# Progressing towards efficiency:
# the role for labor tax progression in reforming social security*

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**Abstract**

We study interactions between progressive labor taxation and social security reform. Increasing longevity necessitates reforming social security due to raising the fiscal strain on the current systems. The current systems are redistributive, which provides (at least partial) insurance against idiosyncratic income shocks, but at the expense of labor supply distortions. A reform which links pensions to individual incomes reduces distortions associated with social security contributions, but ushers insurance loss. The existing view in the literature is that net outcome of such reform is negative. Contrary to this view, we show that progressive labor tax can partially substitute for the insurance loss when social security becomes less redistributive.

**Key words:** social security reform, labor income tax, redistribution, insurance, welfare effects

**JEL Codes:** C68, D72, E62, H55, J26

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# 1 Introduction and motivation

In this paper, we study the progressive labor tax in the context of reforming social security. Social security system in the US to some extent is redistributive, providing partial insurance against income shocks. However: with rising longevity, the current system is bound to put under the unprecedented fiscal strain (Fehr 2000, Diamond 2004, Braun and Joines 2015, Diamond et al. 2016, McGrattan and Prescott 2017). Therefore, some changes appear imperative, Reforms, proposed in the literature, usually involve linking pensions to individual contributions, thus improving efficiency at the expense of the insurance loss. There appears to be a consensus that such social security reforms (a.k.a. privatizations) reduce welfare when incomes are subject to idiosyncratic shocks (Davidoff et al. 2005, Nishiyama and Smetters 2007, Fehr et al. 2008).[1] Welfare gains arise predominantly through a reduction in distortions generated by social security contributions because, with privatized social security, there is a direct link between contemporaneous labor supply and future pension benefits. The origins of the welfare loss stem from the loss of insurance from redistribution inherent in the design of the current social security (see also Heer 2015).

In this paper we propose a novel way of reforming social security. Our reform consists of two elements. First, we replace the current defined benefit payout scheme characterized by regressive replacement rates with a defined contribution payout scheme, which links individual contributions to individual benefits. It raises efficiency as it reduces labor market distortions associated with contribution rates. Second, we propose to accompany this social security reform with adjustments in progressiveness of labor taxation. Specifically, we propose to increase progression in the income taxes. Thus, we partially *replace* the redistribution otherwise provided by social security with the one provided within the tax system. We show that more redistribution during the working periods can fully or partially compensate for the redistribution during retirement. Given the efficiency gains, privatization of social security accompanied by increased labor tax progression can improve welfare. We show that the scope for this improvement crucially depends on the response of labor supply to the social security reform. This result extends the findings of İmrohoroğlu and Kitao (2009) and Heathcote et al. (2008), who studied the response of labor supply to social security and tax progressiveness.

In a stylized theoretical model we provide basic intuitions behind our results. Agents participate in fully redistributive social security, i.e., they all receive the same benefits, regardless of the income heterogeneity during the working period and regardless of individual labor supply. They also pay progressive labor income tax. In this setup, both social security and progressive labor taxation provide insurance against income uncertainty. Then, we replace equal pension benefits with the ones proportional to individual contributions. In this setup, income shocks from the working period carry over to the retirement benefits. We complement this reform with an increase in progressiveness of the labor tax. Effectively, we replace redistributive social security with an arrangement where the individual pension benefit depends solely on individual contributions, but earned income is partially

[1] Throughout the paper we follow the literature and use welfare under the veil of ignorance as normative metric. For example, Hosseini and Shourideh (2019) work with Pareto efficiency.

insurable through progressive labor tax during the working period. We show that so long as labor response is high enough, welfare is raised in a fiscally neutral way.

We take the intuitions derived from this stylized setup to a calibrated computational general equilibrium setup, replicating the features of the US.[2] In this setup, Nishiyama and Smetters (2007) and others have shown that pooling of pension benefits across different histories of wage shocks is key to welfare effects of social security reform. In line with the earlier literature, we eliminate redistribution in social security.[3] However, in contrast to these studies we raise labor tax progression (in the spirit of Benabou 2002, Guner et al. 2014). We thus partially compensate the insurance loss from privatizing social security through greater progression in the instantaneous labor taxation. We study the extent of distortions in labor supply decisions, which allows tentative welfare inference in the spirit of (like Huggett and Parra 2010, Heathcote et al. 2008, Berger et al. 2019, Boar and Midrigan 2020). We characterize the conditions under which disincentives from redistributive social security may be reduced without loss of welfare and show that this depends on Frisch elasticity. We also provide measures of changes in distortion related to the shift in redistribution from social security to labor taxation for one specific variant of such reform. We find that for plausible calibrations of Frisch elasticity, privatizing social security coupled with labor tax progression delivers welfare gains.

To the best of our knowledge, our paper is the first to study the substitution between labor income tax progression and privatizing social security.[4] Our study, nonetheless, links several strands of the literature. First, we build on earlier work on income uncertainty, insurance and redistribution (Nishiyama and Smetters 2007, Heathcote et al. 2008, Huggett and Parra 2010, Golosov et al. 2013, 2016, Heathcote et al. 2017).

Second, our work relates to the rich literature on the social security reform in the US. Nishiyama and Smetters (2007) have linear labor taxation and use consumption tax as their fiscal instrument accompanying pension system reform. Unlike some earlier studies (Nishiyama and Smetters 2007, McGrattan and Prescott 2017, Hosseini and Shourideh 2019), we model a plausible policy of actually actually maintaining mandatory social security, which continues to be on a pay-as-you-go basis.

Third, we expand the government toolkit. Generally, most of the prior literature in this strand worked with linear labor taxation (see e.g. Andolfatto and Gervais 2008, İmrohoroğlu and Kitao

[2]The replacement rates are a progressive function of the contribution base following Old-Age, Survivors, and Disability Insurance (OASDI) with a replacement rate formula based on Average Indexed Monthly Earnings formula (AIME).

[3]We refer to this reform as privatization of the social security, because pensions become fully individualized in our setup, taking the contribution rate as given. Indeed there are two conventions of studying social security privatization in the literature. The first convention is to remove the pension system altogether and have agents finance old-age consumption from the private voluntary savings (e.g. Nishiyama and Smetters 2007, McGrattan and Prescott 2017, Hosseini and Shourideh 2019). The second convention is to introduce a defined contribution pension system, i.e. maintain contributions to social security, but in a setup where the accumulated contributions accrue interest and are converted to pension payments (e.g. Bütler 2000, Poterba et al. 2007, Attanasio et al. 2007, Börsch-Supan et al. 2014). We follow the second strand of the literature: we replace the current redistributive closely resembling public social security in the US with a defined contribution system, holding the contribution rate constant.

[4]Some earlier studies of social security reform implement progressive income taxation (e.g. Nishiyama and Smetters 2007, McGrattan and Prescott 2017, Chen et al. 2016), but to the best of our knowledge none of them uses the *changes* in the progressivity as complementary policy tool to the social security reform. Progressive income taxation has long been demonstrated to provide insurance against idiosyncratic income shocks (Varian 1980, Golosov et al. 2013, Heathcote et al. 2017). Indeed, it appears that, in a life-cycle model with idiosyncratic income shocks, labor taxation should not be linear (Findeisen and Sachs 2017).

2009, Kitao 2014, Vogel et al. 2017).[5] Our result differs from the earlier literature, because the fiscal closures considered earlier attenuate the original effects of the reform, whereas labor income tax progression complements them.

The paper is structured as follows. We discuss the intuitions concerning the role of tax progressivity in a stylized framework in section 2. The theoretical model used for simulations is presented in section 3, while section 4 describes calibration. We present the results of policy experiments in section 5 and extensions in section 6. The final section concludes, emphasizing the contribution to the literature and the policy recommendations emerging from this study.

# 2 Stylized model

We consider an OLG economy with social security and progressive income taxes. We feature two types of social security systems. In the first system, pension benefits are the same for all households, which implies that at the individual level they do not depend on contributions. We call such system Beveridgean. In the second system, pension benefits at the individual level depend on individual contributions, which results in differentiated pensions. We call such system Bismarckian.

## 2.1 Environment

Households live for two periods. For clarity of the arguments, we consider a partial equilibrium, i.e., we assume that the interest rate $r$ is given and the real wage $w_t$ grows at the exogenous rate $\gamma = r$. Furthermore, we assume that population is constant i.e. the size of the generation born in period $t$ is $N_t$ is normalized to two.

In each generation there are two types of households, each of measure one, high-productivity and low-productivity, $\theta \in \{\theta_L, \theta_H\}$ with type specific productivity $\omega \in \{\omega_L, \omega_H\}$. Our economy features a pay-as-you-go (PAYG) social security with contributions $\tau < 1$.

## 2.2 Government

For brevity, we assume that the government needs to collect enough revenue to finance exogenously given level of government expenditure $g_t$, growing at a constant rate $\gamma$. The government revenue is generated by a tax on labor income. The revenue which is not spent on government expenditure is spent on a lump-sum grant $\mu$. Hence, the government budget constraint is expressed as:

$$g_t + \sum_{\theta \in \{\theta_H, \theta_L\}} \mu_t = R_t \equiv \sum_{\theta \in \{\theta_H, \theta_L\}} \tau_\ell (1 - \tau) \omega_\theta w_t \ell_{1,t}(\theta). \tag{1}$$

Without loss of generality, we assume that the government budget is balanced. Relaxing this assumption to account for public debt growing at the rate $\gamma$ does not change our results.

[5] There is a large body of literature that analyzes the effects of systemic reforms of social security in the overlapping generations (OLG) framework (see the reviews by Lindbeck and Persson 2003, Fehr 2009, 2016).

## 2.3 Households

In the first period of their lives, households work $\ell_t$ and either spend their income on consumption $c_{1,t}$ or purchase assets $a_{1,t+1}$ that yield an exogenously given interest rate $r_t$. In the second period of their lives, households retire, that is they do not work and receive old-age pensions denoted by $b_{2,t+1}$ and consume $c_{2,t}$. Households have no bequest motive.

Household of type $\theta$ earns labor income of $y_t(\theta) = (1-\tau)w_t\omega_\theta\ell_t(\theta)$. Households pay progressive labor income tax $T_t(y) = \tau_\ell y_t - \mu_t$, where $\tau_\ell$ denotes the marginal tax rate.

Summarizing, households faces the following budget constraint:

$$\text{first period:} \quad c_{1,t}(\theta) + a_{1,t+1}(\theta) \quad = y_t(\theta) - T_t(y_t(\theta)) \tag{2}$$

$$\text{second period:} \quad c_{2,t+1}(\theta) \quad = (1+r)a_{1,t+1}(\theta) + b_{2,t+1}(\theta) \tag{3}$$

In the stylized model, we assume GHH preferences (Greenwood et al. 1988). This assumption allows to directly study the elasticity of labor with respect to changes of labor wedge associated with the contribution rates. Furthermore, to ease exposition of our results, we assume that consumption today and tomorrow are perfect substitutes. Households of type $\theta$ maximize the following utility function:

$$U(\theta) = \frac{1}{1-\sigma}\left(c_{1,t}(\theta) - \frac{\phi}{1+\eta}(1+\gamma)^t l_{1,t}(\theta)^{1+\eta} + \beta c_{2,t+1}(\theta)\right)^{1-\sigma}, \tag{4}$$

where $\sigma$ captures risk aversion, $\phi$ denotes disutility of labor, and $\eta$ denotes Frisch elasticity of labor supply. In this notation $\beta$ denotes time preference. We assume $\beta^{-1} = (1+r)$.

## 2.4 Social security

In the baseline scenario, there is a Beveridgean social security system: contributions are pooled and every households receives an equal pension benefit. With $w_{t+1} = \gamma w_t$, the pension benefit formula is given by:

$$b^{BEV}_{2,t+1}(\theta) = \tau w_{t+1} \quad \frac{1}{2} \quad \sum_{\theta\in\{\theta_H,\theta_L\}} \omega_\theta\ell_{1,t+1}(\theta). \tag{5}$$

Thus, in the Beveridgean (redistributive) social security, pension benefits for both types are the same $b^{BEV}_{2,t}(\theta_L) = b^{BIS}_{2,t}(\theta_H)$. The growth rate of wages $\gamma$ is the implicit return to social security contributions.

In the reform scenario, social security is of Bismarckian type: pension benefits are related to individual contributions:

$$b^{BIS}_{2,t+1}(\theta) = \tau(1+\gamma)w_t\omega_\theta\ell_{1,t}(\theta). \tag{6}$$

The reform from the Beveridgean system into the Bismarckian one involves two major changes. First, it generates inequality in pensions, thus reducing income insurance implicit in the social security. Second, by linking pension benefits to contributions, it reduces the distortions in labor income taxation, and thus raises efficiency.

## 2.5 Equilibrium and solving the model

**Definition 1** *A competitive partial equilibrium with social security of type $\kappa \in \{BIS, BEV\}$ is an allocation for consumer $\{(c_{1t}(\theta), \ell_{1,t}(\theta), c_{2,t+1}(\theta), a_{2,t+1}(\theta))_{\theta\in\{\theta_L,\theta_H\}}\}$, tax policy $\{T(\tilde{y})\}$ and pension benefits $\{b^{\kappa}_{2,t}\}$ such that:*

- $(c_{1t}(\theta), \ell_{1,t}(\theta), c_{2,t+1}(\theta), a_{2,t+1}(\theta))$ *maximizes utility of household of the type $\theta$ from equation* (4) *subject to budget constraints given by equations* (2) *and* (3)*, given prices, taxes and pension benefits;*
- *tax policy balances the government budget, i.e. equation* (1) *is satisfied;*
- *pension benefits are given by respective formulas* (5) *or* (6)*, depending on the type of the social security system $\kappa$.*

Since households are indifferent between consuming in the first and the second period there there is continuum of solutions of the household problem. For simplicity, we assume that $c_{2,t+1} = 0$ for all types of households and all types social security. With these simplifications we can see the effect on welfare almost by looking at consumption in fist period, which is given by

$$\begin{aligned} c^{BEV}_{1,t}(\theta) &= (1-\tau_\ell(1-\tau))\omega_\theta w_t \ell^{BEV}_{1,t}(\theta) + \mu^{BEV}_t - \frac{1}{2} w_t \tau(\omega_\theta \ell^{BEV}_{1,t}(\theta) - \omega_{-\theta}\ell^{BEV}_{1,t}(-\theta)) \\ c^{BIS}_{1,t}(\theta) &= (1-\tau_\ell(1-\tau))\omega_\theta w_t \ell^{BIS}_{1,t}(\theta) + \mu^{BIS}_t. \end{aligned}$$

Comparing consumption under the two social security systems reveals three effects: the efficiency effect, the decline in redistribution in the social security, and the increase in redistribution in the tax system. The first two effects have been well identified in the prior literature, we propose to consider the role of the third one.

$$\begin{aligned} c^{BIS}_{1,t}(\theta) - c^{BEV}_{1,t}(\theta) = \underbrace{\omega_\theta w_t(\ell^{BIS}_1(\theta) - \ell^{BEV}_1(\theta))}_{\text{efficiency effect}} - \underbrace{\frac{1}{2}\tau w_t(\omega_\theta \ell^{BEV}_{1,t}(\theta) - \omega_{-\theta}\ell^{BEV}_{1,t}(-\theta))}_{\text{social security redistribution effect}} \\ + \underbrace{(\Delta\mu_t - \tau_\ell(1-\tau))\omega_\theta w_t(\ell^{BIS}_1(\theta) - \ell^{BEV}_1(\theta))}_{\text{tax system redistribution effect}} \end{aligned} \quad (7)$$

where $\Delta\mu_t = \mu^{BIS}_t - \mu^{BEV}_t$. Solving the household problem, we get the following formulas determining labor supply:

$$\ell^{BEV}_{1,t}(\theta) = [\frac{1}{\phi}(1-\tau_\ell)(1-\tau)\omega_\theta]^\eta \quad \text{and} \quad \ell^{BIS}_{1,t}(\theta) = [\frac{1}{\phi}(1-\tau_\ell(1-\tau))\omega_\theta]^\eta \quad (8)$$

We employ the notion of the labor wedge which we define it as the discrepancy between a household's marginal rate of substitution between labor and consumption and the wage. In the Beveridgean social security, the labor wedge equals $\tau_\ell + \tau - \tau_\ell\tau$ and includes the social security contributions in the same way as taxes. In the Bismarckian social security, contemporaneous contributions raised from hours worked translate to future income. Under the assumption that $\gamma = r$, the labor wedge equals $\tau_\ell - \tau_\ell\tau$ the contributions no longer distort labor supply decisions.

A brief look at our setup reveals several important observations. First, regardless of the social security, $\theta_H$-type households work more than $\theta_L$-type households. Second, $\theta_H$-type households clearly consume more when we replace the Beveridgean social security with a Bismarckian one (the case of $\theta_L$-type households is less clear-cut, as we elaborate later). Third, the ratio between the labor supply $\theta_H$-type and $\theta_L$-type households is constant and depends on the Frisch elasticity and the productivity ratio:

$$\frac{\ell^{BEV}(\theta_H)}{\ell^{BEV}(\theta_L)} = \frac{\ell^{BIS}(\theta_H)}{\ell^{BIS}(\theta_L)} = \left(\frac{\omega_H}{\omega_L}\right)^{\eta} \equiv \varpi^{\eta} > 1. \tag{9}$$

Fourth, the percentage change in labor supply due to the change in social security arrangements is also constant:

$$\frac{\ell^{BIS}(\theta) - \ell^{BEV}(\theta)}{\ell^{BEV}(\theta)} = \frac{\Delta\ell(\theta)}{\ell^{BEV}(\theta)} = \left(\frac{(1-\tau_\ell(1-\tau))}{(1-\tau-\tau_\ell(1-\tau))}\right)^{\eta} - 1 \equiv \xi^{\eta} - 1 \tag{10}$$

With these observations, we move to providing intuitions on the effects our reform. To this end we start by characterizing the three effects, the efficiency, the social security redistribution and the labor tax redistribution.

**Efficiency effect** is the standard result in the literature on social security reform (Feldstein 1976, Nishiyama and Smetters 2007, Huggett and Parra 2010). Essentially, if in the consumer problem the current social security contributions do not imply future pension benefits, the contributions have the same distortionary effect as taxes. If, however, current contributions imply future benefits, at a fair accrual rate, the contributions are (an admittedly forced) deferment of consumption. In our context, replacing Beveridgean social security with a Bismarckian one reduces labor supply distortion.

**Proposition 1 (Efficiency effect)** *Replacing the Beveridgean social security with the Bismarckian reduces labor wedge, increases labor supply and improves welfare for both both $\theta_H$-type and $\theta_L$-type households.*

The decline in labor wedge and the increase of labor supply follows from equation (8). The improvement of welfare follows from the envelope theorem. Thus, with social security reform from Beveridgean to Bismarckian formula, due to the effciency effect, labor wedge is reduced, labor supply goes up and welfare is increased for both types of households.

**Redistribution in social security** Intuitively, as an effect of replacing Beveridgean social security with a Bismarckian one, $\theta_H$-type households receive higher pension benefit and $\theta_L$-type households receive lower pension benefit. This is a well recognized mechanism, with large body of literature arguing that the insurance provided by redistributive social security is of key importance in evaluating the welfare effects of social security reforms (Davidoff et al. 2005, Nishiyama and Smetters 2007, Fehr et al. 2008). Clearly, an increase in labor supply by $\theta_L$-type households partially offsets this decline to attenuate the decline in $b_{2,t}$.

$$\begin{aligned}
b_t^{BIS}(\theta)-b_t^{BEV}(\theta) &= \tau w_t\omega_\theta \ell_{1,t-1}^{BIS}(\theta)-\frac{1}{2}\tau w_t\sum_{\theta\in\{\theta_L,\theta_H\}}\omega_\theta\ell_{1,t}^{BEV}(\theta)\\
b_t^{BIS}(\theta_H)-b_t^{BEV}(\theta_H) &= \frac{\tau w_t}{2}[\underbrace{\omega_H(\ell_1^{BIS}(\theta_H)-\ell_1^{BEV}(\theta_H))}_{\text{efficiency effect }>0}+\underbrace{(\omega_H\ell^{BIS}(\theta_H)-\omega_L\ell_1^{BEV}(\theta_L)}_{\text{redistribution effect}>0}]\\
b^{BIS}(\theta_L)-b^{BEV}(\theta_L) &= \frac{\tau w_t}{2}[\underbrace{\omega_L(\ell^{BIS}(\theta_L)-\ell^{BEV}(\theta_L))}_{\text{efficiency effect }>0}+\underbrace{(\omega_L\ell^{BIS}(\theta_L)-\omega_H\ell^{BEV}(\theta_H)}_{\text{redistribution effect}<0}]
\end{aligned}$$

In case of $\theta_H$-type households, the pension benefits are higher in Bismarckian system since both the efficiency effect (associated with the increase of labor supply due to pension formula change) and the redistribution effect (associated with making pensions more uneven) are positive. In case of $\theta_L$-type households, the redistribution effect is negative. The overall change in pension benefits in Bismarckian system depends on the relative relative strength of the efficiency and the redistribution effect.

**Proposition 2 (Social security redistribution)** *Consider a reform bundle: a change of social security from a Beveridgean to a Bismarckian formula, and fiscally neutral redistribution through lump-sum grants in the tax system. Such reform bundle entails negative transfers from $\theta_H$-type households to the $\theta_L$-type households through the pension system.*

**Proof of Proposition 2.** First, we compute the redistribution in the social security under the Beveridgean social security as net present value of pension benefits less pension contributions:

$$NT_t^{BEV}(\theta)=\frac{b_{2,t+1}^{BEV}(\theta)}{1+r}-\tau w_t\omega_\theta\ell_{1,t}^{BEV}(\theta)=\frac{\tau w_{t+1}\frac{1}{2}\sum_{\theta\in\{L,H\}}\omega_\theta\ell_{1,t+1}^{BEV}(\theta)}{1+r}-\tau w_t\omega_\theta\ell_{1,t}^{BEV}(\theta).$$

Using $\ell_1^{BEV}(\theta_H)>\ell_1^{BEV}(\theta_L)$, which follows from equation (8):

$$NT_t^{BEV}(\theta_L)=\tau w_t\frac{1}{2}[\omega_H\ell_1^{BEV}(\theta_H)-\omega_L\ell_1^{BEV}(\theta_L)]>0 \quad \text{and} \quad NT_t^{BEV}(\theta_L)=-NT_t^{BEV}(\theta_H)$$

Next, notice that by construction there is no within-cohort redistribution in Bismarckian social security. Finally, we compute the change in transfers through social security due to the reform for both types of individuals. We express it as a percent of low type income

$$\begin{aligned}
\frac{\Delta NT^{Pen}(\theta_L)}{\omega_L w_t\ell_t^{BEV}(\theta_L)} &= -\frac{\tau w_t\frac{1}{2}[\omega_H\ell_1^{BEV}(\theta_H)-\omega_L\ell_1^{BEV}(\theta_L)]}{\omega_L w_t\ell_t^{BEV}(\theta_L)}=-\frac{1}{2}\tau(\varpi^{1+\eta}-1)<0\\
\frac{\Delta NT^{Pen}(\theta_L)}{\omega_L w_t\ell_t^{BEV}(\theta_L)} &= -\frac{\Delta NT^{Pen}(\theta_H)}{\omega_L w_t\ell_t^{BEV}(\theta_L)}=\frac{1}{2}\tau(\varpi^{1+\eta}-1)>0
\end{aligned}$$

■

Thus, the social security reform from Beveridgean to Bismarckian formula, redistributes from $\theta_L$-type households to $\theta_H$-type households. Therefore, it improves welfare of $\theta_H$-type households and impairs welfare of $\theta_L$-type households households.

**Channeling redistribution through progressive tax system** Observe that from equation (8), with $\tau > 0$ the distortions to labor supply are lower in the Bismarckian social security than than in the Beveridgean one. Equation (10) displays the change in labor supply if a reform implements Bismarckian pension benefit formula rather than Beveridgean one. The labor supply increase is of the same magnitude (in percent terms) for both types of households, and depends on Frisch elasticity. With the constant marginal tax rate, the government revenue increases due to labor supply increase. This increase occurs by the same percentage as the labor supply.

$$\frac{R_t^{BIS} - R_t^{BEV}}{R_t^{BEV}} = \frac{\tau_\ell(1-\tau)w_t\omega_H(\Delta\ell(\theta_H)) + \tau_\ell(1-\tau)w_t\omega_L(\Delta\ell(\theta_L))}{\tau_\ell(1-\tau)w_t\omega_H\ell_t^{BEV}(\theta_H) + \tau_\ell(1-\tau)w_t\omega_L\ell_t^{BEV}(\theta_L)} = \xi^\eta - 1 \tag{11}$$

Note that since $\xi > 1$, then the derivative of equation (11) with respect to $\eta$ is given by $\xi^\eta \ln \xi > 0$ and is easy to see that for $\eta \to 0$ and for $\eta \to \infty$

$$\lim_{\eta\to 0} \frac{R_t^{BIS} - R_t^{BEV}}{R^{BEV}} = \lim_{\eta\to 0} \xi^\eta - 1 = 0 \ , \ \lim_{\eta\to\infty} \frac{R_t^{BIS} - R_t^{BEV}}{R^{BEV}} = \lim_{\eta\to\infty} \xi^\eta - 1 = \infty$$

Since $\xi^\eta - 1$ is continuous in $\eta$, for $\eta \to 0$ it converges to $0$, and for $\eta \to \infty$ it converges to $\infty$. Thus the change in government revenue, depending on the value of the Frisch elasticity $\eta$, can attain any value from $0$ to $\infty$.

Next, we show that if we spend extra government revenue on lump-sum grants, then this grant may compensate the losses of the $\theta_L$-type households. The increase in government revenue stems from increased labor supply by *both* $\theta_L$-type and $\theta_H$-type households. With analogous increase in labor supply in percent terms, in absolute terms labor supply increases more for $\theta_H$-type households, thus these households pay in total more taxes in absolute terms. If this revenue is distributed as a lump-sum grant among both types of households, the tax system redistributes from $\theta_H$-type households to $\theta_L$-type households.

**Proposition 3 (Tax system redistribution)** *Consider a reform bundle: a change of social security from a Beveridgean to a Bismarckian formula, and fiscally neutral redistribution through lump-sum grants in the tax system. Such reform bundle entails positive transfers from $\theta_H$-type households to the $\theta_L$-type households through the tax system. The larger $\eta$, the larger are these transfers through the tax system.*

**Proof of Proposition 3.** The change in net tax transfer is given by $\Delta NT_t^{Tax}(\theta) = \Delta\mu_t - \tau_\ell(1-\tau)\omega_\theta w_t \Delta\ell_t(\theta)$. We express it relative to the status quo.

$$\frac{\Delta NT^{Tax}(\theta_L)}{\omega_L w_t \ell_t^{BEV}(\theta_L)} = -\frac{\Delta NT^{Tax}(\theta_H)}{\omega_L w_t \ell_t^{BEV}(\theta_L)} = \frac{1}{2}\tau_\ell(1-\tau)(\xi^\eta - 1)(\varpi^{1+\eta} - 1) > 0$$

Accordingly, the tax system redistributes from $\theta_H$-type households to $\theta_L$-type households. ■

Finally, we show that the reform bundle entailing a change from a Beveridgean to a Bismarckian formula and redistribution of increased labor income tax revenue through a lump-sum grant may improve welfare that is raise the total welfare in the society. In fact, there can be an improvement in welfare in Pareto sense, i.e., welfare of both household types can be raised directly. There are three effects of such a reform: efficiency effect, tax redistribution effect and pension redistribution effect. Efficiency effect improves welfare of both types of households, pension redistribution effect reduces welfare of $\theta_L$-type household and improves welfare of $\theta_H$-type household. Tax redistribution effect has the opposite effect. In other words, the redistribution embedded in the Beveridgean social security may be replaced by redistribution in the tax system when social security reform creates efficiency gains.

**Proposition 4 (Hicks and Pareto welfare improvement)** *Consider a reform bundle: a change of social security from a Beveridgean to a Bismarckian formula, and fiscally neutral redistribution through lump-sum grants in tax system. There exists $\underline{\eta} > 0$, such that for $\eta \geqslant \underline{\eta}$, such a reform bundle improves an utilitarian social welfare function $W = \sum_{\theta \in \{\theta_L, \theta_H\}} U(\theta)$. Furthermore, there exists $\bar{\eta} > \underline{\eta}$, such that for $\eta \geqslant \bar{\eta}$, welfare of both types of households goes up.*

**Proof of Proposition 4.** First, from Proposition 1 we know that welfare of both types goes up due to efficiency effect. Second, the redistribution effect of the reform in the social security formula reduces welfare of $\theta_L$-type household and improves welfare of $\theta_H$-type household. This follows from Proposition 2. Third, change in net transfer through the tax system is positive for $\theta_L$-type households and negative for $\theta_H$-type households follows from Proposition 3. Overall, it is easy to see that $\theta_H$-type households always gain. Therefore, we focus on $\theta_L$-type households.

For Pareto improvement, define $\bar{\eta}$ such that the net redistribution effect for $\theta_L$-type households equals zero, i.e. it satisfies the following equation

$$\frac{\Delta NT^{Tax}(\theta_L)}{\omega_L w_t \ell_t^{BEV}(\theta_L)} = \frac{\Delta NT^{PB}(\theta_L)}{\omega_L w_t \ell_t^{BEV}(\theta_L)} \quad \Leftrightarrow \quad \frac{1}{2}\tau_\ell(1-\tau)(\xi^\eta - 1)(\varpi^{1+\eta} - 1) = \frac{1}{2}\tau(\varpi^{1+\eta} - 1) \quad (12)$$

Notice also that when we cancel out relevant terms the the right left hand side of this equation is increasing with $\eta$, while the right hand side is constant. Furthermore, for $\eta$ between zero and infinity the left hand side also assumes values between zero and infinity. Therefore, there exists $\tilde{\eta} > 0$ that satisfies equation (12).

Since for $\eta = \bar{\eta}$ tax and social security redistribution effects cancel out, then for $\theta_L$-type households welfare rises due to the efficiency effect. By continuity of the left hand side of equation (12) there exists $\bar{\eta} < \tilde{\eta}$ such that for this case the welfare of $\theta_L$-type households remains unchanged after the reform. Thus for all $\eta \geqslant \bar{\eta}$ the reform is Pareto improving.

For utilitarian social welfare, by continuity continuity of the left hand side of equation (12) and of the utility function, for all $\eta$'s in the small enough neighborhood of $\bar{\eta}$ the decline of $U(\theta_L)$ is small enough to be offset by an increase of $U(\theta_H)$, hence $\exists \underline{\eta} < \bar{\eta}$, such that $\forall \eta \geqslant \underline{\eta}$ the reform improves the utilitarian social welfare function $W = \sum_{\theta \in \{\theta_L, \theta_H\}} U(\theta)$. ■

Intuitively, for higher values of the Frisch elasticity the response of labor is stronger. It generates more tax revenue and results in high lump sum transfers. If the response of labor is strong enough the increase in lump sum transfers can make up for the lower pensions of $\theta_L$-type households.

Observe also that since $\eta$, satisfying equation (12) does not depend on $\varpi$, the scope of inequality in a society does not affect the ability to achieve Pareto improvement. By contrast, whether or not a given society has Frisch elasticity above or below $\bar{\eta}$ – i.e. whether or not a reform bundle can yield Pareto improvement – depends on the size of the labor tax wedge before the reform and the size of the social security. Indeed, the larger the tax rate $\tau_\ell$, the smaller $\bar{\eta}$.

### 2.6 Implications for a large computational model

In the stylized setup we portray the key trade-offs. We show that it is possible to improve welfare in Pareto sense even if social security reform completely removes insurance against income shocks. This is possible if reduced labor market distortions boost labor supply enough for labor tax revenues to allow sufficient redistribution in the tax system. We show that the ability to introduce such reform bundle depends crucially on the Frisch elasticity.

Nevertheless our using partial equilibrium setup leads to some simplifications. First, wages are not affected by changes in the labor supply due to reform. Second, all risk is realized in the beginning of lifetime, thus agents do not face any risk during lifetime. Third, with GHH preferences there is no income effect associated with change in disposable income, which may lead to lower response of labor supply to reform. Finally, the US social security is more complicated than the one employed in this section. In a full, calibrated model part of the adjustment occurs via changes in the inter-temporal choices by the households with wages responding to changes in labor supply. Computational model permits identification to what extent the presented intuitions carry through to a general equilibrium setup.

In summary, in the next sections we ask in a fully calibrated setup if appropriate tax reform accompanying a replacement of the current, unsustainable defined benefit pension system in the United States, replicates the above stylized findings for a broad range of assumptions concerning the deep parameters of the model.

## 3 General equilibrium model

**Population dynamics** Households live for $j = 1, 2..., J$ periods and are heterogeneous with respect to age $j$; one period corresponds to 5 years. Households are born at the age of 20, which we denote $j = 1$ to abstract from the problem of the labor market entry timing as well as educational choice. The size of cohort of age $j$ in period $t$ is denoted as $N_{j,t}$ Consumers face age and time-specific survival rates $\pi_{j,t}$, which are unconditional probabilities of surviving up to age $j$ in period $t$. At all points in time, consumers who survive until the age of $J = 20$ die with certitude.

**Productivity heterogeneity** Let be $e_{j,t}$ a deterministic age-efficiency profile, which is a function of the households' age. Let $\epsilon_{j,t}$ be a persistent earnings shock that follows a AR(1) process[6] with

[6] As is standard in the literature (Nishiyama and Smetters 2007, Heathcote et al. 2008, Huggett and Parra 2010, Golosov et al. 2016, Heathcote et al. 2017), we approximate the process above by a first order Markov chain with a transition matrix $\Pi(\ln(\epsilon_{j,t})|\ln(\epsilon_{j-1,t-1}))$.

persistence parameter $\varrho$ and $\varepsilon_{j,t} \sim \mathbf{N}(0, \sigma^2)$;

$$\ln(\epsilon_{j,t}) = \varrho \ln(\epsilon_{j-1,t-1}) + \varepsilon_{j,t}. \tag{13}$$

Individual productivity evolves over lifetime according to the following formula, $\omega_{j,t} = e_{j,t}\epsilon_{j,t}$. Individual may differ in their initial wage shock, the variance of the initial shock realization is given by $\sigma_0^2$.

**Budget constraint** Households aged below the retirement age earn gross labor income $\omega_{j,t} w_t l_{j,t}$, where $w_t$ is the marginal productivity of aggregate labor and $l_{j,t}$ denotes labor supply. Labor income is subject to social security contribution at the rate $\tau$ and progressive labor income tax denoted by $\mathcal{T}(y_{j,t})$ where $y_{j,t} = (1-\tau)w_t/z_t\omega_{j,t}l_{j,t}$. Following Benabou (2002) we use the following schedule

$$\mathcal{T}(y_{j,t}) = y_{j,t} - (1-\tau_\ell)y_{j,t}^{1-\lambda},$$

where the elasticity of post-tax to pretax income is denoted to $1-\lambda$, and level of tax rate is determined by $\tau_\ell$. Note that social security contributions are exempt from labor taxation.

In addition to salary, income also consists of after-tax capital gain $(1-\tau_k)r_t a_{j,t}$ (with $\tau_k$ denoting capital income tax, $r_t$ the interest rate and $a_{j,t}$ denoting assets holdings at age $j$) as well as pension benefits $b_{j,t}$, which households receive once they reach retirement age. There is no income tax on pension benefits. Moreover, since survival rates $\pi_{j,t}$ are lower than one, in each period $t$ there are unintended bequests, which are distributed within cohort, $\Gamma_{j,t}$. Income is used for purchasing consumption goods $c_{j,t}$, which are subject to consumption tax $\tau_{c,t}$ and accumulation of assets $a_{j+1,t+1}$. Assets markets are incomplete; only assets with risk free interest rate $r_t$ are available. In summary, the households face the following instantaneous budget constraint:

$$a_{j+1,t+1} + (1+\tau_{c,t})c_{j,t} = z_t y_{j,t} - z_t\mathcal{T}(y_{j,t}) + b_{j,t} + (1+(1-\tau_k)r_t)\, a_{j,t} + \mu_t + \Gamma_{j,t}, \tag{14}$$

with positive assets ($a_{j+1,t+1} \geqslant 0$), and where $\mu_t$ denotes lump sum subsidies that will be discussed later.

**Social security and social security reform** In the baseline scenario, we replicate the features of social security as currently implemented in the US. It is a pay-as-you-go defined benefit system, with *average indexed monthly earnings* (AIME) defining the beneift drawing rights, that is effectively a replacement rate. The social security has a contribution rate $\tau$. AIME is redistributive: for low earnings the replacement rate is high ($\rho = 90\%$) and for high earnings the replacement rate is low

($\rho = 15\%$).[7] Hence, the drawing rights in *status quo* social security $f^B_{j_1,t+1}$ are defined as:

$$f^B_{j+1,t+1} = F^B(f^B_{j,t}, \omega_{j,t}w_t l_{j,t}) = \frac{1}{j}\left((j-1)\cdot f^B_{j,t} + \frac{\min\{\omega_{j,t}w_t l_{j,t}, \widetilde{\omega w_t l_t}\}}{\overline{\omega w_t l_t}}\right), \tag{15}$$

where $\overline{\omega w_t l_t}$ is average earnings, and $\widetilde{\omega w_t l_t}$ denotes the old-age, survivor and disability insurance cap (OASDI cap); the replacement rate $\rho_{\bar{J},t}$ is consistent with:

$$\rho_{\bar{J},t}\cdot f^B_{\bar{J},t} = 0.9\cdot\min\{f_{\bar{J},t}, F_{1,t}\} + 0.32\cdot\min\{f_{\bar{J},t} - F_{1,t}, F_{2,t}\} + 0.15\cdot(f_{\bar{J},t} - F_{2,t}). \tag{16}$$

To replicate the progressive nature of the replacement rate, we rely on bend points $(F_{1,t}, F_{2,t})$ expressed as a fraction of average earnings (McGrattan and Prescott 2017). The value of the old-age pension benefit for a cohort retiring in period $t$ is given by the following formulas

$$b^B_{\bar{J},t} = \rho_m\rho_{\bar{J},t}\cdot f^B_{\bar{J},t}\overline{\omega w_t l_t} \quad \text{and} \quad \forall j > \bar{J} \quad b^B_{j,t} = (1+r_{l,t})b^B_{j-1,t-1}, \tag{17}$$

where $\bar{J}$ denotes retirement age and $\rho_m$ is set to match steady state pension benefit to GDP ratio[8], and $r_{l,t} = \frac{w_t L_t}{w_{t-1}L_{t-1}} - 1$ is payroll growth rate (with $L_t$ denoting aggregate labor supply),

In the reform scenario, this social security is replaced with a defined contribution system, financed on a pay-as-you-go basis. Contributions are transformed into entitlements $f^R_{j,t}$ which are indexed with the payroll growth rate $r_{l,t}$ and evolve according to the following equation:

$$f^R_{j,t} = (1+r_{l,t})f^R_{j-1,t-1} + \tau\omega_{j,t}w_t l_{j,t}, \tag{18}$$

At retirement they are converted into annuitized pension benefits according to the following formula

$$b^R_{\bar{J}_t,t} = f^R_{\bar{J},t}/LE \quad \text{and} \quad \forall_{j>\bar{J}} \;\; b^R_{j,t} = (1+r_{l,t})b^R_{j-1,t-1}. \tag{19}$$

where $LE = \sum_{s=0}^{J-\bar{J}} \frac{\pi_{\bar{J}+s,t+s}}{\pi_{\bar{J},t}}$ denotes conditional life expectancy at retirement age.

**Consumer problem** An individual state of each household at age $j$ at time $t$ $s_{j,t}$ can be summarized by the level of private assets $a_{j,t}$, pension funds $f_{j,t}$ and idiosyncratic part of individual productivity determined by $\epsilon_{j,t}$, $s_{j,t} = (a_{j,t}, f_{j,t}, \omega_{j,t}) \in \Omega$. A household enters the economy with no assets ($a_{1,t} = 0$) and at the state $s_{j,t}$ the household maximizes the expected value of the lifetime utility. The households discounts future with the time preference parameter $\delta$ and the conditional survival probability $\pi_{j+1,t+1}/\pi_{j,t}$. We define the optimization problem of the household in a recursive form as:

[7] The cap on contributions in our model is replicated as contributions with a $\rho = 0$. In the data, 6% of workers hit the cap, it is 3% of individuals and 2% of income in our model. https://www.ssa.gov/policy/docs/population-profiles/tax-max-earners.html.

[8] The adjustment through $\rho_m$ stems from the fact that AIME is computed based the best 35 years of career in the actual system and it is computed based on the whole working period in our setup. With 5 year periods, selecting the best 35 years is redundant.

$$V_{j,t}(s_{j,t}) = \max_{(c_{j,t}, l_{j,t}, a_{j+1,t+1})} u(c_{j,t}, l_{j,t}) + \delta \frac{\pi_{j+1,t+1}}{\pi_{j,t}} \mathbf{E}\big(V_{j,t+1}(s_{j+1,t+1}) \mid s_{j,t}\big), \tag{20}$$

subject to the budget constraint given by equation (14), formulas for pensions given by (17) or (19), depending on the pension system, and the productivity process given by equation (13). The total time endowment is normalized to one. The instantaneous utility from consumption and leisure, as given by:

$$u(c_{j,t}, l_{j,t}) = \frac{c_{j,t}^{1-\sigma}}{1-\sigma} - \phi \frac{l_{j,t}^{1+\eta}}{1+\eta}. \tag{21}$$

**Production** Using capital $K_t$ and labor $L_t$, the economy produces final output. Production function takes the standard Cobb-Douglas form $Y_t = K_t^{\alpha}(z_t L_t)^{1-\alpha}$ with labor augmenting exogenous technological progress, $z_{t+1}/z_t = \gamma_{t+1}$. Capital depreciates at the rate $d$. Standard maximization problem of the firm yields the interest rate and real wage

$$r_t = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d \quad \text{and} \quad w_t = (1-\alpha) K_t^{\alpha} z_t^{1-\alpha} L_t^{-\alpha}. \tag{22}$$

**Government** The tax revenue $T_t$ is used to finance spending on public goods and services $G_t$, subsidize (if necessary) the social security $subsidy_t$, and service debt $r_t D_{t-1}$ with $\Delta D_t = D_t - D_{t-1}$.

$$G_t + subsidy_t + r_t D_t = T_t + \Delta D_t, \tag{23}$$

$$\text{where } T_t = \sum_{j=1}^{\bar{J}-1} N_{j,t} \int_{\Omega} z_t \mathcal{T}\big(y_{j,t}(s_{j,t})\big) d\mathbb{P}_{j,t} + \tau_{k,t} r_t A_t + \tau_{c,t} C_t - \sum_{j=1}^{J} N_{j,t}\mu_t, \tag{24}$$

$C_t$ and $A_t$ denote, respectively, aggregate consumption and aggregate assets. We assume that $G_t$ is the same both in status quo and in reform.

The budget constraint of the pension system is given by the balance of the total contributions and the total pension benefit payments:

$$subsidy_t = \tau w_t \sum_{j=1}^{\bar{J}} N_{j,t} \int_{\Omega} \omega_{j,t}(s_{j,t}) l_{j,t}(s_{j,t}) d\mathbb{P}_{j,t} - \sum_{j=\bar{J}}^{J} N_{j,t} b_{j,t}. \tag{25}$$

where $b_{j,t} = b_{j,t}^{B}$ in status quo and $b_{j,t} = b_{j,t}^{R}$ in the reform. In status quo, social security balance is financed by the government. With social security privatization (as is our reform), its budget becomes balanced by construction.

In status quo, lump-sum transfer $\mu_t$ is set to zero. In the reform scenario we introduce additional progressivity with positive $\mu_t$. The size of the transfer is fiscally neutral, that is it is set such that the government budget is balanced:

$$\mu_t = \frac{G_t + subsidy_t + r_t D_t - \Delta D_t - \left(\sum_{j=1}^{\bar{J}-1} N_{j,t} \int_{\Omega} \mathcal{T}\big(y_{j,t}(s_{j,t})\big) d\mathbb{P}_{j,t} + \tau_k r_t A_t + \tau_c C_t\right)}{\sum_{j=1}^{J} N_{j,t}}.$$

## 3.1 Equilibrium and model solving

We employ the notion of a recursive competitive equilibrium. Recall that the state of an agent at age $j$ at time $t$ is fully characterized by $s_{j,t} = (a_{j,t}, f_{j,t}, \epsilon_{j,t}) \in \Omega$. We denote the probability measure describing the distribution of agents of age $j$ in period $t$ over the state space $\Omega$ as $\mathbb{P}_{j,t}$. Next we define equilibrium for our economy.

**Definition 2 (Recursive equilibrium)** *A recursive competitive equilibrium is a sequence of value functions* $\{(V_{j,t}(s_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$*, prices* $\{r_t, w_t\}_{t=1}^{\infty}$*, government policies* $\{\tau_c, \tau_k, \tau_l, \lambda, \mu_t, D_t,\}_{t=1}^{\infty}$*, policy functions* $\{(c_{j,t}(s_{j,t}), l_{j,t}(s_{j,t}), a_{j+1,t+1}(s_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$*, social security parameters* $\{\tau, subsidy_t, \rho_m\}_{t=1}^{\infty}$*, aggregate quantities* $\{L_t, A_t, K_t, C_t, Y_t\}_{t=1}^{\infty}$*, and a measure of households* $\mathbb{P}_{j,t}$ *such that:*

- **consumer problem:** *for each $j$ and $t$ the value function $V_{j,t}(s_{j,t})$ and the policy functions $(c_{j,t}(s_{j,t}), l_{j,t}(s_{j,t}), a_{j+1,t+1}(s_{j,t}), f_{j+1,t+1}(s_{j,t}))$ solve the Bellman equation* (20) *for given prices;*
- **firm problem:** *for each $t$, prices $(r_t, w_t)$ are given by equations* (22)*;*
- **government sector:** *the government budget and the PAYG pension system are balanced, i.e. equations* (23), (25) *and* (24) *are satisfied;*
- **markets clear**

$$
\begin{aligned}
\textit{labor market:} \quad L_t &= \sum_{j=1}^{\bar{J}} N_{j,t} \int_{\Omega} \omega_{j,t}(s_{j,t}) l_{j,t}(s_{j,t}) d\mathbb{P}_{j,t}; \\
\textit{capital market:} \quad A_t &= \sum_{j=1}^{J} N_{j,t} \int_{\Omega} a_{j,t}(s_{j,t}) d\mathbb{P}_{j,t}, \\
K_{t+1} &= A_t + D_t; \\
\textit{goods market:} \quad C_t &= \sum_{j=1}^{J} N_{j,t} \int_{\Omega} c_{j,t}(s_{j,t}) d\mathbb{P}_{j,t}, \\
Y_t &= C_t + K_{t+1} - (1-d)K_t + G_t;
\end{aligned}
$$

- **probability measure:** *for all $t$ and for all $j$, $\mathbb{P}_{j,t}$ is consistent with the assumptions about productivity processes and policy functions.*

We solve the consumer problem with value functions iterations. In order to reduce the dimensionality of the state space we use the implicit tax approach (Butler 2002). We discretize the reduced state space $\hat{\Omega} = \hat{A} \times \hat{F} \times \hat{H}$ with $\hat{A} = \{a^1, ..., a^{n_A}\}$, $\hat{F} = \{f^1, ..., f^{n_F}\}$, and $\hat{H} = \{\epsilon^1, ..., \epsilon^{n_H}\}$, where $n_A = 300$, $n_F = 15$, and $n_H = 5$. We interpolate policy and value functions with piece-wise linear functions (using recursive Powell's algorithm). For each discrete $\hat{s}_{j,t} \in \hat{\Omega}$ we find the optimal consumption and labor supply of the agent using Newton-Raphson method.[9]

For given initial distribution $\hat{\mathbb{P}}_{1,t}$ at age $j = 1$ and time $t$ and transition matrix $\Pi(\eta_{j,t}|\eta_{j-1,t-1})$ and the policy functions $\{a_{j+1,t+1}(\hat{s}_{j,t}), f_{j+1,t+1}(\hat{s}_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$ we can compute the distribution in

[9]Due to the nonlinear labor income tax, the consumption-leisure choice has to be solved numerically.

any successive age $j$ and period $t$. It can be interpreted as a fraction of cohort of age $j$ at time $t$ residing at each state of the state space $\hat{\Omega}$.

Once we compute distributions and policy functions for each state, we compute aggregate quantities of consumption, labor and savings. To this end we use Gaussian quadrature method. Once the consumer problem is solved for a given set of prices and taxes, we apply the Gauss-Seidel algorithm to obtain the general equilibrium. Using the outcome of the consumer problem, the value of aggregate capital is updated. The procedure is repeated until the difference between the aggregate capital from subsequent iterations is negligible, i.e. $l_1$-norm of the difference between capital vector in subsequent iterations falls below $10^{-12}$.

### 3.2 Measuring welfare effects

The cohort-specific welfare effects of the reform are defined as a consumption equivalent, expressed as a percent of a lifetime consumption. Consumption equivalent for each agent is a percent of post-reform consumption that they would be willing to give up or receive in order to be indifferent between baseline and reform scenario. We calculate the welfare effect under the veil of ignorance. To derive a formula for the welfare effect analytically, we split the value function in baseline and reform scenario into two parts: $V_c$ (which refers to utility derived from consumption) and $V_l$ (which refers to disutility from working). Therefore the value function for the agent $j$ years old at time $t$ is given by:

$$V_{c,j,t}\left(c_{j,t}(s_{j,t})\right) = \frac{c_{j,t}^{1-\sigma}}{1-\sigma} + \delta\frac{\pi_{j+1,t+1}}{\pi_{j,t}}\mathbf{E}\big(V_{c,j,t+1}\left(c_{j+1,t+1}(s_{j+1,t+1})\right) \mid s_{j,t}\big)$$

$$V_{l,j,t}\left(l_{j,t}(s_{j,t})\right) = \phi\frac{l_{j,t}^{1+\eta}}{1-\eta} + \delta\frac{\pi_{j+1,t+1}}{\pi_{j,t}}\mathbf{E}\big(V_{l,j,t+1}\left(l_{j+1,t+1}(s_{j+1,t+1})\right) \mid s_{j,t}\big).$$

where $c_{j,t}$, $l_{j,t}$, and $a_{j,t}$ solve consumer problem, and $c_{j,t}(\cdot)$, $l_{j,t}(\cdot)$ are police functions for consumption and labor. Hence, $V_{j,t}(s_{j,t}) = V_{c,j,t}(s_{j,t}) - V_{l,j,t}(s_{j,t})$. The consumption equivalent in percent of a lifetime consumption is then given by:

$$M = \left(\frac{V_{c,1,t}^{R} - \left(V_{l,1,t}^{R} - V_{l,1,t}^{B}\right)}{V_{c,1,t}^{B}}\right)^{\frac{1}{1-\sigma}} - 1. \tag{26}$$

In this expression, $V_{1,t}^{B} = V_{c,1,t}^{B} - V_{l,1,t}^{B}$ and $V_{1,t}^{R} = V_{c,1,t}^{R} - V_{l,1,t}^{R}$ refer to lifetime utility of the newborn at period $t$ under the veil of ignorance (before the initial shock is realized), in the baseline and the reform scenario, respectively.

## 4 Calibration

The model is calibrated to match features of the US economy. The model period corresponds to five years. Using microeconomic evidence and the general characteristics of the US economy we established reference values for preferences, life-cycle productivity patterns, taxes, technology growth rates, etc. We calibrate the population using survival probabilities $\pi_{j,t}$ and population growth data based on the United Nations data for 2020. The calibration of the model parameters is summarized in Table 1.

**Productivity heterogeneity.** The idiosyncratic component is specified as a first-order autoregressive process with autoregression $\bar{\varrho}_\eta = 0.97$ and variance $\bar{\sigma}_\eta = 0.021$ which are based on estimates from Borella et al. (2018). In our model each period corresponds to 5 years. Hence we need to recalculate input variables according $\varrho_\eta = \bar{\varrho}_\eta{}^5$ and $\sigma_\eta = \bar{\sigma}_\eta \frac{1-\bar{\varrho}_\eta{}^5}{1-\bar{\varrho}_\eta}$. Deterministic age-specific profiles of productivity $e_{j,t}$ and the variance of the initial shock $\sigma_0$ realization are based on Borella et al. (2018) as well.

**Preferences.** The inverse of intertemporal elasticity of substitution $\sigma = 2$, following the standard in the macroeconomic literature. The discount factor $\delta$ was set at $0.996$ to match the capital to GDP ratio 2.9. Since households face mortality risk, the effective discount rate is below 1 even if $\delta$ slightly larger than one as it might be the case while calibrating the economy for some Frisch elasticities.

We provide a broad range of calibrations for Frisch elasticity, to explore quantitatively the intuitions form the stylized model. Then we set $\phi$ to match the average labor supply equal to 0.33 for each value of Frisch elasticity. We consider $\eta \in \{2.5, 1.67, 1.25, 1, 0.83, 0.71, 0.625, 0.55, 0.5\}$. In our main specification, we set $\eta$ to 1.25, which corresponds to the Frisch elasticity of labor supply equal to 0.8. We present calibrations for all alternative values of the Frisch elasticity in Table A2 in the Appendix.

**Social security** We set the replacement rate ($\rho$) to match the 5.0% ratio of pensions to GDP. The effective rate of contribution $\tau$ was set such that the social security system replicates balanced budget as observed in the data. Retirement age eligibility in the US occurs at 66, which is equivalent to $\bar{J} = 10$.

**Government** Taxes are calibrated using Mendoza et al. (1994) approach. The capital income tax was set to 24.3%, to match 5.4% ratio of the capital income tax revenues to GDP. The marginal tax rate consumption was set to 4.4% to match 2.8% radio of consumption income tax revenues to GDP. The data on ratios between tax revenues and GPD come from the OECD data, see Table A1. Progressive labor income tax function parameter $\lambda = 0.137$ and $\tau_l = 0.037$ were set to match elasticity of post-tax to pretax income following Holter et al. (2019) and 9.2% radio of labor income tax revenues to GDP. In the initial steady state the debt/GDP ratio is equal to 110%.[10] In the status quo and in the reform scenario we keep debt as a constant share of GDP. The fiscal balance is closed by the government consumption $G$, which equals 14% of GDP, which is in the ballpark of values implied by NIPA.

[10] Due to fiscal developments in the U.S., debt/GDP ratio is higher in our study than in the earlier literature.

Table 1: Calibrated parameters for the initial steady state

| Macroeconomic parameters | | Calibration | Target | Value (source) | Model outcome |
|---|---|---|---|---|---|
| Preferences | | | | | |
| $\phi$ | disutility from work | 8.44 | average hours | 33% BEA(NIPA) | 33% |
| $\sigma$ | risk preference | 2 | literature | | |
| $\frac{1}{\eta}$ | Frisch elasticity | 0.8 | literature$^{(a)}$ | | |
| $\delta$ | discounting rate | 0.996 | $K_t/Y_t$ $^{(b)}$ | 2.9 OECD | 2.9 |
| Firm | | | | | |
| $\alpha$ | capital share | 0.33 | | | |
| $d$ | 1-year depreciation | 0.06 | | Kehoe and Ruhl (2010) | |
| Government | | | | | |
| $\tau_c$ | consumption tax | 0.044 | $\tau_c C_t/Y_t$ | 2.8% OECD | 2.8% |
| $\tau_k$ | capital tax | 0.243 | $\tau_k K_t/Y_t$ | 5.4% OECD | 5.4% |
| $\rho_m$ | benefits scaling factor | 0.51 | $\sum_{j=\bar{J}}^{J} N_{j,t} b_{j,t}/Y_t$ | 5.0% BEA(NIPA) | 5.0% |
| $\tau$ | social security contr. | 0.075 | soc. sec. deficit as % GDP | 0.00% | 0.00% |
| $\tau_l$ | labor tax$^{(c)}$ | 0.037 | $\sum_{j=1}^{J-1} N_{j,t} \int_\Omega \mathcal{T}(y_{j,t}(s_{j,t}))d\mathbb{P}_{j,t}/Y_t$ | 9.2% OECD | 9.2% |
| $\lambda$ | labor tax progression | 0.137 | earnings distribution | Holter et al. (2019) | |
| Wage process | | | | | |
| $e_{j,t}$ | age-specific profile | | | Borella et al. (2018) | |
| $\sigma_0^2$ | initial variance | | | Borella et al. (2018) | |
| $\varrho$ | shock persistence | | | Borella et al. (2018) | |
| $\sigma^2$ | shock variance | | | Borella et al. (2018) | |

*Notes:*
We use NIPA for 2011-2015 to obtain macroeconomic aggregates. We use OECD data for 2011-2015 to obtain five-year average share of tax revenues in GDP. We follow Mendoza et al. (1994) in classifying categories of tax revenues to tax types, see Table A1 in the Appendix for details.
$^{(a)}$ Calibration for alternative values of Frisch elasticity are provided in Table A2 in the Appendix
$^{(b)}$ This implies an interest rate 5.3%. For reference, Nishiyama and Smetters (2007) calibrate to an interest rate of 6.3% for mid 2000s.
$^{(c)}$ Effective tax rate for average income is equal to 13.4%, in line with 11.3% reported by Holter et al. (2019).

**Firms** We set the output elasticity to capital equal to $0.33$ The depreciation rate is set to $6\%$ per year following Kehoe and Ruhl (2010). The investment rate implied by the model is equal to 22.1% of GDP, which is consistent with NIPA for the period 2011-2015.

**Productivity growth ($\gamma_t$)** The model specifies the labor augmenting growth of technological progress $\gamma_{t+1} = z_{t+1}/z_t$. The debate about the future of the US growth is ongoing (e.g. Fernald and Jones 2014, Gordon 2016). We assume a steady technological progress at the current rate of 2% per annum, constant over the whole transition path. Note that the technological progress is the same in baseline and reform scenarios, and both systems are of the pay-as-you-go nature.

# 5 Results

The reform does not change the overall contribution rate relative to the baseline scenario. The major difference between the baseline and the reform system is that in the new system, the pensions are directly linked to the contributions which depend on income subject to idiosyncratic shocks. Thus, the income risk carries over to the retirement periods, eliminating the insurance motive implicit in the baseline pension system. We discuss the results in three substantive parts. First, we portray basic intuitions in terms of changes to the budget constraints of the agents. These intuitions are then displayed in simulation results for the individuals. Finally, we show the role of labor response to changes in social security and labor taxation.

### 5.1 Intuitions

Note that through equation (18) the agents link the contributions during the working periods to pension benefits at retirement. Hence, the contemporaneous intra-temporal choice of the agents is less distorted, i.e. they fully internalize the effects of labor supply choice throughout the lifetime. We portray it by rewriting the budget constraint (14) for the respective social security systems. Recall equations (15) and (18), describing the relationship between contributions and benefits in the status quo and in the reform, respectively. In the accumulation period ($\jmath < \bar{J}$), in the reform, the following holds:

$$\begin{aligned} \hat{f}^R_{j+1,t+1} + a_{j+1,t+1} + (1+\tau_{c,t})c_{j,t} &= (1+(1-\tau_k)r_t)a_{j,t} + y_{j,t} - \mathcal{T}(y_{j,t}) + \Gamma_{j,t} \\ &+ (1+(1-\tau_k)r_t)\hat{f}^R_{j,t} + \upsilon^R_{j,t} \cdot \tau w_t \omega_{j,t} l_{j,t} + \mu_t, \end{aligned} \tag{27}$$

where $\hat{f}^R_{j+1,t+1}$ denotes the anticipated (virtual) pension wealth, $\upsilon^R_{j,t}$ denotes the properties of (virtual) pension wealth accumulation, and pension wealth accumulates according to equation (18).[11] Analogously, we can rewrite the budget constraint in the accumulation period under status quo as:

$$\begin{aligned} \hat{f}^B_{j+1,t+1} + a_{j+1,t+1} + (1+\tau_{c,t})c_{j,t} &= (1+(1-\tau_k)r_t)a_{j,t} + y_{j,t} - \mathcal{T}(y_{j,t}) + \Gamma_{j,t} \\ &+ F^B(\hat{f}^B_{j,t}, \omega_{j,t} w_t l_{j,t}) + 0 \cdot \tau w_t \omega_{j,t} l_{j,t} + 0, \end{aligned} \tag{28}$$

where $\hat{f}^B_{j+1,t+1} = F^B(\hat{f}^B_{j,t}, \omega_{j,t} w_t l_{j,t})$ according to equation (15).

Equations (27) and (28) allow to portray the key trade-offs in our reform. First, the extent of labor distortion varies between status quo and our reform: there is "additional" income coming from $\upsilon_{j,t} \neq 0$, with $\upsilon_{j,t} \equiv 0$ in status quo. This generates substitution effect and raises labor supply. The second effect is associated with the lump-sum transfer $\mu_t$. It generates income effect and reduces labor supply in reform relative to status quo. Third, the formulas for $\hat{f}^B_{j,t}$ and $\hat{f}^R_{j,t}$ are different from one another, as evidenced by equations (15) and (18). Relative to status quo, pension formula for the reform scenario implies lower redistribution in the social security, which raises labor supply of high income individuals and lowers labor supply of the low income individuals.

### 5.2 Labor wedge

We operationalize distortions to labor supply decisions as labor wedges (Chari et al. 2007, Berger et al. 2019, Boar and Midrigan 2020). Consider the labor supply choice of household. With marginal

[11] The full derivation of formula for the implicit share of contributions that enter the intertemporal budget constraint $\upsilon^R_{j,t}$ is relegated to Appendix A. It is based on the notion of implicit tax (see Butler 2002)

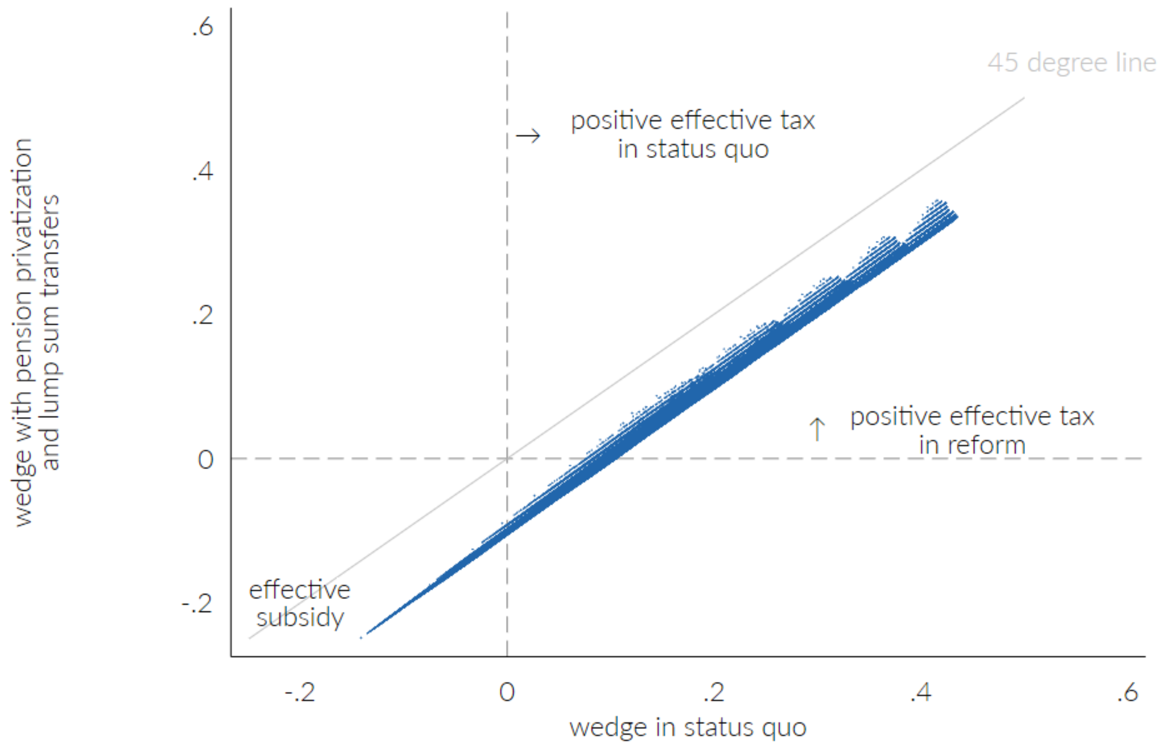
labor income tax denoted as $\mathcal{T}'(y_{j,t}(s_{j,t}))$, we obtain:

$$\varphi l_{j,t}(s_{j,t})^{\phi} = \frac{c_{j,t}(s_{j,t})^{-\theta}}{1+\tau_c}\left[1-(1-\tau)\mathcal{T}'(y_{j,t}(s_{j,t}))-\tau(1-\upsilon_{j,t})\right]w_t\omega_{j,t}(s_{j,t}), \tag{29}$$

with $\upsilon_{j,t}$ introduced above and determining implicit marginal tax stemming from social security. Notice that the implicit marginal tax due to social security may be negative in the case of reform scenario due to the annuitetization offered by social security. Indeed, with reformed social security, $\upsilon_{j,t}$ may be higher than one, details are provided in the Appendix A. Following (Cociuba and Ueberfeldt 2010), we measure it as the discrepancy between a household's marginal rate of substitution between labor and consumption and the wage. The labor wedge faced by household at age $j$ at time $t$ and characterized by the state $s_{j,t}$ is defined by:

$$\vartheta_{j,t}(s_{j,t}) = \frac{(1-\tau)\mathcal{T}'(y_{j,t}(s_{j,t}))+\tau(1-\upsilon_{j,t})-1}{1+\tau_c}+1. \tag{30}$$

Figure 1: The decline of labor distortion ($\vartheta_{j,t}(s_{j,t})$ decreases)




*Notes:* the figure portrays the values of $\vartheta_{j,t}(s_{j,t})$ obtained for all possible combinations of states (in total: 2.2 mln potential outcomes) for both status quo and for the reform. The values of $\vartheta_{j,t}(s_{j,t})$ are obtained using equation (30). Figure A2 depicting the same relationship but accounting for the probability measure $\mathbb{P}_{j,t}$ is available in Appendix C.

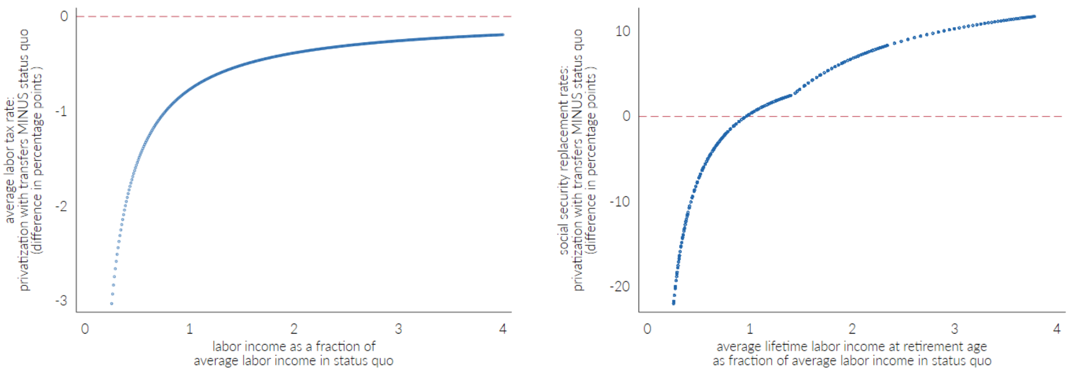
Figure 1 scatters age- and state-specific labor wedges $\vartheta_{j,t}(s_{j,t})$, given by equation (30), before and after the reform. The results are below the 45 degree line, which implies that along the entire state space the wedge is lower in the reform; as there is more labor distortions in the status quo.

Note that nominally no parameters of the tax system, nor social security are changed from status quo – yet, the decline in wedge is substantial and comprehensive. This is due to the efficiency gain from the social security reform, which in general substantially reduces the labor distortions associated with social security contributions: the agents view the social security contributions as a tax in status quo and they view them as a stream of future income once the social security reform is implemented.

### 5.3 Taxes and replacement rates

Next, we look at how average taxes and replacements rates change due to reform. In other words, we study the extent to which we shift insurance from the social security to the tax system. In Figure 2 we report changes in labor taxation along the distribution of lifetime labor income (left panel) and its analog for social security contributions (right panel). Increased insurance and reduced overall labor taxation is portrayed in the left panel by larger declines in the average tax rates for low incomes, which become smaller as income goes up.

Figure 2: The change in average tax rates and replacement rates



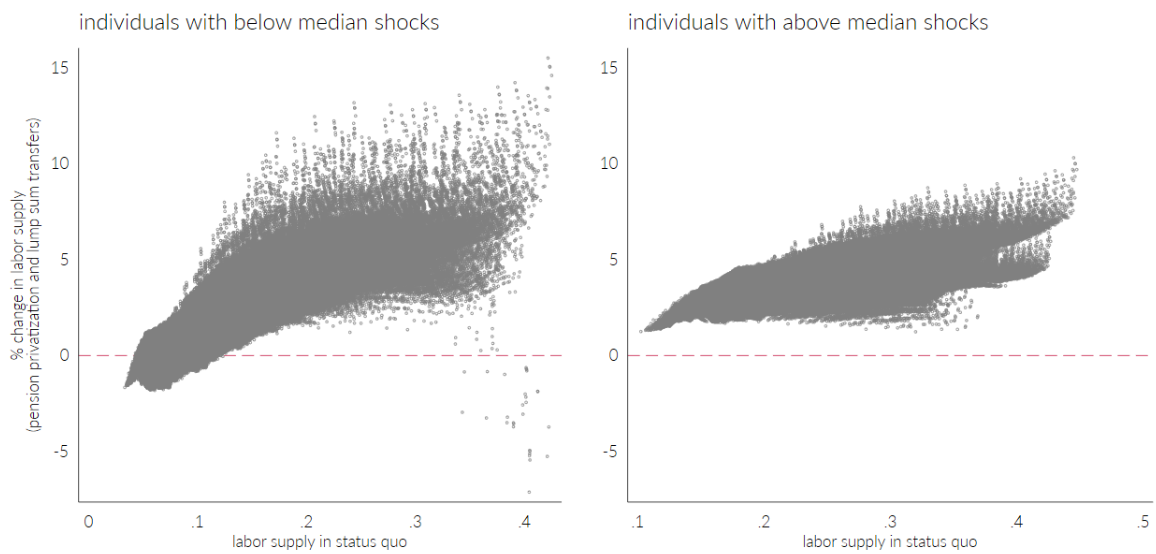

*Notes:* the left panel displays the difference in the average tax rate between the privatization reform with transfers and status quo at each percentile of instantaneous status quo income. The difference is negative, which is consistent with *decline* in taxation along the income distribution. Analogously, the right panel displays a difference in percentage points in the ratios of pension benefits income and lifetime earned income in the reform and status quo. For both status quo and reform we obtain a total stream of pension benefits income and a total stream of earned income. For each state we obtain the ratio between the two streams, to measure replacement rates. We then obtain a difference between reform and status quo at each percentile of lifetime income in status quo (as in the left panel). Negative values reflect a decline in replacement rates, positive values signify an increase in replacement rates, in percentage points. Levels of the tax rates and replacement rates are reported in Figure A3 in Appendix C.

The left panel of this figure shows that the social security privatization accompanied by lump sum transfers increases progressivity of the tax system and results in higher implicit insurance embedded in it. In status quo the average taxes for low income individuals are higher than in the reform by as much as 3 percentage points. The tax decline is lower for high income individuals, but still positive (0.3 percentage points). At the same time pensions for low incomes decline and those of high incomes increase (see the right panel). For the sake of comparison, we compute the replacement rate as a ratio of total pension benefits stream relative to total earned income stream (adjusted for survival and time), and portray them along the distribution of status quo lifetime earned income (that is the social security contribution base). The privatization of social security lowers replacement rates for low income individuals (by approximately 20 percentage points), but raises it substantially for individuals with above average lifetime income (by approximately 10 percentage points).

### 5.4 Labor supply

The decline in labor wedge leads to substantial changes in labor supply. The results are reported in Figure 3, where we portray change of labor supply across realizations of productivity shocks as a function of labor supply in status quo. We see that labor supply increases for almost all individuals. Additionally, labor supply reacts stronger among individuals with higher labor supply. The reaction is more differentiated among individuals with unfavorable shocks realizations. Individuals with high labor supply already in status quo display low reaction to the reform across shocks realizations.

Figure 3: Change in labor supply: scatter plot of labor supply in status quo and under reform




*Notes:* The figure scatters labor supply in status quo and in reform. Each dot corresponds to the an individual with given shock realization. Figure A4 depicting the same relationship but accounting for the probability measure $\mathbb{P}_{j,t}$ is available in Appendix C.

These results are entirely consistent with our intuitions discussed earlier. First, reduction in labor distortions generates substitution effect and increases labor supply. Second, the decline in pensions, for low productive agents, has a negative income effect which makes them work more, and the increase in pensions, for high productive agents, has a positive income effect i.e. their labor supply goes down. Finally, an universal lump sum transfer creates a positive income effect and leads to lower labor supply. Given that labor supply increases almost universally, it appears that the substitution effect of lower distortions dominates the remaining effects. Additionally, income effect of pensions is negative for low-productivity agents and positive for high-productivity agents. Therefore, due to less redistribution social security labor supply of low-productivity agents tends to increases less than of high-productivity agents. In fact, at the median realization of productivity shocks (=1), on average labor supply increases by 3.5 percentage points. Relative to this level, the increase in labor supply is roughly 0.9 percentage points lower for below median realizations and only 0.5 percentage points lower for above median realizations. Thus, we obtain a hump shape in relation to the status quo labor supply. We further find at the median shock realization, standard deviation of labor supply reaction amounts to 1.42 percentage points. Relative to this group, the dispersion is 0.32 percentage points lower for individuals with above median shocks and 1.29 percentage points higher for individuals with below median shocks.[12]

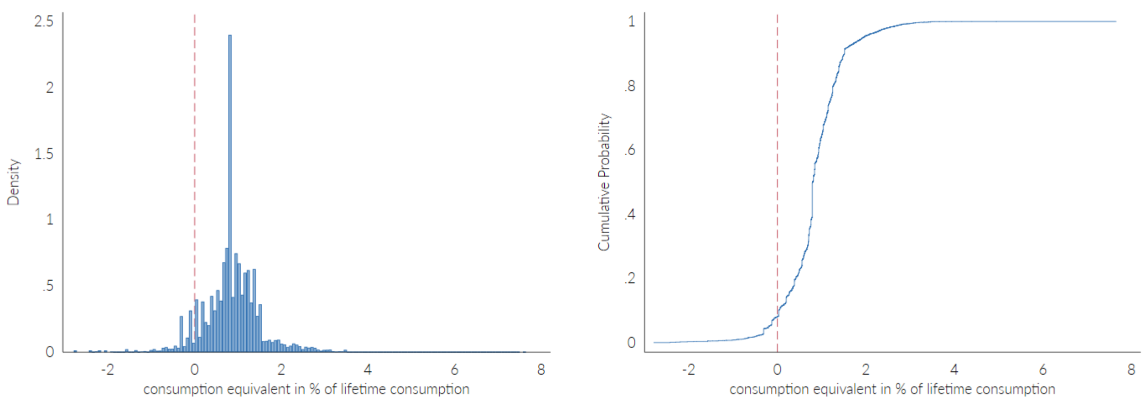
### 5.5 Welfare

Eventually, we study welfare effects. Our results confirm that social security reform and labor tax progression can be complementary. With the efficiency gain, raised tax revenues generate room for increased labor tax progression to substitute (even if only partially) for the insurance loss due to the fact that the new social security is no longer redistributive. In Figure 4 we portray the distribution of welfare effects across ex post differentiated shocks realizations. It shows that from the ex post perspective approximately $90\%$ of agents experiences welfare gain.

Figure 4: Distribution of consumption equivalents: ex post evaluation

(a) distribution

(b) cumulative distribution




*Notes:* The figures portray the outcomes of 2.2 million simulations. For each potential realization of lifetime path of shocks, we use the policy functions to obtain the path of consumption and labor supply, in both status quo and in the reformed system. We then obtain lifetime welfare measure, following equation (26). We obtain the distribution of consumption equivalents across each of the simulated paths, weighted by the probability measure.

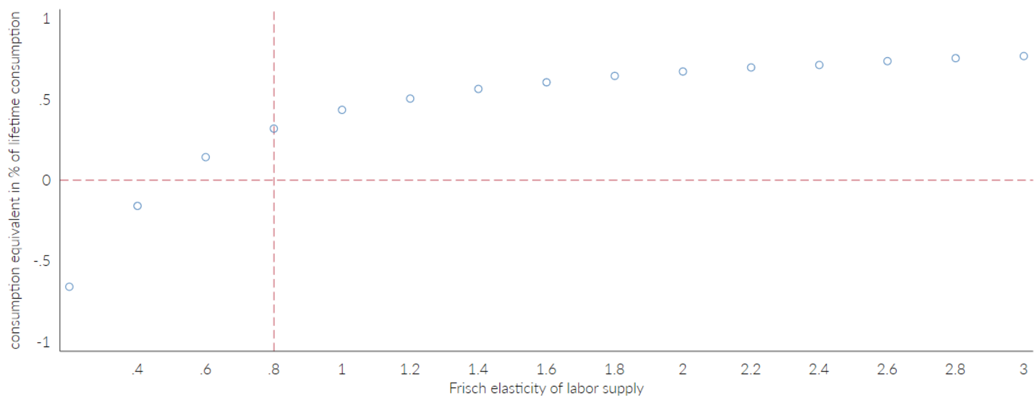
For some individuals ,welfare losses are indeed large and remain so despite the lump-sum transfers. This result stems from the fact that effectively everybody increases labor supply. Thus, they move up the $\mathcal{T}(y_{j,t}(s_{j,t}))$ curve, effectively paying higher marginal income tax. While this increased taxation is compensated for by the lump-sum transfers for most individuals (and overall labor distortion declines), for some individuals disutility of labor supply is relatively high. We interpret this finding to signify

[12]Both sets of estimates – for labor response levels and for dispersion of labor response – were obtained adjusting for the probability measure.

that optimal bundle of social security reform and labor tax progression should be targeted in order to shield specific groups of individuals from large welfare losses.

The intuitions from the theoretical model in Section 2 suggest that overall labor supply elasticity plays paramount role in determining the sign and the size of the response to the reform. To quantify this intuition, we demonstrate the results for alternative calibrations of Frisch elasticity. Figure 5 displays welfare effects across alternative calibrations of the Frisch elasticity. We use the calibration parameters as reported in Table A2 in the Appendix. The vertical dashed line signifies our preferred calibration, as consensus in the literature about plausible values of Frisch elasticity.[13] Our results indicate that for this value the reform delivers positive welfare gains. In line with the theoretical model, we show two main results: the magnitude of the welfare effect, and the origins of the fiscal adjustment. The results show that for higher values of the Frisch elasticity welfare effects become larger.

Figure 5: Welfare effects across alternative calibrations of Frisch elasticity




*Notes:* Each dot represents the welfare effects under the veil of ignorance for a given Frisch elasticity value; see equation (26). The calibration parameters are as reported in Table A2 in the Appendix. The vertical dashed line signifies our preferred calibration, as consensus in the literature about plausible values of Frisch elasticity.

Our results are consistent with the existing literature, but also provide extensions. For example, Heathcote et al. (2008) argue that greater incomes dispersion can be preferred by social planner if high-productivity workers increase labor supply and low-productivity workers reduce it. Our reform partially achieves this objective through realigning incentives in the social security, bundled with a fiscally neutral lump-sum transfer. Heathcote et al. (2008) argue that their result hinges on flexible labor and we show that for Frisch elasticity below 0.6 our reform actually becomes detrimental to welfare.

Note that we find positive welfare effects for Frisch elasticity above this threshold despite going partially against Huggett and Parra (2010) implications. Specifically, Huggett and Parra (2010) argue that high-productivity individuals work too little and low-productivity individuals work too much relative to optimum in the current US system. [14] Our reform is likely amplifying this situation.

[13]See Chetty, Guren, Manoli and Weber (2011), Chetty, Friedman, Olsen and Pistaferri (2011), Chetty (2012).

[14]While Huggett and Parra (2010) work in an open economy, in our environment there are implications from social

Despite relatively large lump-sum transfers, on average labor supply increases among both high-productivity and low-productivity individuals. Notwithstanding, the rise in labor tax revenues due to labor supply response is sufficient to compensate for the insurance loss in our reform.

### 5.6 Macroeconomic and fiscal consequences

Figure 6 reports the macroeconomic adjustments across different Frisch calibrations, quantifying the macroeconomic intuitions. Labor supply increases by approxmiately 2% at plausible values of the Frisch elasticity in the range of 0.6-0.8. For the highest values, it exceeds 4%. At the same time less labor market distortions combined with lump sum transfer increase savings and thus capital. Additionally, higher labor supply increases return to capital which further encourages capital accumulation. Nevertheless, capital increases by less than labor supply so the capital-labor ratio declines. Higher capital and labor lead to higher output. These macroeconomic adjustments give way to fiscal adjustments, which are portrayed in Figure 7. The rise in labor supply leads to increased revenue from labor tax. It turns out to be the mains source of additional tax revenue. The rise in revenue is substantial: in excess of 0.5% of the baseline output for our preferred Frisch elasticity of 0.8. To put this rise in revenues in perspective, recall that total labor tax revenues amount to roughly 9.2% of GDP. Labor tax revenues are not the only ones to rise: greater capital accumulation and increased consumption raise the tax base for the other taxes as well, creating fiscal space for higher lump-sum transfers. Indeed, debt is the only fiscal adjustment that reduces fiscal space for lump-sum transfers. The adjustment in debt is negative due to higher costs of servicing debt (the interest rate rises as $k$ declines).

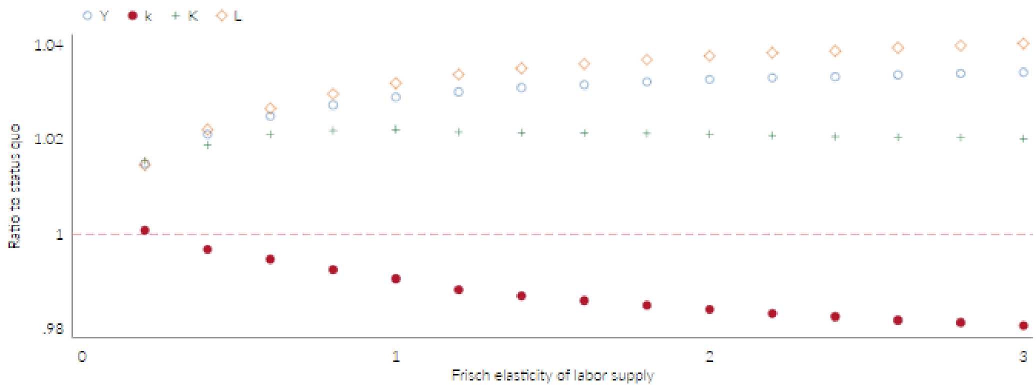
The analysis above shows two major points. First, that the redistribution in tax system can effectively compensate redistribution inherent in the current US social security. Second, that whether or not that actually happens depends largely on the response in labor supply. For plausible levels of Frisch elasticity, welfare implications of privatizing social security in the US are positive so long as increased tax revenue is directed towards greater redistribution through labor taxation. Further, we study the sensitivity of this conclusion to assumptions in our setup.

## 6 Sensitivity analyses

**Population aging** At the root of reasons to analyze social security reforms lies rising longevity of subsequent birth cohorts. Specifically, rising longevity implies that for any given age in retirement, a higher fraction of individuals will survive between $j$ and $j+1$. The current social security system in the US is both redistributive and of a defined benefit nature. Studies show that the necessary fiscal adjustment to provide for pension system imbalance in the US will require an increase in contributions by roughly 40% (Braun and Joines 2015, Vogel et al. 2017) within a decade. The necessary increase in taxes necessary to finance the growing social security imbalance was found to cause significant welfare effects (e.g. Kotlikoff et al. 1999, Huggett and Ventura 1999, Genakoplos et al. 2000, Kitao

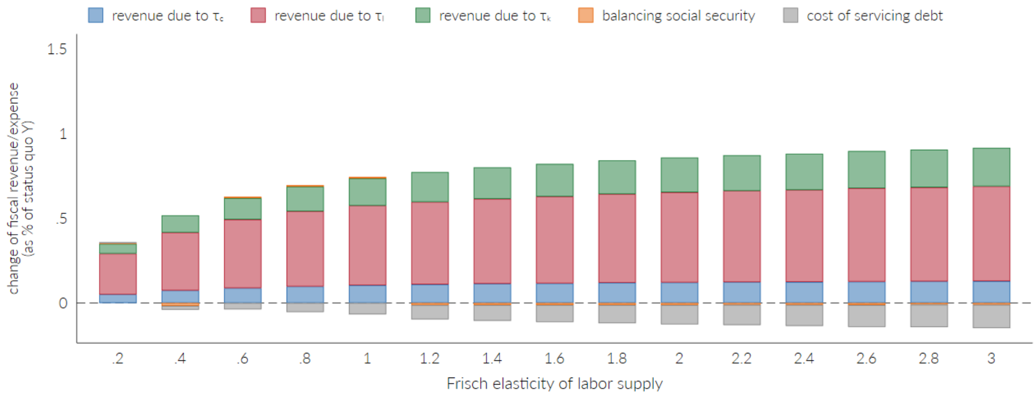
security and labor supply to capital accumulation and interest rates.

Figure 6: Macroeconomic adjustment across alternative calibrations of Frisch elasticity




*Notes:* The graph presents the relation of given macroeconomic variables: $Y$ aggregate output, $k$ capital per effective unit of labor, $K$ aggregate capital, and $L$ the effective aggregate labor; level in the pension privatization and status quo scenario.

Figure 7: Budget revenue changes across alternative calibrations of Frisch elasticity




*Notes:* The graph presents the changes in the government budget between pension privatization and the status quo scenario. The differences in fiscal revenue/expenditures are expressed in the % of status quo aggregate output $Y$.

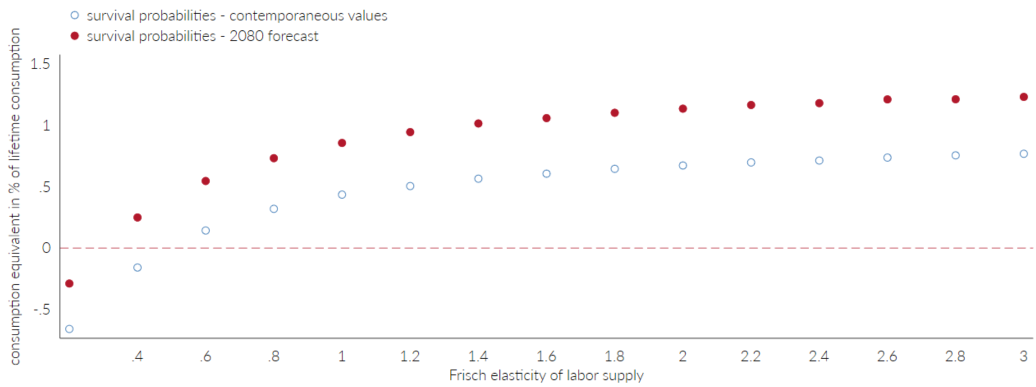
2014). If defined contribution system was to be introduced instead, social security system becomes fiscally neutral.[15] With the current US social security, this implies a rise in expenditure, which is not coupled with increased contributions. This implies the fiscal deficits of roughly 2% of GDP in approximately 2080 (Feldstein 2016). With the proposed reform, higher life expectancy in retirement implies lower pension benefits, but social security maintains balance by design. Figure 8 reports results analogous to Figure 5 with the difference that survival probabilities $\pi_{j,t}$ are taken from the forecast for 2080 in addition to the contemporaneous values.[16]

Welfare gains from our social security reform are in fact larger when longevity in retirement inten-

[15]Longevity translates to lowering per period pension benefit receipts for subsequent cohorts. This type of reform under consideration in the US economy (Feldstein 2005). It was also recommended as a mean to address fiscal instability resulting from longevity by the World Bank and the IMF; it has eventually been implemented as of 1990's in many countries around the world (e.g. Central Europe, Mexico, Sweden and Chile, among others, see Holzmann 2013).

[16]For both status quo and reform, with rising longevity, we also raise the retirement age $\bar{J}$.

Figure 8: Welfare gains are larger with population aging




*Notes:* Welfare effects for given Frisch elasticity values for contemporaneous probabilities of survival and values taken from 2080 UN forecast. Note that the calibrated parameters are in line with Table A2 in the Appendix. Both status quo and reform scenarios share the same probabilities of surviving.

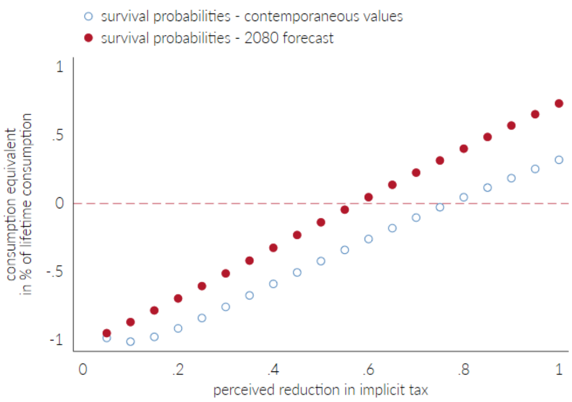
sifies. This result is driven by the fact that rising longevity encourages greater capital accumulation, which reduces the decline in $k$ relative to the results presented in Figure 6, see Figure A6. Indeed, welfare gains arise already for Frisch elasticity as low as 0.4. Note also that welfare losses are lower than in the baseline simulations – and welfare gains are twice as large. Larger welfare gains are related to greater efficiency gains. With the current longevity levels, reaction of capital per effective unit of labor and thus wages is strong, thus dampening the rise in labor supply. With longevity reducing the reaction by capital, the decline in wages is also lower, which amplifies both the gains from increased labor supply and the rise in labor tax base.

**Drivers of labor supply response** Given that our results depend largely on the labor supply response by households to better aligned incentives, one can ask if the size of the reaction is plausible. Admittedly, the reform immediately reduces labor taxation by virtually the entire social security contribution: individuals used to treat the contributions as a tax and suddenly treat them as postponed stream of revenue. Given the magnitude of the contribution rate, the sizable increase in labor supply – roughly 2% to 4% – is internally consistent with within the model. Are these magnitudes plausible in the empirical context?

A large selection of studies reviewed empirical evidence from numerous labor taxation reforms. Admittedly, most of these studies concern labor taxation per se, rather than lifetime optimization, as such reforms are rare. Using evidence from Denmark, Chetty, Friedman, Olsen and Pistaferri (2011) show that people tend to respond to explicit changes in taxation and are relatively inattentive to implicit changes in taxation. Exploiting evidence for Germany Tazhitdinova (2020) finds similar results. By contrast, Lachowska and Myck (2018) show substantial response in behavior to changes as subtle as formula for computing pension benefits. Given this conflicting evidence, we study the sensitivity of our results to internalizing the changes in social security.

We perform the following exercise. For each working age group, certain fraction of contributions

Figure 9: Half-internalizing social security reform is sufficient to deliver welfare gains




*Notes:* Welfare effects across the extent to which individuals internalize reform in social security. The last observation to the right reflects welfare reported in the previous section, whereas all observations to the left show result as if individuals internalize a given fraction of reduction in implicit taxation the nature of the reform.

is subjected to equation (28) and the rest to equation (27). Specifically, given the preferred Frisch of 0.8, we vary the share of income subjected to equation (27) between 0% and 100%. This is to reflect the share of individuals who fully internalize the changes in the social security. Recall the intuitions in section 5.1. In the current exercise all agents receive $\mu_t$ in the magnitude implied by general equilibrium conditions, but we vary the share of individuals whose budget constraint is altered to include $v_{j,t}^R$ and $\widehat{f}_{j+1,t+1}^R$. The results are portrayed in Figure 9. We show that with population aging, roughly half-internalization of the changes in the nature of the social security are sufficient to deliver aggregate welfare gains. In other words, efficiency gains from individuals internalizing the reduced distortion outweigh insurance loss when for each dollar earned, incentives are fully internalized for 55 cents. Thus, it appears that in order to capture the potential in social security reform, moderate levels of economic literacy are sufficient.

# 7 Conclusions and policy implications

In this paper, we conjecture that privatizing social security can improve welfare even in a setup with idiosyncratic income shocks. The existing social security system in the US is to some extent redistributive, providing partial insurance against idiosyncratic income shocks. It was a long standing consensus that privatizing social security raises efficiency due to reduced labor distortion but that it is unable to compensate for insurance loss (Nishiyama and Smetters 2007). We propose to address the insurance loss directly, by coupling the social security reform with increased labor tax progression. We provide a motivating theoretical stylized setup to lay out the basic intuitions and then take our model to the data in a computational general equilibrium setup calibrated to the case of US. We show that such increased progression can indeed be fiscally neutral.

We show that welfare gains from such a bundle of reforms can bring as much as 0.5% of lifetime consumption for plausible calibrations of Frisch elasticity. We show that this magnitude is higher if the reform is implemented for higher values of longevity in retirement. Furthermore, the effects of our proposed reform depend on the share of individuals who internalize the decline in distortion. Our result extends the earlier literature by İmrohoroğlu and Kitao (2009) and Heathcote et al. (2008), who studied the response of labor supply to social security and tax progressiveness.

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# A Pension benefits link to contributions and labor distortion

Let us start with the defining the value of this *virtual assets* $\widehat{f}$ and then adjusting budget constraint accordingly. In the accumulation period (for $j < \bar{j}$) the *virtual assets* from the reformed (defined contribution) pillars accumulate according to:

$$\widehat{f}^{R}_{j+1,t+1} = (1 + (1-\tau_{k,t}))r_t \widehat{f}^{R}_{j,t} + \tau_t w_t \omega_{j,t} l_{j,t} \cdot \upsilon^{R}_{j,t} \tag{A1}$$

Calculating the present values of the streams of the benefit from the PAYG and funded pillar evaluated at time of the retirement is then straightforward. The worker who is $j$ years old at the time $t$ would reach retirement age at time $i = t + \bar{J} - j$. The first term represents the present value of that streams. The second term is simply lifetime expectancy at the age $\bar{J}$ of the worker who is $j$ years old at the time $t$, thus the expected time over which these benefits are going to be obtained. Thus we can treat $\upsilon^{R}_{j,t,\bar{J}}$ as the market price of such benefits.

To calculate the $\upsilon^{R}_{j,t}$ we need to combine two elements: (i) present value of the stream of the benefit from the PAYG and funded pillar evaluated at time of the retirement, and (ii) the present value of this stream of future pension benefits.

For the PAYG DC pillar we have

$$\upsilon^{R}_{j,t,\bar{J}} = \left[\sum_{\kappa=0}^{J-\bar{J}} \frac{\prod_{s=1}^{\kappa}(1+g_{i+s})}{\prod_{s=1}^{\kappa}(1+(1-\tau_{k,i+s})r_{i+s})}\right]\left[\sum_{s=0}^{J-\bar{J}} \pi_{\bar{J},i,i+s}\right]^{-1}.$$

Taking into account discounting the retirement to the present age of the worker, we calculate the present value of the future pension. They are discounted at the market interest rate, adjusted for the survival probability.

$$\upsilon^{R}_{j,t} = \upsilon^{R}_{j,t,\bar{J}}\left[\pi_{j,t,i}\prod_{s=1}^{\bar{J}-j}(1+(1-\tau_{k,t+s})r_{t+s})\right]^{-1}$$

## A.1 Measuring welfare effects

To derive a formula for the welfare effect analytically, we split the value function in baseline and reform scenario into two parts: $V_c$ (which refers to utility derived from consumption) and $V_l$ (which refers to disutility from working). Therefore the value function for the agent $j$ years old at time $t$ is given by:

$$V_{c,j,t}\left(c(s_{j,t})\right) = \frac{c_{j,t}^{1-\sigma}}{1-\sigma} + \delta\frac{\pi_{j+1,t+1}}{\pi_{j,t}}\mathbf{E}\big(V_{c,j,t+1}\left(c(s_{j+1,t+1})\right) \mid s_{j,t}\big)$$

$$V_{l,j,t}\left(l(s_{j,t})\right) = \phi\frac{l_{j,t}^{1+\eta}}{1-\eta} + \delta\frac{\pi_{j+1,t+1}}{\pi_{j,t}}\mathbf{E}\big(V_{l,j,t+1}\left(l(s_{j+1,t+1})\right) \mid s_{j,t}\big).$$

where $c_{j,t}$, $l_{j,t}$, and $a_{j,t}$ solve consumer problem. Hence, $V_{j,t}(s_{j,t}) = V_{c,j,t}(s_{j,t}) - V_{l,j,t}(s_{j,t})$. Assume that $j = J$

$$V_{c,j,t}\left(c(s_{j,t})\right) - V_{l,j,t}\left(l(s_{j,t})\right) = \frac{c_{j,t}^{1-\sigma}}{1-\sigma} - \phi\frac{l_{j,t}^{1+\eta}}{1-\eta}.$$

Denote $x_{\{R,B\}}$ as a optimal choice in reform and baseline scenario. Then $\mu$, share of consumption in the baseline scenario scenario which consumer have to receive to be indifferent to the reform scenario.

$$\frac{\left[(1+\upsilon)c_{j,t,B}\right]^{1-\sigma}}{1-\sigma} - \phi\frac{l_{j,t,B}^{1+\eta}}{1-\eta} = \frac{c_{j,t,R}^{1-\sigma}}{1-\sigma} - \phi\frac{l_{j,t,R}^{1+\eta}}{1-\eta}.$$

Rearranging the above equation we get the following expression to determine the value of $\mu$:

$$(1+\upsilon)^{1-\sigma} = \frac{\frac{c_{j,t,R}^{1-\sigma}}{1-\sigma}}{\frac{c_{j,t,B}^{1-\sigma}}{1-\sigma}} - \frac{\phi\frac{l_{j,t,R}^{1+\eta}}{1-\eta} - \phi\frac{l_{j,t,B}^{1+\eta}}{1-\eta}}{\frac{c_{j,t,B}^{1-\sigma}}{1-\sigma}}.$$

Therefore, using value function notation we get:

$$(1+\upsilon)^{1-\sigma} = \frac{V_{c,j,t}\left(c(s_{j,t,R})\right)}{V_{c,j,t}\left(c(s_{j,t,B})\right)} - \frac{V_{l,j,t}\left(l(s_{j,t,R})\right) - V_{l,j,t}\left(l(s_{j,t,B})\right)}{V_{c,j,t}\left(c(s_{j,t,B})\right)}.$$

For agent at age $j = J-1$ at time $t$ and state $s_{j,t}$ the $\upsilon$ has to be such that:

$$\frac{\left[(1+\upsilon)c_{j,t,B}\right]^{1-\sigma}}{1-\sigma} + \delta\frac{\pi_{j+1,t+1}}{\pi_{j,t}}\mathbf{E}\big(V_{c,j,t+1}\left((1+\mu)c(s_{j+1,t+1,B})\right) \mid s_{j,t}\big) - V_{l,j,t}\left(l(s_{j,t,B})\right) =$$

$$= \frac{c_{j,t,R}^{1-\sigma}}{1-\sigma} + \delta\frac{\pi_{j+1,t+1}}{\pi_{j,t}}\mathbf{E}\big(V_{c,j,t+1}\left(c(s_{j+1,t+1,B})\right) \mid s_{j,t}\big) - V_{l,j,t}\left(l(s_{j,t,B})\right)$$

Using the linearity of expectation we can simplify the above equation and get the following expression, completely analogous to the expression at $j = J$:

$$(1+\upsilon)^{1-\sigma}V_{c,j,t}\left(c(s_{j,t,B})\right) - V_{l,j,t}\left(l(s_{j,t,B})\right) = V_{c,j,t}\left(c(s_{j,t,B} - V_{l,j,t}\left(l(s_{j,t,R})\right)\right)\right).$$

Repeating these steps for each $j = \{J-2, J-3, ..., 1\}$ we eventually obtain the following formula for the welfare effect for the newborn with state $s_{1,t}$:

$$\upsilon = (\frac{V_{c,j,t}\left(c(s_{j,t,R})\right) - \left[V_{l,j,t}\left(l(s_{j,t,R})\right) - V_{l,j,t}\left(l(s_{j,t,B})\right)\right]}{V_{c,j,t}\left(c(s_{j,t,B})\right)})^{\frac{1}{1-\sigma}} - 1.$$

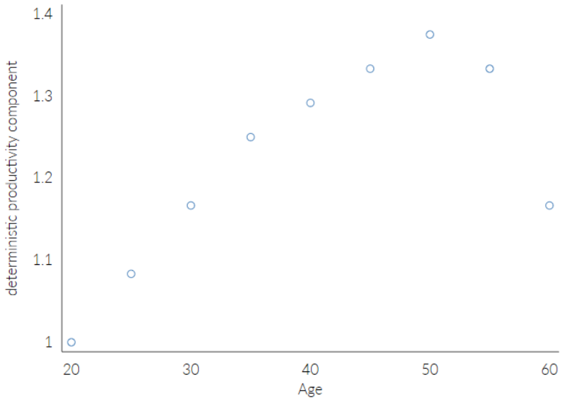
We calculate the following expression to obtain the welfare effects under the veil of ignorance (before productivity shocks materialize):

$$M = \left(\frac{V^R_{c,1,t} - \left(V^R_{l,1,t} - V^B_{l,1,t}\right)}{V^B_{c,1,t}}\right)^{\frac{1}{1-\sigma}} - 1. \tag{A2}$$

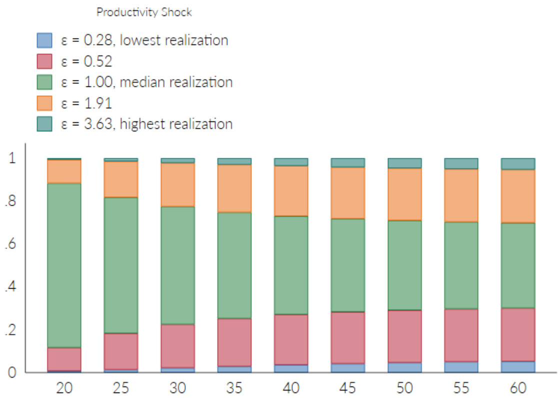
In this expression, $V^B_{1,t} = V^B_{c,1,t} - V^B_{l,1,t}$ and $V^R_{1,t} = V^R_{c,1,t} - V^R_{l,1,t}$ refer to lifetime utility under the veil of ignorance (before the shocks are realized) of an individual living her entire life in the baseline or reformed social security and tax system, respectively.

## B Model calibration

Figure A1: Labor productivity




(a) deterministic productivity component




(b) shock realization

Table A1: Calibration of taxes

| Macroeconomic parameters | | Calibration | OECD code | revenue as % of GDP |
|---|---|---|---|---|
| $\tau_l$ | labor tax | 0.150 | 1110 | 9.2% |
| $\tau_c$ | consumption tax | 0.065 | 5100, 5121 | 2.8% |
| $\tau_k$ | capital tax | 0.130 | 1120, 1200, 4100, 4400 | 5.4% |

*Notes:* Tax rates calibrations following Mendoza et al. (1994), using 5 year averages of tax shares in GDP from (2011-2015).

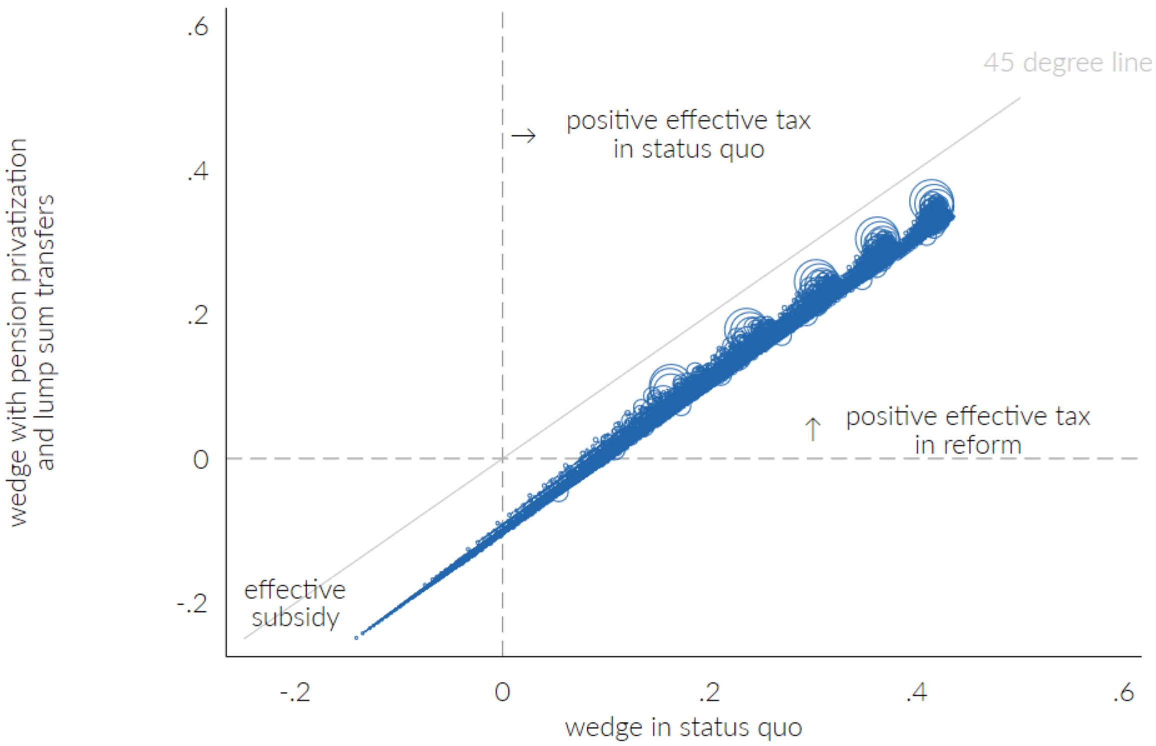
Table A2: Calibrated parameters for the initial steady state across Frisch elasticities

| Macroeconomic parameters | | values of $\frac{1}{\eta}$ | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.4 | 1.6 | 1.8 | 2 | 2.2 | 2.4 | 2.6 | 2.8 |
| $\phi$ | disutility from work | 697 | 37 | 13.90 | 8.44 | 6.25 | 5.10 | 4.40 | 4.00 | 3.67 | 3.42 | 3.21 | 3.09 | 2.94 | 2.87 |
| $\delta$ | discounting rate | 1.02 | 1.01 | 1.00 | 1.00 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| $\tau_l$ | labor income tax | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| $\tau_c$ | consumption tax | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| $\tau_k$ | capital income tax | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |

*Notes:* Targets remain unchanged across the alternative calibrations of Frisch elasticity. For all displayed values, the risk preference parameter is kept at $\sigma = 2$, the annual depreciation rate is kept at $d = 0.06$. We also keep constant the degree of labor tax progression $\lambda = 0.137$ and social security contributions are kept at $\tau = 0.075$ and the pension scaling factor $\rho_m = 0.55$ .

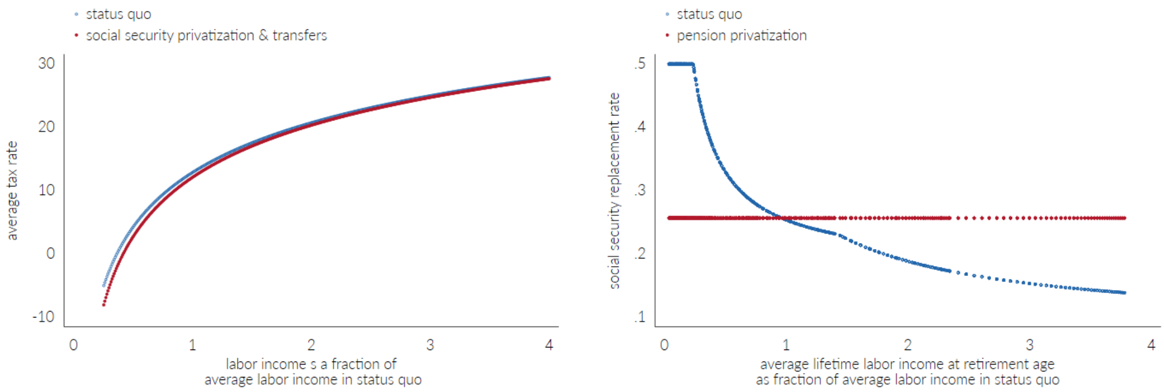
# C Additional results

Figure A2: The decline of labor distortion ($\vartheta_{j,t}(s_{j,t})$ decreases)



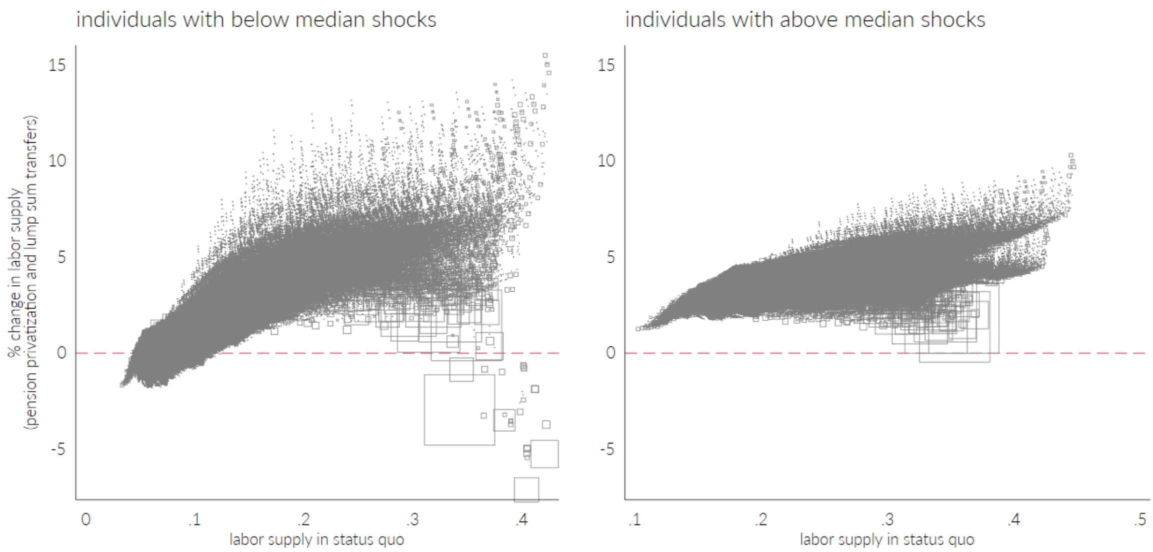

*Notes:* the figure portrays the values of $\vartheta_{j,t}(s_{j,t})$ obtained for every possible combination of states (in total: 2.2 mln potential outcomes) for both status quo and for the reform. The values of $\vartheta_{j,t}(s_{j,t})$ are obtained using equation (30). The size of the circle signifies the probability measure $\mathbb{P}_{j,t}$.

Figure A3: Average tax rate (left) and average replacement rate (right)




*Notes:* Level of the average tax rates along the income distribution in status quo in the left panel. Lifetime income at retirement is the total stream of pension benefits (adjusted for survival). Lifetime earned income is the total stream of earned income (the social security contribution base, likewise adjusted for survival). The ratio between the two streams signifies the replacement rate, here displayed along the income distribution in status quo.

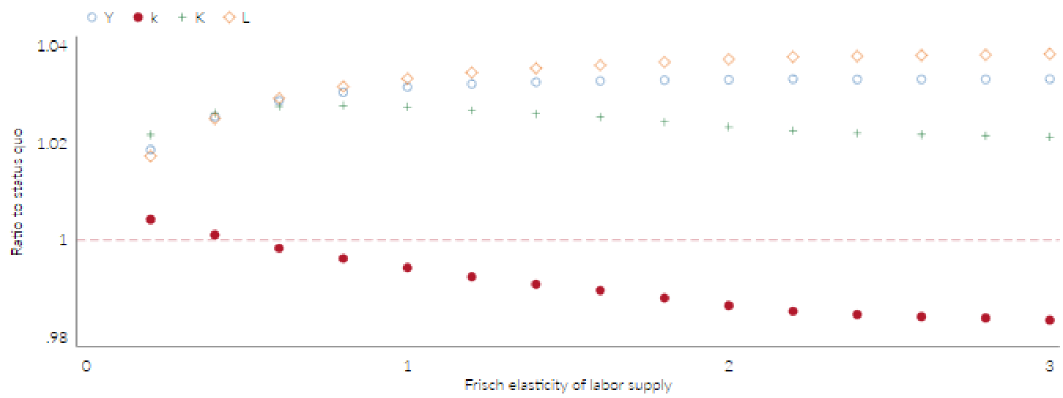
Figure A4: Change in labor supply: scatter plot of labor supply in status quo under reform




*Notes:* The figure scatters labor supply in status quo and change in labor supply due to the reform. Each dot corresponds to the an individual with given shock realization. The size of the square is proportional to the probability of particular shock realization.

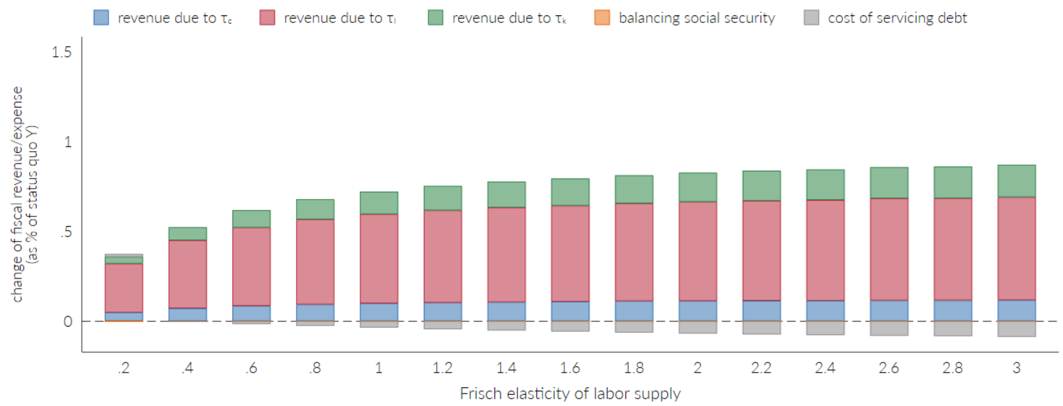
## D Macroeconomic adjustments adjusted for longevity

Figure A5: Sensitivity of results in Figure 6 – adjusted for longevity




*Notes:* see Figure 6.

Figure A6: Sensitivity of results in Figure 7 – adjusted for longevity




*Notes:* see Figure 7.