Brookings Papers
ON ECONOMIC ACTIVITY

BPEA Conference Drafts, March 25, 2021

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Conflict of Interest Disclosure: Byron Lutz is a board member of the National Tax Association. The authors did not receive financial support from any firm or person for this article or from any firm or person with a financial or political interest in this paper. Other than the aforementioned, they are currently not officers, directors, or board members of any organization with an interest in this paper.

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March 12, 2021

Lorena Hernandez Barcena, Jeffrey Cheng, and Manny Prunty provided excellent research assistance. We are particularly grateful to Lorena, who picked up this project mid-way through and got up to speed incredibly quickly. We thank the Center for Retirement Research at Boston College for producing and publicly providing the Public Plans Database which we make significant use of in this paper. We thank Thomas Aaron, Bob Costrell, Ngoc Dao, Greg Duffee, Trevor S. Gallen, Tracy Gordon, Erald Kolasi, Adam Looney, Martin Luby, Deborah Lucas, Robert L. McDonald, Josh McGee, Therese McGuire, Derek Messacar, Jim Poterba, Jonathan Pycroft, Laura Quinby, Joshua Rauh, Kim Rueben, Brian Septon, Juan Carlos Suarez Serrato, David Stemerman, and Tom Terry for helpful comments and suggestions; we particularly thank Jean-Pierre Aubry of the Center for Retirement Research at Boston College for his generosity in terms of sharing his extensive knowledge of state and local pension plan modeling and the pension landscape more broadly. We thank conference and seminar participants at Public Finance Conference (U. of Illinois-Chicago), Boston Federal Reserve, U-Taxi Conference (University of Utah), National Tax Association 2019 Spring Symposium, Brookings Municipal Finance Conference, International Institute of Public Finance Annual Congress, Urban-Brookings Tax Policy Center, 2019 Public Pension Funding Forum (National Conference on Public Employee Retirement Systems), MIT Golub Center for Finance and Policy Annual Conference, Society of Municipal Analysts Conference, University of Chicago Policy Forum, National Tax Association 2019 Annual Conference, Northwestern University, Invitational Seminar on Pensions (National Conference of State Legislators), and NETSPAR International Pension Workshop.

*This paper should not be reported as representing the views of the Bank of England or members of the Monetary Policy Committee, Financial Policy Committee, or Prudential Regulation Authority Board.

**The analysis and conclusions reached in the paper are the authors' alone and do not indicate concurrence by the Board of Governors of the Federal Reserve.

Abstract

In this paper we explore the fiscal sustainability of U.S. state and local government pensions plans. Specifically, we examine if under current benefit and funding policies state and local pension plans will ever become insolvent, and, if so, when. We then examine the fiscal cost of stabilizing pension debt as a share of the economy and examine the cost associated with delaying such stabilization into the future. We find that, despite the projected increase in the ratio of beneficiaries to workers as a result of population aging, state and local government pension benefit payments as a share of the economy are currently near their peak and will eventually decline significantly. This previously undocumented pattern reflects the significant reforms enacted by many plans which lower benefits for new hires and cost-of-living adjustments often set beneath the expected pace of inflation. Under low or moderate asset return assumptions, we find that few plans are likely to exhaust their assets over the next few decades. Nonetheless, under these asset returns plans are currently not sustainable as pension debt is set to rise indefinitely; plans will therefore need to take action to reach sustainability. But the required fiscal adjustments are generally moderate in size and in all cases are substantially lower than the adjustments required under the typical full prefunding benchmark. We also find generally modest returns, if any, to starting this stabilization process now versus a decade in the future. Of course, there is significant heterogeneity with some plans requiring very large increases to stabilize their pension debt.

I. Introduction

State and local government pension plans are important economic institutions in the United States. They hold nearly $5 trillion in assets; their annual benefit payments to beneficiaries are equal to about 1½ percent of national GDP; over 11 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 study 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 pension 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, failure to prefund does not necessarily imply future fiscal costs, a corollary to the idea that public debt may have no fiscal cost in low interest rate environments (e.g. Blanchard 2019).

This paper focuses on state and local government pension systems as we find them today—i.e. partially prefunded and therefore also partially pay-as-you-go — and asks 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 project the annual cash flows of state and local pensions benefits. We find that pension benefit payments in the US, as a share of the economy, are currently near their peak 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 a new and important finding in terms of the fiscal stability of these plans as it indicates that the cash flow pressures they currently face will eventually recede.

In terms of sustainability, we find that under low or moderate real asset return assumptions (0% and 2.5%) and a risk free real discount rate (0%), in aggregate for the U.S. as a whole, state and

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[1] Commentary from academics include the claim that "the threat of default looms" for public pensions (Shoag and Farrell 2017), the statement that these pensions have failed to "provide economic security in old age in a financially sustainable way" (Novy-Marx and Rauh 2014b), 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).

local pensions are not currently sustainable in the sense that pension debt as a share of the economy is set to rise indefinitely. That said, pension debt can generally be stabilized with relatively moderate fiscal adjustments – a conclusion which broadly holds across scenarios in which governments act to stabilize pension debt over the long run, medium run, and immediately. In some exercises, though, under low asset returns, required adjustments are larger. But in all cases, the required adjustments are much smaller than those required to achieve full funding over 30 years. 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 significantly when the start of the stabilization process is pushed ten years out. Overall, while achieving fiscal stability will require adjustments, our results suggest there is no imminent "crisis" for most public pension plans.

Of course, there is significant heterogeneity across plans, with some plans requiring large contribution increases to achieve stability. That said, the plans that require the largest adjustments are not particularly those that are the least funded, reflecting the fact that our focus is on debt stabilization, not full funding. Of course, one might suspect that the least well-funded plans got that way by failing to make sufficient contributions and by ignoring looming imbalances. But we find that many of the most poorly funded plans have in recent years undertaken the largest reforms and increased contribution rates the most; in so doing, many of these poorly funded plans have already made significant progress toward stabilizing their pension debt. Overall, we find that plans that have not undertaken many reforms and that face the largest projected future increases in the ratio of beneficiaries to workers are the ones that need to make the largest adjustments to be sustainable.

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 and when. Failure to fully prefund, in isolation, need not spark a crisis. Second, it is consistent with history; in aggregate, these plans have always operated far short of full prefunding. Third, full prefunding is not necessarily welfare enhancing, as we discuss below.

In terms of methodology, we reverse engineer the future stream of pension benefit payments using the method pioneered by Novy-Marx and Rauh (2011) and also used in Lutz and Sheiner (2014). We use these projected cash flows, in conjunction with economic and demographic assumptions, to analyze the future evolution of each plan's pension debt. We employ this methodology on a sample of 40 state and local pension systems which matches the national distribution of plans in terms of both mean and variance for multiple plan characteristics – e.g. the funding ratio.

Our findings have significant policy relevance beyond directly addressing the sustainability of public pension plans. 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 prior to the Covid-19 pandemic, provision of the core public goods provided by these governments remained depressed: real per-capita spending on infrastructure stood around 25 percent below its previous peak and state and local government employment per capita also remained well below its previous peak. Notably, much of this relative decline in state and local government employment occurred in the K-12 and higher education sectors. Thus, while pension contributions had been rising at a rapid clip, core investments in education and infrastructure were lagging.

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 describes the data and sample selection, section IV outlines our methodology, section V presents the results on pension sustainability under current funding levels and benefit parameters, section VI presents the results on the contribution changes required to stabilize pension debt, and section VII 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 riskiness of the future stream of payment, which depends on the probability that the payments will be honored, among other factors. 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,

[2] The precise discount rate that should be used remains subject to debate, with some arguing for a risk-free rate (e.g. J. Brown and Wilcox 2009; Novy-Marx and Rauh 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).

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 percent pre-funded. Panel B displays similar calculations using a more appropriate 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 percent pre-funding and averaged 55 percent 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 always operated well short of full prefunding. Moreover, the heavy emphasis on full prefunding in discussions of state and local pensions is a relatively recent development. As recently as 2008, many analysts considered a funding ratio of 80 percent to be "sound" practice (Government Accountability Office 2008).

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 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 (J. R. Brown, Clark, and Rauh 2011). In terms of fiscal sustainability, an unfunded PAYGO pension systems—such as the U.S. Social Security system[3]—can be fiscally sustainable in the sense that it requires no outside funding. In particular, a fully unfunded PAYGO system can honor obligations without recourse to outside funding as long as the internal rate of return paid to beneficiaries does not exceed the growth rate of the wage base, equal to working-age population growth plus productivity growth (Samuelson 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. Mature, partially funded systems—which combine partial prefunding with

[3] Although the Social Security system holds assets in an accounting trust fund, it is most accurately described as an unfunded PAYGO system (Feldstein and Liebman 2002).

partial PAYGO —can remain sustainable even in the face of adverse shocks, as accumulated assets provide a buffer.[4] State and local pension plans fall into this partially prefunded category.[5]

More broadly, governments typically hold debt, and unfunded pension liabilities are simply a form of (implicit) debt. Such public debt can be sustainable so long as the government makes appropriate service payments on it.

Pension debt stability when the growth rate of the economy and the interest rate are constant is illustrated by the following identity[6]:

$$c_t = nc_t + \frac{(r-g)}{(1+g)} d \tag{1}$$

where c_t is the pension contribution as a share of the GDP required to keep the share of implicit pension debt to GDP ($d = d_t = d_{t-1}$) stable, nc_t is the normal cost – the liability accrued in period *t* for current employees' future pension benefits – as a share of GDP, *g* is the rate of GDP growth, and *r* is the interest rate. When the rate of interest is greater than the growth rate of the economy, *r*>*g*, contributions have to be sufficient to cover the normal cost and the service costs on the implicit debt in order for the implicit debt to be stable as a share of GDP. A plan that makes this level of required contributions will be stable even if it is less than fully funded. Thus, full funding is not required in order for pensions to be fully able to meet their obligations.

An important element of the pension sustainability equation is the dependence on *r*-*g*. 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. In other words, under these conditions, being unfunded doesn't pose any costs on future taxpayers. If *r*<*g*, then implicit debt can be held constant as a share of the economy with contributions less than the normal cost. This is, of course, simply a restatement of the notion that when *r*=*g*, debt may not entail future fiscal costs, in the sense that it can be rolled over indefinitely without any adjustments to taxes or expenditures (Blanchard 2019; Elmendorf and Sheiner 2017; and Furman and Summers 2019).

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[4] 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 partially prefunded system to a fully prefunded system (Geanakoplos and Zeldes 2009). The desirability of such a transition is an open question and would depend importantly on interest rates and the growth rate of the economy.

[5] In rare instances state and local pension plans operate on a strictly pay-as-you-go basis – e.g. the fire and police pension plan in Portland, Oregon.

[6] This follows from: $d_t = \frac{D_t}{Y_t} = \frac{L_t - A_t}{Y_t} = \frac{L_{t-1}(1+r)+NC_t - B_t}{Y_{t-1}(1+g)} - \frac{A_{t-1}(1+r)+ C_t - B_t}{Y_{t-1}(1+g)} = \frac{d_{t-1}(1+r)}{(1+g)} + nc_t - c_t$, where D_t is the level of the implicit pension debt and C_t, B_t, NC_t, Y_t are the nominal period *t* levels of the annual pension contribution (from both the government and workers), benefit payment, normal cost, and GDP, respectively, and L_t and A_t are liabilities and assets, respectively, at time *t*. Setting $d_t = d_{t-1}$ and solving for c_t yields equation (1). Here we have assumed that assets and liabilities are subject to the same interest rate *r*, an assumption that is relaxed in section *VI* and in some of our projections.

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 unsustainable.

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).[7] Furthermore, to the extent that state and local government expenditures are investments (e.g. schooling) rather than consumption, borrowing is appropriate as the benefits from that spending accrue in the future (Sheiner Forthcoming). 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 (Bagchi 2017; 2019; Glaeser and Ponzetto 2014); unfunded pensions may lower the capital stock (Feldstein 1974).

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 2014a). 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 stabilizing a plan's current pension debt. 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.

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[7] 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.

Boyd, Chen, and Yin (2019), Boyd and Yin (2016b, 2017, 2019) 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. All 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. 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. 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 its current level. Finally, Costrell and McGee (2020) point out that the deterministic approach taken in this paper understates the risk of plan insolvency. Although beyond the scope of the current paper, we acknowledge this as a valid point and aim to address it in future work.

III. Data and Sample Selection

III.A Data

We obtain data from multiple sources on pension plans as of fiscal year 2017. A principle source is the Public Plans Database (henceforth PPD) maintained by the Center for Retirement Research at Boston College (PPD 2017) . The PPD data contains plan-level data, accounting 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 plan's liabilities and benefit 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) Termination rates by age and service[8], (7) retirement rates by age and service and plan tier.

[8] Includes all non-mortality and disability related causes of employment termination.

The AVs and CAFRs provide further critical information relating to plan provisions and actuarial assumptions not available in the PPD: the plan benefit factor[9], normal retirement age, early retirement age, service requirement, vesting requirement, salary averaging method[10], penalty factor for early retirement (percent reduction per year early), plan marriage and spousal benefit assumptions, gender ratio of the active employee 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.) Finally, mortality assumptions are from the Society of Actuaries (SOA).[11]

III.B 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 in Table 1, our sample of plans matches the national PPD sample of plans well, both in terms of means and standard deviation; this holds for both unweighted and weighted samples.[12] Our targeting of the second moment of the plan characteristics yields a sample that includes plans with a relatively strong prefunding position, as well as those with a relatively weak prefunding 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

[9] 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.

[10] The number of years salaries are averaged over when determining the retirement benefits; typically the highest three or five.

[11] 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.

[12] 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 of 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.

rate). It also includes the State Retirement Systems of Illinois and the New Jersey Teachers' Pension and Annuity Fund, which have a ratio of assets to liabilities of roughly 40 percent, respectively, using the plan's assumptions. 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. Table B2 summarizes the inputs for each plan. Finally, as shown in Appendix Figure B2, 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.—over 6,000 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 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), on the other hand, have a significantly larger sample of 116 plans.[13] The different approaches reflect the different aims of the respective papers: ours to estimate the future benefit streams as accurately 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 stages:

(1) Current Worker and Beneficiary Cash Flows: We reverse engineer the future flow of benefit payments to current workers and beneficiaries using plan-specific data and assumptions and the methodology developed by Novy-Marx and Rauh (2011). We use calibration factors to ensure that these cashflows replicate the stated liabilities in the relevant actuarial reports. We then re-estimate these cash flows using our own, uniform across plans, economic assumptions.

(2) New Worker Cash Flows: We project future plan membership growth and then use our economic assumptions and plan-specific benefit parameters to estimate benefits for future workers using the same methodology as used for current workers.

[13] Subsequent works by these authors have even larger sample sizes; e.g. Novy-Marx and Rauh 2014a has a sample of 193 plans.

(3) Estimate sustainability: Finally, we pair the benefit cash flow projections with information on plan assets and our own assumption for discount rates and asset returns to assess the fiscal stability of each plan.

IV.A Estimating Cash Flows for Current Workers and Beneficiaries

To construct the cash flows for current beneficiaries and workers, we first collect the data, inputs, and actuarial assumptions discussed in section III for each plan. For current beneficiaries, we then use the mortality tables to age the initial distribution of the beneficiaries each year and use the information on current beneficiaries' pension benefits by age to calculate annual benefit payments. For current workers, we age the workforce each year (incrementing years of service and age) and use the probabilities of retirement, disability, death, and quits/termination by age and years of service to create a matrix of new beneficiaries by year. We then use the information on pension eligibility, benefit formulas, and economic assumptions to calculate the pension obligations for future beneficiaries by year. These benefit formulas vary by plan tier to capture the effects of reforms implemented between cohorts of active workers.

In order to ensure our projections are as accurate as possible we calibrate our projected cashflows such that they produce each plan's stated actuarial liabilities (AL)—the present discounted value of projected future pension benefits earned to date—as reported in their actuarial valuations. We calibrate separately for current workers, current inactives (individuals who are no longer employees, but remain eligible for pensions in the future), and current retirees.

Although these procedures are conceptually quite straightforward, the actual implementation is substantially more complex. Indeed, the challenging and time-consuming nature of the reverse engineering methodology has almost certainly inhibited research on state and local pensions.[16] Our specific procedures for calculating liabilities, which generally follow Winkelvoss 1993 and our calibration methods, are presented in detail in Appendix Section A. Our uncalibrated estimates were on average quite accurate so the calibration process does not have a large effect on our analysis (see Appendix Table B3).

Finally, we then re-estimate the future benefit flows using our own economic assumptions. We assume the same rates of change of overall nominal wage growth (3.4 percent) and CPI inflation (2.2 percent) for every plan.[14]

[14] These assumptions are consistent with productivity growth of 1.4 percent and a GDP deflator of 2 percent. Our assumption of 2.2 percent annual inflation, as measured in the CPI, is consistent with the Federal Open Market Committee's (FOMC) 2 percent inflation target which pertains to the PCE price index. CPI inflation tends to systematically run above consumer inflations as measured by the PCE price index (e.g. Haubrich and Millington 2014).

IV.B Methodology for Estimating Benefits for New Hires

In order to study the fiscal stability of each plan we also need to estimate benefit cash flows associated with hires made after 2017. New hires in year t (nh_t) are set equal to the previous year's headcount (ee_{t-1}) multiplied by the sum of the projected growth rate in the government's workforce (n_t) and the proportion of withdrawals/retirements from the workforce in the previous year (q_{t-1}).

$$nh_t = ee_{t-1}(n_t + q_{t-1}) \tag{6}$$

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 the government workforce to the working-age population remains constant. We further assume that the age distribution and relative salaries of new hires match the distribution of current employees with fewer than 5 years of service. Each group of new hires then produces a new stream of benefits starting at each future year, 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 employ a variant of the methodology used by the Demographic Group at the University of Virginia Weldon Cooper Center for Public Service. This methodology projects population by age bins using trends in fertility, and in and out migration by state. Our implementation assumes that state population growth eventually converges to the national average—we don't allow states to lose population over the long-run, but we do over the medium run in keeping with past trends. In order to calculate state labor force growth rates, we multiply the working age population in each state by age group by the projected national labor force participation rates by age in the CBO's longer-term budget projection.[15] See Appendix Section D for details. Finally, we calculate total cash flow streams for a given plan by summing the annual flows for beneficiaries, inactive, actives and new hires.

IV.C Methodology for determining current assets

We use data on plan rules and demographics from fiscal year 2017 and project benefit flows forward from that point. However, there have been significant changes in asset values and interest rates since 2017. Accordingly, we update each plan's asset valuation to the end of fiscal 2021 and also base our asset return and discount rate assumptions on financial market data from early calendar year 2021.

[15] 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.

We update the market value of plan assets using the plan's most recent financial report (fiscal year 2019 for most plans and fiscal year 2020 for some plans). Then, to calculate rates of return since the last observed asset valuation to the present (February 12, 2021), we use the asset allocations in the financial reports matched to market rates of return on appropriate indexes.[16] Finally, we use the assumed general asset rate of return—see section *IV.D*—to grow assets from the present to the end of the 2021 fiscal year. On average, we calculate that plan assets will have increased 23 percent since the end of fiscal 2017.

IV.D Asset Returns and Discount Rates

Asset returns: In order to calculate asset exhaustion dates it is necessary to assume a rate of return on plan assets. The rates of return assumed by plans is typically the expected value of returns on the plan's portfolio of assets. 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 and, if so, what that rate should be. 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; Marron 2014).[17] Official estimates of the costs of federal loan programs are not risk adjusted, but CBO's preferred measure, which they call Fair Value, is. CBO produces budget scores using both methods.[18]

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 receive on a risky asset and the cash flows they would receive if the fund invested in safe assets like Treasuries.

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[16] We use eight asset classes (and accompanying indexes): Cash, Commodities (Bloomberg Commodity Index), Domestic Equities (Russell 3000 Index), International Equities (MSCI All Country World Ex-US Index), Fixed Income (Bloomberg Barclays Aggregate Bond Index), Hedge Funds (HFRI Fund of Funds Composite Index), Private Equities (State Street Private Equity Index), and Real Estate (NCREIF Property Index). Indexes were chosen based on the most popular index targets reported in the Boston College PPD for our sample of pension plans.

[17] 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.

[18] The Federal Reform Credit Act of 1990 (FCRA) requires that credit programs be scored by calculating the net present values of loans or guarantees over time, rather than the expected annual cash flows. For a discussion of the pros and cons of risk-adjusting, see Sastry and Sheiner (2015).

However, there are reasons to question whether the market rate of return on safe assets is the appropriate risk-free rate. First, the wedge between the return on Treasuries and riskier investments doesn't only represent risk—it also includes a convenience yield, reflecting the liquidity value of Treasuries and their usefulness as collateral, among other things. Krishnamurthy and Vissing-Jorgensen (2012) estimate that the convenience yield averaged 73 basis points between 1926 and 2008. Using a different methodology, van Binsbergen, Diamond, and Grotteria (2019) estimate a convenience yield of 40 basis points, on average, but note that it is higher in times of financial stress (presumably like now). Second, as noted by Falkenheim (2021), to the extent the risk premium reflects business cycle risk, the government can lower that risk by spreading it across future generations. If the amount of intergenerational risk spreading is less than optimal, then the market risk premium is overstating the cost of risk when borne by the government (and hence future taxpayers). Relatedly, as noted by Sastry and Sheiner (2015), there are benefits to government holding assets that perform well in good times and poorly in bad. If private investors react to temporarily low returns by reducing consumption, but government does not, then government ownership of risky assets may lessen the severity of economic downturns. In that case, taxpayers likely would not be indifferent between pension plans holding Treasuries and risky assets.

It is also unclear whether the cash flows in budget projections *should* be risk adjusted. Certainly that is not standard practice. For example, the Congressional Budget Office projects expected revenues and expenditures over time, even though those cash flows are risky. (Consider the fact that taxes on capital income are a form of asset ownership.) Using market-based prices to risk adjust the cash flows would lead to much larger deficits and debt. But the goal of stabilizing the federal debt using CBO's non-risk adjusted projections is widely accepted, even though it leaves future generations with more risk. An equivalent exercise for the state and local sector would therefore use expected cash flows, rather than risk-adjusted ones. Of course, it is probably true that state and local governments are less able to bear risk than is the federal government. Finally, 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 percent, but we assume a return of 2 percent, then we will, on average, underpredict investment returns and overpredict asset exhaustion.

The issue of risk adjustment in government accounting is an important one, but settling it is well beyond the scope of this paper. Accordingly, we present our estimates using a variety of real (inflation-adjusted) long-run rates of return on the pension assets: two measures of the risk-free rate—the current market rate of 0 percent real return and CBO's projected path for rates on Treasuries—a real return of 2.5 percent, and a real return of 5 percent.

The 0% real rate of return is roughly equal to the current longer-run risk-free rate (putting aside the issue discussed immediately above). Thus, it represents the rate or return that pension plans can achieve with certainty today, based on financial market prices in recent years – i.e. it is the risk-adjusted or risk-neutral rate of return. We obtain the risk-free rate from the yield on the zero coupon 20-year Treasury Inflation Projected Securities (TIPS).[19] As an alternative to the current market risk-free rate, we also present risk-free return results using the CBO's projected path for the real return on 10-year Treasuries. That path increases over time as interest rates normalize from their historically extremely low level and as the federal debt increases over time; it reaches 0.9 percent by 2030 and 2.5 percent by 2049, after which we assume it holds constant (CBO 2020).

The 5% return reflects the 0 percent safe rate plus an equity (or risk) premium of 5 percent.[20] This rate can be viewed as the expected return on a portfolio of risky pension plan assets; it is equal to about what the plans are, on average, assuming and slightly less than what they have received on their assets, on average, over the past 15 years. The 2.5% rate of return represents a middle ground between these rates equivalent to a mixed portfolio containing. An alternative interpretation of these asset return assumptions is to view them as capturing realized asset returns in different future states of the world.[21]

Discount rate: In all cases we discount plan liabilities using the 0% real risk-free rate. This assumption implicitly defines the liability as the amount one would have to pay a private investor to take on the risk. It incorporates the assumption that pension obligations will be paid out in full in nearly all future states of the world and that the value of the payouts (which depends on wages) are uncorrelated with the state of the economy. Neither of these conditions is likely to be strictly true; thus we view this as a conservative assumption.[22] In any case, as we explain below, our results are not very sensitive to the chosen discount rate because we are focusing on stability of the implicit debt, rather than its level. That said, exercises that calculate what is required for plans to be fully funded are very sensitive to this assumption.

V. Results under Current Funding Levels and Benefit Parameters

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 under current funding and benefit parameters in order to determine which plans are currently fiscally sustainable. We

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[19] The yield on the zero coupon 20-year TIPS equaled -0.3 percent on February 12, 2021 – the same date used to obtain financial market data with which to adjust pension plan assets to current values. Taking a slightly longer horizon, the average 20-year TIPS yield from the start of 2020 through February 12 of this year was a similar -0.2. Data based on methodology of Gurkaynak, Sack, and Wright (2008) and obtained at https://www.federalreserve.gov/data/yield-curve-tables/feds200805.csv.

[20] We view the 5 percent equity premium assumption as relatively conservative. Duarte and Rosa (2015) estimate that the equity premium has exceeded 10 percent in the years following the Great Recession; Mehra and Prescott (2003) estimate an equity premium of around 7 percent 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 percent in both the 1960-2018 period and in 2018; and Novy-Marx and Rauh (2014a) and Novy-Marx and Rauh (2011) use an equity premium of 6.5 percent 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 percent in the second half of the 20th century.

[21] In future work we intend to analyze pension stability under stochastic asset returns.

[22] In particular, most pension plans have the legal ability to change the COLA even for existing retirees.

also estimate which plans are likely to exhaust their assets and when. We then explore different horizons over which governments could stabilize their pension debt as a share of their economies.

V.A. Pension benefit payments

Figure 4 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—the starting point for our simulation—beneficiaries are just current beneficiaries, but over time, current beneficiaries (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.

The ratio of beneficiaries to workers in state and local governments is projected to increase about 36 percent from 2017 to 2040 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 33 percent over this time period. We view this similarity as indicating that we have adequately modeled, in aggregate, the future flow of state and local government employees.

Figure 5 shows the annual benefit payments as a share of GDP for the plans in our sample in aggregate, which we refer to as 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 benefit payments were approximately 1.6 percent of GDP. Strikingly Figure 5 indicates benefits are already nearing their peak, rising only about 6 percent over the next 10 years before declining and settling at a level of around 1.4 percent of GDP (14 percent lower). This pattern is surprising given the pattern of aging described above. For social security, for example, benefits relative to GDP are projected to rise 28 percent between 2017 and 2040, and then remain roughly constant thereafter.

What explains these surprising results? If the ratio of beneficiaries to workers is increasing, why isn't the ratio of benefits to GDP? 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. Specifically, since 2007, 12 plans in our sample have legislated changes making their COLA less generous or even eliminating it. A further 5 plans have been able to lower their COLA by reducing or eliminating supplemental or ad hoc COLAs.[23] 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

[23] Fitzpatrick and Goda 2020 note that, because new worker reforms take time to yield budgetary savings, many state and local pension plans have turned to COLA adjustments to address funding concerns. They also document that most COLA adjustments in recent years have been downward adjustments.

benefits over time. The reduced growth in average benefits due to the new hire reforms and COLA adjustments offsets a large share of the effects of the 37 percent growth in the ratio of beneficiaries to workers shown above.

Figure 6 again presents our baseline estimate for benefits payments as a share of GDP (black line), as well as 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 12 percent below where we project them when the current COLAs are maintained, and about 23 percent 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 18 percent, much closer to the 25 percent projected rise in Social Security benefits described above. Clearly, COLAs have a significant impact on benefit flows as a share of the economy. 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 12.5 percent over time, the ratio of benefits to GDP would stabilize at a about the same ratio as today.[24]

Finally, the orange line displays the path of benefits to GDP when both the new worker reforms are eliminated and COLAs are set equal to inflation. In this scenario, benefits as a share of the economy are projected to rise 20 percent between 2017 and 2040– similar to the 28 percent increase projected for social security. Thus, new worker reforms and COLAs explain the majority of the more muted rise in state and local pension benefits compared to social security.

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.[25]

[24] This analysis assumes that these new worker reforms remain in place going forward. Of course, there is a possibility that some of these reforms may be revoked or altered. For instance, the 2010 "tier II" reform instituted for state administered plans in Illinois has been widely criticized for creating a very significant disparity in benefit generosity for employees hired before and after 2011. Moreover, it is possible that the reform may eventually run afoul of federal law (Bruno, Kass, and Merriman 2019).

[25] Other possible explanations for the reduced growth in average benefits, other than changes in COLAs and new worker reforms, include 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

To determine whether plans are fiscally sustainable, we hold the annual contributions of employees and employers (as a share of payroll) fixed at today's level assume that benefits evolve as described in Figure 5. We view this as performing a "current policy" analysis, akin to the current law baselined used by CBO in its projections for the federal budget.[26] Figure 7 shows the path of pension assets in this current policy analysis under our four asset return assumptions. With the 0% and CBO risk-free real rates 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. With a 2.5% rate of return, assets are declining, but not as quickly; they are exhausted in 45 years. If, however, the plans earn 5% on their assets, then plans are stable: At current contribution rates, assets rise indefinitely and the plans face no fiscal stress (indeed, one would argue that current contribution rates are too high, if one could count on a 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 0% real rate of return. For this scenario, the New Jersey Teachers plan would be in trouble—they would fully exhaust their assets in 12 years.[27] The New Jersey Public Employees' Retirement System would be able to stay afloat for 20 years. Results using the CBO interest rate path are broadly similar. With a 2.5% real return, the New Jersey Teachers Plan is still in trouble—their assets would exhaust in 13 years, but most plans wouldn't hit the exhaustion date until far into the future or not at all. With a 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 8 shows what share of liabilities are in plans that exhaust within various time periods. With a 0% rate of return, about 25 percent of liabilities are in plans that are exhausted within 20 years, and about 50 percent of liabilities are in plans that exhaust only after 30 years or never. At a 2.5% return, over 70 percent of plans never exhaust or exhaust only after 30 years. With a 5% discount rate, over 90 percent of plans are in fine shape, whereas the other plans (apart from New Jersey) do exhaust, but not for many decades.

[26] More precisely, we hold contributions as a share of GDP fixed at its current value for each plan tier. Some plans have employee contribution rates that differ by tier. For these plans, as the composition of the workforce shifts over time away from the tier(s) for longer-tenured employees and toward the tier(s) for shorter-tenured employees, the overall plan contribution rate will shift.

[27] The New Jersey plans are particularly noteworthy in that they eliminated their COLA in 2011, which this projection takes into account.

The message from these exercises is that, for the majority of plans, there is no imminent "crisis", in the sense that 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 low and medium return scenarios. Adjustments may be necessary. The questions are: how large are those adjustments, and how urgent are they?

VI. Pension Debt Stabilization

VI.A Pension Debt Stabilization Discussion

Our fiscal sustainability exercises are focused on the following identities concerning the evolution of plans liabilities (L), assets (A) and implicit pension debt (D),

$$L_{t+1} = (1+\delta)L_t - B_{t+1} + NC_{t+1} \tag{5}$$

$$A_{t+1} = (1+r)A_t - B_{t+1} + C_{t+1} \tag{6}$$

where δ is the discount rate used to value the plan liabilities; *r* is the expected return on assets; B_t is the benefit paid out at time t; NC_t is the total normal cost (the present value of liabilities accrued in a year) in year t; C_t is the total contribution. (The difference between δ and r is discussed below).

Dividing (5) and (6) by time *t+1* GDP (Y_{t+1}), subtracting $\frac{L_t}{Y_t}$ and $\frac{A_t}{Y_t}$, respectively, and re-arranging yields the changes in liabilities and assets as shares of GDP from t to t+1:

$$\Delta l_{t+1} = \frac{(\delta - g)l_t}{1+g} - b_{t+1} + nc_{t+1} \tag{7}$$

$$\Delta a_{t+1} = \frac{(r - g)a_t}{1+g} - b_{t+1} + c_{t+1} \tag{8}$$

where lower case denotes variables as a share of GDP and *g* denotes GDP growth.

Debt stability requires $\Delta d_{t+1} = \Delta l_{t+1} - \Delta a_{t+1} = 0$. In steady state, liabilities are constant as a share of GDP, $\Delta l_{t+1} = \Delta l = 0$. Thus, in steady state, $\Delta a = 0$. Setting $\Delta a_{t+1} = 0$ in equation (8) yields the steady-state contribution to stabilize debt at any given asset level and steady-state benefit outflow:

$$c = b - \frac{(r-g)}{(1+g)}a \tag{9}$$

When assets are zero, as in a pure pay-as-you-go system, contributions just have to cover benefits. When r > g, a plan with assets can have contributions lower than benefits in steady state, because some of the asset income can be used to pay for benefits (while some must be reinvested in order for assets to rise with GDP). When r < g, stabilizing debt and assets to GDP actually becomes more costly the larger are the assets.

Note that equation (9) includes only the return on assets, and not the discount rate. When liabilities as a share of GDP are constant, as they are in steady state, stabilizing debt implies stabilizing assets, and the trajectory of assets is wholly independent of the rate used to discount liabilities. Thus, the required contribution to stabilize pension debt is independent of the discount rate. That said, liabilities are not constant in all plans over the first few years of our projections, because of demographic changes and changes in plan rules that take time to work their way through to benefits. Thus, the discount rate assumption we use is not entirely neutral, but the effects of changing that assumption are not economically important.[28]

We use these identities in combination with our projections of benefits cashflows and payroll to assess the fiscal stability of each plan. If pension debt as a share of the economy is declining or stable, then the plan can be viewed as fiscally sustainable; assets will never exhaust, and the plan will be able to pay benefits indefinitely. On the other hand, if debt as a share of GDP rises indefinitely, then the plan is not fiscally sustainable.

VI.B. Stabilization Exercises

Our analysis here involves estimating the changes in pension contributions which would stabilize pension debt as a share of the economy. We perform two stabilization exercises:

(1) Long-Run Stabilization: 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) Medium-Run Stabilization: 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 2020).

Stabilization Exercise 1: Stabilize Implicit Debt as a Share of GDP in the Long Run

Our first stabilization exercise assumes 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, regardless of the

[28] In some of our debt stabilization scenarios, we set $r \neq \delta$. Costrell and McGee (2020) criticize this choice, referring to it as "arbitrage", and note that it is a sharp departure from standard actuarial practice where required contributions are constrained to be at least as high as the cost of newly accrued benefits (normal cost) valued at the actuarial discount rate. However, we present results below in which both r and δ are set equal to a 0% risk-free rate. More fundamentally, this paper focuses on the contribution required to stabilize pension debt and, as discussed above and also by Costrell and McGee (2020), the choice of discount rate has little effect on the contribution required to stabilize pension debt. Thus, harmonizing our asset return and the discount rate would not materially alter our conclusions. Determining the appropriate rate of asset return r, though, has extremely important implications for the required contribution. See section IV.D for a discussion.

value of this stable ratio. This exercise spreads the fiscal costs of future pension obligations and existing pension debt equally across generations as a share of income.

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 9 shows the evolution of the unfunded liability relative to GDP for the US as a whole if real asset returns are 2.5% under the current policy analysis discussed in section V. 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 governments acts now or later. If they act now, the implicit debt to GDP ratio essentially holds steady at around 40 percent in all periods. Waiting to stabilize does not change the steady-state ratio much. If the governments waits 30 years to act—that is, if they maintain their current contribution rate for 30 years and then act to stabilize—the long-run implicit debt to GDP ratio is 50 percent – about 25 percent higher than it would be if the government acted today.

Table 3 presents the contribution increases, as a share of payroll, required to stabilize the debt to GDP ratio for all four asset return scenarios. At a 5% real rate of return, plans are, in aggregate, already stable and can lower contribution. At the 2.5% rate of return, plans must increase contributions by 8.3 percent of payroll. Under the risk-neutral 0% return assumption, contributions must increase by a larger 15 percent.

The contribution changes required to stabilize implicit pension debt don't change very much if the government waits to make contribution changes. If the contribution rate stays at its current level and then increases in 10 years, the increase has to be equal to 9.2 percent of payroll under 2.5% asset returns. 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 only rises to 10.4 percent of payroll. Delaying, though, does result in a somewhat higher level of pension debt in steady state.

Under the risk-neutral 0% asset return assumption, required contributions actually fall if a government delays adjustment. This is a striking result—to simply stabilize the debt, there is nothing gained from increasing contributions now. Indeed, by waiting to act, a plan can contribute much less now, and somewhat less in the future—ultimately stabilizing at a higher debt level at lower future cost. This result follows from the fact that when interest rates are less than the growth rate of the economy, government debt has no fiscal costs (Blanchard 2019). Equivalently, when $r<g$, assets are costly because they constantly shrink as a share of the economy; thus, running down your assets and then beginning the stabilization process allows you to stabilize with a lower contribution rate.

Of course, it is very hard to predict interest rates and there is a risk that rates will rise. Turning to the CBO path of risk-free rates, which have rates rising gradually over time, shows that (a) with interest rates rising over time, plans have to do less to stabilize their debt relative to the 0% return assumption (the required contribution is 9.5 percent of payroll) if they act immediately but (b) there is a greater cost to delay. Amassing assets while returns are low provides little initial benefit, but those assets become valuable in the future when interest rates rise.

This comparison highlights an interesting conundrum—when asset returns are higher, plans are in better shape and need to do less to stabilize their debt. When asset returns are lower, plans are in worse shape, but—for both the lowest and even middle rates of return—there is little benefit to having assets, and so plans are worse off or barely better off by increasing contributions. Of course, assets provide insurance against uncertainty and may allow for smoothing pension contributions over time, and so plans may want to contribute even if there is little benefit when asset returns are certain, as we assume here.

How fiscally onerous would these increased contributions be? To put these contribution changes into context, aggregate pension contributions increased by 10 percent of payroll between 2009 and 2019 and equaled 27 percent of payroll in 2019.[29] Accordingly, if governments act now, a further upward adjustment about equal to the adjustment made over the last decade would be sufficient to stabilize their pension debt under the 2.5% return assumption. Under the CBO risk-free rate of return, the adjustment would be just a bit larger. Under the assumption that the risk-free rate of return stays at 0, plans would have to do quite a bit more—raising their contribution by about twice as much as the increase over the past decade. Overall, we view the contribution changes needed to obtain pension debt stability at the low and medium rates of return as achievable, although they would certainly entail some fiscal strain, particularly under the 0% return scenario.

However, plans could run out of assets along the way, which might be a constraint, both economically—if ratings agencies react by raising borrowing costs— and politically. Figure 10 shows plan assets relative to GDP for each of the 2.5% asset return scenarios. They decline in all, but never approach zero in aggregate.[30] Figure 10 also illustrates that, in aggregate, this stabilization exercise involves plans drawing down assets in order to smooth through the period of peak cash flow demand over the next two decades (see Figure 6).

[29] Based on full PPD sample, updated through fiscal year 2019 (PPD 2017).

[30] However, a number of plans in our sample that are poorly funded now and have responded by cutting COLAs and/or future benefits—like the Illinois state government plans and the New Jersey Teachers plan—do end up with negative assets in the 2.5% scenario. The simulation effectively assumes that these governments issue marketable debt to fund benefits once their assets have been exhausted and thereafter make service payments on the marketable debt at an interest rate equal to the asset return assumption. These governments can be viewed as having issued marketable debt in order to smooth through the period of peak benefit outflows prior to these benefits falling back as a share of the economy in response to the gradual effects of the COLA and benefit reforms. Assets also fall into negative territory in aggregate in the 0% assumption for the "wait 20 years" to stabilize simulation and the 0% and CBO assumptions for the "wait 30 years" to stabilize simulation.

Stabilization Exercise 2: Stabilize Implicit Debt as a Share of GDP in the Medium Run

Another way to assess sustainability 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—e.g. due to credit rating downgrades—whereas targeting today's level is less likely to raise that concern. In addition, a government may wish to simply maintain implicit pension debt in relation to GDP—i.e. intuitively "dig the hole no deeper" while spreading the costs of doing so evenly over 30 years. This exercise is consistent with this objective, on net, over a 30 year horizon.

The middle panel of Table 4 reports the one-time, permanent contribution change required for the implicit debt-to-GDP ratio, at the end of 30 years, to equal it value in 2021 for the US as a whole. It should be noted that, in this experiment, we always allow the pension plan 30 years to get back to the original debt ratio, so that "start in 10 years" means getting back to the 2021 debt-to-GDP level by 2061. We view that as a sensible experiment, because it doesn't require the plan to make extremely large changes in a short period of time, but still requires the plan to eventually return to the same target.

At a 2.5% rate of return on assets, plans would need to increase contributions by 7.2 percent of payroll today, 10.4 percent if they began in 10 years, and 13.8 percent if they began in 20 years. There is little difference between the contributions required under this exercise and the long-run stabilization exercise (left most set of columns) if action is taken today; but the difference becomes somewhat larger if stabilization is delayed. This difference arises because the 30-year exercise requires any increases in debt that occur after 2021 to be paid down, whereas the long-run exercise only requires additional interest be paid on debt acquired after 2021. Appendix Figures A1 and A2 show the trajectory of implicit debt and assets, respectively, under these stabilization exercises.

At an asset return of 0%, contributions would have to increase about 18 percent to ensure that the debt-to-GDP ratio is the same as today's in 30 years, just a bit above the amount required in the stabilize the implicit debt in the long run exercise. However, the differences between the costs of delay across the year 30 years and long run exercises are much larger under these low asset returns, because the costs to stabilize a higher level of debt are negative, 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 0% 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 21.8 percent of payroll; waiting 20 years would boost that required contribution to 24.8 percent (but save 20 years of increased contributions).

In contrast to our focus on stabilizing implicit pension debt, past work on pension funding has often focused on achieving full pre-funding over a fixed period time. The right-most panel of Table 4 presents estimates of the funding increase required to achieve full prefunding over a 30-year horizon. These estimates are broadly similar to those presented in Novy-Marx and Rauh (2014b).[31] 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 very substantially larger than those required to stabilize debt. Under 2.5% asset returns, the contribution boost to reach full funding is roughly four times larger than the increase required to stabilize the debt (36 percent versus 8 percent). The funding increases required to reach full funding under the 0%, 2.5%, and CBO asset return assumptions would constitute a fiscal crisis for state and local governments. The corresponding increases needed to stabilize pension debt in the long run would certainly induce fiscal strain but would fall short of what most observers would label a crisis.

VI.C Variation in Required Contribution Adjustments Across Plans

There is a great deal of variation in the required adjustments across plans. Figure 11 shows the distribution of required adjustments across the asset return assumptions and stabilization exercises. (Appendix Tables A1 and A2 show the results for each plan.) Panel A shows the distribution of required adjustments for plans to stabilize the debt over the long run starting immediately. At a 5% rate of return, no plan needs to increase funding by more than 10 percent of payroll, and 62 percent of liabilities are in plans that could reduce contributions. At both the 2.5% rate of return and CBO's projected risk-free return, only 14 percent of liabilities are in plans that need to increase funding by more than 20 percent of payroll, and less than 40 percent of liabilities are in plans where the contribution increase is more than 10 percent of payroll. At a 0% rate of return, however, 14 percent of liabilities are in plans that need to increase contributions by more than 40% of payroll, and 42 percent need to increase contributions by more than 20 percent of payroll. Thus, under this rate of return assumption, many plans do have to make significant changes.

Panel B of Figure 11 shows the distribution of plan's required contribution changes if they act today for the 30-year, medium-term stabilization exercise. The distribution is quite similar to the results for the long-term stabilization exercise, although the required contributions are generally a bit larger. This is particularly true for the CBO rate of return assumption, because that rate rises over time, making it easier for plans to stabilize over the longer run, but helping less to stabilize over the next 30 years.

[31] One difference is that our pension liabilities are defined using an Accrued Liability concept (generally implemented as the EAN) which includes some benefit obligations associate with future years of service. In contrast, Novy-Marx and Rauh mostly use the narrower Accumulated Benefit Obligation concept which only captures obligations earned to date. Another difference is that our projections include the assumption of mortality improvements over time whereas those of Novy-Marx and Rauh do not.

Finally, Panel C of Figure 11 shows the distribution of required contribution changes for plans to be fully funded by the end of 30 years. At a 5% rate of return, only 4 percent of liabilities are in plans that can lower contributions, while 31 percent of liabilities are in plans where the required contribution increase is greater than 20 percent of payroll. At the 0% rate of return, almost all plans (90 percent) have to increase pension contributions by more than 40 percent of payroll. These comparisons make clear the policy importance of recognizing that pension plans can be stable without being fully funded. An attempt to enact the massive increases in contributions that would be required to move toward full funding at low and moderate asset returns would very likely spark a fiscal crisis. Our analysis, though, demonstrates that these increases of this magnitude are unnecessary for plans to be able to fiscally stable and continue paying benefits.

VI.D Explaining the Variation in Required Contributions to Stabilize the Debt

Perhaps unintuitively, it's not the poorly funded plans that have to make the greatest contributions to stabilize. As shown in Panel A of Figure 12, there is little relationship between funding levels and the required contribution change to stabilize under the medium-term stabilization exercise with the 0% return assumption. Indeed, at low rates of return, having assets is "expensive" because the rate of return is not sufficient to keep current assets growing with GDP; rather than being able to use some of the asset returns to fund benefits, plans have to actively contribute to the plan just to prevent assets from eroding. At a 5% rate of return (Panel B), that is no longer the case, but there is still little relationship between funding and required contribution.

Of course, one reason to expect a relationship between funding level and required changes is that poorly funded plans may be those that have been failing to make sufficient payments and have ignored looming imbalances. But that's not the case.

Figure 13 shows the effects of recent changes to pension plans contributions and the new-hire reforms discussed above on the contribution change required in the medium-term stabilization exercise. To calculate these, we ran a counterfactual simulation that—starting with today's liabilities and assets—assessed the changes in contribution that would be required to stabilize debt in 30 years if plans reversed the reforms to their benefit and eligibility levels and if their contribution rates reverted to those prevailing in 2007.[32] We then calculate the difference between those required changes in contributions and the required changes in contributions we calculate under current plan benefits and contributions. The effects of these reforms on the required contribution to stabilize the debt—plotted on the vertical axis of Figure 14—have been

[32] A more complete analysis of the reforms and changes in contribution level would run the counterfactual starting in 2007, so as to reflect the assets and liabilities that would have prevailed under the counterfactual. Such an analysis, though, is infeasible as our cash flow projection methodology is based on fiscal year 2017 and therefore lacks the ability to perform counterfactual exercises before fiscal 2017.

substantial. For example, without the reforms and contribution increases made by two of the most poorly funded plans—Illinois teachers and Illinois state employees—required contributions to stabilize the debt under the 2.5% asset return assumption would equal more than an *additional* 60 percent of payroll beyond what we calculate under current plan benefits and contributions. [33] And the reforms have been substantial for most plans in our sample.

The size of the changes made by the poorly funded plans have been so large as to make those plans among the healthiest when it comes to the stabilization exercises. As shown in Figure 14, plans that made the largest changes in contributions since 2007 and the biggest reforms to their benefits are currently contributing more than enough to stabilize their debt, even at a 0% rate of return. To the extent these huge increases in contributions have come at the expense of taxpayer services or higher taxes, it is reasonable to question whether they have been too large. Such an analysis, though, is beyond the scope of the current paper.

Another important predictor of which plans need to make the largest contribution changes to stabilize is the projected future change in the ratio of retirees to actives, which can come about because of changes in demographics, past patterns of employment growth, and changes in eligibility rules for pension plans. Plans that are expected to see larger increases in the ratio of retirees to active workers have to make the larger adjustments.[34]

Table 5 presents the results of an OLS regression which assesses which plan characteristics explain—in a descriptive sense—the variation across plans in required contribution changes for all asset returns and the begin now long run and 30-year stabilization exercises. Plans that have made large changes to contributions and benefits (although the benefits piece is not always significant) need to make smaller changes, while plans that are projected to experience an increase in the ratio of retirees to actives have to make the larger changes, regardless of asset return or funding exercise. At the 5% rate of return, plans that are poorly funded also have to make larger adjustments (or, more specifically, can lower their contributions less.)

VII. Conclusion

We find that pension benefit payments in the US, as a share of the economy, are currently near 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 ease. Our results suggest that, under conservative

[33] The effect of the benefit changes vary somewhat by stabilization exercise and asset return.

[34] As noted above, we assume that the growth rate of active workers is equal to our projected growth rate of the labor force in the state or locality as a whole. While we think that assumption is reasonable, it is of course highly uncertain. Similarly, we think our projections for state- and city-specific labor force growth are reasonable, but they are also quite speculative. Thus, the specific contribution rates to stabilize the debt on a plan-by-plan basis are subject to considerable uncertainty. However, the results here illustrate the factors that affect required contribution rates for debt stabilization.

discounting of liabilities and moderate asset return assumptions in aggregate 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, in aggregate there appears to be only limited 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.

An important limitation to our work is its focus on pension plans in isolation from the broader context of state and local governments. For instance, we implicitly assume that these governments are able to reap the fiscal benefits of pension reforms. However, as employers, state and local governments operate in a competitive labor market; reduction in pension benefits may result in the need to boost other forms of compensation, reducing the fiscal savings from the reforms. Our long-run stabilization scenarios provide another example. In this scenario, governments smooth through the period of peak pension cash flow demand by drawing down assets. Rating agencies might respond to this asset drawdown by lowering credit ratings and we fail to account for the higher borrowing costs for marketable debt that might result. More broadly, the various stabilization paths we explore would ideally be examined through the lens of a cost-benefit analysis incorporating the full policy objectives of these governments. For example, by reducing pension funding governments may be able to increase investments in education and infrastructure. These investments may then yield social returns in the future and also provide fiscal benefits in the form of increased tax revenue. On the other hand, these deficits may carry fiscal costs in the future. We leave these broader considerations for future work.

Finally, another important limitation to our work here is our use of deterministic asset return paths. We will incorporate stochastic asset returns in future work.

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Figures and Tables

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)	(1.59)	(1.60)
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)	(0.34)	(0.34)
Projected Percent Active Member Growth	0.28	0.34	0.41	0.41
	(0.54)	(0.55)	(0.59)	(0.55)
Observations	40	179	40	179

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	0% real return	2.5% real return	5% real return	CBO rates
New Jersey Teachers	12	13	15	12
New Jersey PERS	20	27	63	19
Oregon PERS	22	27	42	22
Arizona State Corrections Officers	23	27	34	23
Baton Rouge City Parish RS	24	32	Never	24
Kansas City Missouri ERS	24	30	Never	24
New York State Teachers	24	31	54	25
New Mexico PERA	25	35	Never	26
Florida RS	26	35	Never	27
South Carolina RS	26	39	Never	27
Georgia Teachers	27	36	82	28
Illinois Teachers	28	Never	Never	29
Ohio Teachers	28	40	Never	29
Texas Teachers	29	37	60	30
Rhode Island Municipal	30	61	Never	32
Missouri Teachers	31	43	Never	33
California Teachers	32	42	99	34
LA County ERS	36	53	Never	39
Arizona SRS	37	69	Never	42
NY State & Local ERS	39	76	Never	46
Massachusetts SRS	40	88	Never	49
Oklahoma Police	40	68	Never	46
Maine State and Teacher	42	Never	Never	Never
South Carolina Police	50	Never	Never	Never
Illinois Municipal	51	Never	Never	100
San Francisco City & County	53	Never	Never	72
DC Teachers	56	Never	Never	78
North Dakota Teachers	56	Never	Never	84
Massachusetts Teachers	57	Never	Never	Never
University of California	58	Never	Never	80
San Diego County	69	Never	Never	Never
San Diego City ERS	Never	Never	Never	Never
Georgia ERS	Never	Never	Never	Never
Illinois SERS	Never	Never	Never	Never
Indiana Teachers	Never	Never	Never	Never
Louisiana Municipal Police	Never	Never	Never	Never
Louisiana SERS	Never	Never	Never	Never
Michigan Public Schools	Never	Never	Never	Never
Pennsylvania School Employees	Never	Never	Never	Never
Pennsylvania State ERS	Never	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 in the Long Run

	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
0%	14.91%	12.71%	10.71%	8.82%
2.5%	8.32%	9.16%	9.88%	10.38%
5%	-2.62%	-3.48%	-4.76%	-6.68%
CBO	9.54%	10.33%	11.09%	11.66%

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

	Stabilize Implicit Debt to GDP				Implicit Debt Gets Back to Today's Level in 30 Years				Fully Funded in 30 Years			
Real rate of return	Today	In 10 years	In 20 years	In 30 years	Today	In 10 years	In 20 years	In 30 years	Today	In 10 years	In 20 years	in 30 years
0%	14.91%	12.71%	10.71%	8.82%	17.90%	21.80%	24.79%	26.79%	59.11%	63.57%	66.74%	68.47%
2.5%	8.32%	9.16%	9.88%	10.38%	7.22%	10.41%	13.78%	17.09%	35.91%	39.53%	43.06%	46.18%
5%	-2.62%	-3.48%	-4.76%	-6.68%	-4.32%	-6.04%	-8.29%	-11.34%	14.94%	13.53%	11.42%	8.24%
CBO	9.54%	10.33%	11.09%	11.66%	13.18%	15.97%	19.41%	23.07%	45.18%	46.09%	48.95%	52.35%

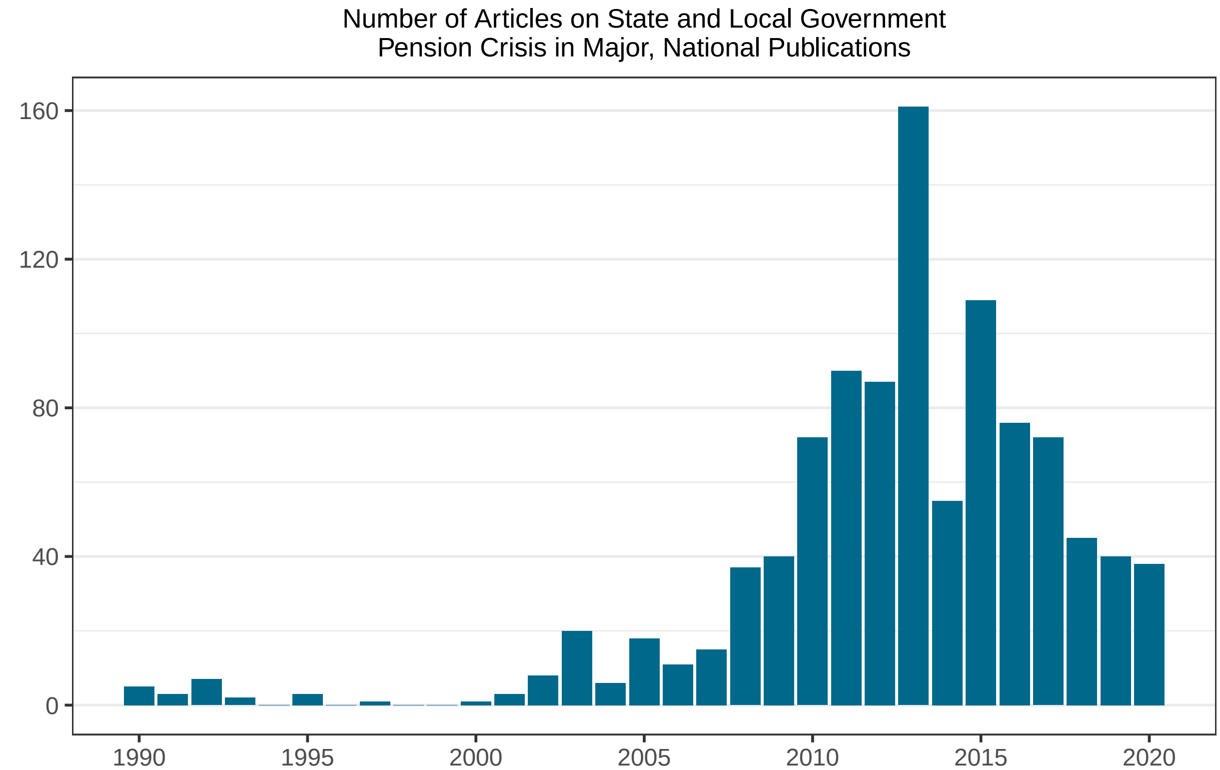
Note: The left panel of the table displays the one-time, permanent percentage point change in contributions as a share of payroll required to stabilize implicit pension debt as a share of GDP for the U.S. in aggregate. The central panel of the table displays the one-time, permanent percentage point change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

Table 5
Explaining the Variation in the Change in Required Contributions Across Plans

		Stabilize Implicit Debt		Same implicit debt in 30 years as share of GDP	
		Coefficient	Std Error	Coefficient	Std Error
Asset Return: 0%					
	Contribution Change since 2007	-0.57*	0.29	-0.53**	0.27
	Effect of Benefit Reforms	-0.53**	0.19	-0.34	0.22
	Change in Retiree/Worker Ratio	0.46**	0.16	0.40**	0.15
	Beginning Funding Ratio	0.29	0.22	0.26	0.21
	Constant	-0.01	0.12	0.03	0.11
	R sq adj	0.54		0.44	
Asset Return: CBO					
	Contribution Change since 2007	-0.55**	0.15	-0.55**	0.21
	Effect of Benefit Reforms	-0.2	0.24	-0.27	0.18
	Change in Retiree/Worker Ratio	0.28**	0.09	0.34**	0.11
	Beginning Funding Ratio	-0.03	0.12	0.1	0.16
	Constant	0.07	0.07	0.06	0.09
	Rsq adj	0.55		0.48	
Asset Return: 2.5%					
	Contribution Change since 2007	-0.57**	0.15	-0.62**	0.19
	Effect of Benefit Reforms	-0.22	0.24	-0.3	0.23
	Change in Retiree/Worker Ratio	0.27**	0.09	0.33**	0.1
	Beginning Funding Ratio	-0.07	0.12	-0.1	0.15
	Constant	0.07	0.06	0.07	0.08
	Rsq adj	0.56		0.51	
Asset Return: 5%					
	Contribution Change since 2007	-0.65**	0.14	-0.71**	0.18
	Effect of Benefit Reforms	-0.48	0.36	-0.48	0.3
	Change in Retiree/Worker Ratio	0.19**	0.08	0.27**	0.1
	Beginning Funding Ratio	-0.49**	0.11	-0.50**	0.14
	Constant	0.15	0.06	0.13	0.08
	Rsq adj	0.6		0.57	

Note: The table displays regression coefficients from regressions of the required contribution changes if plan acts now to stabilize their debt under both stabilization exercises and all asset return assumptions.

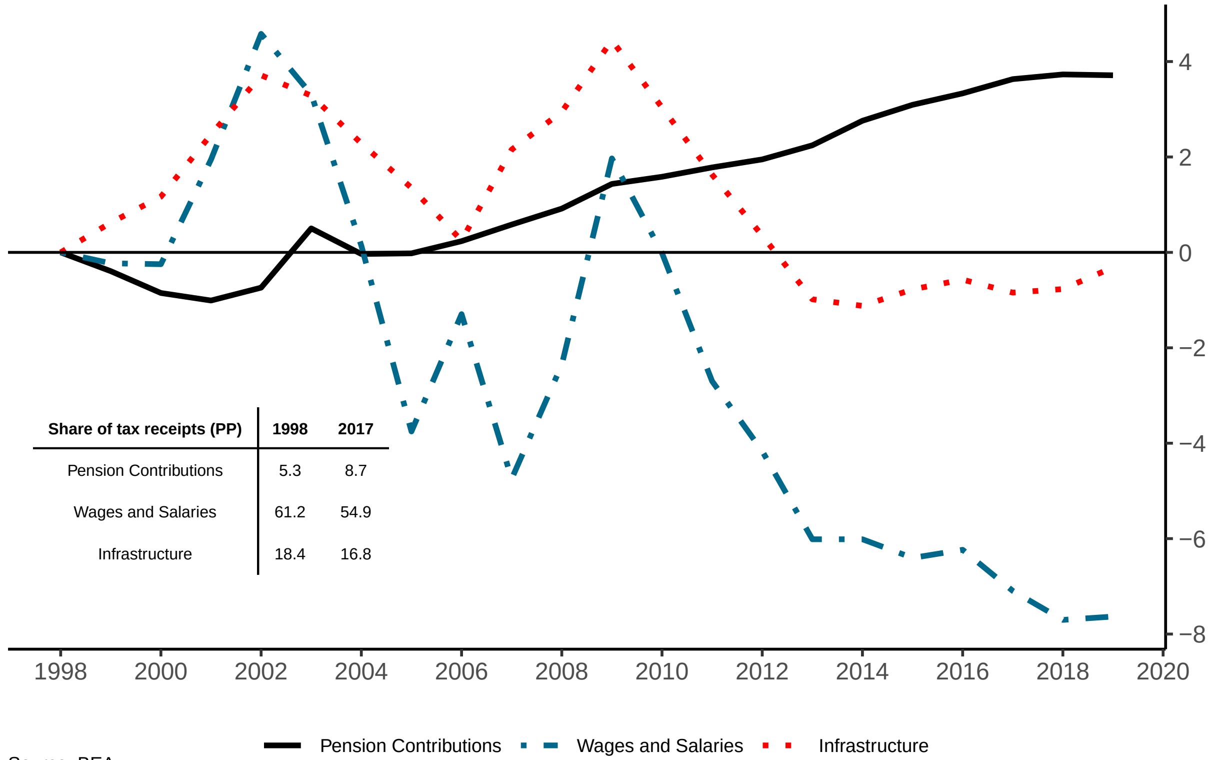
Figure 1



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

Figure 2

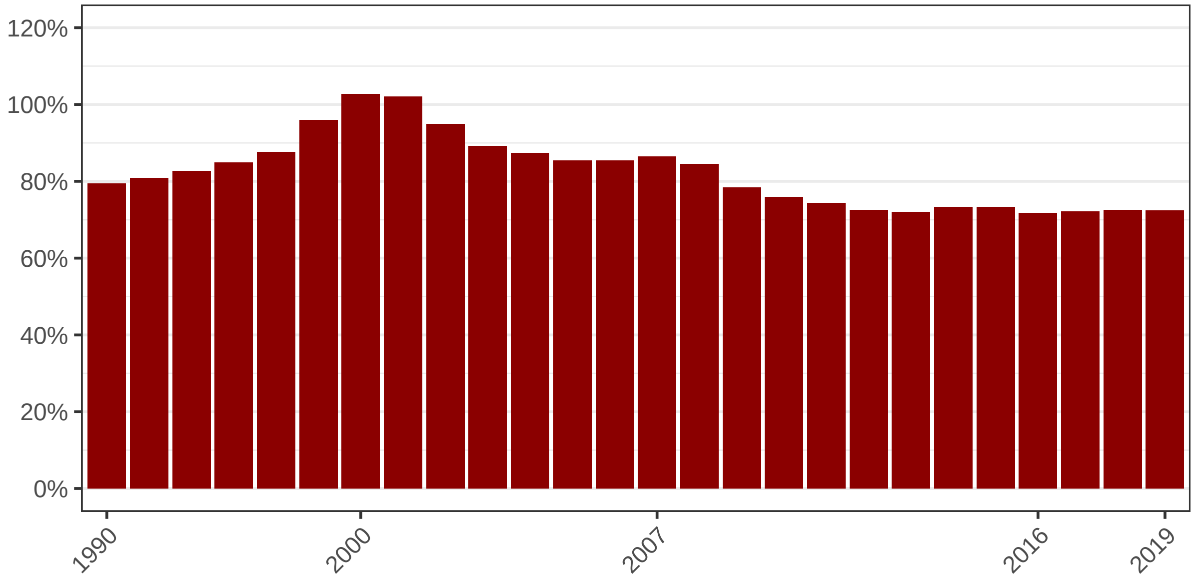
Change in State and Local Government Expenditures as Share of Tax Receipts



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.

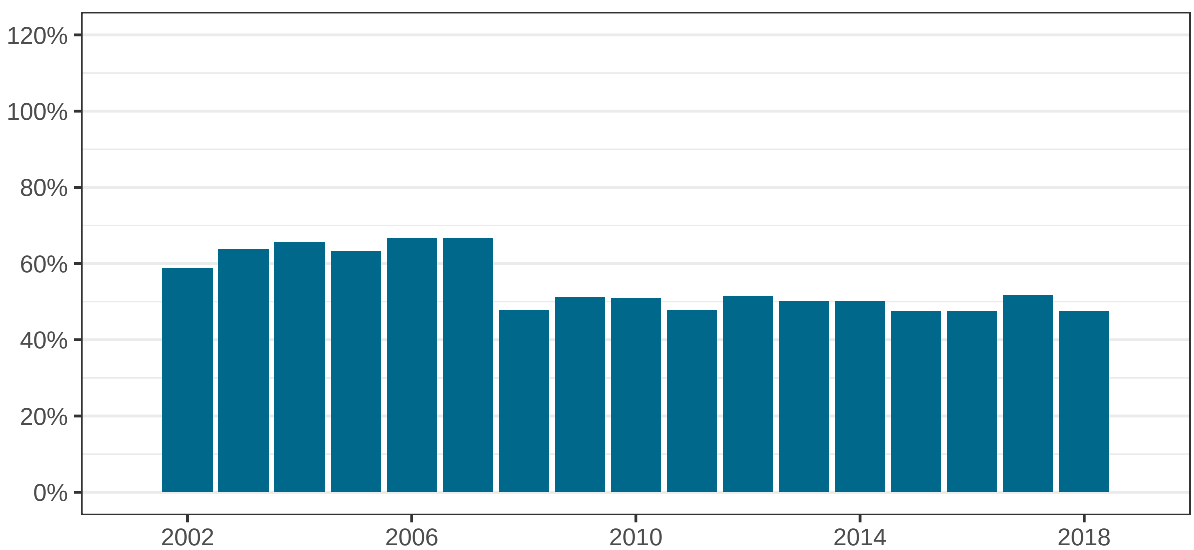
Figure 3

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



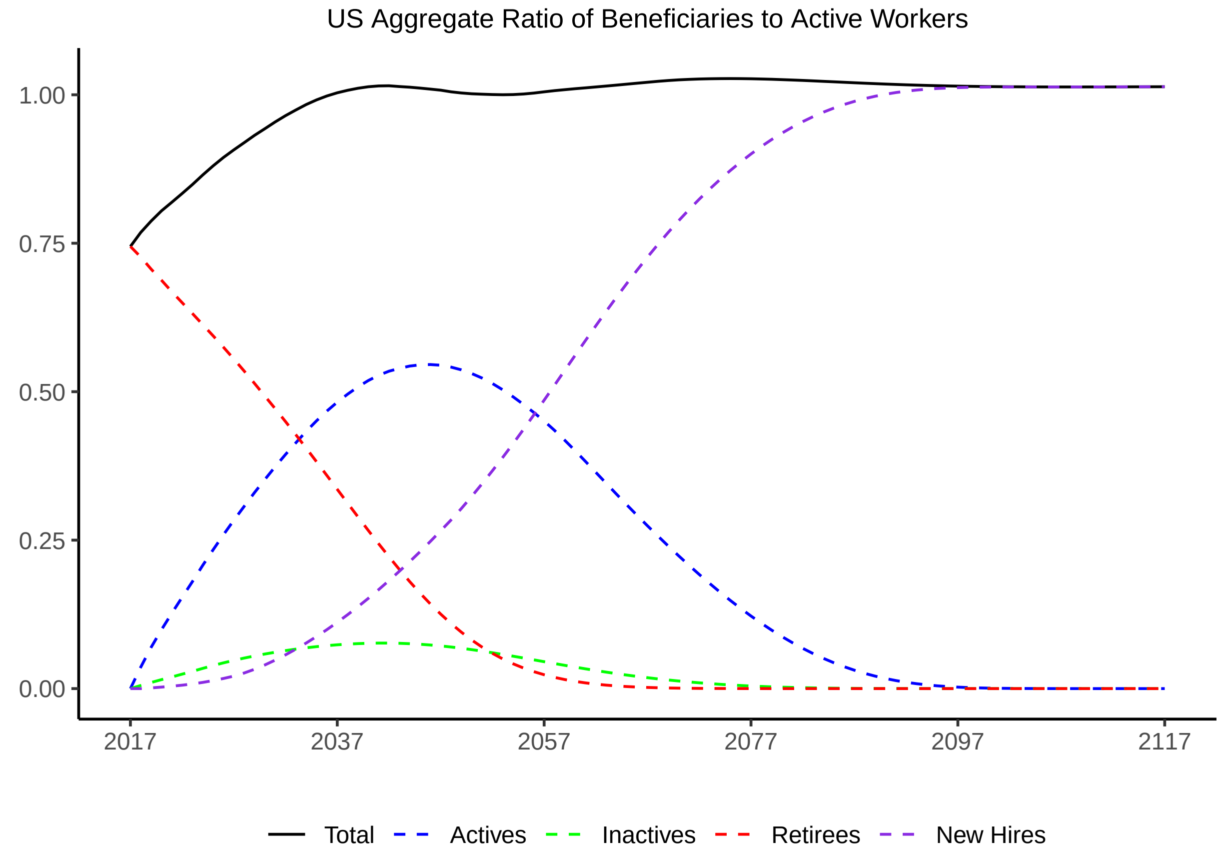
Source: Calculations and figure are from the Center for Retirement Research at Boston College; Aubry, Crawford, and Wandrei (2018).
Note: The 2017 funded ratio involves projections for 18 percent of PPD plans, representing 26 percent of liabilities.
Calculations based on 2017 actuarial valuations (AVs);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

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



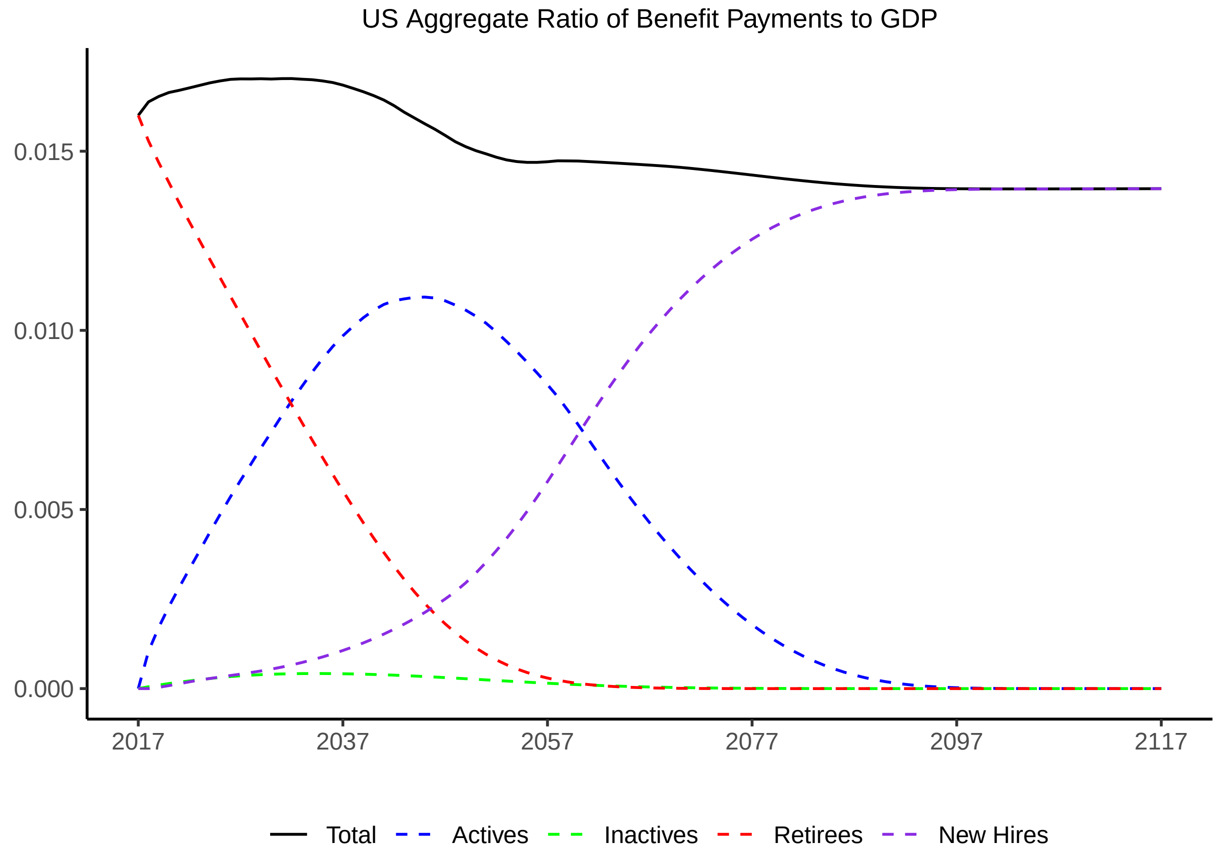
Source: Financial Accounts of the United States. See Hoops, Smith, and Stefanescu (2016) for methodology.

Figure 4



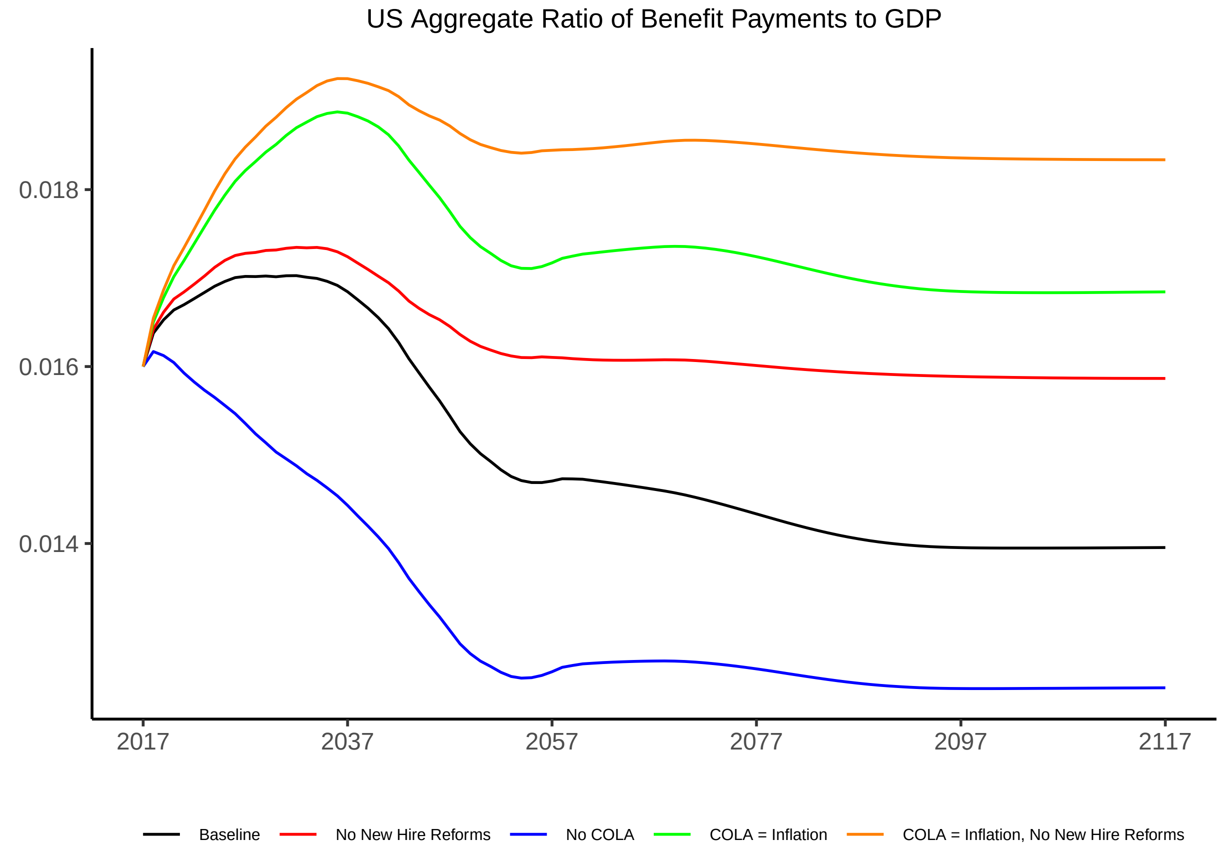
Note: The solid black line displays the ratio of total beneficiaries of state and local government pension plan payments to the state and local government current workforce. The dashed red line displays the ratio of beneficiaries who were receiving benefits as of 2017 – i.e. retirees – to current workers. 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 5



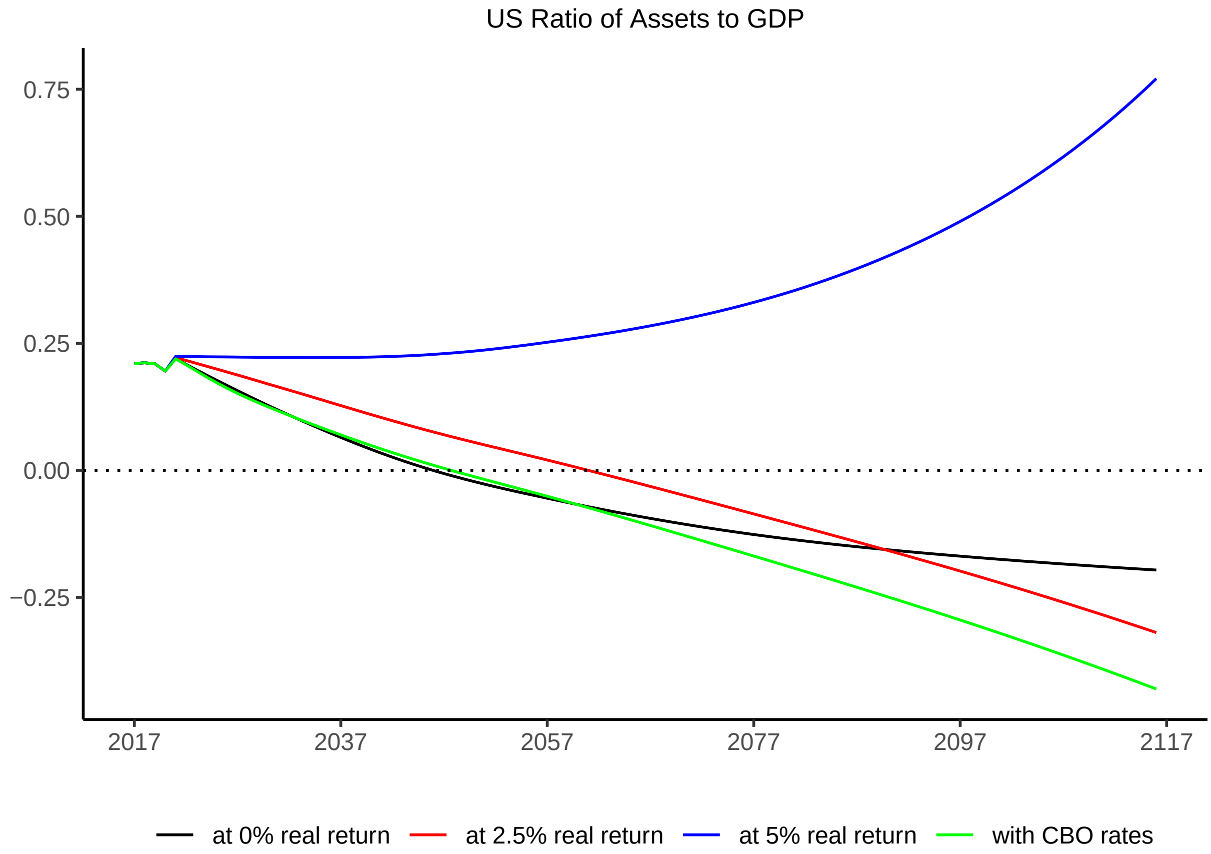
Note: The solid black line displays the ratio of total state and local government pension benefit payments to GDP. The dashed red line displays the ratio of benefit payments to beneficiaries who were receiving benefits as of 2017 – i.e. retirees – to GDP. The dashed blue line displays the ratio of benefit 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 6



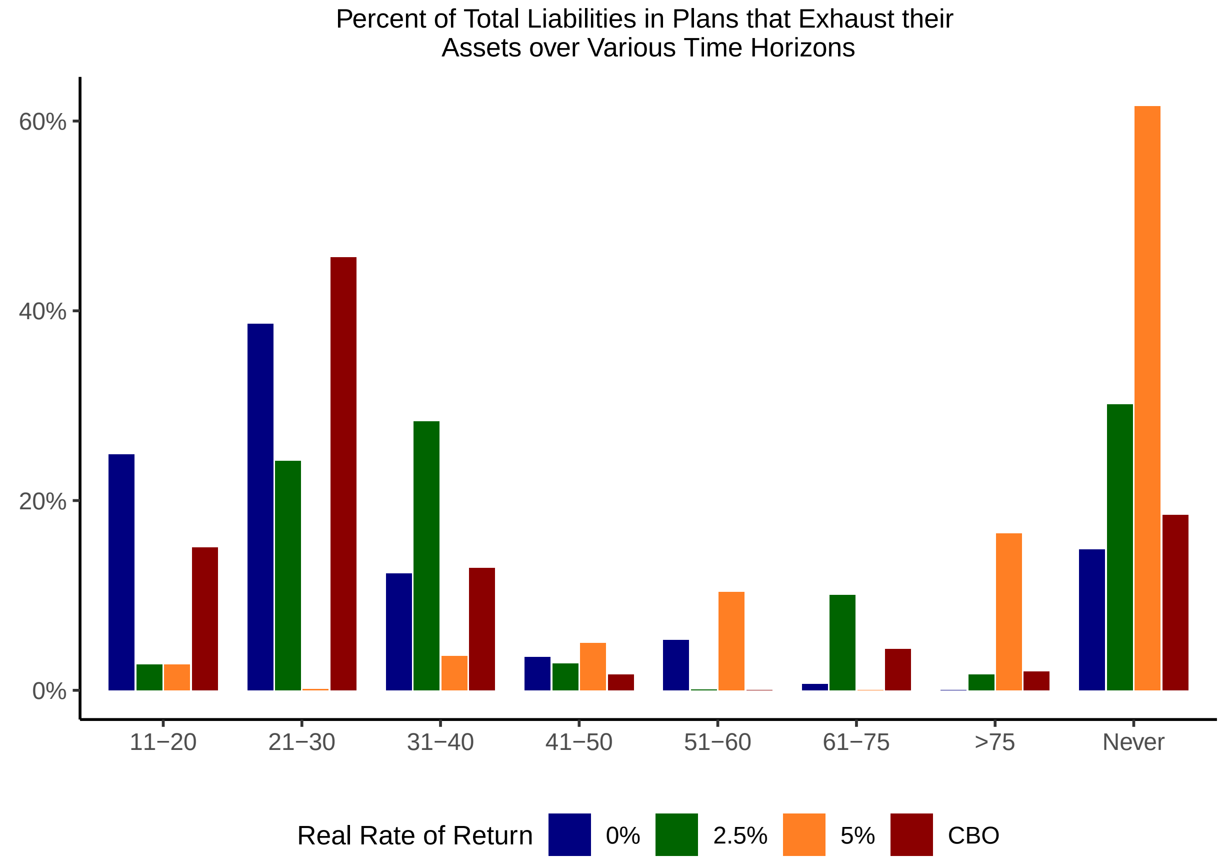
Note: The solid black line displays the ratio of total state and local government pension benefit payments to GDP. The solid red line displays the ratio of total state and local government pension benefit payments to GDP assuming that all pension changes which apply only to new hires – i.e. new worker 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 7



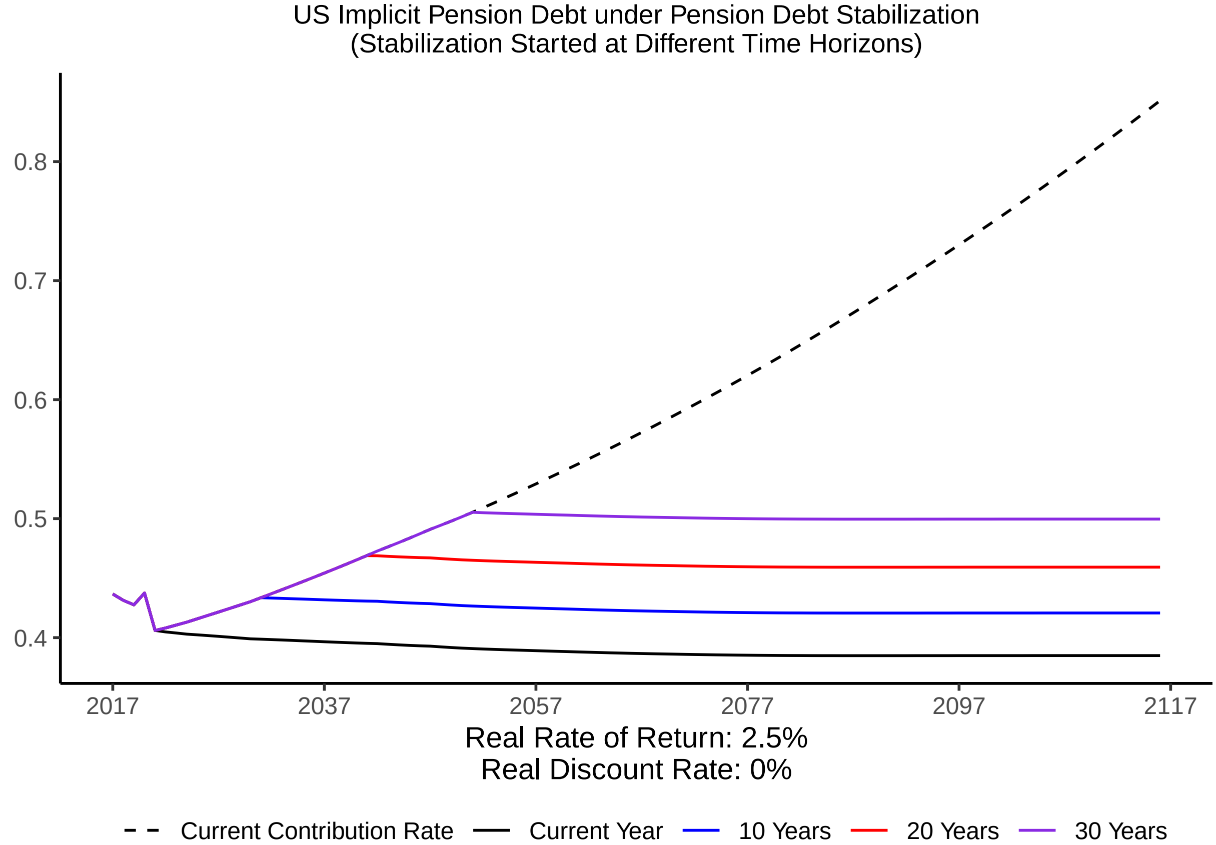
Note: The figure displays pension assets as a share of GDP under varying assumptions about asset returns and assuming that employer contributions as a share of payroll are held fixed at their 2017 value.

Figure 8



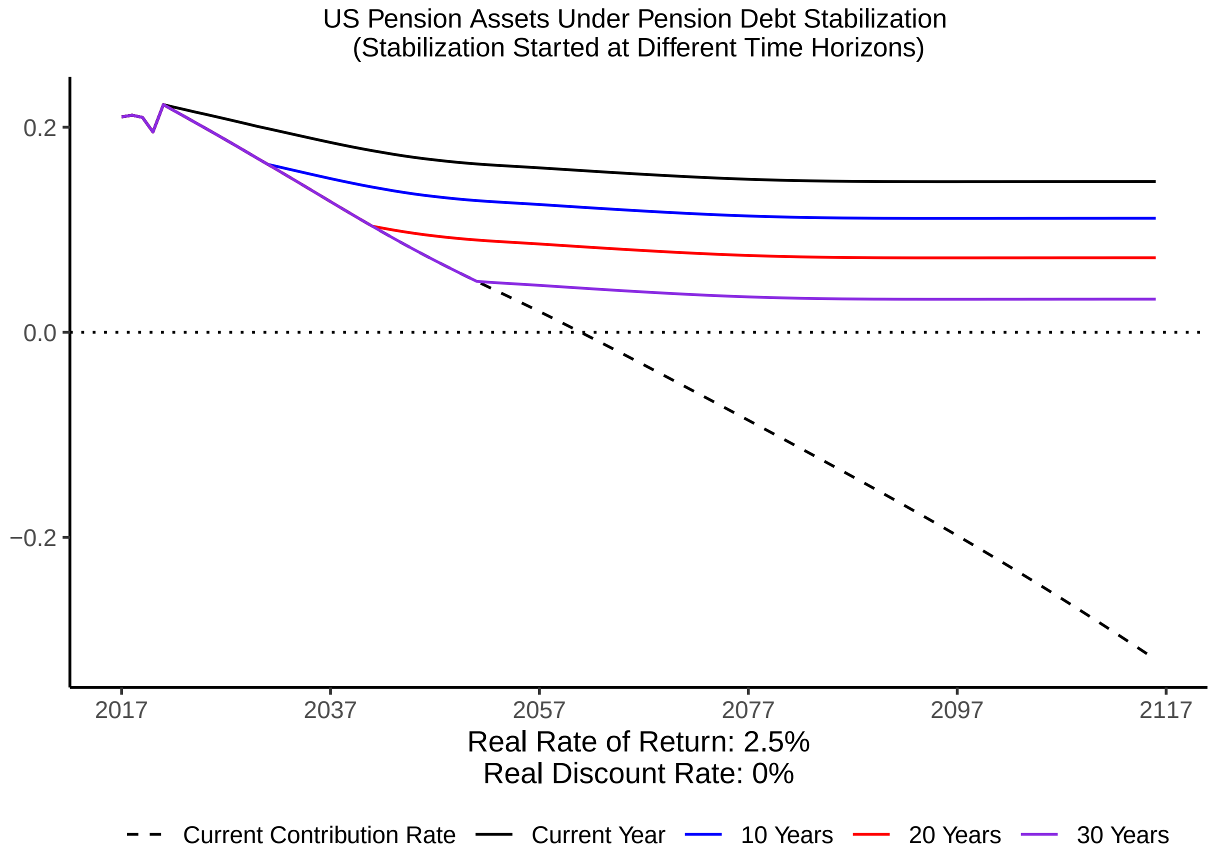
Note: The figure displays the share of total pension liabilities held by plans which exhaust their assets over different time horizons assuming that employer contributions as a share of payroll are held fixed at their 2017 value.

Figure 9



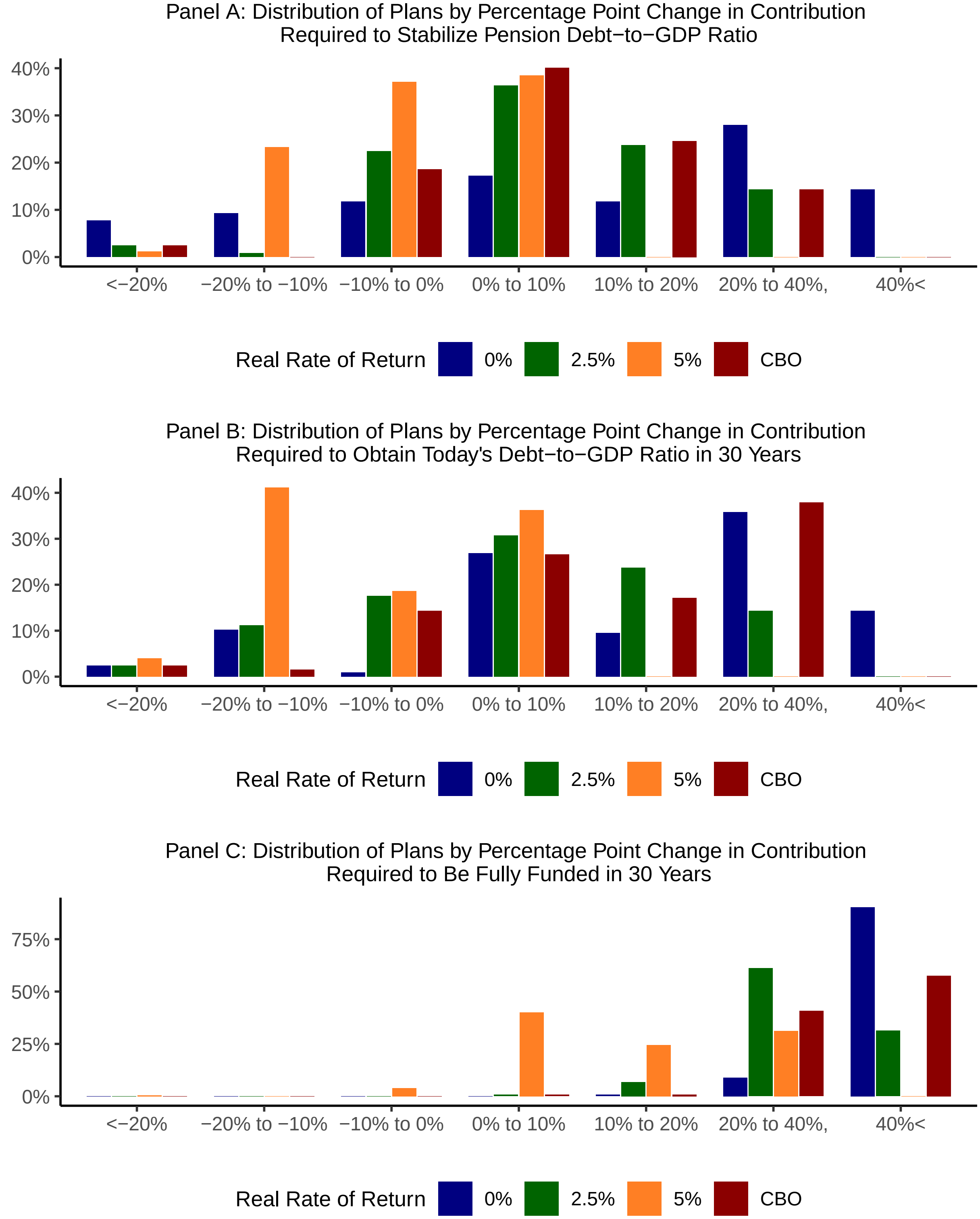
Note: The dashed black line displays implicit pension debt – unfunded pension liabilities – as a share of GDP assuming that assets have a real return of 2.5 percent and that employer contributions as a share of GDP are held fixed at their 2017 value. The solid black line displays implicit pension debt – unfunded pension liabilities – as a share of GDP assuming that assets have a real return of 3 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 10



Note: The dashed black line displays pension assets as a share of GDP assuming that the assets have a real return of 2.5 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 2.5 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.

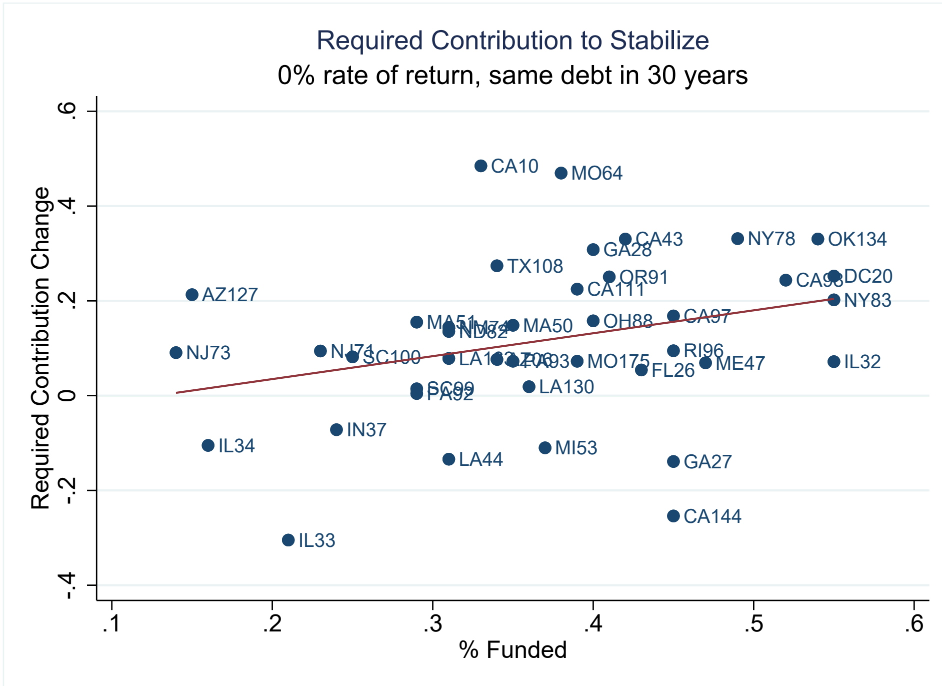
Figure 11



Note: 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, return to today's debt-to-gdp ratio in 30 years, and fully fund in 30 years under different asset return assumptions. The histograms are weighted by liabilities.

Figure 12

Panel A



Panel B

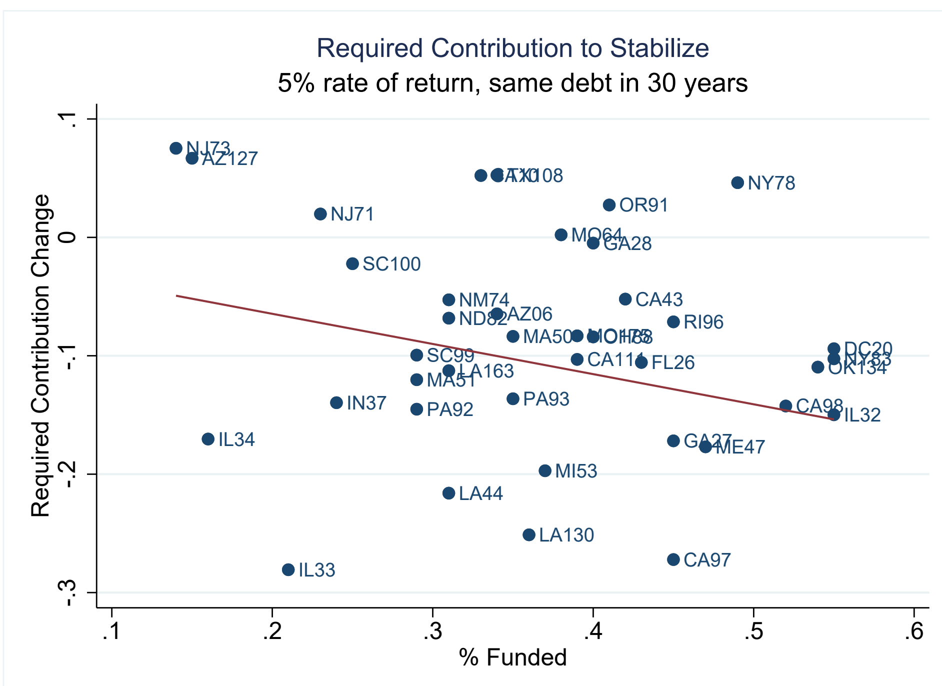


Figure 13

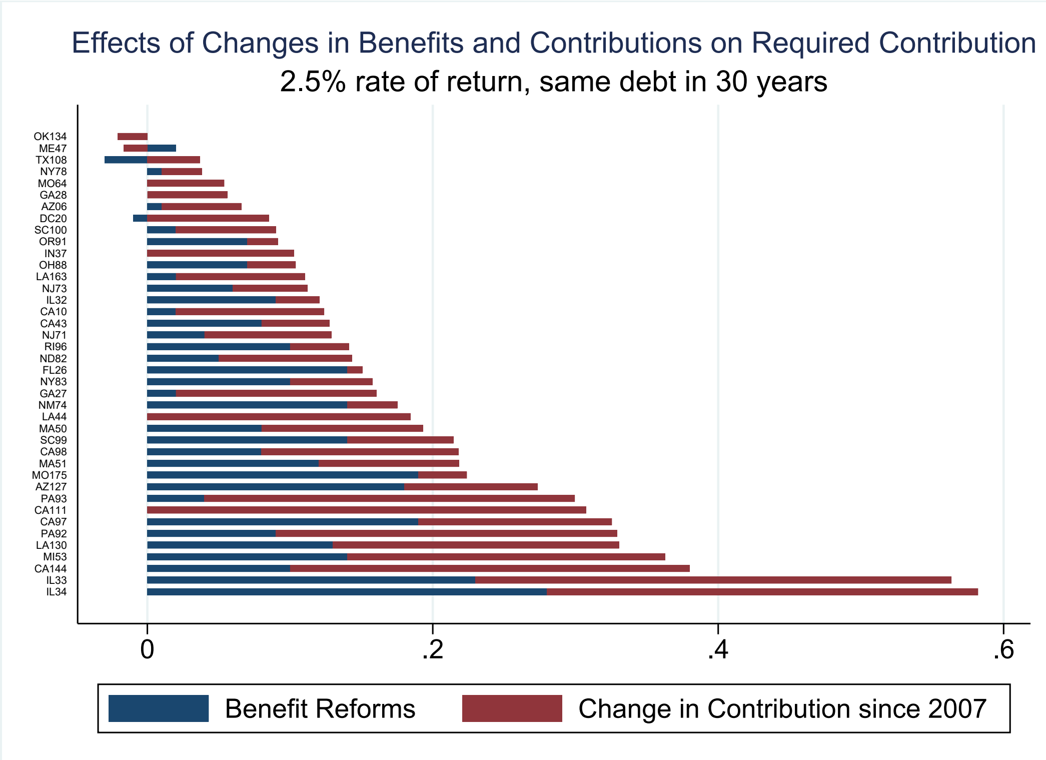
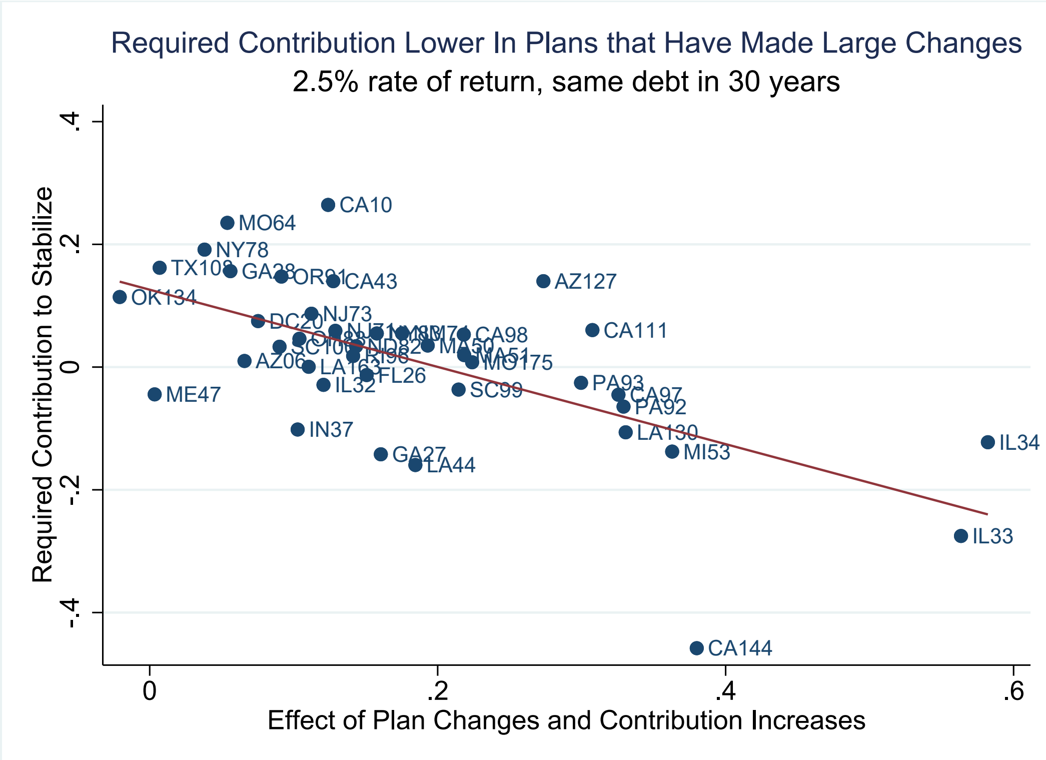

Effects of Changes in Benefits and Contributions on Required Contribution
2.5% rate of return, same debt in 30 years
OK134
ME47
TX108
NY78
MO64
GA28
AZ06
DC20
SC100
OR91
IN37
OH88
LA163
NJ73
IL32
CA10
CA43
NJ71
RI96
ND82
FL26
NY83
GA27
NM74
LA44
MA50
SC99
CA98
MA51
MO175
AZ127
PA93
CA111
CA97
PA92
LA130
MI53
CA144
IL33
IL34
0
.2
.4
.6
Benefit Reforms
Change in Contribution since 2007

Figure 14


Required Contribution Lower In Plans that Have Made Large Changes
2.5% rate of return, same debt in 30 years
Required Contribution to Stabilize
Effect of Plan Changes and Contribution Increases
.4
.2
0
-.2
-.4
0
.2
.4
.6
CA10
MO64
NY78
TX108
OK134
CA43
AZ127
NJ73
DC20
CA98
CA111
AZ06
LA163
FL26
IL32
MO175
SC99
PA93
CA97
PA92
ME47
IN37
LA130
MI53
IL34
GA27
LA44
IL33
CA144

Online Appendix:

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

Jamie Lenney, Bank of England*

Byron Lutz, Federal Reserve Board of Governors**

Finn Schuele, Brookings Institution

Louise Sheiner, Brookings Institution

March 11, 2021

This appendix includes the following:

(1) Tables A.1 and A.2 show the results of our stabilization exercises by plan.
(2) Section A provides a detailed methodology for calculating liabilities and projecting future benefits.
(3) Section B provides detailed information on our sample.
(4) Section C shows how we used the data pulled from the plan's actuarial reports.
(5) Section D provides an accounting of our demographic assumptions.

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 will not perfectly replicate the stated GASB liabilities (AL^{GASB}), we calibrate our projections of nominal 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. 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:

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

The total plan $PVFB^{act}$ 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 ($\mathrm{N}_0^{\mathrm{act}}$).

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

These calculations closely follow that of (Winkelvoss 1993). Creation of the cashflows associated with normal retirement $B_{t,ret}^{act}$ and $PVFB_{x,s}^{ret}$ are detailed below:

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

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

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

$PVFB^{ret}_{x,s}$ is calculated as a discounted probability weighted sum of single/joint[1] life annuities a_i (see eq. A24-A25) 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$\left[\frac{1}{1+\delta}\right]$; $p^{T}_{(x,s),i}$ is the probability of remaining in employment until age i conditional onf current age x and service years s; $q^{ret}_{(x,s),i}$is the probability of retiring at age i however with the exception of workers currently older than the normal retirement age we assume workers retire with probability 1.0 at the normal retirement age; 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 from the AV. Similar calculations are made for the other decrements.

PVFB for deferred retirement:

$$\text{PVFB}^{dret}_{x,s} = \sum_{i=x}^{R} v^{max(r,i)-x}(1+cola)^{max(r,i)-i} p^{T}_{(x,s),i} q^{wth}_{(x,s),i}\left(1-q^{ref}_{(x,s),i}\right) b_{dret}(x,s,i) p^{m}_{i,Max(r,i)}\, , a_{Max(r,i)} \quad (A6)$$

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

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:

$$PVFB^{ref}_{x,s} = \sum_{i=x}^{R} v^{i-x} p^{T}_{(x,s),i} q^{wth}_{(x,s),i} q^{ref}_{(x,s),i}\, b_{ref}(x,s,i) \quad (A8)$$

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

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

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 $\bar{b}(x)$. 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 $N_{t=0,1....}$.

Normal costs and Accrued Liabilities

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[2] (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[3] is the entry age normal which is illustrated below and calculates the normal cost as the level percent[4] 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 $a_{x\ddot{-}s,0}$ (see eq. A26) at the employee's entry age (x-s).

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

$$NC_t = \sum_{x,s} w_{x,s,t}\Pi_{x,s,t}\, NC_{x,s,t} \qquad (A19)$$

The NC varies by entry age and starting salary, the plans aggregate NC at time t is therefore a payroll 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:

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

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

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

[2] E.g. assets achieve the assumed returns, wages grow in line with expectations, the workforce composition evolves as expected and so on.
[3] 91 percent of plans in the PPD in fiscal year 2017.
[4] In a few cases this is calculated as a level dollar contribution.

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:

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

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

Temporary employer annuity:

$$\ddot{a}_{(x,s)} = \sum_{i=x}^{R} E\,[w_i|(x,s)] p_{(x,s),i}^T v^{i-x} \qquad (A26)$$

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, $p_{(x,s),i}^T$.

Calibration

In order to ensure our projections are as accurate as possible we calibrate our projected cashflows such that they produce each plan's stated actuarial liabilities (AL) as reported in their AV's.

The stated actuarial liability for current beneficiaries and inactive plan members (who are no longer accruing benefits) is the discounted sum (or present value) of their projected future benefits discounted using the plan's chosen discount rate (δ). The stated liabilities of current workers is the present value of their accrued normal costs.

Having calculated the liabilities for each group of members we calibrate the cash flows using calibration factors such that the following holds:

$$AL^{act,AV} \equiv v_{c,1}\, AL^{act} \qquad (A27)$$

$$AL^{inact,AV} \equiv v_{c,2} AL^{inact} \qquad (A28)$$

$$AL^{ben,AV} = \sum_{t=0}^{\infty} \left(\left[\frac{1}{1+\delta} \right] \right)^{t} \left(v_{c,3} \right)^{t} B_t^{ben} \qquad (A29)$$

Where $AL^{act,AV}$ and $AL^{inact,AV}$ are the accrued liabilities for active and inactive workers from the 2017 actuarial valuation, AL^{act} and AL^{inact} are the accrued liabilities for active and inactive workers from our calculations, B_t^{ben} is the pension cash flow for current beneficiaries from our calculations, and the $v_{c,i}$ are the calibration factors.

For current employees and current inactives, 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 boost benefits by a roughly constant percent throughout retirement. Accordingly, we make a proportional change to their benefit streams in our projections ($v_{c,1} B_t^{act}$). We also apply the same calibration factor ($v_{c,1}$) to the new hire cash flow projections (see below). We do a similar proportional calibration for the inactive plan members.

$v_{c,3}$ is a geometric calibration factor which ensures that our estimated cash flow for current beneficiaries reproduces the AL for current beneficiaries stated in the AV report when we discount it at the plan's stated discount rate. The choice of a geometric calibration for current beneficiaries 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). Finally, we note that due to the fact our uncalibrated estimates were on average quite accurate,[5] the calibration process does not have a large effect on our analysis (see appendix B, table 3).

[5] In addition to being on average quite accurate for the AL liability concept, our estimates are also on average accurate for the broader PVFB liability concept.

B. Data
See Tables B1, B2, and B3 for details. Figures B1 and B2 show additional detail.

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.

See Table C1.

Table C2 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.

When benefit distributions or relativities were not available by age, as shown in Table C3, 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.

The matrix shown in Table C4 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 ∘ 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.

We decided not to use the salary increases by age and years of service in the AV reports because these produced estimated salary increases that seemed far too low in the first few years and that would have greatly affected the relative salaries by age and service. Given that our exercise stabilizes contributions as a share of GDP, and GDP is determined by overall productivity growth (which we get from CBO) and labor force growth, this would have led to smaller increases in required contributions as a result of the divergent increases in state and local payroll and GDP. Rather than possibly biasing our estimated required contributions downward, we chose to maintain the relative salaries by age and service over time, and simply boost all state and local salaries by productivity growth and inflation. If salaries of state and local employees do indeed grow more slowly over time, then the required contribution increases to stabilize the implicit debt would be smaller.

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

The matrix in Table C5 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.

See table C6.

Retirement probabilities

We assume workers retire at the normal retirement age with probability 1.0. For those aged above the normal retirement age in the initial population we assume they retire with a probability of 0.20 in each until age 75 where they retire with probability 1.0. The 0.20 probability was chosen based on the average post normal retirement age probability reported in the AV's. In previous editions of this work we had implemented retirement matrices with varying probabilities by age and service but this was difficult to maintain in tandem with the rich treatment of plan tiers and reforms.

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 A1.1
Change in Contributions that Stabilizes Ratio of Implicit Pension Debt to GDP, Depending on when Adjustment is Made

		0% real rate of return Make changes:				CBO rates Make changes:			
	Current Contribution	Now	In 10 years	In 20 years	In 30 years	Now	In 10 years	In 20 years	In 30 years
US Aggregate	24%	15%	13%	11%	9%	10%	10%	11%	12%
California Teachers	32%	47%	38%	33%	28%	25%	25%	28%	30%
Missouri Teachers	30%	41%	35%	31%	26%	22%	24%	28%	30%
LA County ERS	27%	33%	28%	24%	20%	16%	17%	18%	20%
Texas Teachers	15%	32%	28%	23%	20%	17%	18%	19%	20%
Oklahoma Police	31%	33%	27%	23%	20%	14%	14%	15%	17%
Georgia Teachers	21%	30%	27%	23%	20%	19%	21%	23%	25%
New York State Teachers	7%	25%	20%	17%	14%	19%	21%	22%	23%
University of California	31%	24%	20%	16%	13%	6%	7%	7%	7%
Arizona State Corrections Officers	22%	23%	20%	16%	14%	16%	17%	18%	20%
San Francisco City & County	28%	22%	18%	15%	13%	6%	7%	7%	8%
Oregon PERS	10%	20%	17%	14%	12%	19%	20%	21%	23%
DC Teachers	21%	20%	16%	12%	10%	6%	6%	6%	7%
San Diego County	49%	16%	13%	11%	9%	2%	2%	2%	2%
NY State & Local ERS	18%	15%	13%	9%	7%	8%	8%	8%	7%
New Mexico PERA	27%	12%	10%	9%	7%	10%	11%	11%	12%
Arizona SRS	22%	11%	10%	9%	7%	4%	5%	6%	6%
Ohio Teachers	26%	9%	8%	9%	8%	8%	9%	12%	14%
North Dakota Teachers	27%	10%	8%	6%	6%	3%	3%	3%	3%
Massachusetts SRS	32%	8%	7%	6%	5%	4%	4%	5%	5%
South Carolina RS	23%	7%	6%	5%	4%	5%	6%	6%	6%
Massachusetts Teachers	40%	7%	6%	5%	5%	1%	1%	2%	2%
New Jersey PERS	21%	5%	3%	2%	1%	6%	5%	4%	4%
Baton Rouge City Parish RS	41%	2%	3%	3%	3%	8%	10%	12%	13%
Illinois Municipal	18%	3%	3%	2%	2%	1%	1%	1%	1%
Rhode Island Municipal	15%	3%	2%	1%	1%	4%	4%	4%	4%
New Jersey Teachers	18%	1%	0%	0%	0%	8%	8%	8%	9%
Kansas City Missouri ERS	19%	-3%	-2%	-2%	-2%	7%	8%	9%	9%
Florida RS	13%	-4%	-3%	-3%	-2%	6%	7%	7%	7%
South Carolina Police	25%	-5%	-4%	-3%	-3%	-1%	-1%	-2%	-2%
Pennsylvania State ERS	37%	-4%	-4%	-4%	-3%	-3%	-4%	-4%	-4%
Maine State and Teacher	26%	-6%	-4%	-3%	-3%	-2%	-1%	-1%	-1%
Louisiana Municipal Police	49%	-6%	-4%	-4%	-3%	-6%	-6%	-7%	-8%
Indiana Teachers	28%	-9%	-7%	-6%	-5%	-9%	-9%	-9%	-10%
Pennsylvania School Employees	37%	-15%	-12%	-9%	-7%	-7%	-7%	-6%	-6%
Georgia ERS	20%	-14%	-12%	-10%	-9%	-7%	-8%	-8%	-9%
Louisiana SERS	45%	-17%	-14%	-12%	-10%	-10%	-9%	-10%	-11%
Michigan Public Schools	36%	-20%	-17%	-14%	-12%	-9%	-9%	-10%	-10%
San Diego City ERS	79%	-28%	-24%	-22%	-18%	-27%	-30%	-34%	-36%
Illinois Teachers	51%	-41%	-35%	-29%	-25%	-7%	-7%	-7%	-9%
Illinois SERS	49%	-45%	-37%	-32%	-27%	-20%	-22%	-24%	-26%

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 A1.2

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

		2.5% real rate of return Make changes:				5% real rate of return Make changes:			
	Current Contribution	Now	In 10 years	In 20 years	In 30 years	Now	In 10 years	In 20 years	In 30 years
US Aggregate	24%	8%	9%	10%	10%	-3%	-3%	-5%	-7%
California Teachers	32%	23%	24%	27%	28%	2%	2%	3%	4%
Missouri Teachers	30%	20%	22%	26%	28%	-2%	-2%	-2%	-3%
Georgia Teachers	21%	17%	20%	22%	23%	1%	3%	4%	6%
New York State Teachers	7%	18%	19%	21%	22%	5%	7%	9%	12%
Oregon PERS	10%	18%	19%	20%	22%	7%	9%	12%	17%
Arizona State Corrections Officers	22%	16%	17%	18%	19%	8%	11%	14%	19%
Texas Teachers	15%	16%	17%	18%	19%	4%	5%	7%	9%
LA County ERS	27%	14%	15%	16%	18%	-5%	-7%	-10%	-13%
Oklahoma Police	31%	12%	12%	13%	14%	-10%	-14%	-20%	-27%
New Mexico PERA	27%	9%	10%	10%	11%	-1%	-1%	-2%	-3%
Baton Rouge City Parish RS	41%	6%	9%	10%	11%	-3%	-3%	-3%	-4%
New Jersey Teachers	18%	8%	8%	8%	9%	8%	11%	14%	19%
Ohio Teachers	26%	7%	8%	10%	12%	-5%	-6%	-7%	-9%
Kansas City Missouri ERS	19%	5%	7%	7%	7%	-1%	-1%	-1%	-2%
NY State & Local ERS	18%	6%	7%	6%	6%	-9%	-12%	-17%	-24%
Florida RS	13%	4%	5%	6%	6%	-3%	-4%	-5%	-8%
South Carolina RS	23%	4%	5%	6%	5%	-1%	-1%	-1%	-2%
University of California	31%	5%	5%	5%	5%	-12%	-16%	-23%	-31%
New Jersey PERS	21%	5%	5%	4%	4%	2%	2%	1%	1%
San Francisco City & County	28%	5%	5%	5%	5%	-15%	-20%	-28%	-38%
Arizona SRS	22%	3%	4%	5%	5%	-4%	-6%	-7%	-10%
DC Teachers	21%	4%	4%	4%	5%	-13%	-18%	-26%	-36%
Massachusetts SRS	32%	3%	3%	3%	4%	-8%	-11%	-15%	-21%
Rhode Island Municipal	15%	3%	3%	3%	3%	-5%	-7%	-10%	-13%
North Dakota Teachers	27%	2%	2%	1%	2%	-8%	-11%	-15%	-21%
Massachusetts Teachers	40%	0%	0%	0%	0%	-13%	-18%	-25%	-34%
Illinois Municipal	18%	0%	0%	-1%	-1%	-11%	-16%	-22%	-30%
San Diego County	49%	0%	-1%	-1%	-1%	-23%	-32%	-44%	-59%
South Carolina Police	25%	-2%	-2%	-2%	-3%	-7%	-9%	-13%	-18%
Maine State and Teacher	26%	-4%	-3%	-3%	-3%	-14%	-20%	-28%	-38%
Pennsylvania State ERS	37%	-4%	-5%	-6%	-6%	-13%	-18%	-25%	-35%
Pennsylvania School Employees	37%	-8%	-8%	-7%	-8%	-13%	-17%	-23%	-31%
Louisiana Municipal Police	49%	-8%	-8%	-9%	-10%	-21%	-28%	-39%	-53%
Illinois Teachers	51%	-8%	-8%	-8%	-10%	-8%	-11%	-14%	-20%
Georgia ERS	20%	-8%	-9%	-9%	-10%	-10%	-14%	-19%	-26%
Indiana Teachers	28%	-9%	-9%	-10%	-10%	-12%	-17%	-22%	-30%
Michigan Public Schools	36%	-10%	-10%	-11%	-12%	-13%	-18%	-25%	-34%
Louisiana SERS	45%	-11%	-11%	-12%	-13%	-15%	-19%	-27%	-37%
Illinois SERS	49%	-21%	-22%	-25%	-27%	-18%	-25%	-35%	-48%
San Diego City ERS	79%	-31%	-34%	-38%	-41%	-56%	-78%	-106%	-145%

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 A2.1
Change in Contributions to Obtain Today's Debt-to-GDP Ratio in 30 Years, Depending on when Adjustment is Made

		0% real rate of return Make changes:				CBO rates Make changes:			
	Current Contribution	Now	In 10 years	In 20 years	In 30 years	Now	In 10 years	In 20 years	In 30 years
US Aggregate	24%	18%	22%	25%	27%	13%	16%	19%	23%
Missouri Teachers	30%	47%	58%	69%	75%	35%	42%	52%	62%
California Teachers	32%	48%	58%	68%	75%	36%	42%	52%	61%
LA County ERS	27%	33%	41%	47%	53%	23%	28%	34%	40%
New York State Teachers	7%	33%	40%	46%	49%	27%	32%	40%	47%
Georgia Teachers	21%	31%	39%	46%	51%	24%	31%	39%	47%
Oklahoma Police	31%	33%	39%	45%	50%	23%	25%	29%	35%
Texas Teachers	15%	27%	34%	39%	44%	21%	25%	31%	38%
DC Teachers	21%	25%	31%	36%	40%	15%	16%	18%	21%
Oregon PERS	10%	25%	30%	34%	37%	21%	27%	34%	42%
San Francisco City & County	28%	24%	29%	33%	37%	15%	16%	18%	20%
University of California	31%	22%	29%	32%	35%	14%	16%	17%	19%
Arizona State Corrections Officers	22%	21%	26%	29%	32%	17%	22%	27%	33%
NY State & Local ERS	18%	20%	25%	27%	27%	14%	17%	18%	19%
San Diego County	49%	17%	20%	23%	25%	7%	7%	6%	7%
Massachusetts Teachers	40%	16%	19%	22%	23%	9%	9%	10%	11%
Ohio Teachers	26%	16%	19%	23%	26%	12%	15%	20%	26%
Massachusetts SRS	32%	15%	18%	20%	22%	10%	11%	13%	15%
New Mexico PERA	27%	14%	17%	18%	20%	12%	14%	17%	21%
North Dakota Teachers	27%	14%	15%	17%	18%	8%	8%	8%	10%
South Carolina RS	23%	8%	11%	12%	12%	6%	8%	10%	12%
Arizona SRS	22%	8%	10%	13%	14%	5%	7%	9%	10%
Rhode Island Municipal	15%	9%	10%	11%	11%	7%	8%	9%	10%
New Jersey PERS	21%	9%	10%	9%	9%	8%	8%	8%	9%
Baton Rouge City Parish RS	41%	8%	10%	11%	11%	7%	10%	15%	19%
New Jersey Teachers	18%	9%	9%	9%	8%	10%	11%	13%	15%
Maine State and Teacher	26%	7%	9%	8%	8%	3%	4%	4%	3%
Illinois Municipal	18%	7%	8%	8%	9%	4%	4%	4%	4%
Kansas City Missouri ERS	19%	7%	8%	7%	6%	7%	9%	12%	14%
Pennsylvania State ERS	37%	7%	6%	5%	5%	3%	1%	-1%	-2%
Florida RS	13%	5%	6%	6%	5%	4%	7%	9%	11%
South Carolina Police	25%	1%	1%	-1%	-1%	0%	-1%	-2%	-2%
Louisiana Municipal Police	49%	2%	1%	-1%	-2%	-3%	-5%	-8%	-11%
Pennsylvania School Employees	37%	0%	-1%	-2%	-4%	-2%	-4%	-5%	-7%
Indiana Teachers	28%	-7%	-9%	-10%	-12%	-8%	-11%	-13%	-16%
Michigan Public Schools	36%	-11%	-15%	-19%	-22%	-10%	-13%	-16%	-20%
Louisiana SERS	45%	-13%	-17%	-21%	-24%	-12%	-14%	-18%	-22%
Georgia ERS	20%	-14%	-17%	-20%	-22%	-12%	-14%	-16%	-19%
Illinois Teachers	51%	-10%	-20%	-27%	-34%	-8%	-14%	-17%	-22%
San Diego City ERS	79%	-25%	-32%	-39%	-44%	-30%	-40%	-52%	-64%
Illinois SERS	49%	-30%	-41%	-49%	-57%	-26%	-33%	-41%	-50%

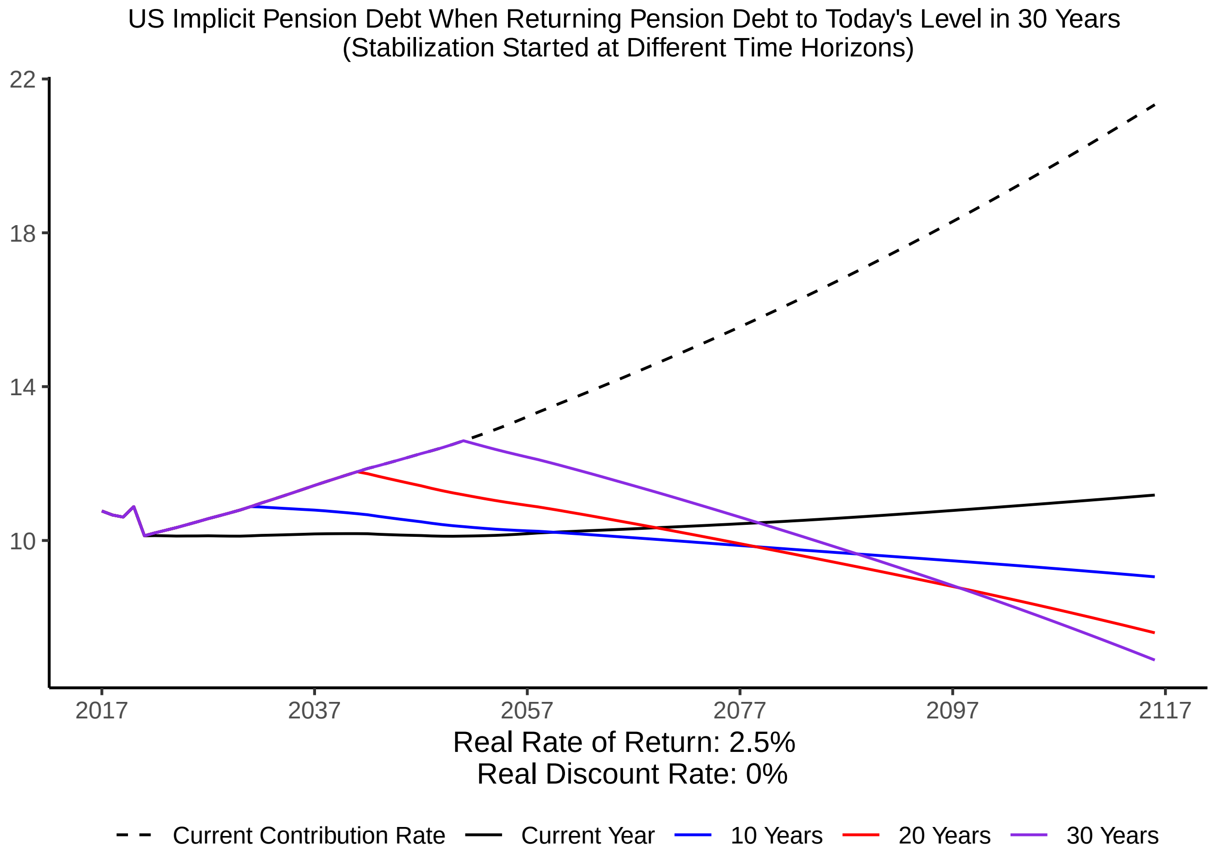
Note: Table displays the percentage point change in contributions as a share of payroll required to obtain today's implicit pension debt as a share of GDP in 30 years for the plans in the estimation sample.

Table A2.2
Change in Contributions to Obtain Today's Debt-to-GDP Ratio in 30 Years, Depending on when Adjustment is Made

		2.5% real rate of return Make changes:				5% real rate of return Make changes:			
	Current Contribution	Now	In 10 years	In 20 years	In 30 years	Now	In 10 years	In 20 years	In 30 years
US Aggregate	24%	7%	10%	14%	17%	-4%	-6%	-8%	-11%
California Teachers	32%	26%	34%	44%	54%	5%	5%	7%	9%
Missouri Teachers	30%	24%	32%	43%	52%	0%	-1%	-1%	-3%
New York State Teachers	7%	19%	26%	34%	41%	5%	7%	11%	16%
Georgia Teachers	21%	16%	23%	31%	39%	0%	1%	3%	5%
Texas Teachers	15%	16%	22%	28%	34%	5%	7%	10%	14%
Oregon PERS	10%	15%	21%	28%	36%	3%	6%	11%	19%
LA County ERS	27%	14%	19%	25%	31%	-5%	-8%	-13%	-18%
Arizona State Corrections Officers	22%	14%	19%	25%	31%	7%	11%	16%	24%
Oklahoma Police	31%	11%	15%	19%	24%	-11%	-17%	-26%	-37%
New Jersey Teachers	18%	9%	11%	13%	15%	8%	11%	17%	25%
DC Teachers	21%	7%	9%	10%	12%	-9%	-18%	-30%	-47%
New Mexico PERA	27%	5%	8%	11%	15%	-5%	-6%	-7%	-9%
University of California	31%	6%	8%	10%	11%	-10%	-17%	-27%	-41%
NY State & Local ERS	18%	5%	8%	9%	10%	-10%	-16%	-24%	-34%
Ohio Teachers	26%	5%	7%	13%	17%	-8%	-12%	-14%	-18%
New Jersey PERS	21%	6%	7%	7%	8%	2%	2%	1%	2%
San Francisco City & County	28%	5%	7%	8%	10%	-14%	-23%	-35%	-52%
South Carolina RS	23%	3%	6%	7%	9%	-2%	-2%	-3%	-4%
Massachusetts SRS	32%	4%	5%	6%	8%	-8%	-13%	-20%	-29%
North Dakota Teachers	27%	3%	3%	4%	4%	-7%	-12%	-19%	-28%
Baton Rouge City Parish RS	41%	0%	3%	7%	11%	-11%	-13%	-14%	-16%
Kansas City Missouri ERS	19%	1%	3%	5%	7%	-8%	-9%	-10%	-11%
Arizona SRS	22%	1%	3%	5%	6%	-6%	-9%	-12%	-16%
Rhode Island Municipal	15%	2%	3%	3%	4%	-7%	-11%	-15%	-21%
Massachusetts Teachers	40%	2%	2%	3%	3%	-12%	-20%	-31%	-47%
Florida RS	13%	-1%	0%	2%	4%	-11%	-13%	-16%	-20%
Illinois Municipal	18%	-3%	-3%	-4%	-4%	-15%	-22%	-32%	-45%
South Carolina Police	25%	-4%	-5%	-6%	-7%	-10%	-15%	-21%	-29%
Maine State and Teacher	26%	-4%	-5%	-6%	-7%	-18%	-28%	-41%	-58%
Pennsylvania State ERS	37%	-3%	-5%	-8%	-9%	-14%	-23%	-34%	-50%
San Diego County	49%	-5%	-5%	-6%	-7%	-27%	-42%	-61%	-87%
Pennsylvania School Employees	37%	-6%	-9%	-11%	-14%	-15%	-23%	-33%	-47%
Indiana Teachers	28%	-10%	-14%	-17%	-20%	-14%	-21%	-31%	-44%
Louisiana Municipal Police	49%	-11%	-14%	-18%	-21%	-25%	-38%	-55%	-78%
Georgia ERS	20%	-14%	-17%	-20%	-24%	-17%	-23%	-32%	-43%
Michigan Public Schools	36%	-14%	-18%	-22%	-26%	-20%	-29%	-40%	-55%
Illinois Teachers	51%	-12%	-18%	-23%	-28%	-17%	-25%	-33%	-42%
Louisiana SERS	45%	-16%	-20%	-24%	-29%	-22%	-30%	-42%	-58%
Illinois SERS	49%	-28%	-37%	-46%	-56%	-28%	-41%	-57%	-78%
San Diego City ERS	79%	-46%	-59%	-73%	-87%	-73%	-107%	-152%	-203%

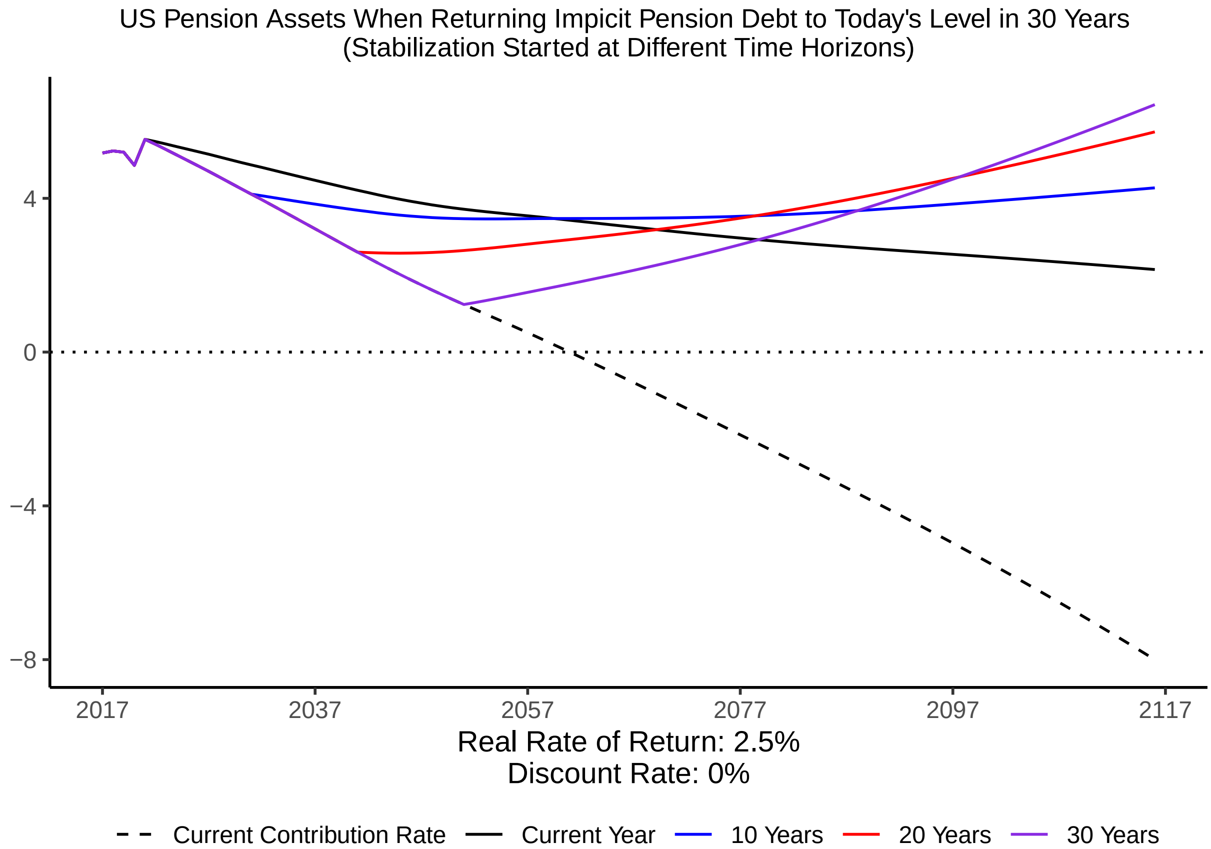
Note: Table displays the percentage point change in contributions as a share of payroll required to obtain today's implicit pension debt as a share of GDP in 30 years for the plans in the estimation sample.

Figure A1



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 2.5 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 2.5 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 A2



Note: The dashed black line displays pension assets as a share of GDP assuming that the assets have a real return of 2.5 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 2.5 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.

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	69.7	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	17.5	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 ($bn)	0.1	8.1	43.2	325.3
Number of active employees	3,047	144,013	864,261	5,760,526
Number of deferred inactive employees	0	18,217	108,612	728,667
Number of current beneficiaries	2,400	106,716	436,243	4,268,628
Average annual salary	40,597	58,667.2	96,900	–
Average annual benefit	15,929	30,489.9	51,132	–
Actuarially required contribution rate	7.7%	22.2%	62.7%	–
Current rate of employee contributions	0%	7.3%	15.5%	–
Current rate of employer contributions	5.8%	19.6%	63.1%	–
Total contribution rate	10.5%	28.9%	77.8%	–
Percent of active employees that are male	22.4%	40.3%	76.5%	–
Average age of current beneficiaries	60.2	70.3	73.5	–
Normal retirement age	50	61	65	–
Normal retirement age (new hires)	50	63.7	68	–
Assumed percent of active employees that are married	55%	80%	100%	–
Joint annuity reduction factor	37.8%	54.3%	100%	–
Percent reduction per year for early retirement	2%	5.4%	10%	–
Growth rate of active employees (yrs 0-20)	-0.8%	0.2%	2.1%	–
Growth rate of active employees (yrs 21-30)	-0.9%	0.1%	1.7%	–
Growth rate of active employees (yrs 31-40)	-0.3%	0.4%	1.9%	–
Growth rate of active employees (yrs 40+)	0.4%	0.4%	0.8%	–
Number of years until vested in plan	1	7	12	–
Cost of living adjustment (new hires)	0%	1%	3%	–
Number of years until vested (new hires)	1	8	16	–
GASB liability ($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%	–

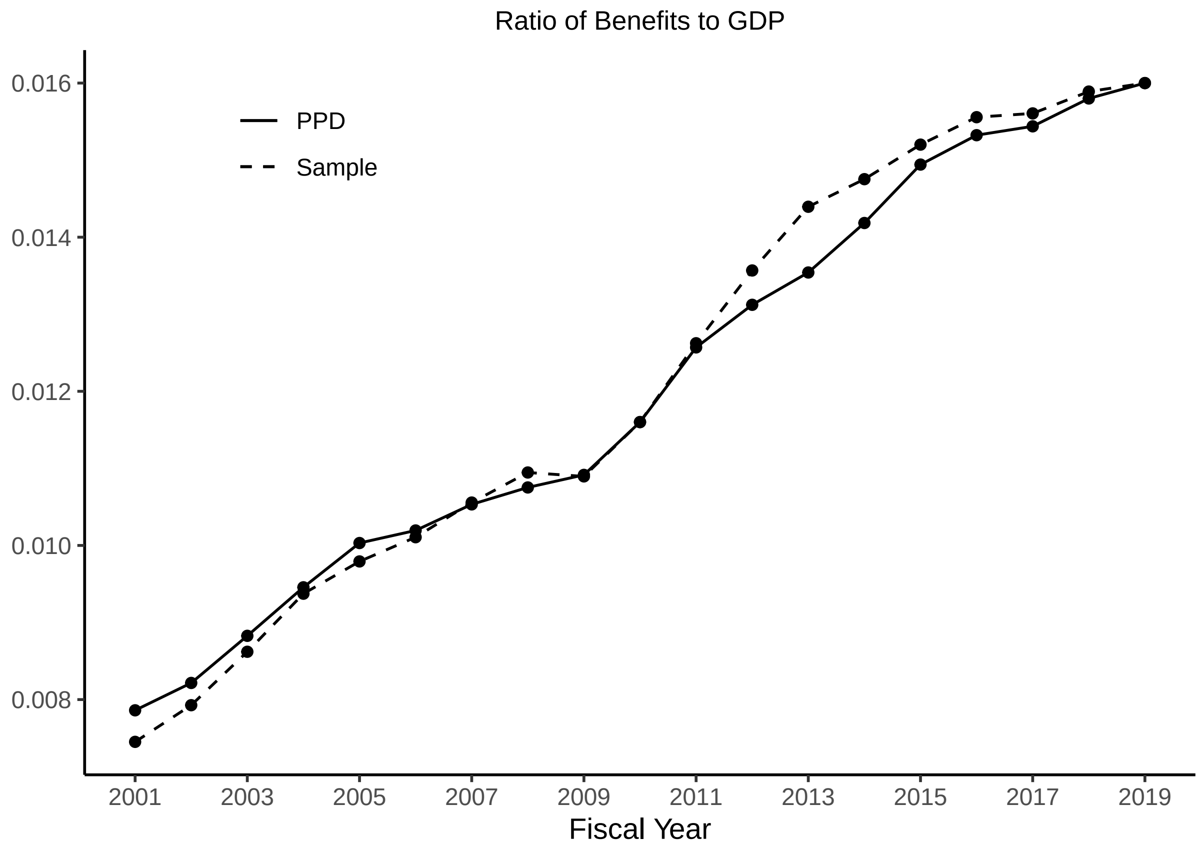
Note:
This table summarizes the input variables utilised in the calculation of the plan level cashflow and liability using the plans stated actuarial assumptions. The data is sourced from the AVs and the Bostong College PPD database.

Table B3
Replication Errors and Calibration Factors

State	Pension Plan	Uncalibrated Liability Error (%)	Calibration factors (v)		
			$vc1$	$vc2$	$vc3$
AZ	Arizona SRS	-0.9	0.976	0.736	1.008
AZ	Arizona State Corrections Officers	-0.5	1.044	0.129	1.011
CA	California Teachers	-6.7	1.136	0.868	1.004
CA	University of California	7.0	0.841	0.777	1.009
CA	San Diego City ERS	-10.6	0.960	2.066	1.016
CA	LA County ERS	-5.7	1.045	0.498	1.012
CA	San Diego County	7.2	1.023	0.309	0.998
CA	San Francisco City & County	5.8	0.941	0.174	1.011
DC	DC Teachers	18.0	0.799	0.472	1.005
FL	Florida RS	2.2	0.918	0.649	1.004
GA	Georgia ERS	-7.0	0.997	2.287	1.012
GA	Georgia Teachers	-7.2	1.037	0.000	1.011
IL	Illinois Municipal	-3.4	0.878	0.000	1.001
IL	Illinois SERS	-0.7	0.981	0.985	1.002
IL	Illinois Teachers	-6.5	1.069	0.871	1.008
IN	Indiana Teachers	-13.7	1.053	0.000	1.026
LA	Louisiana Municipal Police	-7.2	1.016	1.716	1.014
LA	Baton Rouge City Parish RS	-7.8	0.953	0.982	1.016
LA	Louisiana SERS	-13.5	1.008	1.207	1.025
MA	Massachusetts SRS	-11.8	1.219	2.907	1.006
MA	Massachusetts Teachers	-12.0	1.323	0.000	1.004
ME	Maine State and Teacher	3.8	0.822	1.160	1.007
MI	Michigan Public Schools	-5.9	1.274	2.733	0.996
MO	Kansas City Missouri ERS	-15.0	1.131	0.000	1.023
MO	Missouri Teachers	4.1	0.904	0.155	1.003
ND	North Dakota Teachers	-7.3	1.134	0.847	1.006
NJ	New Jersey PERS	-1.7	0.929	0.057	1.016
NJ	New Jersey Teachers	-6.7	0.960	1.491	1.018
NM	New Mexico PERA	-2.0	0.944	0.637	1.008
NY	New York State Teachers	-1.7	0.908	0.430	1.015
NY	NY State & Local ERS	-6.4	1.018	0.920	1.013
OH	Ohio Teachers	-7.4	0.931	0.926	1.018
OK	Oklahoma Police	-3.4	0.935	1.200	1.018
OR	Oregon PERS	-9.3	0.960	1.405	1.016
PA	Pennsylvania School Employees	-6.2	1.086	0.675	1.009
PA	Pennsylvania State ERS	-8.0	1.134	0.000	1.007
RI	Rhode Island Municipal	-5.1	1.026	0.000	1.008
SC	South Carolina RS	-1.8	0.922	0.887	1.010
SC	South Carolina Police	6.3	0.844	1.129	1.001
TX	Texas Teachers	-7.0	1.053	0.728	1.016
US	Total	-4.6	1.028	0.916	1.010

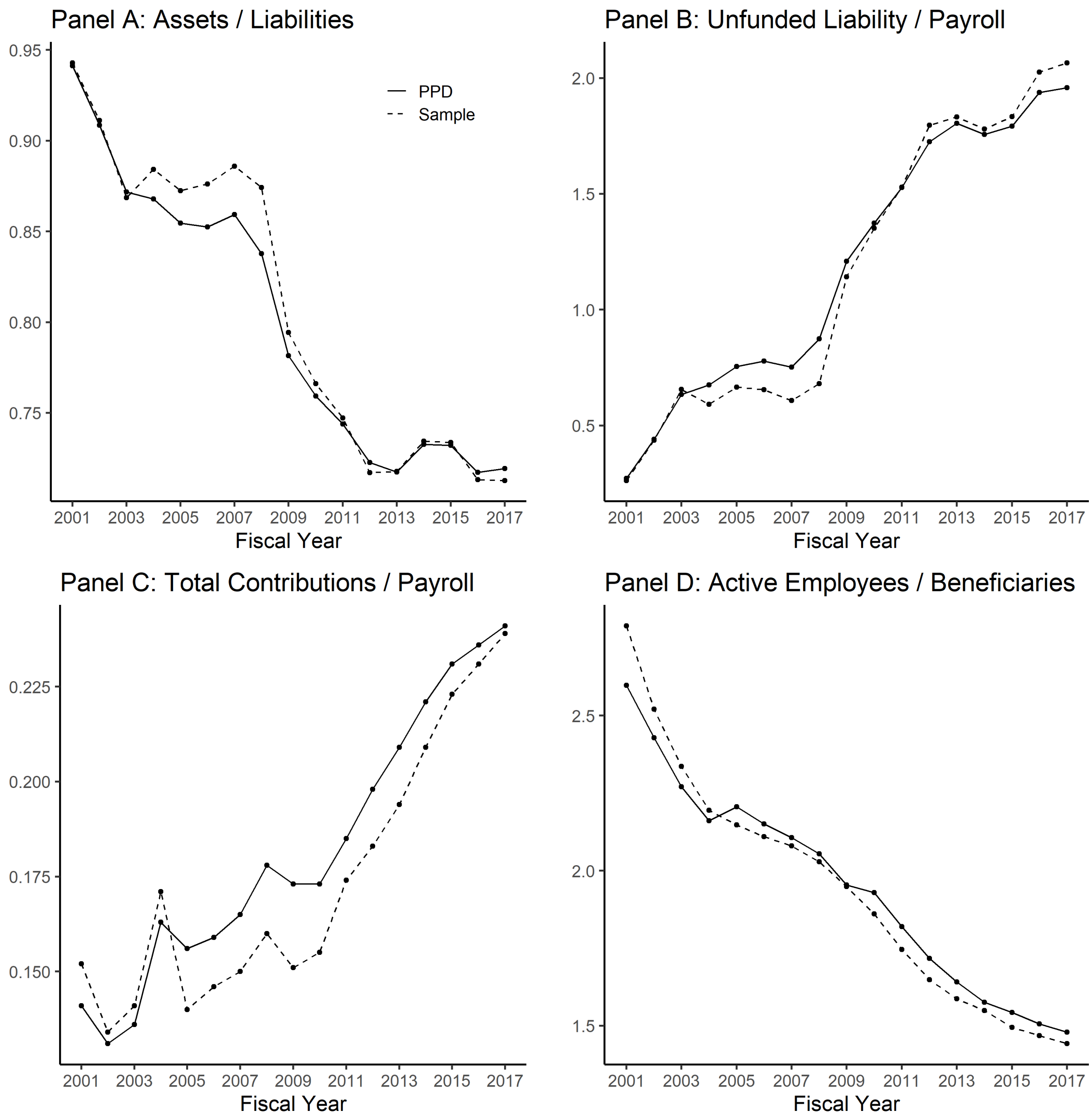
Note:
This table illustrates the accuracy of our replication and cashflows for each plan. The total values are weighted by total liability, active liability, inactive liability, and retired liability respectively. vc1 is the proportional calibration factor for actives, vc2 is the proportional calibration factor for inactives, and vc3 is the geometric calibration factor for retirees.

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.

Figure B2



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

Figure C1

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.

Figure C2

					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.

Figure C3

	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

Figure C4

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.

Figure C5

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.

Figure C6

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.