Stylized Social Security Reforms with Labor Market Frictions

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Abstract

Social Security provides a large fraction of elderly income, however, projected Social Security shortfalls make reforms inevitable. I examine the effect of reforms using a novel overlapping-generations model with search and matching labor market frictions. I find that new labor market channels magnify the long-term beneficial efficiency and equity outcomes of policies encouraging private saving and labor force participation. A cut in benefits or increase in retirement age decreases equilibrium unemployment via higher labor demand, reduced job search slack, and a reinforcing feedback effect between labor demand and supply.

Keywords: lifecycle, Social Security, labor market frictions, job search, overlapping generations

JEL Classification: D15, E27, H55, J11, J26, J64

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1. Introduction

Social Security (SS) provides essential retirement protection for nearly all elderly Americans. It provides 33% of all elderly income and is associated with a significant reduction in poverty among individuals 65 and over. In fact, according to the Social Security Administration (SSA), for over half of older Americans, Social Security benefits make up at least 50% of their income. SSA estimates a decline in Trust Fund[2] assets beginning in 2021 and eventual depletion of the Trust Fund in 2034, after which the program will provide only three-quarters of the current level of benefits. Social Security reforms are inevitable and will have a profound effect on the well-being of the nation's current as well as future working and elderly population. To better understand how possible Social Security reforms may affect the welfare of Americans in the long term, I utilize a novel general equilibrium model that incorporates labor market frictions. More specifically, I study an increase in the social security tax with and without raising the taxable maximum, a decrease in benefits, an increase in the retirement age, and an introduction of capital gains tax. I find that reforms that encourage private saving and labor force participation, such as a decrease in benefits or an increase in eligibility age to receive benefits, have more beneficial long-run outcomes than an increase in social security taxes to sustain the current benefits level. By creating incentives to increase labor supply and accumulate private savings, such policies increase aggregate capital and labor supply and allow for higher output and consumption in the long run. At the same time, however, these reforms negatively affect the consumption of the elderly.

By contrasting models with and without labor market frictions, I identify four labor market channels that affect the workers' behavior and the aggregate economy when social security reforms take place. These are the labor demand, job search slack, labor market participation, and worker competition channels. Reducing benefits and increasing retirement age create downward pressure on the interest rate, which increases firm investment and, subsequently, hiring (labor demand channel). The same reforms also increase the necessity to work and save; thus, the unemployed put more effort into the job search (job search slack channel) decreasing equilibrium unemployment. There is also a positive feedback effect between aggregate job search level and job openings (labor market participation channel). Finally, Social Security reforms may also shift employed workers' age profile. Greater older-worker participation in the labor market increases labor market congestion and thus negatively affects the employment of the young if the interest rate does not decrease sufficiently (unemployed competition channel). Due to these channels reducing Social Security benefits compared to increasing payroll taxation leads to an additional percentage point increase in aggregate output. I conclude that ignoring labor market frictions (and thus these labor market channels) understates the beneficial long-run outcomes of reducing Social Security benefits or increasing the retirement age, and overstates the benefits of increasing taxation.

This paper is part of the literature that examines the effects of fiscal reforms addressing projected shortfalls in Social Security. Among the many notable contributions, Conesa and Krueger (1999),

[2]The Social Security Old-Age and Survivors (OASI) and Disability Insurance (DI) trust funds accumulate Federal Insurance Contributions Act (FICA) and Self-Employment Contributions Act (SECA) tax revenue that is not required for current SS expenses.

De Nardi et al. (1999), Kotlikoff et al. (1999), İmrohoroğlu et al. (1999), Altig et al. (2001), Kotlikoff et al. (2007), Nishiyama and Smetters (2007), Attanasio et al. (2007), Nishiyama (2015) study various ad hoc Social Security reforms in the tradition of general equilibrium life-cycle models. Most original research assumes either exogenous or endogenous labor supply only on the intensive margin. Imrohoroğlu and Kitao (2012) and Kitao (2014) introduce endogenous labor supply on the extensive margin by allowing endogenous retirement. However, none of the previous research on Social Security reforms in the US considers labor market frictions. Labor market frictions play an important role in life-cycle decision-making. The possibility of becoming unemployed affects labor supply decisions and reinforces precautionary savings. As recently shown by Coile and Levine (2007, 2011), and Hairault et al. (2015), labor market frictions also affect the timing of retirement. To account for these factors, I build an overlapping-generations model with a labor market based on search and matching frictions.

In the recent literature, de la Croix et al. (2013) examine population aging and pension reforms in France in an overlapping-generations model with search and matching frictions. These authors find that ignoring labor market imperfections may bias the evaluation of policy reforms, especially when they affect the interest rate. Relative to the model of de la Croix et al. (2013), I include the following innovations: (1) endogenous labor supply on the intensive margin, (2) endogenous job search intensity, and (3) heterogeneous agents. Labor supply endogeneity on the intensive margin allows agents to adjust their labor supply decisions in response to implemented reforms. It also allows the elderly to decrease their labor supply in the later stages of their careers, thus affecting retirement timing. Hours worked vary considerably across age groups, and retirement timing is essential for both Social Security revenues and expenditures; thus, I allow endogenous labor supply on the intensive margin. Aguiar et al. (2013) show that job search behavior varies by age. Since Social Security reforms affect financial need and the benefits from job search, I introduce endogenous job search (innovation 2), which allows agents to increase their likelihood of finding employment and, ceteris paribus, decrease others' likelihood of doing so due to labor market congestion. This innovation allows agents to alter job search behavior in response to undertaken reforms, and affect other unemployed agents' decisions indirectly through changes in labor market tightness. Finally, agent heterogeneity (innovation 3) permits examination of the distributional consequences of reforms. I calibrate the model to the US and study multiple commonly debated, stylized Social Security reforms: an increased labor income tax (Social Security payroll tax), reduced social security benefits, and increased eligibility age, considered separately.

This paper proceeds as follows. I describe the model employed and its calibration in Section 2. I introduce the benchmark economy in Section 3), and, in Section 4, I simulate aging, analyze three stylized social security reforms, and discuss labor market channels. In Section 5, I present robustness of the results and, finally, in Section 6, I conclude.

2. Model

I build a discrete-time general equilibrium overlapping-generations model with search and matching features inspired by de la Croix et al. (2013). The model consists of heterogeneous agents experiencing idiosyncratic productivity shocks, one representative firm employing all workers and renting all capital,

and a government running the social security system. In the following subsections, I describe the components of the model.

2.1. Agents

2.1.1. Demographics

Every period, a new generation of agents of age j_0 enters the economy. Each new generation is of equal size[3] and enter the model with no assets. Agents face lifespan uncertainty and thus may not live up to the terminal age of j_T. The probability that an agent of age j survives to $j+1$ is denoted by m_j with $m_{j_T} = 0$. Throughout their lives, agents go through spells of employment (E) and non-employment (U),[4] before choosing to retire (R). Retirement is a consuming state.

Agents are heterogeneous in age, j, accumulated assets, a, productivity, η, and current labor market state, L. All these agent characteristics define the agent's state vector, $x = \{j, a, \eta, L\}$.

2.1.2. Preferences

Agents derive utility from consumption and leisure according to a time-separable utility function with a subjective discount factor β.

$$E\{\sum_{j=j_0}^{j_T} \beta^{j-j_0} U(c_j, l_j)\} \tag{1}$$

2.1.3. Productivity and Earnings

Each agent in a state x has 1 unit of disposable time to allocate between work, n (if employed), or job search, s (if unemployed), and leisure, l. Agents face productivity, η, that evolves stochastically and affects each agent's effective labor supply. Employed agent in a state, x, earns labor market income, y, which depends on the market wage rate, w, and her effective labor supply, $\hat{n}$. Effective labor supply is a function of her idiosyncratic productivity, and the number of hours worked.

$$y = w\hat{n} \qquad \text{where } \hat{n} = n\eta \tag{2}$$

2.1.4. Agents' Recursive Problem

Living agents are in one of the three distinct labor market states: employed (E), non-employed (U), or retired (R). Retirement state is further classified into multiple states by the timing of retirement, which determines retirement benefits.

Given the state vector, $x = \{j, a, \eta, L\}$, employed agents optimize consumption, c, saving, a', labor supply, n, and retirement timing, ret. Employed agents are subject to the payroll tax, τ_n, to fund social security, and consumption tax, τ_c, to close the budget deficit or surplus. The payroll tax applies up to the taxable maximum level y_s. Labor income above that threshold is not subject to payroll tax.

[3] I abstract from population growth to highlight the labor market channels. Recent literature by Kitao (2014), Nishiyama (2015) study Social Security reforms with population growth.

[4] In the model, I use the term non-employment instead of unemployment because not all agents without a job may choose to search for work. Non-employment includes the unemployed and those who are not in the labor force.

The employed agent's value function is:

$$V(j,a,\eta,E) = \max_{c,a',n,ret} \big\{U(c,1-n) + \beta m_j[\{(1-\chi)E[V(j+1,a',\eta',E)] + (\chi)E[V(j+1,a',\eta',U)]\}(ret=0) + V(j+1,a',R_{j+1})(ret=1)]\big\} \quad (3a)$$

subject to:

$$(1+r[1-\tau_a])a + (\hat{n}w - \tau_n \min\{\hat{n}w, y_s\}) = (1+\tau_c)c + a' \quad (3b)$$

Here, χ is a probability of losing employment at the end of the period, and ret is a binary decision whether to retire at the end of the period ($ret = 1$) or not ($ret = 0$).

Non-employed agents make consumption, c, saving, a', job search effort, s, and retirement timing, ret, decisions.

The value function of a non-employed agent is:

$$V(j,a,\eta,U) = \max_{c,a',s,ret} \big\{U(c,1-s) + \beta m_j[\{p(s)E[V(j+1,a',\eta',E)] + (1-p(s))E[V(j+1,a',\eta',U)]\}(ret=0) + V(j+1,a',R_{j+1})(ret=1)]\big\} \quad (4a)$$

subject to:

$$(1+r[1-\tau_a])a + zw = (1+\tau_c)c + a' \quad (4b)$$

where z is a non-employment transfer parameter.

The retirement state is further classified into multiple states $R = \{R_{j_e} R_{j_e+1} ... R_{j_f}\}$ where j_e is the earliest age at which an agent qualifies for social security benefits, and j_f is the age at which benefits are maximum and do not increase even if retirement is further delayed. Age at retirement determines the benefits, $b(R_i)w$, agent receives for the rest of her life. Retirement is a consuming state in which agents cannot work or search for work.

Retired agents make consumption, c, and saving, a' decisions. They receive social security benefits from the government, b. The retired agent's value function is:

$$V(j,a,R_i) = \max_{c,a'} \big\{U(c,1) + \beta m_j V(j+1,a',R_i)\big\} \quad (5a)$$

where i is age at retirement, subject to:

$$(1+r[1-\tau_a])a + b(R_i)w = (1+\tau_c)c + a' \quad (5b)$$

2.2. The Firm

A representative profit-maximizing firm employs all workers and rents all capital from capital owners. The production follows the Cobb-Douglas production function with constant returns to scale.

$$Y = F(K,N) = K^{\alpha} N^{1-\alpha} \quad (6)$$

where, K is aggregate capital, N is effective aggregate labor, and α is capital's share of output.

The firm posts vacancies in the current period incurring a vacancy posting cost, v, and successful matches become employed in the following period. The firm also makes a capital renting decision. It produces output $F(K, N)$, pays rent, r, to capital holders and wages, w, to workers. The firm's problem can be stated as follows:

$$W(N) = \max_{V,K}\{F(K,N) - (r+\delta)K - wN - vV + (1+r)^{-1}E[W(N')]\} \tag{7}$$

where δ represents capital depreciation, V is the number of posted vacancies posted by the firm. The future profits are discounted at a rate $\frac{1}{1+r}$.

First-order conditions with respect to capital and vacancies yield the following optimality conditions.

$$r = F_K - \delta \tag{8}$$

$$v = (1+r)^{-1}E[F_{N'}N'_V - wN'_V][1 - (\frac{1-\chi-H}{1+r})]^{-1} \tag{9}$$

where H is the decrease in labor supply due to retirements and continuing workers' labor supply readjustment.

Here, the firm pays the marginal product of capital net of depreciation to capital owners and posts vacancies until the marginal benefit equals the marginal cost of an additional vacancy.

Having risk-averse workers heterogeneous in accumulated assets, productivity, age, and making endogenous labor supply decisions on the intensive margin, I abstract from using Nash bargaining for wages. Instead, the representative firm pays a fraction, γ_w, of the marginal product of labor to workers.

$$w = \gamma_w F_N \tag{10}$$

Here, γ_w can be thought of as worker bargaining power.

2.3. Government and Social Security

Government revenues consist of payroll and endogenous consumption taxes represented by τ_n, and τ_c. For one of the reforms, the government uses capital gains tax, τ_a, to raise additional revenue, otherwise, it is set to zero. In addition, the firm collects all agents' accidental bequests and the firm's profits as it owns the firm.[5] The assumption on bequests and profits does not change the conclusions of the model but simplifies the computational problem. I abstract away from all other federal taxes. To replicate current US Social Security, payroll taxes are applied up to a taxable maximum level y_s. Using its revenues (the left-hand side of Equation 11), the government pays social security benefits, b, to retirees and non-employment benefits, z, to agents in non-employment.

[5] In an alternative specification, bequests and profits are distributed among all living agents. The results of the model are qualitatively identical.

For taxation of bequests collection of firm's profit not to have an effect on social security budget, the government consumes the amount equal to this tax revenue: $G = B + \Pi$. The government endogenously adjusts consumption taxes so that the budget is balanced.[6]

$$\int_x \mu(x)[min\{\hat{n}(x)w, y_s\}\tau_n + c(x)\tau_c a(x) r\tau_a]dx + B + \Pi = \int_x \mu(x)w[b(x) + z(x)]dx + G \tag{11}$$

where x is a state vector ($x = \{j, a, \eta, L\}$), $\mu(x)$ is the measure of individuals in state x, $\hat{n}(x)a'(x), c(x)$ represent the effective labor supply, asset holdings and consumption decisions, respectively, of agents in state x, $b(x)w$ and $z(x)w$ represent social security and non-employment benefits going to agents in state x.

2.4. Labor Market Flows

To create labor market frictions and highlight how social security reforms affect the economy via the labor market, I set up a search-matching labor market in the spirit of Mortensen and Pissarides (1994). The labor market dynamics are driven by the endogenous decisions of unemployed agents and the firm. As is standard, labor market matches follow a Cobb-Douglas matching function:

$$M = V^{\phi} S^{1-\phi} \tag{12}$$

where V is the number of posted vacancies, S is the total effective job search of all unemployed which can be thought of as the number of all job applications sent out by the unemployed, and ϕ is the matching elasticity parameter.

The probability of an unemployed agent finding a job, $p(s)$, and the probability of the firm filling a vacancy, q, are as follows.

$$p(s) = sV^{\phi} S^{-\phi} \qquad \text{with} \qquad p(s) \in [0, 0.99] \tag{13}$$

$$q = V^{\phi-1} S^{1-\phi} \tag{14}$$

Job destruction, χ, is exogenous.

The stock of employed, non-employed, and retired agents next period is summarized by the following equations:

$$E' = \int_{x_e} \mu(x_e)(1-\chi)(1 - ret(x_e))m(x_e)dx_e + \int_{x_u} \mu(x_u)(p(s(x_u)))(1 - ret(x_u))m(x_u)dx_u \tag{15}$$

[6] Changes in the consumption tax, τ_c, affect every agent's income by the same proportion. In an alternative model specification, I use lump-sum transfers to balanced the social security budget and the results are qualitatively and quantitatively very similar.

$$U' = \int_{x_e} \mu(x_e)(\chi)(1 - ret(x_e))m(x_e)dx_e + \int_{x_u} \mu(x_u)(1 - p(s(x_u)))(1 - ret(x_u))m(x_u)dx_u \quad (16)$$

$$R' = \int_{x_r} \mu(x_r)m(x_r)dx_r + \int_{x_e} \mu(x_e)(ret(x_e))m(x_e)dx_e + \int_{x_u} \mu(x_u)(ret(x_u))m(x_u)dx_u \quad (17)$$

Here, $\mu(x_e)$ is a measure of employed individuals in state $x_e = \{j, a, \eta, E\}$. Similarly, $\mu(x_u)$, $\mu(x_r)$ are measures of non-employed and retired agents in states x_u and x_r, respectively. $ret()$ is the retirement and $s()$ is the job search effort decision of agents in their respective state spaces, and $m()$ is the survival function.

2.5. Stationary Equilibrium

Given demographic, labor market, and policy variables, an intertemporal equilibrium with labor market frictions is such that:

1. consumption, saving, job search and retirement decisions maximize agents' utility (eqs. 3a, 4a, 5a) subject to their budget constraints (eqs. 3b, 4b, 5b);
2. posted vacancies and hired capital maximize firm profits (eq. 7);
3. population, capital and total effective labor and job search satisfy aggregation conditions: $P = \int_x \mu(x)dx$, $K = \int_x \mu(x)a(x)dx$, $S = \int_x \mu(x)s(x)$ dx, $N = \int_x \mu(x)\hat{n}(x)dx$ where $\mu(x)$ is the measure of agents in state x.
4. labor market flows satisfy eqs. 12, 13, 14.
5. consumption tax is such that the government budget (eq. 11) is balanced;
6. aggregate variables, and distribution of agents across states are stationary.

I solve the model by making an initial guess on aggregate variables, solving the firm's problem, then household's problems using value function iterations over discretized grids, simulating a large number of agents' lives, aggregating and updating the initial guesses until stationarity.[7]

2.6. Calibration

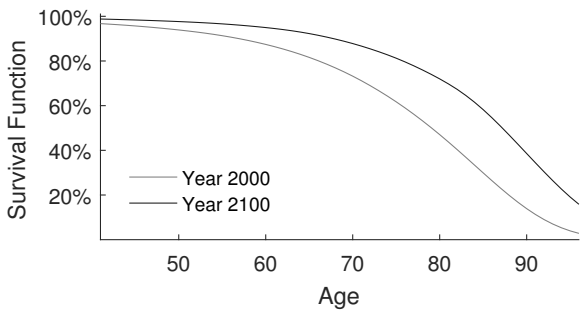
I calibrate employment by age group and social security to broadly match the US in the year 2000 and examine how changes in taxation and social security benefits affect the economy, especially through changes in the labor market. I describe all calibrated parameters below and summarize them in Table 1.

[7] More details are provided in 6.

2.6.1. Demographics

The model period represents 1 year. Agents enter the model at age $j_0 = 18$ as unemployed without any assets. They live up to age $j_T = 100$, but due to uncertain mortality, they may not reach the terminal age. Fertility is kept constant[8] and normalized to 1, and conditional survival probabilities are set according to Bell and Miller (2005) life tables for the year 2000 for the initial steady state. The economy after the demographic transition is represented by survival probabilities as projected by Bell and Miller (2005) for the year 2100. Survival functions show the percentage of agents in a generation still alive at a given age. As shown in Figure 1, survival functions indicate that from 2000 to 2100 there will be significantly more people surviving to old age.

Figure 1: Survival Functions for the Year 2000 and 2100



Survival functions for years 2000 and 2100 according to life tables in Bell and Miller (2005).

2.6.2. Preferences

I use the following time-separable utility function.

$$U(c,l) = \frac{c^{1-\gamma_1}}{1-\gamma_1} + D_j \frac{l^{1-\gamma_2}}{1-\gamma_2} \tag{18}$$

Here, c and l represent consumption and leisure, and D_j represents an age-dependent utility weight on leisure relative to consumption. I introduce parameter D_j to calibrate agents' time spent on labor supply and labor force participation rates at an older age.

The risk-aversion parameter, γ_1, in the utility function is set to 2. Parameter γ_2 is set to 4, which, with employed agents on average spending half of their time on labor supply, yields an intertemporal labor elasticity of 0.3.

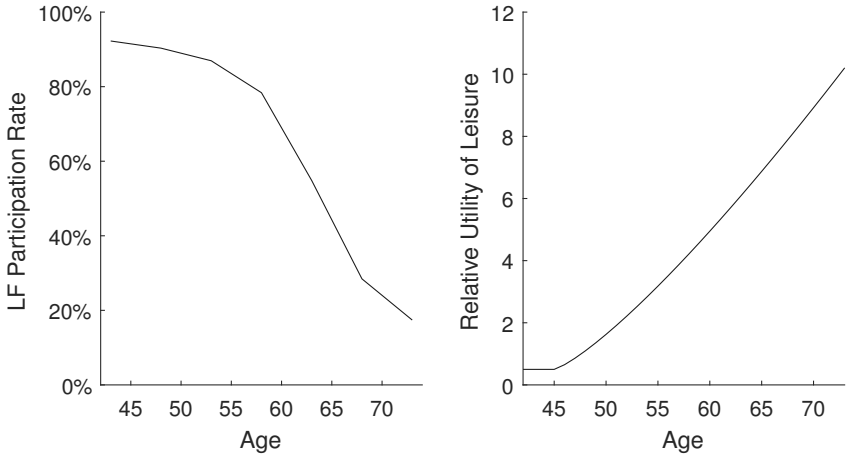
The age-dependent utility weight on leisure relative to consumption is described by Equation 19. d_0 represents the base relative utility weight on leisure. I set d_0 equal to 0.6 so that agents spend half of their disposable time on labor market activities. To replicate the observed labor force participation rates at older age, D_j is increasing with age following the function below with $j_n = 45$, $d_1 = 0.15$ and

[8]There is no consensus yet on how increasing life expectancy or decreasing mortality affects fertility. For related research on aging, mortality and fertility see Hazan and Zoabi (2006), Acemoglu and Johnson (2007), Lorentzen et al. (2008), Mizuno and Yakita (2013).

$d_2 = 1.6$.

$$D_j = \begin{cases} d_0 & \forall j < j_n \\ d_0 + (d_1 j)^{d_2} & \forall j \geq j_n \end{cases} \tag{19}$$

Figure 2: Relative Importance of Utility of Leisure



Left figure shows labor force participation rate for males in the US in 1999 according to Bureau of Labor Statistics. Right figure shows calibrated weight of utility from leisure relative to utility from consumption, D_j.

To match the capital-to-output ratio observed in the US, the discount rate, β, is set to 0.975 which is among the standard values used in the literature.

2.6.3. Productivity

I model the agent's productivity, η, as a function of age, j, and exogenous skill level, h, and a random component, η_2.

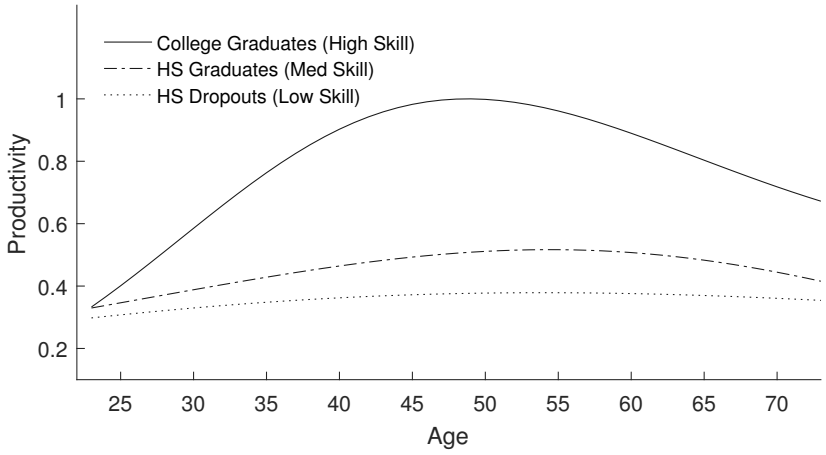
$$\log(\eta) = \eta_1(j, h) + \eta_2 \tag{20}$$

The first term captures the hump-shaped life-cycle productivity profile. Idiosyncratic labor productivity evolves stochastically according to a first-order autoregressive process with $\rho = 0.97$ and $\sigma^2 = 0.02$, as is standard in the literature.[9] I approximate this process to three states using the Tauchen (1986) method.

I estimate age-dependent productivity using Panel Study of Income Dynamics (PSID) data for 1999 by regressing the log of the wage rate of male heads of families on the cubic function of age for three education groups: (1) without a high school degree, (2) with a high school degree but no college degree, and (3) with a college degree. These three groups are represented by low, medium, and high skilled workers in the model. Productivity is normalized to between 0 and 1. Figure 3 shows the estimated age-productivity profiles.

[9] For example, see Heathcote et al. (2010).

Figure 3: Age-Productivity Profiles



Productivity ($\eta_1(j,z)$) profile is measured by regressing log wage rate of male family heads on cubic age function using PSID for 1999. Maximum productivity level of high-skill individuals is normalized to 1.

The skill distribution of newborn agents is fixed to educational attainment in 2000. According to the U.S. Census Bureau, in 2000, approximately 20% Americans were without a high school degree, 56% had a high school degree but not a college degree and 24% had a college degree. While educational attainment is increasing and is expected to further increase in the near term, there are no reliable long-term projections, and thus I assume that the skill level in the economy is fixed.

2.6.4. Firm and Production

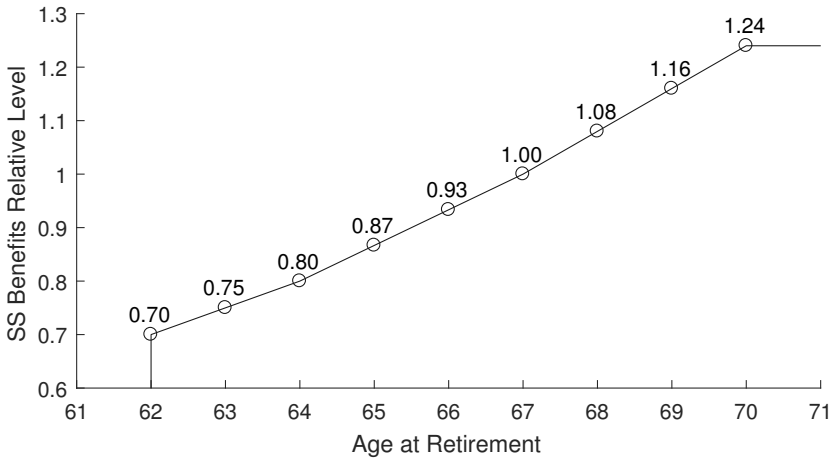
The income share of the capital parameter in the production function is 0.4, as estimated for the US (Giandrea and Sprague, 2017). The depreciation rate is set to 8% which is implied by the equilibrium law of motion and is within the range of values used in the literature. Vacancy cost is calibrated so that employment-to-population by age group matches the adjusted US employment-to-population for 1999.[10]

2.6.5. Government

The government runs a simplified pay-as-you-go social security program in which retirement benefits at full retirement age are approximately 40% of average earnings. To simplify the computational problem, the benefits are dependent only on agent retirement age. An early retirement penalty and late retirement credit replicate current US Social Security regulations. Agents can start receiving social security benefits starting age $j_e = 62$ with a 30% penalty. Full retirement is at $j_n = 67$ with the benefits credit increasing until age $j_f = 70$. This setup creates larger budget deficits as workers choose to retire later and collect social security benefits with a late-claiming credit.

[10]Since all agents in the model participate in the labor force for at least 1 period, BLS employment-to-population data are adjusted to approximately excluding people who never join the labor force. The population size across all age groups is reduced by a fraction that is necessary to equate employment-to-employment and employment-labor force for the 35-39 age group. To limit this adjustment, I use the data on the male population.

Figure 4: Social Security Relative Benefits Level



Social security benefits level as a function of age at retirement. 1.00 indicates full retirement benefits, which are calibrated at approximately 40% of average earnings.

For computational simplicity, all non-working agents receive non-employment benefits independently of their work history. Modeling the actual unemployment benefits based on past earnings would decrease the need for a lot of precautionary savings for those with a good working history, but otherwise would not change the main results. Non-employment benefits are set to approximately 2% of average earnings to prevent agents from having zero consumption.

To pay for all benefits, the government sets a social security tax rate of 12.4% on labor income, representing the current 6.2% tax rate on both the employer and the employee that has been in effect in the US since 1990. Labor income is taxed up to a maximum level y_s. y_s is calibrated to match \$76,200 for 2000, which I set to be 2.5 times average earnings. As in the data, approximately 6% of workers have income above the taxable maximum (Whitman and Shoffner, 2011).

2.6.6. Labor Market

Labor market flows are driven by a Cobb-Douglas matching function with constant returns to scale. The elasticity of matches with respect to vacancies, ϕ, and parameter γ_w, representing workers' bargaining power, are set to 0.50 as is standard in the literature (Petrongolo and Pissarides, 2001).

Due to the time aggregation error, finding the exogenous job separation rate is not straightforward. Since most unemployment is short-term, most workers who lose jobs regain employment before the end of the year. For instance, Fujita and Ramey (2006) find that monthly employment to unemployment transition probability is around 1.5%, while unemployment to employment probability is approximately 50%. A simple computation taking into account probabilities of losing and regaining employment shows that after a 12-month period, there is a stock of around 3% of newly unemployed agents. I set the yearly job destruction parameter, χ, at 0.03.

Table 1: Parameters

Demographics		
j_0, j_T	Age upon entry and Terminal age	18, 100
m_j	Survival probabilities	Bell and Miller (2005)
f_{hi}, f_{me}, f_{lo}	Skill distribution of newly born agents	0.20,0.56,0.24
Preferences		
β	Discount factor	0.975
j_n, d_0, d_1, d_2	Weight on leisure par.	$45, 0.60, 0.15, 1.6$
γ_1	Consumption utility curvature	2
γ_2	Leisure utility curvature	4
Productivity		
ρ_{η_s}	Persistence parameter	0.97
$\sigma^2_{\eta_s}$	Variance parameter	0.02
η_z	Age-dependent productivity	see Section 2.6.3
The Firm and Production Technology		
α	Prod elasticity par, CRS	0.40
δ	Depreciation par.	0.08
v	Vacancy cost par.	5.3
Government		
τ_n	SS Tax on Labor Income	12.4%
j_e	Earliest age of retirement	62
j_f	Age of maximum ret. benefits	70
z	Non-employment benefits par.	0.005
y_s	Taxable earnings parameter	0.045
Labor Market Technology		
φ	Matching elasticity par.	0.50
γ_w	Workers' bargaining power	0.50
χ	Job destruction par.	0.03

Calibrated parameters used in the numerical simulations. See detailed explanation in Section 2.6.

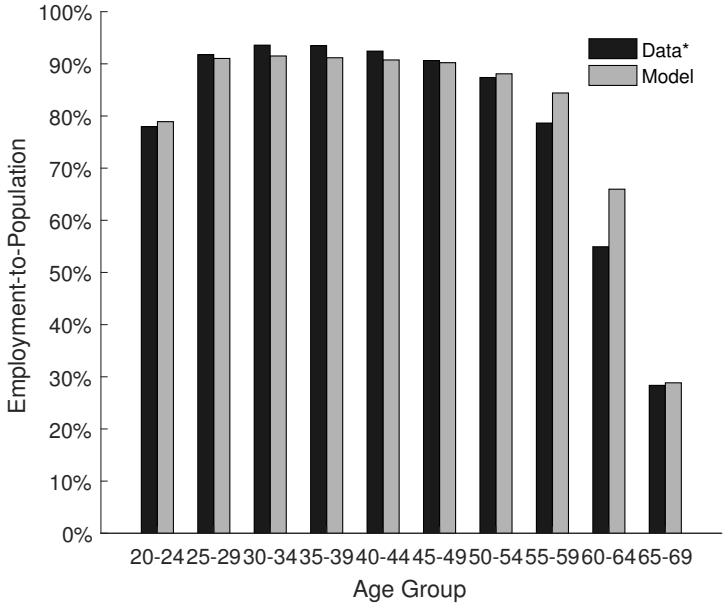
3. The Benchmark Economy

Figure 5 shows the employment-to-population ratio of the benchmark economy. Despite simplifying several important features, it replicates the adjusted US employment-to-population ratio in the US fairly well. The employment-to-population ratio follows a traditional hump-shape with a peak in the age demographic of 30–45. As labor dis-utility rises and the Social Security benefits level stops increasing after 70, no workers in the model choose to stay in the labor force past age 70.

Agents accumulate assets to insure themselves against employment and idiosyncratic productivity shocks, and to be able to supplement social security income in retirement. As is seen in Figure 6, capital accumulation for an average worker continues until age 58 after which assets are used to supplement social security income in retirement. Of course, having no bequest motive and the possibility of large medical expenses at old age, agents dis-save more aggressively than is found in the US data.

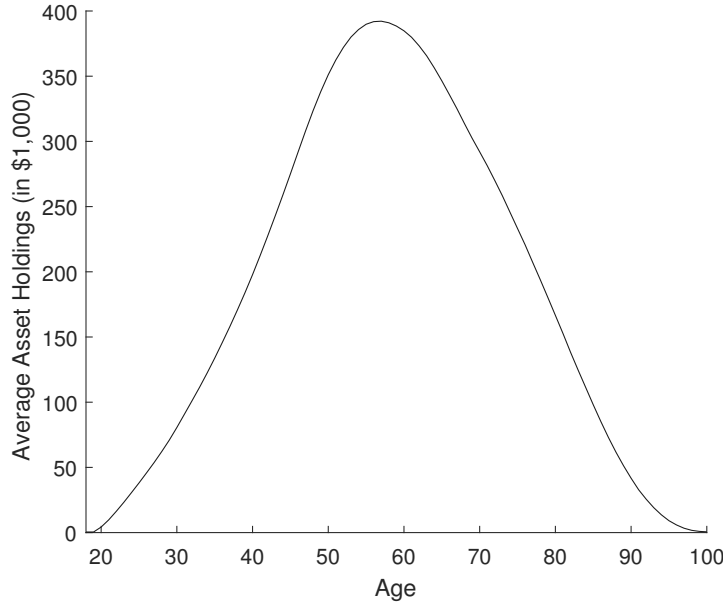
The emphasis in the model is on the labor market and agents' endogenous job search and retirement decisions. Figure 7 shows the job search policy functions of workers in different life-cycle stages. There are multiple factors that determine the job search effort. Over the life cycle, workers' job search behavior follows a hump-shape profile as shown by Aguiar et al. (2013). Younger workers

Figure 5: Employment



Gray bars represent the employment by age group in the model. Black bars represent the adjusted employment by age group in 1999 as explained in Footnote 10.

Figure 6: Mean Asset Holdings



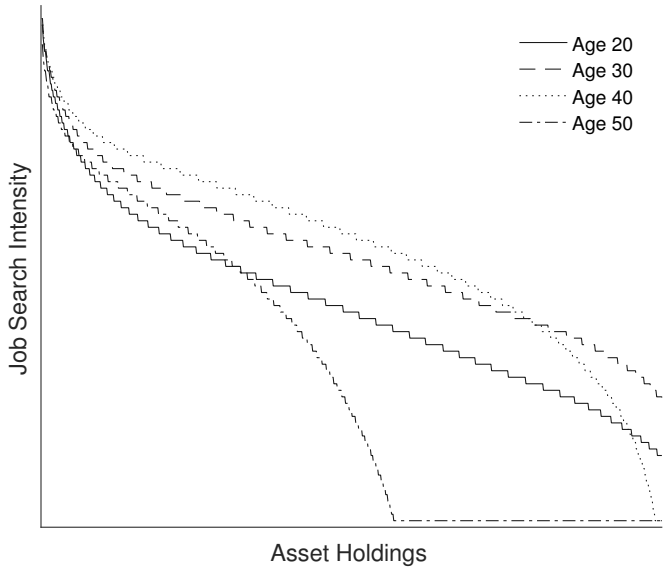
Average asset holdings by age. Benchmark model simulation.

with relatively low potential wages, despite a longer work horizon, ceteris paribus, search at a slightly lower intensity than middle-age workers. Older workers with fewer years remaining to retirement

engage in job search with a lower job search effort. Workers with higher skill levels who have a higher opportunity cost of not working search for work with more intensity. Across all ages and skill levels, agents with fewer assets and lower levels of consumption have higher marginal utilities of consumption and find it optimal to exert higher levels of job search intensity.

Policy functions for saving, labor supply, job search, retirement, and consumption indicate that agents smooth consumption over time by working more and saving in the first half of their lives and dissaving in retirement. Agents with lower asset holdings choose to work more to increase precautionary savings and consumption. The unemployed, whose alternative to retirement is an uncertain job search, retire sooner than those who are employed.

Figure 7: Job Search Policy Function



Job search effort policy functions for medium skilled workers of various ages. Benchmark model simulation.

4. Aging and Reforms

To stylistically replicate population aging and evaluate how fiscal reforms affect the social security shortfall, employment, and the overall economy, I simulate the mortality rate to match the estimated survival function for the year 2100.

Significantly higher survival rates of older individuals (seen in Figure 1) greatly increase the old-age dependency ratio. Without changes to taxation or benefits, scheduled benefits will permanently exceed payable benefits. To close this financing gap, I consider two reforms that reduce social security program commitments and three reforms that involve increasing taxation.

Each reform is calibrated such that, assuming no change in agent behavior, the reform would balance the social security shortfall. Of course, since agents alter their behavior in light of changed

policies, endogenous consumption tax balances the remaining social security shortfall or surplus. The experiment with the following reforms. Reform 1 increases the social security tax on labor income from 12.40% to 18.87%, while Reform 1b increases the same tax to 18.66% but also removes the social security taxable maximum.[11] Reform 2 decreases the benefits by 30.28%, and Reform 3 delays the qualifying age for social security by 6 years. Reform 4 introduces a 13.83% capital gains tax to finance social security. Table 2 shows the main results for each reform relative to a baseline case in which consumption tax finances the social security shortfall (Reform 0).

Table 2: Simulation Results

	Reform 0	Reform 1	Reform 1b	Reform 2	Reform 3	Reform 4
Y (%)	–	-2.12	-2.09	2.67	3.40	-2.81
K (%)	–	-4.55	-4.43	5.47	4.62	-6.30
N (%)	–	-0.47	-0.49	0.84	2.60	-0.41
V (%)	–	-3.16	-3.54	3.74	6.09	-4.14
S (%)	–	2.42	2.09	-1.63	2.26	4.28
E (%)	–	-1.10	-1.11	0.83	5.78	-0.05
AaR	65.99	65.58	65.59	66.23	69.16	66.20
$\tilde{n}$ (%)	–	0.64	0.63	0.02	-3.01	-0.36
$\tilde{s}$ (%)	–	1.36	0.58	0.12	-4.68	1.54
w (%)	–	-1.66	-1.60	1.81	0.78	-2.41
r (%)	4.12	4.43	4.42	3.80	3.98	4.58
Ben (%)	43.64	42.12	42.19	31.13	36.90	44.49
Exp (%)	–	-3.09	-3.16	-28.18	-29.71	-2.44
τ_c (%)	6.54	2.87	2.94	1.97	1.69	1.65
τ_{ss} (%)	12.40	18.87	18.66	12.40	12.40	12.40
τ_a (%)	0.00	0.00	0.00	0.00	0.00	13.83

Reform simulation results. Y, K, N, and C refer to output, aggregate capital, and labor supply, respectively. V, S, E, and AaR refer to job openings posted by the firm, total job search effort, employment, and the average age at retirement, respectively. $\tilde{n}$ and $\tilde{n}$ represent the average labor supply of employed workers and job search intensity of unemployed agents. w is the wage rate, and r is the interest rate. Ben measures the average level of benefits relative to average labor income while Exp refers to government social security expenditures level. τ_c, τ_{ss} and τ_a are the consumption, payroll and capital gains tax rates, respectively. All variables, except AaR, r, Ben, τ_c, τ_{ss}, and τ_a, are presented in percent changes from the benchmark reform (Reform 0). Reform 0: increase in consumption tax on labor income; Reform 1: increase in social security tax on labor income; Reform 1b: increase in social security tax on labor income with a removal of taxable maximum; Reform 2: social security benefits cut; Reform 3: increase in retirement age; Reform 4: introduction of capital gains tax.

4.1. Reform 1: Increased Social Security Tax

Under Reform 1, the social security tax is increased by 6.47 percentage points to 18.87%. This affects the agents and the overall economy through several direct and indirect channels.

Higher social security tax reduces the after-tax labor income disincentivizing labor supply. Labor supply falls, which then negatively affects workers' ability to accumulate assets. One could also expect

[11] The tax rates are similar due to lack of income concentration at the top of the distribution further discussed below.

Table 3: Effects on the Tails of the Distribution

	Reform 0	Reform 1	Reform 1b	Reform 2	Reform 3	Reform 4
All						
K_{20}^{B} (%)	–	-4.77	-3.92	39.00	24.12	-12.15
K_{20}^{T} (%)	–	-4.22	-4.38	2.31	0.84	-5.11
C_{20}^{B} (%)	–	-4.82	-4.80	1.28	2.12	0.01
C_{20}^{T} (%)	–	-0.04	-0.28	-0.33	3.29	-0.07
Retired						
K_{20}^{B} (%)	–	13.50	15.65	259.93	74.62	-40.69
K_{20}^{T} (%)	–	-3.18	-3.54	1.98	-9.92	-5.54
C_{20}^{B} (%)	–	0.91	1.04	-8.02	-3.30	-0.35
C_{20}^{T} (%)	–	1.12	0.81	-1.71	1.04	-0.64

Reform simulation results. K_{20}^{B} and K_{20}^{T} refer to the capital stock held by the bottom and top 20% of the wealth distribution while C_{20}^{B} and C_{20}^{T} refer to the consumption of the bottom and top 20% of the wealth distribution. The bottom part of the table labeled Retired measures capital stock and consumption of the indicated bottom and top two deciles among the retirees only. Results are presented in percent changes from the benchmark reform (Reform 0). Reform 0: increase in consumption tax on labor income; Reform 1: increase in social security tax on labor income; Reform 1b: increase in social security tax on labor income with the removal of taxable maximum; Reform 2: social security benefits cut; Reform 3: increase in retirement age; Reform 4: introduction of capital gains tax.

other possible effects from a change in taxable labor income. For example, firms may substitute monetary pay with untaxed benefits and workers may be less likely to take high-risk occupations as after-tax rewards are lower. Due to the complexity of such factors, occupational choice, risk-taking, fringe benefits (Feldstein, 2005), and other similar factors are not taken into account. Regardless, under this reform, aggregate capital, labor supply, and production decrease by 2.12%, 4.55%, and 0.47%, respectively.

A more dynamic search and matching labor market creates additional mechanisms. First, a larger decrease in aggregate labor supply than aggregate capital increases the interest rate. At a higher interest rate, the firm rents less capital, which reduces the marginal product of labor. Since the demand for labor falls, the firm reduces hiring. Second, the increase in the social security payroll tax decreases the value of employment, i.e., it reduces the take-home benefit of work and increases the incentive to retire. This leads to lower job search intensity and labor force participation, especially among older workers. Employed and unemployed agents retire sooner. Third, a decrease in job search efforts creates a tighter labor market. As it becomes more difficult for the firm to fill a vacancy, the expected profitability of a given vacancy decreases. Given a fixed vacancy posting cost, the firm responds by further reducing the number of new job openings. Compared to the benchmark reform, vacancy postings are 3.16% lower. Due to increased difficulty to find employment is down 1.10% and workers retire around 5 months earlier, compared to Reform 0.

These additional labor market channels contribute to further decline in employment and capital accumulation across all age groups as shown in Figures 8 and 9, and Table 3. The capital stock declines by about the same percentage across the wealth distribution. Negative consumption effect is felt among the young and the least wealthy among whom unemployment is the highest. For the top

20% of the wealth distribution, the fall in consumption is negligible since the drop in capital is made up by an increased interest rate. This reform is beneficial to retirees. Across the distribution, they are able to consume approximately 0.8% more.

Increased payroll taxation's direct and indirect effects make an increase in payroll taxation not sustainable in the long run. Even though more workers are taking early-claiming penalty leading to a 3.09% decrease in social security outflows, a decrease in labor supply and tax revenue leads to an additional 2.87% consumption tax to cover the remaining budget shortfall.

4.1.1. Reform 1b: Removing the Taxable Maximum

The Social Security taxable maximum limits the amount of taxes an individual must pay in a given year. In the US, approximately 6% of workers earn more than the taxable maximum (Whitman and Shoffner, 2011). Eliminating the taxable maximum would make the social security system more progressive, though it would likely be politically difficult. Eliminating the taxable maximum and allowing benefits to increase with social security taxes paid would keep the traditional link between taxes and benefits. This step, however, would do less to close the shortfall.

Reform 1b removes the social security taxable maximum on labor income. Increasing the base of taxable earnings means that the necessary increase in social security taxes to eliminate the shortfall is lower: 18.66% instead of 18.87%. Since my model does not replicate the high concentration of income observed in the US, removing the taxable maximum has a significantly weaker effect on government revenues than it otherwise would. This results in a decline in necessary social security taxes that is much smaller than it would be. Among many estimates, Li (2018) find that increasing the taxable maximum to cover 90% (instead of the current 83%) of covered earnings would decrease the long-run financing gap by around 30%. However, the qualitative result, an overall decline in required tax increases, is anticipated to hold in a more realistic model of the top decile of the income distribution. Another aspect of removing the taxable maximum that is not well captured in my model, due to the lack of sufficient income concentration within the top decile of the distribution, is that removing the taxable maximum would have a larger negative effect on top income earners.

The labor supply effects of this reform differ for individuals above and below the taxable maximum. For individuals with high earnings labor supply falls, and subsequently, capital accumulation falls. Since less than 10% of agents are affected and their incomes are not as well replicated in the model, the effect on the top earners is rather small. A more accurate representation of income concentration in the top decile would likely affect results quantitatively but not qualitatively. One might expect a larger decrease in labor supply, or a decrease in taxable earnings, for example, due to compensation shift towards untaxed fringe benefits (Feldstein, 2005).

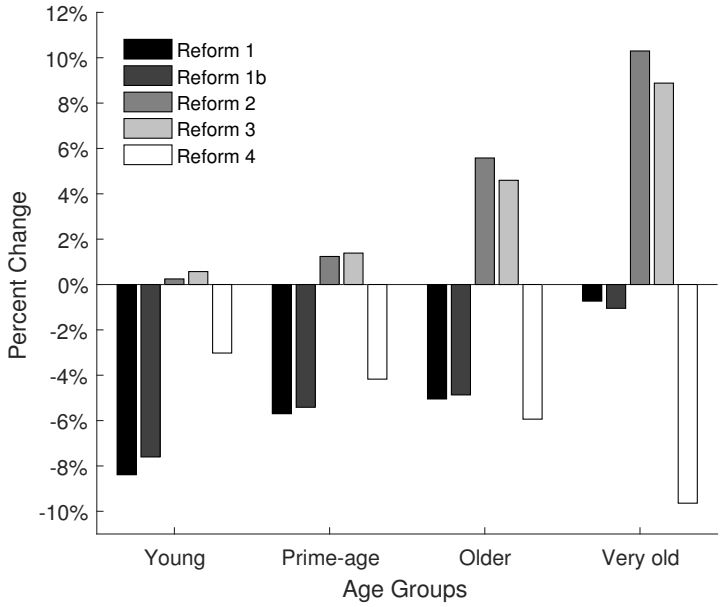
The vast majority of workers are not be negatively affected by removing the taxable maximum, since their income does not reach the threshold earnings. By removing the taxable maximum, the overall social security tax increase necessary to close the financing gap is also lower, which has a positive effect on the vast majority of workers. However, since labor supply decreases by more than under Reform 1, the necessary consumption tax is actually slightly higher, indicating a stronger negative labor supply effect on the most productive workers.

As labor disincentives decrease with a lower tax on labor income compared to Reform 1, a median

employed worker supplies more labor and accumulates more capital, leading to reduced inequality. As shown in Table 3, the bottom 20% of the distribution end up with a lower decrease in capital stock and consumption compared to Reform 1. High earners supply less labor, accumulate less capital, and consume less.

With relatively very little income concentration at the top, Figures 8, 9 and 10 show that older worker capital accumulation, employment and consumption is virtually the same under Reforms 1 and 1b across all age groups.

Figure 8: Capital Stock by Age Group



Capital stock by age group in which agents of age 18 to 29 are considered "young", 30 to 49 – "prime-age", 50-69 – "older", 70 and above – "very old". Results are presented in percent changes from the benchmark reform (Reform 0).

4.2. Reform 2: Social Security Benefits Cut

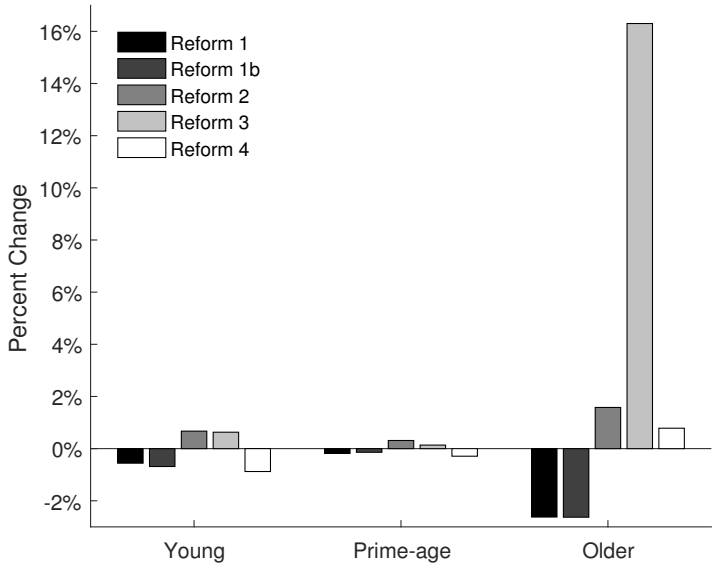
The second stylized reform (Reform 2) decreases social security expenses instead of increasing revenues through taxation. Social security benefits are proportionately reduced by 30.28%.

During working years, employed agents increase their labor supply and save more to supplement lower social security benefits in older age. Aggregate labor supply and capital stock increase by over 0.84% and 5.47%, respectively.

An increase in the capital-labor ratio leads to a lower interest rate and a higher wage rate. As discussed by Kitao (2014), this flattens the labor supply profile: younger workers work slightly less while older workers work slightly more and retire later.

Lower social security benefits greatly incentivize private saving. Across the wealth distribution, agents accumulate and maintain more assets. The decrease in benefits affects the bottom 20% of the distribution more, as agents in this group mostly rely on social security benefits for consumption in old age. To a benefits reduction, agents at the bottom of the wealth distribution respond by holding

Figure 9: Employment by Age Group



Employment by age group in which agents of age 18 to 29 are considered "young", 30 to 49 – "prime-age", 50-69 – "older". Results are presented in percent changes from the benchmark reform (Reform 0).

38.96% more assets as shown in Table 3. In retirement, agents dissave assets to supplement lower social security benefits but still maintain capital at higher levels compared to all other reforms. As social security benefits comprise only a small fraction of the income of the wealthy elderly, the effect on the top of the distribution is very small.

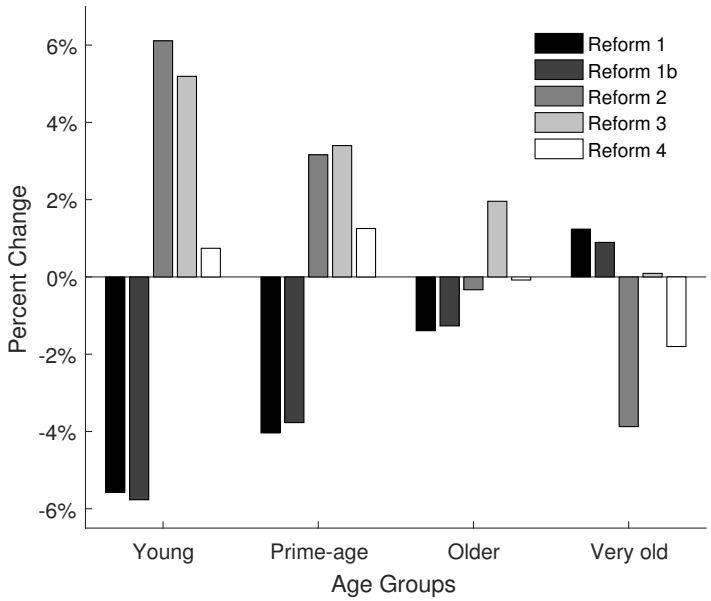
Despite the vastly greater private saving and increased consumption of the young and middle-aged workers, consumption of the elderly is smaller across the distribution as shown in Table 3 and Figure 10. While retirees with the least assets increase private asset holdings by 259.93% to replace the reduced social security benefits, the need to maintain some savings into very old age requires agents to dissave slowly, leading to reduced consumption. The poorest 20% of retirees consume 8.02% less, while the top 20% have consumption loss of 1.71%. Stronger negative effect on the poorer is in line with much of the previous research suggesting that either a benefits cut or increase in retirement age would more than proportionately hurt the bottom of the wealth distribution and increase inequality (Rosnick and Baker, 2012).

The presence of the search and matching labor market in this model creates additional feedback effects. More specifically, reduction of benefits affects interest and wage rates which, in turn, affects the firm's profitability of posting a vacancy. A decrease in the interest rate increases investment (rental capital) and labor demand, and the firm increases job openings. Compared to the benchmark reform, the job openings increase by 3.74%, which together with later retirements lead to a 0.83% increase in the equilibrium employment rate.

More older workers remaining in the workforce and participating in job search with greater effort even at very old age may make it more difficult for younger unemployed workers to find their first jobs. However, the increase in job openings is large enough that the employment rate across all age groups

is higher as shown in Figure 9. Such a large increase in vacancies leads to the highest employment of young and middle-age workers among all reforms examined in this paper.

Figure 10: Consumption by Age Group



Consumption by age group in which agents of age 18 to 29 are considered "young", 30 to 49 – "prime-age", 50-69 – "older", 70 and above – "very old". Results are presented in percent changes from the benchmark reform (Reform 0).

4.3. Reform 3: Increase in Retirement Age

Reform 3 delays social security benefits by 6 years while keeping social security taxes and the benefits level unchanged. Although the aggregate outcomes of this reform are similar to a decrease in benefits (Reform 2), there are some important differences.

Compared to a cut in benefits, an increase in retirement age has a more profound effect on the employment rates of older workers. Agents stay in the labor force significantly longer which results in an older and larger labor force. Experiencing an increasing labor disutility at older ages, older workers supply less labor than younger or prime-age workers. This leads to employment (5.78%) increasing by significantly more than labor supply (2.60%). Older workers exert significantly less job search as the value of remaining employment horizon is short. The average job search effort decreases by 4.68%, as shown in Table 2. This leads to an increase in the number of unemployed workers and a 2.26% higher aggregate job search level.

Asset accumulation behavior also differs significantly compared to Reform 2 (a decrease in benefits). Agents accumulate and hold more higher levels of capital into the middle of their careers, start dissaving sooner and use these private savings to supplement lower labor income at older age before retirement. By assumption, older workers experience increasing labor disutility as they age. For older workers it is optimal to work only a fraction of the hours they did in their prime years. To supplement lower labor earnings in old age before retirement, agents consume accumulated assets. As retirement is shorter, there is less need to maintain large amounts of assets into very old age (see Figure 8).

Compared to the benchmark reform (an increase in consumption tax), an increase in retirement age yields higher consumption across all age groups as shown in Figure 10. Not everyone is able to reach higher consumption levels. Higher retirement age increases elderly unemployment leading to much higher rates of asset decumulation and retirement before reaching full retirement benefits. While under other reforms, agents retire around the age of 66 at which they receive full retirement benefits, for benefits to be at the same level under Reform 3, agents should be retiring 6 years later, at the age of 72. However, the average age at retirement (AaR) is 69.16 indicating that the majority of workers are choosing early retirement coming with an early-claiming penalty. Social security expenses/payments decrease by 29.71% which is even more than under reduced benefits (28.18%). Due to agents coming into retirement with lower asset holdings coupled with lower retirement income, the bottom 20% of retirees consume around 3.30% less than under the benchmark reform.

4.4. Reform 4: Introduction of Capital Gains Tax

A 13.83% capital gains tax directly reduces the after-tax returns on investment and thus the incentive to accumulate private savings. In aggregate, the capital stock decreases by 6.30%, the largest decrease of all reforms. As shown in Figure 8 and Table 3, lower capital holdings are present across all age groups, and similarly across the distribution.

Capital gains taxation also has major implications for employment and labor supply. Workers substitute higher capital accumulation with slightly higher consumption and longer working careers creating downward pressure on the interest rate. This reduces firm's investment and labor demand. The firm posts 4.14% fewer vacancies. While the overall employment level stays virtually unchanged due to higher average retirement age, decreased job openings negatively affect the employment of the young. As shown in Figure 9, this reform creates the largest employment decrease among the youth and middle-aged workers.

The older average age at retirement also leads to higher average social security benefits. Under Reform 4, benefits are 44.49% of average earnings. This together with reduced capital stock would contribute to an increased social security financing gap. However, the higher interest rate increases tax revenues and the lower wage rate decreases benefits (due to benefits being linked to the wage rate). The necessary consumption tax to finance the remaining deficit is the lowest of all reforms, 1.65%.

Capital gains tax affects has a strong effect on capital accumulation. Unemployment increases leading to the capital stock of the bottom 20% falling by 12.15% and the poorest retirees holding 40.69% less in assets. The decrease in capital stock by the top 20% is significantly smaller (5.11%). Changes in consumption shown in Table 3 indicate that the burden of this tax falls on the elderly and the top of the wealth distribution. While the bottom 20% of all agents' consumption is practically not affected relative to the benchmark reform, the top 20% have a small decline. Among retirees who use savings and returns on savings to supplement retirement income, all face a decline in consumption. The rich retirees face a larger decrease in consumption compared to the poor retirees.

4.5. Discussion of Labor Market Channels

As in De Nardi et al. (1999), Imrohoroğlu and Kitao (2012), Kitao (2014), among others, I find that policies that encourage private saving and labor force participation lead to higher consumption for most of the population in the long run compared to reforms that involve higher labor income taxation. Compared to previous research, I implement a frictional labor market that creates new labor market channels through which the reforms affect agent behavior and aggregate outcomes. These new labor market channels affect the labor supply not only on the intensive but also on the extensive margin. Changes in agents' job search and retirement decisions as well as firms' hiring behavior have major implications on capital accumulation, consumption, and overall wellbeing. Previous research on various policy reforms suggests that effects along the extensive margin may be more substantial than along the intensive margin of labor supply (Eissa and Liebman, 1996; Meyer and Rosenbaum, 2001; Meyer, 2002; Eissa and Hoynes, 2006).

To highlight how reforms through these channels affect aggregate capital stock, labor supply, and consumption, I develop an analogous model but with a perfectly competitive labor market. This eliminates job destruction, job-posting by the firm, and job search by the unemployed.[12] I re-run identical stylized reforms using the new model as in Section 4 with all calibrated parameter values as in Section 2.6.

Although the overall results are qualitatively and quantitatively similar between the model with perfectly competitive (model PC) and frictional (model SM) labor markets, as shown in Table 4, there are several important differences due to the presence of the new labor market channels. Distortions due to increased payroll and capital gains taxes and incentives due to lower or postponed benefits in the model with a perfectly competitive labor market are limited to changes in labor supply at the intensive margin without affecting the employment level. I find that changes in workers and firm behavior also significantly affect the extensive margin of labor supply. Due to downward pressure on the interest rate, reduced job search slack, and the labor market participation feedback effect, policies that incentivize labor market participation and private saving yield higher capital stock, employment, and consumption when labor market frictions are present. The opposite happens when payroll taxation is increased - labor demand and vacancies fall further contributing to a decrease in capital stock, labor supply, and consumption. These effects are large. For example, when the labor market is competitive, reducing benefits (Reform 2) relative to increasing payroll taxation (Reform 1) yields 3.94%, 9.25%, and 0.56% higher output, capital stock, and labor supply, respectively. Once labor market frictions are taken into account, benefits of reducing benefits over increasing payroll taxation expand to 4.92%, 10.49%, and 1.32%. That is a 0.98, 1.24, and 0.76 percentage points larger difference.

Not only efficiency but also equity is affected by these labor market channels. Reforms that incentivize private saving and labor force participation (Reforms 2 and 3) lead to lower equilibrium unemployment and shorter spells of unemployment. Increased taxation reduces labor demand and increases job search slack leading to more likely and longer unemployment spells. Risk and expected length of unemployment affect asset accumulation and consumption. For example, when risks of long-

[12] The model is explained in the Appendix B.

term unemployment are lower (Reforms 2 and 3), workers at the bottom of the wealth distribution do not accumulate and maintain as high a level of assets as shown in Figure 11a and, instead, maintain a higher consumption level (Figure 11b). Without frictions, reducing benefits (Reform 2) compared to increasing payroll taxes (Reform 1) raises consumption of the bottom 20% by 4.65% while with frictions this increases by 5.77%.

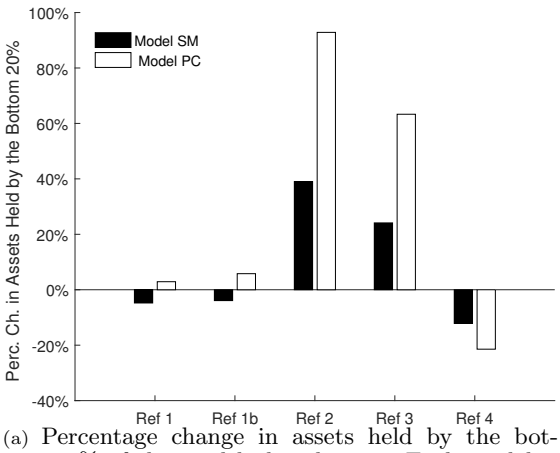
With labor market frictions, and thus these labor demand, job search slack, and participation feedback channels present, both efficiency and equity of private saving and labor supply incentivizing policies are higher than they would be otherwise. Efficiency and equity are lower higher taxes are implemented. In the following subsections, I describe each channel and how it affects workers and the overall economy.

Table 4: Simulation Results Under Alternative Model Variations

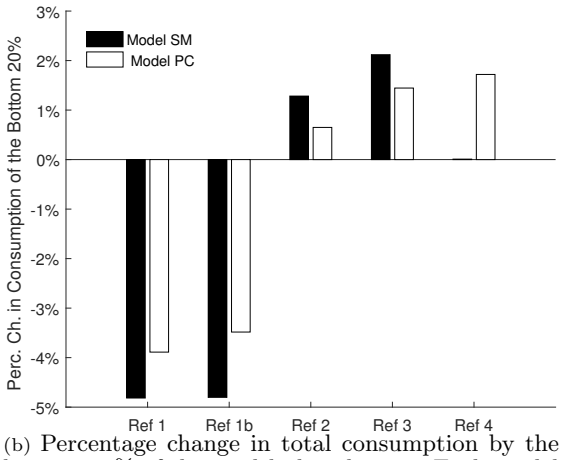
	Reform 0		Reform 1		Reform 1b		Reform 2		Reform 3		Reform 4	
	SM	PC	SM	PC	SM	PC	SM	PC	SM	PC	SM	PC
Y (%)	–	–	-2.1	-1.6	-2.1	-1.5	2.7	2.3	3.4	3.3	-2.8	-2.8
K (%)	–	–	-4.5	-3.9	-4.4	-3.7	5.5	5.0	4.6	4.2	-6.3	-7.0
N (%)	–	–	-0.5	0.0	-0.5	0.0	0.8	0.5	2.6	2.8	-0.4	0.2
V (%)	–	–	-3.2	–	-3.5	–	3.7	–	6.1	–	-4.1	–
S (%)	–	–	2.4	–	2.1	–	-1.6	–	2.3	–	4.3	–
E (%)	–	–	-1.1	–	-1.1	–	0.8	–	5.8	–	-0.1	–
AaR	66.0	65.7	65.6	65.3	65.6	65.3	66.2	66.0	69.2	68.9	66.2	65.9
$\tilde{n}$ (%)	–	–	0.6	0.8	0.6	0.7	0.0	-0.1	-3.0	-3.4	-0.4	-0.3
$\tilde{s}$ (%)	–	–	1.4	–	0.6	–	0.1	–	-4.7	–	1.5	–
w (%)	–	–	-1.7	-1.6	-1.6	-1.5	1.8	1.8	0.8	0.5	-2.4	-3.0
r (%)	4.1	4.8	4.4	5.1	4.4	5.0	3.8	4.4	4.0	4.7	4.6	5.3
Ben (%)	43.6	43.2	42.1	41.6	42.2	41.7	31.1	30.8	36.9	36.7	44.5	44.1
Exp (%)	–	–	-3.1	-2.6	-3.2	-1.9	-28.2	-28.5	-29.7	-29.5	-2.4	-2.6
τ_c (%)	6.5	4.7	2.9	1.0	2.9	1.1	2.0	0.7	1.7	0.5	1.7	-0.5
τ_{ss} (%)	12.4	12.4	18.9	18.9	18.7	18.7	12.4	12.4	12.4	12.4	12.4	12.4
τ_a (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	13.8

Reform simulation results for two alternative models. SM refers to the main model of this paper that features search and matching frictions. PC refers to an alternative version of the model with a perfectly competitive labor market. Y, K, N, and C refer to output, aggregate capital, and labor supply, respectively. V, S, E, and AaR refer to job openings posted by the firm, total job search effort, employment, and the average age at retirement, respectively. $\tilde{n}$ and $\tilde{n}$ represent the average labor supply of employed workers and job search intensity of unemployed agents. w is the wage rate, and r is the interest rate. Ben measures the average level of benefits relative to average labor income while Exp refers to government social security expenditures level. τ_c, τ_{ss} and τ_a are the consumption, payroll and capital gains tax rates, respectively. All variables, except AaR, r, Ben, τ_c, τ_{ss}, and τ_a, are presented in percent changes from the benchmark reform (Reform 0) of the respective model. Reform 0: increase in consumption tax on labor income; Reform 1: increase in social security tax on labor income; Reform 1b: increase in social security tax on labor income with a removal of taxable maximum; Reform 2: social security benefits cut; Reform 3: increase in retirement age; Reform 4: introduction of capital gains tax.

Figure 11: Effects on the Bottom of the Distribution Under Alternative Model Variations



(a) Percentage change in assets held by the bottom 20% of the wealth distribution. Each model is compared to its respective benchmark reform (Reform 0: increase in consumption tax). Model SM: model with search and matching frictions. Model PC: model with perfectly competitive labor market.



(b) Percentage change in total consumption by the bottom 20% of the wealth distribution. Each model is compared to its respective benchmark reform (Reform 0: increase in consumption tax). Model SM: model with search and matching frictions. Model PC: model with perfectly competitive labor market.

4.5.1. Labor Demand Channel

As discussed in de la Croix et al. (2013), there is a connection between the interest rate and unemployment. Policies that incentivize private saving create downward pressure on the interest rate. Firms increase capital investment, which increases the marginal product of labor and thus labor demand, ceteris paribus. While in a frictionless labor market model, an increase in labor demand manifests in higher wages for a given labor supply, in a model with search and matching frictions, the firm responds by also creating more job openings contributing to increased matching rate and lower unemployment. Under Reforms 2 (decreased benefits) and 3 (increased retirement age), the interest rate falls and posted vacancies increase 3.7% and 6.1%, respectively. The opposite is true as well: under Reforms 1, 1b, and 4 (increased payroll and capital gains taxation), the interest rate increases causing job openings to fall 3.2%, 3.5%, and 4.1%, respectively. Figure 9 shows that this is very important for the employment levels of the young and middle-aged workers.

With changes in unemployment and retirement behavior present, reforms lead to much larger changes in labor supply, capital accumulation, and consumption compared to models in which the extensive margin is fixed. There is a greater increase in efficiency than it would be without labor market frictions. For all agents, an overall increase in labor demand reduces the future possibility of long-term unemployment, as an increase in vacancies increases the likelihood of finding a job. Lower risk of long-term unemployment and shorter average spells of unemployment mean workers can maintain more smooth and higher levels of consumption over their lives. This is evident in Figure 11. When labor market frictions are present, Reforms 2 and 3 (that increase job openings and equilibrium employment) lead to lower levels of assets and higher levels of consumption for the bottom of the distribution. On the other hand, the effect on the bottom of the distribution and overall consumption inequality is worse with labor market frictions when taxation is increased.

4.5.2. Job Search Slack Channel

Policy reforms that directly affect employed or retired individuals, also have an indirect effect on unemployed agents. An increase in payroll taxation on labor income diminishes the value of employment and the difference in the value of employment over unemployment. Since an increase in payroll taxes reduces the incentive to look for work, unemployed agents decrease the job search effort (increase job search slack). A lower job search effort across the distribution of unemployed decreases the matching rate and increases equilibrium unemployment. An initial look at average job search intensity may seem to contradict this channel, but this is only because the change in unemployed worker age profile has a stronger effect on job search behavior: the older unemployed – the lower the average job search intensity.

The extensive literature on the relationship between the duration of unemployment and the generosity of unemployment insurance confirms these findings. [13] Research suggests that the duration and level of unemployment benefits are inversely related to job search effort and job-finding rate (Krueger and Mueller, 2010; Card et al., 2007). Similarly, changes in payroll taxation make the benefits higher relative to labor income affecting the behavior of the unemployed.

4.5.3. Labor Market Participation Feedback Effect

The labor market participation feedback effect amplifies the labor demand and job search slack channels. Policies that increase either job search effort or incentivize firms to increase job openings may, in turn, start a reinforcing feedback effect contributing to lower unemployment. Similarly, policies that disincentivize job search or that decrease labor demand create a negative reinforcing effect on employment. The presence of these channels amplifies the effects of policy reforms on long-run equilibrium unemployment in either direction.

This reinforcing feedback effect creates a link between the job search decisions of the unemployed and vacancy posting decisions by firms. An increase in job search levels by the unemployed increases the probability of a given firm filling a vacancy, known as the thick market externality. This thus increases the marginal benefit of posting another vacancy, and firms post more job openings. An increase in vacancies increases the probability of success of a given worker's application. This increases the marginal benefit of posting another job application. Workers respond by increasing job search efforts. This channel works in the other direction as well. This echoes the finding of DeLoach and Kurt (2013) and Gomme and Lkhagvasuren (2015) that job searchers decrease search intensity when the probability of finding a job is low, for example, during economic recessions.

4.5.4. Worker Competition Channel and the Lump of Labor

The presence of endogenous retirement and job search creates a congestion externality. When a worker alters her retirement and/or job search decision, this increases or decreases the probability of the remaining unemployed workers finding employment.

Reforms that decrease or delay benefits decrease the retirement rate and increase labor supply per employed worker. Both of these outcomes cause the capital–labor ratio and thus the interest rate to

[13] For a review, see Krueger and Meyer (2002).

fall, which then decreases demand for labor. The same reforms also prompt the older unemployed to have higher search effort, further increasing competition in the labor market. This decreases the probability of finding a job quickly. The decrease in labor market tightness due to fewer job openings and higher search effort of older unemployed workers results in a decline in job finding among younger workers. Since younger workers have a longer horizon of work opportunities, any policies that increase their probability of youth unemployment or that extend its length will have larger negative consequences.

This effect directly relates to the "boxed economy" or "lump-of-labor" view that increased elderly employment may decrease youth employment.[14] In my model, I find this concern is borne out when policy reforms increase elderly labor market participation without a sufficient increase in private saving. An increase in private savings, ceteris paribus, reduces the equilibrium real interest rate, stimulating investment and labor demand, thus promoting employment of all groups. Under Reforms 2 and 3 when older workers stay in the labor force longer, the interest rate falls sufficiently to increase job openings enough to cause an increase in the employment of the young as well.

Increased life expectancy itself incentivizes private saving as agents prepare for a longer expected retirement. Even if older workers choose to stay in the labor market longer, increased job search effort and capital accumulation via labor demand, job search slack channel, and labor market participation feedback effect leads to lower equilibrium unemployment in the long run across all age groups. Since increased employment allows the government to collect more tax revenues, ignoring these channels may overstate the negative effect population aging has on the social security shortfall.

Similarly, social security reforms may also affect the demographic composition of the workforce. A reduction in social security benefits and an increase in the retirement age create incentives for workers to participate in the labor market longer, which, ceteris paribus, reduces the number of job openings posted and youth employment opportunities. On the other hand, since elderly workers do not work as many hours, this effect can be somewhat muted.

In Table 4, it is evident that the relative difference in the capital, labor supply, and consumption aggregates between models with search and matching frictions and without them is larger under Reform 2 than under Reform 3. Moreover, under Reform 3, labor supply is lower when frictions are taken into account. This is because in the version of the model with a perfectly competitive labor market, due to postponed social security benefits, older workers stay in the labor force longer, supplying slightly less labor every year before they choose to retire. In the model with frictions, some workers above 50 lose their jobs and do not find it optimal to exert a lot of job search effort or completely leave the labor force and begin to dissave until they retire and can claim benefits. Under Reform 3, a larger fraction of the elderly is unemployed before retirement contributing to a lower labor supply. This is in line with Hairault et al. (2010) who find that distance to retirement explains lower job search intensity and lower employment levels of workers just below the retirement age. Marmora and Ritter (2015) find that exit from the labor force is affected by workers' labor market

[14] While most research points against claims of a fixed amount of work (Gruber and Wise, 2010; Walker, 2007; Hebbink, 1993; Banks et al., 2010; Börsch-Supan and Schnabel, 2010; Kalwij et al., 2010), some papers find some degree of substitutability between cohorts (Hamermesh, 1993; Card and Lemieux, 2001; Fitzenberger and Kohn, 2006; Boeri et al., 2017).

status. Unemployed older workers exit at much higher rates than those who are employed. Models that ignore endogenous labor market frictions thus fail to capture important distributional effects of social security reforms.

5. Sensitivity Analysis

The results of the numerical simulations rest on assumptions used in the development of the model. In this section, I check the robustness of the results to alternative parameter values and assumptions. I repeat the previous simulations for different values of key parameters. I re-examine the results with the consumption utility curvature parameters γ_1 equal to {1.5,2.5} instead of 2, γ_2 equal to {3.5,4.5} instead of 4, and workers' bargaining parameter γ_w equal to {0.4,0.6} instead of 0.5. I also examine if changes in educational attainment affect the analysis. The findings using these alternative values and assumptions do not change the main results of the analysis and thus are not discussed or reproduced here. Instead, I discuss how changes in preferences for leisure and the disutility of labor in old age affect agent behavior and the social security shortfall under each reform.

5.1. Preferences

The US population has experienced significant improvement of health in old age and increased life expectancy since 1960s (Beltrán-Sánchez et al., 2015; Woolf and Schoomaker, 2019). The shift to jobs with fewer physical demands, among other factors, has increased individuals' ability to remain in the workforce. Unsurprisingly, the labor force participation rate of Americans 55+ almost doubled between 1990 and 2015: from 11.9% to 22.1%. While health is not explicitly modeled in this paper, the increasing dis-utility of labor in old age, among other factors, represents declining health. To account for trends in health, I allow the dis-utility of labor supply in older age to begin decreasing later than in the benchmark case. By setting j_n from 45 to 52, older workers experience a later decline in labor dis-utility.

The results under the alternative assumption are shown in Table 5. While the results are qualitatively similar, there are some differences in older agents' labor supply, job search, saving, and consumption decisions. Working agents supply slightly less labor during the peak of their careers but remain in the labor force significantly longer into old age, creating a flatter labor supply profile. Similarly, older unemployed workers supply significantly more job search effort into old age. Both employed and unemployed agents retire later. Lower labor dis-utility increases the aggregate labor supply and thus the social security taxable base. As a result, a smaller social security financing gap occurs under each reform requiring a lower consumption tax to balance the budget. In most other aspects, the results are qualitatively identical to the main model as seen in Tables 2 and 5.

6. Conclusion

I analyze stylized social security reforms in a novel overlapping generations model featuring labor market based on search and matching frictions, a firm posting vacancies, heterogeneous agents making endogenous job search and retirement decisions. Consistent with previous research, I find

Table 5: Simulation Results Under an Alternative Labor Disutility Assumption

	Reform 0		Reform 1		Reform 1b		Reform 2		Reform 3		Reform 4	
	SM	PC	SM	PC	SM	PC	SM	PC	SM	PC	SM	PC
Y (%)	–	–	-2.0	-1.8	-2.0	-1.6	2.8	2.1	3.4	3.0	-3.0	-3.0
K (%)	–	–	-4.3	-4.0	-4.3	-3.7	5.6	4.8	5.0	4.5	-6.6	-7.4
N (%)	–	–	-0.3	-0.2	-0.4	-0.1	1.0	0.4	2.3	2.0	-0.5	0.0
V (%)	–	–	-3.6	–	-3.3	–	3.7	–	6.2	–	-4.9	–
S (%)	–	–	1.6	–	1.7	–	-2.2	–	0.2	–	4.1	–
E (%)	–	–	-0.8	–	-0.8	–	0.9	–	5.4	–	-0.1	–
AaR	67.0	67.0	66.7	66.6	66.7	66.6	67.2	67.2	70.0	69.7	67.3	67.2
$\tilde{n}$ (%)	–	–	0.5	0.4	0.4	0.6	0.0	0.0	-3.0	-3.0	-0.4	-0.4
$\tilde{s}$ (%)	–	–	-0.1	–	0.5	–	0.9	–	-4.3	–	-0.1	–
w (%)	–	–	-1.6	-1.5	-1.6	-1.5	1.8	1.7	1.0	1.0	-2.5	-3.0
r (%)	4.5	5.1	4.8	5.4	4.8	5.4	4.1	4.8	4.3	4.9	5.0	5.7
Ben (%)	44.9	45.0	43.6	43.6	43.7	43.6	31.9	32.1	37.1	36.7	45.8	45.8
Exp (%)	–	–	-2.1	-2.8	-2.2	-2.8	-28.6	-29.0	-30.1	-30.4	-2.4	-3.1
τ_c (%)	5.8	4.5	2.2	0.8	2.3	0.9	1.4	0.6	1.1	0.3	0.7	-0.9
τ_{ss} (%)	12.4	12.4	18.9	18.9	18.7	18.7	12.4	12.4	12.4	12.4	12.4	12.4
τ_a (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	13.8

Reform simulation results for two models under an alternative labor disutility assumption. SM refers to the main model of this paper that features search and matching frictions. PC refers to an alternative version of the model with a perfectly competitive labor market. Y, K, N, and C refer to output, aggregate capital, and labor supply, respectively. V, S, E, and AaR refer to job openings posted by the firm, total job search effort, employment, and the average age at retirement, respectively. $\tilde{n}$ and $\tilde{n}$ represent the average labor supply of employed workers and job search intensity of unemployed agents. w is the wage rate, and r is the interest rate. Ben measures the average level of benefits relative to average labor income while Exp refers to government social security expenditures level. τ_c, τ_{ss} and τ_a are the consumption, payroll and capital gains tax rates, respectively. All variables, except AaR, r, Ben, τ_c, τ_{ss}, and τ_a, are presented in percent changes from the benchmark reform (Reform 0) of the respective model. Reform 0: increase in consumption tax on labor income; Reform 1: increase in social security tax on labor income; Reform 1b: increase in social security tax on labor income with the removal of taxable maximum; Reform 2: social security benefits cut; Reform 3: increase in retirement age; Reform 4: introduction of capital gains tax.

that increasing taxation to maintain unfunded social security benefits generates a long-term decrease in capital accumulation, labor supply, and consumption while decreasing benefits and/or delaying retirement deliver welfare-enhancing outcomes in the long run. I also confirm that benefits cut and increased retirement age negatively affect retirees, particularly those in the lowest 20% of the wealth distribution.

As a result of including labor market frictions, I find additional labor market mechanisms through which social security reforms affect the economy. Labor demand, job search slack, and labor market participation channels affect the unemployment and labor force participation rate. Reforms that incentive private saving and labor force participation reduce the interest rate, increase investment and labor demand, decrease job search slack, all of which contribute to lowering the unemployment level and decreasing the risk of long-term unemployment. The largest beneficiaries of these labor market channels are workers without a high level of assets to insure against a negative employment shock. I show that the presence of these channels makes private saving and labor force incentivizing policies,

such as decreasing benefits or increasing retirement age, more efficient and equitable. On the other hand, increased payroll taxation to maintain the current level of benefits increases the interest rate up, decreases labor demand, increases job search slack leading to a higher unemployment rate and worse outcomes for workers at the bottom of the wealth distribution. Via the same channels, increased taxation reduces both efficiency and equity by more than in a model without labor market frictions.

I also address the "boxed economy" that there is a fixed amount of work to be done. Policies that increase older worker labor force participation do not negatively affect the employment outcomes of the young as long as they also decrease interest rate sufficiently. Increased investment due to lowered interested rates increases labor demand and may increase employment across all age groups. Policies that drive the interest rate up such as the capital gains tax may leave the younger population facing fewer job openings and thus lower employment levels.

A perfectly competitive labor market or a labor market based on exogenously determined frictions cannot capture a change in the unemployment rate. I find that such a model may understate the beneficial efficiency and may overstate the negative equity outcomes of private saving and labor supply incentivizing policies. Similarly, they may understate the negative efficiency and and overstate positive equity effect of increasing taxation.

The introduction of additional shocks and increased worker and firm heterogeneity may further expand the analysis of this paper. A more accurate representation of US income and wealth distributions and the introduction of health shocks, among other innovations, may provide new insights about social security reforms' distributive effects. These ideas are left to future research.

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Appendices

Appendix A: The Firm's Vacancy Posting Decision

$$W(K,N) = F(K,N) - (r+\delta)K - wN - vV + (1+r)^{-1}E[W(K',N')] \tag{21}$$

$$N' = (1-\chi-H)N + VqEn'_{new} \tag{22}$$

$$F(K,N) = K^{\alpha}N^{1-\alpha} \tag{23}$$

Take derivative of Eq. 21 with respect to V.

$$v = (1+r)^{-1}E[\frac{\partial[W(K',N')]}{\partial N'}qEn'_{new}] \tag{24}$$

The envelope theorem:

$$\frac{\partial W(K,N)}{\partial N} = \frac{\partial F(K,N)}{\partial N} - w + (1+r)^{-1}(1-\chi-H)E[\frac{\partial W(K',N')}{\partial N'}] \tag{25}$$

Plugging Eq. 25 into Eq. 24 and simplifying, yields the following:

$$\frac{\partial W(K,N)}{\partial N} = v(\frac{1-\chi-H}{qEn'_{new}}) + \frac{\partial F(K,N)}{\partial N} - w \tag{26}$$

Let the firm assume the economy to be in long run equilibrium so that it expects that neither the aggregates, nor its own vacancy decisions will change in the future, so Equation 26 is identical moved one period forward.

$$\frac{\partial W(K',N')}{\partial N'} = v(\frac{1-\chi-H}{qn_{new}}) + \frac{\partial F(K,N')}{\partial N'} - w \tag{27}$$

Plugging Eq. 27 into Eq. 24 and simplifying, yields the following:

$$v = (1+r)^{-1}(\frac{\partial F(K,N')}{\partial N'} - w)qn_{new}[1 - (\frac{1-\chi-H}{1+r})]^{-1} \tag{28}$$

where

$$\frac{\partial F(K,N')}{\partial N'} = (1-\alpha)K^{\alpha}((1-\chi-H)N + Vqn_{new})^{\alpha} \tag{29}$$

$$q = V^{\phi-1}S^{1-\phi} \tag{30}$$

Appendix B: Alternative Model with Perfectly Competitive Labor Market

The alternative model highlights the value added of a frictional labor market. To compare the two models, I make only minimal adjustments to the model and use the same parameter values as described in Section 2.6. The main change to the model is that there is no job destruction ($\chi = 0$),

and thus all agents starting at age 19 are employed until they retire. Job search effort and vacancy posting become irrelevant and thus are removed.

Since description of the model is analogous to the main model, in the subsections below, I show only the parts of the model that are different. Anything not presented in this appendix is identical to the main model.

Agents

$$\text{Unemployed: } V(j,a,\eta,U) = \max_{c,a',ret} \big\{U(c,1) + \beta m_j[\{E[V(j+1,a',\eta',E)]\}(ret=0)+ \\ + V(j+1,a',R_{j+1})(ret=1)]\big\} \quad (31a)$$

subject to:

$$[1+r]a + z = (1+\tau_c)c + a' \quad (31b)$$

Firm

$$W = \max_K \{F(K,N) - (r+\delta)K - wN + E[\tilde{W}]\} \quad (32)$$

Labor Market Flows

In this alternative model, all non-retired agents are employed. Labor market flows are defined by the following equations.

$$E' = \int_{x_e} \mu(x_e)(1 - Ret(x_e))m(x_e)dx_e \quad (33)$$

$$R' = \int_{x_r} \mu(x_r)m(x_r)dx_r + \int_{x_e} \mu(x_e)(Ret(x_e))m(x_e)dx_e \quad (34)$$

Labor supply in any given period is the aggregate effective labor supply of non-retired agents.

$$N = \int_{x_e} \mu(x_e)\hat{n}(x_e)dx_e \quad (35)$$

Definition

Given demographic, labor market, and policy variables, an intertemporal equilibrium is such that:

1. consumption, saving, and retirement decisions maximize agents' utility (eqs. 3a, 31a, 5a) subject to their budget constraints (eqs. 3b, 31b, 5b);
2. hired capital maximizes firm profits (eq. 32);
3. population, capital, and total effective labor satisfy aggregation conditions: $P = \int_x \mu(x)dx$, $K = \int_x \mu(x)a(x)dx$, $N = \int_x \mu(x)\hat{n}(x)dx$ where $\mu(x)$ is the measure of agents in state x.
4. labor market flows satisfy eqs. 33, 35, and 34.
5. consumption tax is such that the government budget (eq. 11) is balanced;
6. aggregate variables, and the distribution of agents across states are stationary.

Appendix C: Solution Technique

The solution is found by making initial guesses on aggregate variables and solving the agent's problem backwards from $j = T$ (agent's last period before exiting the model) to $j = 1$ using value function iterations with discretized grids over state and choice variables.

1. Given the calibrated parameters and specific government policies, make a guess for aggregate capital (K), labor(N), total search effort (S), fraction of labor supply decrease due to retirement (H), average labor supply by a newly hired worker ($\bar{n}_{new}$), and tax rate for consumption (τ_c) that would balance the government's budget.
2. Solve for total output by the firm, interest and wage rate.

   $$Y = K_t^{\alpha} N^{1-\alpha}$$
   $$r = \alpha K^{\alpha-1} N^{1-\alpha} - \delta$$
   $$w = \gamma_w (1-\alpha) K^{\alpha} N^{-\alpha}$$

3. Solve the firm's problem for optimal number of vacancies (V_t).

   $$v = (1+r)^{-1} (\tfrac{\partial F(K,N')}{\partial N'} - w) q n_{new} [1 - (\tfrac{1-\chi-H}{1+r})]^{-1}$$

4. Solve agent's problem to get optimal policies for $\tilde{a}$, c, Ret and n if employed, s if unemployed using value function iterations with discrete grids over choice and state variables.
5. Simulate a large number of agents' lives. Aggregate the assets, labor supply and search effort across all states and find the voluntary retirement rate.

   $$K = \textstyle\int_x \mu(x) a(x) dx$$
   $$N = \textstyle\int_x \mu(x) \hat{n}(x) dx$$
   $$S = \textstyle\int_x \mu(x) s(x) dx$$
   $$H = \textstyle\int_x \mu(x) \hat{n}(x) ret(x) dx + \int_x \mu(x) \Delta\hat{n}(x) (1 - ret(x)) dx$$
   $$\overline{n}_{new} = [\textstyle\int_x \mu(x) \hat{n}(x) I_n(x) dx] / [\int_x \mu(x) I_n(x) dx]$$

   where x is a state vector ($x = \{j, a, \eta, L\}$), $\mu(x)$ is the measure of individuals in state x, $\hat{n}(x)\tilde{a}(x), c(x)$ represent the effective labor supply, asset holdings and consumption decision of agents in state x, and $I_n(x)$ represents an indicator function for whether the agent is a hired worker who was unemployed in the previous period. $\Delta\hat{n}(x)$ represents a change in labor supply from the previous period for a worker in state x.
6. Check whether the aggregates are as guessed and tax rate on consumption balances the budget. If not, update the initial guess using a smoothing parameter in Step 1 and repeat until convergence.