The Sustainability of State and Local Government Pensions: A Public Finance Approach

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Abstract

In this paper, we explore the fiscal sustainability of U.S. state and local government pensions plans. In contrast to much of the recent work on state and local pensions, which has proceeded from the vantage point of financial economics and focused on valuing pension liabilities, we adopt a methodological perspective relatively more rooted in the public finance tradition and assess the sustainability of these pensions on a pay-as-you-go basis and from the standpoint of public debt sustainability. In particular, we examine if under current benefit and funding policies state and local pension plans will ever become insolvent, and, if so, when. We also examine the fiscal costs of stabilizing pensions under a number of different metrics of stability, and examine the costs associated with delaying such stabilization into the future. We explore these questions by reverse engineering the future benefit cash flows of the pension plans using information contained in annual pension actuarial reports and government financial statements and by making long-run macroeconomic and demographic projections. Our results suggest that, under low or moderate asset return assumptions and in aggregate for the U.S. as a whole, pension debt can be stabilized as a share of the economy with relatively moderate fiscal adjustments. Notably, there appear to be only modest returns to starting this stabilization process now versus a decade in the future. Of course, there is significant heterogeneity with some plans requiring large increases to stabilize their pension debt.

I. Introduction

State and local government pension plans are immensely important economic institutions in the United States. They hold nearly $4 trillion in assets; their annual benefit payments to retirees are equal to a bit more than 1½ percent of national GDP; over 10 million beneficiaries rely on these payments to sustain themselves in retirement. In recent years, attention has focused on the plans' large unfunded liabilities; one academic recently estimated that obligations of public pension funds exceed their assets by nearly $4 trillion (Rauh 2017).

The magnitude of these unfunded liabilities has generated widespread concern; indeed, public pensions are often viewed as being in a state of crisis, with the threat of default looming (Figure 1).[1] But it has been understood at least since Samuelson (1958) that the existence of unfunded liabilities does not necessarily imply that a plan is unsustainable, in the sense that it will require outside funding to avoid default. Fully *unfunded*, pay-as-you-go (PAYGO) pension systems can be fiscally sustainable. Moreover, unfunded pension liabilities are a form of (implicit) debt and in today's low-interest rate environment, public debt may have no fiscal cost – i.e. rolling over public debt indefinitely may require no adjustments to taxes or expenditures (e.g. Blanchard 2019).

We ask if, under current policies and funding levels, state and local pension plans are fiscally sustainable over the medium and longer run and if not, what changes are needed? To answer this question, we calculate the annual cash flows of state and local pensions. We find that pension benefit payments in the US, as a share of the economy, are currently roughly at their peak level and will remain there for the next two decades. Thereafter, the reforms instituted by many plans will gradually cause benefit cash flows to decline significantly. Thus, state and local governments may want to smooth through the period of peak benefit payments by drawing down assets or issuing marketable debt.

Using a variety of sustainability measures, we find that, under low or moderate asset return assumptions and in aggregate for the U.S. as a whole, pension debt can be stabilized with

[1] Commentary from academics include the claim that "the threat of default looms" for public pensions (Shoag 2017), the statement that these pensions have failed to "provide economic security in old age in a financially sustainable way" (Novy-Marx and Rauh 2014a), the assessment that in many cases pension payments have proved "unaffordable" (Biggs 2014), and the assertion that public pension systems are in a "dire state" (Ergungor 2017). Members of Congress have expressed concern that state and local pensions are "unsustainable" and that requests for bailouts from the federal government are "inevitable" (JECR 2012); others have called for interventions by the federal government to avoid bailouts – e.g. legislation to make it easier for pension plans to reduce benefits (Bachrach 2016). A major financial institution states that "there are no solutions for some plans given how underfunded they are" (J.P. Morgan 2018). Finally, in the years since the Great Recession, rating agencies have placed increased emphasis on unfunded pension obligations when assessing a government's creditworthiness (e.g. Moody's 2013).

relatively moderate fiscal adjustments. Notably, there appear to be only modest returns to starting this stabilization process now versus a decade in the future: Neither the level at which debt stabilizes as a share of the economy nor the contribution change needed to achieve stabilization increase much when the start of the stabilization process is pushed ten years out. Of course, there is significant heterogeneity across plans, with some plans requiring large contribution increases to achieve stability. Overall, our results suggest there is no imminent "crisis" for most pension plans.

Our focus on pension sustainability, as opposed to the more typical focus on a full prefunding benchmark, is useful and appropriate. First, it provides a clear answer to the pressing question of whether public pensions are likely to spark a fiscal crisis. Second, it is consistent with history; in aggregate, these plans have always operated far short of full prefunding. Third, getting to full prefunding is not necessarily welfare enhancing, as we discuss below.

Our findings have significant policy relevance. State and local governments have been ramping up pension plan contributions substantially in the years since the financial crisis, as can be seen in Figure 2. These increased contributions come at a significant opportunity cost. Despite a long economic expansion, provision of the core public goods provided by these governments remains depressed: real spending on infrastructure stands nearly 30 percent below its previous peak and state and local government employment per capita remains well below its previous peak. Notably, much of this relative decline in state and local government employment has occurred in the K-12 and higher education sectors. Thus, while pension contributions have been rising at a rapid clip, core investment spending in education and infrastructure has been lagging.

Our results also have implications for the risk profile of pension plan assets. Over the last several decades, plans have greatly increased the riskiness of their portfolios (e.g. Lu, Pritsker, Zlate, Anadu, and Bohn 2019 and PEW 2018) . The widespread emphasis on the desirability of full funding has likely contributed to the decision to accept more risk. While a riskier asset profile certainly increases the odds of obtaining full pre-funding over a given time horizon, it also increases the odds assets will be exhausted and a fiscal crisis will ensue. Our results suggest that this implicit gamble may not be advisable for many plans. In particular, for plans which are fiscally sustainable at no additional fiscal cost under conservative asset return assumptions, policy makers may not wish to accept the greater odds of a fiscal crisis associated with a risky asset position. Finally, our results have important implications for intergenerational equity. If existing unfunded liabilities are fiscally sustainable, then concern for intergenerational equity may well dictate that they be paid off only very slowly, if at all, so as not to overly burden a single generation.

The remainder of the paper is structured as follows: Section II provides background information, including a discussion of state and local pensions, paygo pension sustainability, public debt sustainability, and past research on state and local pension sustainability. Section III presents the methodology for the demographic and economic projections, section IV presents the results, and section V concludes.

II. Background

II.A Pension Prefunding and Implicit Pension Debt Sustainability

In order to value implicit pension debt, a rate must be chosen with which to discount the future benefit payments. State and local governments have typically chosen to use a discount rate equal to the assumed rate of return on risky plan assets. However, standard financial principles of valuation suggest that a stream of future payments should be discounted at a rate which reflects the probability that the payments will be honored (i.e. at a rate reflecting the riskiness of future stream of payment). Thus, given the relatively strong legal protections surrounding these payments, it is appropriate to use a discount rate lower than that implied by the expected return on the risky assets held by pension plans.[2] With lower discount rates, pension debt is typically much larger than stated in annual government accounting statements and most plans are far from being fully pre-funded – i.e. assets are well below the present value of future benefit payments(Novy-Marx and Rauh 2011).

Panel A of Figure 3 displays the aggregate funding ratio—the ratio of pension plan assets to the present discounted value of future pension obligations—for a nationally representative sample of pension plans using the pension plans' elevated discount rates. Over roughly the last 30 years, plans have not been fully pre-funded other than a brief period during the height of the dot-com stock market bubble; on average they have been 83% pre-funded. Panel B displays similar calculations using a more conservative AAA corporate bond interest rate, which more properly reflects the riskiness of the promised pension benefits. Over roughly the last 15 years, state and local pension plans have never exceeded 67% pre-funding and averaged 55% pre-funding. Looking back further, as recently as 1978: 1 in 6 pension plans did not prefund to any degree, only 20 to 30 percent of plans were making sufficient contributions to prevent their unfunded liabilities from growing, and a quarter of local plans did not employ actuarial valuations and therefore could not even assess their funding level (United States: Congress 1978).Thus, in aggregate, these plans have long operated well short of full prefunding.

It is often assumed that this failure to fully pre-fund the obligations is inappropriate or undesirable. For example, with regard to past academic work, Boyd and Yin (2016) explicitly state that full pre-funding is "the proper goal" for plans; in many other cases the position is taken more implicitly – e.g. focusing analysis on the fiscal costs of transitioning to full funding (e.g. Novy-Marx and Rauh 2014b). With regard to policy makers, the nation's largest state and local pension plan explicitly advocates for full funding, stating that the "ideal level" of pre-funding is

[2] The precise discount rate that should be used remains subject to debate, with some arguing for a risk-free rate (e.g. Novy-Marx and Rauh 2009 and Brown and Wilcox 2009) and others arguing for a somewhat higher rate, such as that implied by state general obligation debt (e.g CBO 2011) or the AAA corporate bond yield (Lenze 2013).

100 percent (CALPERS 2014). Along similar lines, the Blue Ribbon Panel commissioned by the Society of Actuaries "wholeheartedly believes that .... plans should be pre-funded" (SOA 2014). Finally, ratings agencies typically view "underfunding of pension … benefits as [a] key credit issue" (S&P 2018).

Yet neither in terms of *ex ante* voter welfare or on-going fiscal sustainability is the case for the full pre-funding of public pensions clear (Brown, Clark, and Rauh 2011). In terms of fiscal sustainability, a fully unfunded paygo pension systems can be fiscally sustainable—i.e. require no outside funding. In particular, an unfunded paygo system can honor obligations without recourse to outside funding as long as the internal rate of return paid to retirees does not exceed the growth rate of the wage base, equal to population growth plus productivity growth (Samuleson 1958). Thus, these programs are only unsustainable if their costs rise at a faster pace than the underlying stream of revenue with which they are funded; such an event is typically caused by (1) demographic changes that increase the growth in outlays and/or lower the growth of revenues and (2) benefits rising faster than the underlying source of revenue because of increasing benefits promised over time. In the absence of such shocks, mature, hybrid systems—such as state and local pension plans—can remain sustainable even in the face of adverse shocks, as accumulated assets provide a buffer.[3]

Moreover, governments typically hold debt and unfunded pension liabilities are simply a form of (implicit) debt; state and local governments are infinitely lived and have significant ability to shoulder risk – this is particularly true for state governments. Moreover, public debt can be sustainable in the sense that it may have no fiscal costs – i.e. rolling over the debt indefinitely may require no adjustments to taxes or expenditures. In particular, if the interest rate (r) paid on debt equals economic growth (g), then the debt as a share of the economy will be stable over time assuming the government runs a balanced primary deficit (the deficit excluding interest costs on debt); if $r < g$, then the debt will decline as a share of the economy with a balanced primary deficit. (See Blanchard 2019; Elmendorf and Sheiner 2017; Furman and Summers 2019.)

In principle, the implicit debt held by hybrid pension plans may well be sustainable at no fiscal cost. A simple derivation, using pension terminology, illustrates this point. Define z_t as implicit pension debt as a share of the economy at time t:

$$z = \frac{ID_t}{Y_t} = \frac{AAL_t - Assets_t}{Y_t} \quad (1)$$

[3] Viewed in this light, what is typically referred to as the "unfunded liability" can with equal validity be viewed as the "transition cost" of moving from a hybrid system to a fully prefunded system (Geanakoplos and Zeldes 2009). The desirability of such a transition is an open question.

where ID_t is implicit pension debt, Y_t is GDP, AAL_t is the actuarial accrued liability – the flow of future promised benefit payments earned to date discounted to a present value at interest rate i – and $Assets_t$ are the stock of assets held by the pension plan.

$$\frac{\partial z}{\partial t} = \frac{\frac{\partial AAL_t}{\partial t} - \frac{\partial Assets_t}{\partial t}}{Y_t} - zg \qquad (2)$$

where g denotes GDP growth, $g = \frac{\frac{\partial Y_t}{\partial t}}{Y_t}$. The change in liabilities and assets with respect to time is given as:

$$\frac{\partial AAL_t}{\partial t} = rAAL_t + NC_t - B_t \qquad (3)$$

$$\frac{\partial Assets_t}{\partial t} = rAssets_t + C_t - B_t \qquad (4)$$

where NC_t is the normal cost – the present value of additional pension benefits earned at time t, C_t is the funding contribution made to pension plan, and B_t is the value of pension benefits paid out to beneficiaries.

Assume that pension debt holds steady as a share of GDP by setting $\frac{\partial z}{\partial t} = 0$ in equation (2) and then inserting equations (3) and (4):

$$\frac{rAAL_t + NC_t - \ rAssets_t + C_t}{Y_t} - zg = 0 \qquad (5)$$

Rearranging yields

$$c_t = nc_t + (r - g)z \qquad (6)$$

where c_t is the pension contribution as a share of the GDP and nc_t is the normal cost as a share of GDP.

If the rate of interest and GDP growth are equal, r = g, and the annual contribution to the pension fund equals the normal cost—the pension equivalent of a balanced primary budget—then the existing stock of implicit pension debt can be maintained as a share of GDP at no fiscal cost.

Thus, the presence of an unfunded pension liability in and of itself, even if large in magnitude, does not indicate the liability is unsustainable.[4]

Of course, state and local pension plans do not necessarily meet the above criteria; some plans are clearly on a fiscally unsustainable course and the resulting debt is likely to exert a significant fiscal cost. For instance, a locality such as a city can experience sharp population loss, which would drive down the local tax base (i.e. reduce the growth rate g). Existing pension debt could well rise significantly as a share of the tax base and become unstainable. Overall, it would be very useful to have a stronger sense of which plans are sustainable and which plans are not, as well as a better sense of the magnitude of the fiscal stress likely to arise from placing plans on a sustainable trajectory. This paper aims to provide such information.

II.B Optimal Funding and Intergenerational Equity

In sharp contrast to the emphasis on full funding in most policy discussions of pensions, the theoretical literature on optimal pension funding is decidedly mixed in its conclusions. For example, tax smoothing considerations may dictate a wide range of optimal funding levels, including levels substantially below full funding, depending on economic conditions (D'Arcy, Dulebohn, and Oh 1999). If most voters are borrowers and government borrowing costs are lower than voters' borrowing costs, then no pre-funding is optimal in many instances and can be viewed as the logical "benchmark" (Bohn 2011).[5] In contrast, other papers focus on the costs of not prefunding: Asymmetric information between government employees and other voters over the cost of pensions may allow government workers to accrue rents in the absence of pre-funding (Glaeser and Ponzetto 2014); unfunded pensions may lower the capital stock (Feldstein 1974).

Finally, our focus on pension debt sustainability contrasts with the typical assumption that *extant* unfunded liabilities should be funded as quickly as possible – e.g. pension plans typically assume that unfunded liabilities should be amortized over a 20 to 30 year period. Yet, this period is arbitrary. Moreover, even if one accepts a primary argument for pre-funding—that intergenerational equity demands it (SOA 2014)—this principle provides little guidance on how to address already accrued liabilities. A desire for intergenerational equity could well lead to the conclusion that unfunded liabilities should be addressed over an extremely long period so as not

[4] Nevertheless, it is often assumed that unfunded pension liabilities will entail fiscal costs for the sponsoring government. For example, "when state pension plans are underfunded, someone eventually has to pay for the shortfall" (Johnson, Steuerle, and Quakenbush 2012); "one way or another [the pension underfunding] must be made up by some combination of investing luck, higher taxes, benefit cuts, high inflation that erodes benefits, layoffs, or other compensation sacrifices by employees to cover the deficit" (Bulow 2017). Statements such as these, though, need not be true; carrying debt does not always entail fiscal costs.

[5] Bohn (2011) observes that most US taxpayers are net borrowers and argues that if borrowing entails intermediation costs – if there is a wedge between financial asset returns and the cost of borrowing – then zero funding is optimal for taxpayers who hold debt. Instead of paying taxes to pre-fund pension obligations, borrowers are better off paying down their debt because doing so yields a higher return than the market return earned on assets held in a pension fund.

to overly burden a particular generation of taxpayers. Indeed, the burden placed on the transition generation(s) is often cited as a chief rationale for *not* transitioning a paygo system to a funded system (e.g. Auerbach and Lee 2011).

II.C Related Literature

This paper is related to a number of recent efforts to examine the fiscal health of public pension plans on an ongoing, forward looking basis – an area that represents a gap in the large literature on public pensions (Novy-Marx and Rauh 2014b). These papers examine the on-going flow of future pension obligations, account for the entry of new workers, and explore different paths for asset returns. Novy-Marx and Rauh (2014b) estimate the increase in contributions that would be required for plans to achieve full pre-funding under risk free discount rates over a thirty year horizon. Although the methodology employed in their paper is broadly similar to that used in portions of this paper, the research questions asked differ markedly. Based on the logic articulated above, we examine the stress associated with maintaining a plan's current pension debt or simply continuing current policies. The different questions yield different answers. Novy-Marx and Rauh (2014b) conclude that the cost of transitioning to full pre-funding over thirty years is extremely high in most cases and imply a fiscal burden that would very reasonably be called a crisis. In contrast, our analysis concludes that some plans are currently sustainable over the long run and many others can be rendered sustainable at moderate fiscal cost.

Boyd and Yin (2016b, 2017) and Shoag (2017) allow for stochastic asset returns. They examine the effect of different funding policies, all of which aim to transition to full pre-funding, on the future fiscal position of a single, representative pension plan. Both conclude that under stochastic investment returns, a wide range of future funding levels are possible. Munnell, Aubry, and Hurwitz (2013) also simulate the effect of stochastic investment returns on future funding status and reach similar conclusions. Mennis, Banta, and Draine (2018) provide stress tests for pension systems in 10 states under various asset return assumptions, including stochastic asset returns; their work is related to our calculations for asset exhaustion dates. Similarly, Munnell, Aubry, Hurwitz and Quinby (2011) examine asset exhaustion dates under different asset return assumptions for a large set of pension plans. Boyd and Yin (2016a) consider the influence of demographic characteristics on the funding levels of five pension plans; this work is related to our examination of the effect of population aging on pension finances. Finally, although it does not examine pensions on an ongoing, forward looking basis, Rauh (2017) calculates the contribution needed in the current fiscal year to prevent the unfunded pension liability from rising in the next fiscal year. This exercise has some relation to our calculations of the increase in contributions that would stabilize implicit pension debt at it current level.

III. Data and Sample Selection

III.A Data

We obtain data from multiple sources. A principle source of data on state and local pension plans is the Public Plans Database (henceforth PPD) maintained by the Center for Retirement Research at Boston College (PPD 2017) . The PPD contains plan-level data from 2001 through 2017 for 180 public pension plans; roughly two-thirds of these plans are state government administered plans with the remainder administered by localities. These plans account for 95 percent of state and local pension plan membership and assets in the U.S.

The second major sources of data are the Actuarial Valuations (AVs) and Comprehensive Annual Financial Reports (CAFRs) for the individual state and local plans in our sample for fiscal year 2017. These documents provide the necessary information required to construct reasonable projections of the plans liabilities and cashflows. Specifically, for each state we collect the following matrices/distributions: (1) the age and service distribution of currently employed members (actives), (2) average salaries by age and service for the currently employed members, (3) the age distribution of current beneficiaries, (4) the distribution of average benefits for current beneficiaries by age, (5) mortality assumptions by status (active employee or beneficiary), (6) wage growth assumptions by age and service[6], (7) Termination rates by age and service[7], (8) retirement rates by age and service and tier. The AVs/CAFRs provide further critical information relating to plan provisions and actuarial assumptions not available in the PPD: the plan benefit factors[8], normal retirement age, early retirement age and service requirement, vesting requirements, salary averaging method[9], the penalty factor for early retirement (percent reduction per year early), plan marriage and spousal benefit assumptions, gender ratio of the active population and cost-of-living adjustment assumptions (COLAS). We collect this set of information for each plan “tier”, where each tier has different parameters for employees, typically depending on date of hire. For instance, tiers within a plan might offer different benefit factors and have different normal retirement dates. (Introducing a new tier is a principal mechanism through which plans have enacted reforms in recent years.) See Appendix C for a summary of and examples of these matrices, distributions, and assumptions in the standardized form in which we collect them.

[6] This is wage growth specifically with regards to age/experience and excludes the component attributable to the general level of inflation and productivity growth.
[7] Includes all non-mortality and disability related causes of employment termination.
[8] Annual pension benefits are typically equal to the years of service * final average salary * benefit factor. Thus, the benefit factor is the percent of final salary to which a pension beneficiary is entitled for each year of service.
[9] The number of years salaries are averaged over when determining the retirement benefits; typically the highest three or five.

Two final sources of data pertain to mortality assumptions and demographic. Mortality assumptions are from the Society of Actuaries (SOA).[10] State demographic assumptions are obtained from the Weldon Cooper Center for Public Service (WCCPS) at the University of Virginia. National labor force participation rates are obtained from Congressional Budget Office's (CBO) long-term budget projection (CBO 2017).

III.B Standardization and imputation

The plan AVs and CAFRs while generally similar, present information in a non-standardized format. For example, while most plans will provide assumptions and member statistics along the age and service dimension in 5x5 age/service bins this is not always the case. Furthermore, some plans may provide assumptions or member information only along one dimension (age or service) where our standardized input matrices require it along both. To overcome this, we developed a set of standardized procedures to take the data we extracted from the AVs/CAFRs and put it into the format we required. A simple example concerns cases where wage growth information was only provided along the service dimension. In such instances, we assumed it did not vary by age and vice/versa. See Appendix C for additional information.

III.C Sample selection

We estimate the future annual benefit cash flows for a representative set of 40 state and local government pension plans. Our sample includes the largest 20 public pension plans in terms of liabilities in the PPD database. Our remaining 20 plans are chosen such that our sample matches the national PPD sample in terms of the first and second moments of five plan characteristics measured as of the 2017 fiscal year: the funding ratio (ratio of assets to accrued liabilities calculated using the plan's chosen discount rate), ratio of the unfunded liabilities to current payroll, ratio of current employer pension contribution to payroll, ratio of active plan participants to current beneficiaries, and predicted population growth. The first two characteristics capture how well funded the plan is, the third captures the current budgetary burden of the pension plan, and the final two capture demographic aspects of the plan.

As displayed on Table 1, our sample of plans matches the national PPD sample of plans remarkably well, both in terms of means and standard deviation; this holds for both unweighted and weighted samples.[11] Our targeting of the second moment of the plan characteristics yields a sample that includes plans with a relatively strong fiscal position, as well as those with a

[10] Specifically, we use the SOA's RP-2014 Mortality Tables. We also use the accompanying mortality improvement assumptions (Scale MP-2016) to reflect improving mortality rates over our projection.

[11] Our sample is selected as follows. We randomly select 20 plans from the PPD and add these to the largest 20 plans from the PPD in terms stated liabilities to obtain a sample of 40 plans. We then calculate the sum of squared deviations between the sample and the PPD universe for the 10 targeted moments—i.e. the mean and standard deviation of the five plan characteristics. We iterate 5000 times and take the sample with the lowest sum of squared deviations. For this procedure, the five plan characteristics are first transformed to z-scores with mean equal to 0 and a standard deviation of 1. Thus, the five plan characteristics can be viewed as having equal weight in terms of the sample selection process.

relatively weak fiscal position. For instance, our sample includes the Oklahoma Police Pension & Retirement System and the New York State Teacher's Retirement System, both of which are essentially fully pre-funded (using the plans chosen actuarial assumptions, including discount rate). It also includes the Illinois State Retirement Systems of Illinois and the New Jersey Teachers' Pension and Annuity Fund, which have a ratio of assets to liabilities of roughly 35% and 40%, respectively. Our sample also includes many typical plans such as the Teachers Retirement System of Georgia and the San Diego County Employees Retirement Association, both of which have funding ratios around 75 percent. Appendix Table B1 provides a complete list of plans in our sample. Finally, as shown in Figure 4, our sample also matches the national PPD dynamically in terms of mean plan characteristics.

Our use of a sample of plans, as opposed to the universe of plans, reflects the large number of state and local pension plans in the U.S.—6,284 according to census data—and the extremely labor-intensive nature of reverse engineering the cash flows. Relative to Novy-Marx and Rauh (2011) we conduct a much more detailed, plan-specific reverse engineering of the cash flows; in particular, we use plan-specific distributions, actuarial assumptions, and benefit information (e.g. normal retirement age). Our modeling of plan tiers, which allows us to assess the effects of recent pension reforms, is a further distinguishing factor. Moreover, we have invested considerable effort into accurately modeling each of our 40 plans on a case-by-case basis; e.g. in a number of cases we have consulted with the plan administrators and/or the actuarial firm responsible for the annual actuarial reports in order to resolve uncertainty. Novy-Marx and Rauh (2011), however, have a significantly larger sample of 116 plans.[12] The different approaches reflect the different aims of the respective papers: ours to get the future benefit streams as correct as possible, in particular their time-varying trajectory, theirs to get the overall liability of pension obligations for the entire state government sector.

IV. Methodology

Our methodology for estimating pension fiscal sustainability can be divided into three primary stages:

(1) <u>Reverse engineer future benefit cash flows for current workers and retirees</u>: In the first stage we collect the data, inputs and actuarial assumptions discussed in section III for each plan and use them to calculate the future annual benefit cash flows for current workers and retirees that replicate the stated liabilities in the relevant actuarial reports.

(2) <u>Estimate cash flows for all future workers and retirees</u>: Having satisfied ourselves that we are able to replicate the plan liabilities, new hires are generated based on demographic assumptions.

[12] Subsequent work by these authors have even larger sample size; e.g. Novy-Marx and Rauh (2014b) has a sample of 193 plans.

We then generate total future benefit cash flows for each plan using our own assumptions about relevant macroeconomic variables.

(3) Estimate sustainability: Finally, we pair the cash flow projections with information on plan assets and assumptions on asset returns to conduct our fiscal stability exercises.

IV.A Estimating Cash Flows for Current Workers and Retirees

We construct the future cash flows required under two actuarial liability concepts – the present value of future benefits (PVB) and the actuarial accrued liability (AAL). These concepts only account for liabilities associated with current workers and current retirees; they do not capture liabilities associated with employees hired in the future (after 2017).

The present value of benefits (PVB) is a liability measure which captures both obligations already accrued for retirees and current employees, as well as obligations associated with the future service of current employees; it is equal to the present discounted value of these future benefit payments. To construct these cash flows for current retirees, we simply use the mortality tables to age the retiree population each year and then use the information on current retiree pension benefits to calculate annual benefit payments. For current workers, we age the workforce each year (incrementing years of service as well as age) and use the probabilities of retirement, disability, death, and quits/termination by age and years of service to create a matrix of newly-retired workers by year. We then use the information on pension eligibility and benefits to calculate the pension obligations for future retirees by year.

Although the procedure for producing the cash flows presented here is conceptually quite straightforward, the actual implementation is substantially more complex. Our specific procedures, which generally follow Winkelvoss (1993), are presented in significant detail in Appendix A.

The Actuarially Accrued Liability (AAL) is a narrower liability concept as it only incorporates liabilities accrued *to date* by current workers and retirees (i.e. it does not account for the future accruals of current workers). Although various methods are available for calculating the AAL, the most common by far is the entry age normal (EAN); it envisions employers investing a fixed fraction of an employee's compensation each year so that their pension benefits will be fully funded by the time of retirement. The AAL under this methodology is simply the value of such an account at any given time. It depends on the rate of salary growth and the discount rate, as well as on the likelihood that workers stay employed long enough to receive a benefit. Let p be salary growth and r be the discount rate, and define $\phi = \frac{(1+p)}{(1+r)}$. Also define $S_{a-y,t}$ as the probability of remaining employed from entry age (a-y) to service year t. Then, the $EAN_{a,y,T}$ measure of the AAL is:

$$EAN_{a,y,T} = (\frac{\sum_{i=1}^{y} ø^i S_{a-y,i}}{\sum_{i=1}^{y+T} ø^i S_{a-y,i}}) PVB_{a,y,T} \tag{7}$$

for an employee of age a with y years of service who will retiree T years in the future.

In order to ensure our estimated liabilities match the stated liabilities in the AV reports and our projected undiscounted cashflows are as accurate as possible, we calibrate the cash flows. The calibration factors $v_{c,1}$ and $v_{c,2}$ are defined such that following holds:

$$AAL^{ben,AV} = \sum_{t=0}^{\infty} B_t^{ben} \left(v_{c,1} v\right)^t \tag{8}$$

$$AAL^{act,AV} = v_{c,2} \sum_{t=0}^{\infty} B_t^{act} (v)^t \tag{9}$$

Where v is the plans discount factor $\left[\frac{1}{1+\delta}\right]$, B_t^{ben} is the pension cash flow for current retirees (ben) at time t, act denotes active employees as of 2017, AV denotes a value from a 2017 actuarial valuation. $v_{c,1}$ is a geometric calibration which ensures that our estimated cash flow for retirees reproduces the AAL as stated in the AV report when we discount it at the plan's stated discount rate. The choice of a geometric calibration for current retirees reflects that benefits at time t=0 are known with certainty and that errors are likely to reflect issues with mortality assumptions and COLAs, both of which will accumulate over time; this calibration is similar to that used in (Novy-Marx and Rauh 2011) and (Lutz and Sheiner 2014). Our geometrically calibrated benefit stream for retirees equals $B_t^{ben} * \left(v_{c,1}\right)^t$.

We employ a proportional calibration for current employees. We generally found we were underestimating prospective benefit levels for current employees due to idiosyncratic factors, such as not accounting for unclaimed sick leave, that would boost benefits by a roughly constant percent throughout retirement. Accordingly, we assume a proportional change to their benefit streams. Our calibrated benefit stream for actives equals $B_t^{act} * v_{c,2}$ .We also apply the $v_{c,2}$ calibration factor to new hire cash flow projections (see below) as well.[13] Finally, due to the fact our uncalibrated estimates were on average quite accurate, the calibration process does not have a large effect on our analysis (see appendix B, table 3).

[13] We calibrate the cash flows for inactive employees – former employees as of 2017 not yet receiving benefits – using a separate, proportional calibration.

IV.B Projection of Total Cash Flows

In order to study the fiscal stability of each plan we need to estimate new hires (nh) in each future period t. New hires at time t are set equal the previous year's headcount multiplied by the projected growth rate in the government's workforce (n) and the proportion of withdrawals/retirements from the workforce (q) from the previous year.

$$nh_t = ee_{t-1}(n_t + q_{t-1}) \tag{10}$$

Projected workforce growth (n) is assumed to equal the growth in the working-age population of the state or locality such that the ratio of government workforce to the working-age population remains constant. We further assume that the age (x) distribution and salaries of new hires matches the distribution of current employees with less than 5 years of service. Each group of new hires then produces a new stream of benefits starting at each future year (t), with the value of those future benefits calculated in exactly the same way as they were for the current active workers, but adjusting for changes to plan provisions (reforms) instituted for new hires.

To project the growth of the working-age population in each state, we use a variant of the methodology used by the Demographic Group at the Weldon Cooper Center for Public Service (see appendix D for more information). This methodology addresses trends in fertility, and in and out migration by state. Our implementation assumes that state population growth eventually converges to the national average. Finally, to calculate state labor force growth rates, we project the working age population in each state by age group and multiply that by the projected labor force participation rates by age in the CBO's longer-term budget projection.[14] See Appendix D for details.

Finally, we alter the cashflow projections in our plans by replacing the varying actuarial assumptions with our own assumptions for cpi inflation (2.4 percent) and productivity (1 percent). To get our final cash flow streams for a given plan, we simply add the annual flows for retirees, inactives, actives and new hires.

IV.C Debt dynamics

Our fiscal sustainability exercises our largely focused on the following two identities concerning the evolution of plan debt (D) and assets (A):

$$D_{t+1} = (1 + \delta)D_t - B_t + NC_tP_t \tag{7}$$

$$A_{t+1} = (1 + r)A_t - B_t + c_tP_t \tag{8}$$

[14] For the county or municipal level plans we adjust the state projection by the ratio of the growth rate of the local population to the state population over the period 2010-2018. We then phase out this adjustment linearly over time such that by 2050 the locality is growing at the same rate as the state population.

where δ is the discount rate used to value the plans liabilities; B_t is the benefits paid out at time t; NC_t is the normal cost rate which is multiplied by projected payroll P_t to calculate accrued liability in period t; c_t is the contribution rate as a share of payroll. We use these identities in combination with our projections of benefits and payroll to assess the fiscal stability of each plan. In order to do this, it is necessary to specify the contribution rate to the plan as well as the rate of return likely to be received on the plan assets.

Contribution rate: As discussed above, our goal is to understand how the pension system is likely to stress state and local budgets. As such, we begin with an exercise that holds contributions as a share of payroll fixed at today's level – i.e. we perform a "current policy" analysis. If these are insufficient, then governments will have to increase contributions in the future in order to make benefit payments, either by cutting spending elsewhere or raising taxes. We view this need for additional action as a good measure of fiscal stress.[15]

Asset returns: The rates of return assumed by plans are typically the expected value of returns on the plan's portfolio of assets. As such, using these returns provides the expected path of asset income. In practice, asset returns in any given year will likely be higher or lower than the long-term average. An important question is whether to use a risk-adjusted rate of return to calculate asset returns. This is a difficult and contentious question, and one faced by the federal government in its scoring of credit programs like student loans (e.g. Lucas and Phaup 2008 and Marron 2014).[16] Official estimates of the cash flows from federal loans do not risk adjust, but CBO's preferred measure, which they call Fair Value, does. CBO produces asset cash flows using both methods.

There are pros and cons of risk-adjusting cash flows. On the pro side, risk adjustment prevents plans from appearing healthier simply because they invest in riskier assets. That is, to the extent expected cash flows increase simply because the assets have become riskier, the plan would see no benefit when scored using a risk-free rate of return. Furthermore, if the risk-adjustment factor reflects the tradeoff taxpayers (current and future) would make between a risky stream and a certain one, then future taxpayers should be indifferent between the cash flows pension plans would receive on a risky asset and the cash flows they would receive if the fund invested in safe

[15] One potential objection to this approach is that contributions have been rising steadily since the end of the Great Recession, and current levels might "already" be stressing state and local governments.

[16] Note that this issue is related to, but is not equivalent to, the contentious issue of the correct discount rate for pension liabilities. For instance, Novy-Marx and Rauh (2011) argue that, in order to calculate present values, pension liabilities ought to be discounted at a rate that reflect their riskiness. The value of the assets or the expected return on those assets is not the issue in this debate—the value of the assets is simply the value the market places on them. In the exercise here, the liability cash flows are not the issue; instead it is the assumed return on the assets that is the subject of debate.

assets like Treasuries.[17] On the con side, assuming lower-than-expected rates of return means that, on average, projections will be biased. That is, if the expected return on pension assets is 5%, but we assume a return of 2%, then we will, on average, underpredict investment returns and overpredict asset exhaustion.

To address these issues, we present our estimates using a variety of real (inflation-adjusted) long-run rates of return on the pension assets: a real return of 1.5%, a real return of 3.5%, and a real return of 5.5%. The 1.5% rate is roughly equal to the longer-run risk-free rate in recent year. Thus, it represents the rate or return that pension plans can achieve with certainty, based on financial market prices in recent years – i.e. it is the risk-adjusted or risk-neutral rate of return. The riskless rate of return can be calculated as the average of either the 30-year or 20-year zero coupon Treasury yield from mid-2009, the start of the current business cycle, through the end of 2018, equal to 3.5 and 3.6 respectively, minus the Federal Open Market Committee's (FOMC) 2% inflation target.[18] Alternatively, the yield on the zero coupon 20-year Treasury Inflation Projected Securities (TIPS), which can be directly interpreted as a long-term real riskless rate of return, equaled 1.3% over the current business cycle. [19]

The 5.5% return reflects the 1.5% safe rate plus an equity (or risk) premium of 4%.[20] The 5.5% rate can be viewed as the expected return to a portfolio of risky pension plan assets; it is equal to about what the plans are, on average, assuming and about what they have received on their assets, on average, over the past 15 years. The 3.5% rate of return represents a middle ground between these rates. An alternative interpretation of these asset return assumptions is to view

[17] Elmendorf and Sheiner (2017) argue that not all of the difference between rates on Treasuries and rates on other assets reflects risk; instead, they argue that there is something specific about Treasuries that some investors require, and that when demand rises faster than supply, rates on Treasuries will fall without a change in risk or risk preferences. If this is true, then the rate of return on Treasuries might over-adjust for risk, and a somewhat higher rate should be chosen when properly risk adjusting.

[18] The zero coupon yields are calculated using the methodology of Gurkaynak, Sack and Wright (2007) and can be found at: https://www.federalreserve.gov/econresdata/researchdata/feds200628.xls.

[19] Given that long-term interest rates have been trending downward secularly since at least the late 1990s, it could be argued that the yields should be measured more contemporaneously. However, the 30-year and 20-year zero coupon Treasury yield equaled 3.2 and 3.1, respectively, over 2018, and the yield on the zero coupon 20-year TIP equaled 1.3. Thus, using the yields as measured in 2018 produce only a very slightly lower estimate of the real risk-free rate. Moreover, given that the risk free rate is being used for long-run projections, it could be argued that it is appropriate to calculate it based on a relatively longer historical span of yield data. Doing so smooths through transitory factors, such as fluctuations in yield induced by business cycle dynamics; it also effectively assumes yields will display some tendency to return to historical norms. Using such logic, the CBO assumes that the nominal risk-free rate will be on the order of 5% in the longer-run (CBO 2018).

[20] We view the 4% equity premium assumption as relatively conservative. Mehra and Prescott (2003) estimate an equity premium of around 7% for the U.S. in the 20th century; Rachel and Summers (2019) present estimates (constructed by Aswath Damodaran of NYU) suggesting the equity premium equaled around 5% n both the 1960-2018 period and in 2018; Duarte and Rosa (2015) estimate that the equity premium has exceeded 10% in the years following the Great Recession; and Rauh and Novy-Marx (2011, 2014) use a equity premium of 6.5% for analyzing pension outcomes. That said, there are a wide range of estimates; e.g. Fama and French (2002) calculate a relatively low equity premium of around 3.5% in the second half of the 20th century.

them as capturing different future states of the world, equivalent to a very simplistic implementation of a stochastic asset return exercise.

Finally we discount plan liabilities using the 1.5% risk free rate.

V. Results

In this section, we first examine the fiscal outflows (benefit payments) and inflows (employer and employee contributions and asset income) of our set of pension plans, to determine which plans are likely to exhaust their assets and when. We then explore different ways in which governments could stabilize their pension debt as a share of their economies.

V.A. Pension benefit payments

Figure 5 shows how the ratio of beneficiaries to active workers evolves over time for our set of plans. The top black line shows the total, while the dotted colored lines show the composition. In year 2017, beneficiaries are just current retirees, but over time, current retirees (the dotted red line) die, while current workers (blue line) and current inactive members (green line) retire. Meanwhile the workforce is being populated with new workers, and eventually these new hires (purple line) retire as well .

Just as the U.S. population is aging, so too are states. The ratio of retirees to workers in state and local governments is projected to increase about 33% over the next 25 years, and then roughly stabilize. In comparison, projections by the Social Security actuaries show that, for the U.S. as a whole, the ratio of the Social Security beneficiaries to workers is projected to rise about 34% over the next 30 years. We view this similarity as indicating that we have adequately modeled the future flow of state and local government employees.

Figure 6 shows the annual benefit payments as a share of GDP for the plans in our sample in aggregate, which we are calling the “US plan” and view as a reasonably good proxy for the state and local pension system in the U.S. as a whole.

In 2017, pension plan payments were approximately 1½ percent of GDP. Looking forward, our projections as a share of GDP rise about 10% over the next two decades, and then begin declining as a share of GDP, eventually stabilizing at a level about 9% lower than the current one. This pattern is quite surprising given the pattern of aging described above. For social security, for example, benefits relative to GDP are projected to rise about 25% over the next 20 years, and then remain roughly constant thereafter.

What explains these surprising results? If the ratio of retirees to workers is increasing, why isn’t the ratio of benefits to payroll? First, most pension plans do not fully index their retiree benefits for inflation—the COLA is often well below inflation. Many plans have been lowering or eliminating their COLAs in recent years and this lowers the real value of average benefits over time. Second, pension plans have gradually been making changes over time to lower benefits and raise retirement ages for new hires e.g. see (Aubry and Crawford 2017). These adjustments also reduce average pension benefits over time. The reduced growth in average benefits is enough to offset most of the effects of the 30% growth in the ratio of retirees to workers shown above.

Figure 7 presents our baseline estimate for benefits payments as a share of GDP (black line) and several counterfactual exercises which explore the effect of policy changes. The blue line displays the aggregate cash flows assuming that plans turned off their COLAs entirely, which governments generally (but not universally) can do without violating state constitutions. The result of eliminating the COLAs would be a drop in the ratio of benefits to GDP, such that they would eventually settle an additional 9% below where we project them when the current COLAs are maintained, and about 17% below their level in 2017. In contrast, the green line displays the results of setting all COLAs to equal inflation. Benefit flows rise substantially as a share of GDP over the next two decades and eventually settle at a much high level—indeed, the rise is about 25%, the same as the projected rise in Social Security benefits described above. Clearly, COLAs have a significant impact on benefits flows as a share of the economy. Finally, the red line displays the trajectory of benefits to GDP when the reforms for new workers are eliminated and we instead assume that new hires are subject to the same pension rules as current workers. Rather than declining by 9% over time, the ratio of benefits to GDP would stabilize at a level roughly equal to today's.

As we show below, the fact that pension benefits as a share of payroll are, in aggregate, near their highest level expected over the next few decades is an important finding for understanding the sustainability of state and local finances and the ability of plans to smooth through the next few decades. Notably, as displayed in Appendix Figure B1, the flattening out of pension benefit payments as a share of GDP is apparent in the historical data. Nonetheless, additional work will be required to more fully substantiate the result and decompose its causes. Possible explanations, other than the level of the COLAs and new worker reforms, are sluggish state and local government wage growth over the past 15 years, lower average tenure of benefit recipients over time, and a secular transition toward less generous pension plans due to the relative population shift away the Northeast and Midwest (whose governments tend to have relatively generous pension plans).

V.B. Pension asset projections

Figure 8 shows the path of pension assets assuming that contributions remain fixed at today's level, pension benefit payments evolve as described in Figure 6, above, and the plans these rates of return. With the 1.5% real rate of return, current contributions are insufficient to keep the plans solvent. Despite the projected decline in benefits relative to GDP, assets relative to GDP begin declining immediately, and are exhausted in 30 years. Things look a bit better if the rate of return is 3.5%. With this rate of return, assets are declining, but not as quickly. After 50 years, they are still exhausted. If, however, the plans earn 5.5% on their assets, then there is no issue of fiscal sustainability at all. At current contribution rates, assets rise indefinitely and the plan faces no stress at all (indeed, one would argue that current contribution rates are much too high, if one could count on a 5.5% real rate of return.)

Of course, looking at the US pension system as a whole masks a lot of variation across plans. Table 2 presents the exhaustion dates under these different rate of return assumptions for all the plans in our sample, again assuming that the contribution rates remain the same for each plan as they are today.

In this table, the plans are sorted by the date assets would be exhausted under a 1.5% real rate of return. For this scenario, the New Jersey Teachers plan would be in trouble—they would fully exhaust their assets in 13 years. The New Jersey Public Employees' Retirement System would be able to stay afloat for 20 years. With a 3.5% real return, the New Jersey Teachers Plan is still in trouble—their assets would exhaust in 14 years, but, apart from a few plans, most plans wouldn't hit the exhaustion date until far into the future or not at all. With a 5.5% rate of return, only the New Jersey Teacher's Plan is in any near-term trouble. (The New Jersey Teachers plan has a funding ratio of just 42 percent even using the plan's discount rate, so that changes in asset returns don't matter much because their ratio is so low.)

Figure 9 shows what share of liabilities are in plans that exhaust within various time periods. Even with a 1.5% rate of return, only about 4% of liabilities are in plans that are exhausted within 20 years, and 60% of plans never exhaust or exhaust only after 30 years. With a 5.5% discount rate, over 90% of plans are in fine shape, whereas the other plans (apart from New Jersey) do exhaust, but not for many decades.

The message from these exercises is that, for most plans, there is no imminent "crisis" in pension plans, in the sense that the plans are likely to exhaust their assets within the next two decades. But, many plans are not stable and a sizeable share of plans will exhaust their assets within 30 years under the 1.5% return scenario. Adjustments will be necessary. The questions are: how large is that adjustment, and how urgent is it?

V.C Pension Debt Stabilization

There are various ways to think about pension debt stabilization. Pension debt is stable when it holds at a fixed share of GDP: pension debt is unsustainable if it continuously rises as a share of GDP. Another aspect of pension debt stability is asset exhaustion, which may impose constraints if plans are unable to borrow or only borrow at relatively high rates of interest.

We perform three stabilization exercises:

(1) What one-time and permanent changes in the contribution rate would make implicit pension plan debt eventually stabilize as a share of GDP (without specifying what that share is)? This is similar to the exercise in Sheiner (2018) for the federal debt.
(2) What one-time and permanent changes in contribution would be required in order for the implicit debt as a share of GDP to equal today's ratio in 30 years time? This exercise is similar to the one that the Congressional Budget Office does for the federal debt. (CBO, 2019)
(3) What is the time path of annual changes in contributions required to maintain today's implicit debt to GDP ratio?

Stabilization Exercise 1: Stabilize Implicit Debt as a Share of GDP

As discussed above, when a plan has an unfunded liability, it is equivalent to the sponsoring government having debt. In order to address concerns over intergenerational equity, a government may wish to simply maintain that debt in relation to GDP by making debt services payments equal to the interest rate less the growth rate of GDP (r-g). Along similar lines, when a plan fails to pay its normal cost, this is equivalent to running a deficit. When governments are increasing investment, say by increasing education spending, or acting to stimulate the economy during a recession, it may well be optimal to finance such spending, because the returns are in the future, and will be available to pay off the accrued debt (Elmendorf and Sheiner 2017).

These arguments are particularly strong when interest rates are low. Indeed, when interest rates are lower than GDP growth, i.e. r-g is negative, existing debt as a share of GDP will decline over time with a balanced primary budget. But, even when interest rates are just close to the rate of economic growth, building up assets to get to full funding isn't very appealing—the rate of return is low on them, and so not much is gained by acting sooner rather than later.

To show these tradeoffs, we conduct the following thought experiment. Assume that a government's pension plan is stable so long as the unfunded liabilities relative to GDP are constant at some point in the future. This is just like an experiment that says debt is sustainable if the debt-to-GDP ratio stabilizes. We first calculate the one-time but permanent change in the pension contribution a plan would have to make in order to achieve stability, and then assess how that contribution changes depending on whether the government acts now, acts in 10 years, 20 years, or 30 years.

Figure 10 shows what happens to the unfunded liability relative to GDP for the US plan as a whole if asset returns are 3.5%. The black dotted line shows that without changes in contribution rates, implicit debt to GDP rises at an increasing pace over time. The current situation is unsustainable. The other four lines show the trajectory of the debt-to-GDP ratio if the government acts now or later. Even if the government waits 30 years to act, the implicit debt to GDP ratio isn't much higher than it would be if the government acted today. Table 3 presents these estimates for all three asset return scenarios. Table 4 presents the estimates on a plan-by-plan basis.

Of course, as Table 3 shows, the contributions required to stabilize the implicit debt are higher if the government waits. If the contributions are increased now (and forever thereafter), the increases has to be 4.3% of payroll. If the contribution stays at its current level and then increases in 10 years, the increase has to be equal to 5.5% of payroll. Acting sooner rather than later lowers the required increase, but not by much. Even if the plans wait 30 years to act (i.e. go 30 years without any changes in contributions), the required increase is only 6.8% of payroll. Under the risk-neutral asset return assumption there is no meaningful change in the required contribution boost if a government delays adjustment.

To put these changes into context, aggregate pension funding was increased by nearly 9 percentage of payroll between 2009 and 2017. Accordingly, if governments act now, a further upward adjustment equal to about half of the adjustment made over the last decade would be sufficient to stabilize their pension debt under the 3.5% return assumption. Under the risk-neutral assumption, plans could stabilize their debt by making an adjustment equal to less than 1½ times the adjustment of the last decade.

However, plans could run out of assets along the way, which might be a constraint. Figure 11 shows plan assets relative to GDP for each of the asset return paths. They decline in all, but never hit zero in aggregate. (That said, some plans in our sample do exhaust their assets.)

In contrast to our focus on stabilizing implicit pension debt, past work on pension funding has often focused on achieving full pre-funding. The right-hand side of Table 5 presents estimates of the funding increase required to achieve full funding over a 30-year horizon (with pension liabilities discounted at the 1.5% risk-neutral rate). These estimates are broadly similar to those presented in Novy-Marx and Rauh (2014b).[21] For comparison, the left-hand side of the table repeats our debt-stabilizing contribution increases from Table 3.

The increases required to reach full funding are substantially larger than those required to stabilize debt. Under 3.5% asset returns, the funding boost to reach full funding is roughly five times larger than the increase required to stabilize the debt (20.4% versus 4.3%). The funding increases required to reach full funding under the 1.5% and 3.5% asset return assumptions would constitute a fiscal crisis for state and local governments. The corresponding increases needed to stabilize pension debt would certainly induce fiscal strain, but would fall short of what most observers would label a crisis. Table 6 presents the results for each plan. As shown in Figure 6, at a 3.5% rate of return, no plan needs to increase funding by more than 20% of payroll, and most have to do far less. At a 1.5% rate of return, however, about 30% of plans have to increase

[21] One difference is that our projections include the assumption of mortality improvements over time, which hurts plans fiscal conditions, whereas the Novy-Marx results do not.

funding by more than 20% in order to eventually stabilize their debt to GDP ratio. Thus, under this rate of return assumption, many plans do have to make significant changes.

Stabilization Exercise 2: Implicit Debt as a Share of GDP is Equal to Today's Level in 30 Years

Another way to assess sustainability over the medium-term is to ensure that the implicit debt to GDP ratio is no higher in 30 years than it is today. Very long-run projections are inherently uncertain, so choosing a target implicit debt-to-GDP ratio over the medium term may be a more reasonable policy objective. In addition, the exercise above that stabilized the implicit debt to GDP ratio without specifying its level did not account for potential changes in borrowing costs that might arise if the ultimate debt to GDP ratio were higher than it is today, whereas targeting today's level is less likely to raise that concern.

The right-most column of Table 5 reports the permanent contributions required to return the implicit debt-to-GDP ratio to today's level in 30 years for the US as a whole. The experiment compares the required contributions under the various interest rates and under various timings. It should be noted that, in this experiment, we always allow the pension plan 30 years to get back to the original debt level, so that "start in 10 years" means getting back to the 2017debt-to-GDP level by 2057. We view that as a sensible experiment, because it doesn't require the plan to make massive changes in a short period of time, but still requires the plan to eventually return to the target. In contrast, the middle column—Fully Funded in 30 Years—requires the plan to be fully funded in 2048, regardless of when the changes begin.

At a 3.5% rate of return on assets, plans would need to increase contributions by 4.2% of payroll today, 6.3% if they began in 10 years, and 9% if they began in 20 years. There is little difference between the contributions required under this exercise and the stabilize the implicit debt exercise (left most set of columns) if action is taken today; but the difference becomes larger the longer the delay. This difference arises because the 30-year exercise requires any increases in debt that occur after 2017 to be paid down, whereas the stabilize the implicit debt exercise only requires additional interest to be paid.

At an asset return of 1.5%, contributions would have to increase about 14% to ensure that the debt-to-GDP ratio is the same as today's in 30 years, just slightly above the amount required in the stabilize the implicit debt exercise. However, the differences between the costs of delay in the two exercises are much larger under these low asset returns, because the costs to stabilize a higher level of debt are almost zero (because r-g is close to zero), but the costs to actually pay down debt are quite high, since asset returns are so low. Waiting 10 years to take action at the 1.5% asset return if plans wanted to ensure that the debt ratio returned to this year's level in 30 years would require an increased contribution of 18% of payroll; waiting 20 years would boost that required contribution to 23%.

Figure 13 shows the long-run paths for the implicit debt outcomes for this exercise. If plans act now, then the debt hits today's level in 30 years, and then drifts down very slightly over time. If plans delay and allow the debt to increase above today's level, then the larger contributions required mean that, if they are maintained after 30 years (which is what this exercise assumes), the debt will decrease over time, and plans will eventually be more than fully funded. This is also clear from Figure 14, which shows what is happening to the ratio of pension assets to GDP over time under the various assumptions.

Figure 15 shows the distribution of plan's required contributions if they act today to stabilize at today for the 30-year exercise. At a 3.5% rate of return, most plans need to increase contributions by less than 20%. At a 1.5% rate of return, about 35% of plans need to increase contributions by more than 20%. At a 5.5% return, about 90% of plans could lower contributions.

Stabilization Exercise 3: Hold the Implicit Debt as a Share of GDP Constant at Today's Level

As a final exercise, we assess what contributions would be required if the goal is to maintain the ratio of unfunded liabilities to GDP at today's level. We show what this looks like for the US as a whole in Figure 16. As we noted above, benefits relative to GDP for the US as a whole are at their highest level over the next 20 years or so, meaning that not allowing unfunded liabilities to rise would require higher contributions now, and lower contributions later. As expected, the increase in contribution necessary depends on the assumed asset return: with a 3.5% real rate of return, contributions in the near term would have to increase by about 8% of payroll; at a 1.5% real rate of return the increase would be far larger—about 18% of payroll. At a 5.5% real rate of return, contributions could actually fall below current contributions—reflecting the fact that plans are making efforts to increase their funding status, whereas this exercise does not require them to do so. As we showed above, an alternative is to smooth through these gyrations and simply choose a contribution rate that stabilizes the unfunded liability as a share of GDP.

VI. Conclusion

We find that pension benefit payments in the US, as a share of the economy, are currently at their peak level and will remain there for the next two decades. Thereafter, the reforms instituted by many plans will gradually cause benefit cash flows to decline significantly. This is an important finding in terms of the fiscal stability of these plans over the longer term as it indicates that the cash flow pressure of these plans will eventually recede. Our results suggest that, under moderate asset return assumptions and in aggregate for the U.S. as a whole, pension debt can be stabilized with relatively moderate fiscal adjustments. Of course, stabilization costs are higher if asset returns are lower. There is also significant heterogeneity with some plans being far from stable across a range of asset return assumptions. Finally, there appears to be little advantage to beginning the stabilization process now versus a decade in the future; neither the level at which debt stabilizes as a share of the economy nor the contribution increase needed to achieve stabilization increase much when the start of the stabilization process is pushed a bit further into the future.

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Table 1
Estimation Sample of State and Local Pension Plans

	Unweighted		Weighted	
	Estimation Sample	Public Plans Database National Sample	Estimation Sample	Public Plans Database National Sample
Assets/Liabilities	0.71	0.72	0.71	0.71
	(0.16)	(0.16)	(0.17)	(0.17)
Unfunded Liabilities/Payroll	2.38	2.36	2.04	2.00
	(1.69)	(1.81)	(1.64)	(1.62)
Total Pension Contributions/Payroll	0.29	0.30	0.24	0.25
	(0.13)	(0.16)	(0.10)	(0.12)
Active Members/Retired Members	1.31	1.27	1.35	1.35
	(0.37)	(0.41)	(0.35)	(0.35)
Projected Percent Active Member Growth	0.28	0.34	0.41	0.41
	(0.54)	(0.55)	(0.61)	(0.56)
Observations	40	177	40	177

Note: The table displays means; standard deviations in parentheses. In the rightmost two columns, labeled "weighted", the samples are weighted by the denominator of the plan characteristics for the first four characteristics (e.g. assets/liabilities is weighted by liabilities). Projected percent active member growth is weighted by the number of active members.

Table 2
Plan Exhaustion Dates

	Years until exhaustion		
Pension Plan	1.5% real return	3.5% real return	5.5% real return
New Jersey Teachers	13	14	17
New Jersey PERS	20	31	Never
Oregon PERS	21	27	56
Massachusetts SRS	22	29	Never
Florida RS	25	35	Never
Georgia Teachers	25	35	Never
California Teachers	26	33	53
Illinois Teachers	26	41	Never
Kansas City Missouri ERS	27	Never	Never
New Mexico PERA	27	40	Never
Ohio Teachers	27	Never	Never
Baton Rouge City Parish RS	28	49	Never
Michigan Public Schools	28	Never	Never
Arizona State Corrections Officers	31	43	Never
South Carolina RS	32	62	Never
Texas Teachers	32	41	77
NY State & Local ERS	34	Never	Never
Pennsylvania School Employees	34	Never	Never
LA County ERS	35	55	Never
Missouri Teachers	37	53	Never
Rhode Island Municipal	37	Never	Never
Arizona SRS	39	Never	Never
San Francisco City & County	40	69	Never
New York State Teachers	44	Never	Never
Oklahoma Police	46	73	Never
North Dakota Teachers	53	98	Never
South Carolina Police	54	Never	Never
DC Teachers	55	Never	Never
Maine State and Teacher	55	Never	Never
Pennsylvania State ERS	57	Never	Never
University of California	79	Never	Never
Massachusetts Teachers	79	Never	Never
San Diego City ERS	Never	Never	Never
San Diego County	Never	Never	Never
Georgia ERS	Never	Never	Never
Illinois Municipal	Never	Never	Never
Illinois SERS	Never	Never	Never
Indiana Teachers	Never	Never	Never
Louisiana Municipal Police	Never	Never	Never
Louisiana SERS	Never	Never	Never

Note: Table displays asset exhaustion dates for plans in the estimation sample assuming current contributions as a share of payroll are maintained in perpetuity.

Table 3
Change in Contributions to Stabilize Aggregate US Implicit Pension Debt to GDP

	Increase in contribution rate required if changes are made (percent of payroll):			
Real rate of return	Start Today	Start In 10 years	Start In 20 years	Start In 30 years
1.5%	12.70%	12.89%	13.06%	13.20%
3.5%	4.28%	5.46%	6.82%	8.41%
5.5%	-5.20%	-7.55%	-10.97%	-15.87%

Note: Table displays the one-time, permanent percentage point change in contributions as a share of payroll required to stabilize implicit pension debt as a share of GDP for the U.S. in aggregate.

Table 4
Change in Contributions that Stabilizes Ratio of Implicit Pension Debt to GDP, Depending on when Adjustment is Made

		1.5% real rate of return Make changes:			3.5% real rate of return Make changes:			5.5% real rate of return Make changes:		
	Current Contribution	Now	In 10 years	In 30 years	Now	In 10 years	In 30 years	Now	In 10 years	In 30 years
US Aggregate	24%	13%	13%	13%	4%	5%	8%	-5%	-8%	-16%
Missouri Teachers	30%	38%	38%	38%	14%	16%	24%	-5%	-6%	-12%
California Teachers	32%	28%	28%	28%	10%	14%	26%	-5%	-3%	6%
Georgia Teachers	21%	23%	23%	23%	11%	14%	21%	-1%	-1%	-2%
Oregon PERS	10%	15%	15%	15%	11%	14%	21%	2%	3%	6%
Texas Teachers	15%	26%	26%	26%	12%	14%	20%	1%	2%	5%
New Jersey Teachers	18%	10%	10%	10%	9%	12%	17%	7%	10%	23%
LA County ERS	24%	26%	26%	26%	9%	11%	16%	-5%	-8%	-16%
New Mexico PERA	27%	20%	20%	20%	9%	11%	16%	-3%	-4%	-9%
Oklahoma Police	31%	33%	33%	33%	9%	10%	15%	-10%	-14%	-29%
Arizona State Corrections Officers	22%	17%	17%	17%	8%	9%	13%	1%	1%	0%
Massachusetts SRS	27%	10%	10%	10%	7%	9%	13%	0%	-1%	-1%
San Francisco City & County	27%	20%	20%	19%	5%	6%	9%	-9%	-12%	-24%
Baton Rouge City Parish RS	41%	13%	13%	13%	5%	6%	9%	-7%	-10%	-22%
Massachusetts Teachers	33%	19%	19%	19%	7%	6%	3%	-4%	-13%	-47%
Florida RS	13%	6%	6%	6%	5%	6%	8%	-3%	-5%	-11%
DC Teachers	20%	15%	13%	10%	2%	3%	4%	-10%	-14%	-31%
New York State Teachers	13%	11%	11%	11%	3%	3%	3%	-8%	-13%	-32%
South Carolina RS	23%	7%	7%	7%	2%	2%	4%	-4%	-6%	-11%
NY State & Local ERS	17%	9%	9%	9%	2%	2%	2%	-10%	-16%	-38%
Arizona SRS	22%	8%	8%	8%	1%	1%	2%	-5%	-8%	-16%
North Dakota Teachers	26%	10%	10%	10%	0%	1%	2%	-7%	-9%	-17%
Ohio Teachers	26%	3%	3%	3%	0%	0%	0%	-9%	-14%	-31%
Maine State and Teacher	25%	10%	10%	10%	0%	0%	-1%	-11%	-17%	-39%
Pennsylvania State ERS	36%	8%	8%	8%	-1%	-1%	-1%	-10%	-14%	-31%
New Jersey PERS	21%	-4%	-4%	-4%	-2%	-2%	-3%	-3%	-5%	-11%
South Carolina Police	25%	1%	1%	1%	-2%	-3%	-4%	-8%	-11%	-24%
Rhode Island Municipal	21%	1%	1%	1%	-3%	-3%	-3%	-10%	-14%	-27%
Illinois Teachers	51%	-12%	-12%	-12%	-4%	-4%	-6%	-8%	-12%	-26%
Kansas City Missouri ERS	19%	-9%	-9%	-9%	-4%	-5%	-8%	-11%	-17%	-38%
University of California	31%	7%	7%	7%	-5%	-5%	-7%	-16%	-23%	-48%
Illinois Municipal	18%	-1%	-1%	-1%	-5%	-6%	-8%	-13%	-19%	-41%
Pennsylvania School Employees	37%	-9%	-9%	-9%	-5%	-7%	-11%	-12%	-20%	-47%
Michigan Public Schools	34%	-10%	-10%	-10%	-5%	-8%	-12%	-11%	-19%	-45%
San Diego County	44%	6%	6%	6%	-9%	-11%	-17%	-25%	-36%	-76%
Louisiana Municipal Police	49%	-2%	-2%	-2%	-10%	-13%	-19%	-22%	-34%	-73%
Louisiana SERS	45%	-9%	-9%	-9%	-12%	-14%	-20%	-18%	-27%	-57%
Indiana Teachers	28%	-13%	-14%	-14%	-13%	-16%	-23%	-14%	-21%	-45%
Georgia ERS	26%	-17%	-17%	-17%	-15%	-18%	-25%	-17%	-25%	-53%
Illinois SERS	49%	-26%	-26%	-26%	-13%	-25%	-56%	-11%	-37%	-125%
San Diego City ERS	78%	-14%	-14%	-14%	-25%	-30%	-43%	-44%	-64%	-135%

Note: Table displays the percentage point change in contributions as a share of payroll required to stabilize implicit pension debt as a share of GDP for the plans in the estimation sample.

Table 5
Percentage Point Increase in Contribution Rate Required (Percent of Payroll):

	Stabilize Implicit Debt to GDP			Fully Funded in 30 Years			Implicit Debt Gets Back to Today's Level in 30 Years		
Real rate of return	Start Today	Start In 10 years	Start In 20 years	Start Today	Start In 10 years	Start In 20 years	Start Today	Start In 10 years	Start In 20 years
1.5%	12.70%	12.89%	13.06%	35.57%	55.86%	120.32%	13.97%	18.32%	22.81%
3.5%	4.28%	5.46%	6.82%	20.39%	35.73%	85.25%	4.19%	6.25%	9.05%
5.5%	-5.20%	-7.55%	-10.97%	6.19%	12.39%	33.12%	-5.74%	-9.61%	-14.84%

Note: The left panel of the table displays the one-time, permanent percentage point change in contributions as a share of payroll required to stabilize implicit pension debt as a share of GDP for the U.S. in aggregate. The central panel of the table displays the one-time, permanent percentage point change in contributions as a share of payroll required to achieve full pre-funding in 30 years for the U.S. in aggregate. The right panel of the table displays the one-time, permanent percentage point change in contributions as a share of payroll required to return implicit pension debt as a share of GDP to today's level in 30 years for the U.S. in aggregate.

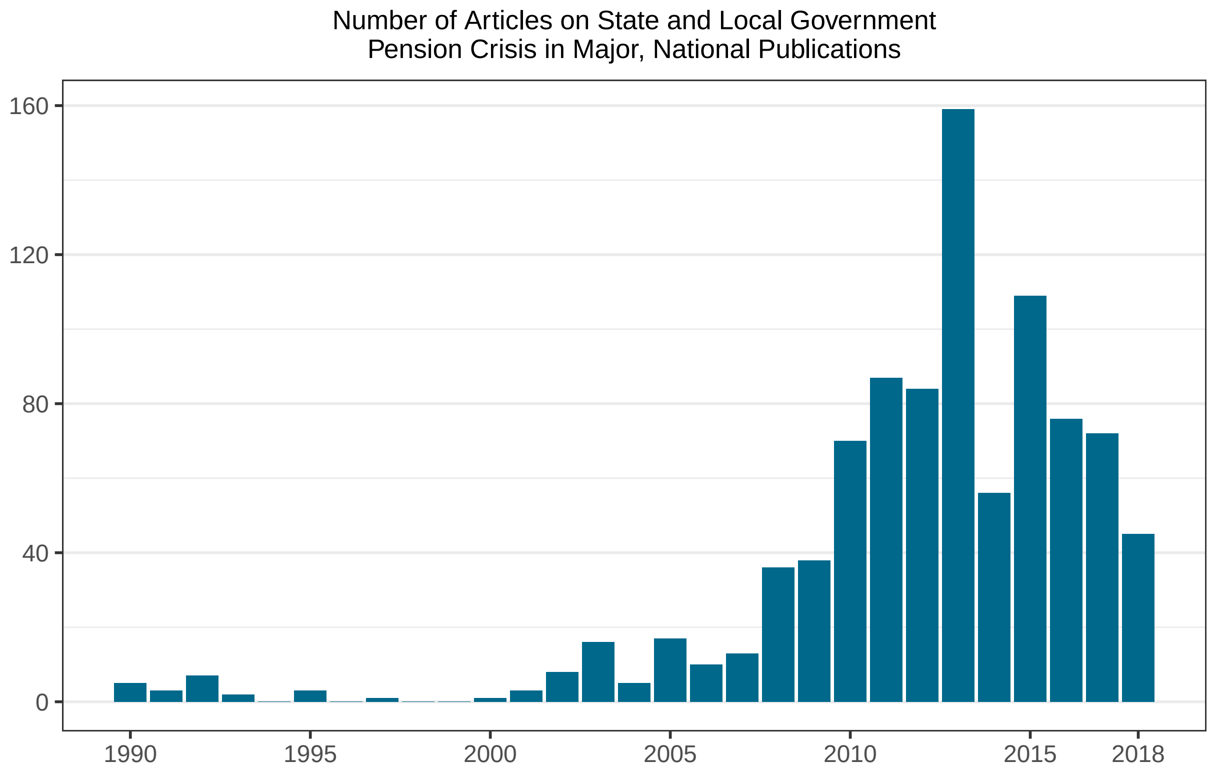
Table 6

Change in Contributions to Obtain Today's Debt-to-GDP Ratio in 30 Years, Depending on when Adjustment is Made

		1.5% real rate of return Make changes:			3.5% real rate of return Make changes:			5.5% real rate of return Make changes:		
	Current Contribution	Now	In 10 years	In 30 years	Now	In 10 years	In 30 years	Now	In 10 years	In 30 years
US Aggregate	24%	14%	18%	27%	4%	6%	12%	-6%	-10%	-23%
California Teachers	32%	27%	39%	64%	12%	21%	48%	-2%	1%	14%
Missouri Teachers	30%	30%	41%	65%	13%	20%	38%	-3%	-5%	-13%
Texas Teachers	15%	21%	28%	43%	12%	17%	30%	3%	4%	8%
Georgia Teachers	21%	24%	31%	46%	11%	17%	32%	-2%	-2%	-3%
New Jersey Teachers	18%	13%	17%	24%	10%	15%	28%	7%	12%	29%
Oregon PERS	10%	19%	25%	37%	9%	15%	31%	-1%	-1%	4%
Oklahoma Police	31%	29%	38%	58%	11%	15%	25%	-7%	-12%	-35%
LA County ERS	24%	22%	29%	46%	8%	12%	24%	-6%	-9%	-22%
Massachusetts SRS	27%	17%	22%	30%	8%	12%	23%	-1%	-2%	-3%
New Mexico PERA	27%	19%	24%	36%	7%	11%	22%	-5%	-7%	-14%
Arizona State Corrections Officers	22%	13%	17%	25%	7%	9%	16%	0%	-1%	-2%
San Francisco City & County	27%	17%	23%	36%	4%	7%	14%	-9%	-14%	-32%
Massachusetts Teachers	33%	21%	25%	30%	9%	7%	-2%	-2%	-14%	-66%
DC Teachers	20%	17%	23%	37%	5%	7%	10%	-6%	-12%	-37%
Florida RS	13%	10%	12%	17%	2%	3%	9%	-8%	-11%	-20%
New York State Teachers	13%	14%	18%	25%	3%	3%	3%	-8%	-16%	-44%
South Carolina RS	23%	8%	10%	15%	2%	3%	6%	-4%	-7%	-15%
Baton Rouge City Parish RS	41%	12%	16%	24%	0%	2%	9%	-12%	-17%	-36%
NY State & Local ERS	17%	14%	18%	25%	2%	2%	3%	-11%	-20%	-53%
Ohio Teachers	26%	12%	13%	15%	1%	1%	0%	-10%	-18%	-44%
North Dakota Teachers	26%	5%	9%	17%	-2%	0%	3%	-8%	-10%	-22%
Arizona SRS	22%	6%	7%	12%	0%	0%	1%	-7%	-11%	-22%
New Jersey PERS	21%	3%	2%	0%	0%	-1%	-3%	-4%	-6%	-15%
Pennsylvania State ERS	36%	8%	11%	18%	-1%	-1%	-2%	-10%	-16%	-41%
Illinois Teachers	51%	12%	8%	0%	2%	-1%	-7%	-7%	-16%	-38%
Maine State and Teacher	25%	9%	13%	21%	-1%	-1%	-2%	-11%	-19%	-52%
Rhode Island Municipal	21%	4%	6%	10%	-3%	-4%	-4%	-11%	-17%	-37%
South Carolina Police	25%	4%	4%	5%	-2%	-4%	-6%	-9%	-14%	-33%
Pennsylvania School Employees	37%	10%	9%	5%	0%	-4%	-14%	-10%	-23%	-64%
University of California	31%	8%	10%	15%	-4%	-6%	-11%	-16%	-26%	-63%
Michigan Public Schools	34%	6%	3%	-4%	-3%	-7%	-18%	-12%	-25%	-64%
Illinois Municipal	18%	1%	1%	1%	-7%	-10%	-15%	-16%	-25%	-58%
Kansas City Missouri ERS	19%	0%	-3%	-10%	-8%	-12%	-19%	-17%	-28%	-61%
Louisiana Municipal Police	49%	3%	2%	0%	-10%	-16%	-31%	-24%	-41%	-100%
San Diego County	44%	2%	2%	5%	-13%	-18%	-30%	-28%	-45%	-103%
Louisiana SERS	45%	-9%	-12%	-18%	-16%	-21%	-36%	-23%	-35%	-80%
Indiana Teachers	28%	-13%	-18%	-28%	-14%	-21%	-38%	-16%	-27%	-62%
Georgia ERS	26%	-16%	-22%	-33%	-18%	-26%	-44%	-22%	-35%	-75%
Illinois SERS	49%	-14%	-37%	-82%	-14%	-42%	-114%	-17%	-55%	-186%
San Diego City ERS	78%	-16%	-22%	-30%	-34%	-47%	-78%	-55%	-85%	-189%

Note: Table displays the percentage point change in contributions as a share of payroll required to obtain today's implicit pension debt as a share of GDP in 30 years for the plans in the estimation sample.

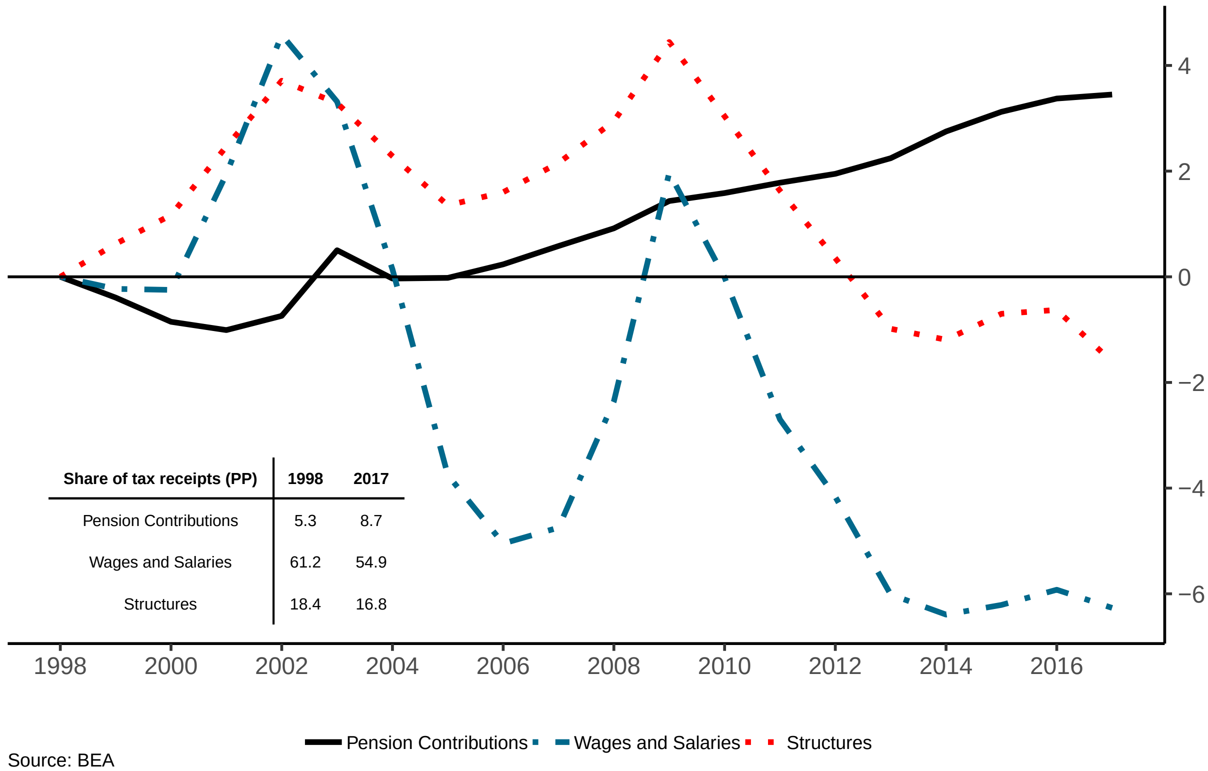
Figure 1



Source: Factiva search of major, national news sources.
Search terms: (state OR local) AND pension AND (crisis OR default).

Figure 2

Change in State and Local Government Expenditures as Share of Tax Receipts

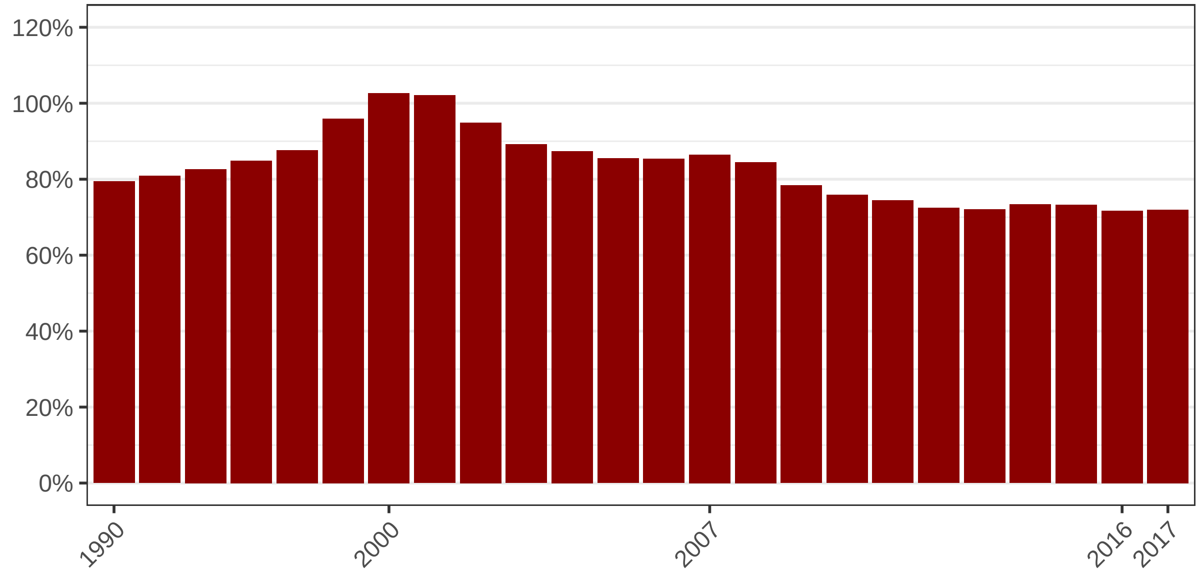


Source: BEA

Note: Graph shows changes in the ratio of State and Local employer pension contributions, wage and salary payments, and investment in infrastructure to current tax receipts.

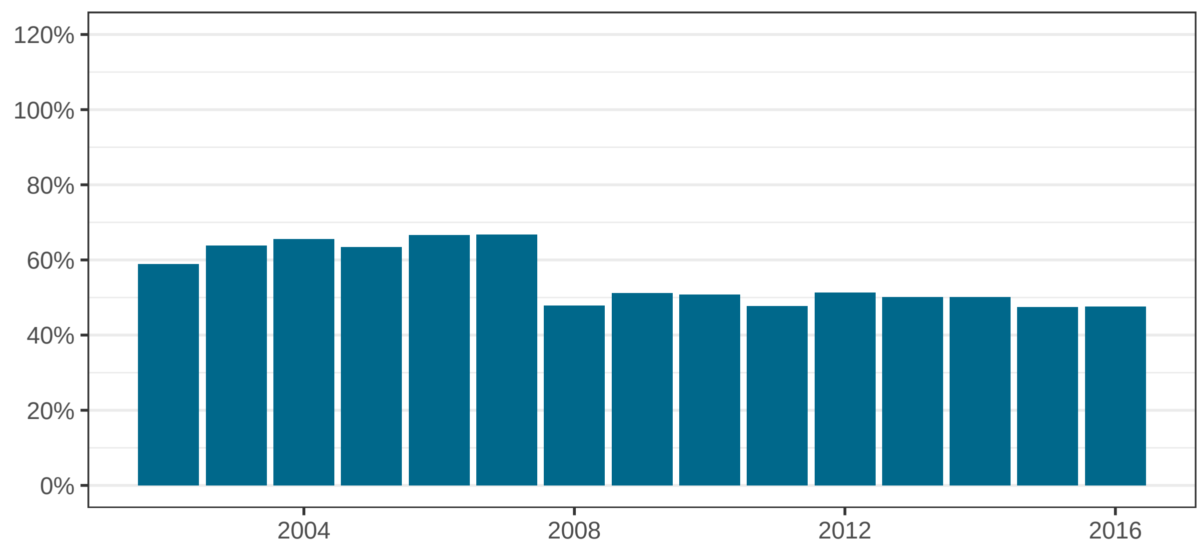
Figure 3

Panel A: State and local Government Pension Funding Ratios Under Plan Chosen Discount Rate



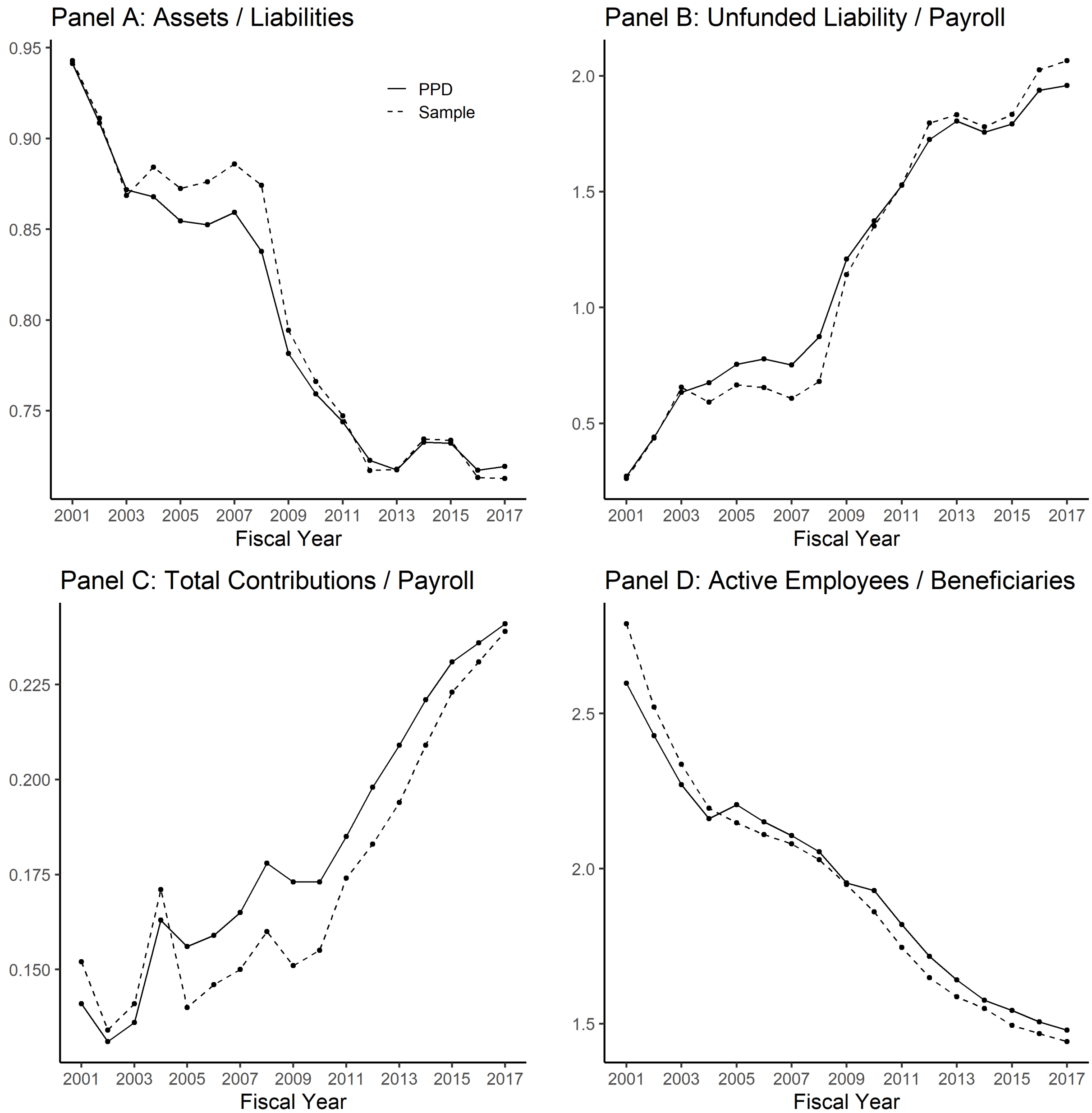
Source: Calculations and figure are from the Center for Retirement Research at Boston College; Aubry, Crawford, and Wandrei (2018).
Note: The 2017 funded ratio involves projections for 18 percent of PPD plans, representing 26 percent of liabilities.
Calculations based on 2017 actuarial valuations (AVs); Center for Retirement Research at Boston College Public Plans Database (PPD) (2001−2017);and Zorn(1990−2000).

Panel B: State and Lcocal Government Pension Funding Ratios Under AAA Corporate−Bond Interest Rate



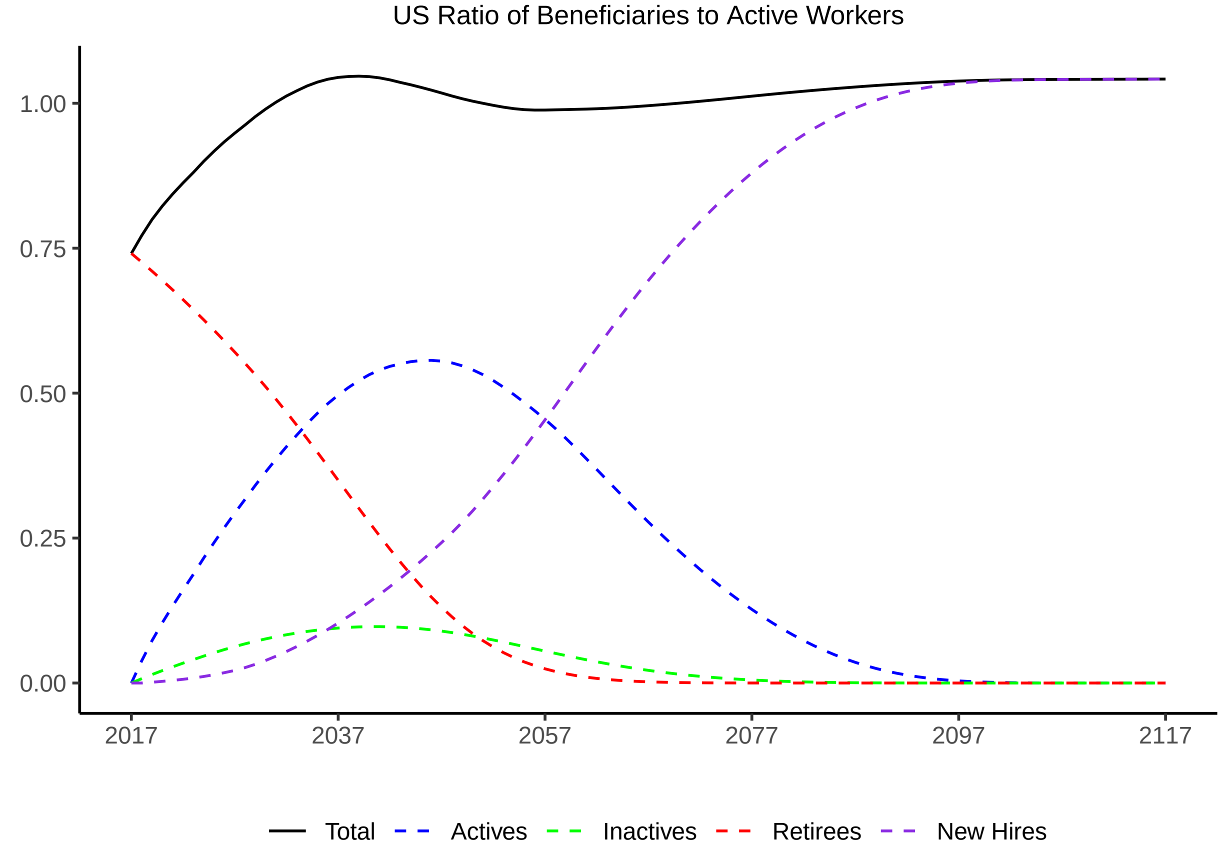
Source: Financial Accounts of the United States. See Hoops, Smith, and Stefanescu (2016) for methodology.

Figure 4



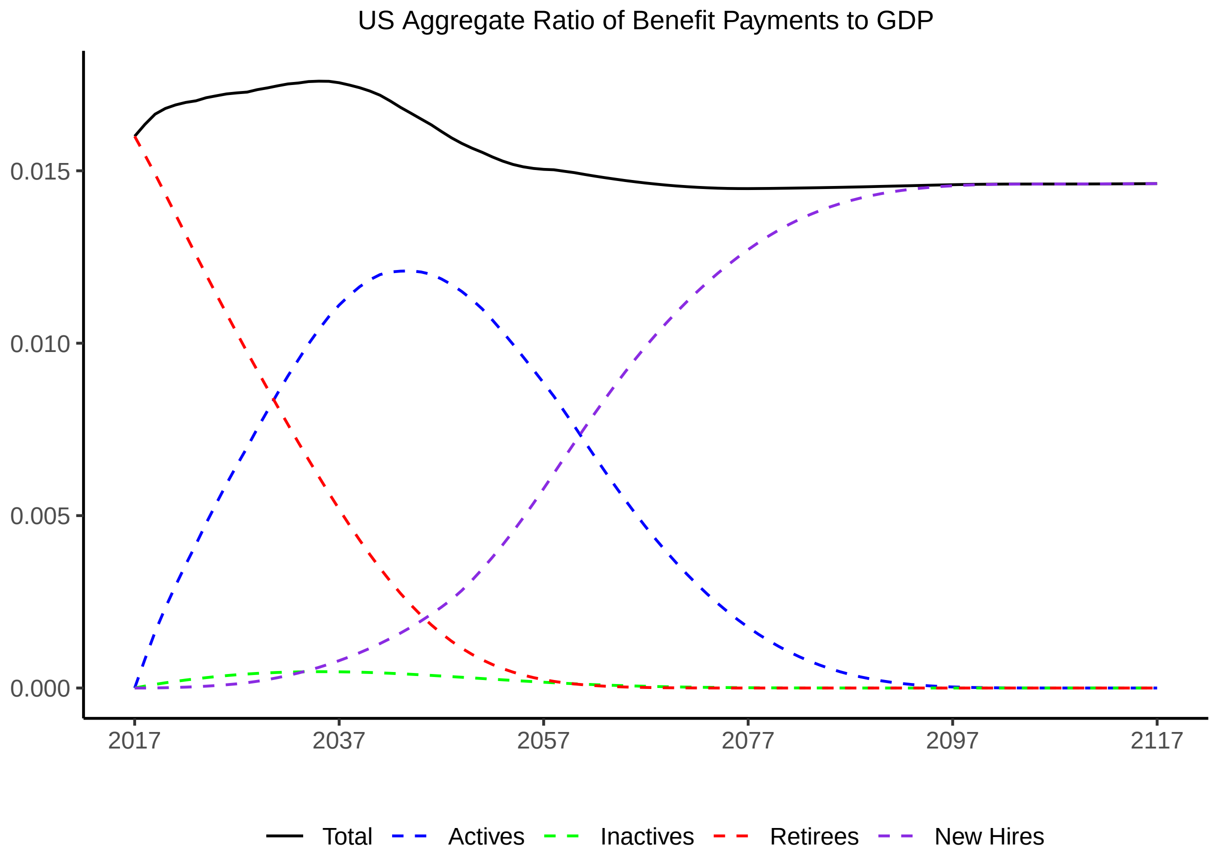
Note: The dashed lines display means for the estimation sample. The solid lines display means for the universe of the PPD.

Figure 5



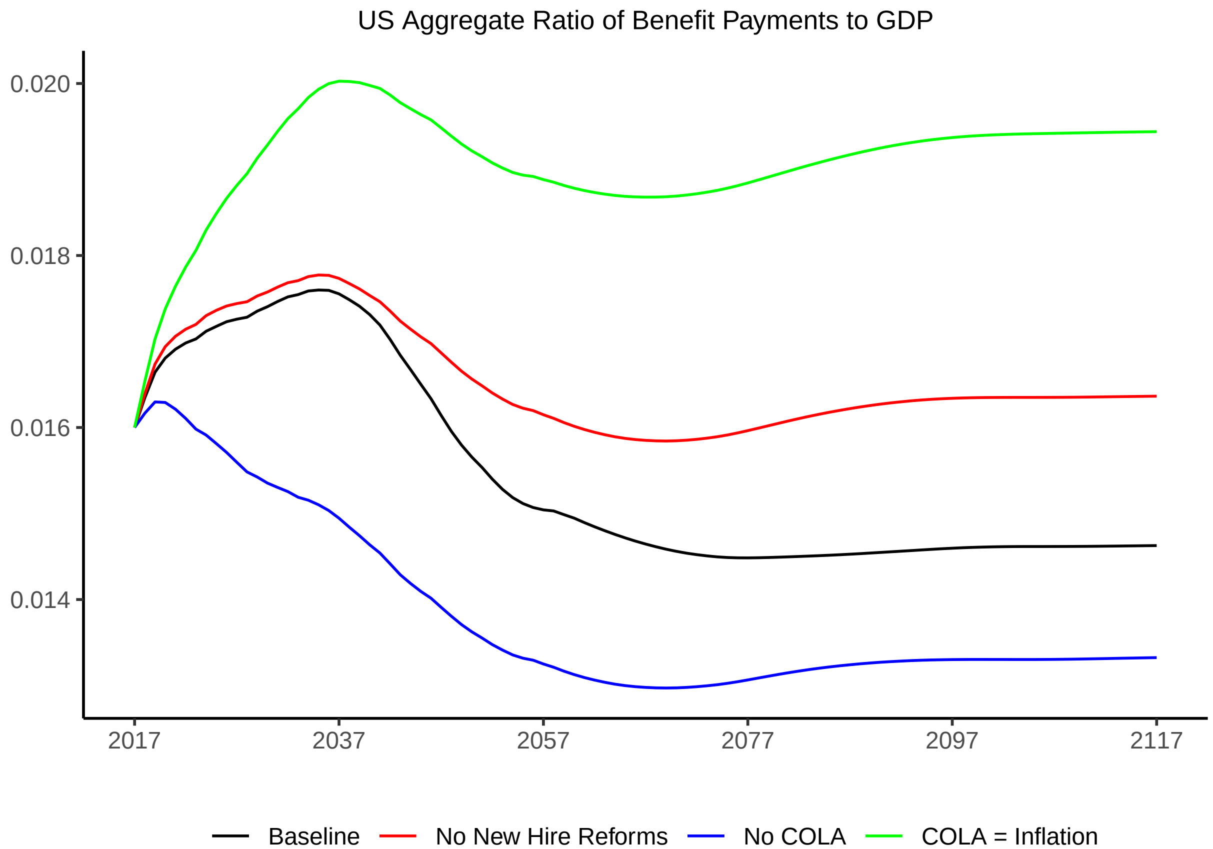
Note: The solid black line displays the ratio of total beneficiaries of state and local government pension plan payments to the state and local government current workforce. The dashed red line displays the ratio of beneficiaries who were receiving benefits as of 2017 – i.e. retirees – to current workers. The dashed blue line displays the displays the ratio of beneficiaries who were employed by a state and local government as of 2017 – i.e. actives – to current workers. The dashed green line displays the ratio of beneficiaries who were no longer employed as of 2017 and who were eligible for a pension benefit, but who had not started to receive the benefit as of 2017 – i.e. inactives — to current workers. The purple dashed line displays the ratio of beneficiaries who were hired after 2017 to current workers.

Figure 6



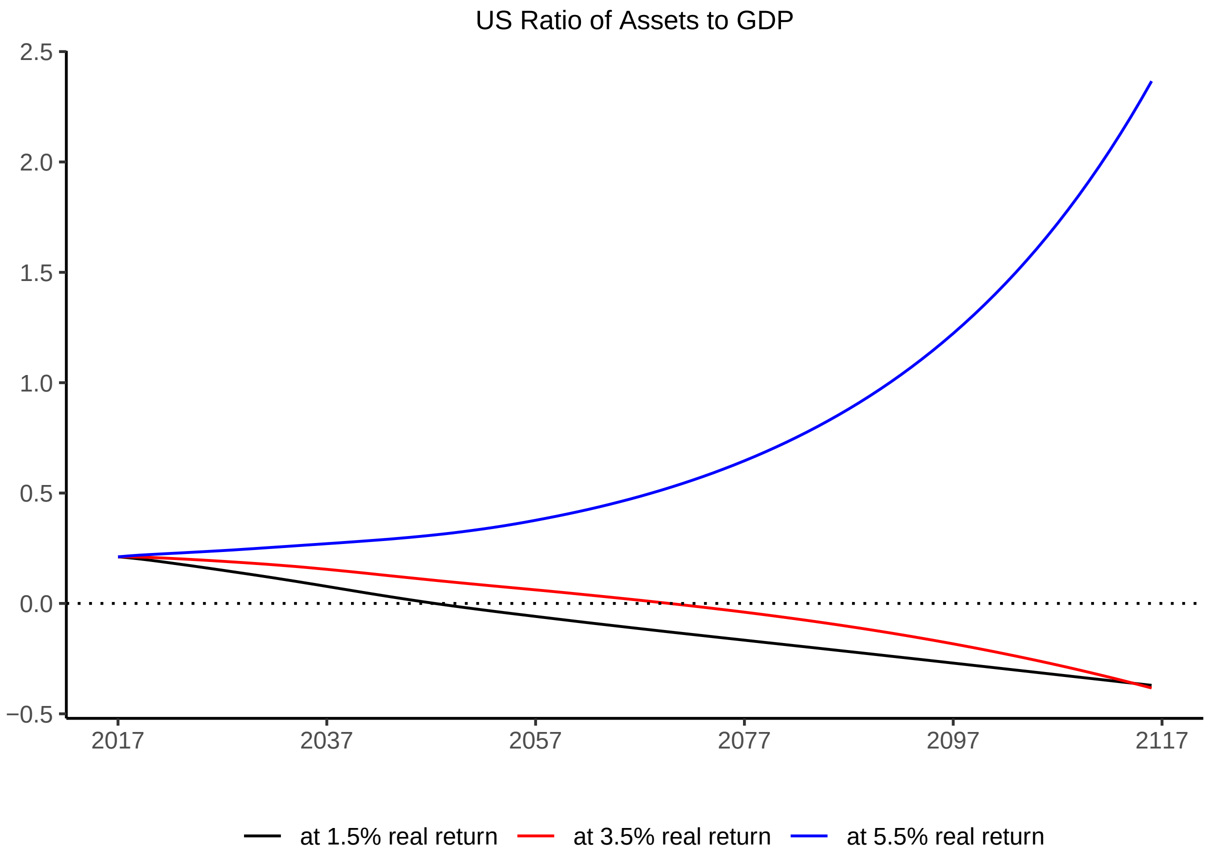
Note: The solid black line displays the ratio of total state and local government pension benefit payments to GDP. The dashed red line displays the ratio of benefit payments to beneficiaries who were receiving benefits as of 2017 – i.e. retirees – to GDP. The dashed blue line displays the ratio of benefit payments to beneficiaries who were employed by state and local government as of 2017 - i.e. actives - to GDP. The dashed green line displays the ratio benefit payments to beneficiaries who were no longer employed as of 2017 and who were eligible for a pension benefit, but who had not started to receive the benefit as of 2017 - i.e. inactives - to GDP. The purple dashed line displays the ratio of benefit payments to beneficiaries who were hired after 2017 to current workers.

Figure 7



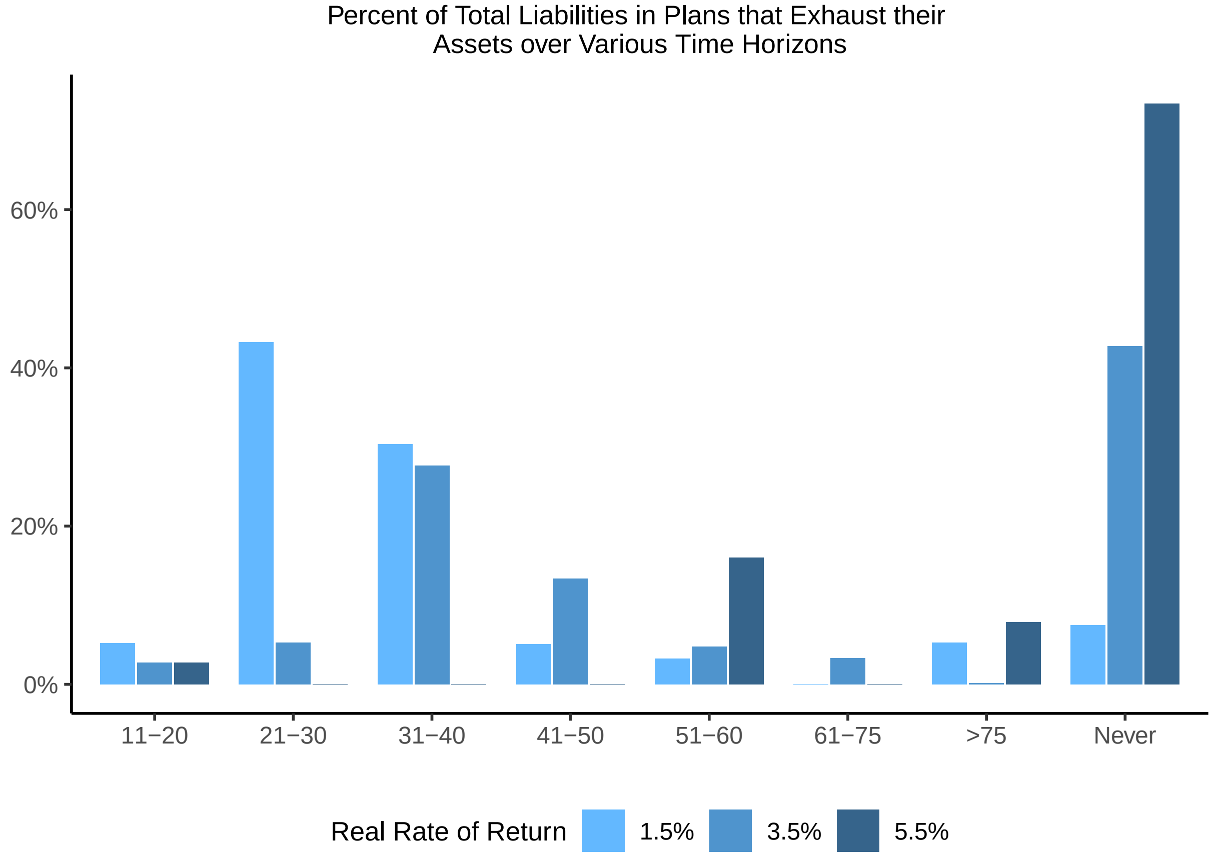
Note: The solid black line displays the ratio of total state and local government pension benefit payments to GDP. The solid red line displays the ratio of total state and local government pension benefit payments to GDP assuming that all pension changes which apply only to new hires – i.e. new worker reforms – are canceled. The solid green line displays the ratio of total state and local government pension benefit payments to GDP assuming that all plans set their cost-of-living adjustment (COLA) to equal the rate of inflation. The solid blue line displays the ratio of total state and local government pension benefit payments to GDP assuming that all plans set their cost-of-living adjustment (COLA) to equal zero.

Figure 8



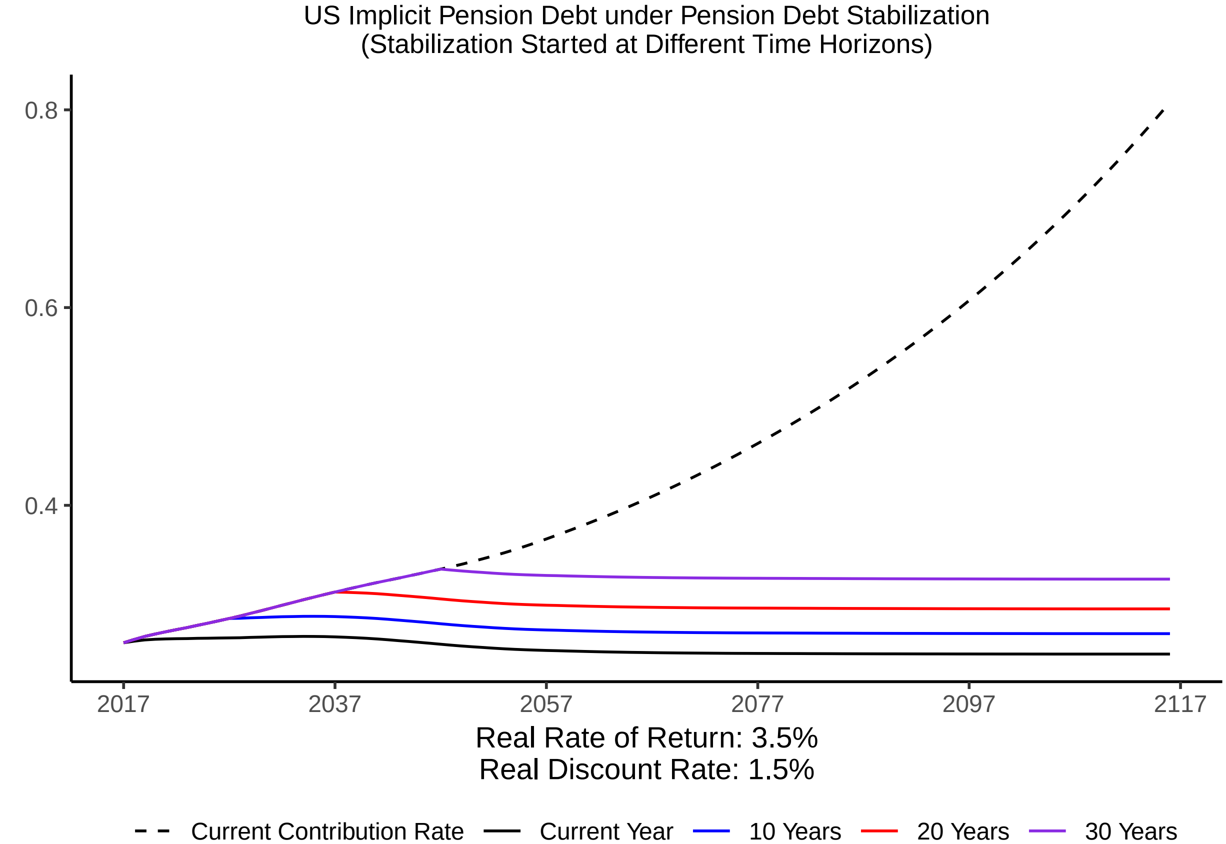
Note: The figure displays pension assets as a share of GDP under varying assumptions about asset returns and assuming that employer contributions as a share of payroll are held fixed at their 2017 value.

Figure 9



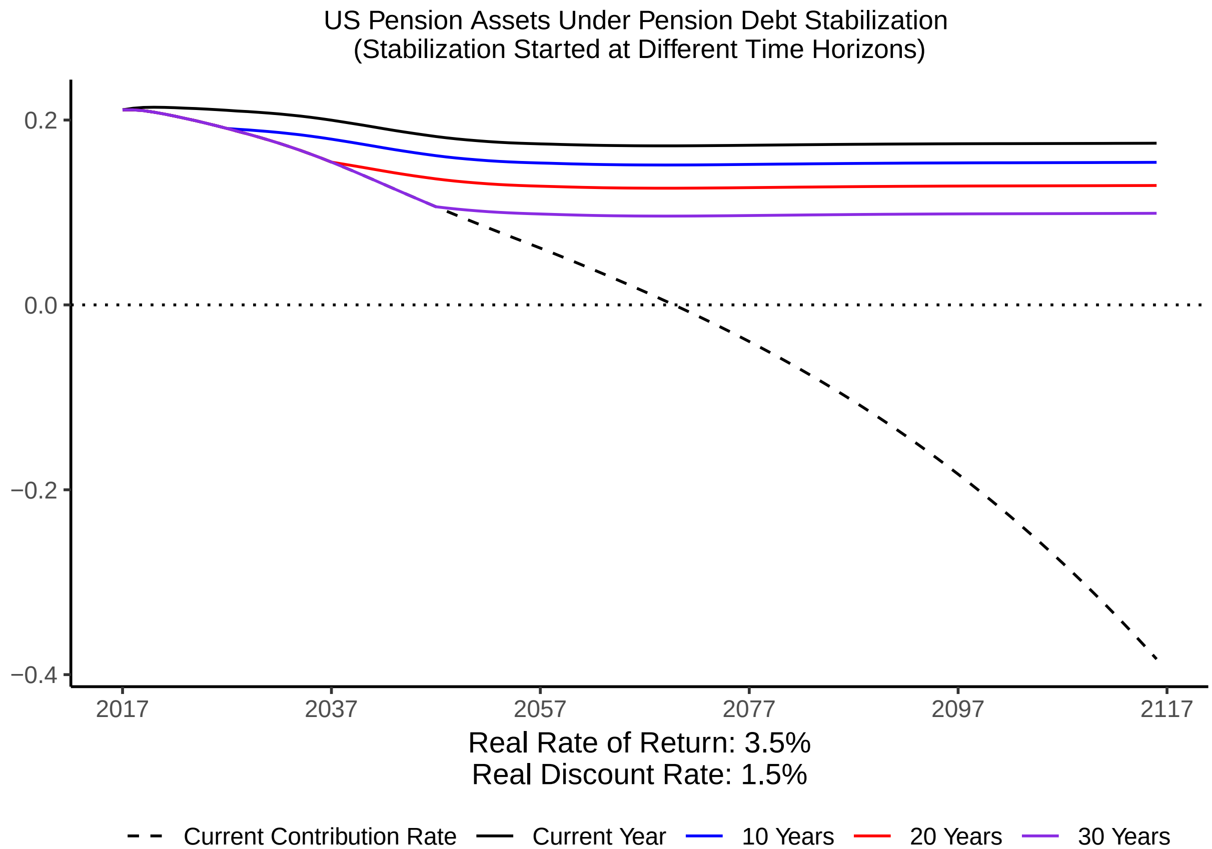
Note: The figure displays the share of total pension liabilities held by plans which exhaust their assets over different time horizons assuming that employer contributions as a share of payroll are held fixed at their 2017 value.

Figure 10



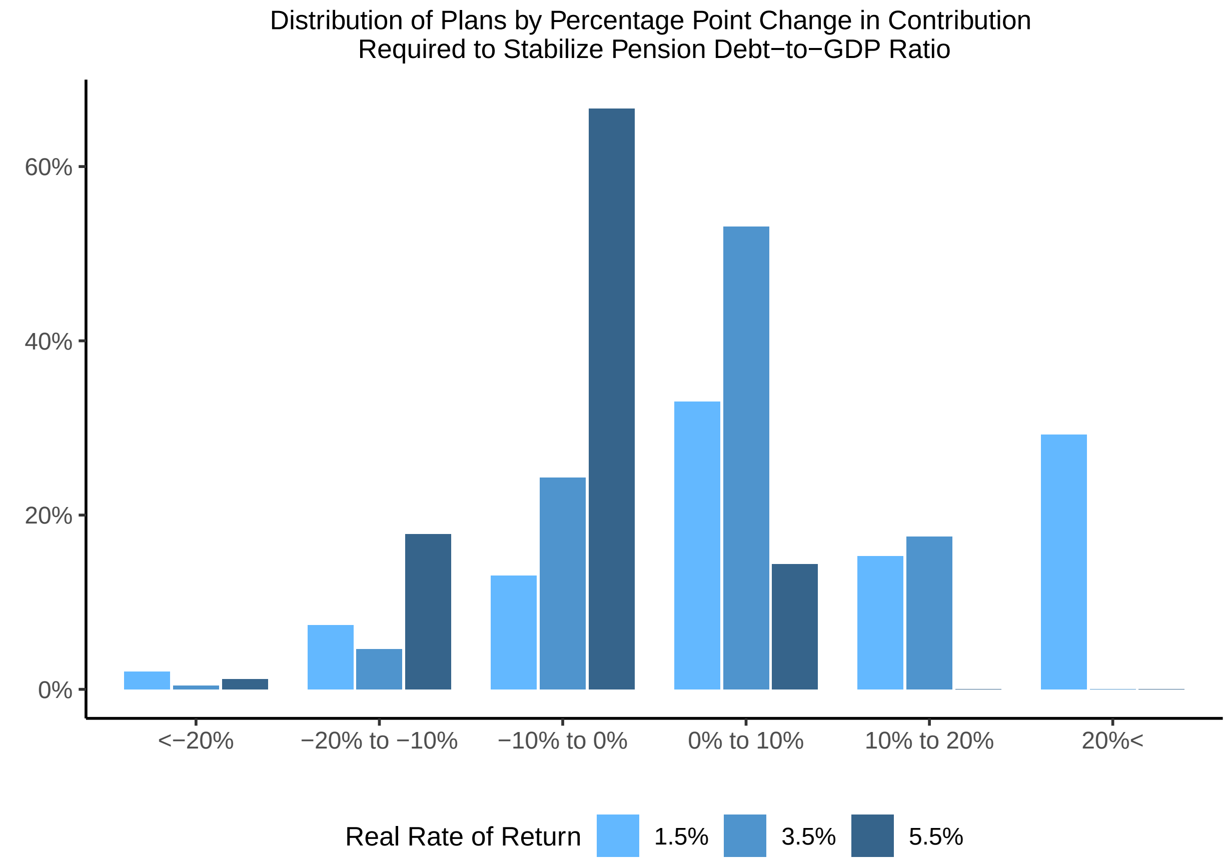
Note: The dashed black line displays implicit pension debt – unfunded pension liabilities – as a share of GDP assuming that assets have a real return of 3.5 percent and that employer contributions as a share of GDP are held fixed at their 2017 value. The solid black line displays implicit pension debt – unfunded pension liabilities – as a share of GDP assuming that assets have a real return of 3.5 percent and that pension contributions as a share of payroll receive an immediate one-time, permanent change such that pension debt eventually stabilizes in the longer-run. The blue, red, and purple solid lines are analogous to the solid black line but assume that the adjustment to pension contributions occurs in 10 years, 20 years, and 30 years, respectively.

Figure 11



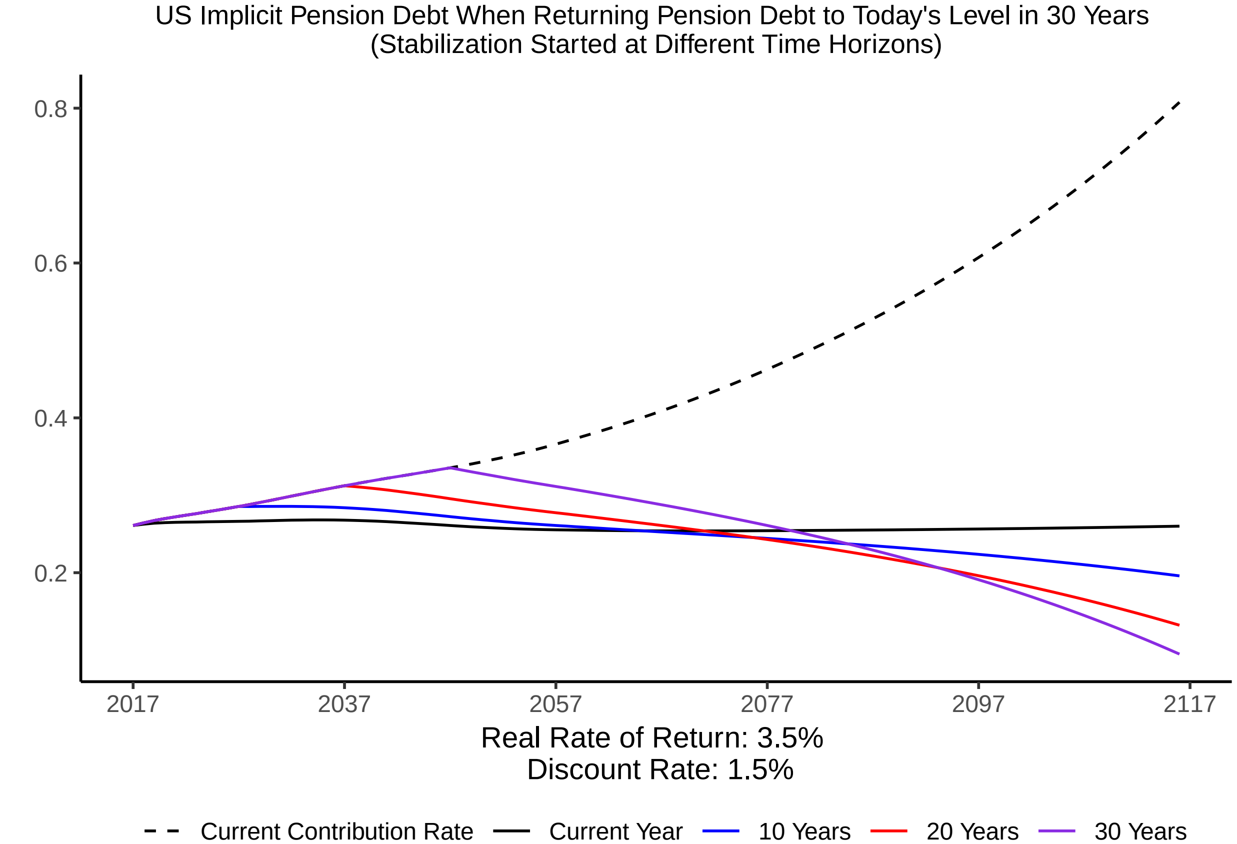
Note: The dashed black line displays pension assets as a share of GDP assuming that the assets have a real return of 3.5 percent and that pension contributions as a share of GDP are held fixed at their 2017 value. The solid black line displays pension assets as a share of GDP assuming that the assets have a real return of 3.5 percent and that pension contributions as a share of payroll receive an immediate one-time, permanent change such that pension debt eventually stabilizes in the longer-run. The blue, red, and purple solid lines are analogous to the solid black line but assume that the adjustment to pension contributions occurs in 10 years, 20 years, and 30 years, respectively.

Figure 12



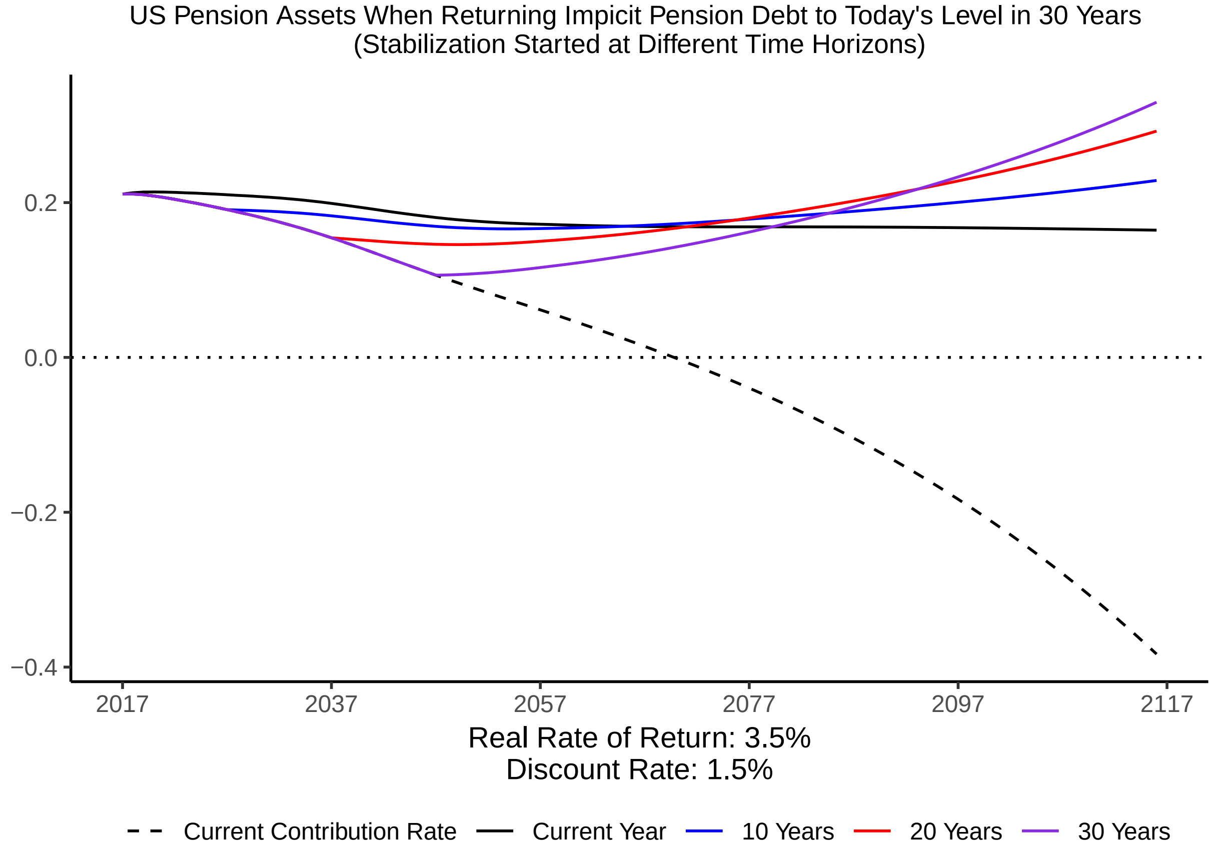
Note: Figure displays the distribution of plans by the percentage point change in contributions (share of payroll) required to stabilize the pension debt-to-gdp ratio under different asset return assumptions. The histograms are weighted by liabilities.

Figure 13



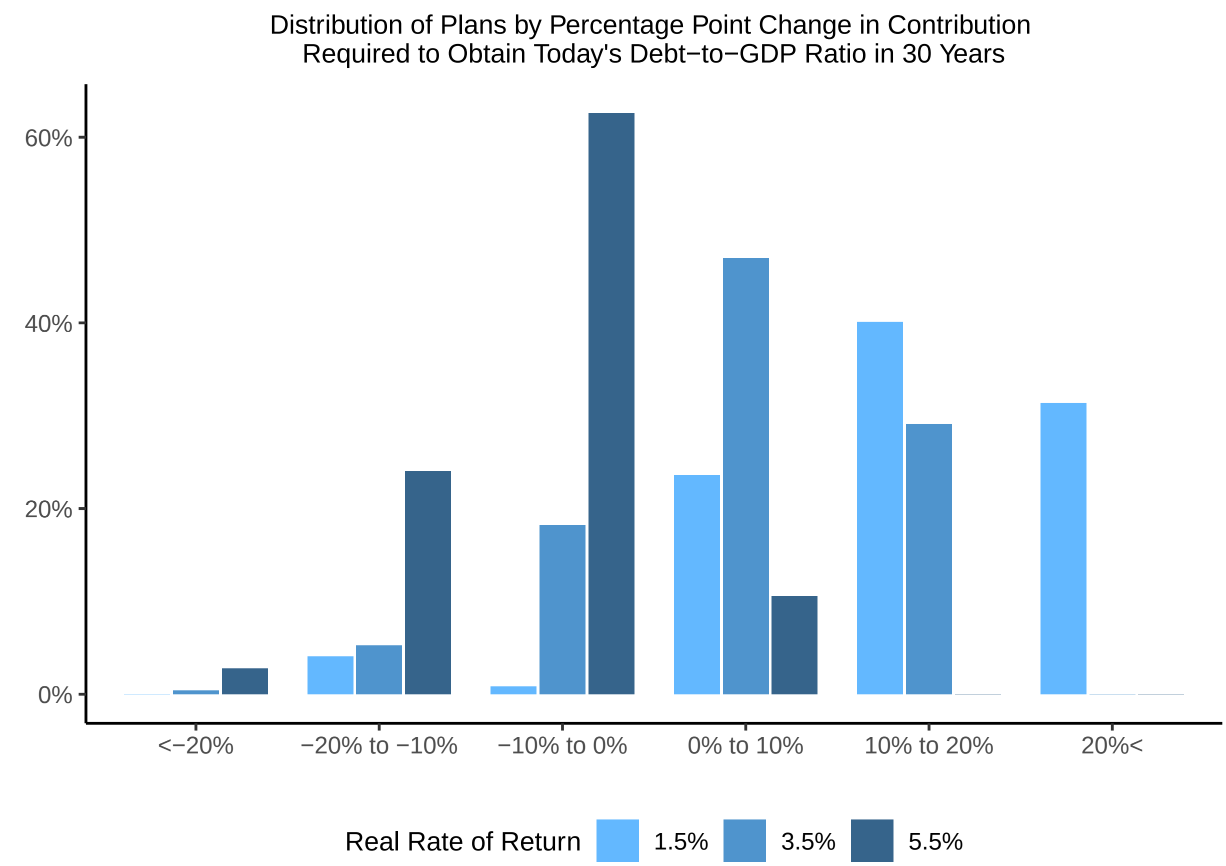
Note: The dashed black line displays implicit pension debt – unfunded pension liabilities – as a share of GDP assuming that assets have a real return of 3.5 percent and that pension contributions as a share of GDP are held fixed at their 2017 value. The solid black line displays implicit pension debt – unfunded pension liabilities – as a share of GDP assuming that assets have a real return of 3.5 percent and that pension contributions as a share of payroll receive an immediate one-time, permanent change such that pension debt returns to today's level in 30 years. The blue, red, and purple solid lines are analogous to the solid black line but assume that the adjustment to pension contributions occurs in 10 years, 20 years, and 30 years, respectively, and pension debt returns to today's level in 40 years, 50 years, and 60 years, respectively.

Figure 14



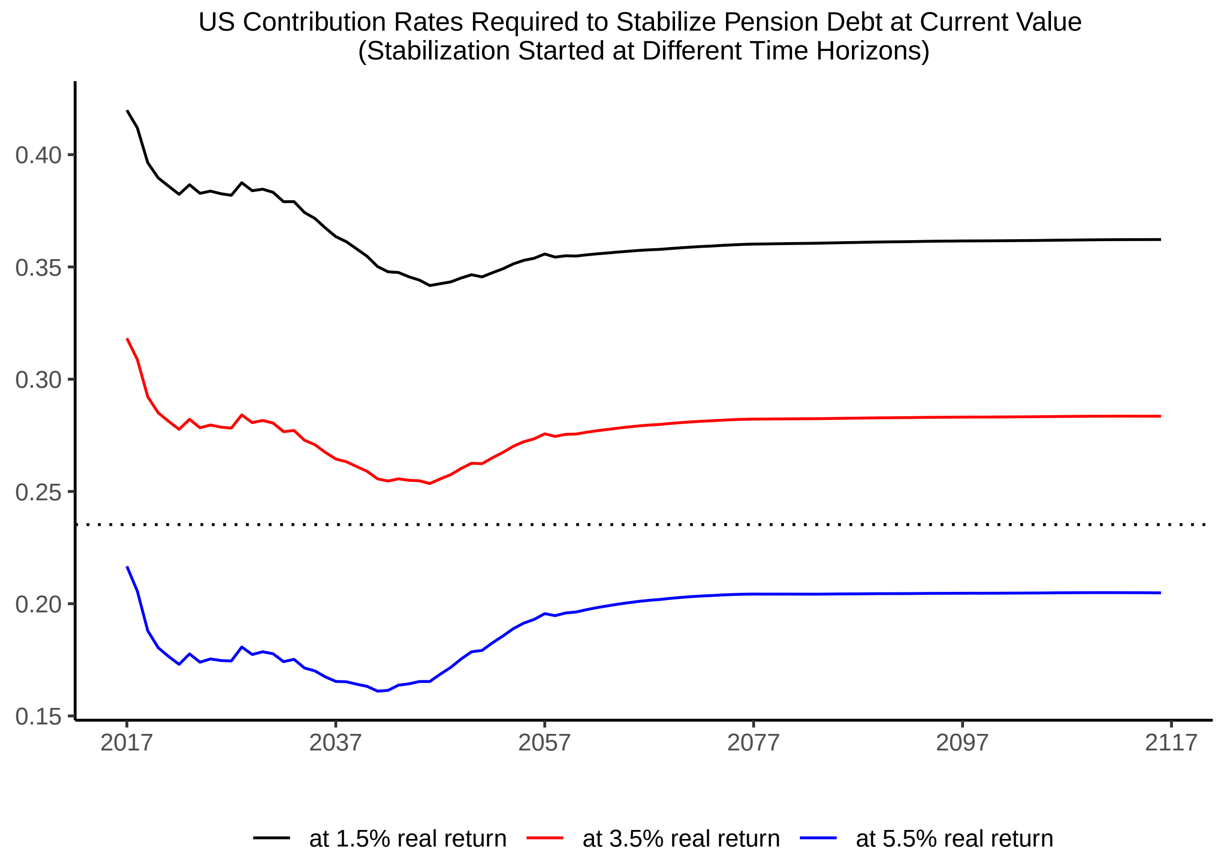
Note: The dashed black line displays pension assets as a share of GDP assuming that the assets have a real return of 3.5 percent and that pension contributions as a share of GDP are held fixed at their 2017 value. The solid black line displays pension assets as a share of GDP assuming that the assets have a real return of 3.5 percent and that pension contributions as a share of payroll receive an immediate one-time, permanent change such that pension debt returns to today's level in 30 years. The blue, red, and purple solid lines are analogous to the solid black line but assume that the adjustment to pension contributions occurs in 10 years, 20 years, and 30 years, respectively, and the pension debt returns to today's level in 40 years, 50 years, and 60 years, respectively.

Figure 15



Note: Figure displays the distribution of plans by the percentage point change in contributions (share of payroll) required to obtain today's pension debt-to-GDP ratio in 30 years under different asset return assumptions. The histograms are weighted by plan liabilities.

Figure 16



(1.5% discount rate)

Note: The dashed black line displays pension contributions as a share of payroll in 2017. The solid black line displays the pension contribution as a share of payroll required to stabilize implicit pension debt as a share of GDP at its current value assuming pension assets yield a real return of 1.5 percent. The solid red line displays the pension contribution as a share of payroll required to stabilize implicit pension debt as a share of GDP at its current value assuming pension assets yield a real return of 3.5 percent. The solid blue line displays the pension contribution as a share of payroll required to stabilize implicit pension debt as a share of GDP at its current value assuming pension assets yield a real return of 1.5 percent.

Appendix

A. Projecting future benefits

Our analysis is underpinned by the replication of the stated accrued liabilities (AL) and annual cost of funding for active members (normal cost or NC) of each plan as reported in the PPD. This requires leveraging the collected plan level inputs and stated actuarial assumptions to calculate the present value of future benefits (PVFB) of vested inactive former employees (inact), current beneficiaries (ben) and the accrued liabilities (AL) of current employees (act). Due to the fact our estimated liabilities AL and normal costs NC will not perfectly replicate the stated GASB liabilities (AL^{GASB}) and normal costs NC^{GASB} for each plan, we calibrate our nominal cashflows of future benefits B^t such that they match.

<u>Present Value of Future Benefits</u>

The PVFB is a liability measure which includes both obligations already accrued, as well as obligations associated with the future service of current employees (who are assumed to retire according to actuarial assumptions). The most complex of these calculations is that of the currently active employees still accruing liability for normal retirement (ret), the possibility of quitting and claiming deferred retirement ($dret$) or refund of contributions (ref), disability (dis) and $death$. For an active employee of age x and number service years s their PVFB is decomposed as follows:

$$\text{PVF}B_{x,s}^{act} = \text{PVF}B_{x,s}^{ret} + \text{PVF}B_{x,s}^{dret} + \text{PVF}B_{x,s}^{dis} + \text{PVF}B_{x,s}^{death} + \text{PVF}B_{x,s}^{ref} \qquad (A1)$$

The total $PVFB^{act}$ is then calculated as a weighted sum over the lower triangular (55 x 55) age service distribution matrix Π^{act} multiplied by the number of active employees in fiscal year 2017 (N_0^{act}).

$$\text{PVFB}^{\text{act}} = N_0^{act} \sum_{\text{x}} \sum_{\text{s}} \Pi_{\text{x,s}}^{\text{act}} \, \text{PVFB}_{\text{x,s}}^{\text{act}} \qquad (A2)$$

Further details of these calculation are detailed in actuarial appendix A and follow closely that of (Winkelvoss 1993), however we outline the details of the calculation for the creation of the cashflows associated with normal retirement $B_{t,ret}^{act}$ and $PVFB_{x,s}^{ret}$ here as it is instructive on the form in which most of these benefits take and how they are calculated, as well as being the predominant accrued liability for active employees.

$$PVFB_{x,s}^{ret} = \sum_{i=x}^{R} v^{i-x} \, p_{(x,s),i}^{T} q_{(x,s),i}^{ret} b_{ret}(x,s,i) a_i \qquad (A3)$$

$$b_{ret}(x,s,i) = \alpha(s+i-x)\big(1-\kappa Max(r-i,0)\big)\boldsymbol{E}\left[\frac{\sum_{j=i-f}^{i} w_j}{f}\middle|(x,s)\right] \qquad (A4)$$

$$E[w_i \mid (x,s)] = w(x,s)(1+\pi_w)^{i-x}\prod_{j=x}^{i}\big(1+\pi_e(j,s+j-x)\big) \qquad (A5)$$

$PVFB_{x,s}^{ret}$ is calculated as a discounted probability weighted sum of single/joint[22] life annuities a_i (see eq A24-A27) multiplied by a benefit formula $b_{ret}(x,s,i)$ conditional on age (x), service (s) and retirement age (i). All the above factors and probabilities are plan specific and obtained from the AVs or PPD: v is the plans discount factor$\left[\frac{1}{1+\delta}\right]$; $p_{(x,s),i}^{T}$ is the probability of remaining in employment until age i conditional on current age x and service years s; $q_{(x,s),i}^{ret}$is the probability of retiring at age i; α is the benefit multiplier; κ is a penalty factor, percent per year reduction, for each year retired before the plans normal retirement age r ; w_i is the salary or expected salary at age x calculated from the recorded salary matrix by age and service and grown out under the plans general and age/service specific wage growth assumptions $\pi_w$and π_e; f is the number of years the final salary is averaged over to determine salary base for the benefit payments. Furthermore, we calculate these identities for married/unmarried (1_μ) and male/females, and weight by the plans aggregate gender ratio and assumed percent married. Similar calculations are made for the other decrements.

PVFB for deferred retirement:

$$\text{PVFB}_{x,s}^{dret} = \sum_{i=x}^{R} v^{max(r,i)-x}(1+cola)^{max(r,i)-i}p_{(x,s),i}^{T}q_{(x,s),i}^{wth}\big(1-q_{(x,s),i}^{ref}\big)b_{dret}(x,s,i)p_{i,Max(r,i)}^{m}\,,a_{Max(r,i)} \qquad (A6)$$

$$b_{dret}(x,s,i) = \alpha(s+i-x)E\left[\frac{\sum_{j=i-f}^{i} w_j}{f}\middle|(x,s)\right] \qquad (A7)$$

Employees who do not claim a refund of contributions are assumed to retire at their normal retirement age and receive a benefit according to current service accrual and the average of their highest f salaries adjusted for the plan's cola.

PVFB for refunds:

$$PVFB_{x,s}^{ref} = \sum_{i=x}^{R} v^{i-x}p_{(x,s),i}^{T}q_{(x,s),i}^{wth}q_{(x,s),i}^{ref}\,b_{ref}(x,s,i) \qquad (A8)$$

[22] Married beneficiaries are assumed to opt for a joint life annuity where in the event of their death, their partner receives a prorated benefit.

$$b_{ref}(x,s,i) = \sum_{j=x-s}^{i} C_{ee}\boldsymbol{E}\left[w_j(1+rd)^{i-j}\middle|(x,s)\right] \qquad (A9)$$

A certain proportion of employees who quit are assumed to claim a refund equal to the sum of previous contributions at a fixed percent of previous salaries C_{ee}adjusted for interest payments at rate rd.

PVFB for disability:

$$PVFB_{x,s}^{dis} = \sum_{i=x}^{R} v^{i-x} p_{(x,s),i}^{T} q_{(x,s),i}^{dis}\, b_{dis}(x,s,i) a_i \qquad (A10)$$

$$b_{dis}(x,s,i) = \alpha(s+nr-x)E[w_i|(x,s)] \qquad (A11)$$

Employees who become disabled immediately begin to receive an annuity calculated based on their current salary and assumed number of years' service had they worked until normal retirement age.

PVFB for early death:

$$PVFB_{x,s}^{dth} = \sum_{i=x}^{R} v^{i-x} p_{(x,s),i}^{T} q_{(x,s),i}^{dth}\, b_{dth}(x,s,i) a_i \qquad (A12)$$

$$b_{dth}(x,s,i) = \alpha(s+i-x)E[w_i|(x,s)] \qquad (A13)$$

In the event of death during employment the spouse is assumed to receive an annuity based on the current salary and service years of the decreased plan member.

Inactive members:

Similar calculations are produced for the inactive deferred plan participants and current beneficiaries.

$$PVFB^{inact} = N_0^{inact} \sum_x \sum_s \Pi_{x,s}^{inact}\, PVFB_{x,s}^{inact} \qquad (A14)$$

$$PVFB_{x,s}^{inact} = \tilde{b}(x,s) p_{x,r}^{m} (1+cola)^{r-x} v^{r-x} a_r \qquad (A15)$$

The distribution of inactive members $\Pi_{x,s}^{inact}$was calculated as the ergodic distribution produced by the age distribution of new hires in fiscal year 2017 and the termination probabilities from the AV (see appendix C). We assume, like most plans, that these members will claim their accrued benefits at the plans normal retirement age subject to surviving to that age $p_{x,r}^{m}$, and adjust their imputed accrued benefits for the plans cost of living adjustment.

Current beneficiaries:

$$PVFB^{ben} = N_0^{ben} \sum_x \Pi_x^{ben} \, PVFB_x^{ben} \qquad (A16)$$

$$PVFB_x^{ben} = \bar{b}(x) a_x \qquad (A17)$$

The $PVFB^{ben}$are calculated using data recorded in the plans AVs on the age distribution of current beneficiaries $\Pi_x^{ben}$and the average benefit by age $\bar{b}(x)$ across that distribution. The sums of the various probability weighted life annuities a_i that go into the calculation of the $PVFBs$ for each category of plan member also produce our nominal projected cashflow vectors $B_{t=0,1....}$ and projections of future head counts $N_{t=0,1....}$.

<u>Normal costs and Accrued Liabilities</u>

Normal costs (NC) represent the annual cost of accrued benefits for active employees. It is the annual contribution that should in theory leave the plan fully funded when the experience of the plan matches expectations along every dimension[23] (Winkelvoss 1993). Normal costs therefore are used to adjust the $PVFB^{act}$ for the present value of future normal costs ($PVFNC$) to arrive at an estimated accrued liability to date for the current active population. These normal costs and accrued liabilities can be calculated using a large swathe of methods but by far the most popular[24] is the entry age normal which is illustrated below and calculates the normal cost as the level percent[25] salary contribution over the employee's career. This is calculated by dividing the present value of future benefits by the present value of future salaries $a_{\ddot{x-s},0}$ at the employee's entry age (x-s).

$$NC_{x,s} = \frac{PVFB_{x-s,0}^{act}}{a_{\ddot{x-s},0}} \qquad (A18)$$

$$NC = \frac{\sum_x \sum_s \Pi_{x,s}^{act} PVFB_{x-s,0}^{act}}{\sum_x \sum_s \Pi_{x,s}^{act} a_{\ddot{x-s},0}} \qquad (A19)$$

The NC varies by entry age and starting salary, the plans aggregate NC therefore is a weighted average of each members individual normal cost. Having calculated the NC we can now calculate the plans present value of future normal costs and total stated accrued liability as follows:

[23] E.g. assets achieve the assumed returns, wages grow in line with expectations, the workforce composition evolves as expected and so on.
[24] 91 percent of plans in the PPD in fiscal year 2017.
[25] In a few cases this is calculated as a level dollar contribution.

$$PVFNC = N_0^{act} \sum_x \sum_s \Pi_{x,s}^{act} NC_{x,s} \ddot{a}_{x,s} \qquad (A20)$$

$$AL^{act} = PVFB^{act} - PVFNC \qquad (A21)$$

$$AL = AL^{act} + PVFB^{inact} + PVFB^{ben} \qquad (A22)$$

where the PVFNC is a sum over the active populations present value of future salaries from their current age x multiplied by their normal cost rate.

Other accrual methods:

Three plans in the sample use the projected unit credit method whereby the accrued actuarial liability is calculated as follows:

$$AL^{act} = \sum_{x,s} \Pi_{x,s}^{act} \frac{s}{r-(x-s)} PVFB_{x,s}^{act} \qquad (A23)$$

Where the present value of future benefits is pro-rated by the ratio of current service level (s) to the service level at normal retirement (r).

<u>Annuity identities</u>

Single life annuity:

$$a_x^S = \sum_{i=x}^{\infty} p_{x,i}^m v^{i-x} (1+cola)^{i-x} \qquad (A24)$$

Where $p_{x,i}^m$is the probability of staying alive from age x until age i; v is a discount factor, cola is a cost of living adjustment. The survival probabilities vary by gender and disability status in accordance with the stated plans assumptions. Mortality probabilities are adjusted for mortality improvement using factors from the SOA MP-2016 tables as the annuitant ages.

Joint life annuity:

$$a_x^J = \sum_{i=x}^{\infty} \left(\left(p_{x,i}^m \left(1 - p_{x,i}^{m(s)}\right) + p_{x,i}^m p_{x,i}^{m(s)} \right) + p_{x,i}^{m(s)} \left(1 - p_{x,i}^m\right) \Phi \right) v^{i-x} (1+cola)^{i-x} \qquad (A25)$$

$$a_x^J = \sum_{i=x}^{\infty} \left(\left(p_{x,i}^m \left(1 - p_{x,i}^{m(s)}\right) + p_{x,i}^m p_{x,i}^{m(s)} \right) + p_{x,i}^{m(s)} \left(1 - p_{x,i}^m\right) \Phi \right) v^{i-x} (1+cola)^{i-x} \qquad (A26)$$

The joint life annuity depends on two lives, the beneficiary and the spouse. In the event of the beneficiary dying the annuity continues to payout at a rate reduced by a factor ϕ long as the spouse is alive.

Temporary employer annuity:

$$\ddot{a}_{(x,s)} = \sum_{i=x}^{R} E\,[w_i|(x,s)]p^{T}_{(x,s),i}v^{i-x} \qquad (A27)$$

The temporary employer annuity is used in calculating the present value of future salaries. It is the sum of the expected discounted future salaries of an employee aged x with service years s, adjusted for the probability of remaining in employment until age i, $p^{T}_{(x,s),i}$.

B. Data

Table B1: Sample plans

Table B2: Plan level inputs summary

Table B3: Replication errors and calibration factors

(Tables located at end of Appendix)

C. Plan matrices and imputations

This section summarizes the plan matrices key to the creation of the cashflows and liabilities and any imputation steps required to take the values reported in each plans AV to the standardized form illustrated below.

As discussed in the main text, the plan AVs and CAFRs while generally similar, present information in a non-standardized format. To overcome this, we developed a set of standardized procedures to take the data we extracted from the AVs/CAFRs and put it into the format we required. A complicated example is the provision of average salary information for active members along the age dimension only. (In a few cases no distributional information was provided at all.) In this case we leveraged the wage growth matrix by age and service to back out a reasonable estimate of implied salary relativities by age and service. These imputed relativities by age and service could then be combined with the plan's active member age service distribution and plan level average salary to obtain imputed average salaries by age and service. Another common issue was that of multiple categories of employees, actuarial assumptions and benefits provisions within consolidated plans. For example, the Los Angeles County Retirement Association is composed of 8 different tiers, 5 for the general population and 3 for safety workers such as police and firefighters. Each tier contained different plan provisions e.g. benefit factors, and actuarial assumptions like retirement rates or pay growth also varied between safety and non-safety members. In cases such as this we aggregated the assumptions into one plan input using appropriate weightings wherever possible, usually the number of active employees or payroll by tier.

We now present each of the matrices, with discussion of imputation procedures where appropriate.

Table C1: Age/service matrix

Age and service distribution (percent of employees)

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	6.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	5.6	4.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	4.1	3.0	4.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	3.1	2.3	2.8	3.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0
45-49	3.0	2.3	2.6	2.9	2.8	0.8	0.0	0.0	0.0	0.0	0.0
50-54	2.3	1.9	2.3	2.3	1.9	2.0	0.6	0.0	0.0	0.0	0.0
55-59	1.9	1.6	2.5	2.2	1.7	1.5	1.2	0.1	0.0	0.0	0.0
60-64	1.1	1.2	1.5	1.6	1.2	1.0	0.7	0.2	0.0	0.0	0.0
65-69	0.5	0.4	0.5	0.5	0.3	0.3	0.2	0.1	0.0	0.0	0.0
70-74	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Note: Data is sourced from the various acturial valuations (FY 2017). Table is an employee weighted average over the 40 plans in sample.

Table C2: Salary relativity matrix

	Salary relativities										
age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25-29	0.76	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-34	0.78	0.95	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35-39	0.80	0.98	1.10	1.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40-44	0.81	0.98	1.11	1.24	1.32	0.00	0.00	0.00	0.00	0.00	0.00
45-49	0.80	0.96	1.08	1.21	1.33	1.40	0.00	0.00	0.00	0.00	0.00
50-54	0.78	0.92	1.03	1.14	1.27	1.38	1.43	0.00	0.00	0.00	0.00
55-59	0.77	0.90	1.00	1.09	1.20	1.32	1.42	1.45	0.00	0.00	0.00
60-64	0.75	0.88	0.98	1.07	1.16	1.26	1.37	1.46	1.44	0.00	0.00
65-69	0.68	0.81	0.92	1.02	1.10	1.19	1.30	1.44	1.48	1.24	0.00
70-74	0.54	0.63	0.72	0.81	0.87	0.94	1.01	1.09	1.17	0.92	0.92

Note: Data is sourced from the various acturial valuations (FY 2017). Table is an employee weighted average over the 40 plans in sample.

This was nearly always entirely available. In a few instances average salaries were only provided by age. In this instance we used the wage growth assumptions to grow out wages along each diagonal and then used the relativities by age, age service distribution matrix and average plan salary to impute a matrix.

Table C3: Current beneficaries

	Employees (%)	Benefit Relativity
40-44	0.2	0.7
45-49	0.8	0.75
50-54	1.7	1.04
55-59	6.1	1.08
60-64	14.5	1.04
65-69	24.9	1
70-74	22.0	0.96
75-79	12.7	0.89
80-84	9.4	0.83
85-89	5.0	0.8
90-94	2.4	0.76
95-99	0.3	0.79
100+	0.0	0.81

When benefit distributions or relativities were not available by age we imputed with the average from the other plans and adjusted such that the average age and benefit level matched the AV. The benefit relativity is the relativity to the average benefit reported in the AV.

Table C4: Inactive age/service matrix

Age and service distribution for inactive vested members (percent of employees)

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	0.0	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	0.0	4.8	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	0.0	7.1	3.9	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
45-49	0.0	8.8	5.9	2.4	0.8	0.1	0.0	0.0	0.0	0.0	0.0
50-54	0.0	10.0	7.8	3.8	2.2	0.7	0.1	0.0	0.0	0.0	0.0
55-59	0.0	9.5	8.7	4.4	2.9	1.6	0.6	0.1	0.0	0.0	0.0
60-64	0.0	3.3	2.2	1.1	0.7	0.5	0.3	0.1	0.0	0.0	0.0
65-69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70-74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: Data is imputed using plans actuarial assumptions and current member statistics. Table is an employee weighted average over the 40 plans in sample.

This matrix was imputed using the withdrawal matrix and distribution of new hires implied by the age service matrix. The matrix describes the current age and number of years service at withdrawal. The imputed matrix is the steady state solution to the following dynamic system of equations:

$$\Pi_t^{inact} = D\Pi_{t-1}^{inact} + D\left(\Pi_{t-1}^{act} \circ Q^{wth}(1-Q^{ref})\right) \qquad (C1)$$

$$\Pi_t^{act} = \Pi_{nh} + D\left(\Pi_{t-1}^{act} \circ (1-Q^{wth})\right)R \qquad (C2)$$

Where Π_t are the inactive and active time t distributions of employees, D shifts the distributions down by one row (ages the population) and R shifts the distributions right by one (increases service level), Q are the refund and withdrawal probability matrices and $\circ$ is the Hadamard product (element wise multiplication). Π_{nh} are the new hires added to the active distribution with an age distribution that matches the current distribution of new hires and adjusted such that the overall distribution Π_t^{act}sum to one i.e. a steady headcount is maintained.

Table C5: Wage growth assumptions

Wage growth assumptions

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	4.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	4.0	2.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	3.9	2.2	1.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	3.7	2.0	1.1	0.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0
45-49	3.7	1.9	1.1	0.8	0.7	0.6	0.0	0.0	0.0	0.0	0.0
50-54	3.7	1.8	1.0	0.8	0.7	0.5	0.4	0.0	0.0	0.0	0.0
55-59	3.6	1.8	1.0	0.7	0.6	0.5	0.4	0.4	0.0	0.0	0.0
60-64	3.6	1.8	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.0	0.0
65-69	3.7	1.8	0.9	0.7	0.7	0.5	0.4	0.4	0.4	0.4	0.0
70-74	3.7	1.9	1.0	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4

Note: Data is sourced from the various acturial valuations (FY 2017). The numbers displayed exclude general wage growth due to general inflation and productivity. Table is an employee weighted average over the 40 plans in sample.

This matrix was constructed by taking the experience (merit) assumptions by age and/or service and using a linear regression to bring the data into our standardized format (55x55 age service matrix). We censored the predicted values below zero. Typically, assumptions were provided in similar form to that of table C3, in instances where this was not the case we adjusted equation X accordingly e.g. removed age variables when wage growth was only presented along the service dimension.

$$\pi_{a,s} = \beta_0 + \beta_1 1_{s<5} + +\beta_2 s + \beta_3 s^2 + \beta_4 s^3 + \beta_5 a + \beta_6 a^2 + \beta_7 a^3 + \epsilon_{a,s} \qquad (C3)$$

Table C6: Withdrawal assumptions

Withdrawal assumptions

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	11.9	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	11.4	5.2	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	10.9	4.7	4.3	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	10.6	4.4	4.0	1.6	1.4	0.0	0.0	0.0	0.0	0.0	0.0
45-49	10.5	4.3	3.9	1.5	1.3	1.2	0.0	0.0	0.0	0.0	0.0
50-54	10.4	4.3	3.9	1.5	1.3	1.2	1.2	0.0	0.0	0.0	0.0
55-59	10.5	4.4	4.0	1.6	1.4	1.4	1.3	1.3	0.0	0.0	0.0
60-64	10.7	4.5	4.1	1.8	1.6	1.5	1.4	1.4	1.4	0.0	0.0
65-69	10.7	4.6	4.2	1.8	1.6	1.5	1.5	1.5	1.5	1.5	0.0
70-74	10.6	4.5	4.1	1.8	1.6	1.5	1.4	1.4	1.4	1.4	1.4

Note: Data is sourced from the various acturial valuations (FY 2017). Table is an employee weighted average over the 40 plans in sample.

$$q^{wth}_{a,s} = \beta_0 + \beta_1 1_{s<5} + +\beta_2 s + \beta_3 s^2 + \beta_4 s^3 + \beta_5 a + \beta_6 a^2 + \beta_7 a^3 + \epsilon_{a,s} \qquad (C4)$$

This matrix was constructed by taking the withdrawal assumptions by age and/or service and using a linear regression to bring the data into our standardized format. We censored the predicted values below zero. Typically, assumptions were provided in similar form to that of table C6, in instances where this was not the case, we adjusted equation C4 accordingly.

Table C7: Refund probabilities

Proability of claiming a refund upon withdrawal

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	100.0	61.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	100.0	60.3	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	100.0	54.4	38.8	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	100.0	52.9	31.9	31.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
45-49	100.0	48.5	22.0	15.0	15.0	10.0	0.0	0.0	0.0	0.0	0.0
50-54	100.0	26.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55-59	100.0	26.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60-64	100.0	26.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65-69	100.0	26.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70-74	100.0	26.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: Data is sourced from the various acturial valuations (FY 2017). Table is an employee weighted average over the 40 plans in sample.

Table C8: Retirement probabilities

Probability of retirement

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	0.0	0.1	0.1	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0
45-49	0.0	0.3	0.3	0.4	0.9	2.3	0.0	0.0	0.0	0.0	0.0
50-54	0.0	1.2	2.9	3.3	4.2	6.2	16.5	0.0	0.0	0.0	0.0
55-59	0.0	2.1	3.5	4.3	5.8	10.9	16.1	18.5	0.0	0.0	0.0
60-64	0.0	7.9	13.0	14.1	18.5	18.7	22.6	23.6	26.9	0.0	0.0
65-69	0.0	13.5	18.8	19.8	20.9	21.3	23.6	24.1	27.3	26.3	0.0
70-74	20.0	45.1	52.3	52.4	52.4	54.2	57.6	57.7	60.0	60.0	66.6

Note: Data is sourced from the various acturial valuations (FY 2017). Table is an employee weighted average over the 40 plans in sample.

Probability of retirement (new hires)

age/service	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
20-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30-34	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-44	0.0	0.1	0.1	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0
45-49	0.0	0.3	1.6	2.1	3.8	4.8	0.0	0.0	0.0	0.0	0.0
50-54	0.0	0.6	2.6	3.2	4.9	7.5	13.9	0.0	0.0	0.0	0.0
55-59	0.0	1.5	4.9	5.9	7.4	12.2	16.8	18.0	0.0	0.0	0.0
60-64	0.0	7.5	14.4	15.5	17.6	21.1	25.2	27.3	28.1	0.0	0.0
65-69	0.0	11.7	21.3	22.1	23.6	27.1	27.9	29.9	31.0	31.0	0.0
70-74	20.0	37.6	59.0	59.1	59.0	60.8	60.8	60.8	60.8	60.8	64.3

Note: Data is sourced from the various acturial valuations (FY 2017). Table is an employee weighted average over the 40 plans in sample.

We collect retirement probabilities for the current actives and new hires. These are different due to reforms such as to the normal retirement age or vesting periods. The probability of normal retirement is set to zero before the minimum retirement age and during the vesting period and 1 at age 75. As with the age and service distributions we used a linear regression to smooth and expand the matrices to a 55x55 matrix.

$$q_{a,s}^{ret} = \beta_0 + \beta_1 1_{a=r} + \beta_2 1_{a>=r} + \beta_3 s + \beta_4 s^2 + \beta_5 s^3 + \beta_6 a + \beta_7 a^2 + \beta_8 a^3 + \epsilon_{a,s} \qquad (C5)$$

Where r is the normal retirement age.

D. Demographic projection

To project the growth of the working-age population in each state, we use a variant of the methodology used by the Demographic Group at the Weldon Cooper Center for Public Service (www.demographics.coopercenter.org). The basic approach is to begin with the population by age group and state in 2010 from the U.S. Census and then to age that population going forward using historical state and national trends.

In particular, using the 1990, 2000, and 2010 censuses, we perform the following calculations for each state and for the country as a whole:

For children younger than 10 in state *j*: We calculate a "fertility rate" that captures the ratio of kids to women of childbearing age:

$$Fertility_{0-4,j} = \frac{Kids_{0-4,2010,j}}{Women_{15-44,2010,j}} \tag{22}$$

$$Fertility_{5-9,j} = \frac{Kids_{5-9,2010,j}}{Women_{20-49,2010,j}} \tag{23}$$

For individuals ages 10 to 65, we create a "survival" rate that captures both mortality and in- and out-migration in five year age groups. To better capture long-run trends, we use the average survival rates from the 2010 and 2000 censuses.

For example, for 20-24 year olds in state *j*, we calculate:

$$Survival_{20-24,j} = .5 * \frac{Population_{20-24,2010,j}}{Population_{10-14,2000,j}} + .5 * \frac{Population_{20-24,2000,j}}{Population_{10-14,1990,j}} \tag{24}$$

For states that are losing population to out-migration, there will be fewer 20-24 year olds in 2010 than there were 10-14 year olds in 2000, and survival will be less than one. For states that are gaining population because of in-migration, survival may be greater than one (depending on whether in-migration is large enough to offset losses due to mortality).

To project the population in 2030, for example, we take the population by 5-year age group by state in 2020 and multiply that by the survival rate for that age group to get an estimate of the population 10 years older in the next decade. Once we have aged the existing population so that we have projections of the population 10-65 in a given year, we then use the fertility rates described above to populate the states with children younger than 10.

Relative trends in population growth across states are assumed to have persistence, but are not permanent. Thus, we don't assume that states that have experienced out- or in-migration, experience it forever. We also assume that state fertility and survival rates converge to national averages over time. In particular, we assume that the future fertility and survival rates are a weighted average of the past rates for a particular state and the overall national average. For 2020, we put a weight of 80% on the state's historical rates and a weight of 20% on the national average, for 2030, we use weights of 50% each, and for 2040, we put a weight of 80% on the national average and 20% on the state.

Table B1:
List of State and Local Pension Plans in Estimation Sample

States	Pension Plan	Funding Ratio (%)	Unfunded Liability to Payroll	Contribution Rate (%)	Ratio of Active Employees to Beneficiaries	Employee Growth Rate (%)
AZ	Arizona SRS	70.5	1.6	22.4	1.4	0.9
AZ	Arizona State Corrections Officers	49.5	2.9	22.0	2.7	0.9
CA	California Teachers	62.6	3.4	32.4	1.5	0.6
CA	University of California	84.8	1.0	31.1	1.8	0.6
CA	San Diego City ERS	71.2	6.1	77.8	0.7	0.6
CA	LA County ERS	79.9	1.7	24.3	1.5	0.6
CA	San Diego County	77.4	2.7	44.0	1.0	0.6
CA	San Francisco City & County	86.3	1.1	26.8	1.1	0.6
DC	DC Teachers	92.5	0.4	20.4	1.3	2.0
FL	Florida RS	84.3	1.1	12.8	1.2	1.1
GA	Georgia ERS	74.7	1.7	26.0	1.2	0.6
GA	Georgia Teachers	74.2	2.2	20.9	1.8	0.6
IL	Illinois Municipal	92.9	0.4	18.2	1.4	-0.3
IL	Illinois SERS	35.5	7.2	48.9	0.8	-0.3
IL	Illinois Teachers	40.2	7.4	50.8	1.4	-0.3
IN	Indiana Teachers	48.1	3.1	30.9	1.2	0.0
LA	Louisiana Municipal Police	71.4	2.8	48.8	1.2	0.3
LA	Baton Rouge City Parish RS	67.9	3.8	40.6	0.8	0.3
LA	Louisiana SERS	63.7	3.7	45.3	0.8	0.3
MA	Massachusetts SRS	64.7	2.3	27.3	1.4	0.3
MA	Massachusetts Teachers	52.1	3.6	33.3	1.4	0.3
ME	Maine State and Teacher	80.9	1.4	25.4	1.1	-0.6
MI	Michigan Public Schools	61.6	3.6	34.4	0.9	-0.4
MO	Kansas City Missouri ERS	83.5	1.3	18.9	1.3	-0.1
MO	Missouri Teachers	84.0	1.5	30.2	1.2	-0.1
ND	North Dakota Teachers	63.7	2.1	25.9	1.3	1.1
NJ	New Jersey PERS	60.1	2.0	20.5	1.4	0.0
NJ	New Jersey Teachers	42.1	3.4	17.8	1.5	0.0
NM	New Mexico PERA	74.9	2.3	27.5	1.3	-0.2
NY	New York State Teachers	97.7	0.2	12.6	1.6	0.1
NY	NY State & Local ERS	94.4	0.4	17.2	1.2	0.1
OH	Ohio Teachers	75.1	2.1	26.1	1.1	-0.3
OK	Oklahoma Police	101.8	-0.1	31.0	1.3	0.5
OR	Oregon PERS	75.4	2.0	10.5	1.2	0.6
PA	Pennsylvania School Employees	56.3	3.4	37.2	1.1	-0.3
PA	Pennsylvania State ERS	59.4	3.1	36.4	0.8	-0.3
RI	Rhode Island Municipal	78.6	1.2	20.8	1.4	-0.4
SC	South Carolina RS	56.3	2.5	23.2	1.4	0.7
SC	South Carolina Police	63.0	2.1	25.3	1.5	0.7
TX	Texas Teachers	80.5	0.8	15.3	2.1	1.4

Note:
This table lists the pension plans in the estimation sample. Funding ratio is the ratio of GASB stated assets to liabilities. Contribution rate is the ratio of total contributions, employer and employee, to current payroll (FY2017).

Table B2: Summary of Plan Inputs

Variable	Min	Mean	Max	Total
GASB liability ($bn)	1	58	287	2,314
GASB assets ($bn)	1	41	180	1,652
GASB discount rate	6.5%	7.3%	8%	–
Plan benefit factor	1.1%	2.2%	3.3%	–
Plan benefit factor for new hires	0.2%	2%	3%	–
Cost of living adjustment	0%	1.5%	3%	–
Wage inflation	1.2%	3.2%	4.2%	–
FY 2017 payroll ($bn)	0.1	8.1	43.2	325.3
Number of active employees	3,047	144,013	864,261	5,760,526
Number of deferred inactive employees	0	18,217	108,612	728,667
Number of current beneficiaries	2,400	106,716	436,243	4,268,628
Average annual salary	40,597	58,667.2	96,900	–
Average annual benefit	15,929	30,489.9	51,132	–
Actuarially required contribution rate	7.7%	22.2%	62.7%	–
Current rate of employee contributions	0%	7.3%	15.5%	–
Current rate of employer contributions	5.8%	19.6%	63.1%	–
Total contribution rate	10.5%	28.9%	77.8%	–
Percent of active employees that are male	22.4%	40.3%	76.5%	–
Average age of current beneficiaries	60.2	70.3	73.5	–
Normal retirement age	50	61	65	–
Normal retirement age (new hires)	50	63.7	68	–
Assumed percent of active employees that are married	55%	80%	100%	–
Joint annuity reduction factor	37.8%	54.3%	100%	–
Percent reduction per year for early retirement	2%	5.5%	10%	–
Growth rate of active employees (yrs 0-20)	-0.8%	0.2%	2.1%	–
Growth rate of active employees (yrs 21-30)	-0.9%	0.1%	1.7%	–
Growth rate of active employees (yrs 31-40)	-0.3%	0.4%	1.9%	–
Growth rate of active employees (yrs 40+)	0.4%	0.4%	0.8%	–
Number of years until vested in plan	1	7	12	–
Cost of living adjustment (new hires)	0%	1%	3%	–
Number of years until vested (new hires)	1	8	16	–
GASB liability ($bn) for current beneficiaries	0.8	34.4	154.3	–
Inflation percentage	1.9%	2.7%	3.5%	–
Number of years salary is averaged in final salary calculation	1	3	5	–
Number of years salary is averaged in final salary calculation (new hires)	2	4	8	–
Plan normal cost	4.7%	14.6%	26.9%	–

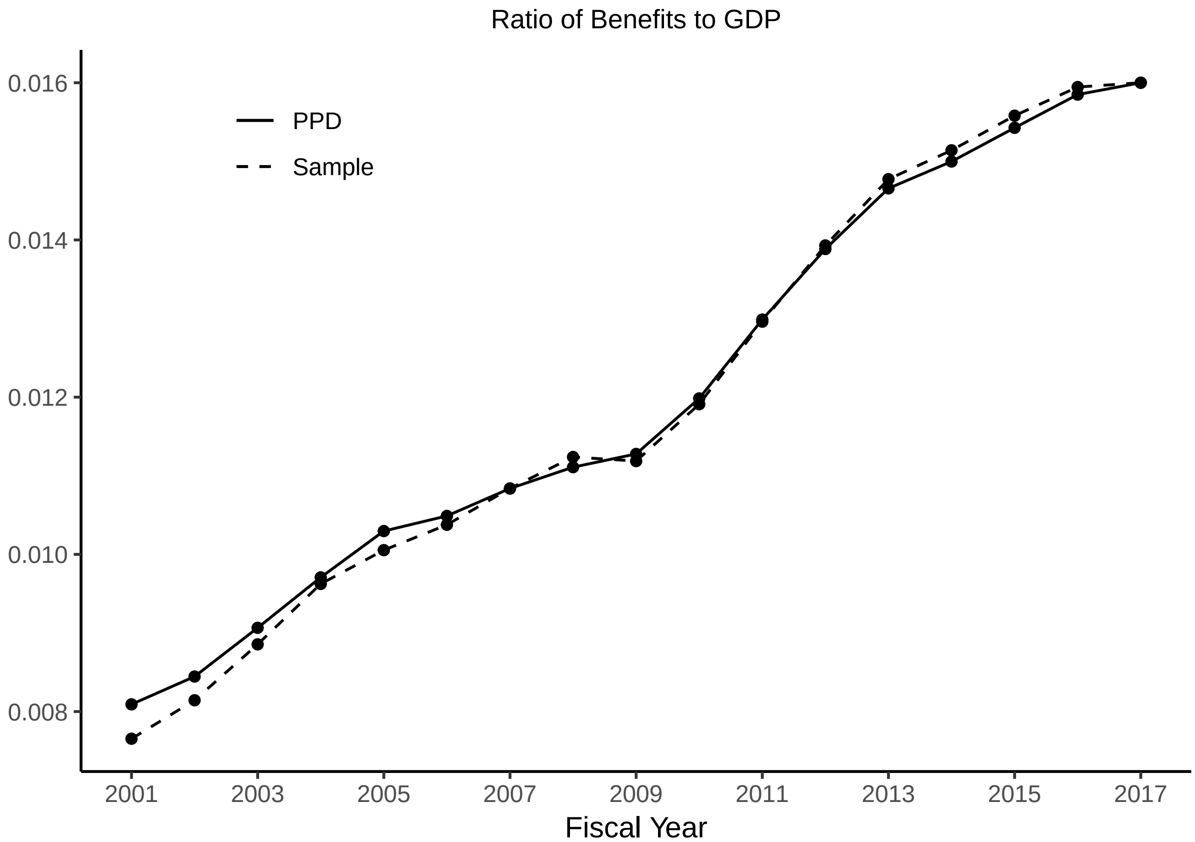
Note:
This table summarizes the input variables utilised in the calculation of the plan level cashflow and liability using the plans stated actuarial assumptions. The data is sourced from the AVs and the Bostong College PPD database.

Table B3:
Replication Errors and Calibration Factors

State	Pension Plan	Uncalibrated Liability Error (%)	Calibration factors (v)		
			$vc1$	$vc2$	$vc3$
AZ	Arizona SRS	-1.6	1.183	0.668	0.995
AZ	Arizona State Corrections Officers	-3	1.17	0.159	1.002
CA	California Teachers	-5	1.171	0.832	0.998
CA	University of California	22.6	0.883	0.326	0.998
CA	San Diego City ERS	-7.3	1.022	2.029	1.008
CA	LA County ERS	0.2	1.03	0.429	1.001
CA	San Diego County	7.5	1.088	0.283	0.995
CA	San Francisco City & County	5.8	1.029	0.177	1.003
DC	DC Teachers	-1.9	1.115	0.707	1.001
FL	Florida RS	3.3	0.997	0.63	0.997
GA	Georgia ERS	0.6	0.994	2.559	0.996
GA	Georgia Teachers	-5	1.107	–	1.002
IL	Illinois Municipal	-5.2	1.04	–	0.989
IL	Illinois SERS	-6.4	1.181	0.745	1.003
IL	Illinois Teachers	-5.9	1.183	0.792	1.003
IN	Indiana Teachers	-12.2	1.173	–	1.014
LA	Louisiana Municipal Police	-4.9	1.075	1.836	1.003
LA	Baton Rouge City Parish RS	-10.3	1.196	1.089	1.009
LA	Louisiana SERS	-9	1.096	1.341	1.012
MA	Massachusetts SRS	-9.5	1.3	2.22	0.996
MA	Massachusetts Teachers	0.1	1.07	–	0.994
ME	Maine State and Teacher	3.4	1.044	1.109	0.989
MI	Michigan Public Schools	5.5	1.197	1.987	0.98
MO	Kansas City Missouri ERS	-2.4	0.9	–	1.016
MO	Missouri Teachers	0.4	1.115	0.135	0.996
ND	North Dakota Teachers	-2.2	1.12	0.867	0.996
NJ	New Jersey PERS	3.3	0.898	4.091	1.003
NJ	New Jersey Teachers	-5.1	1.078	1.639	1.006
NM	New Mexico PERA	-4.1	1.111	0.79	1.003
NY	New York State Teachers	26.6	0.727	0.394	0.979
NY	NY State & Local ERS	-2.6	1.014	1.254	1.004
OH	Ohio Teachers	6.8	0.754	0.437	1.006
OK	Oklahoma Police	8.3	0.909	0.836	0.993
OR	Oregon PERS	-3.8	0.922	1.29	1.009
PA	Pennsylvania School Employees	-4.7	1.153	0.974	0.998
PA	Pennsylvania State ERS	-7.8	1.338	–	0.993
RI	Rhode Island Municipal	-2.4	0.858	–	1.022
SC	South Carolina RS	1.5	0.988	0.906	0.998
SC	South Carolina Police	3.8	1.016	0.936	0.992
TX	Texas Teachers	-2.9	1.068	0.706	1.003
US	Total	0.1	1.06	0.825	0.999

Note:
This table illustrates the accuracy of our replication and cashflows for each plan. The total values are weighted by total liability, active liability, inactive liability, and retired liability respectively.

Appendix Figure B1



Note: The figure displays the ratio of pension benefits to GDP. Pension benefits are obtained from the PPD. The dashed line displays the ratio for the estimation sample used in the paper; the solid line displays the ratio for the entire PPD sample.