earnings inequality than scenarios with earnings-based pension systems. If the increase in earnings inequality is sufficiently comprehensive, a redistributive pension system may in fact increase lifetime inequality. Therefore, the reform of public pensions from flat-benefit accounts to earnings-based individual accounts might not harm economic equality. A return-dominated NDC system introduces an asymmetric tax treatment of labor supply over the course of the life cycle following a compound interest effect. The opportunity cost of foregone investment returns – given the forced savings mechanism of pension contributions – shrinks as the individual approaches retirement. This, in turn, lowers the opportunity cost of education when the individual is young, and it promotes a delayed entry into the labor market following more time spent in tertiary education.

There are numerous avenues for future research. It is important to acknowledge the limits of a stylized representation of public pensions when drawing policy conclusions. Instead of focusing on the precise institutional features of any one pension system, this paper aims to illustrate the incentives implicit in a common feature of modern public pension systems. Naturally, by abstracting from various non-linearities in the contribution–benefit formula and specific eligibility rules, the implicit taxation induced by the contribution rate is simplified. Therefore, it is important to conduct further research in more precise institutional contexts to draw more extensive conclusions regarding the redistributive impact of the structure of particular public pension systems. I do account for a hypothetical minimum pension age as part of a sensitivity analysis, for which the main results of the general equilibrium analysis are robust. However, this only scratches the surface of institutional features, which presumably play a major role in the performance of public pension systems.

Regarding behavioral assumptions, this paper considers rational individuals who perfectly foresee future events and fully comprehend how their behavior interacts with features of the pension system. A consideration for future studies is to integrate various forms of behavioral failures such as time-inconsistency and bounded rationality. Another option would be to consider an age-dependent discount factor to capture an increasing awareness of realized pension wealth as the individuals grow older. As concluded by De Nardi and Fella (2017), the perception of replacement effects can also vary with wealth. If individuals are wealthy enough, incentives implicit in the pension system might not be large enough to influence labor supply behavior over the life cycle.

Last, the normative issue of public pension design and taxation does not boil down to one equity–efficiency trade-off. In a welfare analysis, I find that a fully Beveridgean pension system is preferred if the welfare measure is Rawlsian. If the measure is utilitarian, though, welfare is maximized for a pension system where a Bismarckian pillar and a Beveridgean pillar are given equal weights in the benefit formula. However, the question of according to which merits public pension systems should be evaluated is an open one. For example, should the consumption or income of the retired be given more, or perhaps exclusive, weights in an ideal welfare criterion for public pensions? Should welfare measure utility or income, as its historical purpose has been to alleviate old-age poverty? These questions are indeed intriguing for future research.

Supporting information

Additional supporting information can be found online in the supporting information section at the end of the article.

Online appendix
Replication files

References

Acemoglu, D. (2002), Technical change, inequality, and the labor market, *Journal of Economic Literature 40*, 7–72.

Auerbach, A. J. and Kotlikoff, L. J. (1987), *Dynamic Fiscal Policy*, Cambridge University Press, Cambridge.

Barro, R. J., Mankiw, N. G., and Sala-i-Martin, X. (1995), Capital mobility in neoclassical models of growth, *American Economic Review 85* (1), 103–115.

Beckmann, K. (2000), A note on the tax rate implicit in contributions to pay-as-you-go public pension systems, *Finanzarchiv/Public Finance Analysis 57*, 63–76.

Blundell, R. and MaCurdy, T. (1999), Labor supply: a review of alternative approaches, in O. C. Ashenfelter and D. Card (eds), *Handbook of Labor Economics*, Vol. 3, Chapter 27, North-Holland, Amsterdam, 1559–1695.

Bovenberg, L., Van Ewijk, C., and Westerhout, E. (2012) *The Future of Multi-Pillar Pensions*, Cambridge University Press, Cambridge.

Browning, E. K. (1975), Labor supply distortions of social security, *Southern Economic Journal 42*, 243–252.

Browning, M. and Ejrnæs, M. (2009), Consumption and children, *Review of Economics and Statistics 91*, 93–111.

Buyse, T., Heylen, F., and Van de Kerckhove, R. (2017), Pension reform in an OLG model with heterogeneous abilities, *Journal of Pension Economics & Finance 16*, 144–172.

Caliendo, F. N. and Findley, T. S. (2020), Myopia, education, and social security, *International Tax and Public Finance 27*, 694–720 .

Caliendo, F. N. and Gahramanov, E. (2013), Myopia and pensions in general equilibrium, *Journal of Economics and Finance 37*, 375–401.

Casamatta, G., Cremer, H., and Pestieau, P. (2000), The political economy of social security, *Scandinavian Journal of Economics 102*, 503–522.

Chetty, R. (2006), A new method of estimating risk aversion, *American Economic Review 96* (5), 1821–1834.

Cigno, A. (2008), Is there a social security tax wedge?, *Labour Economics 15*, 68–77.

Conesa, J. C., Kitao, S., and Krueger, D. (2009), Taxing capital? Not a bad idea after all!, *American Economic Review 99* (1), 25–48.

Cremer, H. and Pestieau, P. (2003), Social insurance competition between Bismarck and Beveridge, *Journal of Urban Economics 54*, 181–196.

De Nardi, M. and Fella, G. (2017), Saving and wealth inequality, *Review of Economic Dynamics 26*, 280–300.

Docquier, F. and Paddison, O. (2003), Social security benefit rules, growth and inequality, *Journal of Macroeconomics 25*, 47–71.

Duval, R. (2004), Retirement behaviour in OECD countries: impact of old-age pension schemes and other social transfer programmes, *OECD Economic Studies 2003*, 7–50.

Feldstein, M. (1974), Social security, induced retirement, and aggregate capital accumulation, *Journal of Political Economy 82*, 905–926.

Feldstein, M. (1995), The effects of tax-based saving incentives on government revenue and national saving, *Quarterly Journal of Economics 110*, 475–494.

Fenge, R. and Werding, M. (2004), Ageing and the tax implied in public pension schemes: simulations for selected OECD countries, *Fiscal Studies 25*, 159–200.

Frassi, B., Gnecco, G., Pammolli, F., and Wen, X. (2019), Intragenerational redistribution in a funded pension system, *Journal of Pension Economics & Finance 18*, 271–303.

French, E. and Jones, J. (2012), Public pensions and labor supply over the life cycle, *International Tax and Public Finance 19*, 268–287.

Gahramanov, E. and Tang, X. (2013), Should we refinance unfunded social security?, *Economica 80*, 532–565.

Goda, G. S., Shoven, J. B., and Slavov, S. N. (2011), Implicit taxes on work from social security and Medicare, *Tax Policy and the Economy 25*, 69–88.

Golosov, M., Troshkin, M., Tsyvinski, A., and Weinzierl, M. (2013), Preference heterogeneity and optimal capital income taxation, *Journal of Public Economics 97*, 160–175.

Gourinchas, P.-O. and Parker, J. A. (2002), Consumption over the life cycle, *Econometrica 70*, 47–89.

Gruber, J. and Wise, D. (1999), Social security, retirement incentives, and retirement behavior: an international perspective, *EBRI Issue Brief 209*, 22.

Gruber, J. and Wise, D. A. (2019), *Social Security and Retirement around the World*, University of Chicago Press, Chicago, IL.

Gustafsson, J. (2021), Age-targeted income taxation, labor supply, and retirement, *CESifo Working Paper 8988*.

Hachon, C. (2008), *Do redistributive pension systems increase inequalities and welfare?*, Working paper, https://shs.hal.science/halshs-00285040.

Hachon, C. (2010), Do Beveridgian pension systems increase growth?, *Journal of Population Economics 23*, 825–831.

Hassler, J. and Lindbeck, A. (1997), Optimal actuarial fairness in pension systems: a note, *Economics Letters 55*, 251–255.

Heer, B. and Rohrbacher, S. (2021), Endogenous longevity and optimal tax progressivity, *Journal of Health Economics 79*, 102515.

Ignacio Conde-Ruiz, J. and Profeta, P. (2007), The redistributive design of social security systems, *Economic Journal 117*, 686–712.

Jacobs, B. (2009), Is Prescott right? *Welfare state policies and the incentives to work, learn, and retire, International Tax and Public Finance 16*, 253–280.

Jensen, S. E. H., Lau, M. I., and Poutvaara, P. (2004), Efficiency and equity aspects of alternative social security rules, *FinanzArchiv/Public Finance Analysis 60*, 325–358.

Kamien, M. I. and Schwartz, N. L. (2012), *Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management*, Dover Publications, New York.

Kemmerling, A. and Neugart, M. (2019), Redistributive pensions in the developing world, *Review of Development Economics 23*, 702–726.

Kindermann, F. (2015), Earnings related pension schemes and human capital formation, *Journal of Pension Economics & Finance 14*, 19.

Le Garrec, G. (2012), Social security, income inequality and growth, *Journal of Pension Economics & Finance 11*, 53.

Ludwig, A., Schelkle, T., and Vogel, E. (2012), Demographic change, human capital and welfare, *Review of Economic Dynamics 15*, 94–107.

OECD (2017), Mandatory pension contributions, in *Pensions at a Glance 2017: OECD and G20 Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/pension_glance-2017-29-en.

OECD (2021), Labour Force Statistics by sex and age – indicators, OECD.Stat, https://stats.oecd.org/Index.aspx?DataSetCode=LFS˙SEXAGE˙I˙R#.

Pestieau, P. (1999), The political economy of redistributive social security, IMF Working Paper 99/180, https://www.imf.org/external/pubs/ft/wp/1999/wp99180.pdf.

Prescott, E. C. (2004), Why do Americans work so much more than Europeans?, *FRB Minneaplis – Quarterly Review 28* (July), 2–14.

Sommacal, A. (2006), Pension systems and intragenenerational redistribution when labor supply is endogenous, *Oxford Economic Papers 58*, 379–406.

Thimme, J. (2017), Intertemporal substitution in consumption: a literature review, *Journal of Economic Surveys 31*, 226–257.

Vogel, E., Ludwig, A., and Börsch-Supan, A. (2017), Aging and pension reform: extending the retirement age and human capital formation, *Journal of Pension Economics & Finance 16*, 81–107.

Wallenius, J. (2013), Social security and cross-country differences in hours: a general equilibrium analysis, *Journal of Economic Dynamics and Control 37*, 2466–2482.

Wang, Z. and Li, Y. (2017), An indirect method for inequality constrained optimal control problems, *IFAC-PapersOnLine 50*, 4070–4075.

Wen, X., Pammolli, F., and Gnecco, G. (2015), Labor supply distortion and capital accumulation when public pension systems differ in an aging economy, available at https://ssrn.com/abstract=2664175.

World Bank (1994), *Averting the Old Age Crisis: Policies to Protect the Old and Promote Growth Summary*, Oxford University Press, New York.

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