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

ABSTRACT In this paper we explore the fiscal sustainability of US state and local government pension plans. Specifically, we examine whether, 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

Conflict of Interest Disclosure: The authors did not receive financial support from any firm or person for this paper or from any firm or person with a financial or political interest in this paper. They are currently not officers, directors, or board members of any organization with an interest in this paper. No outside party had the right to review this paper before publication. The analysis and conclusions reached in the paper are the authors' alone and do not indicate concurrence by the Bank of England or members of the Monetary Policy Committee, Financial Policy Committee, Prudential Regulation Authority Board, or the Board of Governors of the Federal Reserve.

a decade in the future. Of course, there is significant heterogeneity, with some plans requiring very large increases to stabilize their pension debt.

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 1.5 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; recent estimates indicate that the obligations of public pension funds exceed their assets by around \$4 trillion.[1]

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 (online appendix figure A1).[2] 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 (Blanchard 2019).

This paper focuses on state and local government pension systems as we find them today—that is, 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 United States, 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

1. See Rauh (2017) and "L.120 State and Local Government Employee Retirement Funds," Board of Governors of the Federal Reserve, https://www.federalreserve.gov/apps/fof/DisplayTable.aspx?t=l.120.

2. Commentary from academics include the claim that "the threat of default looms" for public pensions (Shoag and Farrell 2017, 4) and the statement that these pensions have failed to "provide economic security in old age in a financially sustainable way" (Novy-Marx and Rauh 2014b, 47). Members of Congress have expressed concern that state and local pensions are "unsustainable" and that requests for bailouts from the federal government are inevitable (US Congress Joint Economic Committee 2012). Finally, a major financial institution states that "there are no solutions for some plans given how underfunded they are" (Cembalest 2018, 2).

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 (0.5 percent and 2.5 percent) and a risk-free real discount rate (0.5 percent), for the United States as a whole, state and 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, at the 2.5 percent asset return assumption, pension debt can generally be stabilized with only 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. Under low asset returns, the required adjustments are generally larger, but are nonetheless much smaller than those required to achieve full funding over thirty 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 increases 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.

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 forty state and local pension systems that matches the national distribution of plans in terms of both mean and variance for multiple plan characteristics—for example, the funding ratio. For our main stabilization exercises, we use three deterministic rates of assets returns: the expected return and two lower rates of return that can be viewed as accounting for risk under a certainty-equivalent approach. One of these rates is a market-based risk-free rate of return. We also present an exercise in which realized asset returns are allowed to vary stochastically, allowing us to assess the full distribution of future pension debt and assets.

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 (online appendix figure A2). 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 at about 25 percent below its previous peak, and state and local government employment per capita also remained well below its previous peak.[3] Notably, much of this relative decline in state and local government employment occurred in the K-12 and higher education sectors.[4] 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 I 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 II describes the data and sample selection, section III outlines our methodology, section IV presents the results on pension sustainability under current funding levels and benefit parameters, section V presents the results on the contribution changes required

3. Authors' calculation based on the Bureau of Economic Analysis, National Income and Product Accounts, tables 2.1 and 3.9.6.

4. Authors' calculations based on the Bureau of Labor Statistics, Current Employment Statistics (Establishment Survey).

to stabilize pension debt, section VI presents the results for the stochastic exercises, and section VII concludes.

I. Background

I.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 (Novy-Marx and Rauh 2011; Lucas 2012).[5] 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 prefunded—that is, assets are well below the present value of future benefit payments (Novy-Marx and Rauh 2011).

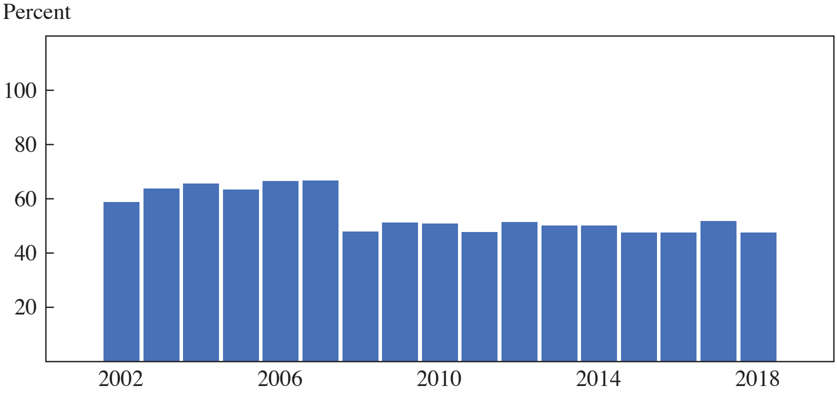
Figure 1 displays the aggregate funding ratio—the ratio of plan assets to the present discounted value of future obligations—for state and local government pensions from the Financial Accounts of the United States.[6] These estimates use the AAA corporate bond interest rate as the discount rate. Over roughly the last fifteen years, state and local pension plans have never exceeded 67 percent prefunding and averaged 55 percent prefunding.[7] Looking back as recently as 1978, one in six 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.

5. The precise discount rate that should be used remains subject to debate, with some arguing for a risk-free rate (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 (CBO 2011) or a high-grade corporate bond yield (Lenze 2013; Lucas 2017).

6. "Financial Accounts of the United States—Z.1," Board of Governors of the Federal Reserve System, https://www.federalreserve.gov/releases/z1/.

7. Even using the plans' own elevated discount rates, these plans rarely have been fully prefunded, averaging just 83 percent funded over the past thirty years (see online appendix figure A3).

Figure 1. 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.

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 prefund the obligations is inappropriate or undesirable. For example, with regard to past academic work, Boyd and Yin (2016b) explicitly state that full prefunding is the proper goal for plans; in many other cases the position is taken more implicitly—for example, focusing analysis on the fiscal costs of transitioning to full funding (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 prefunding is 100 percent.[8] Along similar lines, the blue ribbon panel commissioned by the Society of Actuaries "wholeheartedly believes that . . . plans should be pre-funded" (Society of Actuaries 2014, 19). Finally, ratings agencies typically view "underfunding of pension . . . benefits as [a] key credit issue."[9]

Yet neither in terms of ex ante voter welfare or ongoing fiscal sustainability is the case for the full prefunding of public pensions clear (Brown, Clark, and Rauh 2011). In terms of fiscal sustainability, an unfunded PAYGO

8. From the California Public Employees' Retirement System, *Annual Review of Funding Levels and Risks*, 2014; no longer available online.

9. "U.S. Public Finance 2018 Year in Review," S&P Global Ratings.

pension system—such as the US Social Security system—can be fiscally sustainable in the sense that it requires no outside funding.[10] 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 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 partial PAYGO—can remain sustainable even in the face of adverse shocks, as accumulated assets provide a buffer. State and local pension plans almost always fall into this partially prefunded category.

More broadly, governments typically hold debt, and unfunded pension liabilities are simply a form of (implicit) debt. Such public debt can be sustainable as 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:

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

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.[11] When the rate of interest is greater than the growth rate

10. 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).

11. 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; C_t, B_t, NC_t, and 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 V and in some of our projections.

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. If $r < g$, then implicit debt can be held constant as a share of the economy with contributions less than the normal cost. Of course, the lower is r, the higher is both the pension debt and the normal cost. On net and holding g constant, the lower is r, the more costly it is to achieve long-run pension sustainability.

I.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 prefunding is optimal in many instances and can be viewed as the logical benchmark (Bohn 2011).[12] 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 2021). 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 prefunding (Bagchi 2019; Glaeser and Ponzetto 2014); unfunded pensions may lower the capital stock (Feldstein 1974). Finally,

12. 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 prefund 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.

Lucas (2017) provides a thorough discussion of both the uncertainty surrounding optimal funding levels for state and local pensions, as well as arguments for and against full funding.[13]

I.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 ongoing 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 prefunding 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 they 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 prefunding over thirty years is extremely high in most cases and imply a fiscal burden that would very reasonably be called a crisis. In contrast, our analysis concludes that some plans are currently sustainable over the long run and many others can be rendered sustainable at moderate fiscal cost.

Boyd, Chen, and Yin (2019), Boyd and Yin (2016b, 2017), Yin and Boyd (2019), and Shoag and Farrell (2017) allow for stochastic asset returns. They examine the effect of different funding policies, all of which aim to transition to full prefunding, 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 is 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 ten states under various asset return assumptions, including stochastic asset returns; their work is related to our calculations for asset exhaustion dates. Boyd and

13. As emphasized in Lucas (2017, 20), in a frictionless, perfect market the degree of funding does not matter to taxpayers or beneficiaries; ultimately, only the size and incidence of the obligations matter. However, in the presence of market imperfections "funding decisions have real consequences. Considerations affecting the best choice of funding rules include intergenerational equity, expectations about future economic growth, optimal tax policy, transparency, fiscal constraints and political incentives."

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 he 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) discuss this paper's pension debt stabilization framework with a focus on asset return risk and provide a stochastic analysis of debt stabilization for the California State Teachers' Retirement System (CalSTRS) plan.

II. Data and Sample Selection

We obtain data from multiple sources on pension plans as of fiscal year 2017. A principal source is the Public Plans Database (PPD) maintained by the Center for Retirement Research at Boston College.[14] The PPD contains plan-level data accounting for 95 percent of state and local pension plan membership and assets in the United States.

The next two 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 cash flows. Specifically, for each state we collect the following matrices and 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, and (7) retirement rates by age and service and plan tier.[15]

The AVs and CAFRs provide further critical information relating to plan provisions and actuarial assumptions not available in the PPD: the plan benefit factor, normal retirement age, early retirement age, service requirement,

14. "Public Plans Data," Center for Retirement Research at Boston College, Center for State and Local Government Excellence, and National Association of State Retirement Administrators, https://publicplansdata.org/.

15. Termination rates include all non-mortality and disability-related causes of employment termination.

vesting requirement, salary averaging method, penalty factor for early retirement (percentage reduction per year early), plan marriage and spousal benefit assumptions, gender ratio of the active employee population, and cost-of-living adjustment assumptions (COLAs).[16] 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).[17]

We estimate the future annual benefit cash flows for a representative set of forty state and local government pension plans. Our sample includes the largest twenty public pension plans in terms of liabilities in the PPD. Our remaining twenty 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.[18] Our targeting of the

16. Annual pension benefits are typically equal to the years of service multiplied by final average salary times the benefit factor. Thus, the benefit factor is the percent of final salary to which a pension beneficiary is entitled for each year of service. Typically, the average salary from the highest three to five years is used to determine the final salary.

17. 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.

18. Our sample is selected as follows: we randomly select twenty plans from the PPD and add these to the largest twenty plans from the PPD in terms of stated liabilities to obtain a sample of forty plans. We then calculate the sum of squared deviations between the sample and the PPD universe for the ten targeted moments—that is, the mean and standard deviation of the five plan characteristics. We iterate five thousand 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 zero and a standard deviation of one. Thus, the five plan characteristics can be viewed as having equal weight in the sample selection process.

Table 1. Estimation Sample of State and Local Pension Plans

	Unweighted		*Weighted*	
	Estimation sample	*PPD national sample*	*Estimation sample*	*PPD 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 active member growth	0.28	0.34	0.41	0.41
	(0.54)	(0.55)	(0.59)	(0.55)
Observations	40	179	40	179

Sources: Public Plans Data, https://publicplansdata.org/public-plans-database/; authors' calculations.

Note: Means are displayed, with standard deviations in parentheses. In the two right columns 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 percentage for active member growth is weighted by the number of active members.

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 and Retirement System and the New York State Teachers' Retirement System, both of which are essentially fully prefunded (using the plans' chosen actuarial assumptions). 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 using the plans' 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 a funding ratio around 75 percent. Online appendix table B1 provides a complete list of plans in our sample; online appendix table B2 summarizes the inputs for each plan; and finally, as shown in online appendix figures B1 and 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 United States—over six thousand 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 forty plans on a case-by-case basis; for example, in a number of cases we have consulted with the plan administrators 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.[19] 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.

III. Methodology

Our methodology for estimating pension fiscal sustainability can be divided into three stages: First, 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 cash flows replicate the stated liabilities in the relevant actuarial reports. We then reestimate these cash flows using our own economic assumptions uniformly across plans. Second, 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. 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.

III.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 II 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

19. Subsequent works by these authors have even larger sample sizes; for example, Novy-Marx and Rauh (2014a) has a sample of 193 plans.

retirement, disability, death, and quits or 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 cash flows 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. Our specific procedures for calculating liabilities, which generally follow Winkelvoss (1993), and our calibration methods are presented in detail in online appendix A. Our uncalibrated estimates were on average quite accurate, so the calibration process does not have a large effect on our aggregate analysis (see online appendix table B3).

Finally, we reestimate 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.[20]

III.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 head count (ee_{t-1}) multiplied by the sum of the projected growth rate in the government's workforce (n_t) and the proportion of withdrawals and retirements from the workforce in the previous year (q_{t-1}).

$$nh_t = ee_{t-1}\left(n_t + q_{t-1}\right) \tag{2}$$

20. 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 Personal Consumption Expenditures (PCE) price index. CPI inflation tends to systematically run above consumer inflations as measured by the PCE price index (Haubrich and Millington 2014).

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 five 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 Demographics Research Group at the University of Virginia's 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 from the CBO's 2019 long-term budget projection.[21] See online appendix 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.

III.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 year 2021 and also base our asset return and discount rate assumptions on financial market data from early in the calendar year 2021.

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

21. 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. See CBO (2019, table 10).

in the financial reports matched to market rates of return on appropriate indexes (see online appendix E). Finally, we use the assumed general asset rate of return—see section III.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 year 2017.

III.D. Asset Returns and Discount Rates

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. We primarily present our results using three deterministic asset return assumptions, including the expected rate of return. To address uncertainty in market performance, we also use rates which are risk adjusted downward; these include a risk-adjusted return based on recent market prices.

The question of whether the cash flows in government budget projections *should* be risk adjusted is difficult and contentious.[22] As noted by Kamin (2013), it is not standard practice to risk adjust budget projections. For example, the CBO projects expected revenues and expenditures over time, even though those cash flows are risky. (For example, 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.[23] Furthermore, 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.

On the other hand, risk adjustment prevents plans from appearing healthier simply because they invest in riskier assets. That is, to the extent expected

22. This issue is related to, but not equivalent to, the contentious issue of the correct discount rate to calculate pension liabilities.

23. On the other hand, for credit and loan guarantee programs like student loans, which under the Federal Credit Reform Act of 1990 (FCRA) are scored on a net present value rather than cash flow basis, the CBO does advocate risk adjusting (Lucas and Phaup 2008; Marron 2014). Official estimates of the costs of federal loan programs are not risk adjusted, but the CBO's preferred measure, which they call fair value, is. For a discussion in support of fair value, see Lucas (2012); for a discussion of the pros and cons of risk adjusting, see Sastry and Sheiner (2015).

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 trade-off 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.

In addition, even if one chooses to risk adjust, it is unclear whether the market rate of return on safe assets is the appropriate risk-free rate for government-sponsored pension plans. 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.[24] 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.

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 long-run rates of return on the pension assets: a risk-free real rate of 0.5 percent, a real rate of 2.5 percent, and a real rate of 4.5 percent.

The 0.5 percent real rate of return is roughly equal to the longer-run risk-free rate (putting aside the issues discussed immediately above) in recent years. Thus, it represents the rate of return that pension plans can achieve with certainty today, based on financial market prices in recent years—that is, it is the risk-adjusted or risk-neutral rate of return. We obtain the risk-free rate from the yield on the zero coupon twenty-year Treasury Inflation

24. Our market-based measure of the risk-free rate, which is based on Treasury Inflation Protected Securities (TIPS) yields, may be less affected by this because TIPS are less liquid than other Treasuries.

Projected Securities (TIPS).[25] It is worth noting that the current rate is unusually low by historic standards: indeed, CBO long-run economic projections have the real rate on ten-year Treasuries rising over time, reaching 0.9 percent by 2030 and 2.7 percent by 2051 (CBO 2021). Thus, we view the 0.5 percent rate as very conservative—it is quite plausible that plans will be in better shape over time simply because this rate rises.

The 4.5 percent return reflects the expected real rate of return on a pension portfolio comprised of 20 percent risk-free assets and 80 percent equities. The risk-free assets earn the 0.5 percent risk-free rate and the equities earn this rate of return plus an equity (or risk) premium of 5 percent.[26] This 4.5 percent expected real rate of return is equal to about what the plans are assuming on average and slightly less than what they have received on their assets, on average, over the past fifteen years. The 2.5 percent rate of return is equivalent to a mixed portfolio containing 60 percent risk-free assets and 40 percent equities.[27] An alternative interpretation of these asset return assumptions is to view them as capturing realized asset returns in different future states of the world.

In all cases we discount plan liabilities using the 0.5 percent 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) is 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.[28] In any case, as we explain below, our results are not very

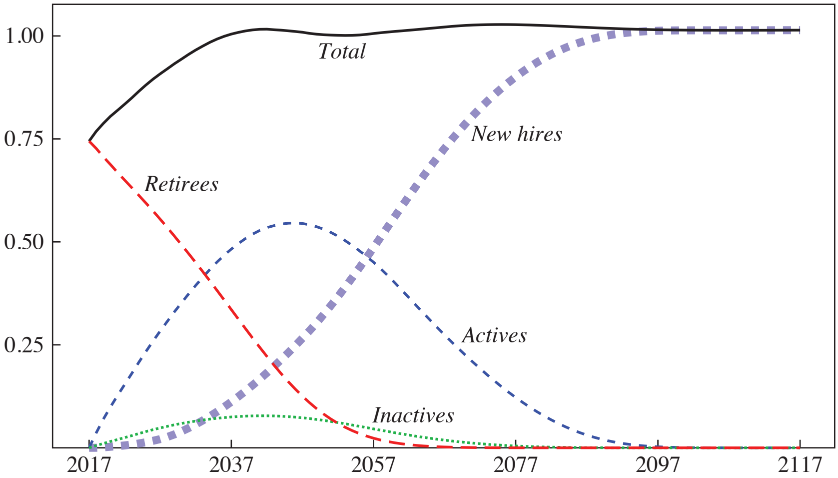
25. The yield on the zero coupon twenty-year TIPS averaged roughly 0.5 percent from the start of 2018 through February 12, 2021. (February 12, 2021, is the date used to obtain financial market data with which to adjust pension plan assets to current values.) The TIPS yield is based on the methodology of Gurkaynak, Sack, and Wright (2008) and obtained at https://www.federalreserve.gov/data/yield-curve-tables/feds200805.csv.

26. We view the 5 percent equity premium assumption as relatively conservative. For example, 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 United States in the twentieth century; and Novy-Marx and Rauh (2011, 2014a) use an equity premium of 6.5 percent for analyzing pension outcomes.

27. Lucas and Zeldes (2009) discuss the *optimal* asset allocation for state and local pensions and demonstrate that a higher-risk, higher-return allocation of assets can be desirable when it causes distortionary tax rates on average to be lower and when it provides a hedge against liability risk. Nonetheless, the authors conclude that these arguments fail to justify the very elevated share of high-risk assets in most state and local pension portfolios.

28. In particular, most pension plans have the legal ability to change the cost-of-living adjustment (COLA) even for existing retirees.

Figure 2. US Aggregate Ratio of Beneficiaries to Active Workers



Source: Authors' calculations.

Note: The solid 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 line labeled "Retirees" displays the ratio of beneficiaries who were receiving benefits as of 2017 to current workers. The dashed line labeled "Actives" displays the ratio of beneficiaries who were employed by a state and local government as of 2017 to current workers. The dashed line labeled "Inactives" 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 to current workers. The dashed line labeled "New hires" displays the ratio of beneficiaries who were hired after 2017 to current workers.

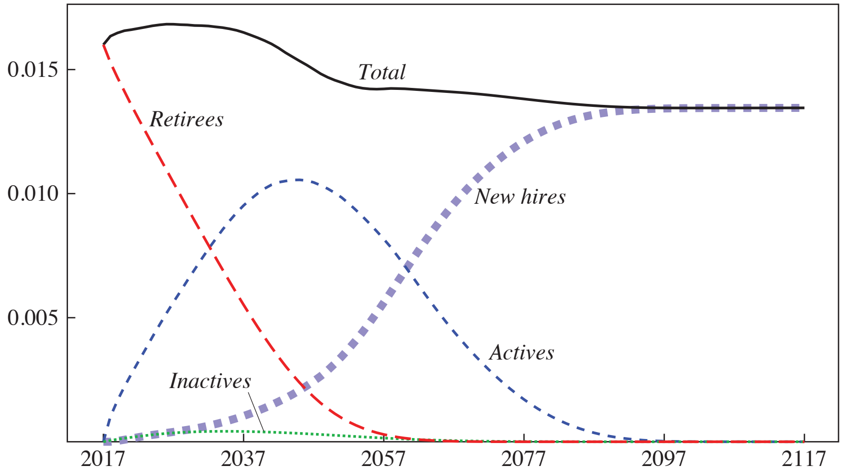
sensitive to the chosen discount rate because we are focusing on stability of the implicit debt rather than its level. That said, exercises that calculate what is required for plans to be fully funded are very sensitive to this assumption.

IV. Results under Current Funding Levels and Benefit Parameters

IV.A. Pension Benefit Payments

Figure 2 shows how the ratio of beneficiaries to active workers evolves over time for our set of plans. The top solid line shows the total, while the dotted lines show the composition. In year 2017—the starting point for our simulation—beneficiaries are just current beneficiaries, but over time, current beneficiaries die, while current workers and current inactive members retire. Meanwhile the workforce is being populated with new workers, and eventually these new hires retire as well.

Figure 3. US Aggregate Ratio of Benefit Payments to GDP



Source: Authors' calculations.

Note: The solid line displays the ratio of total state and local government pension benefit payments to GDP. The dashed line labeled "Retirees" displays the ratio of benefit payments to beneficiaries who were receiving benefits as of 2017 to GDP. The dashed line labeled "Actives" displays the ratio of benefit payments to beneficiaries who were employed by state and local government as of 2017 to GDP. The dashed line labeled "Inactives" 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 to GDP. The dashed line labeled "New hires" displays the ratio of benefit payments to beneficiaries who were hired after 2017 to current workers.

The ratio of beneficiaries to workers in state and local governments is projected to increase about 36 percent from 2017 to 2040 and then roughly stabilize. In comparison, projections by the Social Security actuaries show that, for the United States as a whole, the ratio of Social Security beneficiaries to workers is projected to rise about 39 percent over this time period.[29] We view this similarity as indicating that we have adequately modeled, in aggregate, the future flow of state and local government employees.

Figure 3 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 United States as a whole. In 2017, pension plan benefit payments were

29. These calculations refer to data for Old Age, Survivors, and Disability Insurance (OASDI); "The 2020 OASDI Trustees Report," Social Security, https://www.ssa.gov/OACT/TR/2020/index.html. This is an appropriate comparison because state and local pensions also cover disability as well as retirement.

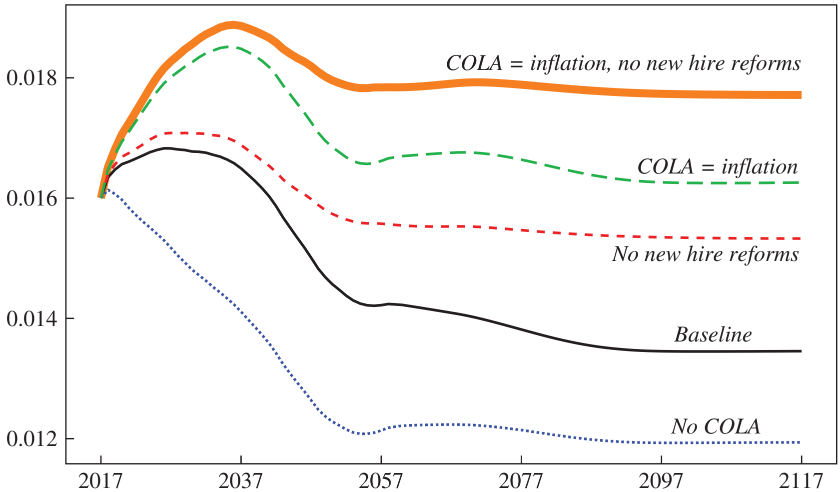
approximately 1.6 percent of GDP. Strikingly, figure 3 indicates benefits are already nearing their peak, rising only about 5 percent over the next ten years before declining to 1.4 percent of GDP by 2070 (about 13 percent lower). This pattern is surprising given the pattern of aging described above. Social Security benefits relative to GDP are projected to rise 21 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 cost-of-living adjustment (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, twelve plans in our sample have legislated changes making their COLA less generous or even eliminating it. A further five plans have been able to lower their COLA by reducing or eliminating supplemental or ad hoc COLAs.[30] Second, pension plans have gradually been making changes over time to lower benefits and raise retirement ages for new hires (Aubry and Crawford 2017). These adjustments also reduce average pension benefits over time. The reduced growth in average benefits due to the new hire reforms and changes to COLAs offsets a large share of the effects of the 36 percent growth in the ratio of beneficiaries to workers shown above.

Figure 4 again presents our baseline estimate for benefits payments as a share of GDP, as well as several counterfactual exercises which explore the effect of policy changes. The lowest 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 15 percent below where we project them when the current COLAs are maintained, and about 26 percent below their level in 2017. In contrast, consider the line displaying 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 higher level—indeed, the rise is about 16 percent, much closer to the 21 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 middle line displays the trajectory of

30. 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 COLAs in recent years have been downward adjustments.

Figure 4. US Aggregate Ratio of Benefit Payments to GDP under Different Scenarios



Source: Authors' calculations.

Note: The line labeled "Baseline" displays the ratio of total state and local government pension benefit payments to GDP. The line labeled "No new hire reforms" 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—that is, new worker reforms—are canceled. The line labeled "COLA = inflation" 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 line labeled "No COLA" displays the ratio of total state and local government pension benefit payments to GDP assuming that all plans set their COLA to equal zero.

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 13 percent over time, the ratio of benefits to GDP would stabilize at about the same ratio as today.[31]

Finally, the top 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 17 percent between 2017 and 2040—reasonably close to the 21 percent increase projected for Social Security. Thus, new worker reforms and

31. 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).

COLAs explain the majority of the more muted rise in state and local pension benefits compared to Social Security.[32] Online appendix table A1 presents benefit payments on a plan-specific basis in 2017 and 2047; for 2047 the “no reforms” and “no reforms and COLA equals inflation” counterfactuals are also displayed.

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 online appendix figure A4, the flattening out of pension benefit payments as a share of GDP is readily apparent in the historical data.

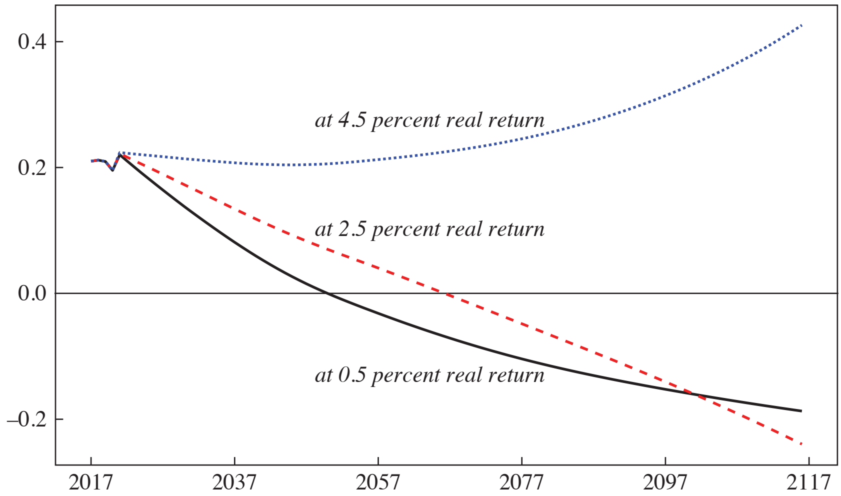
IV.B. Pension Asset Projections

To determine whether plans are fiscally sustainable, we hold the annual contributions of employees and employers (as a share of GDP) fixed at today’s level and assume that benefits evolve as described in figure 4.[33] We view this as performing a current policy analysis, akin to the current law baseline used by CBO in its projections for the federal budget. Figure 5 shows the path of pension assets in this current policy analysis under our three asset return assumptions. With the 0.5 percent real rate of return, current contributions are insufficient to keep the plans solvent. Despite the projected decline in benefits relative to GDP, assets relative to GDP begin declining immediately and are exhausted in about thirty years. With a 2.5 percent rate of return, assets are declining, but not as quickly; they are exhausted in about forty-seven years. If, however, the plans earn 4.5 percent on their assets, then plans are sustainable: at current contribution rates, assets rise indefinitely and the plans face no fiscal stress (indeed, one would

32. 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 fifteen 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 from the Northeast and Midwest (whose governments tend to have relatively generous pension plans).

33. 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. This is particularly an issue with plans that have lowered the generosity of their defined-benefit plan while introducing a defined-contribution plan (i.e., plans that have gone hybrid). We account for both the declining contribution rate and the declining generosity of the defined-benefit plans.

Figure 5. US Ratio of Assets to GDP



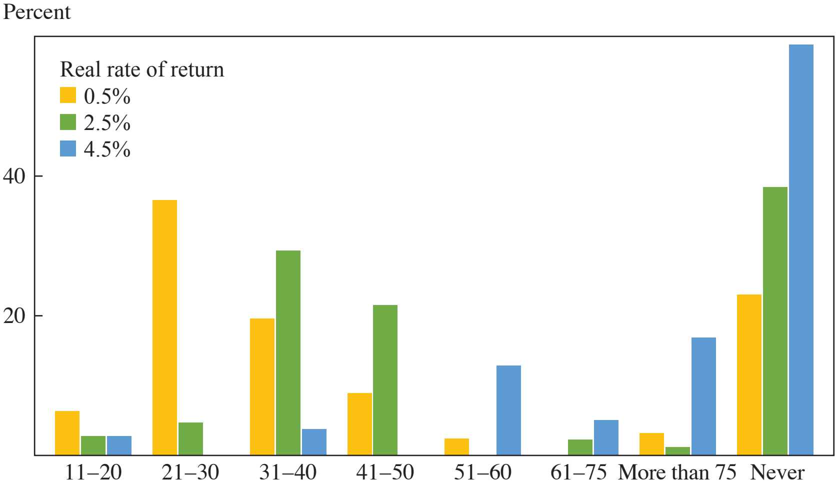
Source: Authors' calculations.
Note: The figure displays pension assets as a share of GDP under varying assumptions about asset returns and assuming that employer contributions as a share of payroll are held fixed at their 2017 value.

argue that current contribution rates are too high, if one could count on a 4.5 percent real rate of return).

Of course, looking at the US pension system as a whole masks a lot of variation across plans. Figure 6 shows what share of liabilities are in plans that exhaust within various time periods. With a 0.5 percent real rate of return, about 6 percent of liabilities are in plans that exhaust within twenty years and 43 percent are in plans that exhaust within the next thirty years; even at this low rate of return, 23 percent of liabilities are in plans that never exhaust. At a 2.5 percent real rate of return, only 7 percent of liabilities are in plans that exhaust within the next thirty years, and 38 percent are in plans that never exhaust. With a 4.5 percent real rate of return, almost 60 percent of liabilities are in plans that never exhaust, whereas the other plans do exhaust, but mostly not for many decades.[34] (Online appendix table A2 reports the exhaustion rates for all the plans under the three rate of return assumptions.)

34. One notable exception is the New Jersey Teacher's Plan, which exhausts in ten years even with a rate of return of 4.5 percent.

Figure 6. Percent of Total Liabilities in Plans That Exhaust Their Assets over Various Time Horizons



Source: Authors' calculations.

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.

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 thirty years under the low return scenario. Adjustments may be necessary. The questions are: How large are those adjustments, and how urgent are they?

V. Pension Debt Stabilization

V.A. Pension Debt Stabilization Discussion

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

$$L_{t+1} = (1+\delta)L_t - B_{t+1} + NC_{t+1} \tag{3}$$

$$A_{t+1} = (1+r)A_t - B_{t+1} + C_{t+1} \tag{4}$$

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

$$\Delta l_{t+1} = \frac{(\delta - g) l_t}{1+g} - b_{t+1} + nc_{t+1} \tag{5}$$

$$\Delta a_{t+1} = \frac{(r - g) a_t}{1+g} - b_{t+1} + c_{t+1} \tag{6}$$

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 (6) yields the steady-state contribution to stabilize debt at any given asset level and steady-state benefit outflow:

$$c = b - \frac{(r-g)}{(1+g)} a \tag{7}$$

When assets are zero, as in a pure PAYGO 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 the assets.

Note that equation (7) 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.[35]

We use these identities in combination with our projections of benefits cash flows 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.

V.B. Stabilization Exercises

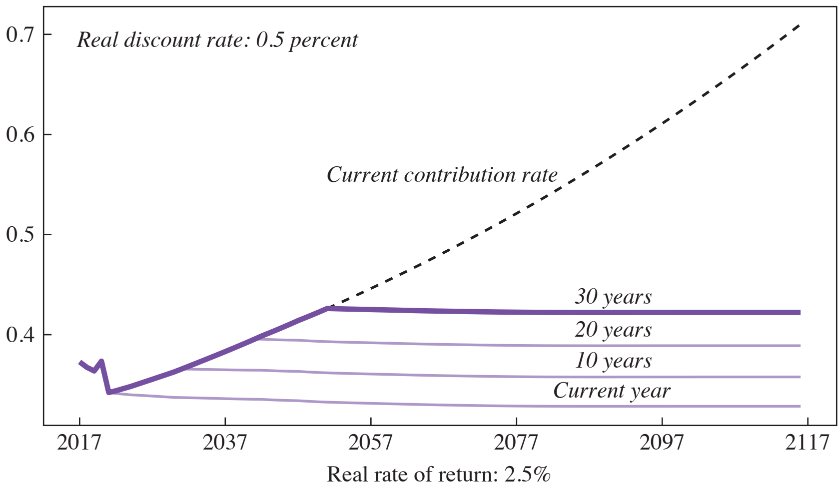
Our analysis here involves estimating the changes in pension contributions which would stabilize pension debt as a share of the economy. We perform two stabilization exercises: First, for long-run stabilization, we ask what onetime and permanent changes in the contribution rate would make implicit pension plan debt eventually stabilize as a share of GDP (without specifying what that share is). Sheiner (2018) does this exercise for the federal debt. Second, for medium-run stabilization, we ask what onetime 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 thirty years' time. CBO (2020) does this type of exercise for the federal debt.

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 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 onetime, but permanent, change in the pension contribution a plan would have to make in order to achieve stability and then

35. 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 0.5 percent 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 III.D for a discussion. See also Lucas (2017, 3) for arguments in favor of delinking the choice of discount rate used to value pension liabilities from choices over funding requirements, for example "it may be sensible to partially link funding rules to expected return on assets."

Figure 7. US Implicit Pension Debt under Pension Debt Stabilization (Stabilization Started at Different Time Horizons)



Source: Authors' calculations.

Note: The dashed 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 line labeled "Current year" 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 onetime, permanent change such that pension debt eventually stabilizes in the longer run. The lines labeled "10 years," "20 years," and "30 years" are analogous to the line labeled "Current year" but assume that the adjustment to pension contributions occurs in ten years, twenty years, and thirty years, respectively.

assess how that contribution changes depending on whether the government acts now, acts in ten years, twenty years, or thirty years. Figure 7 shows the evolution of the unfunded liability relative to GDP for the United States as a whole if real asset returns are 2.5 percent under the current policy analysis discussed in section IV. The dashed 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 33 percent in all periods. Waiting to stabilize does not change the steady-state ratio much. If the governments wait thirty years to act—that is, if they maintain their current contribution rate for thirty years and then act to stabilize—the long-run implicit debt to GDP ratio is 43 percent—about 30 percent higher than it would be if the government acted today. The left panel of table 2 presents the contribution increases,

Table 2. 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*
0.5	12.5	11.1	9.9	8.7	14.7	18.2	21.1	23.4	47.2	51.1	54.1	56.2
2.5	6.9	7.4	8.0	8.6	6.2	8.7	11.5	14.3	30.3	33.2	36.1	38.8
4.5	–1.5	–2.0	–2.6	–3.4	–3.0	–4.0	–5.3	–6.7	14.7	13.9	12.7	11.2

Source: Authors' calculations.

Note: The left panel displays the onetime, permanent percentage point change in contributions as a share of payroll required to stabilize implicit pension debt as a share of GDP for the United States in aggregate. The central panel displays the onetime, 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 thirty years for the United States in aggregate. The right panel displays the onetime, permanent percentage point change in contributions as a share of payroll required to achieve full prefunding in thirty years for the United States in aggregate.

as a share of payroll, required to stabilize the debt-to-GDP ratio for all four asset return scenarios. At a 4.5 percent real rate of return, plans are, in aggregate, already stable and can lower contributions. At the 2.5 percent rate of return, plans must increase contributions by 6.9 percent of payroll. Under the constant risk-free 0.5 percent return assumption, contributions must increase by a larger 12.5 percent. (Online appendix table A3 presents plan-specific changes in required contributions to stabilize pension debt in the long run; online appendix table A4 reports the associated long-run, stabilized implicit debt-to-GDP ratios and also presents the peak debt-to-GDP ratio reached on the transition to the long-run value.)

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 ten years, the increase has to be equal to 7.4 percent of payroll under 2.5 percent asset returns. Acting sooner rather than later lowers the required increase, but not by much. Even if the plans wait thirty years to act (i.e., go thirty years without any changes in contributions), the required increase only rises to 8.6 percent of payroll. Delaying, though, does result in a somewhat higher level of pension debt in steady state. Under the risk-neutral 0.5 percent 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. 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 assets and then beginning the stabilization process allows stabilization with a lower contribution rate—see equation (7).[36]

This comparison highlights an interesting conundrum—when asset returns are higher, plans are in better shape and need to contribute less to stabilize their debt. When asset returns are lower, plans are in worse shape as stabilizing pension debt is more expensive, but for both the lowest and even

36. One of our discussants notes that in some theoretical models, r must exceed g. However, $r < g$ is possible in long-run equilibrium in theoretical models with sufficient risk, particularly those that incorporate significant idiosyncratic uninsurable risk, such as heterogeneous agent New Keynesian (HANK) models. Moreover, as noted by Blanchard (2019, 1197), "the current US situation, in which safe interest rates are expected to remain below growth rates for a long time, is more the historical norm than the exception."

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.

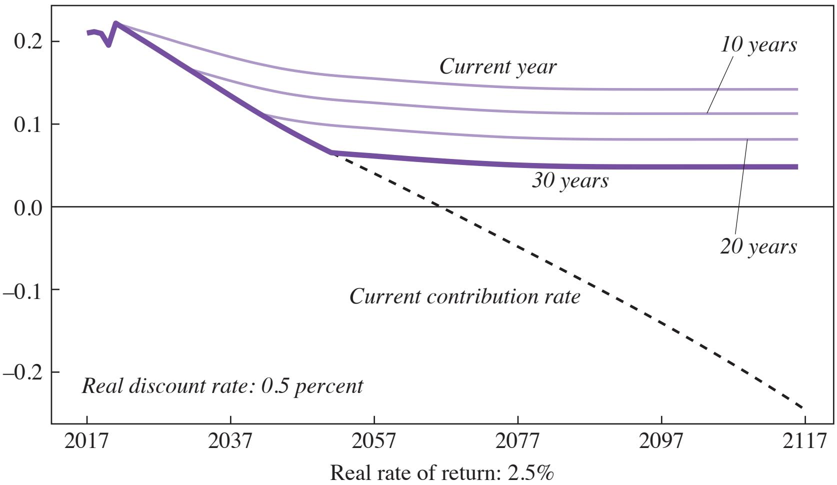
How fiscally onerous would these increased contributions be? To put these contribution changes into context, aggregate pension contributions increased by 10 percent of payroll between 2009 and 2019 and equaled 27 percent of payroll in 2019.[37] Accordingly, if governments act now, a further upward adjustment equal to the adjustment made over the last decade would be more than sufficient to stabilize their pension debt under the 2.5 percent return assumption. Under the 0.5 percent rate of return, plans would have to do more—raising their contribution by 25 percent more than the increase over the past decade. (But, at this low rate of return, plans would be better off not acting in the near term if all they cared about was eventually stabilizing debt.) Overall, we view the contribution changes needed to obtain pension debt stability as achievable, although they would certainly entail some fiscal strain, particularly under the 0.5 percent 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 8 shows plan assets relative to GDP for each of the 2.5 percent asset return scenarios and illustrates that the long-run stabilization exercise involves plans drawing down assets in order to smooth through the period of peak cash flow demand over the next two decades. Although assets decline in these debt stabilization scenarios, they never approach zero in aggregate. That said, some individual plans do exhaust their assets and stabilize at negative asset values in the various scenarios; and assets fall into negative territory in aggregate in the 0.5 percent for the scenario in which they wait thirty years to stabilize (see online appendix table A5).[38] The simulations yielding negative assets effectively assume that these governments issue marketable debt—akin to the pension obligation bonds which have been issued by some governments in the past—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 assumed asset return.

37. Based on full PPD sample, updated through fiscal year 2019.

38. For instance, a number of plans in our sample that are poorly funded now and have responded by cutting COLAs or future benefits or both—such as the Illinois State government plans and the New Jersey Teacher's Plan—end up with negative assets in the 2.5 percent scenario.

Figure 8. US Pension Assets under Pension Debt Stabilization (Stabilization Started at Different Time Horizons)



Source: Authors' calculations.

Note: The dashed 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 line labeled "Current year" 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 onetime, permanent change such that pension debt eventually stabilizes in the longer run. The lines labeled "10 years," "20 years," and "30 years" are analogous to the solid line labeled "Current year" but assume that the adjustment to pension contributions occurs in ten years, twenty years, and thirty years, respectively.

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 thirty 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—for example, 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—that is, intuitively dig the hole no deeper while spreading the costs of doing so evenly over thirty years. This exercise is consistent with this objective, on net, over a thirty-year horizon.

The middle panel of table 2 reports the onetime, permanent contribution change required for the implicit debt-to-GDP ratio, at the end of thirty years, to equal its value in 2021 for the United States as a whole. It should be noted that, in this experiment, we always allow the pension plan thirty years to get back to the original debt ratio, so that starting in ten 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 percent rate of return on assets, plans would need to increase contributions by 6.2 percent of payroll today, 8.7 percent if they began in ten years, and 11.5 percent if they began in twenty years. There is little difference between the contributions required under this exercise and the long-run stabilization exercise (the left panel in table 2) if action is taken today; but the difference becomes somewhat larger if stabilization is delayed. This difference arises because the thirty-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. Online appendix figures A5 and A6 show for the United States as a whole the trajectory of implicit debt and assets, respectively, under these stabilization exercises.

At an asset return of 0.5 percent, contributions would have to increase about 15 percent to ensure that the debt-to-GDP ratio is the same as today's in thirty 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 thirty years and long-run exercises are much larger under these low asset returns, because even though the costs to stabilize a given level of debt are lower the higher that debt, the costs to actually pay down debt are quite high since asset returns are so low. Waiting ten years to take action at the 0.5 percent asset return if plans wanted to ensure that the debt ratio returned to this year's level in thirty years would require an increased contribution of 18.2 percent of payroll; waiting twenty years would boost that required contribution to 21.1 percent (but recall that the plan benefits form the lower contributions over the first twenty years).

Online appendix table A6 presents plan-specific changes in contributions to stabilize over thirty years. Online appendix table A7 presents plan-specific funding ratio estimates for the thirty-year stabilization exercise; the table shows that assets do become negative for a few plans.[39] While many plans do have the ability to issue debt through instruments like pension

39. These are plans with sharply declining liabilities: for debt to remain constant, a decline in liabilities has to be offset by a decline in assets. When the decline in liabilities is large relative to starting assets, maintaining debt can require assets going negative.

obligation bonds, some may not. As an alternative way of assessing stability, we calculated the contributions required for plans to have the same funding ratio in thirty years as they do today. For the United States as a whole, required contributions under this exercise, if the adjustment is made now, are between 2 percent and 4 percent of payroll higher than those required to achieve the same debt in thirty years, depending on the rate of return assumption. These results in aggregate, and by plan, are reported in online appendix table A8.

In contrast to our focus on stabilizing implicit pension debt, past work on pension funding has often focused on achieving full prefunding over a fixed period of time. The rightmost panel of table 2 presents estimates of the funding increase required to achieve full prefunding over a thirty-year horizon. These estimates are broadly similar to those presented in Novy-Marx and Rauh (2014b).[40] The increases required to reach full funding are very substantially larger than those required to stabilize debt. Under 2.5 percent asset returns, the contribution boost to reach full funding in thirty years is roughly four and a half times larger than the increase required to stabilize the debt over the long run (30 percent versus 7 percent). The funding increases required to reach full funding under the 0.5 percent and 2.5 percent return assumptions would be hugely challenging, if not infeasible, for state and local governments.

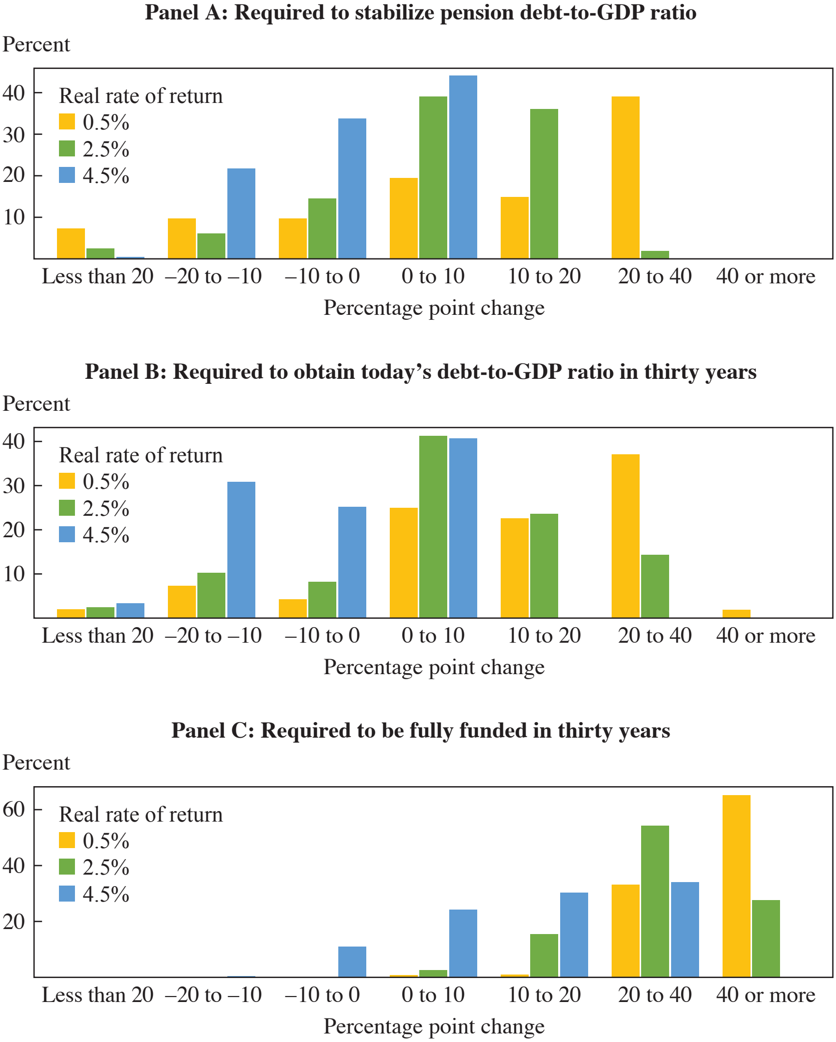
Finally, online appendix A discusses our calculated normal costs; readers interested in comparing the evolution of normal costs over time and in comparing these annual service costs to required contributions under various debt stabilization scenarios should refer to online appendix table A9 and the associated text.

V.C. Variation in Required Contribution Adjustments across Plans

Figure 9 shows the distribution of required adjustments across the asset return assumptions and stabilization exercises. Panel A shows the distribution of required adjustments for plans to stabilize the debt over the long run starting immediately. At a 4.5 percent rate of return, no plan needs to increase funding by more than 10 percent of payroll, and 56 percent of

40. One difference is that our pension liabilities are defined using an accrued liability concept (generally implemented as the entry age normal, or EAN), which includes some benefit obligations associated with future years of service. In contrast, Novy-Marx and Rauh (2014b) 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 (2014b) do not.

Figure 9. Distribution of Liabilities by Percentage Point Change in Contribution



Source: Authors' calculations.

Note: Figure displays the distribution of liabilities 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 thirty years, and fully fund in thirty years under different asset return assumptions. The histograms are weighted by liabilities.

liabilities are in plans that could reduce contributions. At the 2.5 percent rate of return, only 2 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 0.5 percent rate of return, however, 39 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.

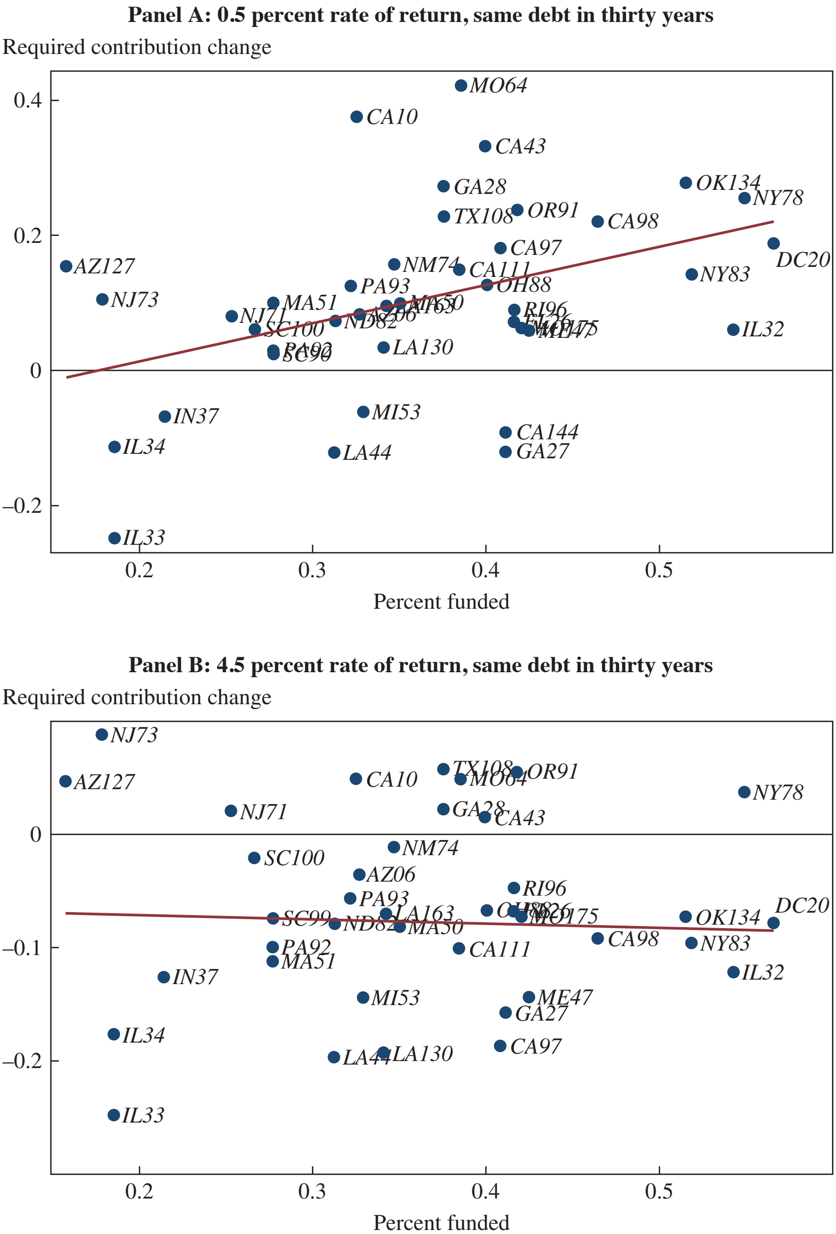
Panel B of figure 9 shows the distribution of plans' required contribution changes if they act today for the thirty-year, medium-term stabilization exercise. The distribution is quite similar to the results for the long-term stabilization exercise, although the required contributions are generally a bit larger.

Finally, panel C of figure 9 shows the distribution of required contribution changes for plans to be fully funded by the end of thirty years. At a 4.5 percent rate of return, only 11 percent of liabilities are in plans that can lower contributions, while 34 percent of liabilities are in plans where the required contribution increase is greater than 20 percent of payroll. At the 0.5 percent rate of return, most plans (65 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 increases of this magnitude are unnecessary for plans to become fiscally stable and continue paying benefits.

V.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 10, there is a positive relationship between funding levels and the required contribution change to stabilize under the medium-term stabilization exercise with the 0.5 percent return assumption. 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 4.5 percent rate of return (panel B), that is no longer the case, but there is 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

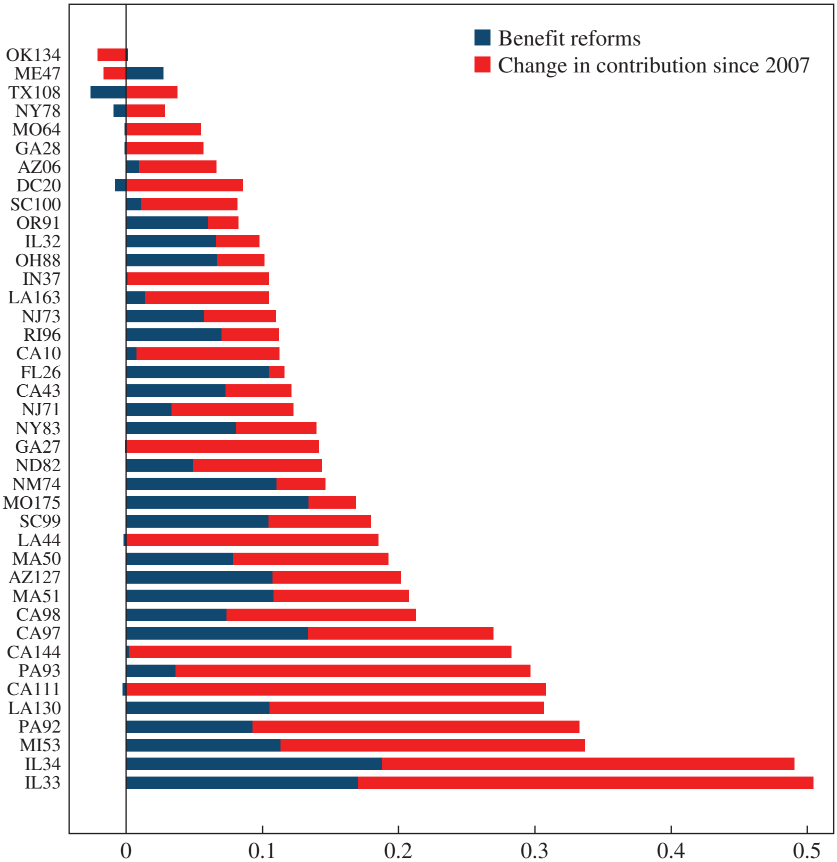
Figure 10. Required Contribution to Stabilize



Source: Authors' calculations.
Note: The labels are the Public Plans Database's assigned pension plan IDs.

Figure 11. Effects of Changes in Benefits and Contributions on Required Contribution

2.5 percent rate of return, same debt in thirty years

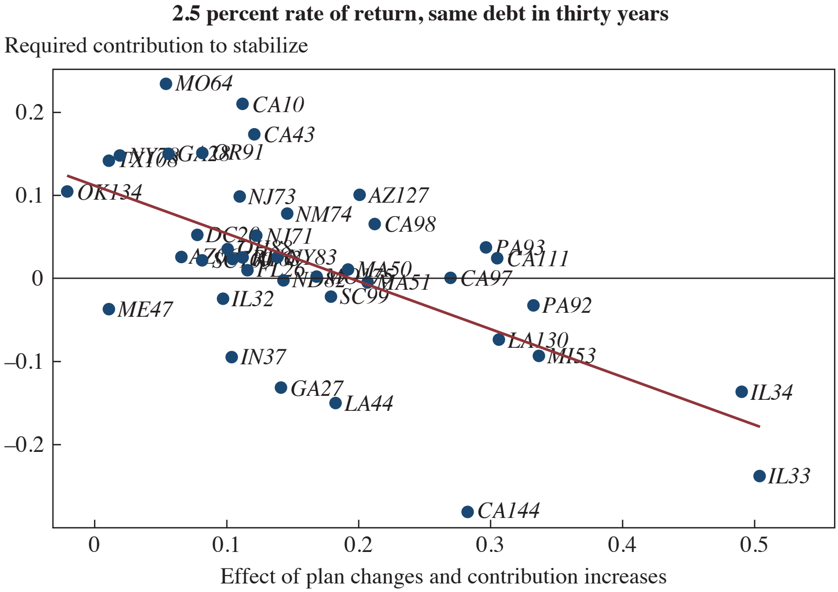


Source: Authors' calculations.
Note: The labels are the Public Plans Database's assigned pension plan IDs.

have been failing to make sufficient payments and have ignored looming imbalances. But that's not the case on average.

Figure 11 shows the effects of recent changes to pension plan 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 thirty years if plans reversed the reforms to their benefit and eligibility levels and if their contribution rates reverted to those prevailing

Figure 12. Required Contribution Lower in Plans That Have Made Large Changes



Source: Authors' calculations.

in 2007.[41] 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 horizontal axis of figure 12—have been 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 in thirty years under the 2.5 percent asset return assumption would equal about an *additional* 50 percent of payroll beyond what we calculate under current plan benefits and contributions.[42] And the reforms have been substantial for most plans in our sample.

41. 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.

42. The effect of the benefit changes vary somewhat by stabilization exercise and asset return.

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. 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 0.5 percent rate of return in many cases (compare figure 11 to online appendix tables A3 and A6). 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.

VI. Stochastic Analysis

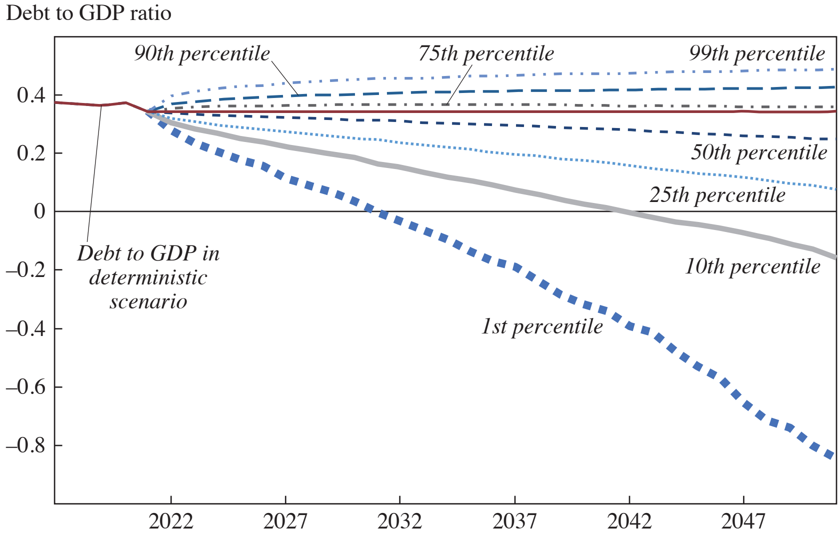
Our approach to asset return uncertainty thus far has been to present results under multiple rates of return, including returns which are lower than the expected rate to account for the costs of risk. An alternative method to explore uncertainty is to calculate the distribution of implicit debt and assets using a stochastic analysis that draws from a distribution of asset returns. For this exercise, plans are assumed to adjust their contributions today so as to hit today's level of pension debt in thirty years' time per the deterministic exercises in the middle panel of table 2. Regardless of the deterministic asset return assumption used to set contribution levels, though, *realized* asset returns are drawn annually from a normal distribution, with a mean return of 6.7 percent (nominal) and a standard deviation of 12 percent.[43] We are therefore implicitly assuming plans continue with their current investment policy. Given our assumption for 2.2 percent CPI inflation, the assumed annual nominal mean rate of return in the stochastic exercises equates to our 4.5 percent real rate of return assumption in the deterministic exercises. The discount rate equals the 0.5 percent real risk-free rate in all cases.[44]

Figure 13 shows the distribution of implicit US aggregate pension debt when plans set their contributions so as to bring implicit debt back to today's

43. These are in keeping with distributions from the literature: see, for example, Yin and Boyd (2019) and "Defined Benefit Program," CalSTRS (California State Teachers' Retirement System), https://www.calstrs.com/defined-benefit-program, which are based on the current composition of pension plans asset portfolios.

44. When assets go negative plans are assumed to issue marketable debt. In the stochastic exercises, the rate of return on this marketable debt is set by the stochastic asset return draws. This is conservative in the sense that a plan may be able to issue debt at a lower mean rate which would improve its fiscal position relative to the results displayed here. That said, in many cases a plan that had exhausted its assets might well be required to pay an elevated rate of return on its debt.

Figure 13. Stochastic Exercise: Debt-to-GDP Percentiles for US Aggregate, Contributions as in Thirty-Year Deterministic Stabilization with 2.5 Percent Real Return on Assets

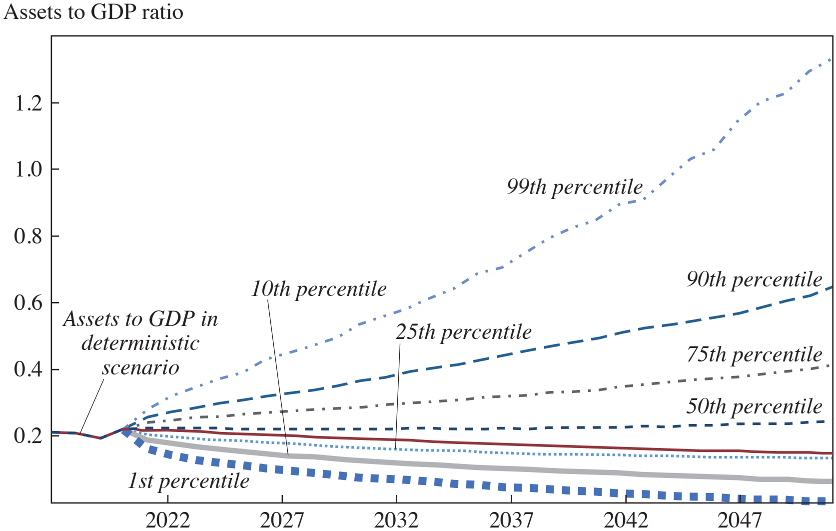


Source: Authors' calculations.

level in thirty years under the deterministic 2.5 percent real rate of return (i.e., contributions increase by 6 percent of payroll as shown on table 2). In this stochastic exercise—in which actual returns average 4.5 percent—pension debt in year 30 falls *below* the starting level of 34 percent of GDP 70 percent of the time; the debt is below 40 percent of GDP 85 percent of the time. But 1 percent of the time, the debt in year 30 rises to above 48 percent of GDP.

If the plans set contributions based on a deterministic real return of 4.5 percent—and therefore lower contributions by 3 percent of payroll so as to have debt back to today's level in thirty years in expectation—the outcomes are less sanguine. Only 37 percent of the time is the debt-to-GDP ratio in year 30 less than the 34 percent starting point; 20 percent of the time it is more than 50 percent of GDP (online appendix figure A7). On the other hand, if the plans base their contributions on the 0.5 percent real rate of return, the median debt at year 30 is 12 percent of GDP; debt is below the 34 percent of GDP starting point 93 percent of the time, and below 42 percent of GDP 99 percent of the time (online appendix

Figure 14. Stochastic Exercise: Assets-to GDP Percentiles for US Aggregate, Contributions as in Thirty-Year Deterministic Stabilization with 2.5 Percent Real Return on Assets



Source: Authors' calculations.

figure A8). Online appendix table A10 presents the distribution of debt in year 30 for this exercise for each plan.

Throughout the paper our focus has been on implicit debt, rather than assets. As we noted above, in the long run, stability of implicit debt implies stability of assets, but nothing in our exercises specifies that those assets be positive. While it might seem intuitive that preventing assets from exhausting is important for plan sustainability—and politically that may be the case—there is little economic difference between small positive or small negative assets (i.e., issuing small amounts of marketable debt to cover liabilities).

Nonetheless, there will likely be political implications to running down pension assets, and so a plan might want to take steps to avoid it. According to our stochastic exercises, and as presented in figure 14, if plans increase contributions to stabilize over thirty years based on a 2.5 percent rate of return, assets in year 30 are positive 99 percent of the time. If they count on a 4.5 percent return, and so contribute less, assets in year 30 turn negative 23 percent of the time, while if they count on a 0.5 percent rate of return, assets in year 30 are positive more than 99 percent of the time. (Online appendix figures A9 and A10 show the national results under these rate of return assumptions; online appendix table A10 shows the distribution of assets in year 30 for each plan.)

Overall, these stochastic exercises provide a way of linking changes in contribution rates to outcomes. When plans assume a 2.5 percent real rate of return, they face a small possibility of much higher debt and asset depletion over time, even though in the majority of cases, their outcomes will be better than those assumed in the deterministic case. How to assess these various outcomes comes down to understanding how costly risk may or may not be for governments.

The stochastic exercises here are stylized and intended to provide an illustration of the risk around our deterministic debt stabilization paths. A more complete stochastic analysis would simulate based on the specific assets held by each individual plan, consider return distributions other than a normal, and so on. And, of course, a more complete analysis would recognize that many aspects of the pension system and government revenues and expenditures are subject to uncertainty—including wage growth, employment growth, mortality, and tenure. It would also take account of the covariances between sources of uncertainty and include an analysis of the states of the world, in particular levels of marginal utility, in which good and bad outcomes occur. We leave all these considerations to future work.

VII. Conclusion

We find that pension benefit payments in the United States, 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 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 increases needed to achieve stabilization increase much when the start of the stabilization process is pushed a bit farther 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.

ACKNOWLEDGMENTS Lorena Hernandez Barcena, Jeffrey Cheng, and Manny Prunty provided excellent research assistance. We are particularly grateful to Lorena, who picked up this project midway through and got up to speed incredibly quickly. We thank Thomas Aaron, Bob Costrell, Ngoc Dao, Greg Duffee, Trevor S. Gallen, Tracy Gordon, Erald Kolasi, Adam Looney, Martin Luby, Robert L. McDonald, Josh McGee, Therese McGuire, Derek Messacar, Jim Poterba, Jonathan Pycroft, Laura Quinby, 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, our *BPEA* editor Jan Eberly, and our *BPEA* discussants Deborah Lucas and Josh Rauh.

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