Population Aging and Optimal Fiscal Progressivity

Fan *(Frank)* Yang*

Dec 9, 2023
[INCOMPLETE AND PRELIMINARY!]

Abstract

This paper provides a comprehensive quantitative analysis of the optimal fiscal reform for an economy facing demographic change. To do so, I build a standard overlapping generation heterogeneous-agent general equilibrium model, augmented with rich household heterogeneity and a realistic fiscal system. To conduct comprehensive fiscal policy reforms, I expand the conventional policy toolkit with payroll tax deduction, which injects more progressivity into the pension system. Moreover, I also consider a novel channel – the fiscal interaction between social security and progressive income tax. The main findings suggest that the optimal pension benefit scheme is flat. In addition, an augmented payroll tax deduction of around 5000$ can improve welfare at the cost of efficiency loss. The optimal reform considering fiscal interaction also features a flat pension scheme, but a less progressive income tax and slightly higher payroll tax cap. Such reduction in the income tax progressivity balances equity and distortions, improving efficiency significantly compared to reforms of the social security system only. While population aging does not alter the patterns of the optimal policy, it raises the optimal level of fiscal progressivity compared to the counterparts under the status quo. The key reason for this is that as low-skill households live longer, the benefits of progressive policies increase.

*McGill University, Department of Economics, 855 Sherbrooke St. W., Montréal, Québec, H3A 2T7, Canada. E-mail: fan.yang11@mail.mcgill.ca.

1 Introduction

Population aging will pose a significant fiscal challenge to the US economy. According to projections by the Social Security Administration (SSA, 2022), demographic changes will deplete the trust fund for Social Security, one of the primary income sources for older Americans, by 2033. Consequently, sustaining the social security budget necessitates fiscal reforms.

In addition to filling the budget gap, fiscal reform should also care about its distributional effects. Firstly, current social security is less progressive than its benefit scheme shows after accounting for differential mortality risk (e.g., Goda et al. (2011); Coronado et al. (2011)). The key idea is that the social security progressivity gets attenuated by the fact that low-skilled individuals have a shorter lifespan than high-skilled. As a result, the lifetime benefit-contribution ratio gets discounted for the low-skilled while bonused for the high-skilled. Therefore, from a lifetime perspective, low-skilled individuals might be collecting inadequate benefits due to lower progressivity.

Furthermore, the social security progressivity is projected to remain at a similar level as current (CBO (2006); Biggs et al. (2009)). However, this projection assumes sustainable social security payment at the current level. In addition, the projection also ignores the potential distributional effects along with balancing the budget gap. For instance, social security benefit makes up about 56% and 33% of low- and high-skilled retirees' total income[1], respectively. If reducing benefits is a strategy to balance the budget deficit, it could impact low-skilled people disproportionately due to their higher reliance on social security benefits. Thus, fiscal reform, especially the social security part, should take these potential regressive effects into account.

Secondly, the US tax-transfer system features progressive taxes, which provide insurance for idiosyncratic shocks and also redistribute toward low-income people (Conesa and Krueger, 2006). Thus, the progressive income tax can substitute or complement some of the social security's progressivity. Moreover, the inevitable social security reform can have spillover effects on the tax base, which also has implications for optimal income tax reform. Ignoring such fiscal interaction between two fiscal

[1]The income share is based on the author's calculation using Current Population Survey (CPS) dataset. The total income consists of investment income, government transfer, private, and public pension

policies can put the economy at sub-optimal allocation.

For instance, ceteris paribus, suppose the optimal social security benefit is more progressive by assigning more benefits to low-income people. This can disincentivize their saving, which in turn lowers the income tax base. As a result, the income tax rate needs to increase to finance government expenditure, which further distorts the behaviors. Such deterioration in aggregate efficiency can be mitigated by lowering the income tax progressivity through weakening the second channel, which can lower the welfare loss induced by solely progressive social security reform. Therefore, it is essential to take such fiscal interaction into account in the analysis of the optimal policy.

In short, the optimal fiscal reform (with population aging) should consider: i) a sustainable fiscal budget, ii) distributional effects, and iii) the interaction between social security and the tax-transfer system. To analyze the effects of the fiscal reforms satisfying these conditions simultaneously, we need a quantitative model that is capable of several aspects. Firstly, the model should capture realistic government budgets and policy tools. Secondly, the model needs to incorporate realistic household heterogeneity. In addition, the model-generated income distribution should be close to the data. All of these elements are essential for not only satisfying the three conditions, but also generating reliable quantitative results. To the best of my knowledge, most of the existing literature focuses on the first two conditions while ignoring the last fiscal interaction condition.

Therefore, this paper aims to study the comprehensive optimal fiscal reform(s) under population aging. To answer this quantitative question, I build a standard overlapping-generation heterogeneous-agent general equilibrium model following closely Auerbach et al. (1987) and Kitao (2014). I augment the standard model with skill-specific idiosyncratic productivity shock and skill-specific age-dependent mortality risk for households, which are relevant to the attenuated social security progressivity. During working age, households adjust labor supply along both intensive and extensive margins. After paying income and payroll tax, they allocate disposable income to consumption and saving. During retirement, households live on their wealth and social security benefits.

In the model economy, the government has two separate budgets. It levies a progressive income tax to finance exogenous government expenditure. Meanwhile, the government also collects a payroll tax from the salary of working-age earners to fund social security payments to retirees. Such intergenerational design is a pay-as-you-go (PAYG) system. The progressive income tax is modeled using a log-linear approximation (Benabou, 2002), which captures net transfers to low-income households and the tax progressivity. The social security PAYG system in the model, as in reality, is composed of a capped linear payroll tax and a concave benefit scheme. The quantitative model is calibrated to the US economy and performs well along both targeted and untargeted moments.

Using the calibrated model, I perform three sets of fiscal reforms, holding both social security revenue and expenditure at their current levels. For each experiment, I first compute the optimal reform under the status quo to infer the mechanisms at work. Then I compare the reform's effects under the status quo with the counterpart under an aging economy with hypothetical 2100 demographics, which features a lower population growth rate and improved survival probability. The first two sets of reforms are solely happening within the social security system, while the last one considers a simple integrated fiscal reform:

1. Adjust payroll tax cap and social security benefit progressivity
2. Adjust payroll tax cap, social security benefit progressivity, and payroll tax deduction, which makes payroll tax more progressive
3. Adjust payroll tax cap, social security benefit progressivity, income tax progressivity, which allows fiscal interaction

In each set of reforms, I explore the optimal combination of the policy tools that maximize the new-borns expected utility. Under the status quo, the optimal policy features a flat social security benefit. In addition, a payroll tax deduction of 14590$ combined with the flat benefit improves welfare by strengthening redistributive effects. The optimal integrated fiscal reform features flat social security benefit, but is accompanied by a slightly less progressive income tax and higher payroll tax cap.

Although a flat pension benefit raises welfare, the gain in aggregate efficiency is small. On the one hand, a flat pension benefit scheme redistributes more toward low earners during retirement, which disincentivizes their work and saving due to income effects. On the other hand, high earners work and save more for their retirement due to lower social security benefits. Thus, the net effect of these two opposite forces results in a slight efficiency gain.

On top of the flat pension benefit, a payroll tax deduction injects more progressivity into the social security system: it removes payroll tax for some low earners but leads to a higher payroll tax rate for the other earners. The labor supply decreased as higher payroll tax lowers the marginal benefit of working. Moreover, the general equilibrium effect through higher income tax further distorts households' behaviors. As a result, compared to the sole flat pension reform, the aggregate efficiency gets worse while the welfare improves, which is mainly due to a large redistributive effect.

As noted before, the social security reform ignores the fiscal interaction with progressive income tax, which could be sub-optimal. The optimal integrated fiscal policy implies the flat pension benefit needs to be accompanied by a slightly higher payroll tax cap and a less progressive tax system, both of which stimulate most households to work and save more. Such integrated fiscal reform generates intermediate welfare gain compared to the others, but significantly improves aggregate efficiency. Therefore, with a proper balance between progressivity and efficiency, optimal fiscal reform ensures equity and promotes growth.

Compared to the status quo, the optimal policy under the 2100-demographic share the same pattern but with slightly higher fiscal progressivity. The optimal payroll tax deduction increases by 4000$ approximately, and the optimal income tax progressivity increases by one percentage point accompanied by a higher payroll tax cap.

The rise in fiscal progressivity under an aging economy can be attributed to the improved survival probability. In particular, longer-lived low-skilled households contribute positively to the marginal benefit of a more progressive policy in the social planner's problem, which drives optimal progressivity to a higher level.

1.1 Related Literature

This paper contributes to two strands of literature. First, it contributes to large literature on social security reform under demographic change.[2] De Nardi et al. (1999), Kitao

[2]Extensive literature studies single or unconventional reform such as privatization, means-tested pension, and other pension-financing reform, are out of the scope of this paper. (e.g., İmrohoroglu et al. (1995) and Conesa and Krueger (1999) compared PAYG and full-funded pension program; Kotlikoff

(2014) and Nishiyama (2015) analyzed several conventional social security reforms with demographic change. The benchmark reform of this paper shares a similar policy toolkit as theirs, but with more heterogeneity elements in the model. These new elements are essential for capturing the distributional effect of the reform. In addition, this paper also expands the policy toolkit for comprehensively exploring progressive fiscal reforms.

This paper also complements the literature on social security progressivity. Fehr et al. (2013) analyzed the effect of raising social security's progressivity under the German economy; Bagchi (2019) highlights the essential role of differential mortality in analyzing optimal social security progressivity; Arapakis (2022) explores the optimal social security benefit and progressivity combination. The most related paper is by Jones and Li (2023), which has a similar setup as this paper and also finds flat social security benefits is optimal. However, none of these papers considers progressive payroll tax reform, which is one of the novel policy tools analyzed in this essay. Furthermore, these papers do not consider the fiscal interaction between social security and progressive income tax, which has implications for welfare-improving along the efficiency dimension.

This paper contributes to the growing literature that explores joint fiscal reform, especially along the fiscal progressivity dimension, with broader policy toolkit and demographic change analysis. Hosseini and Shourideh (2019) and Tran and Zakariyya (2022) studied the interaction between progressive tax and means-tested pension without adjustments on the payroll tax side. Makarski et al. (2022) analyzed the contribution of labor tax progressivity in privatizing social security, which removes the redistributive channel of the pension program. Their reform shares a similar rationale as my last set of reforms, while my reforms have a broader scope.[3] Instead of focusing on specific policy tools or reforms (e.g., privatization in Makarski et al. (2022)), I conduct large-scale simulations that adjust several policy tools simultaneously. Thus, my paper enables a more comprehensive exploration and study of optimal fiscal policy.

et al. (2007) studied consumption-tax as a way for financing social security; Ndiaye (2018) analyzed age-dependent tax; McGrattan and Prescott (2017) proposes asset subsidy in financing pension program; Behaghel and Blau (2012) and Lalive et al. (2022) focuses on the adjustment in retirement age).

[3]In addition, Wu (2021) and Brendler (2023) also analyze fiscal policy under demographic changes. However, different from the Ramsey approach I used, they utilized the inverse-optimum approach to infer the social preferences for income redistribution. My paper complements their work with the complementary approach and allowing flexible adjustments in social security progressivity.

The remainder of the chapter is organized as follows: Section 3.2 formulates the quantitative model, followed by calibration in section 3.3. In section 3.4, I assess the model's performance by comparing untargeted aggregates and distributional moments. Lastly, I analyze counterfactual fiscal reforms in section 3.5. Section 3.6 concludes.

2 The Model

To analyze the comprehensive fiscal reforms under a realistic demographic environment, I construct an incomplete market heterogeneous-agent overlapping generation general equilibrium model following the setup in Auerbach et al. (1987) and Kitao (2014) closely.

2.1 Demographics

The economy consists of overlapping generations with the population growth rate of n_p. Agents work until the mandatory retirement age (J_r) and live until the maximum lifespan (J). The survival probability ($s_j(\eta)$) depends on the age (j) and permanent skill (η). the survival probability is set to zero at the end of the lifespan ($s_J(.) = 0$).

2.2 Household Problem

At each period, the economy consists of a continuum of agents that are heterogeneous in age (j), wealth (a), permanent skill (η), and idiosyncratic productivity(ϵ). Agents are born with zero assets ($a_{j=1} = 0$) and a permanent skill level (η). The time endowment in each period is one, from which agents choose work and leisure hours.

During working age ($j = 1 \dots J_r - 1$), agents face an uninsurable idiosyncratic labor productivity shock every period, which follows a skill-specific finite-state Markov-Chain $\Pi^{\eta}(\epsilon'|\epsilon)$. Moreover, a deterministic age-dependent wage efficiency(ψ_j), which reflects human capital accumulation, also affects the agent's effective wage rate. As a result, the endowment of the effective labor at age j is $w\eta\psi_j\epsilon$, where w is the market wage rate.

Agents adjust labor supply along both intensive and extensive margins. Similar to Kitao (2014), I assume the disutility of participation (ζ_j) as an age-specific time cost, which aims to capture the employment status at the ages close to retirement. If an individual chooses to work for h hours, they earn a salary of $w\eta\psi_j\epsilon h$, and zero otherwise.

In addition to the earnings, agents also get the investment income (ra) from their wealth, where r corresponds to the market interest rate. Both earnings and investment income are subject to a progressive income tax, which is approximated using the log-linear approximation for the post-tax disposable income y^d (Heathcote et al., 2017).

Agents then allocate the disposable resources to consumption(c) and saving(a'). Working-age($j < J_r$) households value consumption, dislike working and discount future utility using a discount factor β and survival probability $s_j(\eta)$. Taking the income tax scheme (λ, τ), market prices (w, r), and aggregate distribution (Γ) as given, agents maximize the expected discounted utility by choosing how much to consume(c), save(a'), and hours of work(h). The formulation of the working-age households' problem is:

$$
\begin{aligned}
V(j,a,\eta,\epsilon) \quad &= \quad \max_{c,a',h} \frac{c^{1-\sigma}}{1-\sigma} + \theta \frac{(1-h-\zeta_j \mathbb{1}(h>0))^{1-\gamma}}{1-\gamma} + \beta s_j(\eta) E(V(j+1,a',\eta,\epsilon')|\epsilon,\eta) \\
& \quad s.t. \quad c + a' \leq a + y^d(w\eta\psi_j\epsilon h + ra); \\
& \quad a' \quad \geq 0; \;\; c \geq 0; \;\; h \in [0,1]
\end{aligned}
$$

where $y^d(.)$ denotes disposable income and the disutility of employment($\zeta_j \mathbb{1}(h>0)$) is evoked only when agents decide to work. The expected value function is calculated using a skill-specific transition matrix of idiosyncratic productivity. In addition, at the last working age ($j = J_r - 1$), the agent's problem becomes a bit different since there is no uncertainty in productivity next period due to retirement. With the same constraint set, the Bellman equation becomes:

$$
V(j,a,\eta,\epsilon) \quad = \quad \max_{c,a',h} \frac{c^{1-\sigma}}{1-\sigma} + \theta \frac{(1-h-\zeta_j \mathbb{1}(h>0))^{1-\gamma}}{1-\gamma} + \beta s_j(\eta) V^R(j+1,a',\eta,\epsilon)
$$

After agents retire ($j \geq J_r$), they collect investment income and social security benefits. I assume the pension benefit(SS) depends on the labor efficiency level one year before retirement ($\eta\epsilon^{J_r-1}$). Therefore, retirees decide on consumption and saving under a deterministic setting. The formulation of the retirees' ($j \geq J_r$) problem is:

$$
\begin{aligned}
V^R(j,a,\eta,\epsilon) &= \max_{c,a'} \frac{c^{1-\sigma}}{1-\sigma} + \frac{\theta}{1-\gamma} + \beta s_j(\eta) V^R(j+1,a',\eta,\epsilon) \\
& s.t. \quad c + a' \leq a + y^d(ra) + SS(w\eta\bar{\psi}\epsilon\bar{h}); \;\; c \geq 0; \;\; a' \geq 0
\end{aligned}
$$

At the last age ($j = J$), agents consume everything on hand and do not save ($a'_{j=J} = 0$).

2.3 Government

The government levies a progressive income tax on households to cover an exogenous expenditure (G). I employ the log-linear tax function (e.g., Benabou (2002); Bakış et al. (2015); Heathcote et al. (2017)) to represent the U.S. progressive tax system. Denote y, y^d as the taxable and disposable income, respectively. The taxable income consists of both earnings and investment income for working-age households. Following Kitao (2014), the pension income is not taxable for retirees. Thus, total income tax revenue ($\mathcal{T}$) is:

$$
\begin{aligned}
\mathcal{T}(\lambda,\tau) &= \int_{s\in\mathcal{S}} \left[y(s) - y^d(s) \right] d\Gamma(s) = \int_{s\in\mathcal{S}} \left[y(s) - \lambda y(s)^{1-\tau} \right] d\Gamma(s) \\
where \; y(s) &= \begin{cases} w\eta\psi_j\epsilon h + ra & if \; j \leq Jr-1 \\ ra & if \; j \geq Jr \end{cases}
\end{aligned}
$$

where $(j,a,\eta,\epsilon) = s \in \mathcal{S}$ demotes a state bundle. $\tau \in (0,1]$ governs the income tax system's progressivity, and λ controls the average tax rate and balances the government expenditure. The disposable income function $y^d(.)$ captures the progressive tax system. The average tax rate, $ATR = 1 - \lambda y^{-\tau}$, increases as income increases for a given $\tau > 0$, which fits the definition of the progressive tax.[4] Moreover, a higher τ implies a more progressive system as it captures the change rate of ATR.

Another fiscal budget – the social security budget works as follows: government collects payroll tax from workers' salaries to finance the social security benefit for retirees. Such intergenerational financing way is also known as pay-as-you-go(PAYG). On the revenue side, the payroll tax consists of a linear tax rate (τ_{ss}) up to an earning

[4]Notably, the tax paid equals to $y - \lambda y^{1-\tau}$, which is negative if $y \leq \lambda^{1/\tau}$. This negative tax happens at the bottom of the income distribution, as it captures the targeted transfer program in the U.S

cap ($\bar{E}$). Thus, for households with earnings of $E = w\eta\psi_j\epsilon h$, the payroll tax liability is:

$$t^{ss}(E|\tau_{ss}, \bar{E}) = \tau_{ss} * \min\{w\eta\psi_j\epsilon h, \bar{E}\}$$

On the expenditure side, the statutory social security benefit is a piecewise linear function of average lifetime earnings. In this paper, I assume the benefit depends on the average earnings at the productivity one year before retirement age ($\tilde{E}^{J_r-1} = w\eta\bar{\psi}\epsilon^{J_r-1}\bar{h}$). $\bar{\psi}$ is the average of the working-age age-dependent efficiency and $\bar{h}$ denotes the average hours of work conditional on working, which is about 1/3 of the total time endowment.

In addition to the simplification of the benefit base, I approximate the statutory piecewise benefit scheme with a continuous concave function $SS(\tilde{E}^{J_r-1}) = \alpha_0(\tilde{E}^{J_r-1})^{\alpha_1}, \alpha_0, \alpha_1 \in [0, 1]$, which is the functional form used in Arapakis (2022). The parameter α_0 controls the overall social security benefit scale, and α_1 governs benefit progressivity. $\alpha_1 = 0$ indicates a flat pension benefit worth α_0, which is the most progressive scheme. $\alpha_1 = 1$ corresponds to the linear benefit scheme, which has no redistributive power. Such approximation not only fits the statutory scheme well, but also enables us to conduct social security progressivity reforms flexibly.

In summary, given policy parameter (τ, α_1), household behavior and the distribution (Γ), the government adjusts the average tax parameter (λ) to balance the budget (1) and adjusts the social security benefit scale parameter (α_0) to balance the social security budget (2):

$$G = \mathcal{T}(\lambda, \tau) = \int_{s\in\mathcal{S}} \left[y(s) - \lambda y(s)^{1-\tau}\right] d\Gamma(s) \tag{1}$$

$$\mathcal{T}^{ss}(\tau_{ss}, \bar{E}) = \int_{s\in\mathcal{S}} \tau_{ss} * \min\{E(s), \bar{E}\} d\Gamma(s) = \int_{s\in\mathcal{S}} \alpha_0 \tilde{E}^{J_r-1}(s)^{\alpha_1} d\Gamma(s) = \mathcal{SS}(\alpha_0, \alpha_1) \tag{2}$$

2.4 Firm

A representative firm produces a good, which is used to consume and save, with Cobb-Douglas technology in a competitive market. Taking the production factor prices (w, r) as given, the firm solves a static profit maximization problem by choosing how much efficient labor to hire (L) and how much capital to rent (K).

$$\max_{K,L} F(K,L) - \delta K - rK - wL; \; where \; F(K,L) = K^{\alpha}L^{1-\alpha}$$

The first order conditions of the firm are:

$$\begin{aligned} F_K(K,L) &= \alpha\left(\frac{K}{L}\right)^{\alpha-1} = r + \delta \\ F_L(K,L) &= (1-\alpha)\left(\frac{K}{L}\right)^{\alpha} = w \end{aligned}$$

2.5 Welfare Measure

The welfare criteria for screening optimal reform is the new-borns' expected utility. Following Bakış et al. (2015) closely; I firstly compute the certainty equivalence of consumption($\hat{c}$) and labor($\hat{h}$) for each new-born with a state bundle $s_0 = (j = 1, a = 0, \epsilon, \eta) \in \mathcal{S}$ before and after the reform.[5] Then, the consumption equivalence variation ($\%\mathcal{W}$), which is a measurement for the welfare change due to policy reform, solves the following equation

$$V(\hat{c}^1(s_0), \hat{h}^1(s_0)) = V((1 + \%\mathcal{W}(s_0))\hat{c}^0(s_0), \hat{h}^0(s_0))$$

where the superscript $i \in \{0, 1\}$ denotes to pre-and post-reform respectively. Lastly, the aggregate welfare change is computed as the weighted sum of the consumption equivalence variation for all newborns.

[5]Denote $V(s_0) = V^c(s_0) + V^n(s_0)$ as the value of state bundle s_0, the certainty equivalent levels of consumption($\hat{c}$) and leisure($n = 1 - \hat{h}$) solve the following equations:

$$\begin{aligned} V^c(s_0) &= E\sum_{t=0}^{J} \beta^t (\Pi_{i=1}^t s_i(\eta)) \frac{c(s_t)^{1-\sigma}}{1-\sigma} = \frac{\hat{c}(s_0)^{1-\sigma}}{1-\sigma}\left(\sum_{t=0}^{J} \beta^t (\Pi_{i=1}^t s_i(\eta))\right) \\ V^h(s_0) &= \theta E\sum_{t=0}^{J} \beta^t (\Pi_{i=1}^t s_i(\eta)) \frac{(1 - h(s_t) - \zeta_j \mathbb{1}(h(s_t) > 0))^{1+\gamma}}{1+\gamma} = \frac{1 - \hat{h}(s_0)^{1+\gamma}}{1+\gamma}\left(\sum_{t=0}^{J} \beta^t (\Pi_{i=1}^t s_i(\eta))\right) \end{aligned}$$

3 Calibration

In this section, I describe how I calibrate the model to replicate the U.S. economy in the 2010s. I first preset some parameters' values to the levels that are widely used or estimated in the literature. Then, I calibrate the remaining parameters to match the moments from the data.

3.1 Demographic and Preference

The model period is one year. Agents born at age 20 ($j = 1$), retire at an exogenous retirement age 65 ($J_r = 46$) and live until age 100 ($J = 81$). The population growth rate is set to 1.1% under the status quo, and decreases to 0.5% under 2100-demographics (Kitao, 2014). The skill-specific survival probabilities $\{s_j(\eta)\}_{j=1}^{J}$ for the two demographics are the ones from Kudrna et al. (2022) (See Figure 1).

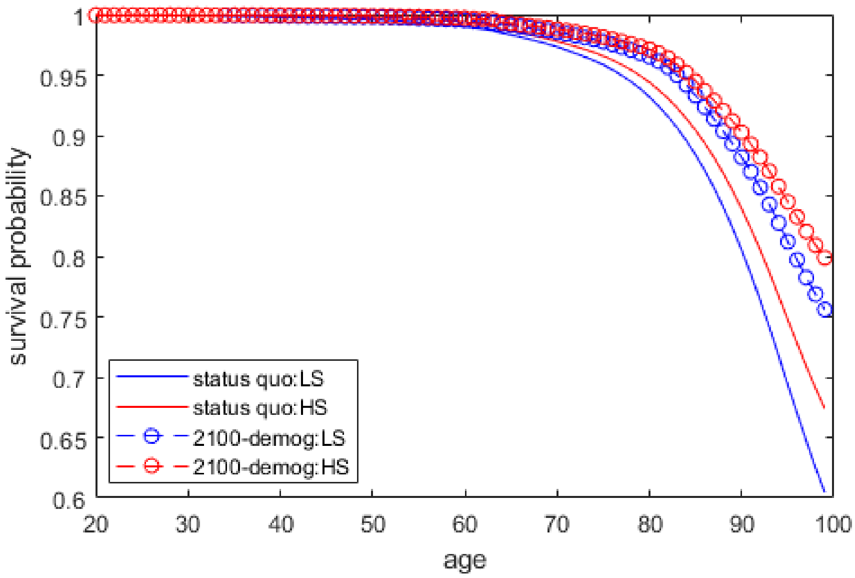

Figure 1: Age-dependent Survival Probability: Status Quo and Aging

The preference parameter set includes discount factor (β), coefficient of relative risk aversion (σ), inverse Frisch elasticity of labor supply (γ), and disutility of work (θ). Moreover, following closely to Kitao (2014), I model the age-dependent employment disutility as: $\zeta_j = \nu_1 + \nu_2 j^{\nu_3}$.

I set the σ equal to 1.5, which is a standard level in the literature. The curvature parameter of labor utility γ is set to 2.4, which implies a Frisch elasticity of 0.82

(Kaymak et al., 2022).[6] After anchoring the utility curvature, I calibrate the three employment disutility parameters ν_is to match the participation rates over different lifecycle stages, specifically the 50s, 60s, and overall average rates. The remaining preference parameters (θ, β) are jointly calibrated to match average hours of work and the capital-output ratio, respectively (See Table 1).

3.2 Productivity Process

I assume that the total labor efficiency (ω) is a product of permanent skill(η), age-dependent efficiency$\{\psi_j\}_{j=1}^{J_r-1}$, and stochastic (ϵ) elements. Furthermore, I assume the stochastic element follows skill-specific first-order autoregressive process with white noise μ, which follows a standard normal distribution with the standard deviation of σ_μ^η:

$$\ln \omega = \ln \eta + \ln \psi + \ln \epsilon; \;\; \textit{where} \; \ln \epsilon \sim AR(1, \rho^\eta, \sigma_\mu^\eta)$$

The permanent skill element $\eta \in \{\eta^L, \eta^H\}$ takes two values with equal probability. The levels of the components are set $\ln \eta^L = -\ln \eta^H = \sigma_\eta$, where σ_η is the one from Conesa et al. (2009). The skill-specific parameters for stochastic productivity are set based on Jones and Li (2023), which are used to construct the productivity grid and transition matrix using the Tauchen algorithm. Lastly, the age-dependent efficiency is the one from Kitao (2014).

3.3 Production, Tax, Transfer

According to National Income and Product Account (NIPA), I set the capital income share (α) equal to 0.35, and calibrate the deprecation rate (δ) to match the annual risk-free interest rate around 4%.

The tax progressivity is set to be 0.18 as what Heathcote et al. (2017) estimated. The exogenous government expenditure(G) is calibrated to match the government expenditure-output ratio of 0.17.

[6]The Frisch elasticity of labor supply in this formulation is $\frac{1}{\gamma}\frac{1-\bar{h}}{\bar{h}}$, where $\bar{h}$ is the average hours of work.

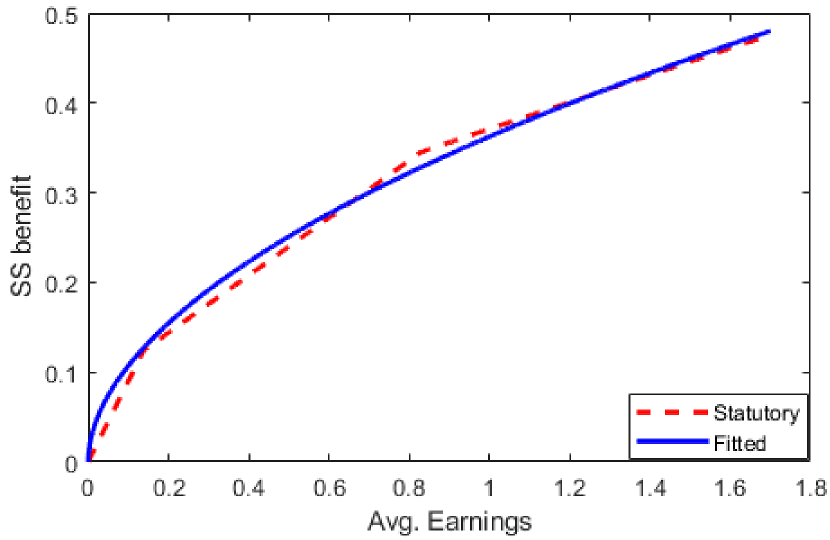

Figure 2: Social Security Benefit: Statutory v.s. Approximation

The payroll tax system features a payroll tax rate (τ_{ss}) of 0.1 and an earning cap ($\bar{E}$) worth 106800$, which are the levels used in Kitao (2014). The parameters for the social security benefit scheme are set to be $(\alpha_0, \alpha_1) = (0.36, 0.53)$. Figure 2 compares the statutory piecewise benefit scheme (red dashed line) with the fitted one (blue line), which performs well and enables us flexibility in adjusting the benefit progressivity. Table 1 summarized the calibrated parameter values.

Parameter	Description	Value	Targeted moment	Level
β	discount rate	0.984	K/Y	3
θ^L	labor disutility	1.5	Avg. Hours	0.3
θ^H	labor disutility	0.75	Avg. Hours	0.34
ν_1, ν_2, ν_3	employment disutility	0.07,0.05,2.89	Emp.Rate(50s,60s,all)	0.89, 0.59, 0.75
G	Gov.Expense	0.21	G/Y	0.18
δ	Depreciation	0.078	r^*	4%
		Selected Preset Parameters		
n_p	population growth rate	1.1%	Conesa et al. (2009)	
s_j	survival prob		Kudrna et al. (2022)	
σ	CRRA	1.5	standard	
γ	Frisch Elasticity	2.4	Kaymak et al. (2022)	0.82
τ_{ss}	payroll tax rate	0.1	Kitao (2014)	
α_1	SS progressivity	0.53	fitted	
τ	tax progressivity	0.18	Heathcote et al. (2017)	
$\{\rho^H, \rho^L, \sigma_\mu^H, \sigma_\mu^L\}$	Productivity Process	{0.939,0.958,0.145,0.114}	Jones and Li (2023)	
σ_η	skill std. dev	0.374	Conesa et al. (2009)	

Table 1: Endogenous Calibrated and Preset Parameters

4 Benchmark Economy

In this section, I start by computing some moments based on the status quo benchmark economy and compare them with the data to evaluate the model's performance. The assessment begins by comparing some aggregate variables, followed by a distributional one. Lastly, I analyze the differences in demographic structure between the status quo and the aging benchmark economy under 2100 demographics.

4.1 Aggregates

In Table 2, I compare some relevant untargeted aggregates from the model with the counterpart from real data. Firstly, the ratio of aggregate social security expenditure to output (SS/Y) aligns with the data, which entails reasonable distribution and social security benefit modeling.

Additionally, I calculate the income share of pensions for the retirees in both model and data. This identity is essential in determining the degree of the lifecycle motive of saving. If the model-generated income share of pension is higher than the data, then agents in the model tend to save less, and vice versa. For the purpose of comparability of retirees' income composition, I use the Current Population Survey (CPS) data to construct the elder income profile as the sum of investment income and social security benefits. As is shown in the second row of Table 2, results are consistent between the model and data.

Regarding households' behavior, as I only targeted the average hours of work in the calibration, I further checked the untargeted variation in work hours to ensure the validity of the labor supply decision. Moreover, combined with the estimated productivity process from the literature, the valid labor supply behavior can ensure a reasonable earning distribution. Overall, the untargeted aggregates are consistent with US data.

	Data	Model	Source
SS/Y	0.05	0.056	CBO (2019)
$\left(\frac{ss_j}{ss_j+ra_j}\right)_{j\geq J_r}$	0.73	0.7	CPS
CV_H	0.27	0.2	CPS
$Pr(E > \bar{E})$	0.06	0.102	CPS
$Pr(a = 0)$	0.08	0.106	Kim (2022)

Table 2: Untargted Aggregates

The model also generates similar distributional outcomes, which will be assessed in detail in the next subsection. At the end of Table 2, I list two simple distributional moments. The first one is the share of people with earnings exceeding the payroll tax cap($Pr(E > \bar{E})$. This moment is important for the later reforms that involve altering the payroll tax cap. It captures how many agents will be affected by a sudden increase in the payroll tax rate from zero to a positive level due to raising the tax cap, which in turn affects aggregate change through a compositional channel.

The second moment is the share of zero wealth, which partially reflects a reasonable wealth distribution, and the result is close to what Kim (2022) estimated using the Panel Study of Income Dynamics (PSID) dataset. In the next subsection, we will further examine the model's performance in terms of the stationary distribution, which is essential for the valid analysis of later policy reforms' distributional effects.

4.2 Distribution

One of the objectives of the fiscal policy lies in its distributional effect, where it redistributes resources from high- to low-income people. To ensure the validity of the fiscal reform analysis, it is crucial for the model to generate the distributional outcomes of the benchmark economy that are close to the counterparts in the data. Notably, the model is only calibrated for some aggregate variables' levels in the steady state, and these distributional outcomes are not directly targeted[7].

In Figure 3, I plot five percentiles for income and wealth, normalized by the cor-

[7]The key distribution-related parameters in the calibration stage are the idiosyncratic productivity process parameters, which is estimated by Jones and Li (2023) using PSID data. However, this cannot fully capture the income and wealth distribution.

responding mean level. The red dashed line is generated using the calibrated model, and the blue line is calculated from the data, where I employ CPS data for computing income distribution percentiles and PSID for wealth.

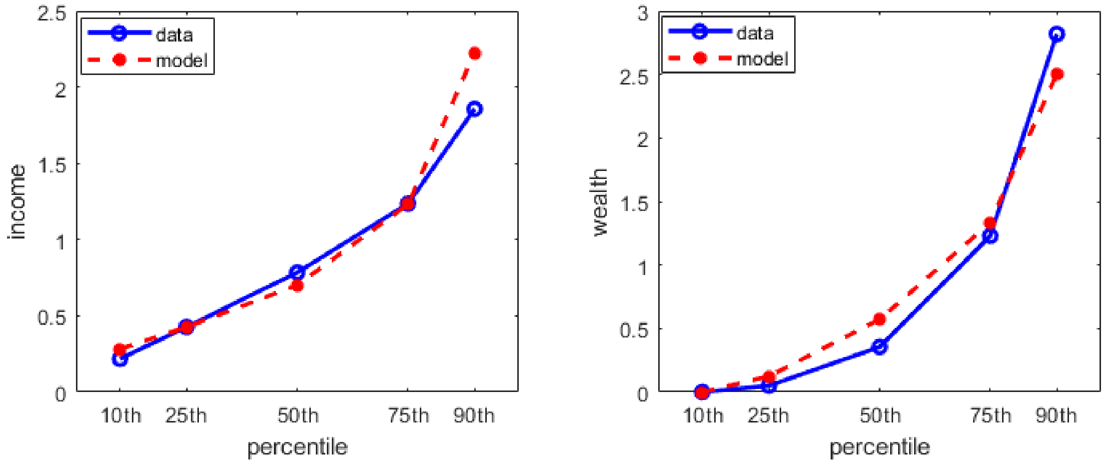

Figure 3: Model Fit: Income and Wealth Distribution

The calibrated model is capable of approximating the pre-tax income distribution well. As shown in the left panel of Figure 3, the model-generated percentiles are close to the data. Such consistency ensures the validity of the subsequent fiscal reform analysis that involves redistribution along the income distribution.

Another distributional assessment of the model performance is along the wealth distribution. The model's result is a bit higher than the data around the middle of the distribution. Different from the data, households cannot borrow in the model, which restricts the lower bound of wealth to zero. In addition, saving into liquid assets serves as the key self-insurance for idiosyncratic shock and non-employment scenarios in the model. Therefore, the percentiles of the wealth distribution are a bit higher in the model. In addition to the percentile comparison, the model also generates the Gini coefficients for income (0.423) and wealth(0.6), which is comparable with the counterparts calculated in the data (0.475,0.73).[8]

In summary, the calibrated model performs reasonably well in terms of both targeted and untargeted moments under the status quo. In the next subsection, I will briefly describe another benchmark economy that features hypothetical 2100 demographics and discuss the comparison between two benchmark economies.

[8]Gini coefficient for wealth is lower in the model, which can be explained by the slightly more concentrated percentiles as in the right diagram of the Figure 3.

4.3 Aging Baseline: 2100-demographic

The aging benchmark economy shares the same parameter set with the status quo except for i) half of the population growth rate (n_p : 1.1% $\rightarrow$ 0.5%), and ii) improved survival probability as plotted in Figure 1. The stationary age distribution of two benchmark economies is plotted in Figure 4, where the blue line corresponds to the status quo and the red dashed line refers to the aging economy according to the projected 2100 demographics. The green vertical line is at the retirement age of 65, which divides population into working-age and retirees.

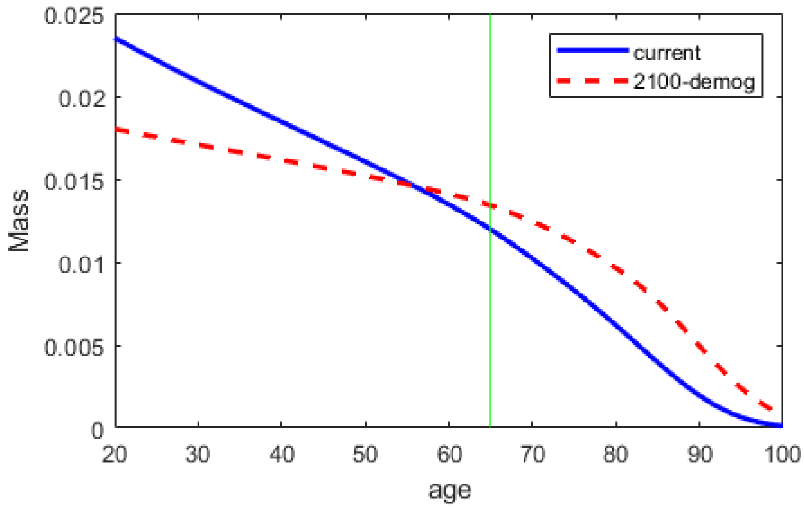

Figure 4: Population Mass: Status Quo v.s. Aging

Compared to the status quo, the mass of working-age (on the left of the green line) shrinks while the one of retirees expands. Such a pattern will pose significant fiscal burdens directly through the PAYG pension system, since the payroll tax base becomes smaller than the larger benefit demanded. These intuitions get confirmed by comparing the relevant variables between the status quo and the aging benchmark economy. To sustain the social security revenue and expenditure at the current level, the payroll tax rate needs to increase by 0.1 percentage point[9], and the benefit scale needs to decrease by 35%. As a result, households in the aging economy save more and work more, which reduces the newborns' expected utility. Thus, in the next section, we will explore possible optimal fiscal reforms that can effectively improve welfare.

[9]The general equilibrium effect of a higher wage explains the small increase in the payroll tax

5 Policy Reform

In this section, I use calibrated model conducting three sets of fiscal reforms, and report the ones that maximize the welfare criteria discussed in section 3.2.5. In each reform, the social security revenue and expenditure are fixed at the benchmark level, which is achieved by adjusting the payroll tax rate (τ_{ss}) and benefit scale (α_0), respectively.

The first two sets are the reforms within the social security system while the last one considers a simple integrated fiscal reform:

1. Adjust payroll tax cap($\bar{E}$) and social security benefit progressivity(α_1)
2. Adjust payroll tax cap($\bar{E}$), social security benefit progressivity(α_1), and payroll tax deduction(ξ), which makes payroll tax more progressive
3. Adjust payroll tax cap($\bar{E}$), social security benefit progressivity(α_1), and income tax progressivity(τ), which allows fiscal interaction

5.1 Mainstream SS reforms with(out) Aging ($\Delta(\bar{E}, \alpha_1)$)

	Status Quo	2100-demog
	Policy Parameters	
$\Delta\tau_{ss}$	-	0.05pp
$\%\Delta\alpha_0$	-15.73	-10.42
$\bar{E}/\bar{E}_0$	1.0	1.0
α_1	0	0
τ	0.18	0.18
	% Δ variables	
Y	0.447	0.025
C	0.404	0.048
K	0.432	-0.282
H	-0.441	-0.533
ER	-0.008	-0.325
w	-0.012	-0.172
r	0.061	1.302
CEV	1.32	1.39

Table 3: Mainstream Reforms

Table 3 reports the effect of the optimal reforms with respect to the status quo and aging baseline. The **upper panel** shows the adjustments in the policy parameters: percentage point change in the payroll tax rate($\Delta\tau_{ss}$); percentage change in benefit scale($\%\Delta\alpha_0$); the ratio of post- and pre-reform payroll tax cap ($\bar{E}/\bar{E}_0$); the post-reform progressivity levels of SS benefit (α_1) and income tax(τ). The **lower panel** exhibits the effects on the aggregate variables. The abbreviations correspond to output (Y); consumption (C); wealth (K); hours of work (H); employment rate (ER); market wage rate (w) and interest rate (r); consumption equivalence variation (CEV), which measures the welfare change as a result of reform.

Within this conventional reform category ($\Delta(\bar{E}, \alpha_1)$), the optimal social security features the same payroll tax cap as in benchmark ($\bar{E}/\bar{E}_0 = 1$) but a flat ($\alpha_1 = 0$) social security benefit. Under the status quo, as we change the progressive social security benefit scheme to a flat one ($\alpha_1 : 0.53 \rightarrow 0$), the benefit size decreases by 15.73% to keep the expenditure the same as in the status quo baseline. Figure 5 plots the benefit scheme before and after the reform. Compared to the benchmark, the pension benefit increases for low-earners while declines for high-earners.

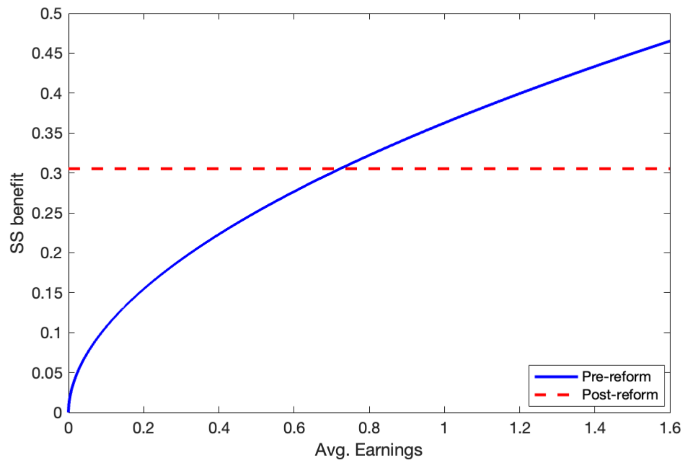

Figure 5: Pre- and Post-reform Pension Benefit Scheme

The aggregate efficiency improves slightly as the output, consumption, and saving are a bit higher than the baseline. To explore the mechanisms, I plot the skill-specific life-cycle behavior changes pre- and post-reform in Figure 6.

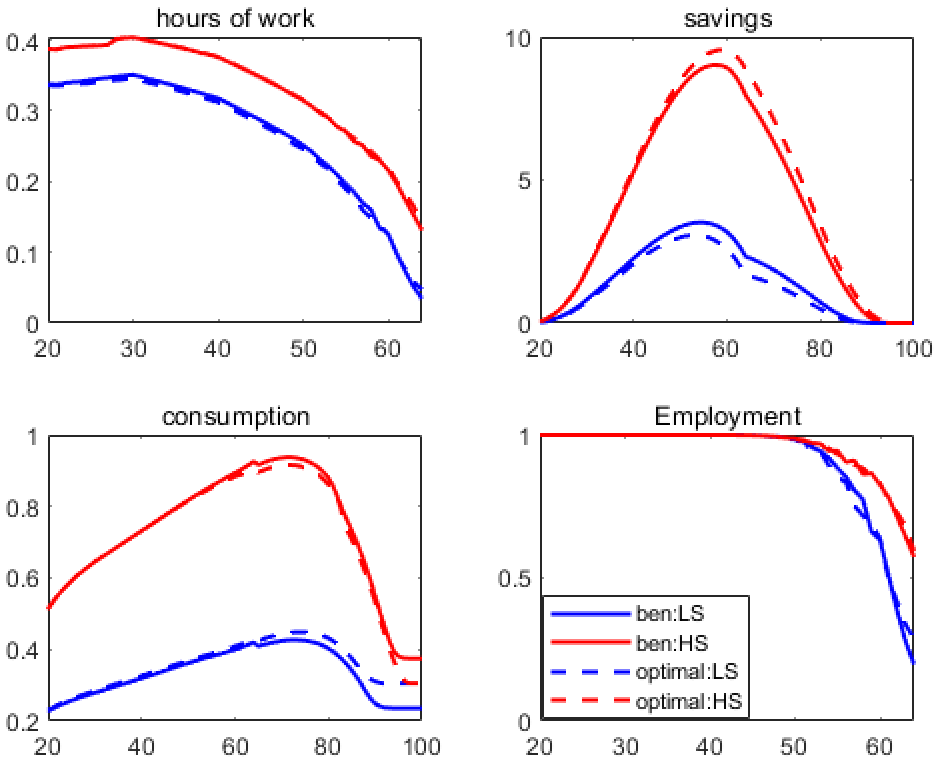

Figure 6: Status Quo: Optimal Reform I

As a result of lower pension benefits, some high-skill agents work slightly longer and save more for their elder life. On the contrary, low-skill agents are now entitled to a higher social security benefit, which disincentivizes their working and saving through an income effect. These two opposite forces lead to slight increases in aggregate efficiency. Compared to the baseline, the welfare increases by 1.32%, which aligns with the increase in aggregate consumption and leisure. However, as we can infer from the behavior changes, high-skilled agents are more likely to suffer welfare loss.

Similar patterns are observed in the aging economy, except for the tiny efficiency gain and lower saving. Comparing Figure 7 with the one under status quo, the improvement in efficiency is mainly restrained by the low-skilled agent. The income effect is amplified by the improvement in the survival probability, which raises the agent's overall discount factor and enhances the transmission of intergenerational distortions from generous pension benefits. As a result, the reductions in low-skilled saving, hours of work, and employment are more significant than ones under the status quo.

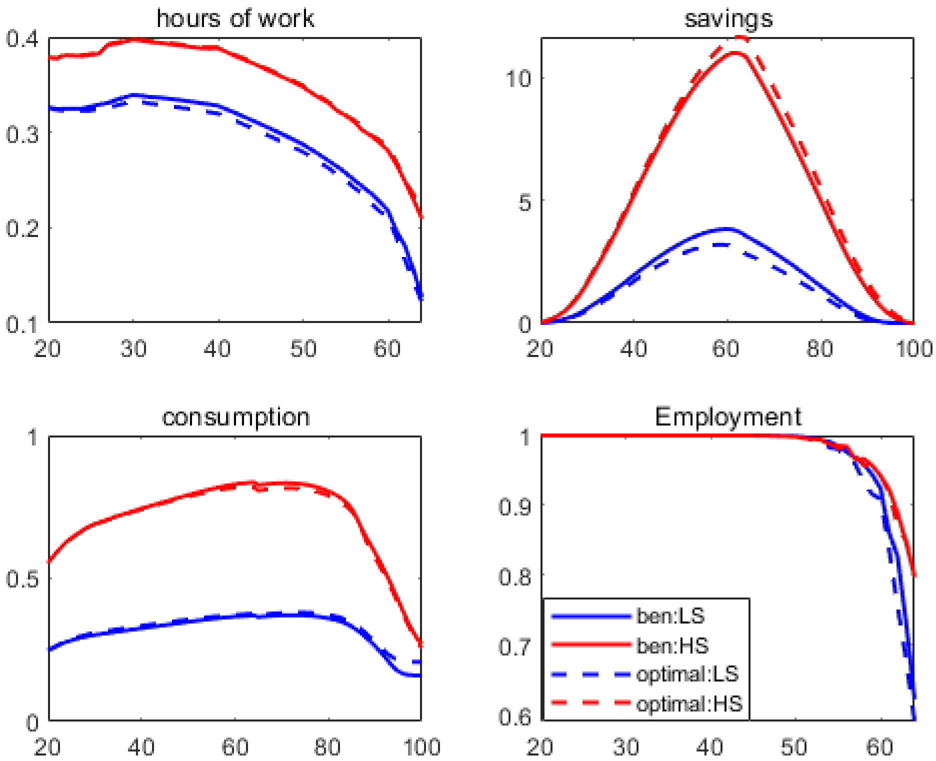

Figure 7: 2100-Demographic: Optimal Reform I

The welfare gain under the aging economy is slightly larger than the status quo's, mainly benefiting from increased leisure and more redistributive effects for longer-lived low-skill people.

5.2 Mainstream SS tools plus Progressive Payroll tax with(out) Aging ($\Delta(\xi, \bar{E}, \alpha_1)$)

In addition to the first set of reforms, I add more progressivity into the social security system through the payroll tax. A simple way of modeling progressive payroll tax is introducing a payroll tax deduction (ξ), which removes payroll tax liability for some low earners. However, as the social security revenue is fixed, a higher payroll tax rate will be imposed for workers with earnings that is higher than the deduction. Thus, the formulation of payroll tax becomes:

$$t^{ss}(E|\xi, \tau_{ss}, \bar{E}) = \tau_{ss} * \min\{\max\{w\eta\psi_j\epsilon h - \xi, 0\}, \bar{E}\}$$

Table 4 shows the outcomes of the optimal reform within this category ($\Delta(\xi, \bar{E}, \alpha_1)$). The patterns of optimal pension progressivity and payroll tax cap are the same as in the last category. The optimal payroll tax deduction is worth about 14590$ and 18570$ under status quo and aging economy, respectively. To maintain the same payroll tax revenue, the payroll tax rate increases significantly in both scenarios as some low-earners no longer contribute. Unlike the simple flat pension reform, most of the aggregate efficiency declines significantly after introducing a payroll tax deduction.

	Status Quo	2100-demog
	Policy Parameters	
$\Delta\tau_{ss}$	3.81pp	14.72pp
$\%\Delta\alpha_0$	-15.73	-10.42
$\bar{E}/\bar{E}_0$	1.0	1.0
α_1	0	0
τ	0.18	0.18
ξ	0.22	0.28
	% Δ variables	
Y	-1.828	-2.546
C	-1.796	-2.416
K	-3.358	-4.501
H	-3.750	-3.841
ER	1.063	0.412
w	-0.882	-1.128
r	4.686	8.666
CEV	1.58	1.79

Table 4: Mainstream Reforms + Payroll Tax Deduction

Comparing Figure 8 and Figure 6, which illustrates the simple flat pension reform, we notice the overall patterns of flat social security benefits are preserved but with non-trivial disincentivizing effects among high-skilled people. The reason can be attributed to the direct effect of higher payroll tax. As is shown in the upper right panel, the increase in high-skilled saving is much less compared to the previous section. This is due to the reduction in disposable income, which is arisen from larger increase in the payroll tax rate. The same reason applies to the larger decline in high-skilled people's consumption.

Labor supply is affected through the substitution effect: higher payroll tax lowers the marginal benefit of working, which lowers hours of work. Unlike the adjustment along the intensive margin, employment increases for both skill types but more significantly among the low-skilled group, which benefits from the incentivizing effect of the zero payroll tax liability.

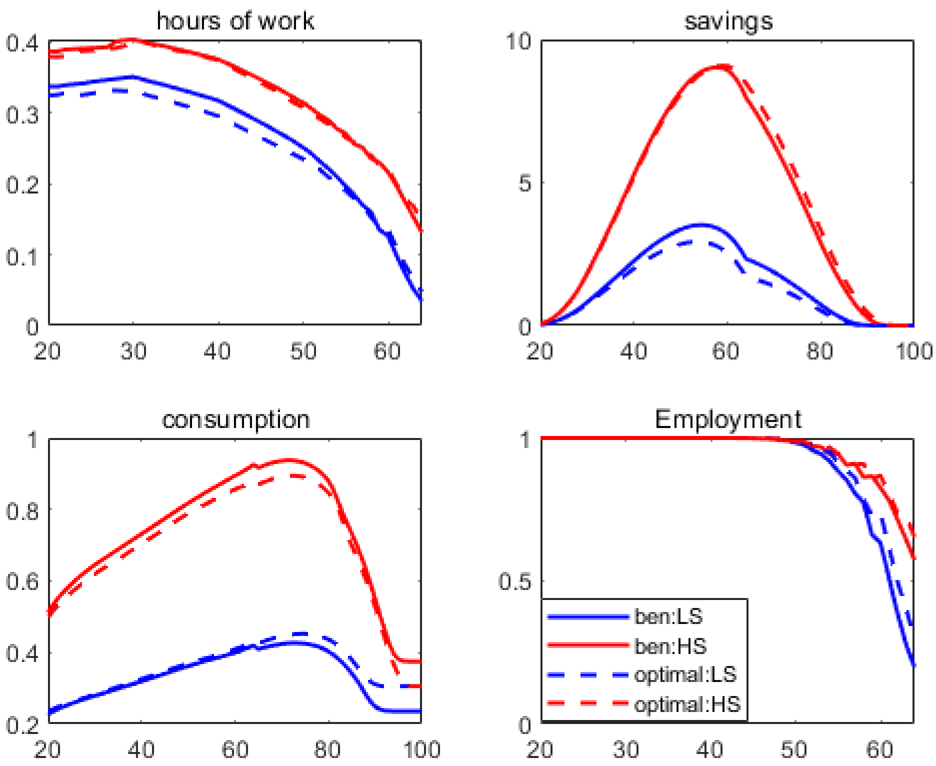

Figure 8: Status Quo: Optimal Reform II

Based on the comparison in the two columns of Table 4, the efficiency change is much worse under the aging economy. Figure 9 shows the behavior response under the aging economy. Unlike the changes in the status quo, the saving of high-skilled agents is almost the same as the pre-reform. In addition, the improvement in employment almost vanished in the aging economy. Both phenomena entail the existence of larger distortionary effects.

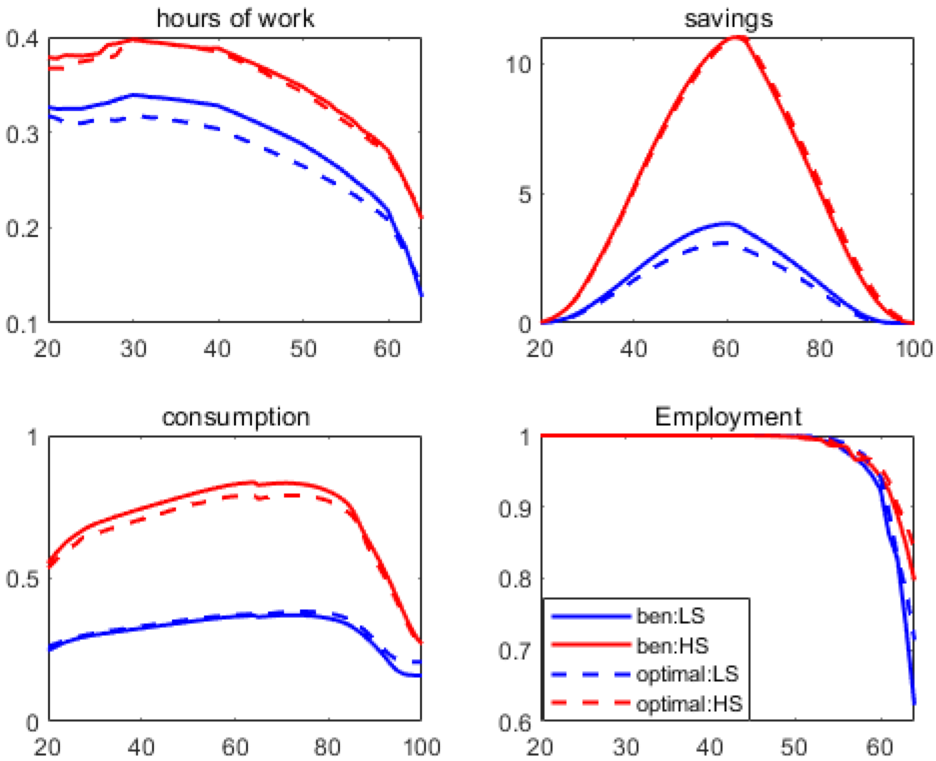

Figure 9: 2100-Demographic: Optimal Reform II

A larger payroll tax change in the aging economy can explain most of the larger deterioration in efficiency. A higher payroll tax rate not only lowers more marginal benefit of working, but also reduces more disposable income, which results in much less saving and consumption. Furthermore, due to the larger distortionary effect on working and saving, a smaller income tax base implies a higher income tax rate to balance the government expenditure budget. Such spillover effect can further distort the agents' behaviors. Both channels explain a larger decline in aggregate efficiency.

Notably, the optimal payroll tax deduction is higher under the aging economy. The optimal deduction balances the benefit and cost. On the one hand, a larger deduction benefits some low-earners with tax advantage that raises their disposable income. On the other hand, it hurts high-earners by taxing more heavily. On top of the direct effects of changing payroll tax, the general equilibrium effect from income tax also distorts agents' behavior. The degree of the benefit and cost positively relates to longevity, which improves under the 2100 demographic and is one of the fundamental differences compared to the status quo. Figure 10 plots the percentage changes in the survival probability across skill types. The improvement in the low-skilled longevity is higher than the ones of the high-skilled, which biased the optimal policy toward more progressive. As a result, the optimal payroll deduction under 2100-demographic is larger compared to the status quo.

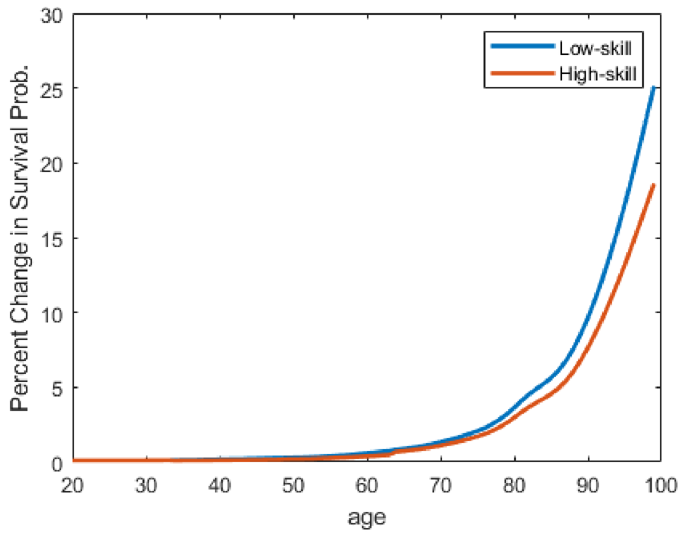

Figure 10: Percentage Change in Age-dependent Survival Probablity

Compared to the optimal reform in Section 5.1, the progressive payroll tax reform generates more welfare gains, which is mainly driven by more redistribution toward low-skilled households, as the aggregate efficiency is worse under this reform.

5.3 Optimal Fiscal Progressivity with(out) Aging ($\Delta(\tau, \bar{E}, \alpha_1)$)

Up to now, the fiscal reforms are solely within the social security system. Notably, as we saw in the previous analysis, the fiscal system (social security & progressive income tax) interacts through the agent's behaviors. These behavior responses toward social security reform directly impact the income tax base, which affects the income tax rate for financing government expenditure. In response to the tax rate change, agents further adjust their behaviors. Such spillover effect through the general equilibrium channel actually undermines the aggregate efficiency in the previous section, which we should consider in the analysis of optimal policy.

In addition, a more progressive social security system scheme provides some degree of insurance. Similarly, progressive income tax also provides insurance toward idiosyncratic shock and redistributes resources intragenerationally, which serves as an imperfect substitute for social security. Given the linkage between these two important fiscal programs, this section explores and assesses the optimal joint reform of the social security and progressive income tax. To do so, I conduct large-scale simulations over many dimensions of policy tools simultaneously, which include payroll tax cap ($\bar{E}$), progressivity of income tax (τ) and social security (α_1).

	Status Quo	2100-demog
	Policy Parameters	
$\Delta\tau_{ss}$	-0.48pp	-0.6pp
$\%\Delta\alpha_0$	-15.73	-10.42
$\bar{E}/\bar{E}_0$	1.1	1.2
α_1	0	0
τ	0.145	0.155
	% Δ variables	
Y	3.199	1.654
C	2.928	1.529
K	5.288	2.582
H	1.192	0.586
ER	0.240	-0.301
w	1.127	0.514
r	-5.822	-3.857
CEV	1.45	1.49

Table 5: Mainstream Reforms + Progressive Income Tax

Table 5 presents the optimal policy and its aggregate effects. The optimal policy features a flat social security benefit, a slightly higher payroll tax cap, and a lower tax progressivity. The payroll tax rate decreases around 0.5 percentage points as a result of more high-earners being subject to positive payroll tax.

The optimal progressivity of income tax decreased from 0.18 to approximately 0.15. This decline indicates that fiscal progressivity is larger than optimal when we solely flatten the social security benefit scheme as in Section 5.1. Generally speaking, excessive fiscal progressivity can induce more distortionary effects on agents' behaviors, which can result in a sub-optimal allocation. Indeed, compared to sole flat pension benefit reform (e.g., Table 3), Table 5 shows that the aggregate efficiency improves substantially after allowing the tax progressivity to adjust simultaneously.

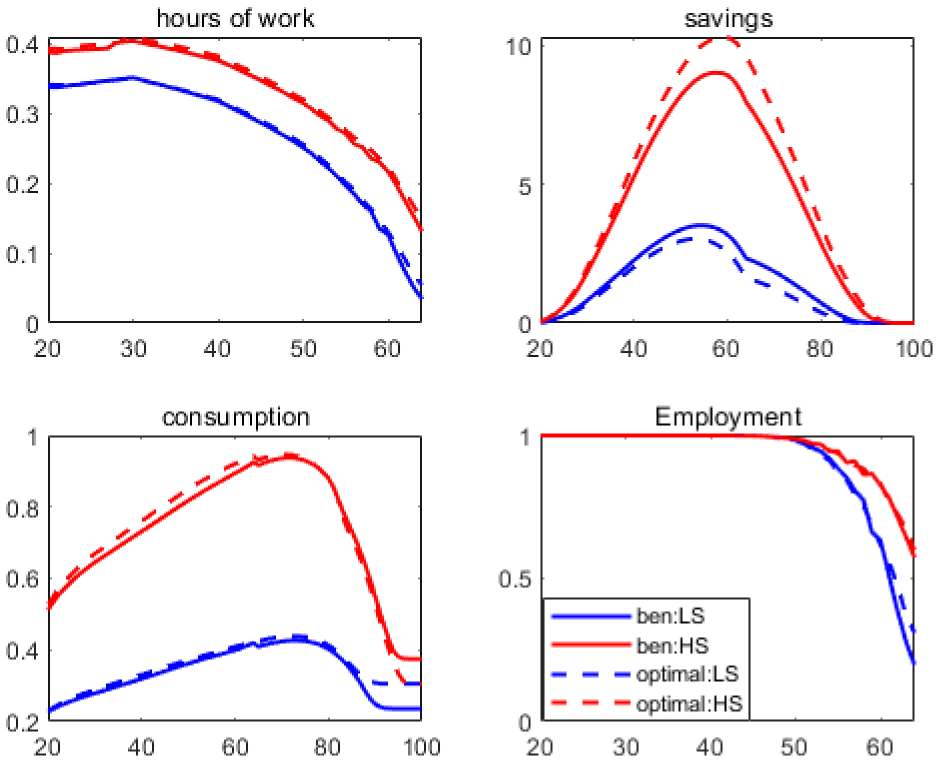

Figure 11: Status Quo: Optimal Reform III

Figure 11 presents the behavior response under the status quo. Firstly, the reform incentivizes labor supply, which can be attributed to the positive substitution effect. The payroll tax on salary is lower for most of the earners and a lower progressivity of income tax also reduces the marginal distortions. In addition, as the main respondents for the income tax change, high-skilled agents' saving increase more compared to Figure 6. Finally, high-skilled agents' life-cycle consumption profile is the highest among all three sets of reforms, which in turn benefits their welfare.

Figure 12 illustrates the response under aging economy, which share the same pattern as above, except for a reduction in employment. Regarding the optimal fiscal progressivity, the optimal policy under aging is slightly more progressive: the optimal progressivity of income tax increases by one percentage point, accompanied by an increase in the payroll tax cap of 10 percentage points. Such higher progressivity under the aging economy shares the same reasoning of longevity as discussed in the previous section.

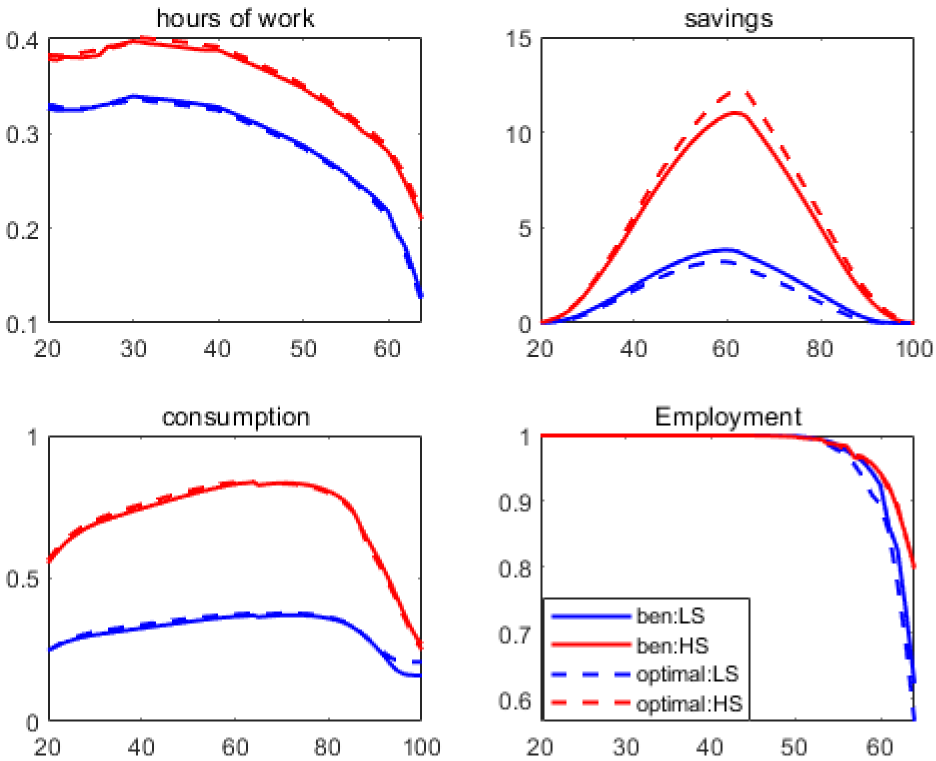

Figure 12: 2100-demographic: Optimal Reform III

In summary, although both payroll tax deduction and joint fiscal reform generate higher welfare gains compared to the simple flat benefit reform, their emphases differ. The progressive payroll tax reform emphasizes the equity aspect, as it largely redistributes toward low-earners with the cost on high-earners. In contrast, the joint fiscal reform addresses the excessive fiscal progressivity and derives the welfare gain mainly from the efficiency side.

6 Summary and Concluding Remarks

Motivated by the depleting U.S. social security trust fund and attenuated pension progressivity considering longevity inequality, I construct a standard OLG model and examine three sets of progressive fiscal reforms. The fiscal reforms take into account the following elements: i) a sustainable fiscal budget, ii) distributional effects, and iii) the interaction between social security and the tax-transfer system.

The main results suggest the optimal social security benefit is flat. In addition to a flat benefit, a payroll tax deduction, which serves as a proxy for a progressive payroll tax, can improve welfare, offering large redistributive gains. A joint fiscal reform, where income tax progressivity is also allowed to change, suggests the flat pension benefit is over-progressive. It is counteracted by a lower optimal income tax progressivity and slightly higher payroll tax cap. Although the welfare gain is modest among the three sets of reforms, this joint reform results in a substantial improvement in aggregate efficiency. Moreover, the optimal fiscal progressivity under the aging economy is higher than in the status quo. This can be attributed to the longer-lived low-skill households, who raise the marginal benefit of a progressive policy in the social planner's problem.

References

Arapakis, K. P. (2022). *Essays in the Economics of Aging*. Doctoral, UCL (University College London). Publication Title: Doctoral thesis, UCL (University College London).

Auerbach, A. J., Kotlikoff, L. J., et al. (1987). *Dynamic fiscal policy*. Cambridge University Press.

Bagchi, S. (2019). Differential mortality and the progressivity of social security. *Journal of Public Economics*, 177:104044.

Bakış, O., Kaymak, B., and Poschke, M. (2015). Transitional dynamics and the optimal progressivity of income redistribution. *Review of Economic Dynamics*, 18(3):679–693.

Behaghel, L. and Blau, D. M. (2012). Framing social security reform: Behavioral responses to changes in the full retirement age. *American Economic Journal: Economic Policy*, 4(4):41–67.

Benabou, R. (2002). Tax and education policy in a heterogeneous-agent economy: What levels of redistribution maximize growth and efficiency? *Econometrica*, 70(2):481–517.

Biggs, A. G., Sarney, M., and Tamborini, C. R. (2009). A progressivity index for social security. *Issue Paper*, (2009-01).

Brendler, P. (2023). Rising earnings inequality and optimal income tax and social security policies. *Journal of Monetary Economics*, 134:35–52.

CBO (2006). Is social security progressive? Technical report.

CBO (2019). The budget and economic outlook: 2019 to 2029. Congress of the United States, Congressional Budget Office. Washington, DC.

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

Conesa, J. C. and Krueger, D. (1999). Social Security Reform with Heterogeneous Agents. *Review of Economic Dynamics*, 2(4):757–795.

Conesa, J. C. and Krueger, D. (2006). On the optimal progressivity of the income tax code. *Journal of Monetary Economics*, 53(7):1425–1450.

Coronado, J. L., Fullerton, D., and Glass, T. (2011). The progressivity of social security. *The BE Journal of Economic Analysis & Policy*, 11(1).

De Nardi, M., İmrohoroğlu, S., and Sargent, T. J. (1999). Projected U.S. Demographics and Social Security. *Review of Economic Dynamics*, 2(3):575–615.

Fehr, H., Kallweit, M., and Kindermann, F. (2013). Should pensions be progressive? *European Economic Review*, 63:94–116.

Goda, G. S., Shoven, J. B., and Slavov, S. N. (2011). Differential mortality by income and social security progressivity. pages 189–204.

Heathcote, J., Storesletten, K., and Violante, G. L. (2017). Optimal tax progressivity: An analytical framework. *The Quarterly Journal of Economics*, 132(4):1693–1754.

Hosseini, R. and Shourideh, A. (2019). Retirement Financing: An Optimal Reform Approach. *Econometrica*, 87(4):1205–1265.

İmrohoroglu, A., Imrohoroglu, S., and Joines, D. H. (1995). A life cycle analysis of social security. *Economic theory*, 6:83–114.

Jones, J. B. and Li, Y. (2023). Social security reform with heterogeneous mortality. *Review of Economic Dynamics*, 48:320–344.

Kaymak, B., Leung, D., and Poschke, M. (2022). Accounting for wealth concentration in the united states.

Kim, H. (2022). Education, Wage Dynamics, and Wealth Inequality. *Review of Economic Dynamics*, 43:217–240.

Kitao, S. (2014). Sustainable social security: Four options. *Review of Economic Dynamics*, 17(4):756–779.

Kotlikoff, L. J., Smetters, K., and Walliser, J. (2007). Mitigating america's demographic dilemma by pre-funding social security. *Journal of monetary Economics*, 54(2):247–266.

Kudrna, G., Tran, C., and Woodland, A. (2022). Sustainable and equitable pensions with means testing in aging economies. *European Economic Review*, 141:103947.

Lalive, R., Magesan, A., and Staubli, S. (2022). How social security reform affects retirement and pension claiming. *American Economic Journal: Economic Policy*.

Makarski, K., Tyrowicz, J., and Komada, O. (2022). Progressing towards efficiency: The role for labor tax progression in reforming social security.

McGrattan, E. R. and Prescott, E. C. (2017). On financing retirement with an aging population: On financing retirement with an aging population. *Quantitative Economics*, 8(1):75–115.

Ndiaye, A. (2018). Flexible retirement and optimal taxation. *Available at SSRN 3057820*.

Nishiyama, S. (2015). Fiscal policy effects in a heterogeneous-agent olg economy with an aging population. *Journal of Economic Dynamics and Control*, 61:114–132.

Tran, C. and Zakariyya, N. (2022). Progressive Pension and Optimal Tax Progressivity.

Wu, C. (2021). More unequal income but less progressive taxation. *Journal of Monetary Economics*, 117:949–968.