SINS OF THE PAST, PRESENT, AND FUTURE: ALTERNATIVE PENSION FUNDING POLICIES

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ABSTRACT: Our goal in this paper is to better understand pension funding dynamics with a focus on sustainability and intergenerational equity. We examine the steady-state properties of deterministic models and simulations of stochastic models to illuminate the implications of recently proposed policies to alleviate funding pressures and of certain modeling assumptions. We close by proposing a policy evaluation framework that better incorporates risk and the intertemporal tradeoffs between current contributions and likely future outcomes. We illustrate throughout with the California Teachers Retirement System (CalSTRS), which publicly provides particularly full projections of the underlying cash flows.

The specific origin of this paper is our evaluation of the funding policy recommended in an influential paper presented at last year's Brookings Municipal Finance Conference (Lenney, Lutz, and Sheiner, 2019; hereafter LLS) that aims to stabilize pension debt at existing levels relative to the size of the economy or public payroll. The authors conservatively discount liabilities using a low-risk rate, but nonetheless conclude that public pension finances could be stabilized, in the aggregate, with relatively minor increases in contribution rates. By examining the underlying math, we show that the proposed policy rests on assumed arbitrage profits between the expected returns on risky assets and the low-risk interest on liabilities. In fact, these assumed arbitrage profits, together with the delinking of contributions to liabilities and their rate of accrual, are the factors that obviate the need for a dramatic rise in the contribution rate. We show that, in the presence of uncertain investment returns, the recommended policy would carry significant risk of pension fund insolvency and a jump in contributions to the pay-go rate, which is much higher.

We then illustrate the general policy issue of the tradeoff between current and future contributions, using the metric of the expected value of contributions, in a simple preliminary attempt to incorporate risk into the policy debate over intergenerational equity. Finally, we conclude with our agenda for future research on how to generalize our formal approach to the analysis of pension funding policy for the intergenerational allocation of contributions and benefit risk.

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1. Introduction and Summary

Public pension costs are growing faster than government budgets. For example, Figure 1 depicts the growth of employer contributions for public K-12 schools, the largest sector participating in public pensions.[1] Taxpayer contributions have grown (in 2019 dollars) from $544 per pupil in 2004 to $1,481 in 2019, more than doubling the share of current education expenditures going to pay for pensions, from 4.8 percent to 11.1 percent (Costrell, 2020).

Rising pension debt (i.e., unfunded liabilities) has been the primary driver of higher government contributions (see Figure 2). Several high-profile organizations in the public pension community, including the Society of Actuaries Blue Ribbon Panel on Pension Plan Funding (SOA, 2014) and the Government Finance Officers Association (GFOA, 2016), have recommended that governments aim to fully fund their pensions in 15 to 20 years. However, even under current practice (often 20 to 30 years) the increasing cost of paying down the debt is causing widespread fiscal distress and crowding out expenditures for current services, such as K-12 salaries, the subject of recent teacher strikes (McGee, 2019). In reaction to these trends, a spate of recent papers argues that the pursuit of full funding creates unnecessary budgetary strains and that governments should be less aggressive in paying down the pension debt.[2] In short, these papers claim the dramatic rise in pension contributions to pay off the debt unnecessarily imposes the sins of past under-funding on the current generation.

[1] See Anzia, 2019 for the impact of rising pension costs on municipal and county budgets.
[2] See, most notably, Lenney, Lutz, and Sheiner, 2019, and Sgouros, 2019, 2017, for the National Conference on Public Employee Retirement Systems and UC Berkeley's Haas Institute.

To evaluate this line of thought, we focus on the influential paper presented at last year's Brookings Municipal Finance Conference (Lenney, Lutz, and Sheiner, 2019; hereafter LLS) because it provides the most rigorous, concrete recommendations and modeling of effects. There are three key features of the LLS model. First, and most directly aimed at alleviating budgetary stress, the proposed policy drops the goal of paying down pension debt, replacing it with the goal of stabilizing pension debt relative to the size of the economy. This funding policy rolls over existing debt indefinitely (p. 1) and would, in LLS's view, be "sustainable." Second, while the model considers various assumed rates of return on assets, the preferred rate, underlying its key result, is about 6 percent (3.5 percent real). This is about 1.25 percentage points more conservative than the current median pension plan assumption, so this would tend to raise contributions. Finally, as emphasized by the authors, the model adopts the further conservative practice of discounting liabilities at a low-risk rate (about 4 percent, or 1.5 percent real), rather than the assumed return on risky assets. As the paper states, this follows "standard financial principles of valuation...which more properly reflects the riskiness of the promised pension benefits," resulting in much larger measured pension debt (p. 3). The paper's headline result is that the proposed funding policy of stabilizing pension debt would, in the aggregate, only modestly raise required contributions (about 4 percent of payroll), despite the model's conservative assumptions.

In this paper, we examine the analytics of the underlying model to better understand this result. Our first key finding is that the LLS model departs even more sharply from standard actuarially determined contribution (ADC) policy than previously recognized. ADC provides for two components of the contribution: the cost of newly earned benefits ("normal cost") and amortization payments on the pension debt. The LLS policy is aimed at reducing the amortization payments, but it further departs from ADC by keeping contributions below the normal cost. Reducing the discount rate raises the normal cost, but under the actuarial approach, contributions would at least cover these costs of newly accrued benefits, even if payments on the debt do not target full funding. In the LLS model, however, this is not the case. Liabilities are discounted at the low-risk rate, and new liabilities accrue correspondingly at the low-risk normal cost rate, but contributions fall well short of this.

The reason for this implication of the model lies in the treatment of risk. Although the model explicitly recognizes the guaranteed nature of pension benefits by discounting liabilities at a low-risk rate, the funding policy continues to rely on the assumed return on risky assets. Specifically, the proposed policy implicitly rests on assumed arbitrage profits between the expected return on risky assets and the low-risk interest on liabilities. These assumed arbitrage profits are the factor that reduces the contribution rate below the full cost of newly earned low-risk benefits in the LLS model.

We show that, in the presence of uncertain investment returns, the recommended policy would carry significant risk of pension fund insolvency. Thus, while at first glance the LLS paper's recommended funding policy might appear both novel and prudent, in key respects it reproduces the risky features of current practice. In fact, as we show, the model's reduction of the discount rate on liabilities has little or no effect on the contribution rate, as the model continues to embed the assumed return on risky assets. In the end, it is the contribution rate that matters for the intergenerational allocation of risk, regardless of what funding model and associated assumptions generates that rate. Low contributions now raise the risk of adverse consequences for future public workers and taxpayers.

We begin with a brief review of the basics of pension funding. We highlight key features of current actuarial funding policy that have been subject to critique: (1) over-optimistic expected returns; (2) the use of expected returns on risky assets to discount liabilities; and (3) as critiqued by LLS, the goal of fully amortizing pension debt. Using the example of California State Teachers' Retirement System (CalSTRS), we drop each of these assumptions sequentially to arrive at LLS's deterministic model with a full understanding of the policy's implications for contributions, asset accumulation, and debt. We develop the simple steady-state math implicit in the model to show the important, unrecognized role of arbitrage profits in the proposed policy, and the misleading role attributed to the discount rate in this policy. Since arbitrage profits are risky, we then proceed to a stochastic analysis of the policy, to examine its impact on the likelihood of insolvency and expected future contributions. We then consider the tradeoffs among alternative contribution rates in the general context of intergenerational equity. The LLS paper frames their proposed policy as a move toward intergenerational equity by releasing the current generation from the sins of past underfunding. In so doing, however, it brings into question the converse principle of intergenerational equity: paying for current services as they are rendered without imposing excessive cost of risk on future generations. The contribution policy – however formulated – governs the intergenerational allocation of costs and benefits, both of which carry risk. We consider a simple representation of the intergenerational tradeoffs – current vs. expected future contributions – as a first step toward the incorporation of risk into equitable funding policy, and we outline next steps in doing so more generally.

II. How Does Pension Funding Work in General?

There are two sources of pension funding and two uses: contributions and investment income go to cover the payment of benefits and the accumulation of assets. Of these four flow variables, the stream of benefit payments is exogenous to our analysis (determined by the tiered benefit formulas and workforce assumptions), and investment income is governed by the sequentially determined stock of assets and the exogenous series of annual returns. This leaves the series of contributions and that of asset accumulation, which are mechanically linked. That is, the *funding policy is simultaneously a contribution policy and an asset accumulation policy*.

Formally, this relationship is captured in the basic asset growth equation:

$$(1)\ A_{t+1} = A_t(1+r_t) + \boldsymbol{c_t} W_t - c_{pt} W_t\,,$$

where A_t denotes assets at the beginning of period t, r_t are the returns in period t, W_t is payroll, while $\boldsymbol{c_t}$ and c_{pt} are the contribution and benefit payment rates, respectively, as proportions of payroll[3] (see Table 1 for notation). Assets grow by investment earnings, plus contributions, net of benefit payments. The contribution policy sets asset growth, given returns and benefit payments.

This framework is general. It covers the spectrum from actuarial pre-funding of benefits to pay-go funding and policies that lie in between. But it helps focus on the fundamental tradeoffs between these policies without getting overly distracted by their details. Suppose the system is ongoing and converges to a steady-state ratio of assets to payroll, $(A/W)^*$. Let g denote the assumed growth rate of payroll. Thus, the steady-state growth of assets must also be g. Dividing through (1) by A_t and re-arranging, we have the steady-state version of (1):

$$(1^*)\ c_p = \boldsymbol{c^*} + (r-g)(A/W)^*.$$

As equation (1*) shows, benefit payments are covered by a mix of contributions and investment income (net of growth), where the mix is determined by the funding policy. At one extreme is a policy of pay-go, where no assets are accumulated and the contribution rate equals

[3] To fix magnitudes, the current average contribution rate for state and local funds is about 25 percent, and the current pay-go rate is about 40 percent (we will illustrate more specifically with the example of CalSTRS below).

the benefits payment rate c_p. At the other pole is a policy of full-funding, where assets are built up to equal liabilities (discussed below), so the income from those assets (net of growth) helps fund benefits, reducing reliance on contributions; that accumulation of assets, of course is the purpose behind the full-funding policy's higher contributions in the short-run (equation (1)). Policies such as the LLS paper's policy of rolling over existing pension debt lie somewhere in between pay-go and full-funding, with an intermediate mix between contributions and investment income to cover benefits, where the mix is governed by the existing debt ratio.

What considerations should inform the choice of a funding policy? The principle underlying actuarial pre-funding is that intergenerational equity requires taxpayers to pay for services as they are rendered; just as salaries are funded out of current revenues, so should the cost of pre-funding retirement benefits as they are earned, rather than when they are paid out. However, the failure to fully and accurately pre-fund benefits leaves large unfunded liabilities, which creates another intergenerational issue, raised by the LLS paper: which generation(s) should carry the burden of past liabilities? It will also be important to consider the allocation of risk among generations. We begin, however, by examining specific alternative funding policies in a deterministic context, as in both the actuarial full-funding and LLS models.

III. Liabilities and Actuarial Full-Funding

To this point, it has not been necessary to specify the equation for liabilities, analogous to that of assets, as the relationship between asset accumulation and contributions is fully captured by (1). Liabilities enter the funding policy picture when they are used to set the asset accumulation target, as in the full-funding approach. The liability equation is:

$$(2)\ L_{t+1} = L_t(1+d) + c_{nt}W_t - c_{pt}W_t,$$

where L_t denotes liabilities accrued by the beginning of period t, d is the discount rate applied to future benefits, and c_{nt} denotes the "normal cost" rate, the present value of newly accrued liabilities as a percent of payroll.[4] Previously accrued liabilities grow by the discount rate as the present value of benefits is rolled forward, plus newly accrued liabilities, minus benefit payments that extinguish existing liabilities.

The actuarial full-funding approach sets the asset accumulation target equal to estimated liabilities. When assets equal liabilities, pre-funding benefits only requires contributions that cover newly accrued liabilities – the estimated normal cost. Contributions at this rate, over the careers of any entering cohort would fully pre-fund the benefits of that cohort if the actuarial assumptions are fulfilled. Assets would continue to accumulate in step with liabilities.

When actuarial assumptions do not pan out or when actual contributions fall short of normal cost, unfunded liabilities ensue. That is, benefits that have been earned are not fully pre-funded, creating pension debt. Under the actuarial full-funding approach, when assets fall short of estimated liabilities, amortization payments are added to the normal cost contributions to pay off the pension debt. Funding policies typically set amortization payments as a fixed percentage of payroll that is calculated to pay off the debt over a specified period (often 20-30 years). Once full-funding is reached (assets = liabilities), contributions revert to the normal cost rate.

For the remainder of this paper we use the example of CalSTRS to illustrate the effect of different funding policies on asset accumulation and contributions. We chose CalSTRS because the system publishes projected cash flows to 2046, the date at which it plans to reach full funding; our own calculations extend the projections another 30 years to 2076.[5]

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4 The standard method is known as "entry age normal," which smoothes the accrual rate over one's career. On average, this is currently calculated at about 14 percent, based on discounting at the assumed rate of return.

5 CalSTRS's projections are found in Tables 14-15 of the [2018 valuation]. We supplement these with the 2017 valuation for the 2018 starting values. Payroll for 2018 is drawn from the 2018 valuation and grown at CalSTRS's

Figure 3a depicts the path of assets and liabilities, as a multiple of payroll, calculated for CalSTRS's full-funding policy, under the assumed return on assets of 7.00 percent, which is also used to discount liabilities. Assets accumulate from 2018's funded ratio of 64 percent to 100 percent in 2046. To reach full funding by then requires adding amortization payments to normal cost contributions, as depicted in Figure 3b. Taken together, the contribution rate is slated to ratchet up from 32 percent to a level of 38 percent until the debt is extinguished, at which point contributions revert to the normal cost rate of 18 percent.

Meanwhile, the payment rate for benefits is considerably higher. The gap is filled by investment income from the accumulated assets. The pay-go rate is projected by CalSTRS to rise from 46 percent to a peak of 57 percent, as depicted in Figure 3b. It then starts to decline as those hired after 2013, with a lower benefit formula, reach retirement; we calculate that, without further benefit changes, c_p will decline to a steady-state value of 46 percent.

The key features of the actuarial full-funding policy to focus on here are: (i) the assumed return on assets is used as the discount rate to calculate liabilities; and (ii) contribution rates are set high enough to grow assets until they equal calculated liabilities, after which they drop precipitously. As we will show, these are the key analytical features that distinguish existing policy from the LLS paper's recommended approach.

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assumed rate of 3.5 percent. Starting values for liabilities and assets are also drawn from the 2018 valuation and grown according to equations (1) and (2). Together these provide cash flows as percentages of payroll, as well as assets and liabilities as multiples of payroll. Beyond 2046, we calculate steady-state pay-go and normal cost rates (drawn from Costrell 2018b and Costrell and McGee 2019). We assume a glide path from the end of the CalSTRS projection (2046) to those steady-state values by 2063, 50 years after CalSTRS's newest benefit tier went into effect.

IV. Debt Rollover Policy: Deterministic Analysis

The LLS paper proposes a policy that attenuates the growth in contributions compared to the actuarial policy of full-funding, aiming instead to simply stabilize public pension finances at the existing debt ratio. The LLS model departs from the two key features of the standard actuarial model identified above in the following respects: (i) a low-risk rate is used to discount liabilities, but assets are expected to deliver returns that exceed the discount rate; and (ii) the policy's goal is not to pay down the pension debt, but to roll it over, maintaining debt as a constant ratio of the state's gross domestic product or the plan's payroll.[6] We now explore the implications of this model's funding policy.

Baseline Assumptions

Our deterministic analysis will focus on the LLS paper's preferred scenario where the discount rate used to calculate liabilities is set to 1.5 percent real, the assumed return on assets is 3.5 percent real, and inflation is 2.4 percent. For simplicity, we round the nominal discount rate to 4 percent and the assumed return to 6 percent (so LLS is 1 percent more conservative than CalSTRS in assumed return). We first consider the effect of rolling the pension debt over and then turn to the implications of decoupling the discount rate from the assumed return. As we will show, the debt rollover policy reduces contribution growth, as intended. The low-risk discount rate, however, framed as an additional conservative assumption, has virtually no effect on contributions when decoupled from the assumed return on assets.

[6] We will focus on the ratio of debt to payroll, since the contribution rate is specified as a percent of payroll.

(i) <u>Pension Debt Rollover; Discount Rate = Assumed Return</u>

The debt rollover policy establishes a path of asset accumulation that is parallel to the path of liabilities, rather than rising to meet liabilities as in Figure 3a. Figure 4a depicts these parallel paths, with both assumed return and discount rate of 6 percent.[7] The corresponding full-funding policy is also shown with the dashed line. The full-funding policy would take assets from their current level of about 6 times payroll up to the liability level of 10 times payroll and would then follow the liability path thereafter. The debt rollover policy, however, would maintain the debt-to-payroll ratio. This is represented by the parallel paths of assets and liabilities, with a constant difference between the two of 4.3 times payroll.

The asset accumulation path under the policy of debt rollover corresponds to a contribution path that differs markedly from that of full funding, as shown in Figure 4b.[8] The full-funding contribution rate is quite elevated, with large amortization payments until the debt is paid off in 2046, at which point contributions drop to the normal cost rate.[9] By contrast, the debt rollover contribution rate is relatively stable, after an initial jump. It is below the full-funding rate during the amortization period, since it is not aimed at amortizing the debt, but it remains above the normal cost rate in perpetuity, since additional payments are required to maintain the debt-to-payroll ratio. It is this latter point that we wish to emphasize: contributions remain above normal cost under the policy of maintaining the debt ratio, so long as the discount rate on

[7]As compared with Figure 3a, where CalSTRS's discount rate is 7 percent, the drop to 6 percent increases liabilities from 9 times payroll to something over 10, where it hovers for the remainder of the projection period. As discussed in a later section, this is not an exact steady state, but nearly so. To calculate the initial liability, we draw on the GASB 67 report, which gives liabilities at plus/minus 1 percentage point from the assumed return. CalSTRS 2018 reports a 13.5 percent increase in liabilities at 1 percentage point below assumed (6.1 percent vs. 7.1 percent in that report). That is the percentage increase we apply to the 2019 liability. The normal cost rate is rediscounted at 6 percent (and again at 4 percent for the next simulation), as calculated in Costrell 2018b.

[8] The "pay-go rate," depicted as the top curve, is identical to that depicted in Figure 3b, since it is independent of the discount rate, the assumed return and the funding policy.

[9] Of course, the full-funding contributions in Figure 4b exceed those of Figure 3b, due to the lower assumed return.

liabilities is not distinguished from the assumed return on assets.

(ii) Discount Rate < Assumed Return

The LLS paper notably sets the discount rate on liabilities at a low-risk rate of 1.5 percent real, or about 4 percent nominal. This is two percentage points below their preferred assumption for the return on assets. This has a very substantial impact on measured liabilities, as depicted in Figure 5a.[10] The ratio of liabilities to payroll jumps to nearly 14 (instead of about 10 at the 6 percent discount depicted in Figure 4a), eventually hovering around 12.6. This raises the debt ratio to 7.6 times payroll, much higher than the ratio of 4.3 at 6 percent discount. However, the recommended funding policy is to simply maintain that debt ratio, so asset accumulation remains on a path parallel to the liability path, but with a much wider gap. The result is that the asset accumulation path is virtually unchanged from that depicted in Figure 4a. Dropping the discount rate 2 percentage points below the assumed return has almost no effect on asset accumulation under the LLS model. In fact, if one looks closely at Figures 5a and 4a, one can see that it is slightly *lower*. That is, a more conservative discount rate on liabilities leads, perhaps paradoxically, to slightly *slower* asset accumulation. We discuss the math behind this below.

We now turn to contributions. Figure 5b depicts the contribution rate under the LLS model, with a discount rate of 4 percent and assumed return of 6 percent. The contribution rate levels off at about 33 percent of payroll.[11] The contribution path is almost identical to that depicted in Figure 4b, at discount rate = assumed return of 6 percent. There is, however, a

[10] CalSTRS goes beyond the GASB 67 requirement cited above and reports liabilities at plus/minus 3 percentage points from the assumed return. CalSTRS 2018 reports a 50.0 percent increase in liabilities at 3 points below (4.1 percent vs. 7.1 in that report). That is the percentage increase we apply to the 2019 liability, beginning of year.
[11] LLS report a substantially greater jump in the CalSTRS contribution rate than we find, to about 42 percent, perhaps due to a different series of assumed cash flows. We hope to verify this once the LLS team releases its data.

striking difference. As we saw in Figure 4b, when the discount rate equals the assumed return the contribution rate required to maintain the debt ratio exceeds the normal cost rate. However, when the discount rate is dropped 2 points below the assumed return, as in LLS's preferred scenario, the normal cost rate jumps to well above the contribution rate.[12]

What is the significance of this result? The LLS paper appropriately applies a low-risk discount rate to the normal cost calculation, but, in a marked departure from the actuarial approach, its proposed funding policy fails to cover normal costs (let alone amortization of the debt). Thus, what is claimed to be a conservative assumption, adopting a highly prudent discount rate – in accord with long-standing finance economics – does not translate into contributions that cover currently accruing liabilities. This violates the general principal of generational equity, paying for services as they are rendered, at least as operationalized by the concept of normal cost. In a risky world, the issue of generational equity may be more complex, as discussed below. Nonetheless, it is a striking result of the LLS model that as the discount rate is cut to the low-risk rate, normal costs rise dramatically, but contributions do not. This not only departs from traditional actuarial principals, but also from actual private sector practice, where contributions are required to cover normal cost at a low-risk discount rate, plus amortization.

As we shall see, what lies behind this result is the assumption of arbitrage profits between the return on (risky) assets and (low-risk) interest on liabilities; these assumed profits help fund the accruing liabilities without the full complement of contributions. In this respect, the policy differs little from current practice, which also bets on the returns from risky assets; using a low-risk discount rate on liabilities does not change that.

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12 We have been unable to verify that this result obtains in the LLS simulations, as the authors have declined to disclose their normal cost rates. However, the math, discussed below, is clear that this result should obtain. Note also that we find the normal cost rate increases by a larger factor than liabilities do, as the discount rate is dropped. Liabilities rise by a factor of 1.50 with a 3 point drop in the discount rate, but normal cost rises by a factor of 2.24.

(iii) The Math Behind the Results

Our simulation of the LLS policy generates two surprising results from the drop in the discount rate that require further explanation. First, despite the much higher debt ratio, there is almost no impact – or even slightly negative – on asset accumulation and contribution rates. Why is this? Second, the normal cost rate jumps from below the contribution rate to well above it, so contributions fail to cover newly accruing liabilities. How, then, does the policy keep debt from rising? Let us take these in turn.

Why doesn't a cut in the discount rate force a rise in contributions?

Under traditional actuarial funding practice, where the discount rate equals the assumed return, we know that a cut in that rate dramatically raises required contributions. Why is this not the case under the LLS model, when the discount rate is cut below the assumed return? We have already seen the basic answer to this question in equation (1*). For any given steady-state ratio of (A/W), and assumed return on assets, r, the steady-state contribution rate c^* is totally independent of the discount rate, d. These conditions do not exactly hold under the LLS model, since the funding policy is designed to stabilize the debt ratio, $(L – A)/W$, rather than the asset ratio, but the result is nearly the same.

For a more detailed analysis, note first that the cut in d sharply raises initial liabilities, $(L/W)_0$. The policy begins by simply adding the hike in $(L/W)_0$ to the initial debt ratio to establish the rediscounted debt ratio $[(L\text{-}A)/W]_0, \equiv U_0$. The asset accumulation policy is then set to maintain this new debt ratio. That trajectory is $(A/W)_t = (L/W)_t - U_0$, parallel to that of $(L/W)_t$ as discussed above. Thus, the only impact on asset accumulation of the cut in d would be through a change in the trajectory of $(L/W)_t$ beyond the initial rediscounting. As equation (2) shows, the cut in interest on liabilities works against the rise in normal cost (i.e., the more rapid accrual of new liabilities). In our CalSTRS simulation, the reduced interest on liabilities actually outweighs the rise in normal cost. As a result, $(L/W)_t$ drops a bit *more* over time at d = 4 percent (from 13.53 to 12.66, as depicted in Figure 5a) than it does at d = 6 percent (from 10.23 to 9.96, in Figure 4a). Consequently, the asset ratio *(A/W)*, moving in parallel, also drops more at d = 4 percent than at d = 6 percent. Thus, in this case, slightly *fewer* assets are accumulated with a lower discount rate, despite this purportedly conservative assumption; it greatly magnifies liabilities, but slightly *de*celerates asset accumulation and contributions.

More generally, cutting the discount rate has little impact one way or the other on asset accumulation and contributions under the debt rollover policy, despite the appearance of being a major step in the direction of fiscal prudence. It is the assumed return on assets that matters most, independent of the discount rate on liabilities. Cutting the discount rate makes liabilities jump, but since the new debt is absorbed, there is no need for a jump in the trajectory of assets. All that is needed is for asset growth to track that of liabilities thereafter. The growth of liabilities is reduced by the cut in interest and raised by the rise in normal cost, so little change is required, one way or the other, in contributions.

How is debt stabilized, when contributions fail to cover new liabilities?

How do we resolve the puzzle that the debt ratio is held in check even as contributions fail to cover new liabilities? The answer is simple: the policy is banking on arbitrage profits between the return on risky assets and the low-risk interest on liabilities. This can be readily shown with the math that follows from equations (1) – (2) (LLS equations (7) – (8)). The unfunded liability, using (1) – (2) is:

(3) $UAL_{t+1} = L_{t+1} - A_{t+1} = L_t(1+d) - A_t(1+r_t) + (c_{nt} - c_t)W_t$

The debt rollover policy is to maintain constant ($(UAL/W)_0$, so UAL_t grows at rate g. Taking r as deterministic (as in the LLS paper), we delete its time subscript, and obtain, from (3),

(4) $UAL_{t+1} = (1+g)UAL_t = L_t(1+d) - A_t(1+r) + (c_{nt} - c_t)W_t$.

Rearranging and simplifying, this implies:

(5) $c_t = c_{nt} + (UAL/W)_0(d - g) - (A/W)_t(r - d)$, or, in words,

contributions = normal cost + interest (net of growth) on UAL – arbitrage profits.[13]

Without arbitrage profits, contributions must exceed normal cost, to service the pension debt. But the assumed arbitrage profits, implicitly built into the LLS model, allows the debt-stabilizing contribution rate to fall well short of normal cost, as in the CalSTRS example.[14]

The math of true and near steady states

Figure 5a seems to depict convergence on a steady state for *A/W* and *L/W*, with a corresponding steady state for *c* in Figure 5b. This is not in fact a true steady state, but rather a near steady state, which we can analyze as if it were a true one. First, we show why it is not a true steady state and then we consider the characteristics of the steady state that it is near, which will allow us to further interpret the characteristics of the LLS model.

13 LLS's description (p. 21, November version) of the debt-stabilizing contribution rate includes the first two terms, but omits the third term, i.e., the arbitrage profits, incorrectly indicating that contributions exceed normal cost.

14 The contribution rate for debt service (2nd term in (5)) levels out at 3.8 percent of payroll, but is outweighed by assumed arbitrage profits at 10.1 percent of payroll. The 6.3 point difference bridges the gap between the normal cost rate of 39.5 percent and the contribution rate of 33.2 percent, depicted in Figure 5b. More generally, c will exceed c_n if the ratio of the funded to unfunded ratio, $f/(1 - f)$, exceeds the ratio $(d - g)/(r - d)$.

To see why the system does not converge to an exact steady state, it is sufficient to analyze equation (2), the law of motion for liabilities. As stated earlier, this dynamic is independent of the funding policy – the contribution rate does not enter the equation. That is, equations (2) and (1) can be thought of as a recursive system. Specifically, equation (2) can be expressed as a first-order linear difference equation in the liability ratio, *L/W*:

$$(2') \quad (L/W)_{t+1} = [(1+d)/(1+g)](L/W)_t + (c_n - c_p)/(1+g),$$

where we have dropped the time subscripts on c_n and c_p to analyze the behavior of *L/W*, once c_n and c_p have settled into their steady-state values. The solution is:

$$(2'') \quad (L/W)_t = b^t[(L/W)_0 - (L/W)^*] + (L/W)^*,$$

where $b = [(1+d)/(1+g)]$ and $(L/W)^* = (c_p - c_n)/(d - g)$.[15]

For $d > g$, the system is divergent from the steady-state value of $(L/W)^*$. Thus, unless the system happens to land at that value by the time c_p and c_n reach their steady-state values, we would drift further away from $(L/W)^*$. For d close to g (4.0 vs. 3.5 percent in our CalSTRS simulation of the LLS model), the speed of divergence is slow. As depicted in Figure 5a, *(L/W)* dips to 12.62 by the time c_p and c_n stabilize, which is close to, but still exceeds the true steady-state value of 12.02, so it drifts up only imperceptibly over the projection period.[16] The concluding trajectory is flat enough to be considered a near steady state, so the analytical characteristics of an exact steady state may be informative.

There are actually a few steady states to consider. We have just examined the steady state in *(L/W)*, but we have previously examined the steady state in *(A/W)*. As we saw in

[15] As $d \to g$, $c_n \to c_p$, and $(L/W)^* \to -\partial c_n/\partial d$, by L'Hôpital's Rule. For comparison with the CalSTRS steady-state values given below, that limiting value of $(L/W)^*$ is found numerically to be 12.96.

[16] For Figure 4a, where d is 6.0 percent vs. g of 3.5 percent, the upward drift in *(L/W)* is more perceptible, but still very slow, from a low of 9.72 by time c_p and c_n stabilize (vs. steady state of 9.06), rising only to 9.96 by the end of the projection period. For d = 7.0 percent, the speed of divergence is more noticeable, so, as Figure 3a depicts, *(L/W)* drifts a bit more rapidly away from its steady-state value of 7.96, rising from 8.87 to 9.36.

equation (1*), under a true steady-state for *(A/W)*, c^* is exactly independent of *d*. This illuminates our finding that under the debt rollover policy, *(A/W)* is approximately independent of *d* (compare Figures 4a and 5a), and so is the contribution rate *c* (compare Figures 4b and 5b).[17] As discussed above, in a true steady state for *(A/W)*, the contribution rate, c^*, covers the gap between the benefit payment rate, c_p – which is exogenous – and investment income (net of growth), $(r – g)(A/W)^*$. The discount rate does not enter, only the return on assets.

Further insight can be gleaned by relaxing the steady state condition to require only that the funded ratio $f = (A/L)$ be constant, rather than *(A/W)*. That is, the growth rates of *A* and *L* need not equal *g*, but, instead, equal each other. This is also not exactly true under the debt rollover policy (it requires, instead, that the growth rate of $(L – A)$ equal *g*, as examined in (3) – (5)), but it is almost true in our simulations.[18] Formally, from (1) and (2) we can derive the growth rates of assets and liabilities, respectively, as $r + (c^* – c_p)(W/A)$ and $d + (c_n – c_p)(W/L)$. Setting these equal to each other gives the contribution rate for a steady state funded ratio, f^*:[19]

(6) $c^* = [f^*c_n + (1 – f^*)c_p] – (r – d)(A/W).$

The first term is a funded-ratio-weighted average of the normal cost rate and pay-go rate, while the second term is the offset from arbitrage profits (as in equation (5)). This equation gives us further insight into the reasons why the cut in *d* below *r* in the LLS model has little or no effect on the steady-state contribution rate. The cut in *d:* (i) raises the normal cost rate; (ii) shifts the weight of the first term toward the pay-go rate (by reducing f^*); and (iii) unveils the arbitrage profits used to help defray the required funding. As we have seen, the net effect is zero, according to equation (1*), or approximately so, in our near steady state. This interpretation

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[17] The contribution rate *c* is not exactly constant in Figures 4b and 5b, even after c_n is stabilized, because *(A/W)* is not exactly constant. As equation (5) shows, slight variation in $(A/W)_t$ leads to slight variation in c_t.
[18] The funded ratio rises from 39.8 to 40.0 percent in Figure 5b, and from 55.8 to 56.9 percent in Figure 4b.
[19] This expression generalizes Costrell, 2018a, equation (5) for $d < r$.

makes it all the more important to understand the risks involved by relying on arbitrage profits when contributions fail to cover currently accruing liabilities. For this, we need to consider a stochastic model, where the returns on risky assets are recognized as, in fact, risky.

V. Debt Rollover Policy: Stochastic Analysis

Up to this point, we have only considered various pension funding policies under consistent, deterministic investment returns. However, annual investment returns are inherently risky and have large implications for the effects of funding policy on pension finances (Ferrell and Shoag, 2016; Boyd and Yin, 2017; Biggs, 2014). By ignoring risk, LLS's proposed policy dramatically underestimates the probability of future insolvency and the additional cost that would impose on future cohorts. Formally, we investigate the implications of setting a constant contribution rate under LLS's proposed debt rollover policy. As in the deterministic analysis, we use CalSTRS as an illustrative example, for which we found the policy's fixed contribution rate to be 33 percent. The primary risk of employing this funding strategy in a stochastic environment is that the plan may exhaust its assets. Even if the expected returns pan out at the LLS assumption of 6 percent return over the long haul, the risk of insolvency is non-zero for mature plans, where the primary cash-flow is negative – payouts exceed contributions (as the CalSTRS graphs above indicate). This is because the early years may be the ones with below average returns (Boyd and Yin, 2017). If the plan goes insolvent, governments must begin making annual contributions to cover retiree benefit payments (i.e. the pay-go rate). As noted earlier, such an event would result in a large jump in contributions for most plans. The average contribution rate for state and local funds is about 25 percent and the current pay-go rate is about 40 percent. For CalSTRS those figures are approximately 32 percent and 46 percent respectively.

We use Monte Carlo simulation to model CalSTRS finances over time in the presence of uncertain investment returns. Specifically, we use equations (1) and (2) to model the evolution of plan assets and liabilities over a 100 year projection period. We produce 1,000,000 such projections for each scenario of the contribution rate and the distribution of investment returns.

We generate stochastic investment returns using the lognormal distribution with three different geometric mean and standard deviation combinations: a 5 percent mean return with 7 percent standard deviation, 6 percent with 11 percent, and 7 percent with 15 percent. We estimated the standard deviation values associated with each target return using the publicly available, forward looking capital market assumptions published by Callan.[20] We estimated the portfolio allocation that would generate each target return across a diversified portfolio including large cap U.S. equities (e.g., S&P 500), small/mid Cap U.S. equities (e.g., Russell 2500), Global ex-U.S. Equity (e.g., MSCI ACWI ex USA), real estate (e.g., NCREIF ODCE), private equity (e.g., Cambridge Private Equity), and aggregate U.S. bonds (e.g., Bloomberg Barclays Aggregate). We then applied that allocation using Callan's estimated standard deviation and asset class correlations to calculate the associated standard deviation values for each return.

Investing in risky assets creates two types of uncertainty for retirement plans: 1) long-term return risk and 2) volatility risk. The first represents uncertainty about what the long-term average annual rate of return will be, while the second is uncertainty about year-to-year swings in asset values even when one correctly predicts the long-term rate of return. Both types of risks have important implications as we demonstrate below.

Figure 6 presents our estimate for the probability that CalSTRS runs out of assets with the contribution rate of 33 percent that our simulation of the LLS paper's funding policy suggests

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[20] We performed a similar exercise using capital the market assumptions published by BlackRock and J.P. Morgan. The results were consistent across the three firms' assumptions.

in a deterministic environment, for LLS's preferred assumption of 6 percent returns. We estimate CalSTRS would have a probability of reaching pay-go that rises to 11 percent over 30 years and 35 percent over 50 years.[21,22] Thus, even when long term average annual returns meet expectations, plans would still face a significant chance of insolvency because of return volatility. In addition, relatively minor over-estimates of future returns could lead to big increases in the probability of running out of money. For example, if average returns are only 5 percent, the risk of insolvency over the next 50 years rises from 35 percent to 57 percent.

Figure 7 depicts key points in the distribution of funded ratios (under the LLS assumption of 4 percent discount rate) over time. A full-funding policy would put probability of 100 percent on reaching that goal over the amortization period, but we estimate that CalSTRS would only have a 25 percent chance of reaching full funding in 70 years (see 75th percentile line) under LLS's proposed debt rollover policy. Indeed, the median funded ratio from our simulations slowly declines over time eventually reaching zero at year 78. This contrasts dramatically with the deterministic path for the same contribution rate, shown in Figure 5a above, where the funded ratio stabilizes at 40 – 45 percent. In the stochastic environment, we find that the contribution rate would have to be a few points higher to stabilize the median funded ratio, illustrating how precarious plan funding is.

This analysis helps us present a very simple illustration of the tradeoffs between current and future generations under such a policy. Suppose the contribution rate remains fixed at the deterministic debt-rollover policy of 33 percent so long as the fund is solvent but jumps to the

[21] As noted above, this simulation was based on a starting point of the 2018 valuation.

[22] These results vary with assumed volatility. The February 12 preliminary conference paper by Lenney, Lutz, and Sheiner posit that a portfolio with 3.5 percent expected real return – 6 percent nominal – can be structured with 6.5 percent standard deviation. This appears to be little more than half the volatility implied by industry assumptions. Running our simulation with 6.5 percent standard deviation generates pay-go probabilities of only 2 percent and 24 percent by years 30 and 50, vs. 11 and 35 percent.

pay-go rate if and when the money runs out and, conversely, the contribution rate falls to the plan's current normal cost rate (at CalSTRS's 7 percent discount rate) when it reaches full funding. We can then readily calculate the expected value of the contribution rate over time. It is simply the insolvency- and full-funding-weighted average of the three contribution rates. We depict the result in Figure 8. This diagram, of course, closely tracks Figure 6 (but not exactly, since the pay-go rate varies over time, as depicted in prior figures).

The LLS debt-rollover policy's conclusion of only a modest rise in the contribution rate applies to the present, but as time goes by, the expected contribution rate rises. CalSTRS is a somewhat conservative example because its current contribution rate is closer to its pay-go rate than the average pension plan; many pension plans would thus face a greater rise in our metric of expected future contributions. Of course, this is a very over-simplified representation of the tradeoffs, but it illustrates the type of analysis that would inform a consideration of intergenerational equity with risky returns. We consider more general treatments of the issue in our conclusion.

VI. ALTERNATIVE CONTRIBUTION RATES

Any funding policy ultimately boils down to a sequence of contribution rates and asset accumulation. A variety of models, whether actuarial full-funding, debt rollover, or statutory fiat, can generate any given path of contributions, under selected assumptions. Indeed, it is fair to say that actuarial assumptions are often chosen, in part, to generate politically palatable contribution rates. To evaluate alternative funding policies, therefore, it suffices to examine directly the contribution and asset sequences. Of course, our evaluation of those sequences will also depend on our assumptions, but we can at least "cut out the middle man," of which model generates the sequence. In this section, we illustrate by examining very simple variants on the policy discussed above. That is, we compare the tradeoffs generated by the 33 percent constant contribution rate with those generated by alternative constant contribution rates.

Figure 9 expands Figure 8 to present the sequence of expected contribution rates, under three initial rates: 33, 36, and 40 percent. A higher initial contribution rate reduces the probability of later insolvency and pay-go, and also increases the probability of reaching full funding, so ultimately, for both reasons, results in lower expected contribution rates in the future. This is depicted by curves crossing in Figure 9. This provides a very simple illustration of the intergenerational tradeoffs, by no means dispositive, but nonetheless indicative of the choices policy-makers face. As simple as this analysis is, we would contrast it with the deterministic debt-stabilization approach, which, effectively, simply consists of the horizontal line consistent with a stable debt ratio at any given starting level. That approach to generational equity begins with the notion of cutting amortization payments to avoid the visitation of past sins on the current generation, but it ends there, without examining the impact of low contribution rates today on future generations.

VII. IMPLICATIONS OF A SHARP DROP IN INITIAL ASSET VALUES

Our modeling is based on stochastic returns, from a given starting point, which raises the questions of how important that starting point is. We know from experience that markets can periodically experience sharp declines that may be quickly reversed (as in the spring of 2020), but may take much longer (as in 2008). Given the chances that markets take another dip that is hard to recover from, it is valuable to consider the implications of an initial market loss on CalSTRS long-term finances.

Figure 10 depicts the distribution of CalSTRS funded ratios following a 20 percent asset decline in the first year if the contribution rate were set, again, to the 33 percent rate considered above.[23] The 20 percent market loss would fall 26 percent short of the assumed 6 percent return, reducing CalSTRS's first-year funded ratio from approximately 44% to 33%. In this scenario, we estimate that in the median sequence of subsequent returns, the plan will run out of assets in 37 years – twice as fast, absent the 20 percent drop. Conversely, CalSTRS would have roughly a 1 in 16 chance of reaching full funding over 50 years, a third of the chance with no drop.

Figure 11 shows CalSTRS's expected contribution following a 20 percent asset loss. For a 6 percent average rate of return, the expected contribution would rise above 40 percent, approaching the pay-go rate (45 percent), as there is a much greater risk of insolvency (33 percent instead of 11 percent by year 30) and much smaller chance of reaching full funding (3 percent vs. 11 percent by year 30). Together these figures illustrate the sizeable impact the initial starting position will have on the results. A policy of simply rolling over debt, regardless of hits to its initial size, would thus run afoul of the risks associated with low funding ratios.

VIII. CONCLUSION

The LLS paper from last year's Brookings Municipal Finance Conference is right to raise the issue of intergenerational equity, but by narrowly focusing on stabilizing pension debt, fails to put forward a meaningful definition of equity or a practical means to pursue it. We agree that the cost of paying down public pension debt is crowding out spending in other areas like

[23] The 33 percent contribution rate is the rate we found to deterministically stabilize the debt ratio without the 20 percent market loss; it stabilized the funded ratio at about 40 percent. To deterministically stabilize the debt ratio after the 20 percent market drop would require a contribution rate of 37 percent; this would stabilize the funded ratio at a much lower level, 28 percent. The stochastic simulation at 37 percent contribution with a 20 percent market drop looks similar to that of the 33 percent contribution without the market drop. For example, in both cases the median funded ratio goes to zero in 70+ years.

infrastructure and education, and that pension funding policy should consider these impacts. However, we have shown that perpetually rolling over pension debt leaves plans in a precarious financial position and substantially increases the chance that they will run out of assets. If that occurs, government contributions will need to roughly double, dramatically increasing the expected pension contribution for future taxpayers and putting public workers benefits at risk.

Standard actuarial practice pursues intergenerational equity by employing funding rules that seek to ensure each generation pays for the services they receive. These rules do this through the concepts of normal cost and amortization, which together, in theory, should result in fully funded benefits for each cohort of workers and taxpayers. In practice, these rules have failed to adequately link earned benefits and contributions, leading to the accumulation of large pension debt. A primary cause of public pensions' current financial problems was the failure to adequately consider the risks involved and the implications of those risks and uncertainties for future generations of public workers and taxpayers.

The alternative proposed in the LLS paper has two features that end up reproducing the basic problem. First, despite a nod to fiscal conservatism by using a low-risk rate to discount liabilities, the proposed funding policy is largely decoupled from the discount rate. The policy continues to make the same risky bet that plans are making today, by banking on arbitrage profits between the risky return on assets and the low-risk rate on liabilities. Since the proposed funding policy would leave plans with a large and perpetual debt, by design, it substantially increases solvency risk, and thus, increases future taxpayers' expected cost and decreases workers' benefit certainty, especially in a period of tightening government revenues.

Second, the proposed funding policy removes any connection between contributions and the liabilities incurred by public workers' benefits. If the goal is simply to stabilize the debt at some arbitrary level relative to the state's gross domestic product or payroll, then there is nothing to keep governments from resetting the target every few years if contributions fail to stabilize the debt. Under the proposed funding policy, the only meaningful constraint is the pay-go contribution, which our modeling shows plans may well reach over time. Despite the shortcomings of traditional actuarial practice, it does promote generational equity by linking benefit accruals and contributions, thereby compelling each generation of taxpayers to pay for the services they receive.

While we find significant fault with both existing actuarial funding policy and the LLS paper's proposed funding policy, we welcome the challenge of re-conceptualizing the goal of intergenerational equity in a risky world. The expected contribution metric we propose is a simple first step to better incorporate risk and its impact on future cost into funding policy deliberations. Our future work will refine and expand this metric in several ways.

Our first extension would be to consider richer contribution policies. In this paper, the contribution rate is a step function, constant until jumping to pay-go upon insolvency or dropping to normal cost at full funding. Actuarial funding is also discontinuous at insolvency, but continuous above it. A natural extension would be to formulate a continuous function between contributions and funding levels, rising gradually toward pay-go as insolvency approaches.

A second extension would be to incorporate social risk-aversion into the metric for future contributions. Expected contribution is the probability-weighted contribution rate -- linear in the contribution rates. This can be easily generalized to various degrees of risk-aversion with non-linear functions of the contribution rate, as in standard economic formulations. Specifically, since contributions represent social disutility, we would look at functions that express the rising marginal social disutility from higher contribution rates.

The extensions above would provide more credible representations of the inter-temporal tradeoffs, while maintaining the general point captured even in this paper's simple metric: lower contributions now imply greater likelihood of higher contributions later. This is the basic tradeoff that must be evaluated in forming contribution policy, but the choice depends on how society – or its policy-makers – weigh that tradeoff. Those preferences can be represented using standard inter-temporal social welfare functions. The two key parameters are: (1) the discount rate to be applied to future disutility (incorporating risk-aversion as indicated above); and (2) the degree of intertemporal substitution of social welfare. Variations in these two parameters will generate variations in the optimal contribution policy. This kind of economic analysis cannot prescribe what those policy preferences should be – as captured in those parameters – but it can show how the optimal funding policy varies with those preferences. This would provide a richer understanding of what intergenerational equity means for pension funding policy. We believe such analysis would help us learn from the sins of the past rather than repeating them in the present, imposing likely burdens on the future, and thereby help us find a better approach for dealing with risk.

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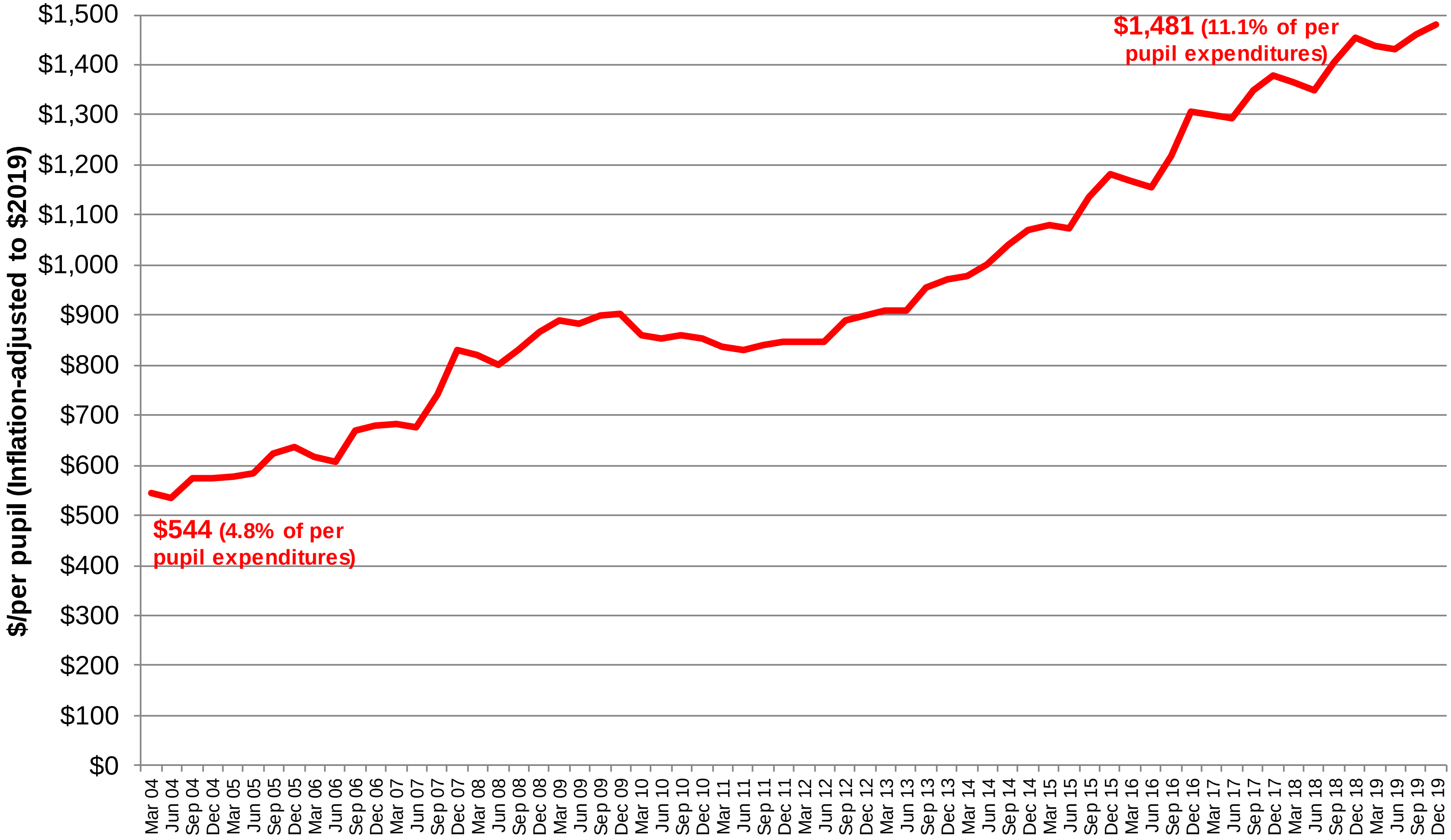
Table 1: Pension Funding Notation
L = accrued liabilities, the present value of future benefits earned to date
A = assets on hand
UAL = unfunded accrued liabilities = L – A, “pension debt”
f = funded ratio, A/L (full funding goal is f = 100%)
W = payroll
c = contributions as % of payroll
c_p = benefit payments as % of payroll (“pay-go rate”)
c_n = newly accrued liabilities as % of payroll (“normal cost rate”)
r = return on assets
d = discount rate used to calculate present value of liabilities
g = growth rate of payroll

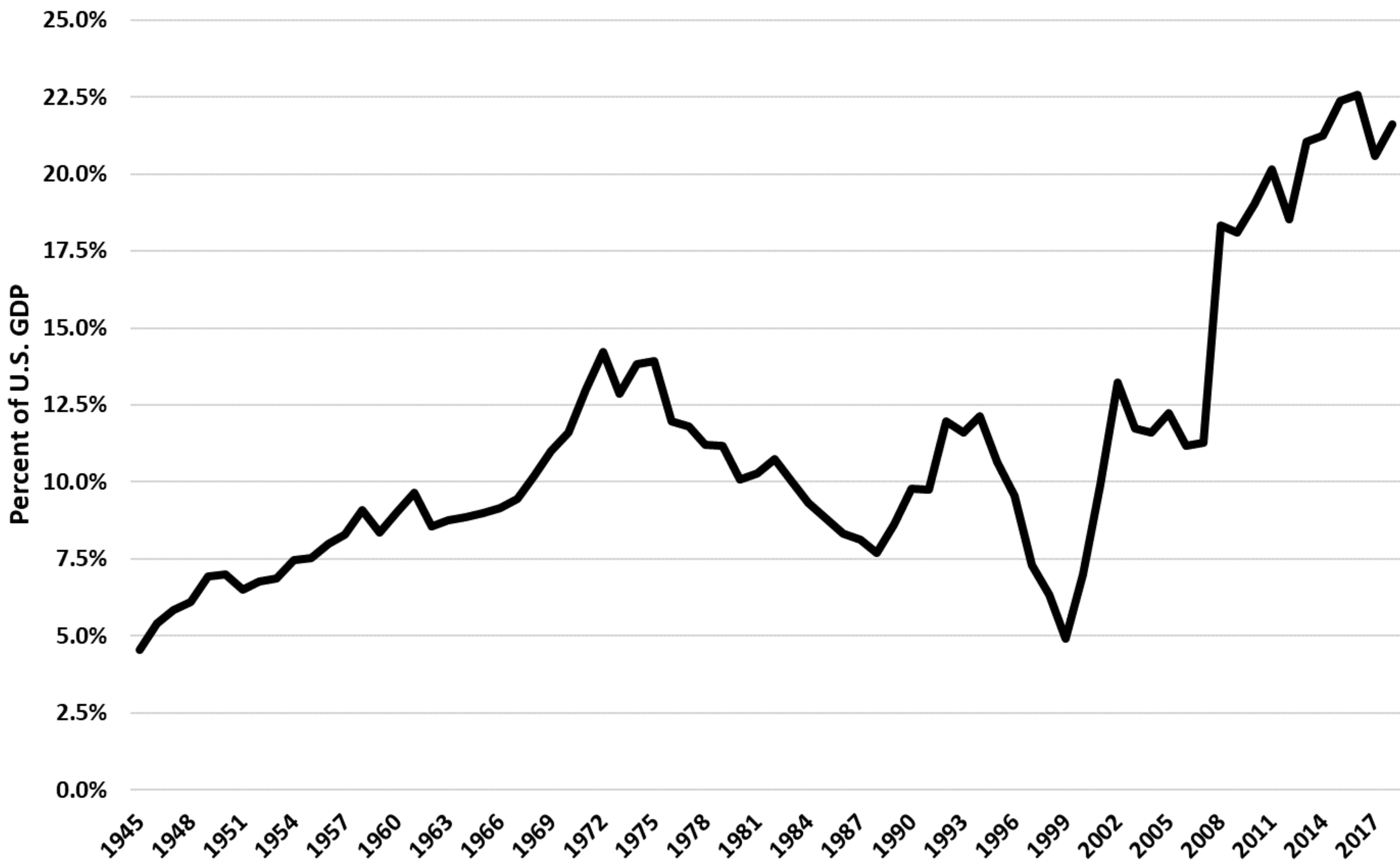
Figure 1. Employer Contributions Per Pupil for Retirement Benefits

U.S. Public Elementary and Secondary Schools, teachers & other employees, 2004-2019



Sources: BLS, National Compensation Survey, Employer Costs for Employee Compensation;
NCES Digest of Education Statistics; BLS, CPI; author's calculations explained in Robert M. Costrell:
http://www.teacherpensions.org/blog/school-pension-costs-have-doubled-over-last-decade-now-top-1000-pupil-nationally
Note: Does not include retiree health benefits or Social Security

Figure 2. State and Local Pension Debt as a Percentage of U.S. Gross Domestic Product (GDP), 1945-2018



Sources: Federal Reserve Financial Accounts of the United States; Bureau of Economic Analysis; authors' calculations

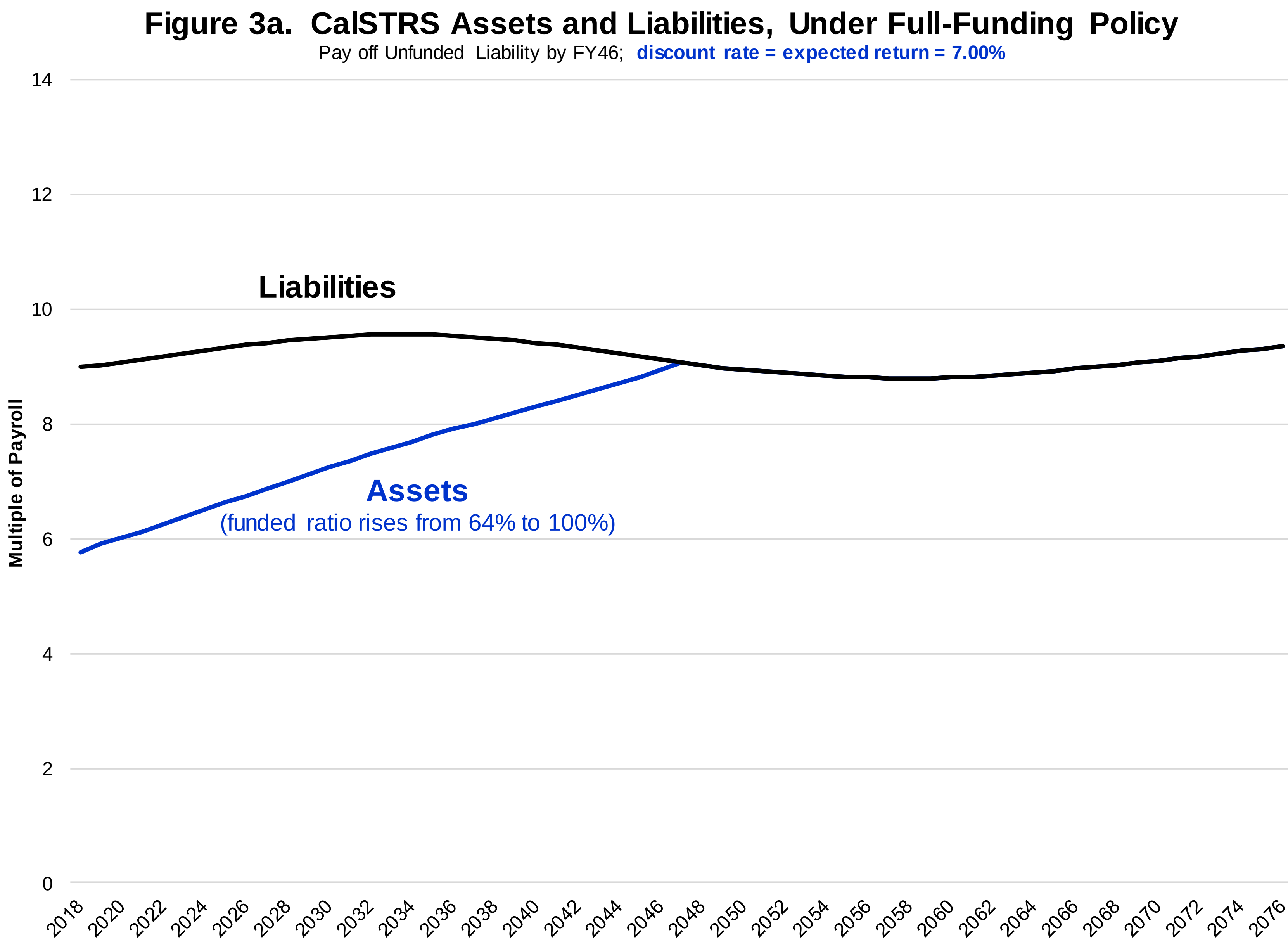


Figure 3a. CalSTRS Assets and Liabilities, Under Full-Funding Policy
Pay off Unfunded Liability by FY46; discount rate = expected return = 7.00%
Liabilities
Assets
(funded ratio rises from 64% to 100%)
Multiple of Payroll
0
2
4
6
8
10
12
14
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
2052
2054
2056
2058
2060
2062
2064
2066
2068
2070
2072
2074
2076

Figure 3b. CalSTRS Contribution & Benefit Rates; Full-Funding Policy

Pay off Unfunded Liability by FY46; **discount rate = assumed return = 7.00%**

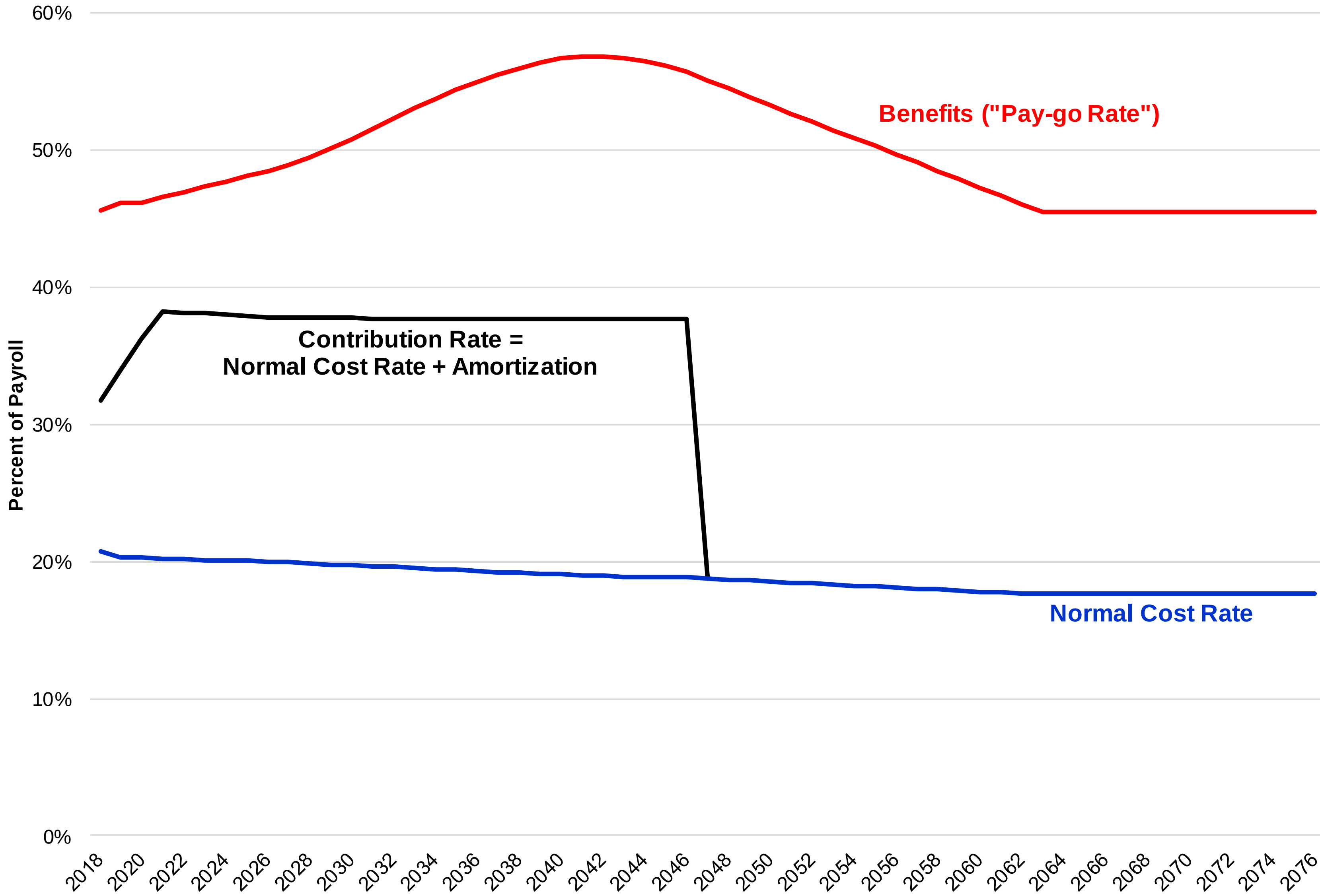
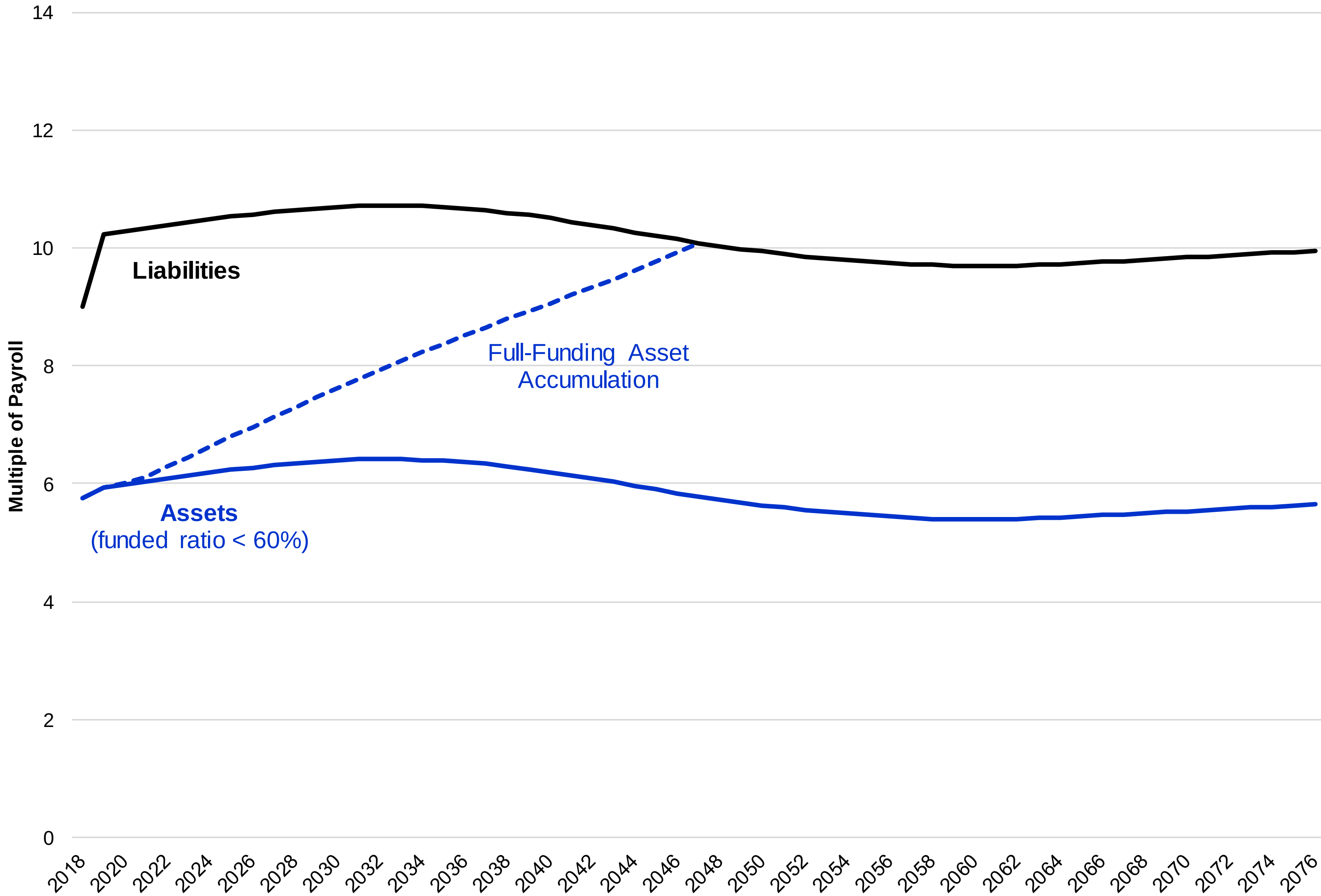


Figure 4a. CalSTRS Assets & Liabilities: Debt Rollover Policy, d = r

Maintain rediscounted debt ratio. **discount rate = expected return = 6.00%**



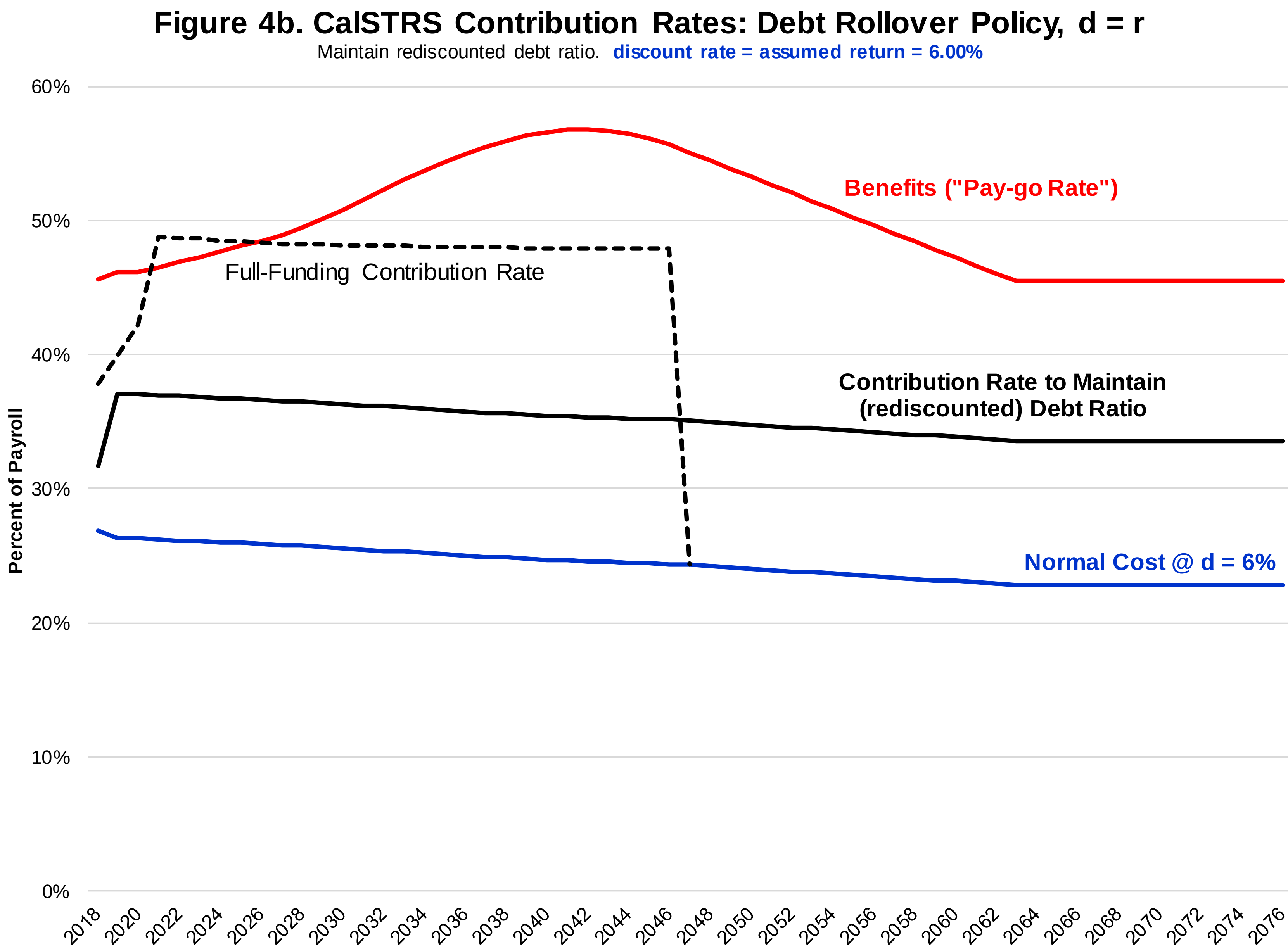


Figure 4b. CalSTRS Contribution Rates: Debt Rollover Policy, d = r
Maintain rediscounted debt ratio. discount rate = assumed return = 6.00%
Percent of Payroll
60%
50%
40%
30%
20%
10%
0%
Benefits ("Pay-go Rate")
Full-Funding Contribution Rate
Contribution Rate to Maintain (rediscounted) Debt Ratio
Normal Cost @ d = 6%
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
2052
2054
2056
2058
2060
2062
2064
2066
2068
2070
2072
2074
2076

Figure 5a. CalSTRS Assets & Liabilities: Debt Rollover Policy, d < r

Maintain rediscounted debt ratio. discount rate = 4.00%, expected return = 6.00%

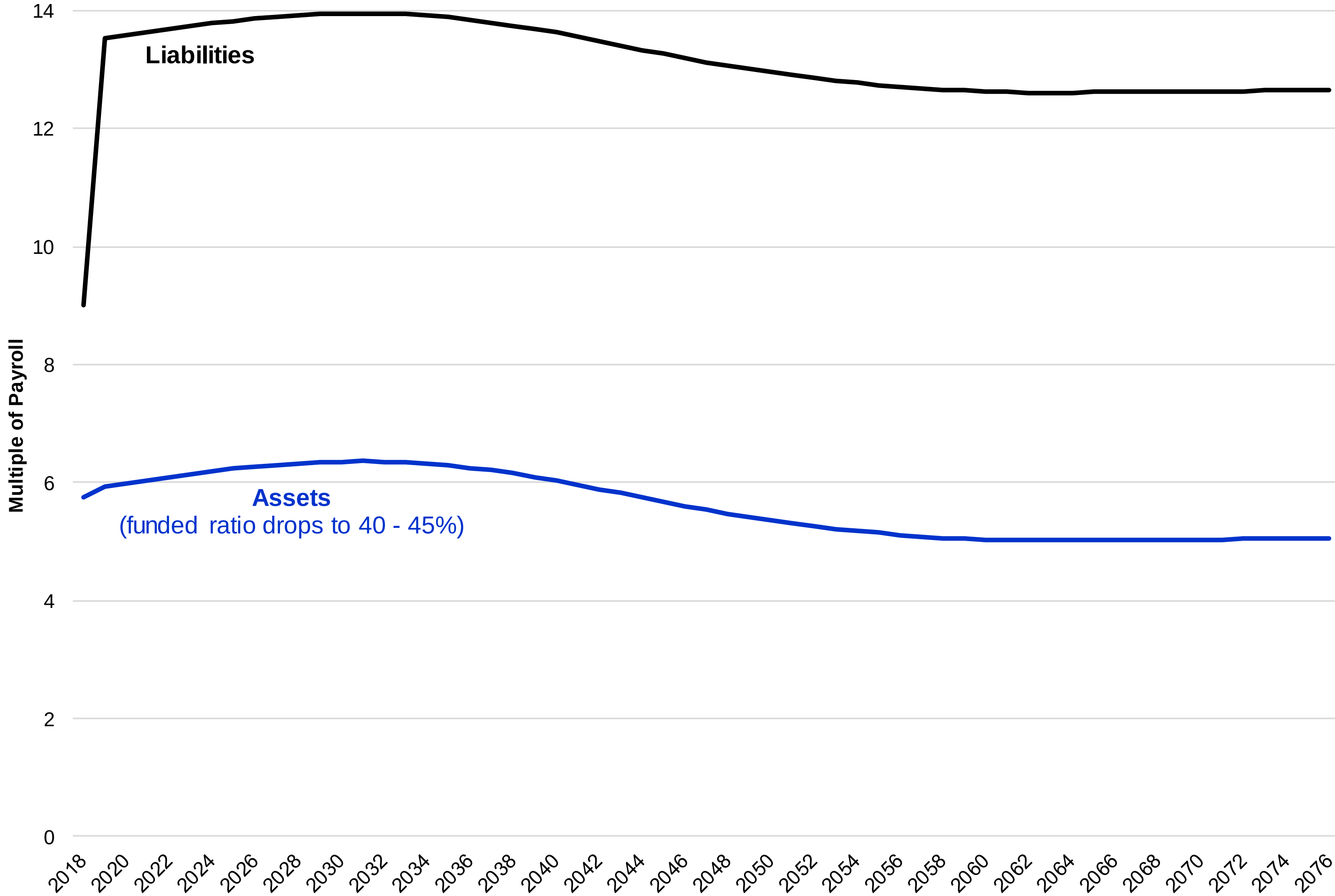
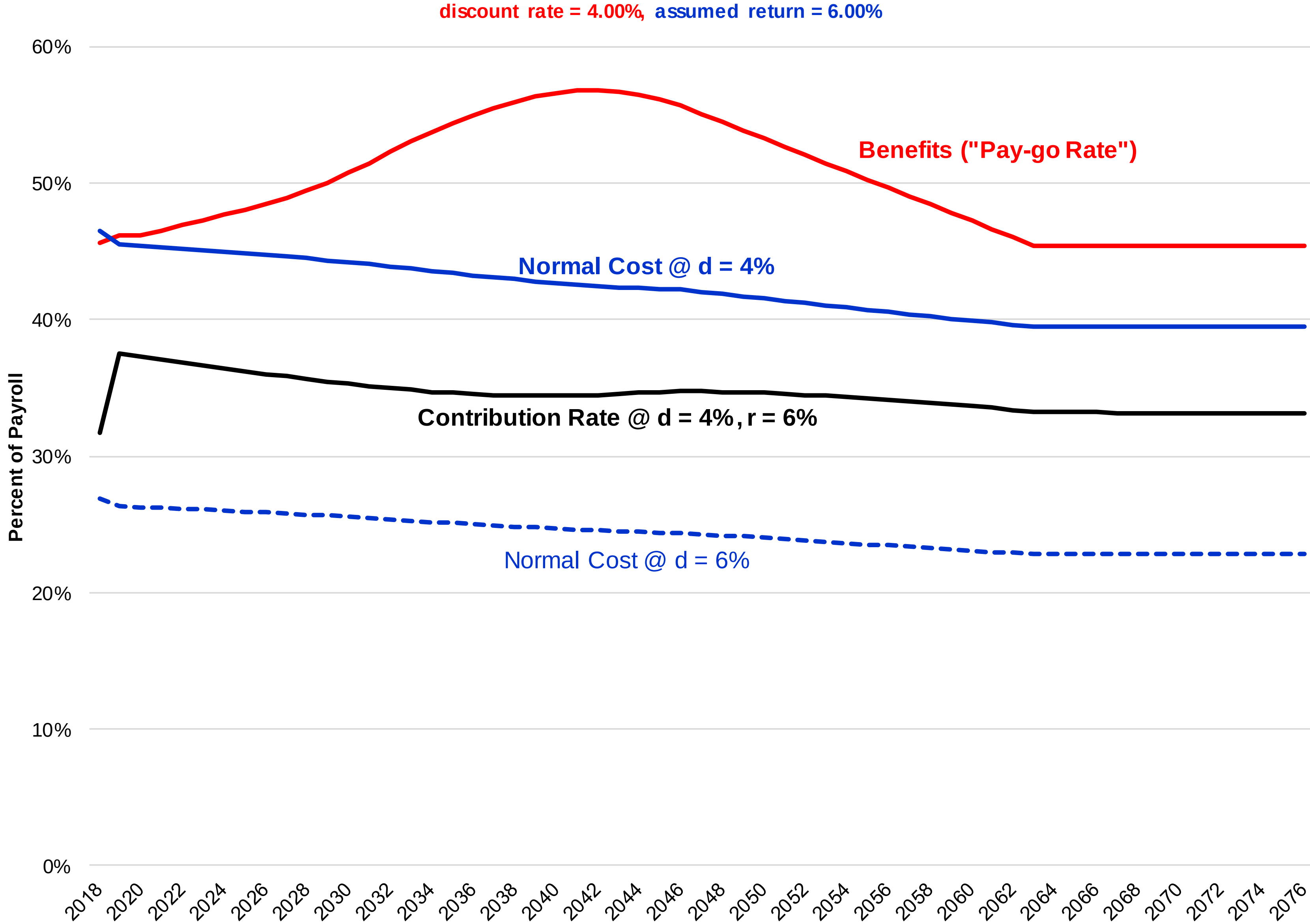


Figure 5b. CalSTRS Contribution Rates: Debt Rollover Policy, d < r



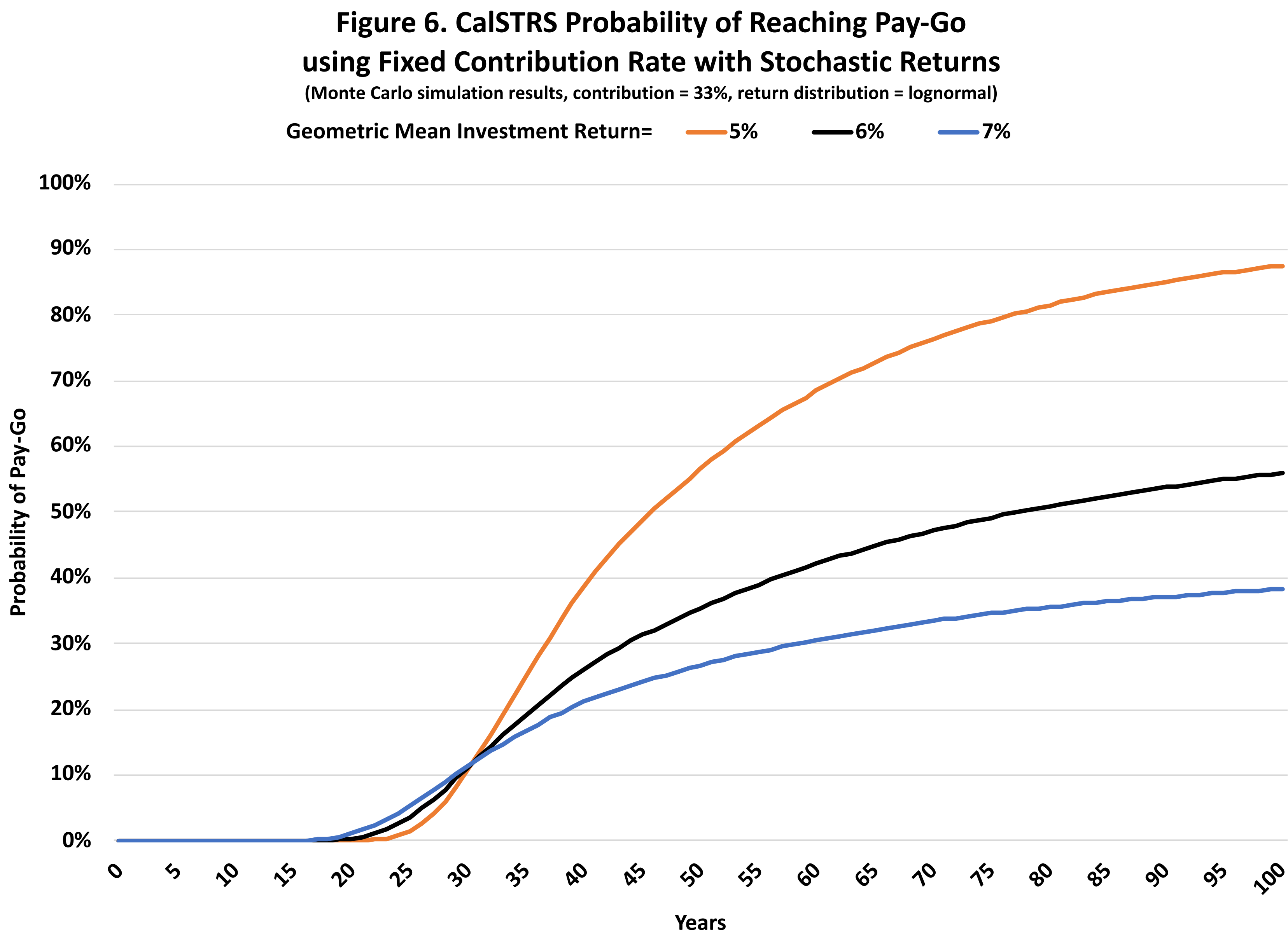
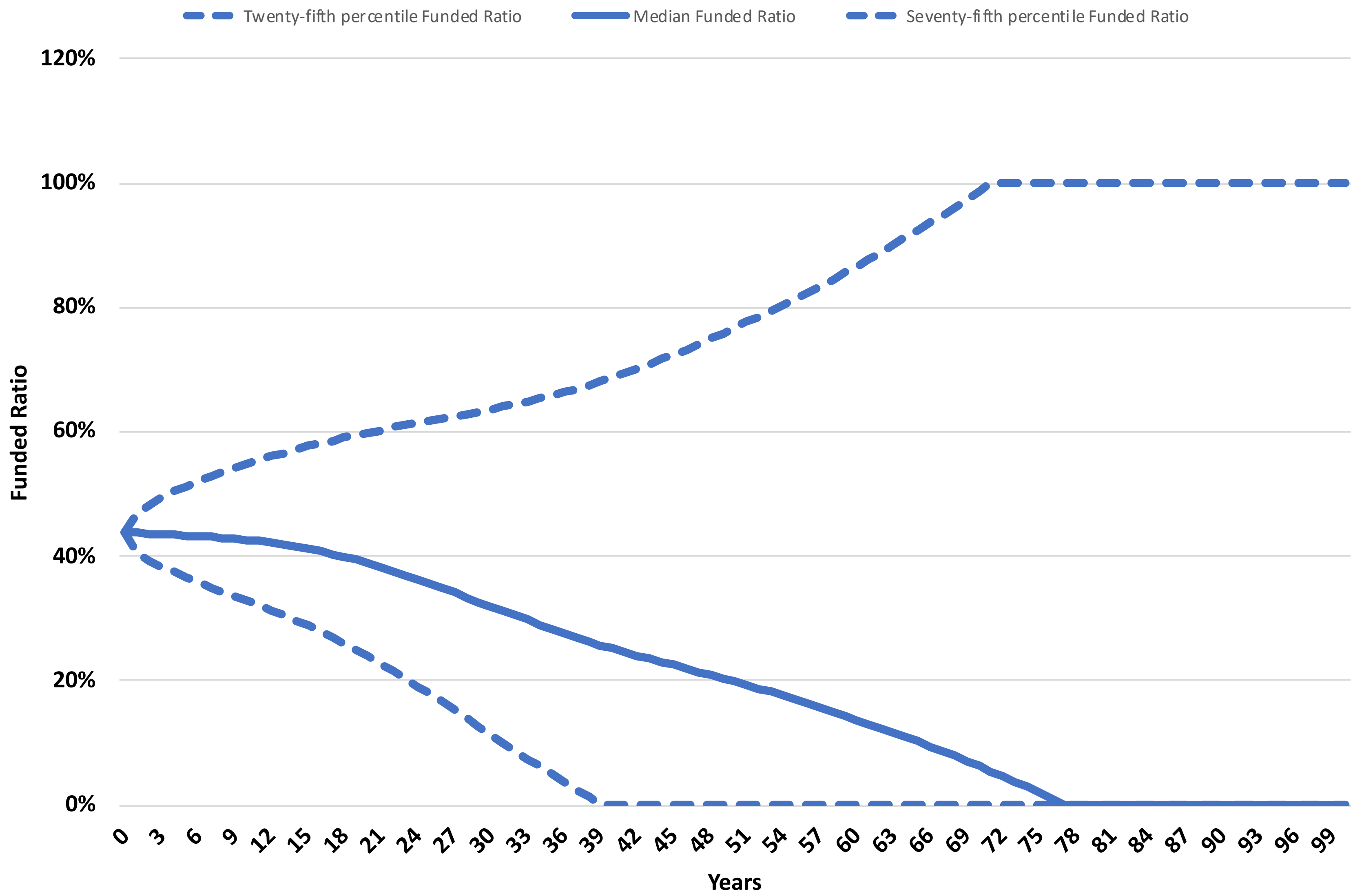


Figure 6. CalSTRS Probability of Reaching Pay-Go
using Fixed Contribution Rate with Stochastic Returns
(Monte Carlo simulation results, contribution = 33%, return distribution = lognormal)
Geometric Mean Investment Return=
5%
6%
7%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability of Pay-Go
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Years

Figure 7. CalSTRS Funded Ratio with Stochastic Returns

(Monte Carlo simulation results, , contribution = 33%, geometric mean return = 6%, return distribution = lognormal)



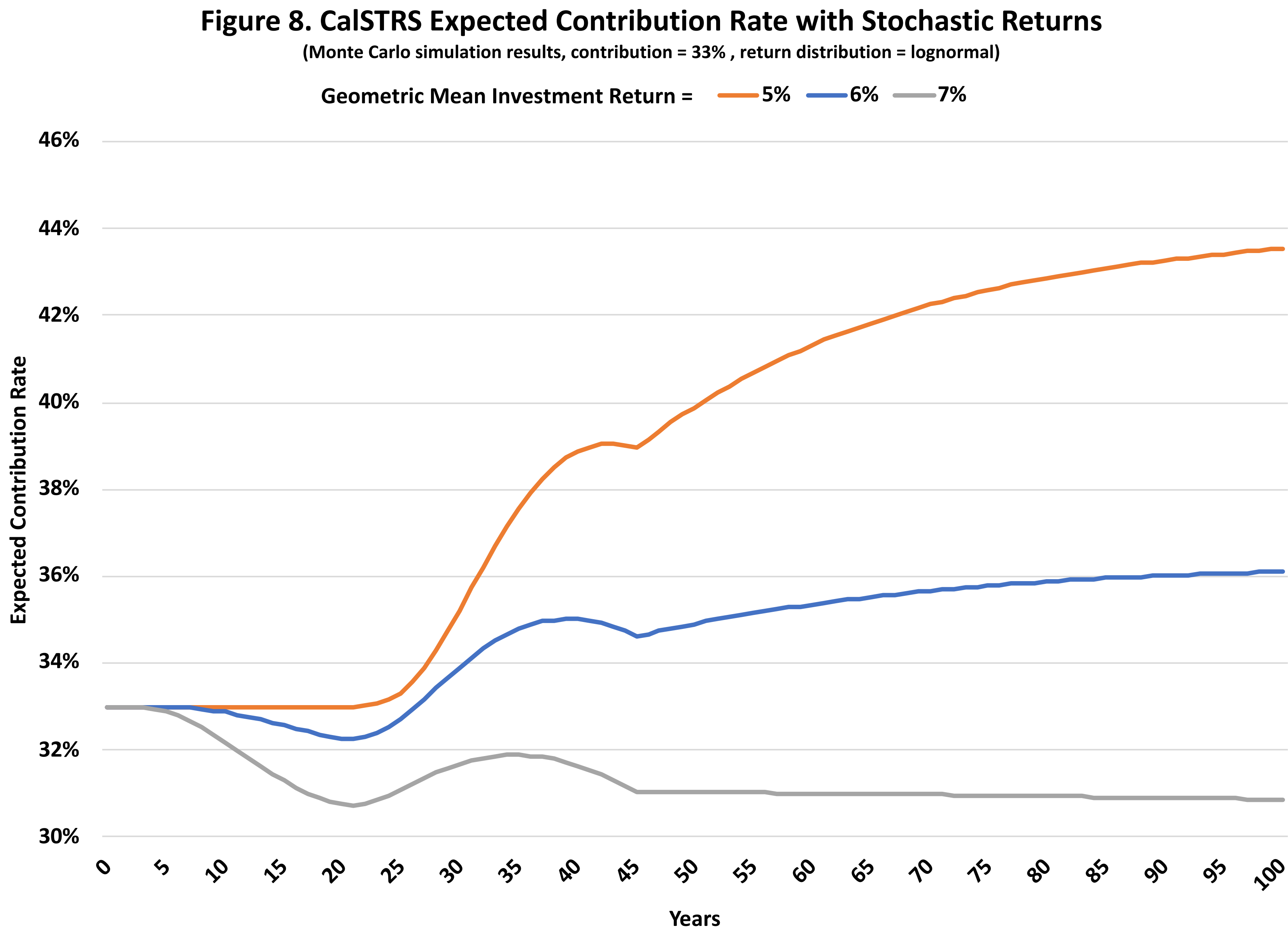
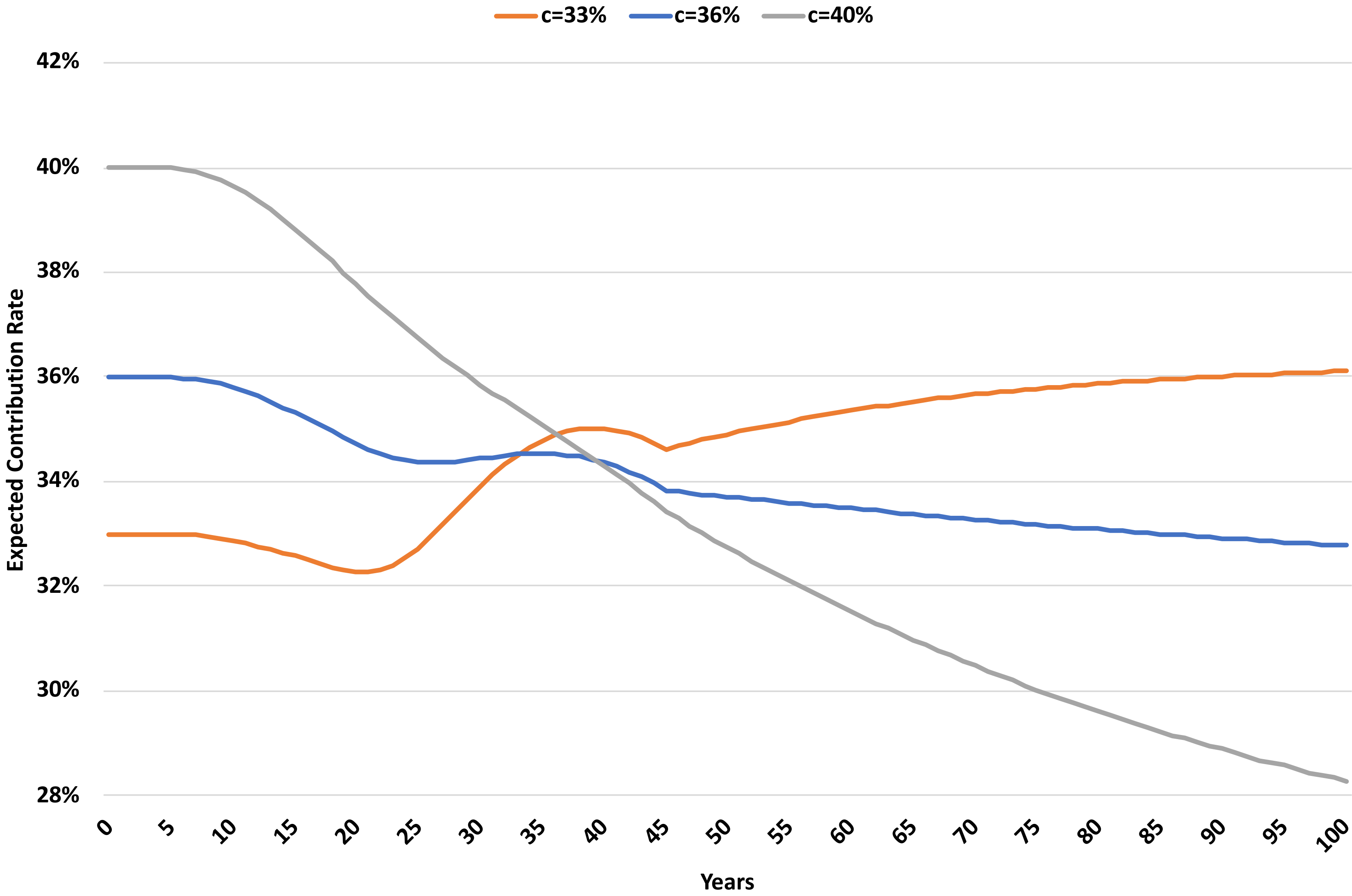


Figure 8. CalSTRS Expected Contribution Rate with Stochastic Returns
(Monte Carlo simulation results, contribution = 33% , return distribution = lognormal)
Geometric Mean Investment Return =
5%
6%
7%
46%
44%
42%
40%
38%
36%
34%
32%
30%
Expected Contribution Rate
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Years

Figure 9. CalSTRS Expected Contribution Rate with Stochastic Returns

(Monte Carlo simulation results, return distribution = lognormal, 6% geometric mean return)



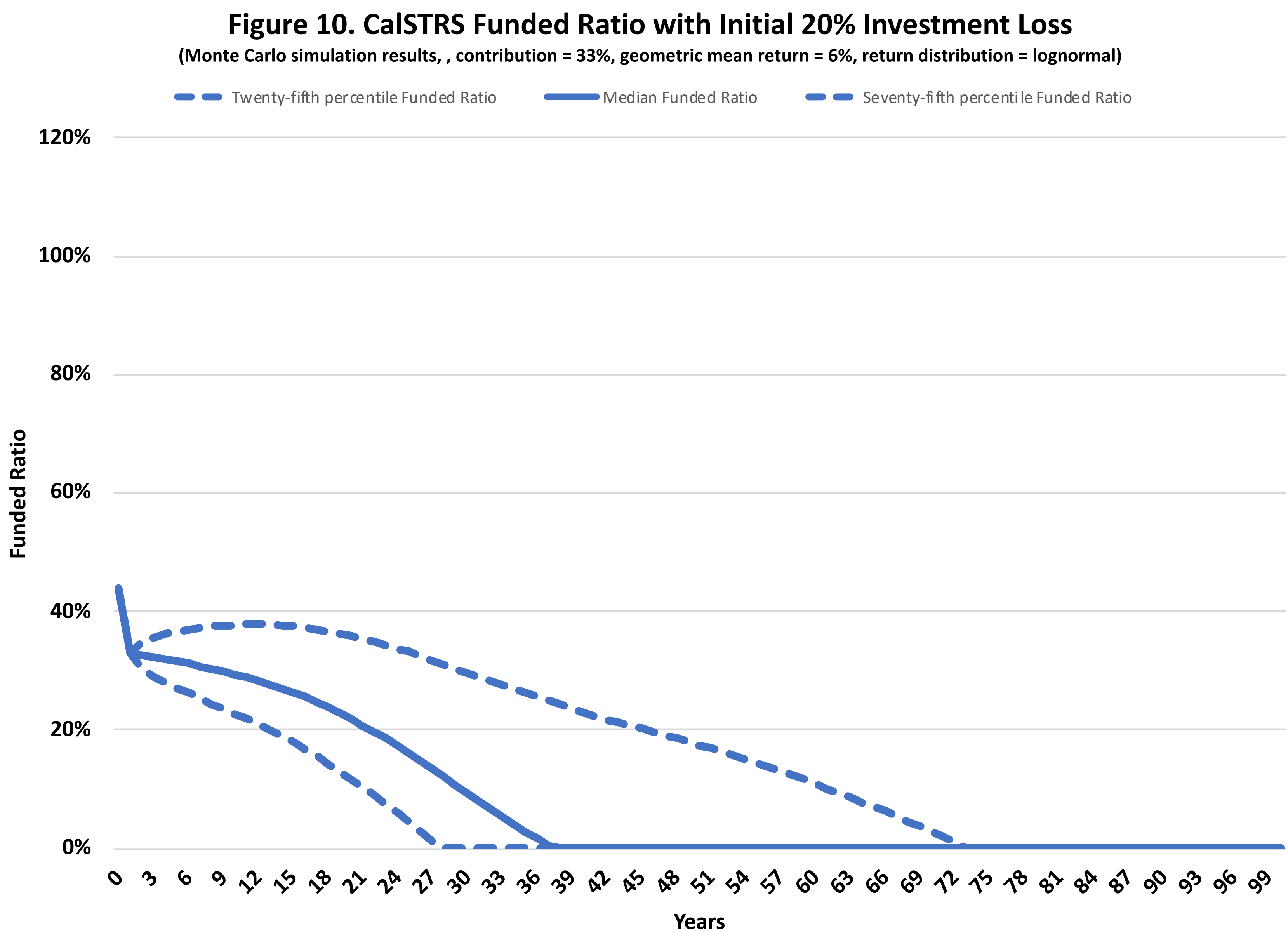


Figure 10. CalSTRS Funded Ratio with Initial 20% Investment Loss
(Monte Carlo simulation results, , contribution = 33%, geometric mean return = 6%, return distribution = lognormal)
Twenty-fifth percentile Funded Ratio
Median Funded Ratio
Seventy-fifth percentile Funded Ratio
120%
100%
80%
60%
40%
20%
0%
Funded Ratio
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99
Years

Figure 11. CalSTRS Expected Contribution Rate with Initial 20% Investment Loss

(Monte Carlo simulation results, contribution = 33%, return distribution = lognormal)