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ABSTRACT

Progressing Towards Efficiency: The Role for Labor Tax Progression in Reforming Social Security*

We study interactions between progressive labor taxation and social security reform. Increasing longevity puts fiscal strain that necessitates the social security reform. The current social security is redistributive, thus providing (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 incurs insurance loss. We show that the progressive labor tax can partially substitute for the redistribution in social security, thus reducing the insurance loss.

JEL Classification: C68, D72, E62, H55, J26

Keywords: social security reform, labor income tax, redistribution, insurance, welfare effects

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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 is, to some extent, redistributive, providing partial insurance against income shocks. With rising longevity, however, the current system is bound to come under 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 (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 US social security (see also Heer 2015).

We propose a novel social security reform consisting of two elements. First, we replace the current defined benefit payout scheme characterized by within cohort redistribution with a defined contribution payout scheme, which links individual contributions to individual benefits. By reducing labor market distortions associated with contribution rates, the first element of our proposed reform raises efficiency. Second, we adjust redistribution within 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. Our results extend 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 insurable through redistributive 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

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

[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).

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] In contrast to these studies, however, 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 instantaneous labor taxation. We study the extent of distortions in labor supply decisions, which allows tentative welfare inference (in the spirit of 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 these conditions depend on the 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 the 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 links several strands of the literature. First, we build on earlier work on income uncertainty, insurance and redistribution (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), McGrattan and Prescott (2017), Hosseini and Shourideh (2019). We model a plausible and feasible policy of 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 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 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.

[3] We refer to this reform as social security privatization, because pension benefits 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 system 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).

[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 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 argumentative clarity, we consider a partial equilibrium setup, 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 (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 γ. The government revenue T_t is generated by a tax on labor income. The revenue which is not spent on government expenditure is spent on a lump-sum grant μ. Hence, the government budget constraint is expressed as:

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

Without loss of generality, we assume that the government budget is balanced. Relaxing this assumption to account for public debt would not change our results.

2.3 Households

In the first period of their lives, households work ℓ_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 θ 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 τ_ℓ denotes the marginal tax rate.

Summarizing, households face the following budget constraint:

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

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

In the stylized model, we assume GHH preferences (Greenwood et al. 1988). This assumption allows the direct study of labor elasticity with respect to changes in 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 θ maximize the following utility function:

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

where σ captures risk aversion, ϕ denotes disutility of labor, and η denotes the Frisch elasticity of labor supply. In this notation β denotes the discount factor. 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 $w_{t+1} = (1+\gamma)w_t$, the pension benefit formula is given by:

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

Thus, in the Beveridgean (redistributive) social security, pension benefits for both types are the same $b_{2,t}^{BEV}(\theta_L) = b_{2,t}^{BIS}(\theta_H)$. The growth rate of wages γ 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:

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

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 solution

Definition 1 *A competitive partial equilibrium with social security of type $\kappa \in \{BIS, BEV\}$ is an allocation for consumer $\{(c_{1t}(\theta), \ell_{1,t}(\theta), c_{2,t+1}(\theta), a_{2,t+1}(\theta))_{\theta \in \{\theta_L, \theta_H\}}\}_{t=0}^T$, tax policy $\{T_t(y_t)\}_{t=0}^T$ and pension benefits $\{b_{2,t}^\kappa(\theta)\}_{t=0}^T$ 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 θ 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 κ.*

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

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

Comparing consumption under the two social security systems reveals three effects: the efficiency effect, the decline in redistribution through the social security, and the increase in redistribution through 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.

$$\begin{aligned} c_{1,t}^{BIS}(\theta) - c_{1,t}^{BEV}(\theta) = \underbrace{\omega_\theta w_t(\ell_1^{BIS}(\theta) - \ell_1^{BEV}(\theta))}_{\text{efficiency}} - \underbrace{\frac{1}{2}\tau w_t(\omega_\theta \ell_{1,t}^{BEV}(\theta) - \omega_{-\theta}\ell_{1,t}^{BEV}(-\theta))}_{\text{redistribution through social security}} \\ + \underbrace{(\Delta\mu_t - \tau_\ell(1-\tau))\omega_\theta w_t(\ell_1^{BIS}(\theta) - \ell_1^{BEV}(\theta))}_{\text{redistribution through labor taxes}} \end{aligned} \tag{7}$$

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

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

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

Having taken a brief look at our setup, observe several important phenomena. First, regardless of the social security, θ_H-type households work more than θ_L-type households. Second, θ_H-type households clearly consume more when we replace Beveridgean with Bismarckian social security (the case of θ_L-type households is less clear-cut, as we elaborate later). Third, the ratio between the labor supply θ_H-type and θ_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 of our reform: the efficiency effect, 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 wedge.

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

The decline in labor wedge and the increase of labor supply follows from equation (8). The improvement to welfare follows from the envelope theorem. Thus, due to the efficiency effect, social security reform from Beveridgean to Bismarckian, reduces the labor wedge, raises labor supply and improves welfare both types of households.

Redistribution through social security Intuitively, after replacing Beveridgean with Bismarckian social security, θ_H-type households receive higher pension benefits and θ_L-type households receive lower pension benefits. This is a well recognized mechanism, with a 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 θ_L-type households partially offsets this by attenuating 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 θ_H-type households, the pension benefits are higher in the 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 the case of θ_L-type households, the redistribution effect is negative. The overall change in pension benefits in the Bismarckian system depends on the relative relative strength of the efficiency and the redistribution effect.

Proposition 2 (Redistribution through social security) *Consider the following reform bundle: social security is changed from a Beveridgean to a Bismarckian formula with fiscally neutral redistribution through lump-sum grants in the tax system. Such reform bundle entails negative transfers from θ_H-type households to the θ_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 θ_L-type households to θ_H-type households.

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

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

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

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

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

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

Proposition 3 (Redistribution through progressive tax system) *Consider the following reform bundle: social security is changed from a Beveridgean to a Bismarckian formula with fiscally neutral redistribution through lump-sum grants in the tax system. Such reform bundle entails positive transfers from θ_H-type households to the θ_L-type households through the tax system. The larger η, the larger these transfers are.*

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 θ_H-type households to θ_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 aggregate welfare (raise the total welfare in the society). In fact, there can be an improvement in welfare in the Pareto sense, i.e., welfare of both household types can be raised directly. There are three effects of such a reform: the efficiency effect, the tax redistribution effect and the pension redistribution effect. The efficiency effect improves welfare of both types of households, pension redistribution effect reduces welfare of θ_L-type household and improves welfare of θ_H-type household. The tax redistribution effect has the opposite effect. In other words, the redistribution embedded in Beveridgean social security may be replaced by the redistribution in the tax system when social security reform creates efficiency gains.

Proposition 4 (Hicks and Pareto welfare improvement) *Consider the following reform bundle: social security is changed from a Beveridgean to a Bismarckian formula with fiscally neutral redistribution through lump-sum grants in the 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 the efficiency effect. Second, the redistribution effect of the reform in the social security formula reduces welfare of θ_L-type households and improves welfare of θ_H-type household. This follows from Proposition 2. Third, that the change in net transfer through the tax system is positive for θ_L-type households and negative for θ_H-type households follows from Proposition 3. Overall, it is easy to see that θ_H-type households always gain. Therefore, we focus on θ_L-type households.

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

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

Notice also that one we simplify this equation, the left hand side of this equation is increasing with η, while the right hand side is constant. Furthermore, for η 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 $\eta = \tilde{\eta}$ tax and social security redistribution effects cancel out, then for θ_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 θ_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 of the left hand side of equation (12) and of the utility function, for all η'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 higher 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 θ_L-type households.

Observe also that since η, satisfying equation (12) does not depend on ϖ, 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 the 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 social security. Indeed, the larger the tax rate τ_ℓ, 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 the 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 use of a 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 at the beginning of life, thus agents do not face any risk during their 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, 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 modeling permits the identification of the extent to which presented intuitions carry through to a general equilibrium setup.

In the next sections, we ask 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 in a fully calibrated setup.

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 $J = 16$ die with certitude.

Productivity heterogeneity Let $e_{j,t}$ be a deterministic age-efficiency profile. Let $\epsilon_{j,t}$ be a persistent earnings shock that follows AR(1) process[6] with persistence parameter ϱ 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 the lifetimes according to the following formula, $\omega_{j,t} = e_{j,t}\epsilon_{j,t}$. Individuals may differ in their initial wage shock, and the variance of the initial shock realization is given by σ_0^2.

Budget constraint Households aged below the retirement age earn gross labor income $\omega_{j,t}w_t\ell_{j,t}$, where w_t is the marginal productivity of aggregate labor and $\ell_{j,t}$ denotes labor supply. Labor income is subject to social security contribution at the rate τ and progressive labor income tax denoted by $\mathcal{T}(y_{j,t})$ where $y_{j,t} = (1-\tau)w_t/z_t\omega_{j,t}\ell_{j,t}$ (where z_t denotes technological progress defined later). 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 pre-tax income is denoted to $1-\lambda$, and tax rate is determined by τ_ℓ. Note that social security contributions are exempt from labor taxation.

In addition to salary, income also consists of post-tax capital gain $(1-\tau_k)r_t a_{j,t}$ (with τ_k denoting capital income tax, r_t the interest rate and $a_{j,t}$ 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 evenly distributed within cohort, $\Gamma_{j,t}$. Households purchase consumption goods $c_{j,t}$, which are subject to consumption tax $\tau_{c,t}$ and accumulate 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 holdings ($a_{j+1,t+1} \geqslant 0$), and where μ_t denotes lump sum subsidies that will be

[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 $\Pi(\ln(\epsilon_{j,t})|\ln(\epsilon_{j-1,t-1}))$.

discussed later.

Social security and social security reform In the baseline scenario, we replicate the features of current social security 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. Social security features contribution rate τ. 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 $f^B_{j1,t+1}$ are defined as:

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

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

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

where $(F_{1,t}, F_{2,t})$ denote bend points replicating the progressive nature of the replacement rate, and are expressed as a fraction of average earnings (McGrattan and Prescott 2017). The value of the old-age pension benefits in period t are given by the following formulas:

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

where $\bar{J}$ denotes retirement age and ρ_m is set to match steady state pension benefit to GDP ratio[8], and $r_{l,t} = \frac{w_t L_t}{w_{t-1}L_{t-1}} - 1$ signifies the 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:

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

The link between benefits and contributions is thus direct, which gives rise to linking contemporaneous labor supply with retirement benefits (see Appendix A for formal derivation Butler 2002). At retirement the entitlements are converted into an annuitized pension benefit according to the following formula:

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

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

[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 ρ_m stems from the fact that AIME is computed based on the best 35 years of career in the actual system, while in our setup it is computed based on the whole working period. With 5 year periods, selecting the best 35 years is redundant.

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 $a_{j,t}$, the pension entitlements $f_{j,t}$ and individual productivity determined by $\epsilon_{j,t}$, $s_{j,t} = (a_{j,t}, f_{j,t}, \omega_{j,t}) \in \Omega$. A newborn 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 discount factor δ 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:

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

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 is given by:

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

Production Using capital K_t and labor L_t, the economy produces the 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. The 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 $r_t D_t$ with $\Delta D_{t+1} = D_{t+1} - D_t$.

$$G_t + subsidy_t + r_t D_t = T_t + \Delta D_{t+1}, \tag{23}$$

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

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

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

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

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 in our reform), its budget becomes balanced by construction.

In the status quo, lump-sum transfer μ_t is set to zero. In the reform scenario, we introduce additional progressivity with positive μ_t. The size of the transfer is fiscally neutral, that is it is set such that the government budget constraint is satisified with the level of debt from the status quo:

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

3.1 Equilibrium and model solving

We employ the notion of a 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 Ω as $\mathbb{P}_{j,t}$. Next we define equilibrium for our economy.

Definition 2 (Competitive equilibrium) *A competitive equilibrium is a sequence of value functions* $\{(V_{j,t}(s_{j,t}))_{j=1}^{J}\}_{t=0}^{\infty}$*, policy functions* $\{(c_{j,t}(s_{j,t}), \ell_{j,t}(s_{j,t}), a_{j+1,t+1}(s_{j,t}))_{j=1}^{J}\}_{t=0}^{\infty}$*, prices* $\{r_t, w_t\}_{t=0}^{\infty}$*, government policies* $\{\tau_c, \tau_k, \tau_l, \lambda, \mu_t, D_{t+1}\}_{t=0}^{\infty}$*, social security parameters* $\{\tau, subsidy_t, \rho_m\}_{t=1}^{\infty}$*, aggregate quantities* $\{L_t, A_t, K_t, C_t, Y_t\}_{t=0}^{\infty}$*, and a measure of households* $\{\mathbb{P}_{j,t}\}_{t=0}^{\infty}$ *such that:*

- **consumer problem:** *for each* j *and* t *the value function* $V_{j,t}(s_{j,t})$ *and the policy functions* $(c_{j,t}(s_{j,t}), \ell_{j,t}(s_{j,t}), a_{j+1,t+1}(s_{j,t}), f_{j+1,t+1}(s_{j,t}))$ *solve the Bellman equation (20) given prices and government policies;*

- **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 constraints are satisfied, i.e. equations (23), (25) and (24) are satisfied;*

- **markets clear**

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

- **probability measure:** *for all* t *and for all* j*,* $\mathbb{P}_{j,t}$ *is consistent with 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 a given initial distribution $\hat{\mathbb{P}}_{1,t}$ at age $j = 1$, time t, transition matrix $\Pi(\epsilon_{j,t}|\epsilon_{j-1,t-1})$, 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 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 the 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 status quo and reform scenario steady states.

Our main results use aggregate welfare effects under the veil of ignorance, that is before the shocks are realized. The details of the derivation are reported in Appendix B. In some analyses, we obtain results for all possible realizations of shocks, we refer to these results as ex post welfare.

4 Calibration

The model is calibrated to match features of the US economy. Using microeconomic evidence and the general characteristics of the US economy we established the 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 $\bar{\varrho}_\epsilon = 0.97$ and variance $\bar{\sigma}_\epsilon = 0.021$ which are based on estimates from Borella et al. (2018). In our model, each period corresponds to five years. Hence we need to recalculate input variables according $\varrho_\epsilon = \bar{\varrho}_\epsilon{}^5$ and $\sigma_\epsilon = \bar{\sigma}_\epsilon \frac{1-\bar{\varrho}_\epsilon{}^5}{1-\bar{\varrho}_\epsilon}$. Deterministic age-specific profiles of productivity $e_{j,t}$ and the variance of the initial shock σ_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 δ is set at 0.996 to match the capital to GDP ratio

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

2.9. Since households face mortality risk, the effective discount rate is below 1 even if δ is slightly larger than 1, as it might be the case while calibrating the economy for some Frisch elasticities.

We provide a broad range of calibrations for the Frisch elasticity, to explore quantitatively the intuitions for the stylized model. Then we set ϕ to match the average labor supply equal to 0.33 for each value of the Frisch elasticity. We consider $\eta \in \{0.2, 0.4, 0.6, ..., 2.8, 3\}$ In our main specification, we set the Frisch elasticity η to 0.8. We present calibrations for all alternative values of the Frisch elasticity in Table A2 in Appendix.

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

Table 1: Calibrated parameters for the initial steady state

	Macroeconomic parameters	Calibration	Target	Value (source)	Model outcome
	Preferences				
ϕ	disutility from work	8.44	average hours	33% BEA(NIPA)	33%
σ	risk preference	2	literature		
η	Frisch elasticity	0.8	literature$^{(a)}$		
δ	discounting rate	0.996	K_t/Y_t $^{(b)}$	2.9 OECD	2.9
	Firm				
α	capital share	0.33			
d	1-year depreciation	0.06		Kehoe and Ruhl (2010)	
	Government				
τ_c	consumption tax	0.044	$\tau_c C_t/Y_t$	2.8% OECD	2.8%
τ_k	capital tax	0.243	$\tau_k K_t/Y_t$	5.4% OECD	5.4%
ρ_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%
τ	social security contr.	0.075	soc. sec. deficit as % GDP	0.00%	0.00%
τ_l	labor tax$^{(c)}$	0.037	$\sum_{j=1}^{\bar{J}-1} N_{j,t} \int_{\Omega} \mathcal{T}(y_{j,t}(s_{j,t})) d\mathbb{P}_{j,t}/Y_t$	9.2% OECD	9.2%
λ	labor tax progression	0.137	earnings distribution	Holter et al. (2019)	
	Wage process				
$e_{j,t}$	age-specific profile			Borella et al. (2018)	
σ_0^2	initial variance			Borella et al. (2018)	
ϱ	shock persistence			Borella et al. (2018)	
σ^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 the 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).

Government Taxes are calibrated using Mendoza et al. (1994) approach. The capital income tax is set to 24.3%, to match 5.4% ratio of the capital income tax revenues to GDP. The marginal tax rate consumption is 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 $\tau_l = 0.037$ are set to match elasticity of post-tax to pre-tax income following Holter et al. (2019) and 9.2% ratio of the 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. It equals 14% of GDP, which is in the ballpark of values implied by NIPA.

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 (γ_t) The model specifies the labor augmenting growth rate of technological progress $\gamma_{t+1} = z_{t+1}/z_t$. The debate about the future of US growth is ongoing (e.g. Fernald and Jones 2014, Gordon 2016). We assume technological progress at the current rate of 2% per annum. Note that the technological progress is the same in status quo and in the 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 against income risk implicit in the status quo social security. 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 reflected in simulation results. Finally, we show welfare, macroeconomic and fiscal consequences of our reform as well as the role played by the strength of the labor response.

5.1 Intuitions

Note that in the reformed social security, equations (18)-(19) 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)-(17) and (18)-(19), 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:

$$\begin{aligned} \widehat{f}^R_{j+1,t+1} + a_{j+1,t+1} + (1+\tau_{c,t})c_{j,t} \quad &= (1+(1-\tau_k)r_t)a_{j,t} + y_{j,t} - \mathcal{T}(y_{j,t}) + \Gamma_{j,t} \\ &+ (1+(1-\tau_k)r_t)\widehat{f}^R_{j,t} + \upsilon^R_{j,t}\cdot \tau w_t \omega_{j,t}\ell_{j,t} + \mu_t, \end{aligned} \tag{26}$$

where $\widehat{f}^R_{j+1,t+1}$ 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] Analo-

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

gously, we can rewrite the budget constraint in the accumulation period under status quo as:

$$\begin{aligned}\widehat{f}^B_{j+1,t+1} + a_{j+1,t+1} + (1+\tau_{c,t})c_{j,t} &= (1+(1-\tau_k)r_t)a_{j,t} + y_{j,t} - \mathcal{T}(y_{j,t}) + \Gamma_{j,t} \\ &\quad + F^B(\widehat{f}^B_{j,t}, \omega_{j,t}w_t l_{j,t}) + 0 \cdot \tau w_t \omega_{j,t}\ell_{j,t} + 0,\end{aligned} \tag{27}$$

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

Equations (26) and (27) portray the key trade-offs in our reform. First, the extent of labor distortion varies between the 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 μ_t. It generates income effect and reduces labor supply in the reform relative to status quo. Third, the formulas for $\widehat{f}^B_{j,t}$ and $\widehat{f}^R_{j,t}$ 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 lowers labor supply of high income individuals and raises 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 labor income tax denoted as $\mathcal{T}'(y_{j,t}(s_{j,t}))$, we obtain:

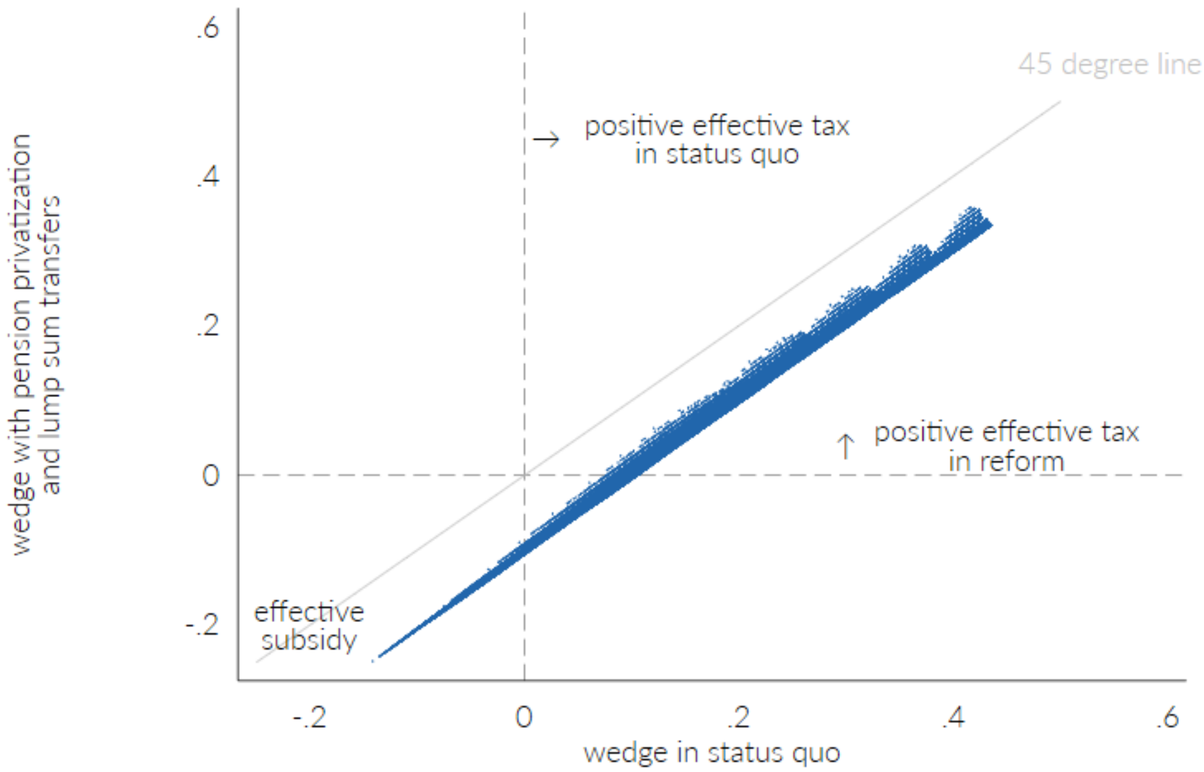
$$\phi\ell_{j,t}(s_{j,t})^{\frac{1}{\eta}} = \frac{c_{j,t}(s_{j,t})^{-\sigma}}{1+\tau_c}\left[1-(1-\tau)\mathcal{T}'(y_{j,t}(s_{j,t})) - \tau(1-\upsilon_{j,t})\right] w_t\omega_{j,t}(s_{j,t}), \tag{28}$$

with $\upsilon_{j,t}$ introduced earlier 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 1; details are provided in the Appendix A. Following (Cociuba and Ueberfeldt 2010), we measure it as the discrepancy between the 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:

$$\vartheta_{j,t}(s_{j,t}) = \frac{(1-\tau)\mathcal{T}'(y_{j,t}(s_{j,t})) + \tau(1-\upsilon_{j,t}) - 1}{1+\tau_c} + 1. \tag{29}$$

Figure 1 scatters age- and state-specific labor wedges $\vartheta_{j,t}(s_{j,t})$, given by equation (29), before and after the reform. The results are below the 45 degree line, which implies that along the entire state space the labor wedge is lower in the reform. Note that nominally neither parameters of the tax system, nor social security are changed relative to the status quo – yet, the decline in wedge is substantial and comprehensive. This is the efficiency gain from the social security reform. The agents view the social security contributions as a tax in the status quo and they view them as a stream of future income once the social security reform is implemented.

Figure 1: The decline of labor wedge



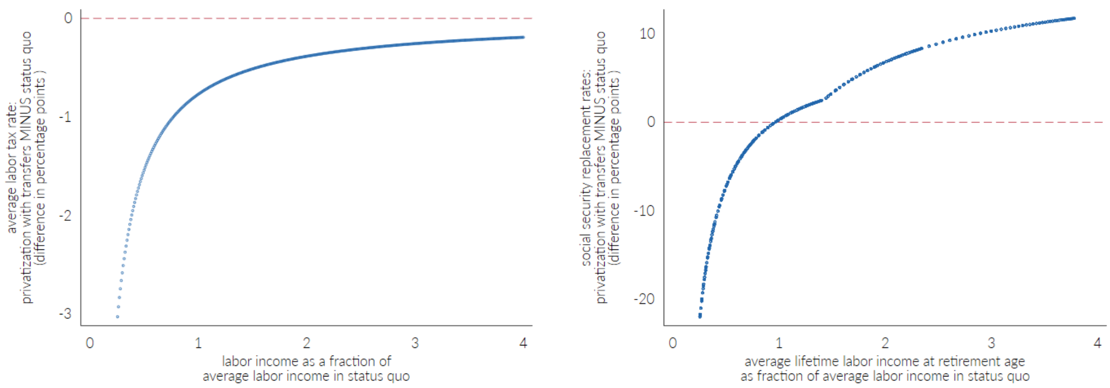
Notes: the figure portrays the values of $\vartheta_{j,t}(s_{j,t})$ obtained for all possible combinations of states (in total: 2.2 mln potential outcomes) for both status quo and for the reform. The values of $\vartheta_{j,t}(s_{j,t})$ are obtained using equation (29). Figure A2 depicting the same relationship but accounting for the probability measure $\mathbb{P}_{j,t}$ is available in Appendix D.

5.3 Taxes and replacement rates

Next, we look at how average tax rates and replacement 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 is portrayed in the left panel by larger declines in the average tax rates for low incomes, which become smaller as income goes up. Furthermore, overall laor taxation changes.

The left panel of this figure shows that the social security privatization accompanied by an increase in lump sum transfers results in more progressive tax system. Therefore, it provides more implicit insurance. In the reform scenario, the average tax rates for low income individuals are lower than in status quo by as much as 3 precentage points. For income individuals, the gain is smaller, 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 relative to total earned income (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

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 D.

percentage points), but raises it for individuals with above average lifetime income (by approximately 10 percentage points).

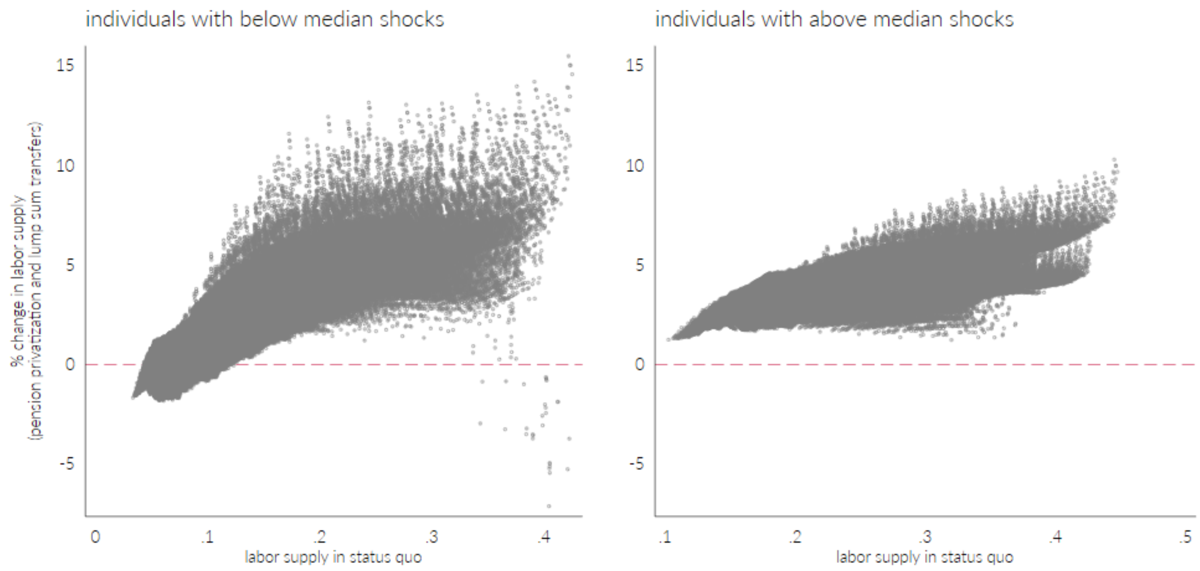
5.4 Labor supply

The decline in the labor wedge leads to substantial changes in labor supply. The results are reported in Figure 3, where we portray the 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. The increase is larger on average among individuals with below median realizations in a given period. Additionally, labor supply reacts more strongly among individuals with level higher labor supply. The labor supply reaction is more differentiated among individuals with unfavorable shocks realizations.

These results are entirely consistent with our intuitions discussed earlier. First, the reduction in labor wedge 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. Third, a 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, the income effect of pensions is negative for low-productivity agents and positive for high-productivity agents. The relative response for labor supply for different income groups depends on the relative strength of these effects.

To quantify these intuitions we obtain mean change in labor supply for productivity shocks realizations below median ($\omega < 1$), at median ($\omega = 1$) and above median ($\omega > 1$). We use probability measure $\mathbb{P}_{j,t}$

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 depicts the same relationship accounting for the probability measure $\mathbb{P}_{j,t}$ is available in Appendix D.

to reweight the observed distribution of labor supply changes. We show that at the median realization of productivity shocks ($\omega = 1$), on average, labor supply increases by 3.5 percentage points due to our reform bundle. We confirm that on average, change in labor supply is larger for realizations at the high end of the distribution than at the low end of the distribution. Specifically, we obtain 2.59% and 2.97%, respectively. Thus, the results reveal a hump shape in relation to the status quo labor supply.[12] 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 1.29 percentage points higher for individuals with below median shocks and 0.32 percentage points lower for individuals with above median shocks.

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 the 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 social security, and bundling it with a fiscally neutral lump-sum transfer. Heathcote et al. (2008) argue that their result hinges on flexible labor and we show that for the Frisch elasticity below 0.6 our reform actually becomes detrimental to welfare.

5.5 Welfare

Our results confirm that social security reform and labor tax progression can be complementary. In the proceeding sections, we argue that our reform has three main effects. First, the efficiency effect that benefits all agents. Second, the pension redistribution effect that benefits high income individuals and

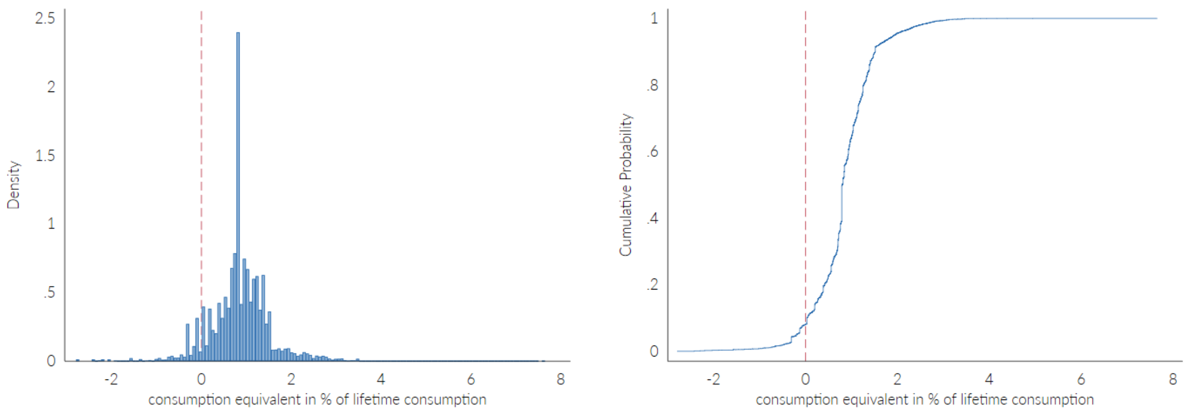
[12] The differences between these means are highly statistically significant. Once labor supply is adjusted for age profile, the results become -0.33% below median, 0.57% at median and 0.05% above median.

is disadvantageous to the low income ones. Third, the tax system redistribution effect that works in the opposite direction. Overall, the net effect is of quantitative nature. We find that for the preferred Frisch elasticity of 0.8 the welfare gain under the veil of ignorance expressed in consumption equivalent amounts to 0.32% of lifetime consumption. With the efficiency gain, raised tax revenues generate room for increased labor tax progression to substitute (even if only partially) for the insurance loss from reduced redistribution in social security.

Figure 4: Distribution of consumption equivalents: ex post evaluation

(a) distribution

(b) cumulative distribution



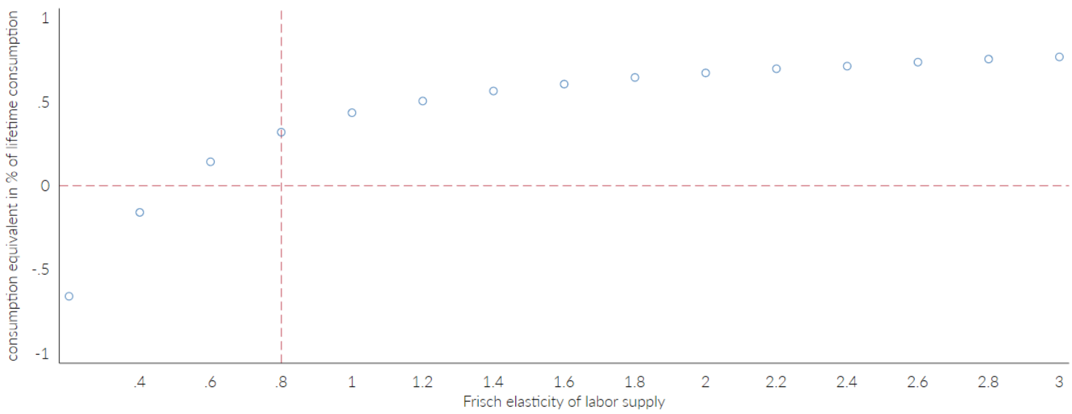
Notes: The figures portray the outcomes of 2.2 million simulations. For each potential realization of lifetime path of shocks, we use the policy functions to obtain the path of consumption and labor supply, in both status quo and in the reformed system. We then obtain lifetime welfare measure, following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

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 experience welfare gain. There are some individuals, for whom welfare losses are negative despite the lump-sum transfers. For them the loss of income due to less redistributive pension system is too large to be compensated with the lump-sum transfers and the efficiency gain. We interpret this finding to signify that optimal bundle of social security reform and labor tax progression should be targeted in order to shield specific groups of individuals from welfare losses.

The intuitions from the theoretical model in Section 2 suggest that the labor supply elasticity plays a 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 the 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, following the consensus in the literature about plausible values of the 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.

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

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 (**??**). The calibration parameters are as reported in Table A2 in the Appendix. The vertical dashed line signifies our preferred calibration, following the consensus in the literature about plausible values of the Frisch elasticity.

Note that we find positive welfare effects for the Frisch elasticity above this threshold. 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 raises labor supply more for the high-productivity individuals and less so for the low-productivity individuals, thus moving the economy towards an optimum proposed by Huggett and Parra (2010). Notwithstanding, the rise in labor tax revenues due to labor supply response is sufficient to compensate for the insurance loss in our reform.

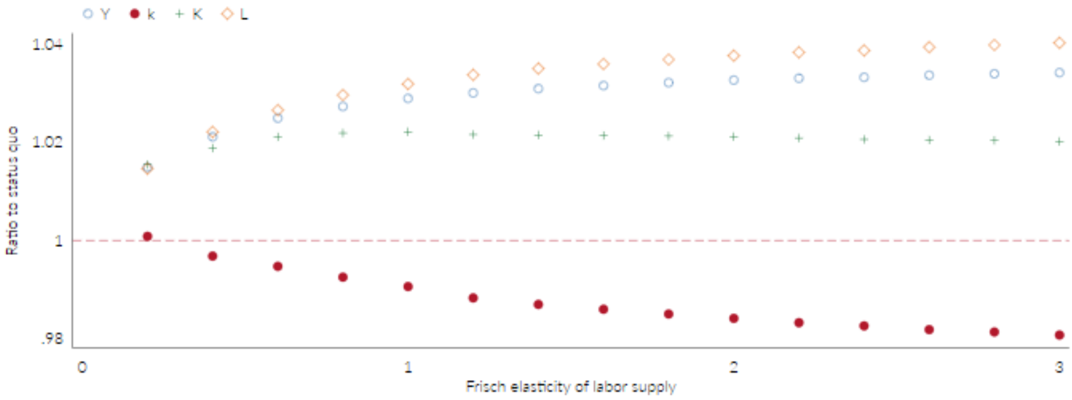
5.6 Macroeconomic and fiscal consequences

Figure 6 reports the macroeconomic adjustments across different Frisch calibrations, quantifying the macroeconomic intuitions. Labor supply increases by approximately 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, the reduction of the labor wedge combined with lump-sum transfers increase savings and thus capital. Additionally, higher labor supply increases returns 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 main 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

[14] While Huggett and Parra (2010) work in an open economy, in our environment there are implications from social security and labor supply to capital accumulation and interest rates.

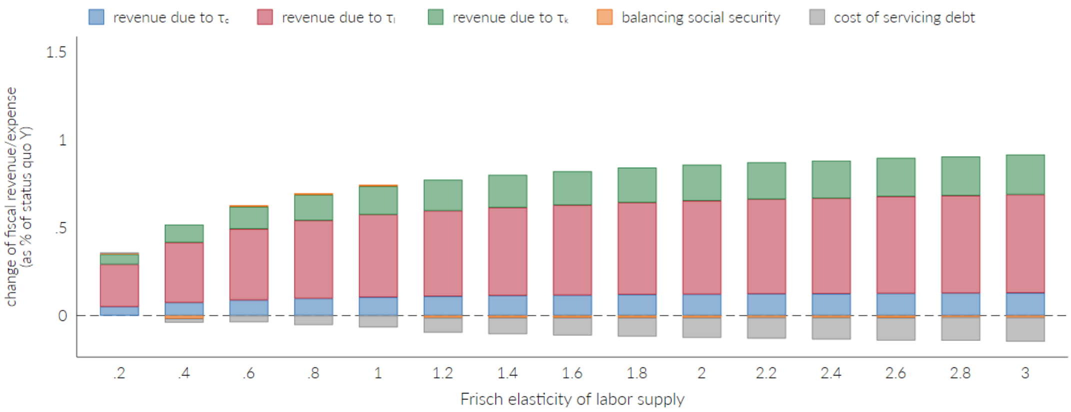
of servicing debt (the interest rate rises as capital-to-labor ratio declines).

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



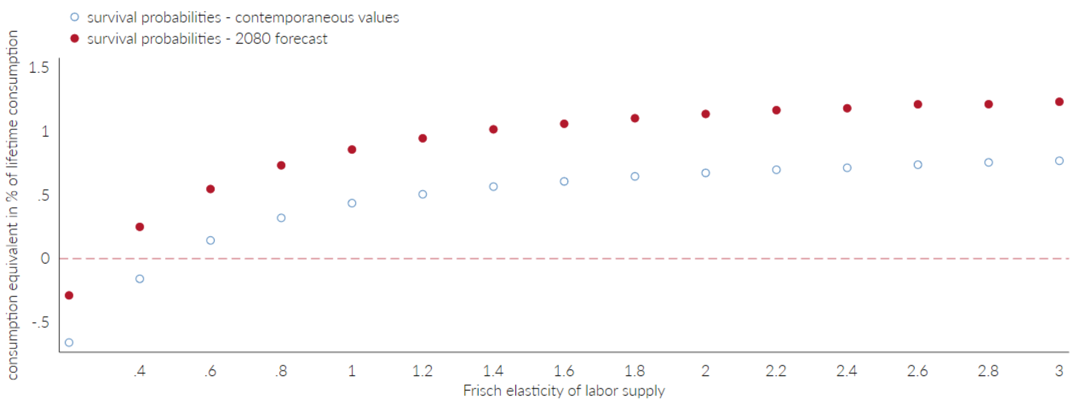
Notes: The graph presents the changes in the government budget between pension privatization and the status quo scenario. The differences in fiscal revenue/expenditures are expressed in the % of status quo aggregate output Y.

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 the 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. Next, we study the sensitivity of this conclusion to assumptions in our setup.

6 Sensitivity analyses

Population aging Rising longevity of subsequent birth cohorts is the underlying cause of the social security reforms. 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) or-else a rise in deficit of roughly 2% of GDP by 2080 (Feldstein 2016). It was established that such adjustments would cause significant welfare effects (e.g. Kotlikoff et al. 1999, Huggett and Ventura 1999, Genakoplos et al. 2000, Kitao 2014). Instead, introduction of a defined contribution system makes social security fiscally neutral.[15] This is why, with our proposed reform, welfare gains are higher with longevity. 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]

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.

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 the 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, capital declines due to the reform, which lowers wages and thus dampens the rise in labor supply. By contrast, with raised longevity, capital accumulation is higher and thus the reaction of capital to the reform is lower. With smaller effect on wages, there is higher rise in labor supply, in relative terms. Overall, rising longevity amplifies the increase in labor supply and thus gives rise to greater efficiency gains and more redistribution through progressive labor taxation.

Drivers of labor supply response Given that our results depend largely on the labor supply response by households to better aligned incentives, we check how sensitive are our results to this response. Admittedly, the reform reduces labor wedge by virtually the entire social security contribution: individuals

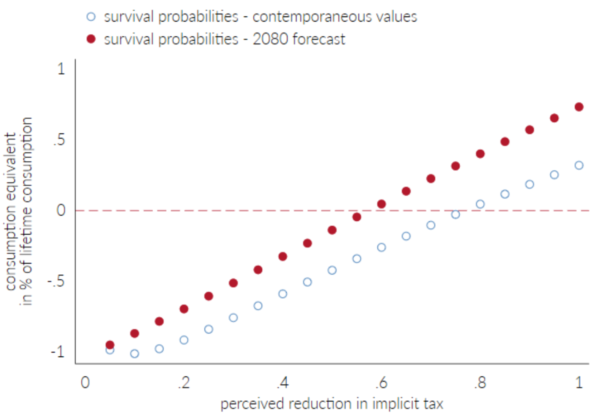
[15] Longevity translates to lowering per period pension benefit receipts for subsequent cohorts. This type of reform under consideration in the US economy (Feldstein 2005). It was also recommended as a mean to address fiscal instability resulting from longevity by the World Bank and the IMF; it has 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 $\bar{J}$.

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 within the model.

Numerous studies review evidence from labor taxation reforms to provide the bounds for plausible labor supply response. 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. Admittedly, most of these studies concern labor taxation per se, rather than lifetime labor wedge, as such reforms are rare. One such example is a study by Lachowska and Myck (2018), who show substantial response in behavior to changes as subtle as formula for computing pension benefits.

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 results as if individuals internalize only a given fraction of the reduction in implicit taxation caused by the reform.

We perform the following exercise. For each working age group, a certain fraction of contributions is subjected to equation (27) and the rest to equation (26). Specifically, given the preferred Frisch elasticity of 0.8, we vary the share of income subjected to equation (26) between 0% and 100%, the complement is subjected to equation (27). This modeling strategy reflects the share of individuals who internalize the changes in the social security; recall the intuitions from section 5.1. The results are portrayed in Figure 9. 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 wedge outweigh insurance loss if, for each dollar earned, incentives are fully internalized for 55 cents on labor income. We conclude that in order to capture the potential in social security reform, moderate levels of economic literacy are sufficient.

7 Conclusions

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 wedge but necessitates an insurance loss (Nishiyama and Smetters 2007). We propose a reform bundle which addresses both efficiency and insurance channels directly: couple privatizing social security with increasing 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 US. We show that the increase in labor tax progression can be achieved in a fiscally neutral way.

Lifetime consumption equivalent of such bundle of reforms amounts to 0.32% for plausible calibrations of the Frisch elasticity. Moreover, this value increases to approximately 0.73% if the reform is implemented for higher values of longevity in retirement and individuals fully internalize the decline in labor wedge. For positive welfare effects to emerge, it is enough if roughly half of the individuals do. 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

The accumulation of entitlements in the reformed, defined contribution social security occurs according to:

$$f^R_{j,t} \quad = \quad (1 + r_{\ell,t})f^R_{j-1,t-1} + \tau_t w_t \omega_{j,t} \ell_{j,t} \tag{A1}$$

Let *virtual assets* $\widehat{f}^R$ represent the $f^R_{j,t}$ as if the entitlements were actual assets, that is as if they accumulated at market interest rate and were subject to survivor premium. In the accumulation period (for $j < \bar{j}$) the *virtual assets* from the reformed, defined contribution, social security accumulate according to:

$$\widehat{f}^R_{j+1,t+1} \quad = \quad (1 + (1 - \tau_{k,t}))r_t \widehat{f}^R_{j,t} + \tau_t w_t \omega_{j,t} \ell_{j,t} \cdot \upsilon^R_{j,t} \tag{A2}$$

where $\upsilon^R_{j,t}$ denotes the implicit tax or subsidy, that is a fraction of the contributions that does not convert to annuity at retirement or, alternatively, additional return on the contribution that would not be obtained in the capital market. There are several mechanisms behind $\upsilon^R_{j,t}$. First, contributions are exempt from capital income tax. Second, contributions receive an annuity premium, which is unavailable in the capital market. Third, the contributions accrue at $r_{\ell,t}$ rather than at r_t.

Consider the present value of forgoing contributions to the funded pillar. The worker who is j years old at the time t would reach retirement age at time $i = t + \bar{J} - j$. Future pension benefits, received as of age $\bar{J}$, have to be discounted to age j at interest rate r_t and adjusted capital income tax that would have been due if the contributions were private savings $\tau_{k,t}$ and accounting for the probability of survival until retirement age $\prod_{s=0}^{J-\bar{J}} \pi_{\bar{J},s}$.

To calculate the $\upsilon^R_{j,t}$ we combine two elements: (i) present value of the stream of the benefits evaluated at retirement, and (ii) the present value of the stream of future pension benefits.

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

After some rearrangements, we obtain:

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

B Measuring welfare effects

To measure the welfare effects of the reform we want to separate the effects attributable to utility of consumption and disutility of labor. Let

$$W_t^c = \mathbb{E}_t \left[\sum_{j=1}^{J} \left(\delta^j \pi_{j,t+j-1} \frac{(c(s_{j,t+j-1}))^{1-\sigma}}{1-\sigma} \right) \right]$$

denote lifetime utility from consumption (under the veil of ignorance), where $c(s_{j,t})$ is the optimal consumption. Analogously, let

$$W_t^\ell = \mathbb{E}_t \left[\sum_{j=1}^{J} \left(\delta^j \pi_{j,t+j-1} \frac{\phi}{1+\frac{1}{\eta}} \ell(s_{j,t+j-1})^{1+\frac{1}{\eta}} \right) \right]$$

denote lifetime disutility from working, where $\ell(s_{j,t})$ denotes optimal labor supply.

It is convenient to define $W^c(\Lambda)$ as:

$$W_t^c(\Lambda_t) = \mathbb{E}_t \left[\sum_{j=1}^{J} \left(\delta^j \pi_{j,t+j-1} \frac{((1+\Lambda_t)c(s_{j,t+j-1}))^{1-\sigma}}{1-\sigma} \right) \right].$$

Note that the following expression holds $W_t^c(\Lambda_t) = (1+\Lambda)^{1-\sigma} W_t^c$.

Denote the status quo and the reform as B and R, respectively. The consumption equivalent in percent of lifetime consumption Λ solves the following equation:

$$W_t^{c,B}(\Lambda_t) - W_t^{\ell,B} = W_t^{c,R} - W_t^{\ell,R}$$

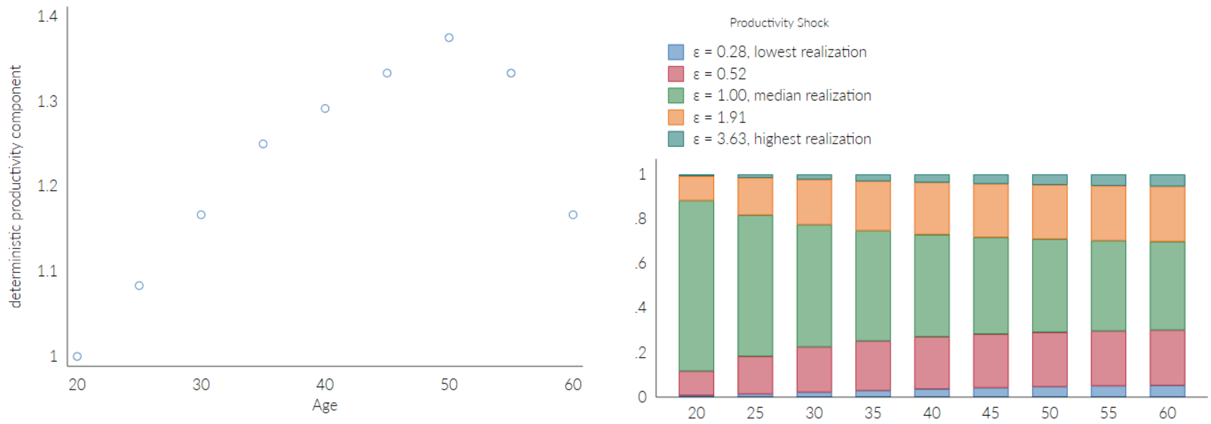
Thus, we obtain the formula for Λ

$$\Lambda_t = \left(\frac{W_t^{c,R} - \left(W_t^{\ell,R} - W_t^{\ell,B} \right)}{W_t^{c,B}} \right)^{\frac{1}{1-\sigma}} - 1. \tag{A3}$$

In this expression, $W_t^{c,B} - W_t^{\ell,B}$ and $W_t^{c,R} - W_t^{\ell,R}$ refer to lifetime utility under the veil of ignorance (before the shocks are realized) of an individual living her entire life in the status quo and reformed social security and tax system, respectively.

C 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
τ_l	labor tax	0.150	1110	9.2%
τ_c	consumption tax	0.065	5100, 5121	2.8%
τ_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).

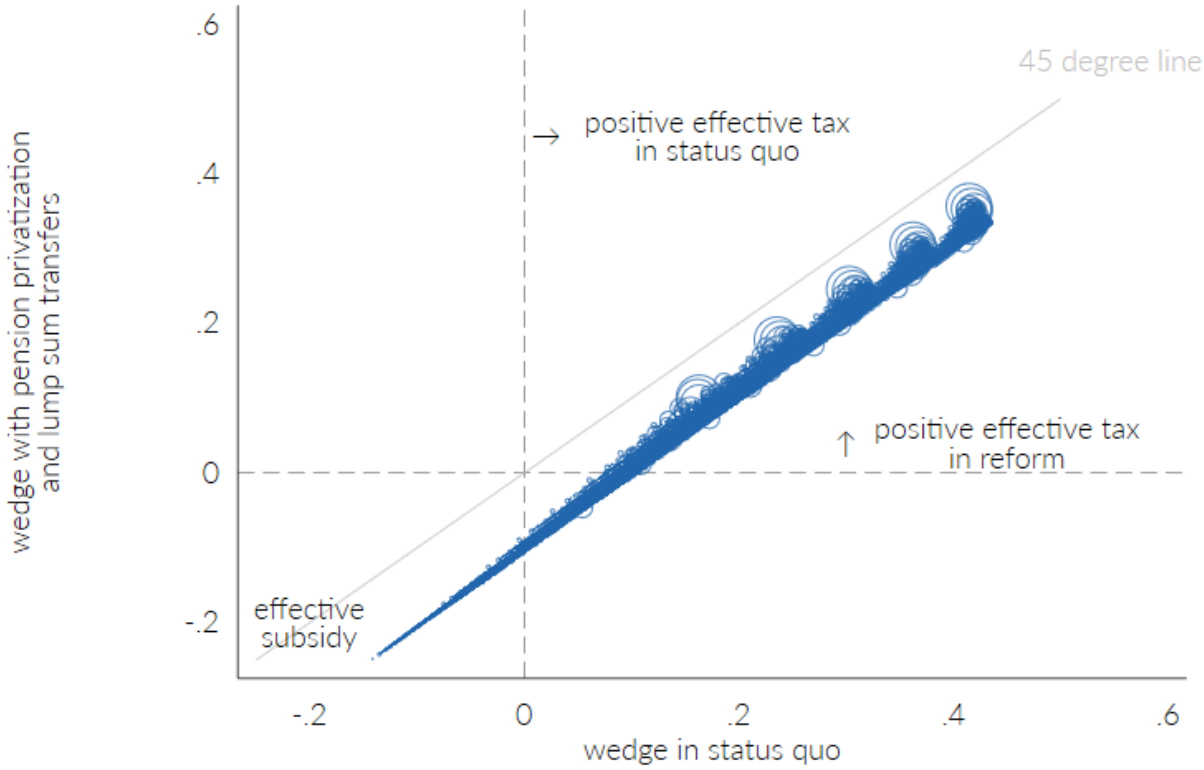
Table A2: Calibrated parameters for the initial steady state across Frisch elasticities

Macroeconomic parameters		values of η													
		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
ϕ	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
δ	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
τ_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
τ_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
τ_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 the 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 $\rho_m = 0.55$.

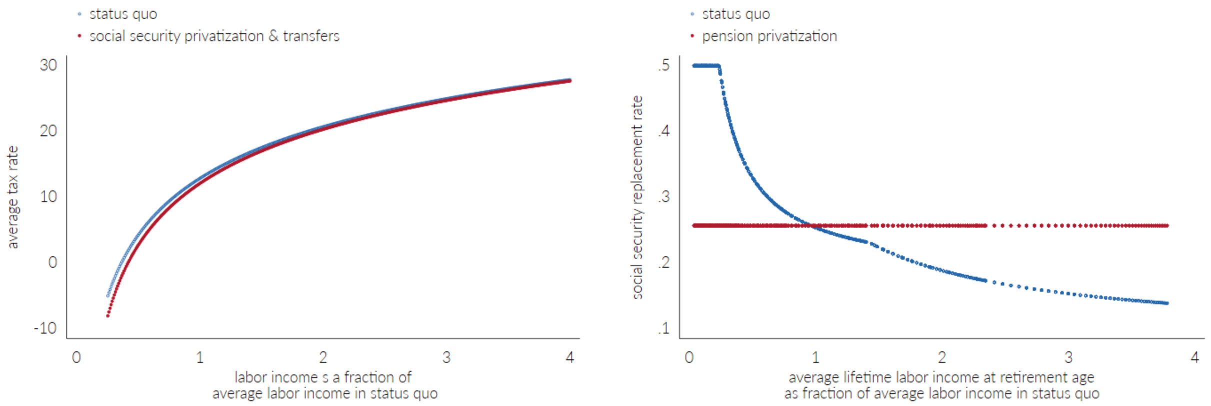
D Additional results

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



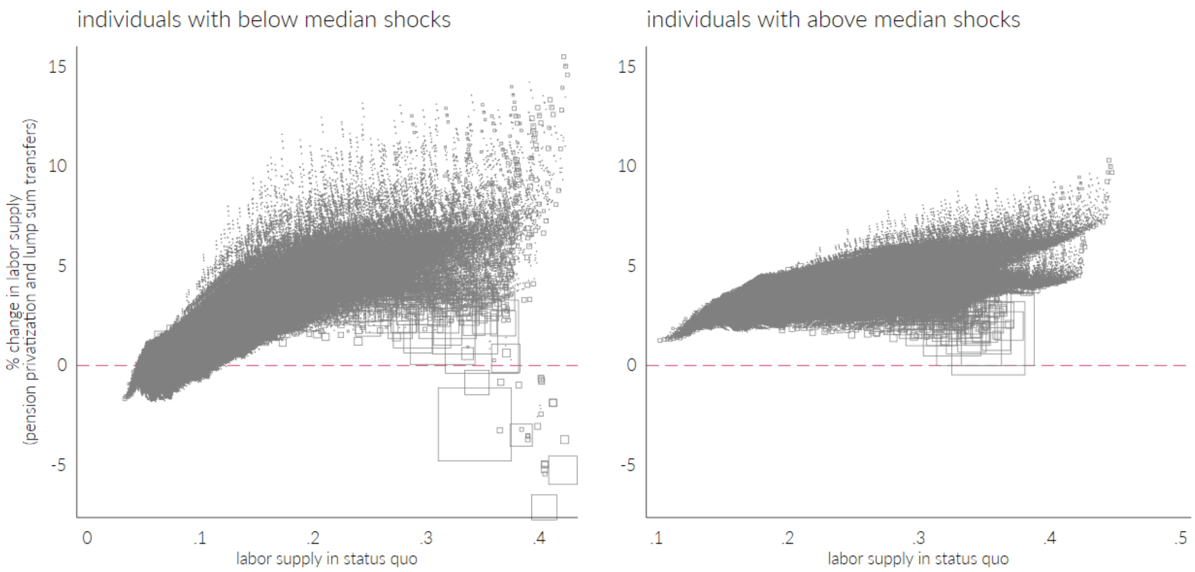
Notes: the figure portrays the values of $\vartheta_{j,t}(s_{j,t})$ obtained for every possible combination of states (in total: 2.2 mln potential outcomes) for both status quo and for the reform. The values of $\vartheta_{j,t}(s_{j,t})$ are obtained using equation (29). The size of the circle signifies 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.

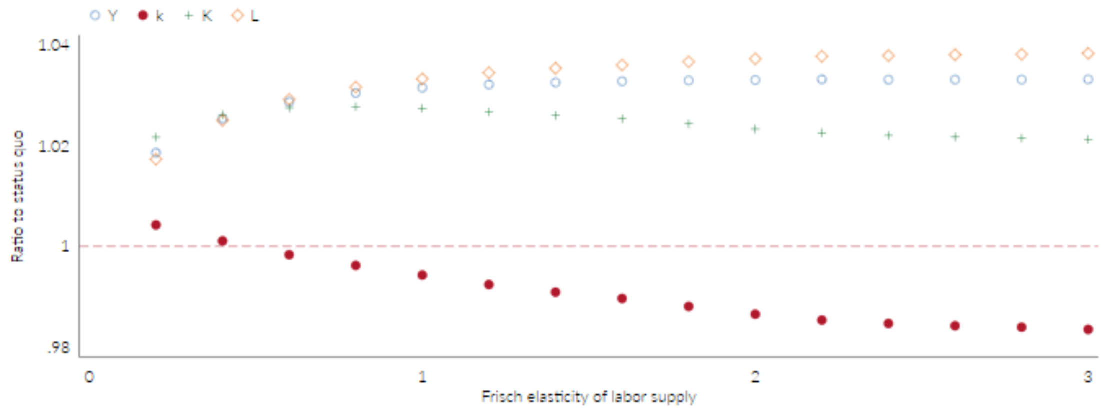
Figure A4: Scatter plot of labor supply in status quo against the change in labor supply due to reform



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.

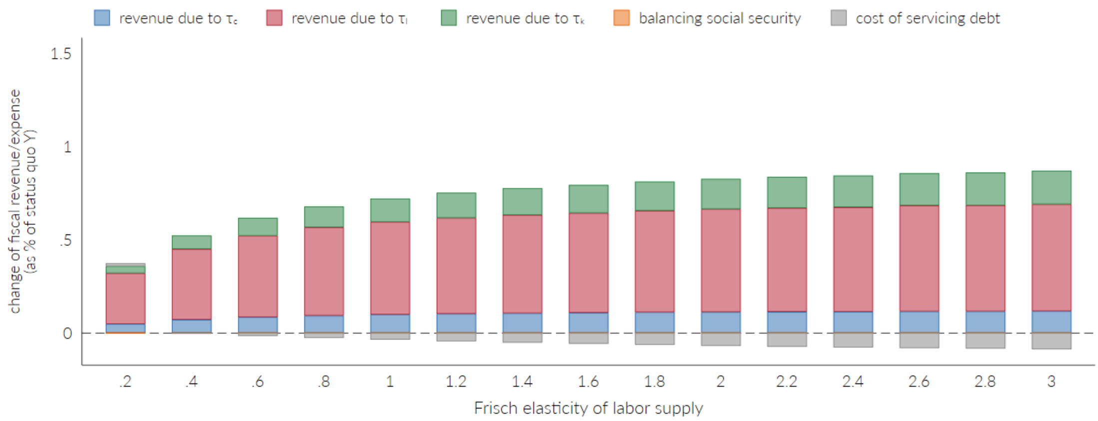
E Macroeconomic adjustments adjusted for longevity

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.