Evaluating U.S. State Pension Policy *

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Abstract

We use an overlapping generations framework to evaluate the impact of state pension reform on public and private workers, and apply this analysis to all fifty U.S. states. We consider (i) closing the pension plan to new entrants, (ii) reducing pension benefits together with wage increases and (iii) suspending cost-of-living-adjustments (COLAs). While each reform effectively reduces long run taxes, variation in fiscal and demographic features creates significant differences in state outcomes. Closing the plan to new entrants generates the most even distribution of welfare gains across job sectors and age cohorts, while COLA suspensions prove particularly harmful to public workers.

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1 Introduction

It has been well-documented that in the aggregate, U.S. state pension plans do not have sufficient funds to finance future retirement benefits. For example, Public Plans Data documents that as of 2020, U.S. state pensions were operating with a 72% funded ratio such that the aggregate underfunded gap was in excess of $1.5 trillion. The ultimate burden of financing underfunded pension systems falls on taxpayers, as they are responsible for public employee wages and benefits. Given this, analysis related to altering state pension systems should properly account for all affected constituencies.

Several states have considered reforms to their defined benefit pension systems.[1] These reforms usually include replacing some part of the defined benefit or DB plan (i.e. a guaranteed retirement income) with some version of a defined contribution or DC plan (i.e. a guaranteed contribution that the beneficiary invests). While reforms of this type reduce the amount of risk underwritten by taxpayers, they are also always contentious. Reform discussions are contentious for predictable reasons- public employees are asked to give up a guaranteed benefit in exchange for taking on extra risk.

In this paper, we develop a heterogeneous overlapping generations model framework which is able to evaluate the impact of pension reform on relevant constituencies within a state- public workers affected by changes to retirement benefits as well as private workers affected by taxes. Our approach is unique in the sense that we apply our state-level analysis to all fifty U.S. states and quantify welfare effects by job sector and age cohort. The scope of our analysis allows us to learn which state characteristics are most relevant for producing effective reform outcomes, and how reform effects are borne by current workers and retirees.

In particular, the model is comprised of a joint distribution of workers who solve a life-cycle problem subject to the fiscal policy of the state and other demographic trends over time. Workers vary by age, wealth and job sector, working in either the private or public sector. Public sector workers are enrolled in a state-run DB pension plan whereas private sector workers individually save for retirement. Each agent solves a lifecycle portfolio choice model similar to Cocco, Gomes, and Maenhout [2005] in that they live through two stages

[1] See Brainard and Brown [2018] for a comprehensive list of recent state pension reforms.

(working and retirement) and make decisions over consumption/savings and asset portfolios each period. Agents are exposed to three sources of risk: mortality, wage and market risk. In addition, both public and private employees are subject to a wage tax which varies with the management and health of the state-run pension plan. In terms of fiscal policy, the government operates under fixed rules which require it to finance public sector wages and pension benefits with a balanced budget. The government is also responsible for managing the pension fund which involves the investment of pension assets (portfolio management) as well as the raising of contributions (savings) for current and future benefits. Two features are key to generating the chronic pension underfundedness that is observed in the data. First, states value their pension liabilities with unrealistically high discount rates such that liabilities grow faster than investment returns. Second, states contribute an insufficient amount of funds each period to their pension asset pool.

The calibration of the quantitative model is divided into two sets: universal and state-specific parameters. State-specific parameters mostly relate to demographic features and fiscal characteristics which are obtained from state financial reports. This allows considerable tractability in parameterizing the model to a specific state and/or point in time for our analysis.

For our main policy experiment, we examine the positive and normative impact of three generalized pension reforms for all fifty states, as well as the District of Columbia. In the first reform (Closed Reform), we consider the impact of closing the pension plan to new entrants and increasing new entrants' wages by 5%.[2] In the second reform (Hybrid Reform), we consider the impact of a hybrid pension system which partially reduces pension benefits for current and future workers but compensates them with a 5% wage increase. Finally, we consider the impact of a partial cost-of-living-adjustment (COLA) freeze which reduces the real value of pension benefits for public workers by 1.5% annually and offers no additional compensation.

In terms of the positive analysis, we find that each reform significantly reduces pension liabilities such that states experience a persistent reduction in taxes, and this is enough to

[2]This wage increase is similar to a defined contribution (DC) plan with matching if workers were to always save at least 5% of their wage income.

offset any transfers for increased wages. When averaged across states, the Closed Reform generates a 23% reduction in pension liabilities after 45 years. For the Hybrid and COLA reforms, those numbers are 40% and 25%, respectively. Given its impact on pension liabilities, the Hybrid Reform generates the largest drop in taxes: a level reduction of 1.1%, on average. While the COLA Reform creates the largest initial drop in liabilities and taxes, due to the immediate impact that COLA assumptions have on the valuation of pension liabilities, the Closed and Hybrid reforms lead to lower taxes in the long run. For each reform, state-level differences arise with respect to the timing, magnitude and direction of change in relevant fiscal aggregates. In large part, the differences are caused by variation in the size of the pension benefit and public sector, as well as demographic age trends for each state.

In terms of the normative analysis, we find that, generally, all private and public workers experience welfare gains from the Closed Reform and that those gains are distributed the most evenly across job sectors and age cohorts. In terms of age, younger worker cohorts experience the largest gains as they benefit from the long run reduction in taxes which frees up additional resources for consumption and saving. Under the Hybrid Reform, private workers experience even larger welfare gains due to the larger tax reduction, but public workers have mixed results. In particular, young workers benefit from lower taxes and the 5% wage increase such that this offsets losses from the reduced pension benefit. Conversely, middle-aged public workers experience significant welfare losses and are highly sensitive to benefit reductions, given their proximity to retirement. Lastly, we find that the COLA reform is the most contentious in the sense that private workers experience the largest welfare gain of the three reforms while public workers experience the largest welfare loss. For public workers, a freeze in COLAs effectively reduces the real value of pension benefits and this proves particularly harmful. While this type of uncompensated adjustment in retirement benefits has significant negative effects for public workers, it is a commonly employed reform used by states to quickly reduce their pension liabilities.[3]

Section 2 of this paper provides additional background with respect to U.S. state public pension plans. Section 3 reviews related literature on pension policy. Section 4 provides

[3]Since 2009, more than half of U.S. state have proposed or implemented some form of COLA reform (see Brainard and Brown [2018]). While such changes are often challenged in courts, most have been upheld.

details of the model. Section 5 details the calibration of the quantitative model and covers relevant data sources. Section 6 presents results from the main policy experiments, and Section 7 concludes the paper.

2 Background and Empirical Observations

In the aggregate, state pension plans in the United States are significantly underfunded and their condition has deteriorated over the last two decades. In this section, we document this decline and expand upon the underlying causes for chronic pension underfundedness which will, in turn, help inform modeling assumptions utilized in the paper. We use data from the Public Plans Database (PPD) which is provided by the Center for Retirement Research at Boston College (CRR) and the MissionSquare Research Institute and supported by the National Association of State Retirement Administrators (NASRA). This data is annual in frequency and spans the years 2000 to 2020.

A pension funded ratio is the ratio between current assets A and liabilities L of a pension plan. Thus, when the plan does not have enough assets to cover liabilities, the funded ratio is less than one, and this is a common indicator of poor pension health. Pension liabilities are present value calculations for all future benefits that the plan has guaranteed. For example, if a plan was committed to paying an infinite, deterministic stream of aggregate benefits B at a rate r, then liabilities would be $L = \frac{1+r}{r}B$. Importantly, unlike U.S. private pensions, state plans have additional flexibility in choosing their discount rate r. Under Government Accounting Standards Board (GASB) ruling 25, pension plans choose discount rates based upon their expected investment return.[4] By choosing a high discount rate, the pension can reduce the value of its liabilities and immediately improve its funded ratio.[5]

Figure 1 plots the average public plans funded ratio, as well as the asset and liability components of the funded ratio over time. As can be seen in the top panel, even with high discount rates, the average funded ratio has declined from nearly 100% in the early 2000s to 71.5%. As of 2020, given that states have an aggregate pension liability of $5 trillion, this

[4]According to the 2021 Milliman Corporate Pension Funding Study, the average discount rate of the top 100 U.S. corporate pensions was 3.08% in 2019, whereas the average state pension plan used a rate of 7.18%.

[5]In our example, $\frac{\partial L}{\partial r} = -\frac{B}{r^2} < 0$ for any positive discount rate r.

implies a deficit in excess of $1.5 trillion.

[Figure 1 Here]

Throughout this time period, pension liabilities have continued to grow (bottom panel). A large body of research has sought to quantify the magnitude of the funding crisis and underscore the role of unsound accounting practices which mask the problem.[6] For example, Novy-Marx and Rauh [2011a] find that by using appropriate discounting assumptions for liabilities, public pension liabilities are, conservatively, 38% higher than their reported value. See also Novy-Marx and Rauh [2011b], Andonov and Rauh [2021], Brown and Wilcox [2009] and Anzia et al. [2019]. Also, an aging workforce is another attributing factor which has led to the growth in pension liabilities over this time period.[7]

When a pension plan is underfunded, it is commonly the result of low investment returns or low savings (called contributions in pension parlance). In the aggregate, the current decline in public pension funded ratios is due to both. Figure 2 plots the average level of pension contributions relative to the Annual Required Contribution known as ARC. The ARC is the estimated level of contributions such that a pension plan is fully funded in the long run, on average. Therefore, contributions falling below their ARC are often a signal of insufficient saving. As can be seen in the figure, aggregate pension contributions have failed to satisfy their ARC over the whole sample period.

[Figure 2 Here]

In addition to low savings, U.S. pension plan investment returns have historically underperformed relative to their target returns. As mentioned earlier, pension target returns are especially important because plans discount their liabilities with the same rate. Thus,

[6]Specifically, Government Accounting Standards Board (GASB) ruling 25 and Actuarial Standard of Practice (ASOP) item 27 allow public pension liabilities to be discounted with their expected portfolio return.

[7]See De Nardi, Imrohoroglu, and Sargent [1999] for a reference to the impact an aging workforce has on the U.S. Social Security system. In this paper, we utilize state-level demographic data from UVA Weldon Cooper to project how demographic change can affect pension liabilities for each state.

by setting a high target return, plans can automatically reduce the present value of pension liabilities and improve their funded ratio. Despite this immediate benefit, liabilities grow at the rate of their discount factor and plans risks insolvency if they cannot achieve the long run target returns. In FY 2020, for example, the weighted average target rate of return for public plans was 7.13% whereas the average portfolio return was 6.4%.

Figure 3 plots the hypothetical value of two portfolios, normalized to 1 in year 2000. The first portfolio's value is obtained from the target returns of U.S. state pension plans, assuming that all returns are re-invested with the principal each year. The second portfolio's value is obtained from the actual returns experienced by the plans. As is made clear, the actual portfolio significantly underperformed the target portfolio over the sample period such that it was 26.6% below its target value in 2020. This corresponds to returns underperforming by 1.6% on an annualized basis.

[Figure 3 Here]

In summary, U.S. public pension plans have experienced a continual decline in funded health for the past two decades. This decline is due to low savings and low investment returns, which are linked to the discounting assumption made with respect to liabilities. Further, with an aging workforce, pension liabilities and benefit distributions have continued to grow. Together these features generate chronic underfundedness which places an increasing burden on current (and future) workers in both the public and private sectors. This fact has prompted many states to consider a transition to alternative retirement schemes which utilize individual retirement accounts. Further, our analysis will properly account for these relevant institutional and fiscal features.

3 Related Literature

We utilize a heterogeneous overlapping generations model with fixed prices where 80-year-lived agents spend their first 45 years working and their remaining 35 in retirement. The individual lifecycle problem of model agents is most similar to Cocco, Gomes, and Maenhout [2005] and Campbell, Gomes, and Maenhout [2001], where agents live through a working and retirement period and make decisions related to consumption/savings as well as their financial asset portfolio. See also Chai, Horneff, Maurer, and Mitchell [2011] and Horneff, Maurer, Mitchell, and Stamos [2009]. Importantly, agents are born into one of two job sectors: the public sector where they receive an exogenous wage process and guaranteed pension benefit, or the private sector where they receive a different wage process as well as individual retirement savings accounts. The environment is intended to replicate that of a U.S. state and its defined benefit pension system.

The model is used to evaluate reforms to a state-level pension system and thus relates to a large literature which examines the risk-sharing benefits of public retirement systems, as well as the costs (and benefits) of transitioning to alternative retirement schemes. While public retirement systems can be used to complete markets and improve welfare (Diamond [1977], Ball and Mankiw [2007] and Shiller [1999]) they can also be a source of inefficiency arising from a host of political constraints which lead to poor management (Monahan [2015], Andonov, Hochberg, and Rauh [2018], Pennacchi and Rastad [2011] and Bradley, Pantzalis, and Yuan [2016]). For these reasons, a significant literature has investigated the normative and positive effects of reforming a pension system. Often, the focus has been on how reform effects are distributed across generations (Cui, De Jong, and Ponds [2011], Gollier [2008], Krueger and Kubler [2002]) while others have highlighted important sources of intra-generational heterogeneity (Huggett and Ventura [1999], Conesa and Krueger [1999], Fuster, Imrohoroglu, and Imrohoroglu [2003], Imrohoroglu, Imrohoroglu, and Joines [1995]). Often, these papers focus on pension systems which are universal in scope, implying that all model agents participate in the the program and are therefore affected in similar ways by changes to the system. However, for state pensions, many workers are not enrolled in the pension system but are nonetheless affected by state fiscal policy, and in potentially different ways.

While the overlapping generations framework can be used to evaluate the impact of reform at short and long horizons, a considerable amount of focus is given to the transitional effects of reform (Nishiyama and Smetters [2007]). This is important because current generations are often the most acutely affected and this can affect the political viability of such reforms.

For example, papers which evaluate transitions from a pension system to one of individual accounts often find significant welfare losses for the current generation (McKiernan [2021] and De Nardi, Imrohoroglu, and Sargent [1999]) while some others find that gains are possible (McGrattan and Prescott [2017]).

Relative to the literature, this paper focuses on the transitional effects of pension reform at the state-level and contributes in two ways. First, in addition to intergenerational welfare effects, we explicitly account for how welfare effects are borne across a state's public and private sector. While private workers do not receive pension benefits, they are affected by tax policy which funds the pension and this can lead to divergent welfare outcomes when considering reforms. Second, we apply our quantitative analysis to all fifty U.S. states. By re-calibrating the model and re-running each policy experiment, we gather important insights as to which state characteristics are the most relevant for determining effective reform outcomes.

U.S. state pension plans suffer from a variety of institutional features and constraints which limit their ability to remain solvent in the long run. Monahan [2015] and Beermann [2013] describe the current, chronic underfundedness as a symptom of underlying fiscal constraints and limited commitment on the part of state legislatures. While most states face balanced budget constraints, pension contributions are not an explicit component of their liabilities. Thus, lowering pension contributions is a means of relaxing fiscal pressures. This is particularly appealing as the costs of underfundedness (e.g. insolvency risk) materialize long after the current political cycle. See also Fitzpatrick and Monahan [2015], Monahan [2010] and Monahan [2017]. In our model, states set unrealistically high discount rates and are able to under-contribute to their pension fund in a way that is consistent with the data. In addition, related research has explicitly focused on the constraints and incentives which determine government decisions within the context of pension plan management (see Myers [2021], Myers [2019] and Pennacchi and Rastad [2011]). In our paper, for tractability we assume the state government follows a rule-based policy to balance its budget each period. This policy determines how pension contributions and taxes vary with the funded ratio of the pension over time and in a way that is consistent with empirical trends for U.S. state pension plans.

4 Model

We use a heterogeneous overlapping generations model with fixed prices to analyze the effects of state-level pension reform. Model agents solve a lifecycle problem with fixed working and retirement periods and differ with respect to their job sector, wealth and age. Sector of employment determines the compensation the worker receives in terms of wages and retirement benefits. We assume that all public sector workers receive a state-sponsored pension. During the lifecycle, agents are exposed to three sources of risk: wage, mortality and market risk. Both wage and mortality risk are idiosyncratic whereas market risk is an aggregate shock to investment returns. Lastly, there exists a state fiscal authority which follows a set of rules to fund public sector wages and contributions to the pension plan.

Lifecycle Problem. Agents in a U.S. state s are born at age $t = 1$ and can live to age $t = 80$ but are subject to mortality risk, given by the conditional survival probabilities $p(t+1|t)$ for each age. Agents have CRRA preferences over consumption

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \tag{1}$$

and discount the future at a rate $\beta \in (0, 1)$. Each period, agents solve a consumption/savings problem along with a portfolio problem. Specifically, given beginning-of-period wealth x, agents choose consumption c and savings a to satisfy the budget constraint

$$c + a = x \tag{2}$$

and choose a risky asset portfolio share $\alpha \in [0, 1]$ where $R' \sim N(\mu, \sigma)$ is the risky asset gross return next period and R^f is the risk-free rate. Given the recursive structure of the problem, we use prime notation to indicate objects realized in the following period.

Agents work for the first 45 years and then enter retirement. During the working period, agents receive a wage $w(s, j, t, \epsilon, \eta)$ which is a function of their state s of residence, job sector $j \in \{pub, priv\}$, age and idiosyncratic shocks (ϵ, η) where ϵ is a transitory shock to wages and η is a persistent shock. More specifically, ϵ is a mean-zero, normally distributed random variable with variances σ_ϵ^2 and η is a random walk

$$\eta' = \eta + \omega' \tag{3}$$

where ω' is a mean-zero, normally distributed random variable with variance σ_ω^2. Upon reaching retirement, agents receive a sector-specific annuity b_{sj}. In particular, all public sector workers are enrolled in a state-funded pension plan and receive a pension $\bar{b}_s$ as a component of their retirement annuity $b_{sj=pub}$. Lastly, during the working period, agents are subject to a wage tax $\tau(s, \chi, T)$ which depends upon state demographics, the pre-contribution funded ratio χ of the pension, as well as model time $T = 0, 1, 2...$ in years.[8] The law of motion on next-period agent wealth during the working period can be expressed as

$$x' = \underbrace{\left[\alpha R' + (1-\alpha)R^f\right]a}_{\text{portfolio return}} + \underbrace{\big(1 - \tau(s, \chi', T+1)\big)w(s, j, t+1, \epsilon', \eta')}_{\text{after-tax wages}} \tag{4}$$

In solving the recursive worker problem, we define an agent's point in the state space by the vector $\boldsymbol{\varsigma} = \big(s, x, t, j, \eta, \chi, T\big)$. Thus, for a given individual state, the agent solves

$$\begin{aligned} V(\boldsymbol{\varsigma}) = \max_{c,a,\alpha} \quad & u(c) + \beta p(t+1|t) E\big[V(\boldsymbol{\varsigma}')|\boldsymbol{\varsigma}\big] \\ s.t. \quad & c + a = x \\ s.t. \quad & x' = \left[\alpha R' + (1-\alpha)R^f\right]a + \big(1 - \tau(s, \chi', T+1)\big)w(s, j, t+1, \epsilon', \eta') \\ s.t. \quad & \chi' = \Gamma(s, \chi, R', T) \\ s.t. \quad & c \geq 0, \quad \alpha \in [0, 1] \\ s.t. \quad & \text{exogenous processes } \{R', \eta', \epsilon'\} \end{aligned} \tag{5}$$

where the agent faces short-selling portfolio constraints and also conditions upon the law of motion Γ for the pension funded ratio which affects the next-period wage tax. In the retirement period of the lifecycle, the state space reduces to $\boldsymbol{\varsigma}^r = \big(s, x, t, j\big)$ as the agent is no longer subject to wage risk or wage taxes. Also in retirement, the wealth law of motion

[8] The funded ratio χ and tax formula will be explicitly derived in the following section.

reduces to

$$x' = \left[\alpha R' + (1-\alpha)R^f\right]a + b_{sj} \tag{6}$$

where the annuity benefit depends upon the agent's sector of employment.

State Fiscal Authority. We assume the state is populated by a continuum of agents of mass M_s who are distributed according to the joint distribution $\Phi : s \times j \times t \times T \rightarrow [0,1]$ which is a function of the state, job sector, agent age and model time.[9] Further, cohort growth rates $\phi(s,t,T)$ induce a law of motion for Φ over time. The state fiscal authority must balance the budget each period and raise taxes to fund public sector wages and the state pension plan. Specifically, for any given state s, time period T and pension funded ratio χ, the authority sets τ to balance the budget

$$\begin{aligned}\tau \sum_{j=\{pub,priv\}} \sum_{t=1}^{45} \Phi(s,j,t,T) \int\int w(s,j,t,z_1,z_2)dF(z_1,z_2) = C(s,\chi,T) + \\ \sum_{t=1}^{45} \Phi(s,pub,t,T) \int\int w(s,pub,t,z_1,z_2)dF(z_1,z_2)\end{aligned} \tag{7}$$

where the left-hand side represents tax revenues which fund pension contributions $C(s,\chi,T)$ and public wages on the right-hand side.[10] Equation (7) thus implies the tax formula $\tau(s,\chi,T)$ as shown in the lifecycle problem of Equation (5).

Aggregate pension contributions are a function of the state, funded ratio and model time, and can be summarized as

$$C(s,\chi,T) = \theta_s\left[NC(s,T) + AUFL(s,\chi,T)\right] \tag{8}$$

where $NC(s,T)$ represents normal cost expenditures and $AUFL(s,\chi,T)$ represents the cost of repaying the amortized unfunded liability of the pension. Essentially, pension contributions account for newly accrued benefits (*normal costs*) and old deficits (*amortized unfunded*

[9] For notational ease, we normalize M_s to 1 in this section but relax the assumption when calibrating the model to particular states.

[10] Given that workers are subject to idiosyncratic wage risk via (ϵ,η), the cross-section of worker wages are integrated over with the joint distribution $F(z_1,z_2)$. These are assumed to be independent shocks; thus, $F(z_1,z_2) = F_1(z_1)F_2(z_2)$.

liability). Importantly, the parameter θ_s represents the state's willingness to pay contributions such that a value of $\theta_s < 1$ results in insufficient contributions to properly fund the pension.

The normal cost for the pension fund is computed as

$$\begin{aligned} NC(s,T) &= \sum_{k=1}^{45} \Phi(s,pub,k,T) \sum_{m=1}^{35} \frac{p(45+m|k)}{(1+r_s)^{45-k+m}} \frac{w_{sk}}{\sum_{l=1}^{45} w_{sl}} \bar{b}_s \\ &= \underbrace{\sum_{k=1}^{45} \Phi(s,pub,k,T)}_{\text{aggregation}} \quad \underbrace{\tilde{\beta}(k)}_{\text{discount factor}} \quad \underbrace{\tilde{b}_s(k)}_{\text{accrued benefit}} \end{aligned} \tag{9}$$

where r_s is a state-specific rate to discount the measure and $\{\omega_{sk}\}_{k=1}^{45}$ are average wages for each public sector age cohort in state s. The outer summation accounts for the size of each age cohort currently working in the public sector, and thus is an aggregation term for determining the cost. For a given age cohort, the inner summation computes the present value of newly accrued pension benefits where the benefit is discounted by mortality risk and the rate r_s. The ratio $\frac{w_{sk}}{\sum_{l=1}^{45} w_{sl}}$ is an accrual factor that represents the agent being vested in the pension benefit $\bar{b}_s$ over the working period of their lifecycle.

As for the amortized unfunded liability cost term in Equation (8), some additional notation and accounting must first be introduced. Each period, the fiscal authority manages the investment portfolio of the pension, as well as contributions to the fund.[11] To calculate required contributions the state must first compute the discounted present value of pension liabilities $PVL(s,T)$ at model time T. In the baseline model, we assume the state uses the Entry Age Normal (EAN) method to value liabilities, as this is the most prominent valuation formula used by U.S. public plans. Thus, at model time T, the present value of liabilities is

$$PVL(s,T) = \sum_{j=0}^{\infty} \frac{1}{(1+r_s)^j} \sum_{k=45}^{80} \Phi(s,pub,k,T+j)\alpha(s,k,T+j)\bar{b}_s \tag{10}$$

where $\alpha(s,k,T+j)$ is the EAN accrual factor for a worker of age k at time $T+j$ in state s,

[11]It is assumed the state follows a fixed investment strategy α_s for its risky asset share.

written

$$\alpha(s,k,T+j) = \begin{cases} 1, & \text{if} \quad k-j \geq 45 \\ \frac{\sum_{k=1}^{k-j} w_{sk}}{\sum_{k=1}^{45} w_{sk}}, & \text{if} \quad k-j < 45 \end{cases} \tag{11}$$

As Equation 10 makes clear, pension benefits accrue fractionally over the working period of a specific agent; that is, even though benefits $\bar{b}_s$ are guaranteed at retirement, they accrue slowly as a liability of the state. In addition, the state discounts pension liabilities at particular rate r_s, which corresponds to their investment portfolio target return.

For ease of notation, we define the post-contribution funded ratio as $\tilde{\chi} = \tilde{\chi}(s, \chi, T)$ which is a function of the state, pre-contribution funded ratio χ and model time T. Then, the law of motion for the next period pre-contribution funded ratio is defined as

$$\begin{aligned} \chi' =& \frac{\text{Gross Assets} - \text{Distributions}}{PVL(s, T+1)} \\ =& \frac{[\alpha_s R' + (1-\alpha_s)R^f]\tilde{\chi} PVL(s,T) - \bar{b}_s \sum_{k=45}^{80} \Phi(s, pub, k, T+1)}{PVL(s, T+1)} \\ =& \Gamma(s, \chi, R', T) \end{aligned} \tag{12}$$

Given this, the amortized unfunded liability $AUFL(s, \chi, T)$ is computed as

$$AUFL(s,\chi,T) = (1-\chi)PVL(s,T)\frac{r_s}{1-(1+r_s)^{-\bar{T}_s}} \tag{13}$$

where $\bar{T}_s$ is the amortization window and all deficits are amortized using the pension discount factor. In summary, each period the state recognizes newly accrued benefits (Equation 9) and amortized deficits (Equation 13) as required costs which must be raised in order to fully fund the pension, in the long run. Despite this, the state only contributes a fraction θ_s which leads to chronic pension underfundedness.

Equilibrium. An equilibrium is defined as a set of stochastic processes $\{R', \epsilon', \eta'\}$, deterministic aggregates $\{\Phi(s, j, t, T)\}$ and state fiscal policy $\{\bar{b}_s, r_s, \theta_s, \alpha_s, \bar{T}_s\}$ such that for periods $T = 0, 1, 2, ...$

1. Agents solve their lifecycle problem in Equation 5

2. The fiscal authority sets τ to balance the budget in Equation 7

3. Pension policy rules induce the law of motion in Equation 12

$$\chi' = \Gamma(s, \chi, R', T)$$

For our purposes, we are interested in how pension reform affects consumer welfare as well as relevant fiscal aggregates at the state-level. This will involve solving the public and private worker lifecycle problem at time $T = 0$ under both a baseline and reform scenario for all age cohorts, and then simulating outcomes for fiscal projections.[12] Details of the analysis are provided in Section 6.

5 Calibration

In calibrating the model to a particular state environment, we identify two sets of parameters: *universal* parameters which are common across states and *state-specific* parameters which are unique to the given state of interest. Time periods are interpreted as one year.

Universal Parameters. Table 1 details the set of universal parameters. While we account for price level differences in wages and benefits across states, we employ the same functional form for the wage process. Specifically, we use the the form and estimates from Cocco, Gomes, and Maenhout [2005] which utilizes PSID data to estimate wages as a function of age as well as the error processes, using the method of Carroll and Samwick [1997].[13] Specifically, worker wages are defined as

$$\begin{aligned} w(s, j, t, \epsilon, \eta) =& \lambda_{sj} e^{f(t)+\epsilon+\eta} \\ =& \lambda_{sj} e^{b_0+b_1 t+b_2 \frac{t^2}{10}+b_3 \frac{t^2}{100}+\epsilon+\eta} \end{aligned} \tag{14}$$

[12]The numerical solution of the agent lifecycle problem was developed with the aid of program codes provided by Fehr and Kindermann [2018].

[13]Wages are defined broadly as to include total reported labor income plus unemployment compensations, workers compensations, social security, supplemental social security, other welfare, child support and total transfers for the head of household.

with parameter values $\{b_0, b_1, b_2, b_3\} = \{-1.9317, .3194, -.0577, .0033\}$.[14] The parameter λ_{sj} controls for wage differences by job sector and state. Using data from the BEA, we set the within-state wage gap between public and private sector workers at 91% such that $\lambda_{sj=pub} = 0.91\lambda_{sjpriv}$ for each state. Conditional survival probabilities were obtained from the National Center for Health Statistics (NCHS).

[Table 1 Here]

For investment return assumptions, we use data estimates from Navega Strategies which are also standard in the literature. Specifically, we employ a 4% real equity return premium over a 2% risk-free rate with equity return volatility set at approximately 16%.

State Parameters. State-specific parameters relate to details of the fiscal and demographic environment. The majority of pension-relevant data comes from the Public Plans Database which is provided by the Center for Retirement Research at Boston College (CRR) and the MissionSquare Research Institute and supported by the National Association of State Retirement Administrators (NASRA). The underlying data comes from comprehensive annual financial reports that are publicly released by individual plans.[15] Table 2 details the key parameters of interest. While we assume a constant pension benefit, which is known at the beginning of employment, most pensions accrue based upon formulas which factor in a worker's wages, wage growth and years of service. Thus, in determining pension benefit $\bar{b}_s$ we compute the average benefit, given aggregate data on benefit distributions and total number of annuitants. Further, model agents receive sector-specific annuities b_{sj} meant to replicate additional retirement benefits, such as U.S. Social Security. Information on state-level Social Security distributions are taken from the Social Security Administration congressional report and sectoral wage gaps λ_{sj} are applied to these, as well, given that Social Security is a function of past wages/contributions. In many states, public employees enrolled in a pension

[14] Cocco, Gomes, and Maenhout [2005] wage estimates were based upon dollar estimates using 1992 as a base year. We use the CPI to update measures to 2018 dollars so as to match the nominal value of pension benefits, detailed in the State-Specific Parameters section.

[15] When multiple plans exist in a state, data is aggregated up or weighted by the value of liabilities, across individual plans.

plan receive partial or no Social Security coverage; we also account for this using the Public Plans data.

[Table 2 Here]

Data such as the current pension funded ratio, current pension liabilities, discount rate and the pension portfolio strategy are also taken from annual financial reports. We internally set the population parameter M_s such that the computed total value of pension liabilities is equal to the nominal level observed in the data.

We use state-level measures and projections for the distribution of age cohorts, provided by the Weldon Cooper Center for Public Service at the University of Virginia. While this data pertains to total state populations, we are interested in the current workforce, as well as retirees who were previously in the workforce. To make this transformation, we employ labor force participation rates from the BEA, as well as state information about the ratio of pension annuitants to active workers. Refer to Appendix A.2 for a more detailed description. Table 3 provides state-level information with respect to trends in age demographics. It is clear from this table of projections that most states will experience an increase in their retired workforce which can cause additional strain on the pension system.

[Table 3 Here]

To further illustrate this point, Figure 4 plots the evolution of the cross-section of age cohorts over time for the representative U.S. state. Cross-sections in Year 20 and 40 make clear that an aging workforce will put significant demands upon the distribution of pension benefits to retirees, and this will play an important role in determining the long-term health of state pension funds in the model forecast.

[Figure 4 Here]

We further assume that, in the baseline model, all states properly adjust the nominal value of pension benefits for changes in cost of living, an assumption we relax when evaluating pension reforms in Section 6. Lastly, the state parameter θ_s is determined based upon the average ratio of pension contributions to their Annual Required Contributions (ARC) for each state.

Table 4 provides each state's calibration. In terms of total liabilities, the largest public pensions plans reside in California (\$1.2 Trillion), New York (\$578 Billion), Texas (\$354 Billion) and Illinois (\$352 Billion). States with the lowest funded ratios include Kentucky (45%), Illinois (46%), Connecticutt (47%) and New Jersey (51%). Conversely, the only states or territories in our sample which are fully funded or better are South Dakota (100%) and the District of Columbia (105%).

[Table 4 Here]

As mentioned previously, contributions as a percentage of Annual Required Contributions (ARC) is a standard benchmark to assess whether pension plans are saving appropriately. In our sample, the states which contribute the lowest relative amounts include New Jersey (52%), Illinois (75%), North Dakota (75%) and Pennsylvania (76%) while those that contribute the full amount or better includes Alaska, Arizona, District of Columbia, Georgia, Indiana, Maine, Missouri, Mississippi, Nebraska, New Hampshire, Oklahoma, South Carolina, South Dakota, Tennessee, Utah, Vermont, Wisconsin and West Virginia. Even if states do contribute their full ARC, it is not enough to guarantee a fully funded pension in the long run: the ARC calculation is based upon the discounted value of liabilities which will be unrealistically low if plans use high discount rates. Also, states have a fairly consistent public sector size, ranging from 7% of the workforce (Nevada) to 15% (Wyoming). Lastly, the values of pension benefits ($\bar{b}_s$) and total public employee retirement benefits ($b_{sj=pub}$) in Table 4 have been normalized using state-level differences in the cost of living. States which offer the most generous pension plans include California (\$36k), Colorado (\$36k), Connecticut (\$41k), Georgia (\$39k), Illinois (\$44k), Massachusetts (\$38k), Nevada (\$41k) and Ohio (\$37k). Lastly, while not listed in the table, the average social security coverage for a public sector worker with pension benefits is 77.6%.[16]

6 Evaluating Reforms

In this section, we estimate the state-level effects of pension reform on fiscal aggregates and consumer welfare. In terms of procedure, we first calibrate the quantitative model to each state, then solve and simulate the baseline model. Then, we solve and simulate the reform version of the model which allows us to compute consumer welfare. We use consumption-equivalent welfare as our metric and details of the calculation are provided in Section A.1. We perform this analysis on all fifty states as well as the District of Columbia.

We consider three generalized reforms which have been proposed or implemented in the past for U.S. state pension plans. In the first reform, the public pension plan is closed to all new entrants and new entrants receive increased wages in place of the old pension (Closed Reform). In the second reform, both current and future workers' pension benefits are reduced and those workers are compensated with increased wages (Hybrid Reform). In the third reform, Cost-of-Living-Adjustments for current and future retirees are partially suspended (COLA Reform). While each reform is not modeled after a particular state's historical experience, elements of the reforms have been proposed or implemented in a variety of states.[17]

Table 5 contains the baseline forecasts for each state, listing the level of fiscal aggregates at 15, 30 and 45 year horizons. For most states, pension liabilities are predicted to grow due to the accrual of new benefits, an aging workforce and high discount rates. For example, the model predicts California pension liabilities to grow from \$1.2 trillion, as measured in 2020, to \$1.9 trillion in 2065. Other than the District of Columbia, all states are predicted to be

[16]This is an unweighted average. If weighted by the size of a plan's liabilities, the average social security coverage is 70%.

[17]For example, similar to Reform 1, the Oklahoma legislature closed its defined benefit pension plan to certain new entrants in 2015 and enrolled those new workers in a defined contribution plan with 6% matching. Similar to Reform 2, the Rhode Island General Assembly established a hybrid retirement plan which reduced the pre-existing pension benefit and created a mandatory defined contribution plan. For current workers, the size of the pension reduction varied with years of work experience within the public sector. Similar to Reform 3, many states have engaged in partial or full suspensions of their COLAs (Rhode Island [2011], Utah [2010], New Jersey [2011], Colorado [2018], Minnesota [2018] to name a few).

under-funded in the long run with 36 states operating with funded ratios below 90%. Due to the increase in pension liabilities and shrinking tax base (i.e. relatively less workers-to-retirees), state taxes and tax volatility are forecast to increase over the next 45 years.

[Table 5 Here]

In what follows, for each reform we provide tables which list state-level outcomes together with figures which depict the reform's impact on a representative state. The representative state is used for illustrative purposes to highlight the key effects of each reform. Observed variation in state-level effects are then further explored.

Reform 1: Closed to New Entrants

Under the Closed Reform, the state pension plan is closed to all new entrants such that current workers retain full pension benefits $\bar{b}_s$ while all new hires receive a 5% wage increase but no pension. The 5% wage increase is comparable to a DC program with a 5% match, given that the workers always save at least 5% of their annual wage. Table 6 provides the effect of the Closed Reform on relevant fiscal aggregates for each state.

[Table 6 Here]

To understand these effects, we first examine the reform's impact on the representative state's average path of pension liabilities (Figure 5) over the next 45 years. Because pension liabilities accrue during an agent's working period, and the reform maintains all existing pension benefits, there is no immediate reduction in pension liabilities. Further, the effect of reducing liabilities is slow but significant in the long run: liabilities are reduced by nearly 23% after 45 years, on average. At the state-level (Table 6), the total reduction ranges from 12.4% to 26.1% with the majority of states experiencing reductions near the that of the representative state. States which experience the largest drop in long run liabilities (such as Kentucky, New York and Utah) are the same states which either have more generous initial pension benefits or are forecast to have a relatively large young workforce over the next 45 years (see Table 3).[18]

[Figure 5 Here]

Figure 6 plots average tax rates for the representative state under both scenarios. Despite the wage increase of new entrants to the public sector, the average tax rate falls: the model predicts an average state tax reduction of 1.1%, in levels, which is approximately 8.5% lower than the baseline. Thus, the reduction in pension-related taxes is more than enough to offset and properly fund the wage increase. Factors which cause the drop in liabilities are the same which reduce taxes- states which offer the most generous pension benefits or expect the largest growth in a young workforce experience the largest tax reduction.[19]

[Figure 6 Here]

Figure 7 plots the welfare effects of the closed pension reform for all working age cohorts and both job sectors (public and private). Because private sector workers are not directly affected by pension benefits, all welfare effects for private workers come from the timing, level and volatility of wage taxes. In addition, since current public sector workers experience no change in their retirement benefits, their welfare effects are similar to the private sector.

[Figure 7 Here]

As is evident from the figure, all working age cohorts and job sectors experience, on average, an increase in welfare with more pronounced results for young worker cohorts. Because the majority of the reform effects (in terms of lower taxes) occur in the long run, older workers experience little variation or impact in terms of their welfare. Alternatively, younger workers

[18] By closing the pension to future public workers, there exists a relatively large reduction in future liabilities for states which were forecast to have many new entrants to the workforce.

[19] This fact will be further illustrated with regression analysis at the end of the section.

experience a prolonged period of lower taxes which frees up additional resources for consumption and/or savings during their working period. Private workers experience a slightly larger welfare gain, on average, due to the sectoral wage gap.

Table 7 lists the individual welfare results for each job sector, state and select age cohorts. In addition, it presents sector- and state-averages based upon the relative distribution of age cohorts. The states of Alaska, California, Colorado, Connecticut, Georgia, Illinois and Mississippi experience the largest welfare gains.[20]

[Table 7 Here]

State-level variation in welfare results is caused by differences in the timing, reduction and volatility of post-reform taxes relative to the baseline scenario. For example, in terms of timing, while California's 45 year reduction in tax rates (10.1% drop relative to the baseline) is quite common in our sample, the state experiences a 10% relative reduction in tax rates by Year 30, which is a large outlier, and this generates large welfare gains within the state relative to others with more delayed reductions. The state-level average welfare results may further vary based upon the distribution of age cohorts. Figure 8 provides a heat map for the average state welfare effects under the Closed Reform.

[Figure 8 Here]

We now consider the underlying state characteristics which are the most significant determinants of welfare effects under the Closed Reform. We start by plotting the relationship between state characteristics and the average welfare effects (see Figure 9). Specifically, we focus on state pension contributions as a fraction θ_s of ARC, initial funded ratios $\chi(s, T = 0)$, the relative size of the public sector (as measured in proportion) and the initial level of pension benefits $\bar{b}_s$.[21] Not surprisingly, welfare effects share a strong, positive relationship with

[20]Conversely, Indiana, Kansas, North Dakota, New Hampshire, Pennsylvania, Tennessee and Vermont were the states which experienced the lowest, yet still positive, average welfare gains.

[21]Because current public workers are affected only through the tax policy in the Closed Reform, it is reasonable to look at the average welfare effect of each state. In later reforms, it will be necessary to consider

the size of pension benefits within a state. Further, states with a low a funded ratio seem to benefit more from the closed pension reform but the relationship does not appear strong. Initial funded ratios can be low for a variety of reasons (e.g. low contributions, unusually low investment returns or discounting assumptions) thus it may not be a proper indicator for how states would benefit from closing their pension system.

[Figure 9 Here]

To provide some interpretation and magnitude to our analysis, we utilize simple regressions which regress state welfare outcomes on state-specific characteristics. In addition to variables plotted in Figure 9, we also regress upon the discount rate r_s, the current proportion of retirees in each state (*Current Old*), the forecast proportion of retires in 45 years (*Future Old*) as well as interactions of the discount rate with the funded ratio and contribution fraction θ_s. The results are reported in Table 8.

[Table 8 Here]

In all candidate regression models, the estimated coefficients for size of pension benefits $\bar{b}_s$ and size of the public sector $p_{s,pub}$ are robust and significant. Both of these characteristics have a positive impact on welfare- higher initial pension benefits and larger public sectors lead to larger welfare gains when transitioning to a system of individual retirement accounts with increased wages. For pension benefits, the interpretation is that every \$1,000 increase in initial pension benefits is associated with a 0.44 basis point increase in welfare. In terms of the public sector, every %1 increase in the job sector's size is associated with a 0.79 basis point increase in state welfare.

In summary, the Closed Reform generates a slow but significant decline in long run pension liabilities which reduces taxes in a way that can properly fund a 5% wage increase for new public workers. The net effect is a reduction in taxes over the entire forecast period. Welfare results are positive for the majority of age cohorts and job sectors, and across all states,

differences in welfare outcomes by job sector.

with young workers benefiting the most. In terms of state differences, states which benefit the most (in terms of tax reduction and consumer welfare) are those which have the more generous pre-existing pension systems and/or those which are forecast to have a large influx of young workers, over the next 45 years.

Reform 2: Hybrid Plan with Wage Compensation

Under the Hybrid Reform, instead of closing the plan to new entrants, pension benefits for current and future workers are simply reduced and additional compensation is provided in the form of a wage increase. Specifically, current public workers aged 60 to 65 retain the original pension and receive no wage increase while younger cohorts receive anywhere from 50% to 100% benefit retention on a linear scale between the ages of 20 and 65 along with a 5% wage increase. All future workers receive 50% of the original pension benefit plus the wage increase, as well. Table 9 provides the effect of the Hybrid Reform on relevant fiscal aggregates for each state.

[Table 9 Here]

Because the Hybrid Reform reduces pension benefits for current workers, it has an immediate effect on pension liabilities, reducing them by roughly 3.5% on average for the representative state (see Figure 10). While the Closed Reform eliminates pension liabilities after 80 years, the Hybrid Reform generates a larger liability reduction throughout the sample period of 45 years- liabilities drop by 40% relative to the Baseline scenario.[22] Within the cross-section of state outcomes (see Table 9), there exists fairly little variation around the average reduction in pension liabilities. The observed variation is, again, primarily caused by the size of a state's initial pension benefit as well as forecast demographic change.

[Figure 10 Here]

[22] The comparable number for the Closed Reform is 23%.

The reform translates into a lower average tax level, relative to both the Baseline and Closed Reform scenario (see Figure 11). While this is the average effect, some states do experience higher taxes within the first 10 years of reform; specifically, Indiana, Kansas, Montana, North Dakota, New Hampshire, New Jersey, Tennessee, Vermont and Wyoming experience an initial increase in taxes. These states experience short run increases in taxes for two reasons: lower initial pension benefits and a large middle-aged workforce. For the former, states which offer low initial pension benefits (such as Indiana, Kansas, Tennessee and Vermont) have relatively less cost-savings to fund wage increases when they reduce the pension benefits of workers. For the latter, states which have a higher proportion of middle-aged workers must fund larger wage increases because the 5% wage hike is attached to higher salaries, on average. For example, the average age of the New Jersey workforce is 42.1, relative to the group average of 41.8, where a large proportion of current workers are between the peak earnings ages of 45 and 60. Despite initial increases in taxes, all states are forecast to have lower long run taxes, relative to both the Baseline and Closed Reform scenarios.

[Figure 11 Here]

Figure 12 plots average welfare effects by age cohort and for each job sector. For private sector workers, the average state experiences a welfare gain under the reform. The effect is most pronounced for younger age cohorts who are better able to capture the low tax environment over a long horizon. On the other hand, welfare results are mixed across public sector age cohorts. For young workers, the reduction in pension benefits is more than offset by the 5% wage increase which allows them to save and compound the equity premium for the remainder of their lifecycle. In addition, public workers nearing retirement (ages 60 to 65) remain mostly indifferent as they retain their original pension benefit and thus are affected only through taxes. Conversely, middle-aged public workers experience a welfare loss- they are too close to retirement such that the 5% wage increase is not sufficient to offset their losses from the reduced pension. Given that welfare gains are so high for young public workers, there is possibly a budget-neutral way in which to alter the reform package for middle-aged public workers such that they experience welfare gains.

[Figure 12 Here]

We now consider some of the underlying differences in state characteristics which lead to variation in the welfare results. Table 10 provides welfare outcomes at the state level. The vast majority of states experience private sector welfare gains for all working age cohorts. The states which do experience welfare losses (specifically, Kansas, North Dakota and Tennessee) are the same states which experience an initial increase in taxes during the first 10 years of reform. While taxes are lower in the long run, this is not enough to offset the early incidence of increased taxes. Figure 13 provides a heat map for the average state welfare effects under the Hybrid Reform.

[Table 10 Here]

Public worker welfare is affected through both the tax channel as well as the direct change to retirement benefits. Unlike the Closed Reform, where current public workers retain their old pension benefit, the Hybrid Reform alters worker retirement benefits and leads to large movements in consumption-equivalent welfare. Figure 14 provides a scatter plot of public sector welfare change and various state-level characteristics, related to the pension plan. Unlike private sector workers who have increasing welfare gains in the size of the original pension benefit, public workers have a significant negative relationship (bottom right panel)- the larger the original pension benefit, the larger the welfare loss. In addition, public sector workers have a significant, positive relationship with the level of Social Security coverage (top left panel). Because the state pension and Social Security both act as insurance against low consumption states in retirement and agents are risk-averse, the existence of Social Security coverage dampens any welfare losses which occur when the pension benefit is reduced. The scatter plot and regression analysis is not particularly helpful in illustrating the effects of fiscal characteristics (such as the public sector size) because these factors affect tax policy which is of second-order importance to public workers under the Hybrid Reform.

[Figure 14 Here]

Regression Table 11 provides additional interpretation by regressing public sector welfare effects on relevant state characteristics. The negative relationship between original pension benefits and public welfare effects remains a robust and statistically significant feature- every \$1,000 increase in pre-reform pension benefits is associated with a 3 basis point welfare loss for public employees. In our sample of states, there exists a range in pension benefits of approximately \$28,000 suggesting variation in welfare effects on the order of 1.4%, holding all else constant. Social Security coverage also retains its significant positive relationship with welfare outcomes- increasing coverage by 50% is associated with a 25 basis point welfare gain. The size of the public sector, as measured by the proportion $p_{s,pub}$ is a significant feature explicitly related to the tax environment and not the retirement benefits of public employees. The estimates suggest that a 1% increase in the proportion of public employees is associated with a 2 basis point increase in welfare gains under the Hybrid Reform. This result is considerably larger than the estimated effect in the Closed Reform scenario (which was $<$ 1 basis point) suggesting more welfare sensitivity to the size of the public sector in the Hybrid Reform. While the magnitudes are larger, the sample variation is quite small- states' public sectors range from 7% to 15%.

[Table 11 Here]

Table 12 provides similar regression analysis for private sector workers as was performed in the Closed Reform regression Table 8. Similar results hold: private sector workers experience larger welfare gains when the original pension benefit is more generous and/or the public sector is larger. Coefficient estimates for pre-reform pension benefits $\bar{b}_s$ and public sector size p_s^{pub} are both larger in magnitude under the Hybrid Reform. This increase is mainly driven by the size and timing of tax reductions in the Hybrid reform which makes welfare gains more sensitive to the state characteristics.

[Table 12 Here]

In summary, the Hybrid Reform significantly reduces pension liabilities relative to the Closed Reform, in the short and long run of our forecast period. This is associated with a larger reduction in state taxes, as well. For private workers, the vast majority of states and age cohorts experience welfare gains. In states where this is not the case, it is due to an initial increase in taxes to fund higher wage increases for public workers. While young and old public workers benefit from the hybrid pension plan, middle-aged workers experience welfare losses. These losses are due to an insufficient wage increase to offset their pension reduction.

Reform 3: Suspension of Cost-of-Living-Adjustments (COLAs)

Under the COLA Reform, the real value of pensions are reduced through the partial suspension of Cost-of-Living-Adjustments (COLAs) which are used to keep pace with changes in the price level. In practice, this type of reform is perhaps the most prevalent among U.S. state pension plans.[23] For our application, we assume that states in the Baseline scenario keep pace with cost of living changes by increasing the nominal value of pension benefits. In the reform, we allow the real value of pension benefits to decrease by 1.5% annually, starting from the date a public employee enters retirement. For example, if a pension recipient was promised $20,000 in annual benefits, the real value would fall to $17,200 after 10 years, $14,800 after 20 years and $12,700 after thirty years. Thus, small changes in state COLAs can have significant effects upon the real value of retirement benefits. Table 13 provides the effect of the Hybrid Reform on relevant fiscal aggregates for each state.

[Table 13 Here]

Figure 15 plots the impact of the COLA Reform on pension liabilities, relative to the Baseline and other reform scenarios. It is clear that the COLA reform has a significant and immediate impact on liabilities, reducing them by 16.9% in the first year of reform. It is important to note that the COLA Reform has more of a level effect on plan liabilities- while pension benefits are reduced, the plan still has considerable growth in liabilities over the next

[23] See Brainard and Brown [2018].

45 years. At the end of our forecast horizon, plan liabilities are, on average, 25.2% lower than the Baseline scenario and this drop is similar to the Closed Reform scenario.

[Figure 15 Here]

There does exist some variation in the effect of the COLA reform on plan liabilities (see Table 13). The states which experience the largest initial drop in liabilities (the states of Alaska, Arizona, New Hampshire, New Mexico and Nevada) are the same states which have the most back-loaded benefit distributions in their pension systems.[24] For example, the state of Arizona is forecast to pay out 16% of all its benefit distributions in the next 10 years, while the average state pays out 18%. States with back-loaded pension distributions benefit more from the COLA reform because those benefits are substantially reduced in value by the COLA suspension. [25]

Figure 16 plots the forecast average state tax rate for the COLA reform, relative to the Baseline and other reforms. Clearly, the large initial drop in plan liabilities is accompanied by a large drop in state taxes, more so than any other reform. However, due to the continued growth in pension liabilities, taxes trend up near the end of our forecast horizon. While they are still 0.8% lower than the Baseline scenario, it is clear that the Closed and Hybrid reforms generate lower long run taxes for the state.

[Figure 16 Here]

In Figure 17, we plot the average welfare effects by age cohort and for both job sectors.

[24] In the first year of reform, these states experiences a pension liability reduction of 71%, 48%, 50%, 49% and 57%, respectively.

[25] To see how this works mechanically in a stylized example, assume a stream of pension distributions $\{B_0, B_1, ...\}$ where $B_t = \gamma_t B$, such that $\sum_t \gamma_t = 1$. Then consider current pension liabilities $P = \sum_t \frac{B_t}{(1+r)^t}$ and liabilities after the COLA freeze $\hat{P} = \sum_t B_t(\frac{1-\alpha}{1+r})^t$. We are interested in how $\Delta P = P - \hat{P}$ is affected by front- or back-loaded benefits. Consider an increase in front-loaded benefits $\frac{\partial \Delta P}{\partial B_1} \equiv \frac{\partial \Delta P}{\partial \gamma_1}$ which can be expressed as

$$\frac{\partial \Delta P}{\partial \gamma_1} = B[\frac{1+r}{r+\alpha} - \frac{1+r}{r}]$$

This object is negative when COLAs do not keep pace with inflation (i.e. $\alpha > 0$). Thus, liability reductions decrease (increase) when pension benefits are front-loaded (back-loaded) in a reform with partial COLAs.

The COLA suspension imposes significant welfare losses on all public worker age cohorts and particularly those nearing retirement. Essentially, the reform reduces the discounted real value of retirement benefits with no additional compensation provided. Older workers are acutely affected along two dimensions. First, they have less time to accumulate precautionary savings and those savings lead to a significant disruption in their consumption smoothing. Second, they discount their retirement future less heavily because of their proximity to the date. Private sector workers, on the other hand, uniformly experience large welfare gains and this is driven by the near-term tax reductions, even though the long run tax rates are expected to rise. All together, the COLA reform is the most contentious in the sense that welfare gains/losses are distributed the most unevenly across job sectors.

[Figure 17 Here]

Table 14 provides more granularity in the welfare outcomes within each state and across age groups. In only a handful of states (Alaska, Arizona, Mississippi, New Mexico, Vermont, West Virginia and Wyoming) do public sector workers experience welfare gains. In these circumstances, the initial tax benefit received is enough to offset the future loss in value of their retirement benefit- agents value the immediate additional resources freed up from tax reductions more than the future pension guarantee. Figure also 18 provides a heat map for average welfare outcomes in each state.

[Table 14 Here]

We plot the public sector welfare effects of the COLA Reform for 20 year-old and 55-year old age cohorts for each state in Figure 19. This highlights import differences which arise due to a worker's proximity to retirement. For example, while both agents are better off with Social Security coverage (top left panel), 55 year-old workers are particularly more sensitive, in level and slope. Similarly, both types of public workers experience welfare losses which increase in the size of the initial pension benefit, but young public workers are considerably less sensitive when compared to 55 year-old workers who are within ten years of their retirement date.

[Figure 19 Here]

To provide some interpretation for public worker welfare effects under the COLA Reform, and highlight the relative differences between young and old workers, Table 15 provides regression analysis for the welfare effects of 20 and 55 year-old public sector workers. Young public worker welfare does not have a significant relationship with initial pension benefits- per the earlier discussion, the tax effect dominates young worker welfare relative to the retirement income effect in this case. This result is further confirmed by the significant relationship that fiscal parameters (such as the funded ratio or ARC contribution fraction) have on young public worker welfare. Both young and old public worker welfare effects share a significant negative relationship with the funded ratio, or put differently, lower funded ratios are associated with higher welfare gains- a low funded ratio is an indication of increasing taxes such that workers would favor a reduction in pension liabilities to offset this future tax hike. With respect to the funded ratio, every 1% decline in the pension funded ratio is associated with a 0.5 basis point welfare loss from COLA reform instead of a 0.1 basis point loss for old workers. These numbers are economically significant.[26] Similar to the Closed Reform, public workers are more receptive to the COLA reform when they have higher Social Security coverage, as the Social Security benefit substitutes for the pension in terms of risk free retirement income. Older public workers are considerably more sensitive, given their proximity to retirement- a 50% increase in Social Security coverage is associated with a 55 basis point increase in welfare while the same number is 7.5 basis points for young workers. We perform similar regression analysis for the average private worker (see Table 16) and find similar results with respect to the Closed and Hybrid pension reforms.

[Table 15 Here]

[26]For example, the difference between a fully funded pension and one with an 80% funded ratio leads to a 0.1% welfare effect difference, everything else held constant.

In summary, we find that the COLA reform is the most effective in generating an immediate reduction (improvement) in state pension liabilities (funded ratios) which leads to a short term drop in taxes, but that these effects are transitory. In fact, both the Closed and Hybrid reforms generate lower long run taxes. Furthermore, while COLA reforms are quite common in practice, it appears that they are the most contentious for the way in which welfare gains are distributed throughout the state population- public workers receive no compensation for the loss in real value of their pension benefit, while private workers benefit considerably more. Further, the negative effects of the COLA Reform are mostly borne by older public workers who are nearing retirement and have little time to adjust their consumption-savings behavior.

7 Conclusion

U.S. state public pension plans have failed to maintain sufficient funded ratios which has cast doubt on their ability to finance future retirement benefits. Because of this, many states have considered reforms which emphasize individual retirement accounts and less state management. Since the ultimate burden of funding the public pension system falls on taxpayers, proper reform analysis should account for all the relevant constituencies involved as well as important variation in state characteristics.

We examine the impact of three generalized public pension reforms through the use of an overlapping generations model which can be calibrated at the state-level. We consider closing the pension to new entrants with wage compensation (Closed Reform), partially reducing benefits for current and future workers with wage compensation (Hybrid Reform) and the uncompensated suspension of Cost-of-Living-Adjustments (Cola Reform).

In terms of the positive analysis, we find that the Hybrid Reform is the most effective at reducing pension liabilities and taxes throughout our forecast period of 45 years. While the COLA Reform leads to the largest initial drop, the continued growth of pension liabilities leads to a relative increase in taxes throughout the forecast period. The key state-level characteristics which affect the direction and magnitude of change are those related to the generosity of the initial pension system, the size of the public sector and the relative distribution of age cohorts in both the working and retired population.

In terms of the normative analysis, we find that the Closed Reform uniformly improves welfare for working private and public sector workers, and this result hinges on the ability of pension cost savings to fund worker wage increases. Younger workers are more acutely affected due to their ability to take advantage of the long run lower tax environment. In the Hybrid Reform, young public workers experience welfare gains, implying that the 5% wage hike is enough to offset the partial reduction of benefits, while middle-age workers experience significant welfare losses. For the most part, private workers in all states experience larger welfare gains, relative to the Closed Reform. Finally, the COLA reform proves to be the most contentious in that welfare gains are almost exclusively experienced within the private sector and not in the public sector.

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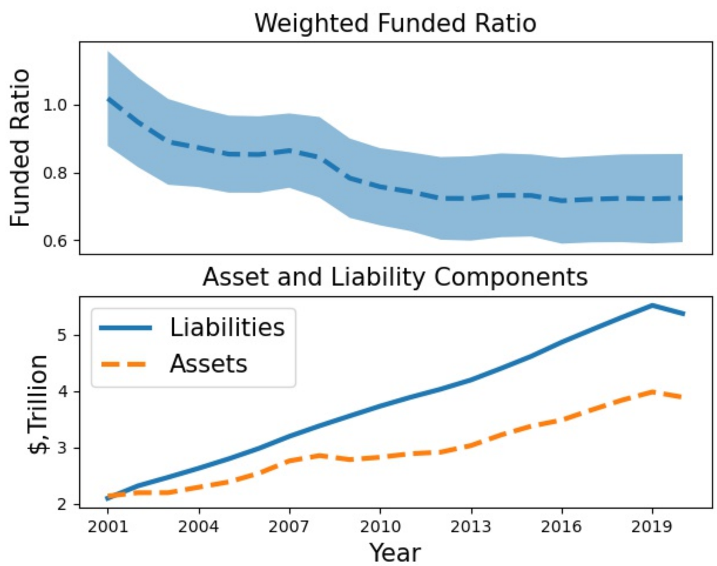

Figure 1

Notes: The top panel plots average funded ratios for each year, weighted by the size of plan liabilities, and volatility bands are computed based upon the weighted standard deviation for each year. In the lower panel, plan liabilities and assets are simply summed for each year.

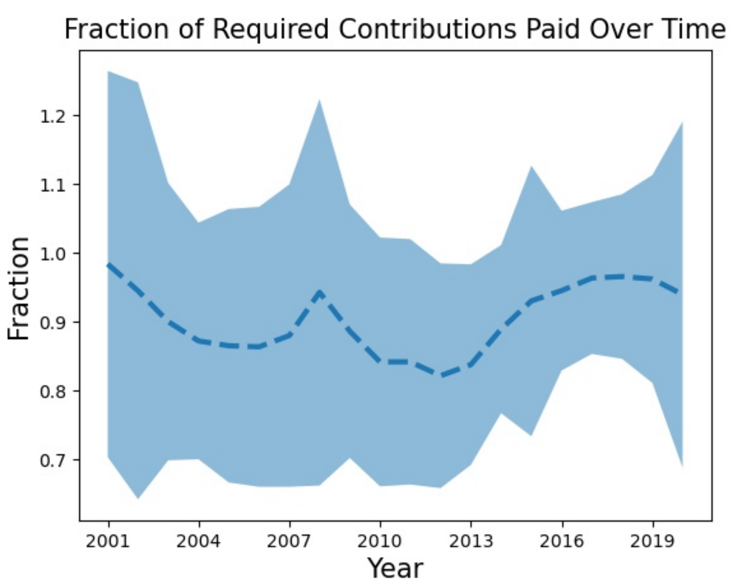

Figure 2

Notes: Average contributions as a fraction of ARC are weighted by the size of plan liabilities, and volatility bands are computed based upon the weighted standard deviation for each year.

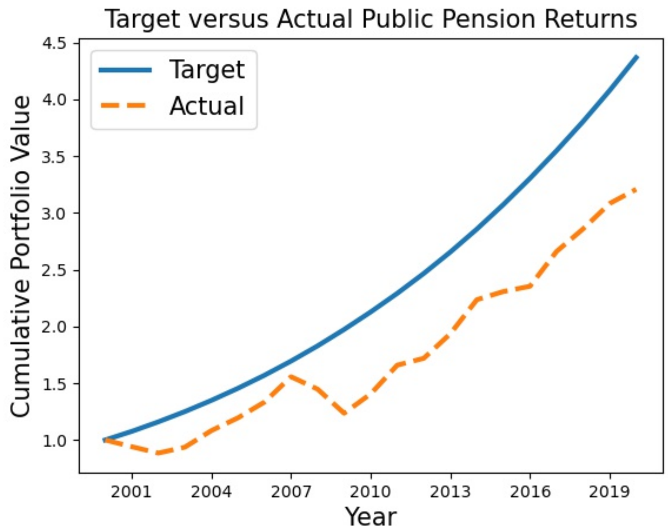

Figure 3

Notes: For each time period, an average target return and actual return are computed, weighted by the size of plan liabilities. These rates are then applied to a hypothetical portfolio, normalized to value 1 in year 2000, where annual returns are continually re-invested with the principal.

Table 1: Universal Parameters

Parameter	**Label**	**Value**	**Source/Target**
β	Discount Factor	0.985	Standard
γ	Risk Aversion	10	CGM [2005]
r_f	Risk-free Rate	.02	Navega
μ_r	Equity Premium	.04	Navega
σ_r	Equity Vol	.157	Navega
$\{f(t)\}$	Age Wage Trend	—	CGM [2005], PSID
σ^ϵ	Transitory Vol	.0584	CGM [2005], PSID
σ^ν	Persistent Vol	.0169	CGM [2005], PSID
$\{p(t+1\|t)\}$	Mortality Risk	—	NCHS
$\lambda_{s,j}$	Sector/State Wage Gap	—	BEA

Table 2: State-Specific Parameters

Parameter	**Label**	**Source/Target**
$\bar{b}_s$	Pension Benefit	State Reports
$\{b_{sj}\}$	Total Retirement Benefits	SSA
r_s	State Discount Rate	State Reports
$PVL(s, T = 0)$	Initial Pension Liabilities	State Reports
$\chi(s, T = 0)$	Initial Funded Ratio	State Reports
θ_s	Contribution Fraction of ARC	NASRA
α_s	Pension Portfolio	State Reports
$\mathbf{\Phi}$	Agent Distribution	UVA Weldon Cooper, NASRA, BEA
M_s	Total Population	2020 PVL
$\bar{T}_s$	Amortization Window	State Reports

Table 3: State Demographic Information

	Year 0		Year 15		Year 30		Year 45	
State	Young	Old	Young	Old	Young	Old	Young	Old
AK	30	18	23	30	16	48	4	80
AL	25	23	23	31	21	35	18	45
AR	25	23	23	31	22	34	19	41
AZ	27	25	23	38	18	47	10	67
CA	30	19	26	27	24	32	20	41
CO	29	19	26	28	23	34	15	52
CT	25	22	21	32	17	37	12	46
DC	37	13	32	12	39	9	42	5
DE	26	24	22	34	19	39	14	51
FL	24	26	20	36	18	40	13	48
GA	29	19	27	28	23	34	16	48
HI	25	24	22	35	20	42	15	58
IA	25	23	24	30	22	33	18	41
ID	26	23	24	31	22	36	16	51
IL	28	21	25	29	22	33	18	44
IN	27	21	25	29	22	33	18	43
KS	27	22	25	30	23	34	18	45
KY	25	22	24	30	22	35	18	45
LA	27	20	24	28	22	30	18	38
MA	27	21	23	30	20	34	15	42
MD	27	20	24	28	21	32	17	40
ME	20	27	16	41	13	49	8	63
MI	26	23	21	32	18	37	13	47
MN	26	21	23	31	20	38	14	52
MO	26	23	23	31	21	35	17	45
MS	25	22	23	31	22	37	18	48
MT	23	25	20	33	18	35	12	44
NC	27	22	26	30	23	35	18	46
ND	27	20	24	26	21	27	15	33
NE	27	22	25	29	24	31	20	40
NH	23	24	16	40	11	51	5	66
NJ	26	21	23	29	20	33	16	41
NM	25	26	20	38	16	48	9	70
NV	28	23	23	36	17	49	7	76
NY	28	20	24	26	23	28	21	33
OH	25	23	22	31	20	35	15	45
OK	27	22	26	27	25	29	22	35
OR	25	24	22	30	21	34	16	49
PA	25	24	21	32	19	36	14	44
RI	27	22	21	33	19	38	13	47
SC	26	23	23	31	22	36	18	46
SD	25	23	23	31	21	35	17	44
TN	26	22	24	29	23	33	19	42
TX	30	18	29	25	26	30	21	41
UT	32	17	31	24	27	29	19	39
VA	27	20	25	29	22	34	17	46
VT	22	26	16	41	12	50	6	67
WA	27	21	24	28	22	32	17	45
WI	25	23	21	34	18	41	12	56
WV	21	26	20	34	19	38	16	48
WY	24	23	22	32	19	37	14	51

Note: The top table row provides the forecast year. In the second table row, *Young* refers to the percentage of the model population between the ages 20-30 and *Old* refers to the percentage of the model population which is retired (i.e. age 65 or older).

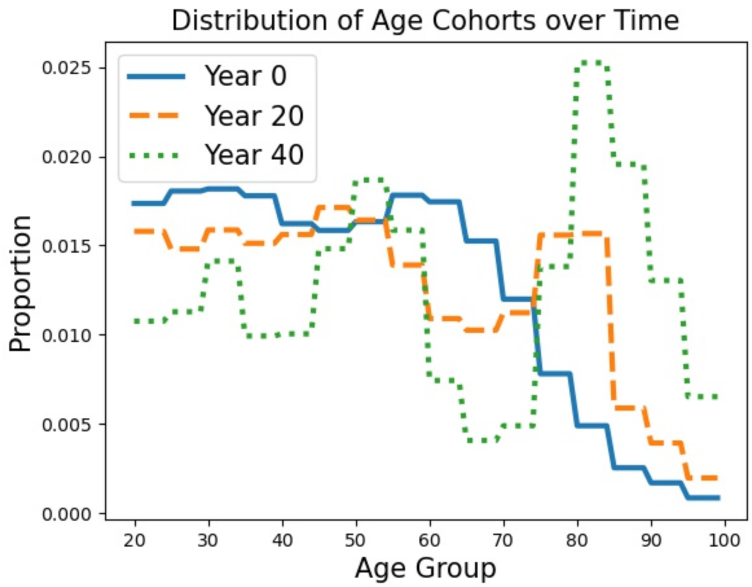

Figure 4

Notes: Each cohort distribution plot is an average across all the states considered in our sample.

Table 4: State-level Calibration Parameters

State	θ	r^p	PVL	χ^0	$\bar{b}$	b^{pub}	Sector	α^p
	ARC Cont	Discount	Liabilities	Funded Ratio	Pension	Total Annuity	Public Size	Portfolio
	Frac	%	\$ billion	FR	\$ Thousand	\$ Thousand	Prop	%
AK	1.08	7.36	22	0.67	27	27	0.13	85
AL	0.96	7.69	57	0.69	25	41	0.12	66
AR	0.95	7.37	32	0.79	22	38	0.11	82
AZ	1.00	7.42	81	0.64	30	46	0.09	84
CA	0.90	7.17	1178	0.71	36	45	0.09	76
CO	0.84	7.26	81	0.61	36	36	0.10	77
CT	0.98	7.35	75	0.47	41	50	0.09	73
DC	1.00	6.50	8	1.05	25	25	0.04	67
DE	0.99	7.00	11	0.84	22	38	0.10	65
FL	0.92	7.19	200	0.81	24	40	0.08	77
GA	1.00	7.25	124	0.76	39	54	0.09	69
HI	0.95	7.00	31	0.55	23	39	0.10	81
IA	0.98	7.03	43	0.83	21	36	0.11	71
ID	0.99	7.00	18	0.91	20	36	0.11	72
IL	0.75	6.96	352	0.46	44	50	0.09	70
IN	1.00	6.75	36	0.62	17	33	0.09	70
KS	0.81	7.73	30	0.69	18	34	0.12	77
KY	0.88	6.43	72	0.45	30	38	0.10	66
LA	0.99	7.42	65	0.68	27	27	0.10	77
MA	0.92	7.22	108	0.57	38	38	0.08	77
MD	0.89	7.38	80	0.74	23	39	0.09	79
ME	1.00	6.87	17	0.83	22	22	0.10	83
MI	0.94	6.89	126	0.62	24	39	0.09	78
MN	0.81	7.50	83	0.80	25	41	0.10	76
MO	1.12	7.38	84	0.80	33	40	0.10	74
MS	1.04	7.75	46	0.60	27	43	0.13	70
MT	0.89	7.58	14	0.71	21	37	0.11	69
NC	0.99	7.00	112	0.87	22	38	0.11	61
ND	0.75	7.74	8	0.69	22	38	0.11	75
NE	1.03	7.51	17	0.82	29	45	0.11	70
NH	1.00	7.24	15	0.60	19	35	0.09	75
NJ	0.52	7.37	169	0.51	33	49	0.09	73
NM	0.88	7.25	43	0.66	28	44	0.14	68
NV	0.96	7.50	57	0.75	41	41	0.07	74
NY	0.99	6.94	578	0.86	25	41	0.10	70
OH	0.98	7.39	253	0.76	37	37	0.09	72
OK	1.07	7.37	40	0.81	23	37	0.12	66
OR	0.96	7.20	86	0.74	31	47	0.09	79
PA	0.76	7.23	169	0.56	25	41	0.08	71
RI	0.99	7.00	15	0.54	33	47	0.08	71
SC	1.00	7.24	58	0.55	22	38	0.11	78
SD	1.06	6.53	12	1.00	23	39	0.10	60
TN	1.00	7.24	55	0.97	16	32	0.09	70
TX	0.89	7.28	354	0.77	25	31	0.09	81
UT	1.00	6.95	34	0.87	26	42	0.10	77
VA	0.82	6.79	110	0.76	23	39	0.10	80
VT	1.09	7.49	7	0.64	18	34	0.10	65
WA	0.94	7.48	82	0.95	23	39	0.11	78
WI	1.00	7.03	115	0.98	26	42	0.10	64
WV	1.07	7.46	18	0.79	22	38	0.13	86
WY	0.82	7.00	10	0.73	21	37	0.15	79

Table 5: Baseline Forecast for Fiscal Aggregates

	PVL			FR			Tax			Tax Vol		
State	15y	30y	45y	15y	30y	45y	15y	30y	45y	15y	30y	45y
AK	34	51	60	95	88	74	17.1	18.5	27.2	0.9	2.1	8.1
AL	68	81	89	95	93	87	14.2	14.4	14.8	0.4	0.6	0.9
AR	38	43	47	95	93	89	13.3	13.4	13.7	0.4	0.5	0.7
AZ	105	135	153	87	84	74	12.4	13.0	15.5	0.9	1.4	3.1
CA	1439	1722	1901	97	94	89	12.3	12.4	12.8	0.4	0.6	0.8
CO	103	136	160	92	90	81	12.8	13.1	14.2	0.5	0.8	1.6
CT	90	106	114	93	93	89	13.0	13.1	13.5	0.7	0.8	1.2
DC	6	5	4	112	116	119	5.3	5.3	5.3	0.0	0.0	0.0
DE	13	16	18	95	92	86	11.8	12.0	12.4	0.4	0.5	0.9
FL	235	269	288	90	87	83	9.4	9.5	9.7	0.4	0.5	0.7
GA	158	201	229	98	95	88	12.6	12.8	13.4	0.4	0.7	1.2
HI	39	49	55	88	87	79	11.9	12.2	13.1	0.6	0.8	1.5
IA	49	56	61	97	96	92	13.2	13.2	13.4	0.3	0.4	0.6
ID	22	28	32	96	93	86	12.5	12.7	13.3	0.3	0.5	1.0
IL	428	515	571	83	86	80	12.4	12.4	13.0	0.6	0.8	1.2
IN	44	52	57	98	96	92	10.8	10.9	11.0	0.2	0.3	0.4
KS	36	43	49	89	87	81	13.1	13.2	13.6	0.3	0.4	0.7
KY	88	105	115	88	91	87	13.1	13.2	13.6	0.5	0.6	1.0
LA	76	88	96	99	97	94	12.9	13.0	13.2	0.3	0.4	0.6
MA	129	149	161	94	93	90	10.7	10.8	11.0	0.4	0.5	0.7
MD	95	112	123	96	94	90	10.5	10.6	10.7	0.3	0.3	0.5
ME	22	27	29	89	85	77	12.1	12.6	13.7	0.7	1.1	1.8
MI	152	180	197	92	91	87	11.3	11.4	11.7	0.4	0.5	0.8
MN	105	131	147	90	85	76	11.5	11.8	12.5	0.4	0.6	1.1
MO	100	118	130	99	97	93	13.1	13.3	13.7	0.5	0.7	1.0
MS	56	68	76	96	93	87	16.8	17.1	17.9	0.6	0.9	1.4
MT	15	18	20	91	91	87	12.6	12.6	12.9	0.4	0.5	0.7
NC	136	164	182	98	95	90	12.7	12.9	13.1	0.3	0.4	0.7
ND	9	10	11	93	94	91	12.7	12.8	12.8	0.2	0.3	0.3
NE	20	23	25	99	98	94	13.5	13.6	13.9	0.4	0.5	0.7
NH	20	25	27	86	83	75	10.8	11.2	12.3	0.6	0.9	1.6
NJ	201	235	256	61	59	49	11.3	11.5	12.0	0.4	0.6	0.8
NM	56	73	83	83	80	68	18.1	19.1	23.8	1.2	1.9	4.3
NV	79	109	127	89	83	69	10.8	11.8	17.5	0.9	1.6	4.9
NY	651	718	759	101	100	99	12.1	12.1	12.2	0.2	0.3	0.3
OH	301	357	393	96	94	89	12.8	13.0	13.4	0.5	0.7	1.1
OK	45	51	55	102	101	99	14.6	14.7	14.8	0.3	0.3	0.4
OR	102	126	145	95	93	86	12.3	12.5	13.1	0.5	0.7	1.2
PA	198	226	244	82	84	79	9.5	9.6	9.8	0.4	0.4	0.6
RI	18	21	23	93	93	89	10.9	11.1	11.4	0.5	0.6	0.9
SC	70	83	91	94	93	88	13.6	13.7	14.1	0.4	0.6	0.9
SD	15	17	19	99	98	94	12.8	12.9	13.1	0.3	0.4	0.6
TN	65	76	83	98	96	92	10.2	10.2	10.4	0.2	0.2	0.4
TX	438	542	611	98	94	89	11.4	11.5	11.7	0.3	0.4	0.6
UT	44	55	62	100	97	92	12.0	12.1	12.4	0.3	0.4	0.7
VA	135	165	184	92	89	83	11.7	11.9	12.2	0.3	0.5	0.8
VT	9	11	13	89	87	77	12.5	12.9	14.4	0.6	0.9	1.8
WA	99	121	138	97	94	88	12.9	13.1	13.5	0.3	0.5	0.8
WI	145	180	201	95	91	83	12.6	13.0	13.9	0.5	0.8	1.4
WV	21	25	27	95	92	87	16.3	16.5	17.0	0.6	0.8	1.3
WY	12	15	16	89	87	79	17.4	17.7	18.5	0.6	0.8	1.4

Note: This table provides baseline forecasts for each state at horizons of 10, 20 and 30 years. The Present Value of Liabilities (PVL) is stated in Billions of Dollars. The Funded Ratio (FR), Tax and Tax Volatility are presented in % units.

Table 6: % Change in Fiscal Aggregates Under Closed Pension Reform

	PVL			FR			Tax			Tax Vol		
State	15y	30y	45y	15y	30y	45y	15y	30y	45y	15y	30y	45y
AK	-0.3	-2.4	-12.4	-2.2	-6.7	-14.2	-2.9	-5.2	-3.8	7.1	10.4	-1.7
AL	-0.3	-3.9	-22.6	-3.1	-13.1	-38.2	-2.5	-5.9	-6.5	11.4	31.6	17.9
AR	-0.4	-4.4	-24.5	-2.9	-12.3	-34.8	-2.2	-5.3	-7.4	9.4	27.2	22.3
AZ	-0.3	-3.0	-16.2	-3.1	-11.9	-25.7	-3.0	-6.5	-4.1	5.5	12.3	-1.0
CA	-0.4	-4.0	-21.8	-3.0	-13.3	-38.7	-3.8	-10.0	-10.1	11.6	34.2	30.4
CO	-0.3	-3.2	-16.7	-3.5	-13.7	-34.0	-3.5	-8.3	-6.4	9.8	25.5	11.7
CT	-0.3	-3.8	-21.6	-3.1	-12.0	-37.1	-3.6	-11.0	-11.7	9.1	28.0	23.6
DC	-0.5	-7.5	-50.4	-1.6	-4.1	-20.3	-3.5	-7.8	-16.5	5.9	2.5	81.3
DE	-0.4	-4.1	-21.9	-2.5	-11.7	-33.3	-2.2	-5.5	-5.5	8.7	25.2	14.1
FL	-0.4	-4.4	-24.6	-2.5	-12.2	-38.3	-2.0	-5.0	-6.1	5.8	18.1	10.8
GA	-0.4	-3.8	-20.1	-2.9	-13.7	-35.2	-4.8	-11.9	-9.7	13.7	38.7	22.2
HI	-0.3	-3.5	-18.4	-3.2	-10.9	-26.3	-2.0	-4.7	-5.4	6.4	15.4	4.4
IA	-0.4	-4.3	-23.1	-2.7	-10.9	-30.6	-2.2	-5.2	-7.6	11.9	34.2	32.3
ID	-0.3	-3.5	-18.1	-2.6	-10.6	-25.5	-2.2	-4.6	-5.8	10.6	27.2	15.5
IL	-0.4	-4.4	-23.1	-4.5	-16.9	-46.2	-3.2	-8.2	-8.6	5.4	22.5	13.1
IN	-0.4	-4.7	-24.0	-2.7	-11.3	-30.9	-1.7	-4.6	-5.4	12.5	37.6	30.5
KS	-0.3	-3.4	-19.5	-3.7	-15.6	-42.3	-1.3	-2.6	-2.2	8.8	23.5	12.4
KY	-0.5	-5.2	-25.6	-4.1	-13.3	-34.2	-2.6	-7.0	-8.8	7.8	27.2	17.2
LA	-0.4	-4.2	-23.7	-2.5	-9.7	-30.0	-2.9	-6.8	-11.6	10.7	33.8	36.2
MA	-0.4	-4.3	-23.7	-2.9	-12.1	-38.6	-3.6	-9.9	-11.8	9.4	29.7	29.2
MD	-0.3	-3.8	-21.1	-2.7	-12.3	-38.5	-2.1	-5.6	-6.5	9.9	32.4	33.6
ME	-0.4	-3.8	-19.9	-1.7	-7.6	-23.4	-1.6	-4.1	-6.0	3.8	8.0	0.0
MI	-0.4	-4.2	-22.1	-2.6	-10.8	-33.0	-2.2	-6.2	-7.2	7.6	21.8	18.7
MN	-0.3	-3.6	-19.7	-3.1	-13.5	-38.8	-1.9	-4.0	-4.1	6.9	16.0	4.4
MO	-0.3	-4.0	-22.1	-2.3	-10.3	-29.3	-4.1	-10.1	-13.6	11.7	34.8	28.2
MS	-0.3	-3.9	-22.3	-3.1	-12.0	-32.6	-3.0	-6.8	-8.4	12.5	28.5	13.4
MT	-0.3	-3.0	-17.3	-2.8	-10.2	-31.0	-1.5	-3.0	-6.0	7.3	22.2	21.1
NC	-0.4	-4.3	-22.6	-2.8	-14.2	-37.3	-2.7	-6.5	-5.3	13.7	41.0	25.4
ND	-0.3	-3.8	-22.3	-3.6	-10.6	-37.1	-1.4	-2.6	-6.4	11.5	30.5	40.1
NE	-0.3	-3.8	-21.8	-2.8	-11.5	-32.4	-3.6	-8.3	-11.4	14.3	43.2	41.3
NH	-0.3	-3.3	-18.1	-2.2	-8.9	-26.9	-1.2	-3.2	-3.0	3.9	8.7	-1.8
NJ	-0.4	-4.3	-23.9	-6.0	-33.0	-130.5	-1.3	-3.0	-1.0	0.4	3.9	-1.7
NM	-0.3	-2.9	-15.2	-3.2	-11.0	-26.6	-1.9	-3.3	-2.6	4.4	7.8	-5.0
NV	-0.3	-2.5	-13.3	-2.8	-11.6	-24.7	-4.0	-7.9	-0.4	6.2	11.7	-3.8
NY	-0.4	-4.8	-26.1	-2.2	-9.6	-33.5	-2.9	-7.9	-11.3	13.4	47.7	69.6
OH	-0.3	-4.0	-22.1	-2.6	-11.8	-35.2	-3.7	-9.8	-11.3	9.9	30.5	23.6
OK	-0.4	-4.3	-24.6	-2.5	-10.8	-31.6	-3.2	-7.7	-10.9	16.8	59.5	66.5
OR	-0.3	-3.5	-18.0	-2.7	-10.3	-27.2	-3.1	-7.8	-9.7	9.6	24.6	16.4
PA	-0.3	-4.1	-22.6	-4.1	-15.5	-48.7	-1.4	-3.5	-4.1	4.7	16.9	11.7
RI	-0.4	-4.3	-23.0	-3.1	-10.7	-33.2	-3.1	-8.6	-10.9	8.9	25.5	21.5
SC	-0.4	-4.1	-22.3	-3.1	-11.7	-32.4	-2.2	-5.6	-6.9	9.9	27.5	19.2
SD	-0.5	-4.8	-24.2	-2.2	-8.6	-24.2	-2.6	-5.7	-10.1	12.8	35.2	30.3
TN	-0.4	-4.2	-23.2	-2.5	-12.6	-35.6	-1.7	-4.3	-4.4	12.4	39.4	32.6
TX	-0.4	-4.4	-23.4	-3.1	-14.4	-38.9	-2.9	-7.0	-7.0	12.7	37.1	26.8
UT	-0.5	-4.9	-25.4	-2.9	-11.4	-24.6	-3.7	-7.4	-11.6	15.3	36.7	21.2
VA	-0.4	-4.4	-22.2	-2.9	-12.8	-36.0	-1.9	-4.9	-5.2	7.6	22.6	15.5
VT	-0.3	-2.8	-15.6	-2.4	-8.5	-24.0	-1.3	-2.9	-2.5	5.4	11.3	-1.3
WA	-0.3	-3.3	-18.0	-2.4	-11.4	-32.2	-2.3	-5.6	-6.2	9.6	30.6	24.5
WI	-0.4	-4.0	-20.8	-2.2	-10.6	-28.4	-2.6	-5.6	-6.6	7.9	20.8	6.2
WV	-0.3	-4.0	-22.5	-2.4	-10.1	-27.3	-2.2	-5.7	-8.6	7.4	21.1	13.1
WY	-0.3	-3.2	-16.9	-2.7	-9.6	-26.2	-1.5	-2.6	-5.3	5.5	14.2	8.6

Note: All numbers correspond to % deviations from the baseline forecast numbers, presented in Table 5.

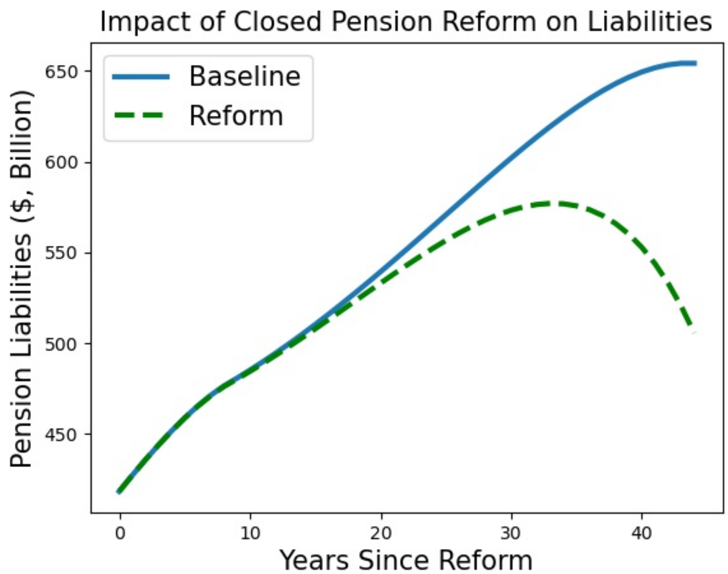

Figure 5: Weighted-Average Path of Closed Reform Public Pension Liabilities

Notes: The plots represent the weighted average pension liabilities under each scenario, where the weighting comes from the size of each state's total liabilities.

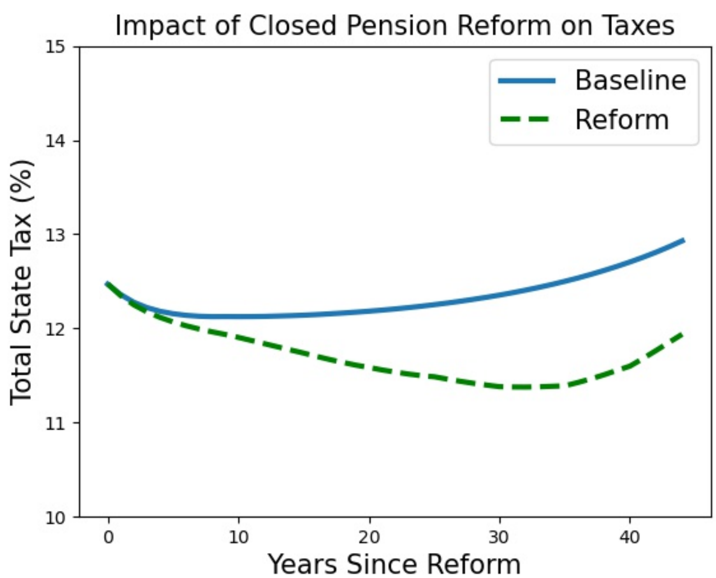

Figure 6: Weighted-Average Path of Taxes Under Closed Reform

Notes: The plots represent the weighted average wage tax under each scenario, where the weighting comes from the size of each state's total liabilities.

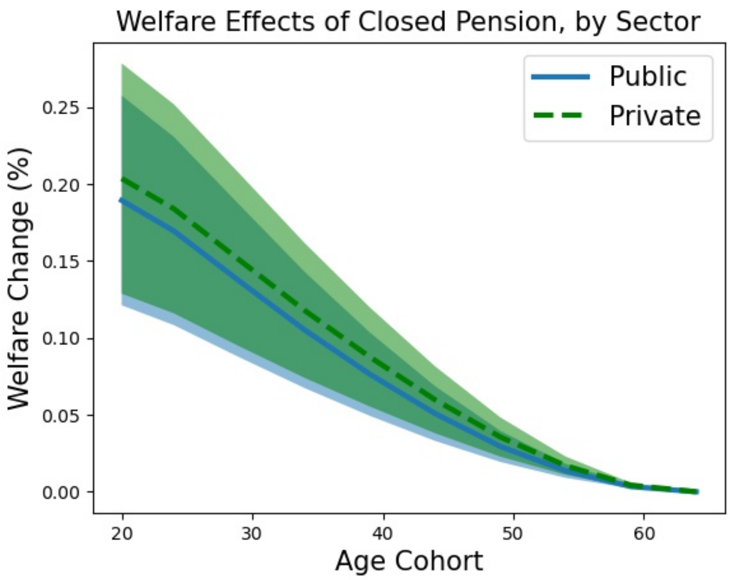

Figure 7: Weighted-Average Welfare Effects from Closed Reform, by Age and Job Sector

Notes: The plots represent the weighted average welfare effects for each age cohort under each scenario, where the weighting comes from the size of each state's total liabilities. Shaded areas represent volatility bands, computed from the cross-section variation across states.

Table 7: Closed Pension Welfare by State, Sector, Age Cohort

	Public					Private					Averages		
State	20 Yr	30 Yr	40 Yr	50 Yr	60 Yr	20 Yr	30 Yr	40 Yr	50 Yr	60 Yr	Pub	Priv	State
AK	0.29	0.21	0.13	0.05	0.01	0.31	0.22	0.13	0.05	0.01	0.12	0.13	0.13
AL	0.21	0.15	0.08	0.03	0.00	0.22	0.17	0.10	0.04	0.01	0.08	0.09	0.09
AR	0.17	0.12	0.07	0.03	0.00	0.18	0.13	0.08	0.03	0.00	0.07	0.07	0.07
AZ	0.23	0.17	0.10	0.04	0.00	0.25	0.19	0.11	0.05	0.01	0.10	0.11	0.11
CA	0.27	0.19	0.10	0.04	0.00	0.29	0.22	0.12	0.05	0.01	0.11	0.13	0.13
CO	0.28	0.21	0.12	0.04	0.00	0.29	0.22	0.13	0.05	0.01	0.12	0.13	0.13
CT	0.30	0.21	0.11	0.04	0.00	0.34	0.25	0.13	0.05	0.01	0.11	0.13	0.13
DC	0.09	0.06	0.03	0.01	0.00	0.09	0.06	0.03	0.01	0.00	0.04	0.04	0.04
DE	0.16	0.12	0.06	0.03	0.00	0.17	0.13	0.07	0.03	0.00	0.06	0.07	0.07
FL	0.12	0.08	0.05	0.02	0.00	0.13	0.09	0.05	0.02	0.00	0.04	0.05	0.05
GA	0.34	0.25	0.13	0.05	0.01	0.37	0.29	0.16	0.06	0.01	0.14	0.16	0.16
HI	0.15	0.11	0.06	0.03	0.00	0.16	0.12	0.07	0.03	0.00	0.06	0.07	0.07
IA	0.15	0.11	0.06	0.03	0.00	0.16	0.12	0.07	0.03	0.00	0.06	0.07	0.07
ID	0.14	0.10	0.06	0.02	0.00	0.15	0.11	0.07	0.03	0.00	0.06	0.06	0.06
IL	0.28	0.20	0.11	0.04	0.00	0.31	0.23	0.13	0.05	0.01	0.11	0.13	0.13
IN	0.10	0.07	0.04	0.02	0.00	0.10	0.08	0.04	0.02	0.00	0.04	0.04	0.04
KS	0.09	0.07	0.04	0.02	0.00	0.10	0.08	0.05	0.02	0.00	0.04	0.04	0.04
KY	0.24	0.18	0.10	0.04	0.00	0.26	0.20	0.11	0.05	0.01	0.09	0.10	0.10
LA	0.21	0.15	0.08	0.03	0.00	0.21	0.15	0.09	0.04	0.01	0.08	0.09	0.09
MA	0.24	0.17	0.09	0.04	0.00	0.25	0.19	0.10	0.04	0.01	0.09	0.10	0.10
MD	0.12	0.09	0.05	0.02	0.00	0.13	0.10	0.05	0.02	0.00	0.05	0.05	0.05
ME	0.15	0.10	0.06	0.02	0.00	0.15	0.11	0.06	0.02	0.00	0.05	0.05	0.05
MI	0.16	0.11	0.06	0.02	0.00	0.17	0.12	0.07	0.03	0.00	0.06	0.07	0.07
MN	0.14	0.10	0.06	0.02	0.00	0.15	0.11	0.07	0.03	0.00	0.05	0.06	0.06
MO	0.29	0.21	0.11	0.04	0.00	0.31	0.23	0.13	0.05	0.01	0.11	0.12	0.12
MS	0.30	0.21	0.12	0.05	0.01	0.32	0.24	0.14	0.06	0.01	0.12	0.13	0.13
MT	0.11	0.08	0.05	0.02	0.00	0.12	0.09	0.05	0.02	0.00	0.04	0.05	0.05
NC	0.19	0.14	0.08	0.03	0.00	0.20	0.15	0.09	0.04	0.00	0.08	0.09	0.08
ND	0.10	0.07	0.04	0.02	0.00	0.10	0.07	0.05	0.02	0.00	0.04	0.04	0.04
NE	0.26	0.19	0.11	0.04	0.00	0.28	0.21	0.13	0.05	0.01	0.10	0.12	0.12
NH	0.10	0.07	0.04	0.01	0.00	0.10	0.07	0.04	0.02	0.00	0.03	0.04	0.04
NJ	0.13	0.09	0.05	0.02	0.00	0.14	0.11	0.06	0.02	0.00	0.05	0.06	0.06
NM	0.26	0.19	0.11	0.04	0.00	0.28	0.21	0.13	0.05	0.01	0.10	0.12	0.11
NV	0.25	0.19	0.11	0.04	0.00	0.27	0.21	0.12	0.05	0.01	0.11	0.12	0.12
NY	0.18	0.13	0.07	0.03	0.00	0.20	0.14	0.08	0.03	0.00	0.07	0.08	0.08
OH	0.29	0.21	0.11	0.04	0.00	0.31	0.23	0.13	0.05	0.01	0.11	0.12	0.12
OK	0.24	0.17	0.09	0.04	0.00	0.25	0.19	0.11	0.04	0.01	0.09	0.10	0.10
OR	0.22	0.16	0.09	0.03	0.00	0.24	0.18	0.10	0.04	0.00	0.09	0.10	0.10
PA	0.10	0.07	0.04	0.02	0.00	0.11	0.08	0.05	0.02	0.00	0.04	0.04	0.04
RI	0.21	0.15	0.08	0.03	0.00	0.24	0.17	0.10	0.04	0.01	0.08	0.09	0.09
SC	0.18	0.13	0.07	0.03	0.00	0.19	0.14	0.08	0.03	0.00	0.07	0.08	0.08
SD	0.19	0.13	0.08	0.03	0.00	0.20	0.15	0.09	0.04	0.00	0.07	0.08	0.08
TN	0.09	0.07	0.04	0.01	0.00	0.09	0.07	0.04	0.02	0.00	0.04	0.04	0.04
TX	0.18	0.13	0.07	0.03	0.00	0.18	0.14	0.08	0.03	0.00	0.08	0.08	0.08
UT	0.21	0.15	0.09	0.03	0.00	0.22	0.17	0.10	0.04	0.01	0.10	0.11	0.11
VA	0.14	0.10	0.06	0.02	0.00	0.15	0.11	0.07	0.03	0.00	0.06	0.06	0.06
VT	0.11	0.08	0.04	0.02	0.00	0.11	0.08	0.05	0.02	0.00	0.04	0.04	0.04
WA	0.16	0.11	0.06	0.02	0.00	0.17	0.12	0.07	0.03	0.00	0.06	0.07	0.07
WI	0.20	0.14	0.08	0.03	0.00	0.21	0.16	0.09	0.04	0.00	0.07	0.08	0.08
WV	0.22	0.16	0.09	0.03	0.00	0.24	0.17	0.10	0.04	0.00	0.08	0.09	0.09
WY	0.16	0.12	0.07	0.03	0.00	0.17	0.13	0.08	0.03	0.00	0.06	0.07	0.07

Note: All numbers correspond to % deviations in consumption-equivalent welfare (as defined in the Appendix), relative to the Baseline scenario. Sector-level and State-level averages are weighted by the relative size of age cohorts and job sectors. State-level averages are used in the Closed Reform heat map of Figure 8.

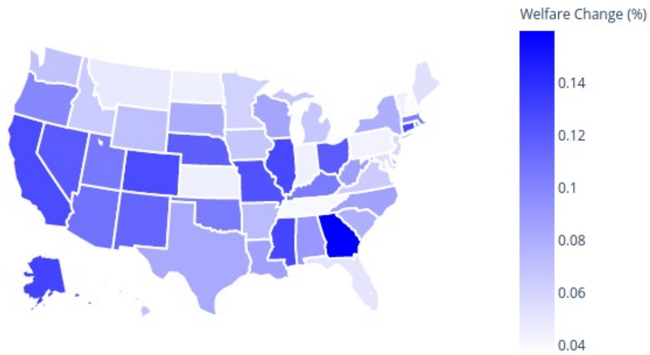

Figure 8: State-Level Welfare Effects of Closed Pension Reform

Notes: State-level welfare numbers are computed based upon the relative proportion of each age cohort and job sector.

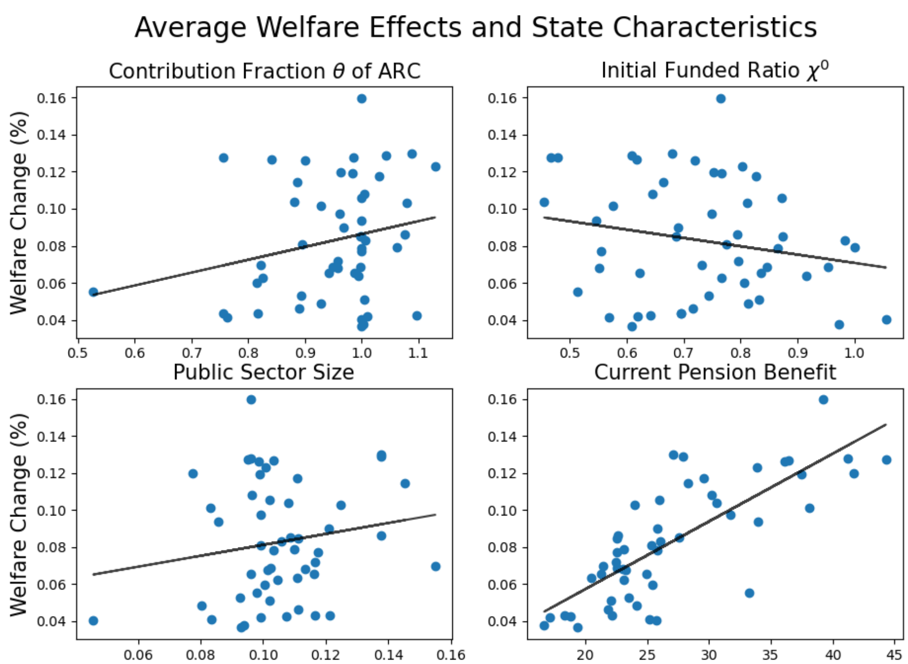

Figure 9: State-Level Welfare Effects of Closed Pension Reform

Notes: State-level welfare numbers are computed based upon the relative proportion of each age cohort and job sector.

Table 8: Regression Analysis for Determinants of Closed Reform Welfare Effects

	(1) Δ Welfare	(2) Δ Welfare	(3) Δ Welfare	(4) Δ Welfare
Constant	-0.1127^{***}	-0.2266^{***}	0.0833	0.2119
	(0.015)	(0.016)	(0.276)	(0.241)
Benefit $\bar{b}_s$	0.0043^{***}	0.0046^{***}	0.0046^{***}	0.0044^{***}
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
Pub Sector $p_{s,pub}$	0.7638^{***}	0.7687^{***}	0.7793^{***}	0.7919^{***}
	(0.119)	(0.068)	(0.083)	(0.091)
Funded Ratio $\chi(s, T = 0)$		0.0163	-0.1421	-0.2431
		(0.011)	(0.171)	(0.176)
ARC Cont. θ_s		0.0963^{***}	-0.0709	-0.0903
		(0.013)	(0.369)	(0.329)
Discount r_s			-4.3119	-5.4216^{*}
			(3.709)	(3.249)
Int. $r_s \times \chi(s, T = 0)$			2.2683	3.5890
			(2.467)	(2.522)
Int. $r_s \times \theta_s$			2.2648	2.6196
			(5.009)	(4.468)
Current Old				-0.0024^{***}
				(0.001)
Future Old				0.0002
				(< 0.001)
Observations	51	51	51	51
R-squared	0.785	0.909	0.914	0.938
Adj R-squared	0.776	0.902	0.900	0.925
F-stat	96.76	131.9	85.4	88.06

Note: This table displays the results from regressing welfare change on state-level characteristics. Welfare change is in percentages. *Current Old* represents the percentage of the population which is retired at time $T = 0$. *Future Old* represents the percentage of the population which is retired at time $T = 45$. All other explanatory variables have the same units as listed in Table 4. The coefficients are displayed with robust standard errors below in parenthesis. We also denote the statistical significance of each estimate using stars (*p<0.1, **p<0.05, ***p<0.01).

Table 9: % Change in Fiscal Aggregates Under Hybrid Pension Reform

	PVL			FR			Tax			Tax Vol		
State	15y	30y	45y	15y	30y	45y	15y	30y	45y	15y	30y	45y
AK	-9.2	-18.8	-33.9	-7.5	-12.9	-23.2	-5.3	-7.9	-9.3	13.5	0.8	-22.1
AL	-11.7	-24.9	-39.7	-10.4	-23.8	-51.0	-3.8	-7.3	-7.1	23.3	19.4	-10.6
AR	-11.9	-25.5	-40.3	-8.7	-21.3	-46.1	-3.3	-6.7	-7.7	14.3	14.5	-2.3
AZ	-10.4	-21.7	-36.1	-10.2	-20.6	-37.0	-5.0	-8.5	-7.8	6.6	-1.6	-23.2
CA	-11.7	-24.6	-39.4	-9.7	-23.1	-50.9	-6.9	-12.1	-10.8	23.0	23.5	2.2
CO	-10.8	-22.1	-36.3	-12.2	-24.4	-48.2	-5.7	-9.7	-7.6	18.9	14.4	-12.2
CT	-11.2	-24.6	-40.0	-12.7	-23.4	-49.7	-6.9	-13.4	-12.7	18.8	18.8	-5.0
DC	-14.1	-31.7	-47.2	-3.5	-6.3	-30.2	-6.0	-10.6	-16.3	5.9	-8.9	139.9
DE	-11.6	-24.7	-39.7	-8.2	-21.1	-45.1	-3.4	-6.7	-6.2	15.0	13.2	-12.3
FL	-12.1	-26.1	-41.5	-8.8	-23.7	-52.8	-3.2	-6.4	-6.7	8.1	4.5	-15.0
GA	-11.7	-23.9	-38.1	-8.6	-22.0	-44.7	-8.9	-14.2	-11.3	26.5	25.5	-5.2
HI	-10.7	-22.6	-37.1	-11.1	-20.3	-38.8	-2.7	-5.9	-6.5	8.6	3.8	-17.1
IA	-11.6	-25.2	-40.2	-8.1	-19.4	-42.6	-3.1	-6.5	-7.6	21.5	24.6	5.8
ID	-10.8	-22.3	-36.6	-7.6	-18.3	-36.4	-3.0	-5.7	-6.2	17.8	16.5	-7.2
IL	-12.0	-25.2	-39.8	-18.1	-34.3	-68.9	-5.2	-9.3	-8.0	4.7	9.7	-12.4
IN	-12.2	-25.5	-40.1	-9.2	-19.4	-41.2	-2.0	-5.3	-5.5	25.4	27.3	5.1
KS	-10.8	-23.7	-38.7	-12.6	-28.9	-60.9	-0.8	-2.7	-2.6	14.4	11.7	-14.0
KY	-12.8	-26.1	-40.5	-14.7	-25.5	-49.3	-3.8	-8.1	-8.3	9.4	15.4	-5.7
LA	-12.0	-25.7	-40.6	-8.3	-17.7	-41.4	-5.1	-9.2	-11.6	23.5	23.9	10.1
MA	-11.9	-25.8	-41.1	-11.2	-23.1	-51.6	-6.7	-12.4	-12.4	20.0	19.4	0.6
MD	-11.3	-24.4	-39.4	-9.3	-22.5	-51.6	-3.2	-6.8	-6.9	21.1	23.5	5.2
ME	-11.1	-23.6	-38.5	-6.5	-16.0	-34.5	-2.8	-6.1	-7.8	2.4	-4.8	-20.7
MI	-11.7	-24.7	-39.7	-9.9	-20.9	-45.3	-3.4	-7.6	-7.8	13.2	11.9	-6.0
MN	-11.1	-24.0	-39.1	-10.2	-25.8	-57.0	-2.7	-5.1	-5.0	10.3	3.1	-19.8
MO	-11.5	-24.9	-39.9	-7.4	-17.6	-38.4	-8.0	-13.4	-14.4	21.6	23.4	0.7
MS	-11.8	-24.9	-39.6	-10.2	-21.0	-43.6	-4.9	-8.9	-9.3	23.3	15.0	-12.9
MT	-9.8	-21.8	-36.8	-11.2	-22.2	-48.0	-1.6	-3.7	-5.6	16.3	17.8	-3.5
NC	-11.9	-24.7	-39.2	-8.0	-22.8	-47.6	-4.0	-7.5	-5.9	24.4	27.9	-3.1
ND	-11.5	-25.8	-41.5	-12.9	-24.5	-58.1	-1.3	-3.3	-5.9	23.8	28.2	13.6
NE	-11.3	-24.7	-39.8	-8.3	-20.0	-43.7	-6.3	-10.5	-11.6	28.7	34.0	11.0
NH	-10.6	-22.8	-37.9	-9.7	-19.3	-40.0	-1.4	-4.3	-5.0	4.7	-3.8	-24.3
NJ	-11.9	-25.9	-41.2	-25.3	-76.8	-206.1	-1.3	-2.8	-0.5	-7.5	-13.3	-18.3
NM	-10.0	-20.8	-35.4	-10.9	-22.2	-43.6	-3.0	-4.7	-5.2	3.1	-5.4	-26.8
NV	-9.7	-19.7	-34.3	-9.5	-20.3	-37.2	-7.3	-10.1	-6.5	9.0	-1.1	-25.8
NY	-12.2	-26.3	-41.5	-6.9	-17.7	-44.2	-5.1	-9.9	-11.2	28.1	43.1	38.9
OH	-11.6	-24.9	-39.9	-8.9	-21.3	-46.6	-7.2	-12.5	-12.2	20.0	19.1	-4.5
OK	-11.8	-25.6	-40.6	-7.4	-18.4	-42.0	-5.2	-9.4	-10.8	35.1	52.2	34.2
OR	-10.6	-22.2	-36.3	-8.7	-18.5	-37.9	-5.6	-10.1	-10.5	17.8	15.8	-5.7
PA	-11.5	-25.1	-40.3	-15.7	-34.1	-73.3	-1.5	-3.8	-3.8	4.3	5.4	-13.7
RI	-11.7	-25.3	-40.6	-11.2	-21.0	-45.5	-5.8	-11.1	-11.4	16.8	15.8	-5.6
SC	-11.7	-24.6	-39.2	-10.7	-20.7	-43.0	-3.2	-7.0	-7.5	17.8	15.2	-5.4
SD	-12.1	-25.8	-40.8	-6.4	-15.8	-35.6	-4.3	-7.6	-9.7	22.7	27.2	6.2
TN	-11.9	-25.0	-39.6	-7.6	-21.1	-45.9	-2.0	-4.9	-4.7	21.7	28.0	4.1
TX	-12.4	-25.6	-40.2	-8.9	-23.3	-50.3	-4.4	-8.2	-7.6	21.1	22.6	-0.7
UT	-12.2	-25.0	-39.0	-7.3	-18.0	-35.4	-5.8	-9.2	-11.2	24.4	23.6	3.0
VA	-12.0	-24.8	-39.3	-9.1	-22.7	-49.9	-2.6	-5.8	-5.6	12.2	10.5	-7.3
VT	-9.8	-21.3	-36.2	-9.5	-18.1	-35.8	-1.5	-3.8	-4.6	9.0	-0.1	-25.1
WA	-10.7	-22.6	-37.1	-7.9	-20.1	-43.5	-3.6	-6.9	-6.9	19.1	21.3	-1.1
WI	-11.5	-24.3	-39.2	-7.0	-18.8	-40.4	-4.5	-7.6	-7.6	12.8	7.3	-18.3
WV	-11.5	-24.4	-38.7	-7.6	-17.5	-36.7	-3.7	-7.7	-9.3	10.9	7.7	-9.6
WY	-10.1	-21.5	-36.2	-9.7	-20.1	-43.2	-1.5	-3.3	-5.2	9.5	6.2	-10.9

Note: All numbers correspond to % deviations from the baseline forecast numbers, presented in Table 5.

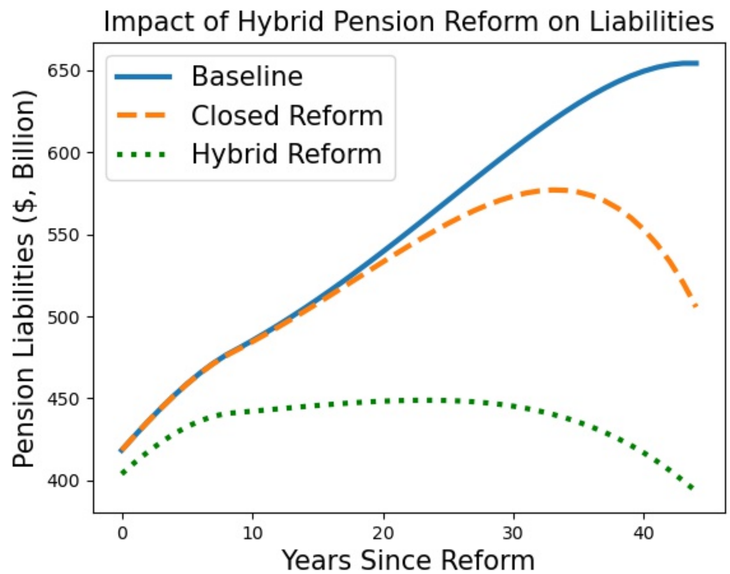

Figure 10: Weighted-Average Path of Hybrid Reform Public Pension Liabilities

Notes: The plots represent the weighted average pension liabilities under each scenario, where the weighting comes from the size of each state's total liabilities.

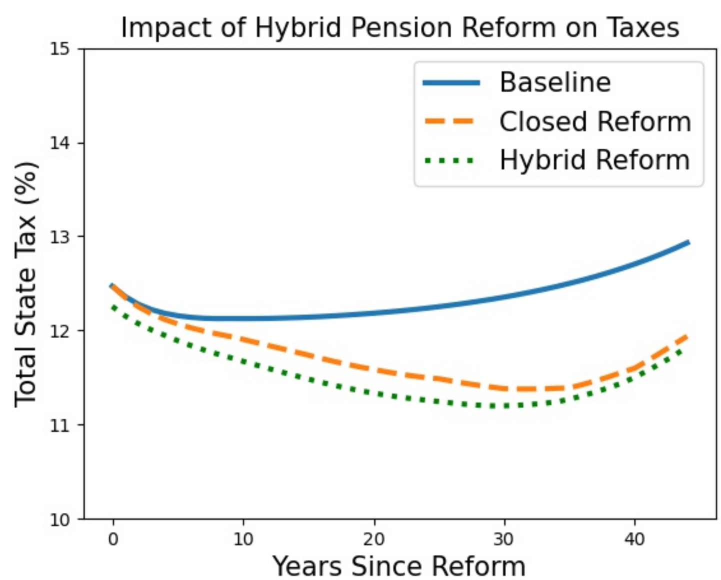

Figure 11: Weighted-Average Path of Taxes Under Hybrid Reform

Notes: The plots represent the weighted average wage tax under each scenario, where the weighting comes from the size of each state's total liabilities.

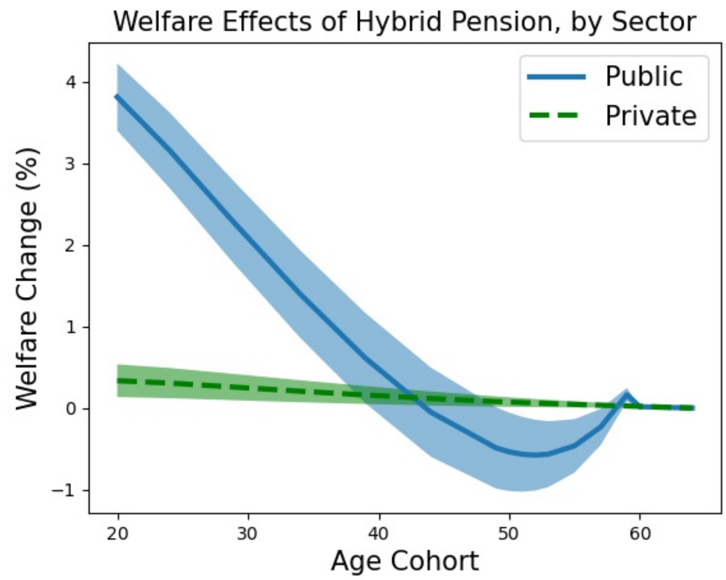

Figure 12: Weighted-Average Welfare Effects from Hybrid Reform, by Age and Job Sector

Notes: The plots represent the weighted average welfare effects for each age cohort under each scenario, where the weighting comes from the size of each state's total liabilities. Shaded areas represent volatility bands, computed from the cross-section variation across states.

Table 10: Hybrid Pension Welfare by State, Sector, Age Cohort

	Public					Private					Averages		
State	20 Yr	30 Yr	40 Yr	50 Yr	60 Yr	20 Yr	30 Yr	40 Yr	50 Yr	60 Yr	Pub Avg	Priv Avg	State Avg
AK	3.64	1.91	0.19	-0.84	0.17	0.65	0.47	0.30	0.16	0.05	0.70	0.29	0.35
AL	4.10	2.54	0.85	-0.32	0.19	0.34	0.26	0.16	0.08	0.03	1.08	0.15	0.26
AR	4.12	2.65	1.03	-0.13	0.22	0.23	0.17	0.10	0.04	0.01	1.20	0.09	0.22
AZ	3.96	2.33	0.60	-0.57	0.14	0.54	0.41	0.27	0.14	0.04	1.00	0.26	0.33
CA	3.49	1.78	0.01	-1.08	0.05	0.54	0.43	0.28	0.15	0.05	0.58	0.27	0.30
CO	3.05	1.30	-0.43	-1.41	0.02	0.54	0.43	0.28	0.15	0.04	0.19	0.27	0.26
CT	3.48	1.64	-0.22	-1.33	0.01	0.72	0.58	0.38	0.21	0.07	0.30	0.34	0.34
DC	2.81	1.35	-0.06	-0.87	0.13	0.12	0.09	0.05	0.02	0.00	0.54	0.06	0.08
DE	4.07	2.61	1.01	-0.13	0.22	0.26	0.20	0.12	0.06	0.02	1.19	0.11	0.22
FL	3.82	2.39	0.82	-0.26	0.19	0.21	0.16	0.09	0.04	0.01	1.01	0.09	0.16
GA	3.75	2.00	0.15	-1.02	0.05	0.74	0.59	0.39	0.21	0.06	0.66	0.37	0.40
HI	4.05	2.57	0.96	-0.18	0.21	0.26	0.19	0.12	0.06	0.02	1.17	0.11	0.22
IA	4.10	2.66	1.06	-0.07	0.24	0.19	0.14	0.08	0.03	0.01	1.23	0.08	0.21
ID	4.12	2.71	1.14	-0.00	0.24	0.16	0.12	0.07	0.02	0.01	1.32	0.07	0.21
IL	3.10	1.27	-0.57	-1.60	-0.04	0.62	0.50	0.33	0.18	0.05	0.08	0.30	0.28
IN	4.16	2.84	1.35	0.23	0.29	0.05	0.03	0.01	-0.00	-0.00	1.44	0.01	0.16
KS	4.14	2.78	1.25	0.13	0.27	-0.00	-0.01	-0.03	-0.03	-0.01	1.41	-0.02	0.16
KY	3.68	2.02	0.29	-0.81	0.11	0.46	0.37	0.24	0.12	0.03	0.65	0.21	0.26
LA	3.26	1.64	0.03	-0.91	0.14	0.35	0.26	0.17	0.08	0.03	0.48	0.16	0.19
MA	2.85	1.10	-0.60	-1.53	-0.00	0.51	0.40	0.26	0.14	0.05	0.04	0.24	0.23
MD	3.86	2.42	0.86	-0.23	0.19	0.15	0.11	0.06	0.03	0.01	1.08	0.06	0.16
ME	3.41	1.87	0.35	-0.57	0.21	0.29	0.21	0.12	0.05	0.01	0.55	0.10	0.15
MI	3.92	2.42	0.80	-0.31	0.18	0.27	0.20	0.12	0.06	0.02	1.02	0.11	0.20
MN	3.84	2.36	0.75	-0.35	0.17	0.21	0.15	0.09	0.04	0.01	0.99	0.09	0.18
MO	3.59	1.86	0.08	-1.01	0.08	0.64	0.50	0.33	0.17	0.06	0.54	0.30	0.32
MS	4.33	2.66	0.85	-0.40	0.18	0.57	0.44	0.28	0.15	0.05	1.11	0.26	0.37
MT	4.00	2.57	1.01	-0.11	0.22	0.10	0.07	0.04	0.01	0.00	1.10	0.04	0.15
NC	4.12	2.65	1.03	-0.13	0.22	0.27	0.21	0.13	0.06	0.02	1.25	0.12	0.25
ND	3.91	2.49	0.94	-0.16	0.21	0.03	0.01	-0.01	-0.01	-0.00	1.16	-0.00	0.13
NE	4.00	2.38	0.64	-0.53	0.15	0.49	0.38	0.25	0.13	0.04	0.98	0.23	0.31
NH	4.11	2.72	1.19	0.07	0.26	0.15	0.10	0.05	0.02	0.01	1.18	0.05	0.15
NJ	3.45	1.86	0.21	-0.84	0.07	0.18	0.13	0.07	0.03	0.00	0.56	0.07	0.12
NM	4.37	2.66	0.82	-0.43	0.17	0.60	0.44	0.28	0.14	0.04	1.10	0.26	0.38
NV	2.79	1.00	-0.74	-1.69	-0.04	0.67	0.52	0.34	0.19	0.06	-0.04	0.33	0.30
NY	3.93	2.43	0.79	-0.34	0.18	0.30	0.23	0.14	0.07	0.03	1.07	0.14	0.23
OH	3.06	1.27	-0.49	-1.47	0.02	0.64	0.51	0.33	0.18	0.06	0.09	0.30	0.28
OK	4.17	2.64	0.95	-0.23	0.21	0.35	0.27	0.17	0.08	0.03	1.20	0.16	0.29
OR	3.81	2.19	0.47	-0.67	0.12	0.45	0.35	0.23	0.12	0.04	0.81	0.21	0.27
PA	3.71	2.27	0.72	-0.35	0.17	0.13	0.09	0.05	0.02	0.00	0.92	0.05	0.12
RI	3.66	2.01	0.27	-0.83	0.09	0.48	0.38	0.25	0.14	0.04	0.69	0.23	0.27
SC	4.17	2.68	1.04	-0.12	0.22	0.26	0.19	0.12	0.06	0.02	1.22	0.11	0.24
SD	4.11	2.64	1.01	-0.15	0.22	0.31	0.24	0.15	0.07	0.02	1.17	0.14	0.25
TN	4.12	2.83	1.36	0.25	0.29	0.04	0.02	-0.00	-0.01	-0.01	1.42	0.00	0.14
TX	3.52	2.00	0.42	-0.59	0.16	0.25	0.19	0.11	0.05	0.02	0.84	0.11	0.19
UT	3.94	2.43	0.79	-0.35	0.18	0.33	0.26	0.16	0.08	0.03	1.25	0.17	0.28
VA	3.95	2.49	0.91	-0.20	0.20	0.18	0.13	0.07	0.03	0.01	1.14	0.07	0.18
VT	4.23	2.83	1.27	0.13	0.27	0.15	0.10	0.05	0.02	0.01	1.26	0.05	0.18
WA	4.02	2.56	0.96	-0.18	0.21	0.20	0.15	0.08	0.03	0.01	1.18	0.08	0.21
WI	4.02	2.48	0.81	-0.34	0.18	0.38	0.30	0.19	0.09	0.03	1.02	0.17	0.26
WV	4.38	2.85	1.13	-0.10	0.23	0.37	0.28	0.16	0.07	0.02	1.17	0.14	0.29
WY	4.30	2.80	1.13	-0.06	0.24	0.15	0.09	0.05	0.01	0.00	1.26	0.05	0.24

Note: All numbers correspond to % deviations in consumption-equivalent welfare (as defined in the Appendix), relative to the Baseline scenario. Sector-level and State-level averages are weighted by the relative size of age cohorts and job sectors. State-level averages are used in the Hybrid Reform heat map of Figure 13.

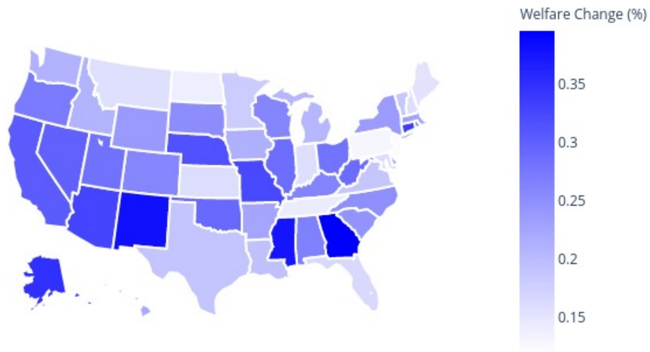

Figure 13: State-Level Welfare Effects of Hybrid Pension Reform

Notes: State-level welfare numbers are computed based upon the relative proportion of each age cohort and job sector.

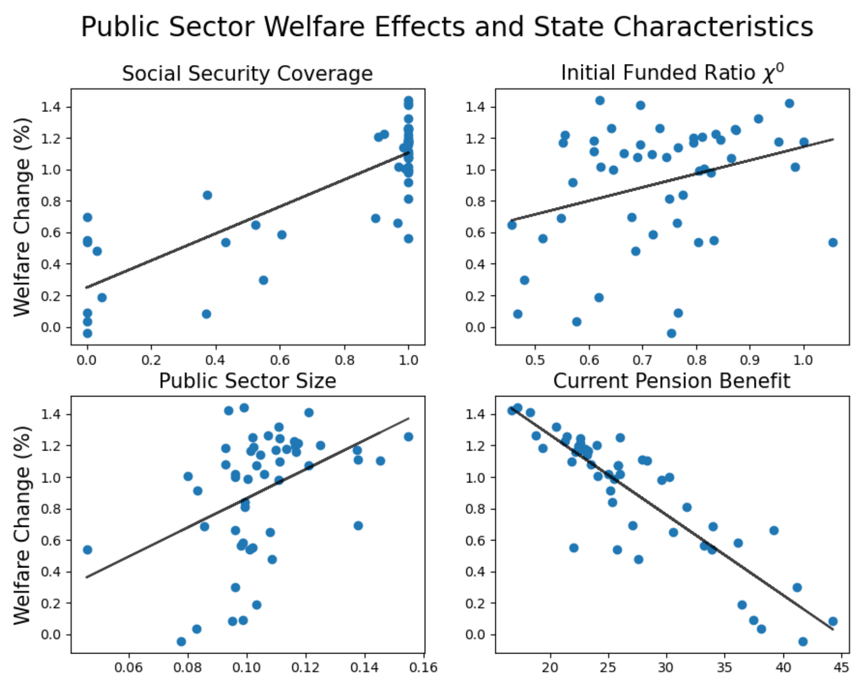

Figure 14: Public Sector Welfare Effects of Hybrid Pension Reform

Notes: Sector-level welfare numbers are computed based upon the relative proportion of each age cohort within the state's job sector.

Table 11: Regression Analysis for Determinants of Hybrid Reform Public Welfare Effects

	(1)	(2)	(3)	(4)
	Δ Pub. Welfare	Δ Pub. Welfare	Δ Pub. Welfare	Δ Pub. Welfare
Constant	2.860***	1.4704***	1.2185***	1.0028***
	(0.100)	(0.092)	(0.113)	(0.208)
Benefit $\bar{b}_s$	−0.0509***	−0.0357***	−0.0345***	−0.0319***
	(0.004)	(0.002)	(0.002)	(0.002)
SS Coverage		0.5215***	0.4984***	0.5268***
		(0.047)	(0.045)	(0.037)
Pub Sector $p_{s,pub}$			2.2685***	2.4597***
			(0.659)	(0.506)
Funded Ratio $\chi(s, T = 0)$				0.0850
				(0.066)
ARC Cont. θ_s				0.3296***
				(0.095)
Discount r_s				−3.7594
				(2.882)
Observations	51	51	51	51
R-squared	0.770	0.953	0.963	0.974
Adj R-squared	0.766	0.951	0.960	0.971
F-stat	173.6	1043.0	793.0	484.8

Note: This table displays the results from regressing public sector welfare change on state-level characteristics. Average public welfare change is listed in percentages. *SS Coverage* is listed as a proportion between 0 and 1. All other explanatory variables are in the same units as listed in Table 4. The coefficients are displayed with robust standard errors below in parenthesis. We also denote the statistical significance of each estimate using stars (*p<0.1, **p<0.05, ***p<0.01).

Table 12: Regression Analysis for Determinants of Hybrid Reform Private Welfare Effects

	(1) Δ Priv. Welfare	(2) Δ Priv. Welfare	(3) Δ Priv. Welfare	(4) Δ Priv. Welfare
Constant	-0.3788^{***}	-0.7320^{***}	-0.0665	-0.0213
	(0.050)	(0.042)	(0.722)	(0.631)
Benefit $\bar{b}_s$	0.0141^{***}	0.0149^{***}	0.0149^{***}	0.0145^{***}
	(0.001)	(< 0.001)	(0.002)	(0.001)
Pub Sector $p_{s,pub}$	1.4090^{***}	1.3243^{***}	1.3649^{***}	1.2244^{***}
	(0.405)	(0.261)	(0.314)	(0.282)
Funded Ratio $\chi(s, T = 0)$		-0.0071	-0.1672	-0.0981
		(0.022)	(0.380)	(0.441)
ARC Cont. θ_s		0.3651^{***}	-0.1797	-0.1732
		(0.022)	(0.896)	(0.852)
Discount r_s			-10.0267	-9.2744
			(9.634)	(8.433)
Int. $r_s \times \chi(s, T = 0)$			2.3235	1.5665
			(5.429)	(6.258)
Int. $r_s \times \theta_s$			7.3846	6.9952
			(12.088)	(11.543)
Current Old				-0.0029^{***}
				(0.001)
Future Old				0.0013^{***}
				(< 0.001)
Observations	51	51	51	51
R-squared	0.808	0.952	0.954	0.967
Adj R-squared	0.800	0.948	0.947	0.960
F-stat	111.2	280.0	195.8	230.4

Note: This table displays the results from regressing private sector welfare change on state-level characteristics. Average private welfare change is listed in percentages. *SS Coverage* is listed as a proportion between 0 and 1. All other explanatory variables are in the same units as listed in Table 4. The coefficients are displayed with robust standard errors below in parenthesis. We also denote the statistical significance of each estimate using stars (*p<0.1, **p<0.05, ***p<0.01).

Table 13: % Change in Fiscal Aggregates Under COLA Freeze

	PVL			FR			Tax			Tax Vol		
State	15y	30y	45y	15y	30y	45y	15y	30y	45y	15y	30y	45y
AK	-27.1	-31.0	-31.9	2.2	2.9	3.4	-4.7	-7.5	-16.8	-31.1	-35.3	-33.8
AL	-19.9	-23.3	-24.8	1.5	1.8	2.9	-3.5	-4.0	-5.0	-21.7	-27.5	-30.0
AR	-19.6	-22.9	-24.3	0.9	1.4	2.2	-3.1	-3.5	-4.1	-20.8	-26.3	-28.4
AZ	-23.2	-27.6	-29.3	2.9	2.5	3.6	-5.2	-7.1	-11.8	-24.4	-30.0	-31.4
CA	-20.9	-24.4	-25.8	1.3	1.8	2.9	-4.2	-4.7	-5.6	-23.4	-28.9	-30.7
CO	-23.3	-27.7	-29.2	2.9	2.8	4.4	-4.4	-5.4	-8.1	-26.0	-32.8	-33.6
CT	-21.0	-24.0	-25.1	2.8	2.1	2.7	-5.3	-5.9	-6.9	-23.1	-29.0	-30.3
DC	-13.6	-13.9	-14.1	-0.2	-0.2	-0.3	-3.1	-3.1	-3.1	-13.5	-14.7	-13.8
DE	-21.2	-24.5	-25.7	1.6	2.0	3.1	-3.4	-4.0	-5.2	-23.5	-28.9	-30.8
FL	-19.5	-22.4	-23.5	1.8	1.8	2.4	-3.5	-4.1	-4.8	-20.1	-24.9	-26.5
GA	-21.4	-25.4	-27.1	1.0	1.8	2.9	-4.8	-5.5	-7.2	-24.6	-30.4	-32.5
HI	-23.1	-27.0	-28.6	3.7	2.5	3.7	-3.9	-4.8	-7.2	-24.6	-30.0	-32.2
IA	-20.6	-23.8	-25.0	1.1	1.6	2.3	-3.0	-3.3	-3.8	-22.6	-28.7	-31.0
ID	-23.2	-27.5	-29.1	1.3	2.4	3.6	-3.1	-3.7	-5.3	-26.5	-33.0	-34.3
IL	-20.7	-24.1	-25.4	5.8	2.9	4.0	-4.9	-5.5	-6.9	-21.4	-27.3	-29.2
IN	-20.6	-23.9	-25.2	1.4	1.6	2.4	-2.5	-2.8	-3.3	-23.4	-28.9	-31.2
KS	-21.3	-24.9	-26.2	3.1	2.7	4.1	-2.5	-3.0	-4.0	-22.7	-28.6	-30.8
KY	-20.3	-23.6	-25.0	4.2	1.9	2.7	-4.0	-4.4	-5.4	-20.6	-27.5	-29.5
LA	-19.5	-22.8	-24.1	0.8	1.4	2.0	-3.6	-3.9	-4.4	-21.3	-27.3	-29.3
MA	-20.0	-22.9	-23.9	2.0	1.5	2.2	-4.6	-5.0	-5.7	-21.3	-26.9	-28.8
MD	-20.8	-24.3	-25.6	1.3	1.8	2.9	-3.0	-3.3	-3.9	-23.0	-28.8	-31.4
ME	-22.3	-25.9	-27.3	1.8	2.2	3.1	-4.0	-5.3	-7.7	-22.9	-28.2	-29.8
MI	-21.1	-24.5	-25.8	2.4	2.0	2.8	-3.6	-4.1	-5.0	-22.4	-28.6	-30.3
MN	-21.5	-24.9	-26.1	2.2	2.7	4.3	-3.3	-4.3	-6.1	-23.3	-28.5	-29.0
MO	-20.5	-23.8	-25.0	0.7	1.3	2.2	-4.7	-5.2	-6.1	-23.2	-28.5	-30.4
MS	-19.9	-23.4	-24.9	1.3	1.5	2.5	-3.9	-4.6	-5.9	-21.4	-27.6	-29.6
MT	-22.6	-26.8	-28.3	3.3	3.0	4.5	-3.2	-3.6	-4.5	-24.9	-33.1	-35.8
NC	-20.8	-24.4	-26.0	1.0	1.8	2.7	-3.1	-3.6	-4.4	-23.6	-30.1	-32.3
ND	-19.4	-22.5	-23.3	2.2	1.8	2.4	-2.5	-2.6	-2.9	-20.1	-26.9	-29.2
NE	-20.5	-23.8	-25.1	0.8	1.6	2.3	-3.9	-4.2	-4.9	-23.9	-29.6	-31.6
NH	-22.7	-26.3	-27.6	3.7	2.9	3.7	-3.7	-5.1	-7.9	-23.8	-28.9	-29.8
NJ	-19.7	-22.6	-23.7	14.3	10.3	14.3	-3.3	-4.0	-5.3	-18.5	-21.9	-24.1
NM	-24.3	-28.8	-30.3	6.2	4.3	5.4	-4.9	-7.1	-13.0	-25.0	-31.0	-31.7
NV	-25.1	-29.8	-31.3	3.2	3.3	4.5	-6.4	-9.7	-18.6	-27.7	-32.6	-32.6
NY	-19.4	-22.3	-23.4	0.5	1.1	1.5	-3.3	-3.5	-3.6	-21.3	-27.0	-29.1
OH	-20.4	-23.8	-25.1	1.2	1.7	2.7	-4.7	-5.3	-6.4	-22.3	-28.3	-30.3
OK	-19.5	-22.7	-24.0	0.4	1.1	1.6	-3.3	-3.5	-3.7	-22.6	-28.0	-31.1
OR	-22.9	-27.3	-29.1	1.9	2.4	3.6	-4.3	-5.0	-6.9	-25.8	-32.3	-34.3
PA	-20.4	-23.6	-24.8	6.2	3.5	4.5	-3.3	-3.7	-4.6	-20.0	-26.3	-29.0
RI	-20.6	-23.7	-24.7	2.4	1.7	2.6	-4.6	-5.1	-6.1	-22.8	-27.4	-29.4
SC	-20.6	-24.2	-25.8	1.9	1.7	2.8	-3.3	-3.8	-4.7	-22.0	-27.7	-30.3
SD	-20.9	-23.9	-24.8	0.7	1.5	2.2	-3.3	-3.7	-4.3	-23.9	-29.2	-31.6
TN	-20.2	-23.7	-25.3	0.6	1.5	2.2	-2.4	-2.7	-3.2	-22.4	-28.8	-31.1
TX	-19.9	-23.3	-24.7	0.8	1.4	2.6	-3.1	-3.5	-4.2	-21.7	-27.0	-29.4
UT	-21.0	-24.2	-25.6	0.7	1.4	2.0	-3.4	-3.9	-4.6	-23.4	-28.7	-30.2
VA	-21.3	-24.8	-26.2	2.0	2.2	3.2	-3.0	-3.5	-4.5	-23.0	-28.0	-30.1
VT	-23.6	-27.8	-29.2	3.6	3.1	4.3	-3.9	-5.2	-8.7	-26.1	-31.9	-32.1
WA	-22.2	-26.4	-28.1	1.2	2.2	3.5	-3.2	-3.7	-4.8	-25.6	-32.0	-34.1
WI	-21.6	-25.1	-26.3	1.0	2.2	3.4	-3.8	-4.8	-6.8	-24.2	-29.5	-30.2
WV	-20.4	-24.1	-25.9	0.7	1.5	2.6	-3.5	-4.1	-5.2	-21.4	-27.4	-29.9
WY	-23.8	-28.2	-29.6	3.7	3.3	5.0	-3.1	-3.9	-5.6	-25.8	-32.5	-34.3

Note: All numbers correspond to % deviations from the baseline forecast numbers, presented in Table 5.

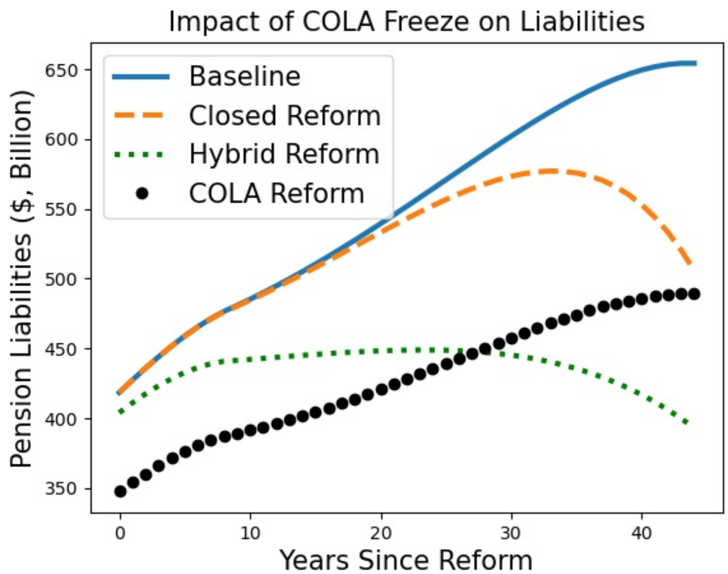

Figure 15: Weighted-Average Path of COLA Reform Public Pension Liabilities

Notes: The plots represent the weighted average pension liabilities under each scenario, where the weighting comes from the size of each state's total liabilities.

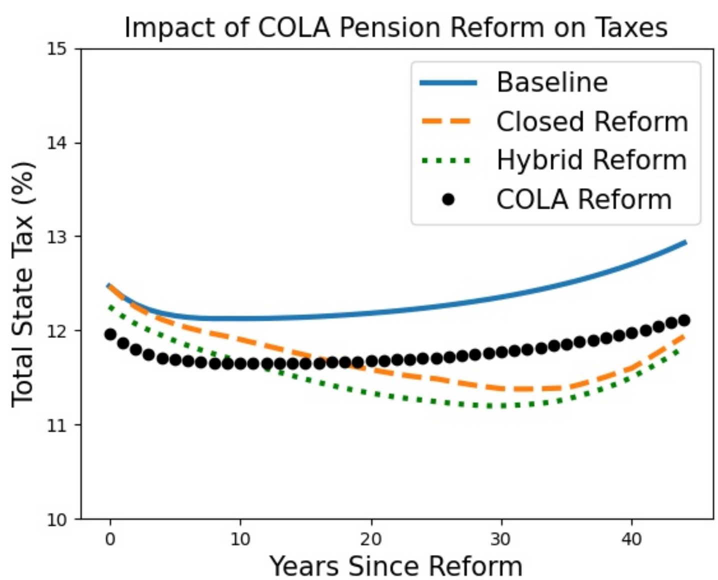

Figure 16: Weighted-Average Path of Taxes Under COLA Reform

Notes: The plots represent the weighted average wage tax under each scenario, where the weighting comes from the size of each state's total liabilities.

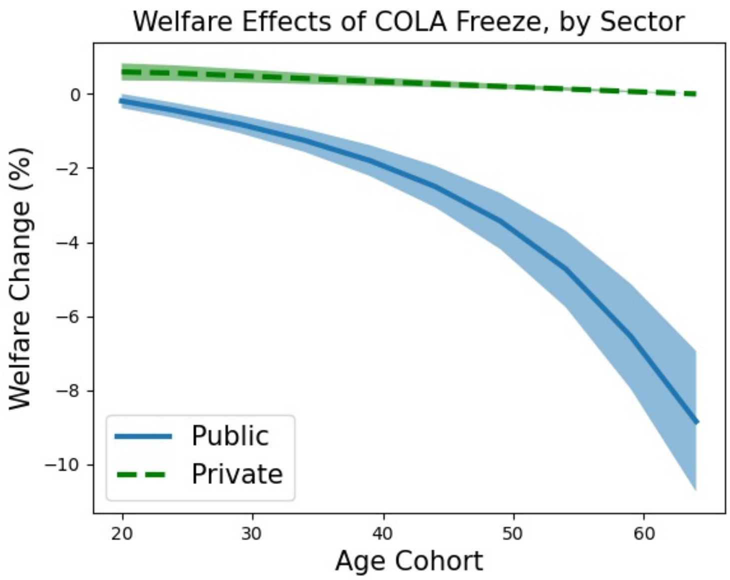

Figure 17: Weighted-Average Welfare Effects from COLA Reform, by Age and Job Sector

Notes: The plots represent the weighted average welfare effects for each age cohort under each scenario, where the weighting comes from the size of each state's total liabilities. Shaded areas represent volatility bands, computed from the cross-section variation across states.

Table 14: COLA Freeze Welfare by State, Sector, Age Cohort

	Public					Private					Averages		
State	20 Yr	30 Yr	40 Yr	50 Yr	60 Yr	20 Yr	30 Yr	40 Yr	50 Yr	60 Yr	Pub Avg	Priv Avg	State Avg
AK	0.25	-0.70	-2.05	-4.12	-8.01	1.32	0.99	0.65	0.37	0.11	-3.28	0.63	0.09
AL	-0.10	-0.69	-1.64	-3.19	-6.14	0.63	0.53	0.38	0.23	0.07	-2.79	0.33	-0.05
AR	-0.17	-0.68	-1.51	-2.89	-5.55	0.48	0.41	0.29	0.17	0.06	-2.53	0.25	-0.07
AZ	0.07	-0.64	-1.75	-3.51	-6.74	0.90	0.73	0.50	0.28	0.09	-2.86	0.46	0.14
CA	-0.34	-1.09	-2.29	-4.32	-8.19	0.62	0.52	0.37	0.22	0.07	-3.50	0.34	-0.03
CO	-0.34	-1.21	-2.56	-4.83	-9.24	0.76	0.63	0.44	0.26	0.08	-4.01	0.41	-0.05
CT	-0.13	-0.99	-2.38	-4.67	-8.91	0.93	0.79	0.56	0.34	0.11	-4.12	0.48	0.04
DC	-0.78	-1.39	-2.35	-4.02	-7.36	0.11	0.10	0.07	0.04	0.02	-3.07	0.07	-0.07
DE	-0.17	-0.69	-1.51	-2.89	-5.53	0.48	0.40	0.28	0.16	0.05	-2.57	0.25	-0.04
FL	-0.29	-0.81	-1.64	-3.04	-5.75	0.38	0.32	0.22	0.13	0.04	-2.77	0.19	-0.05
GA	-0.23	-1.00	-2.23	-4.26	-7.97	0.73	0.61	0.43	0.25	0.08	-3.45	0.39	0.02
HI	-0.03	-0.59	-1.47	-2.91	-5.63	0.65	0.54	0.37	0.22	0.07	-2.51	0.33	0.04
IA	-0.18	-0.68	-1.48	-2.82	-5.41	0.46	0.39	0.28	0.16	0.05	-2.49	0.24	-0.08
ID	-0.15	-0.64	-1.41	-2.70	-5.17	0.46	0.39	0.27	0.15	0.05	-2.27	0.24	-0.04
IL	-0.33	-1.24	-2.67	-5.07	-9.56	0.79	0.66	0.47	0.28	0.09	-4.25	0.42	-0.02
IN	-0.19	-0.59	-1.24	-2.33	-4.47	0.34	0.29	0.21	0.13	0.04	-2.04	0.18	-0.04
KS	-0.15	-0.59	-1.30	-2.48	-4.76	0.42	0.35	0.24	0.14	0.05	-2.12	0.22	-0.06
KY	-0.18	-0.90	-2.03	-3.91	-7.53	0.71	0.60	0.43	0.26	0.08	-3.46	0.37	-0.04
LA	-0.43	-1.15	-2.28	-4.17	-7.91	0.54	0.46	0.33	0.20	0.07	-3.69	0.29	-0.14
MA	-0.51	-1.35	-2.69	-4.98	-9.45	0.60	0.51	0.37	0.22	0.07	-4.40	0.32	-0.07
MD	-0.29	-0.80	-1.61	-2.99	-5.66	0.36	0.31	0.22	0.13	0.04	-2.60	0.19	-0.06
ME	-0.28	-0.97	-2.02	-3.71	-6.94	0.62	0.50	0.34	0.19	0.06	-3.65	0.27	-0.13
MI	-0.19	-0.74	-1.63	-3.12	-5.96	0.51	0.43	0.31	0.18	0.06	-2.80	0.26	-0.03
MN	-0.23	-0.79	-1.69	-3.18	-6.03	0.48	0.40	0.27	0.16	0.05	-2.78	0.24	-0.06
MO	-0.26	-1.01	-2.23	-4.27	-8.18	0.71	0.60	0.43	0.25	0.08	-3.76	0.37	-0.04
MS	0.09	-0.58	-1.64	-3.36	-6.53	0.89	0.74	0.53	0.32	0.11	-2.86	0.46	0.01
MT	-0.13	-0.64	-1.46	-2.82	-5.41	0.51	0.43	0.30	0.18	0.06	-2.59	0.25	-0.06
NC	-0.19	-0.70	-1.53	-2.91	-5.56	0.47	0.39	0.28	0.16	0.05	-2.49	0.25	-0.06
ND	-0.27	-0.76	-1.55	-2.89	-5.49	0.37	0.32	0.23	0.14	0.05	-2.54	0.20	-0.12
NE	-0.19	-0.82	-1.84	-3.53	-6.72	0.60	0.51	0.37	0.22	0.07	-3.00	0.32	-0.04
NH	-0.04	-0.53	-1.29	-2.53	-4.90	0.55	0.45	0.31	0.18	0.05	-2.40	0.26	0.01
NJ	-0.38	-1.04	-2.08	-3.85	-7.17	0.46	0.38	0.26	0.15	0.05	-3.38	0.23	-0.12
NM	0.48	-0.32	-1.52	-3.34	-6.59	1.36	1.06	0.71	0.39	0.11	-2.77	0.64	0.14
NV	-0.23	-1.22	-2.72	-5.18	-9.86	0.99	0.77	0.50	0.28	0.08	-4.22	0.48	0.12
NY	-0.30	-0.84	-1.72	-3.22	-6.11	0.41	0.35	0.25	0.15	0.05	-2.76	0.22	-0.08
OH	-0.41	-1.27	-2.64	-4.96	-9.47	0.72	0.61	0.43	0.26	0.08	-4.48	0.37	-0.11
OK	-0.17	-0.72	-1.61	-3.10	-5.96	0.53	0.46	0.33	0.20	0.07	-2.65	0.29	-0.08
OR	-0.17	-0.84	-1.91	-3.68	-6.99	0.66	0.56	0.39	0.23	0.07	-3.11	0.35	0.00
PA	-0.30	-0.83	-1.68	-3.13	-5.91	0.39	0.33	0.23	0.14	0.04	-2.85	0.20	-0.05
RI	-0.21	-0.91	-2.03	-3.90	-7.38	0.66	0.56	0.40	0.24	0.08	-3.41	0.35	0.03
SC	-0.07	-0.60	-1.46	-2.87	-5.57	0.60	0.50	0.36	0.22	0.07	-2.52	0.31	-0.02
SD	-0.20	-0.72	-1.56	-2.96	-5.65	0.46	0.39	0.28	0.16	0.05	-2.65	0.24	-0.08
TN	-0.25	-0.64	-1.25	-2.30	-4.37	0.26	0.22	0.15	0.09	0.03	-2.04	0.14	-0.07
TX	-0.42	-1.02	-1.98	-3.62	-6.85	0.39	0.33	0.24	0.14	0.05	-2.99	0.22	-0.10
UT	-0.28	-0.83	-1.73	-3.23	-6.13	0.44	0.37	0.26	0.16	0.05	-2.42	0.25	-0.02
VA	-0.24	-0.76	-1.58	-2.97	-5.65	0.42	0.35	0.25	0.14	0.05	-2.55	0.22	-0.07
VT	0.09	-0.42	-1.20	-2.46	-4.81	0.68	0.55	0.38	0.22	0.07	-2.31	0.32	0.03
WA	-0.21	-0.73	-1.56	-2.96	-5.65	0.46	0.38	0.27	0.15	0.05	-2.52	0.24	-0.07
WI	-0.16	-0.75	-1.68	-3.22	-6.13	0.57	0.47	0.32	0.18	0.05	-2.87	0.28	-0.05
WV	0.04	-0.52	-1.43	-2.89	-5.63	0.72	0.61	0.43	0.25	0.08	-2.67	0.35	-0.06
WY	0.08	-0.48	-1.37	-2.80	-5.45	0.75	0.62	0.43	0.24	0.07	-2.42	0.37	-0.06

Note: All numbers correspond to % deviations in consumption-equivalent welfare (as defined in the Appendix), relative to the Baseline scenario. Sector-level and State-level averages are weighted by the relative size of age cohorts and job sectors. State-level averages are used in the COLA Reform heat map of Figure 18.

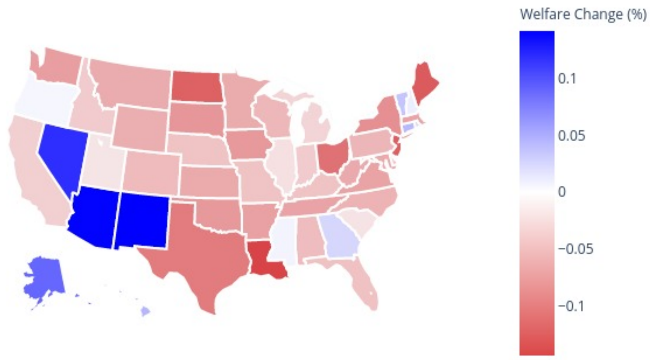

Figure 18: State-Level Welfare Effects of COLA Pension Reform

Notes: State-level welfare numbers are computed based upon the relative proportion of each age cohort and job sector.

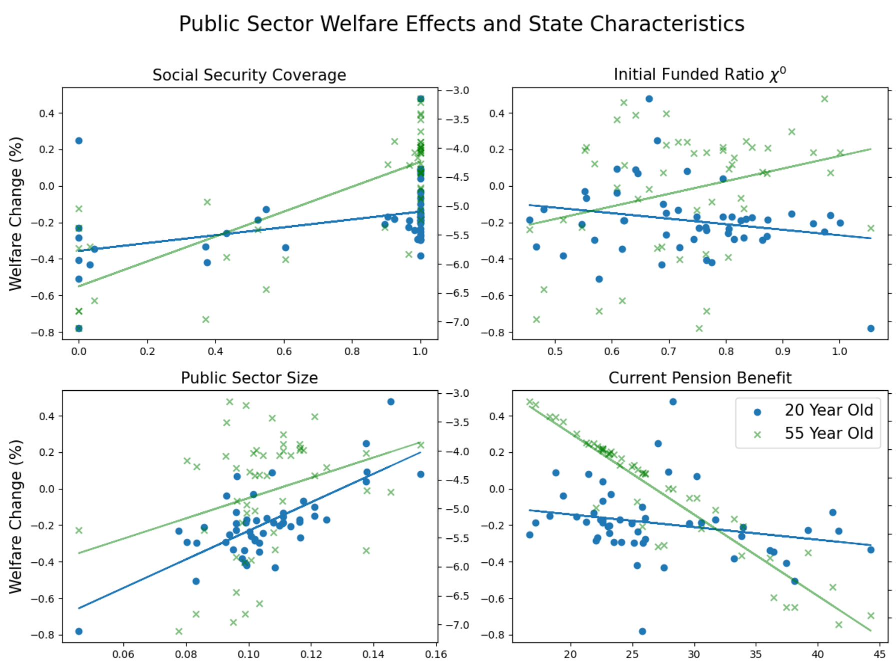

Figure 19: Public Sector Welfare Effects of COLA Pension Reform

Notes: In each panel, welfare effects are plotted for 20-Year-Old (left vertical axis) and 55-Year-Old workers (right vertical axis) in each state.

Table 15: Regression Analysis for Determinants of COLA Reform Public Welfare Effects

	(1) 20 yr Δ Welfare	(2) 20 yr Δ Welfare	(3) 55 yr Δ Welfare	(4) 55 yr Δ Welfare
Constant	-1.1346^{***}	-1.2935^{***}	-2.2951^{***}	-2.1564^{***}
	(0.168)	(0.305)	(0.094)	(0.230)
Benefit $\bar{b}_s$	0.0028	0.0005	-0.1139^{***}	-0.1152^{***}
	(0.003)	(0.003)	(0.002)	(0.002)
SS Coverage	0.1328^{*}	0.1521^{**}	1.1090^{***}	1.1068^{***}
	(0.072)	(0.062)	(0.025)	(0.027)
Pub Sector $p_{s,pub}$	7.2778^{***}	6.3724^{***}	-2.0584^{***}	-2.2806^{***}
	(1.412)	(1.475)	(0.450)	(0.519)
Funded Ratio $\chi(s, T = 0)$		-0.4459^{***}		-0.1587^{**}
		(0.094)		(0.070)
ARC Cont. θ_s		0.6023^{***}		0.0688
		(0.122)		(0.096)
Discount r_s		0.7754		-0.3698
		(4.40)		(3.042)
Observations	51	51	51	51
R-squared	0.584	0.711	0.996	0.997
Adj R-squared	0.558	0.671	0.996	0.996
F-stat	18.72	20.35	2893.0	1502.0

Note: This table displays the results from regressing public sector welfare change on state-level characteristics for 20- and 55-year old age cohorts. Public welfare change is listed in percentages. *SS Coverage* is listed as a proportion between 0 and 1. All other explanatory variables are in the same units as listed in Table 4. The coefficients are displayed with robust standard errors below in parenthesis. We also denote the statistical significance of each estimate using stars (*p<0.1, **p<0.05, ***p<0.01).

Table 16: Regression Analysis for Determinants of COLA Reform Private Welfare Effects

	(1) Δ Priv. Welfare	(2) Δ Priv. Welfare	(3) Δ Priv. Welfare	(4) Δ Priv. Welfare
Constant	-0.4382^{***}	-0.3109^{***}	-0.5294^{***}	-0.4408^{***}
	(0.086)	(0.107)	(0.102)	(0.120)
Benefit $\bar{b}_s$	0.0123^{***}	0.0113^{***}	0.0111^{***}	0.0103^{***}
	(0.001)	(0.001)	(0.001)	(0.001)
Pub Sector $p_{s,pub}$	3.9127^{***}	3.7450^{***}	3.5321^{***}	2.9324^{***}
	(0.675)	(0.689)	(0.661)	(0.474)
Funded Ratio $\chi(s, T = 0)$		-0.1117^{***}	-0.2087^{***}	-0.1268^{***}
		(0.052)	(0.042)	(0.031)
ARC Cont. θ_s			0.3325^{***}	0.2338^{***}
			(0.067)	(0.045)
Discount r_s				-0.9517
				(1.28)
Current Old				-0.0045^{*}
				(0.003)
Future Old				0.0042^{***}
				(0.001)
Observations	51	51	51	51
R-squared	0.687	0.704	0.792	0.922
Adj R-squared	0.674	0.685	0.774	0.910
F-stat	48.59	34.78	49.46	105.5

Note: This table displays the results from regressing private sector welfare change on state-level characteristics. Average private welfare change is listed in percentages. *SS Coverage* is listed as a proportion between 0 and 1. All other explanatory variables are in the same units as listed in Table 4. The coefficients are displayed with robust standard errors below in parenthesis. We also denote the statistical significance of each estimate using stars (*p<0.1, **p<0.05, ***p<0.01).

A Appendix

A.1 Welfare Analysis

We utilize consumption-equivalent welfare as our metric for normative analysis. Suppose a worker's optimal consumption policy function $\{c_t^*\}_{t=1}^{80}$ yields ex-ante expected welfare V^* via

$$V^* = E\Big[\sum_{t=1}^{80} \beta^t \big(\prod_{j=1}^{t} p_j\big) \frac{c_t^{*1-\gamma}}{1-\gamma}\Big]$$

where p_j is the conditional probability of surviving to date $j+1$, given the worker is alive at age j. We define the consumption-equivalent (CE) welfare as a scalar $\bar{c}^*$ such that

$$\begin{aligned} V^* =& \sum_{t=1}^{80} \beta^t \big(\prod_{j=1}^{t} p_j\big) \frac{\bar{c}^{*1-\gamma}}{1-\gamma} \\ \Rightarrow \bar{c}^* =& \Big[\frac{V^*(1-\gamma)}{\sum_{t=1}^{80} \beta^t \big(\prod_{j=1}^{t} p_j\big)}\Big]^{\frac{1}{1-\gamma}} \end{aligned}$$

In our main analysis, we report cohort-specific measures of welfare at model time $T = 0$ and thus compute an average, given the cross-section of workers. Specifically, for a given age cohort and job sector, workers vary by their wealth x and persistent wage shock η. Given a joint distribution of these state variables $F(x, \eta|t, j)$, we can compute the age-sector consumption-equivalent welfare as

$$\bar{c}(t, j) = \int\int \bar{c}^*(x, \eta|t, j) dF(x, \eta|t, j)$$

where $\bar{c}^*(x, \eta|t, j)$ is the consumption equivalent welfare for a particular pairing of wealth and persistent wage shock. Since we do not directly observe the current distribution of workers, varied by wealth and wage shocks, there is no direct way to compute the joint distribution F. As a second-best solution, we construct F through simulating the baseline model and then collecting the observed cross-sections of (x, η) for each job sector, age cohort and state.

Given baseline consumption-equivalent welfare $\bar{c}^{base}(t, j)$, welfare gains from reform are reported as percentage deviations

$$100^{*}\frac{\bar{c}^{ref}(t,j)-\bar{c}^{base}(t,j)}{\bar{c}^{base}(t,j)} \quad \forall t,j$$

and for each state s where $\bar{c}^{ref}$ is consumption-equivalent welfare under the policy reform.

A.2 Computing Age Cohort Distributions

We assume age cohort distributions are invariant to job sector; that is,

$$\Phi(s,t,T) = prob(pub)\tilde{\Phi}(t,T) + \big(1 - prob(pub)\big)\tilde{\Phi}(t,T)$$

Define data cohort distributions as $G(t,T)$ for age group t and time T, as well as labor force participation rates $\gamma(t)$, the ratio of annuitants to workers ϕ and cohort growth rates $\phi(t,T)$.[27] To construct $\tilde{\Phi}$ as the model analogue to G, we apply the following procedure

1. For $T = 1$

   - for working cohorts, apply labor force participation rates

     $$\tilde{\Phi}(t,1) = \gamma(t)G(t,1) \qquad \forall t = 1,...,45$$

   - For retired cohorts, set

     $$\tilde{\Phi}(t,1) = \bar{\kappa}G(t,1) \qquad \forall t = 46,...,80$$

     where the κ is recovered from the model-implied ratio of annuitants to workers ϕ, given by

     $$\phi = \frac{\bar{\kappa}\sum_{t=46}^{80} G(t,1)}{\sum_{t=1}^{45}\tilde{\Phi}(t,1)}$$

   - Normalize joint distribution $\tilde{\Phi}(\cdot,1)$

[27]The Weldon Cooper data is organized in 5-year age bins, while our model accounts for individual ages. To account for this, we take the proportions within each age bucket and evenly apply it to individual age buckets.

2. For $T = 2, ...$

   - For each cohort, apply growth rates

$$\tilde{\Phi}(t, T+1) = \phi(t, T)\tilde{\Phi}(t, T) \qquad \forall t = 1, ..., 80$$

   - Normalize joint distribution $\tilde{\Phi}(\cdot, T)$

A.3 Calculating Real Value of Pension Benefit with COLAs and Inflation

Assume constant rate of inflation π. Suppose COLA rates are ω. Then, given a date-0 nominal pension b_0, future nominal pensions are

$$b_t = (1+\omega)^t b_0$$

and the real value of date-t pension benefits is simply

$$\tilde{b}_t = \Big(\frac{1+\omega}{1+\pi}\Big)^t b_0$$

In our model, we assume the nominal (and real) pension benefit b is constant over time. In the reform, if COLAs are frozen then, simply adjust pension benefits at date t as

$$b_t = \Big(\frac{1}{1+\pi}\Big)^t b$$

where π is the long-run constant rate of inflation. If COLAs are reduced, but not frozen, to a rate ω, then simply

$$b_t = \Big(\frac{1+\omega}{1+\pi}\Big)^t b$$

A.4 Fiscal Mechanisms and Key State Parameters

In this section, we examine how relevant model parameters can impact fiscal outcomes. In particular, we vary the size of pension benefits $\bar{b}_s$, the discount factor employed for valuing liabilities r_s, the risky asset share of the pension investment portfolio α_s, size of public sector and the fraction of contributions relative to ARC θ_s. In terms of outputs, we consider the impact over time that these parameter changes have upon the state's funded ratio, volatility of funded ratio, level and volatility of taxes, as well as the value of pension liabilities. The baseline quantitative model in this section is representative of the total U.S. public pension system, weighted by total liabilities. The representative model has an annual pension benefit of \$34,000, full Cost-of-Living-Adjustments, a pensions liabilities discount factor of 7.2%, an initial funded ratio of 72%, a risky asset portfolio share of 74% and it is assumed that the state contributes 92% of its Annual Required Contribution.

Figure 20 shows the simulated average effect over time, measured in years, from varying the size of the pension benefit between \$5,000 and \$40,000. Changes in this value introduce level effect changes to pension liabilities and state taxes but has no impact on the level or volatility of funded ratios: while increased benefits affect the size of total liabilities it does not affect the funding mechanisms via normal costs or the amortized unfunded liability. In the simulations, a hump-shaped pattern emerges for the average funded ratio and this feature is robust across different levels of the pension benefit. In the first ten years, the model forecasts a general improvement in the funded ratio, suggesting that current levels are unusually low given normal investment returns and contributions. Conversely, over the longer horizon, from ten to forty-five years, the model forecasts a significant deterioration in the funded ratio. This deterioration is driven by demographic change as well as discount rate assumptions used by public pension plans.

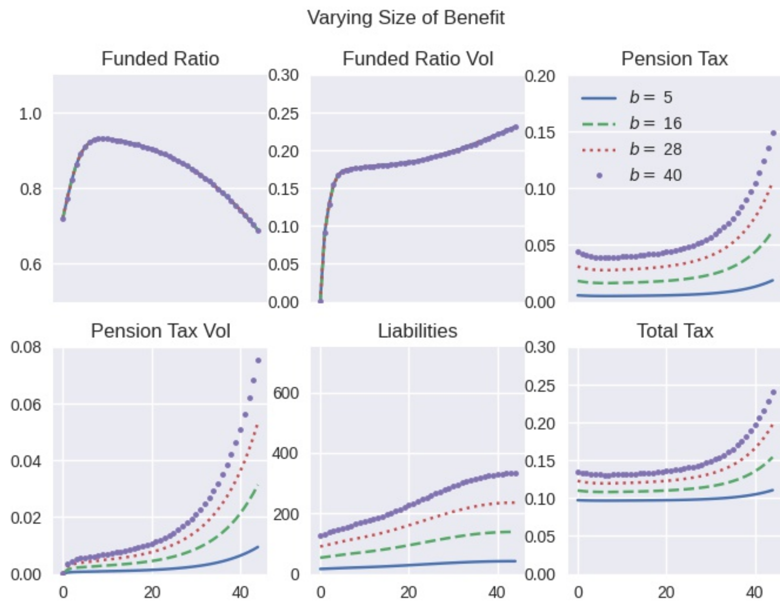

Figure 20: Comparative Static Exercise for Pension Benefit $\bar{b}_s$

As the U.S. population continues to age, this puts additional strain on the pension system by both increasing the size of pension liabilities, as well as the distribution of annual benefits to current retirees each year. In addition, by setting a high discount rate (7.2% in our representative example), states are able to reduce the current value of liabilities and avoid large contributions, in the present. However, if investment returns are unable to match the discount rate, then states will eventually be unprepared to finance the large future pension distributions, as is highlighted in Figure 20.

Figure 21 plots the impact of varying the state discount factor between 2% and 9%, but keeping the initial funded ratio constant. Previously mentioned accounting mechanisms show up here, as well: for high discount rates, pension liabilities shrink and can improve the funded ratio, all else constant, but over time, as pension distributions to retirees are realized and investment returns targets are not met, the funded ratio begins to decline.

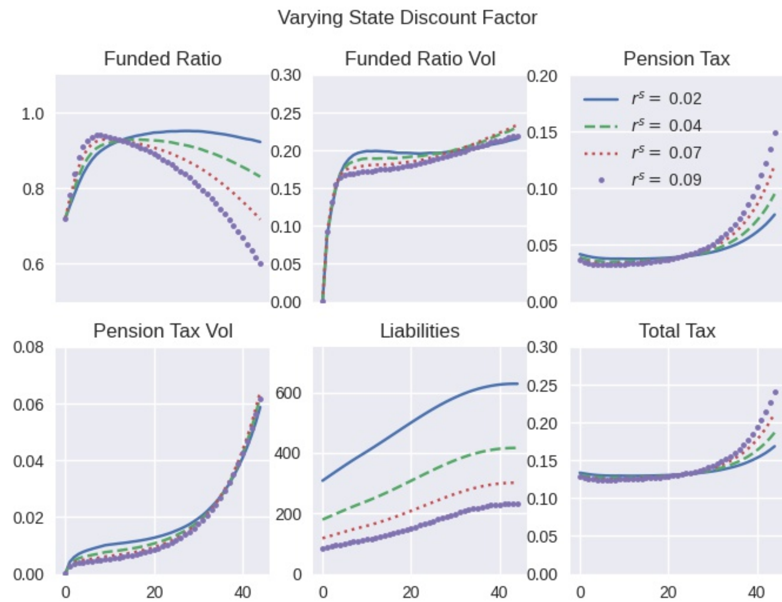

Figure 21: Comparative Static Exercise for Discount Rate Assumptions

Figure 22 plots the impact of varying the risky asset share of the pension portfolio. Higher levels of portfolio risk correspond to increased volatility in the funded ratio as well as the state tax to fund the pension, but allowing for some portfolio risk allows the fund to benefit from the equity premium and meet discount rate assumptions.

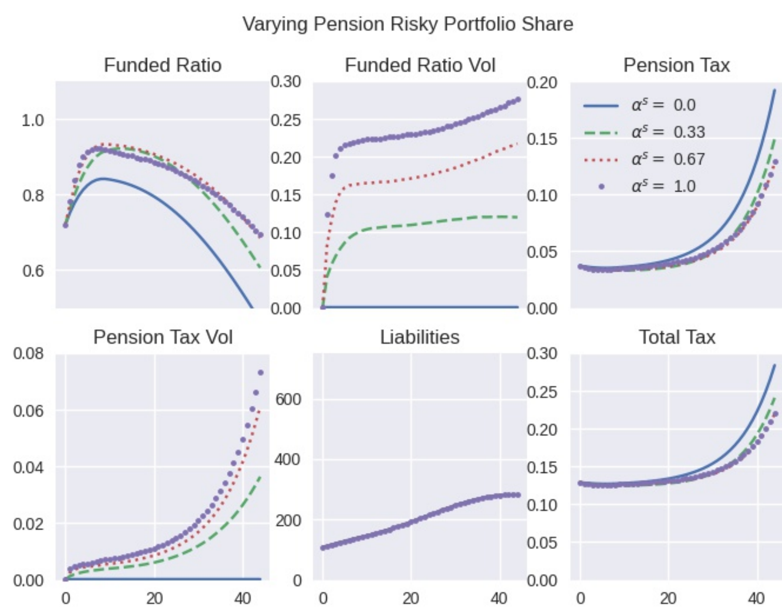

Figure 22: Comparative Static Exercise for Pension Portfolio Risk α_s

Figure 23 examines the impact of varying the public job sector from 1% to 35% of the total state population. All else equal, a larger public sector leads to an increase in pension liabilities and the corresponding taxes to fund that sector's retirement benefits as well as wages.

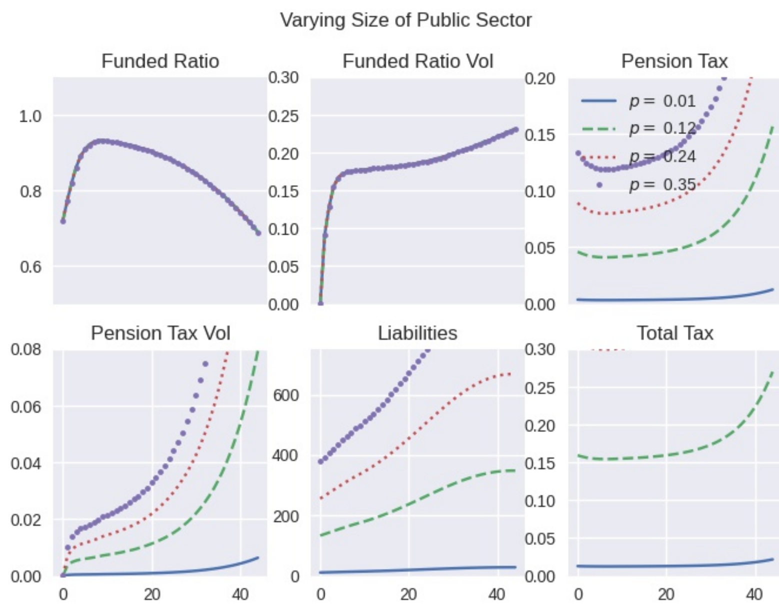

Figure 23: Comparative Static Exercise for Public Sector Size

Lastly, Figure 24 plots the impact of varying the amount of Annual Required Contributions between 50% and 110%. Increases in the value of θ are associated with higher contributions, an improved funded ratio, increased short-run taxes and long-run benefits via lower taxes and tax volatility. Even paying in excess of the ARC is not sufficient to maintain a fully funded pension in the long run due to the demographic change and discount rate assumptions that states currently use.

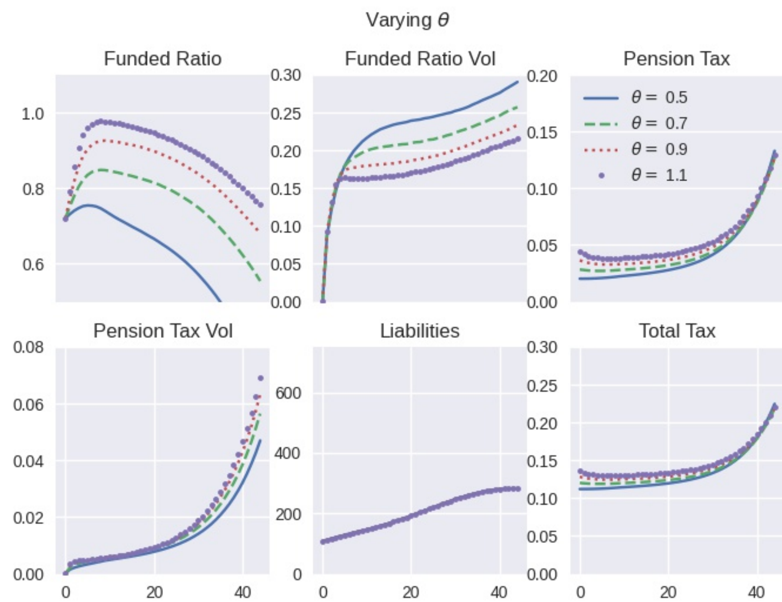

Figure 24: Comparative Static Exercise for Fraction of ARC Paid θ_s