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## PENSION SIMULATION PROJECT

# HOW PUBLIC PENSION PLAN INVESTMENT RISK AFFECTS FUNDING AND CONTRIBUTION RISK

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## HOW PUBLIC PENSION PLAN INVESTMENT RISK AFFECTS FUNDING AND CONTRIBUTION RISK

January 2017

## Executive Summary

The decline in risk-free interest rates since the 1980s and 1990s has created a very difficult investing environment for public pension plans. Before the decline, the typical plan could have achieved its investment-return assumptions while taking very little risk. As rates declined, public plans faced a choice: Either reduce investment-return assumptions and request much higher contributions from governments, or maintain assumptions, avoid increasing contributions from governments, and take on much greater risk.

For the most part, public pension funds have maintained their investment-return assumptions, perhaps in the belief that interest rate declines were temporary and that in the longer run high investment returns could again be obtained at low levels of risk. But maintaining their assumptions implicitly required them to invest in riskier assets.

We modeled the implications of a sustained reduction in risk-free interest rates by examining a prototypical pension plan under three scenarios:

- *The good old days:* The pension plan can expect to earn a 7.5 percent return with very little investment-return volatility, or risk. This is similar to what plans might have been able to achieve two or three decades ago. As the name implies, pension plans no longer have this beneficial choice available.
- *Invest in riskier assets:* In response to declining risk-free rates, the pension plan maintains a 7.5 percent earnings assumption but invests in riskier assets. Even though it can expect a long-run compound return of 7.5 percent, some years will be much higher and some will be much lower. Our measure of investment-return volatility, the standard deviation, is 12 percent in this scenario. This is similar to what many public pension plans did as risk-free rates fell.
- *Lower assumed return:* In this scenario, instead of investing in riskier assets in response to declining risk-free rates, the pension plan lowers its earnings assumption to 3.5 percent and remains invested in relatively low-risk assets, with a standard deviation of 1.8 percent. This forces it to raise contributions from governments. For the most part, public pension plans have not done this (although they have raised contributions in response to investment shortfalls). Lowering risk and raising contributions remains an option.

Pension plans were not limited to one response or the other — they could have chosen to be in-between.

We modeled the finances of our prototypical pension fund over thirty years, assuming that employers pay full actuarially determined contributions. Our analysis shows that plans faced a fundamental trade-off, shown in Table 2 on page 15: If they moved into riskier assets, the risk to the pension fund would

increase significantly but government contributions would remain low. The riskier-assets scenario resulted in a 16.9 percent probability for our prototypical plan that plan funding would fall below 40 percent sometime during the thirty years — a level that has been associated with crises in several states.

If instead of moving into riskier assets the plan lowered assumed investment returns, the risk to the pension fund would remain minimal, but employer contributions would have to triple, and would stay high for all thirty years of the simulation period. This dramatic increase in required contributions may go a long way toward explaining why plans have taken on increased investment risk.

We also examined what would happen if plan earnings assumptions, which are in the range of 7 to 8 percent for most plans, are too optimistic, as some professional market forecasts suggest. We simulated a scenario in which the true expected compound return is 1.5 percentage points lower than the assumed return of 7.5 percent. In that scenario the plan has a more than one in three chance of experiencing severe underfunding at some point over the next thirty years, which is more than twice as high as when the investment earnings assumption is met. Employer contributions as a percentage of payroll would be expected to rise substantially over time, whereas if the return assumption is met they would fall over time; by the end of thirty years, the median employer contributions in this scenario are about 50 percent higher than when investment return assumptions are met.

Reducing risk remains an option for plans today, but only at the expense of raising employer contributions. As unpalatable as this may be, given the risk of severe underfunding at today's current level of risk taking, moving in this direction may be advisable.



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## PENSION SIMULATION PROJECT

# HOW PUBLIC PENSION PLAN INVESTMENT RISK AFFECTS FUNDING AND CONTRIBUTION RISK

### Introduction

Public pension funds receive contributions from governments and employees, and invest those funds with the goal of having enough money to pay future benefits when due. Governments and pension funds can't predict the future with certainty, so they adjust contribution requirements to reflect experience – requesting higher contributions if experience hasn't been as good as expected, or reducing requirements if experience has been better than expected.

The biggest uncertainty is how well the pension fund's investments will do. Currently public pension funds have approximately \$3.7 trillion in assets, about two-thirds of which are invested in stocks, real estate, hedge funds, and other assets subject to investment risk. Thus, investment returns can be much greater or less in any given year than pension funds expect. This creates risks that employer contributions may have to rise considerably, or may be able to fall considerably. It also creates risks that plan funding will fall to very low levels, particularly if governments do not pay actuarially determined contributions. Conversely, very good investment returns could lead to significant plan overfunding.

Understanding these issues is important because if contributions rise sharply, governments may have to raise taxes significantly, or cut services sharply. Or governments may be unwilling to pay requested contribution increases and may seek to cut pension benefits.

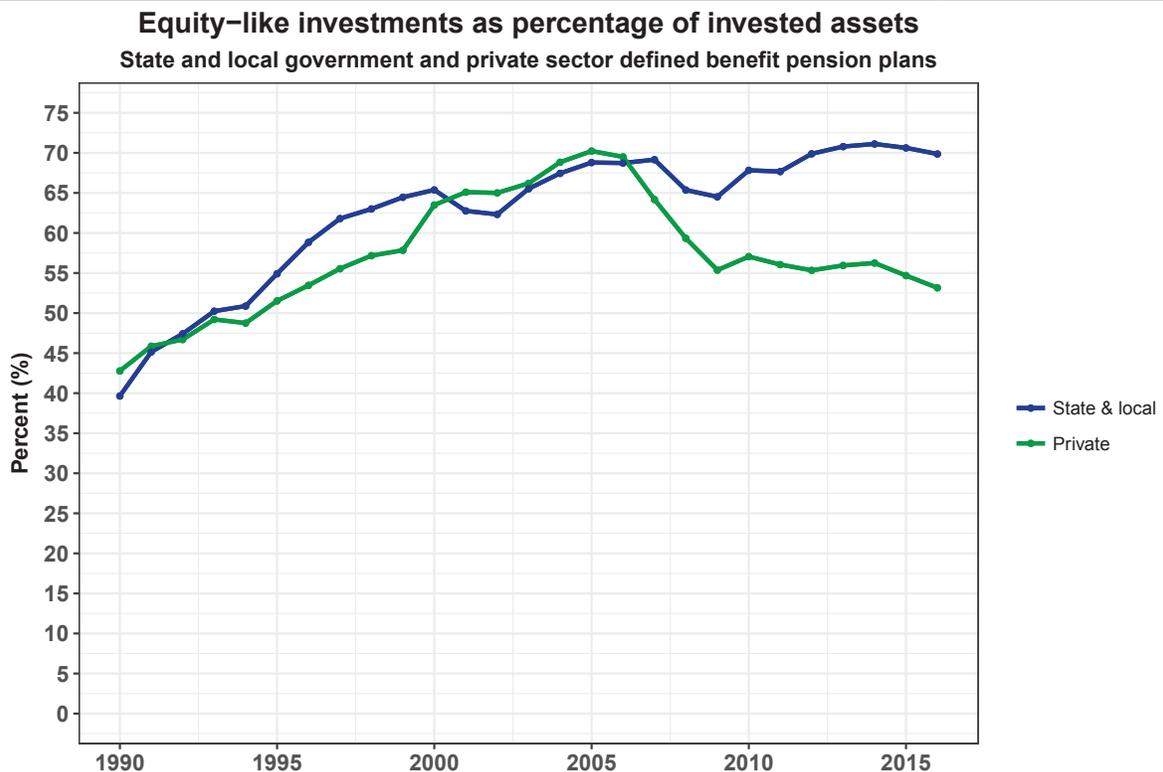
In a previous report we examined how plan funding policies and practices affect the risks of underfunding and of sharp contribution increases.<sup>1</sup> The key conclusions of that work are that (1) public plans commonly use funding methods that allow unfunded liabilities to be repaid over very long periods of time; (2) an average plan that is 75 percent funded now would only reach about 85 percent funding after thirty years, even if all investment return assumptions are met on average and even if governments pay full actuarially determined contributions; and (3) such a plan would have about a one in six chance of falling below 40 percent funding in a thirty-year period, a level associated with fiscal crises in several pension systems.

In this report, we examine how risks of underfunding and of contribution increases are affected by fund investment practices and experience.

### Public Pension Plan Investment Risks Have Increased Over Time

Public pension plans in the U.S. now invest nearly two-thirds of their assets in equity-like investments, up from one-quarter in the 1970s and about 40 percent in 1990. While public plans once were more conservative investors than private defined benefit plans, they now have a much greater share of their assets invested in equity-like investments than do private plans (see Figure 1<sup>2</sup>).

Figure 1. Public Pension Funds Have Increased Their Investments in Equity-Like Assets



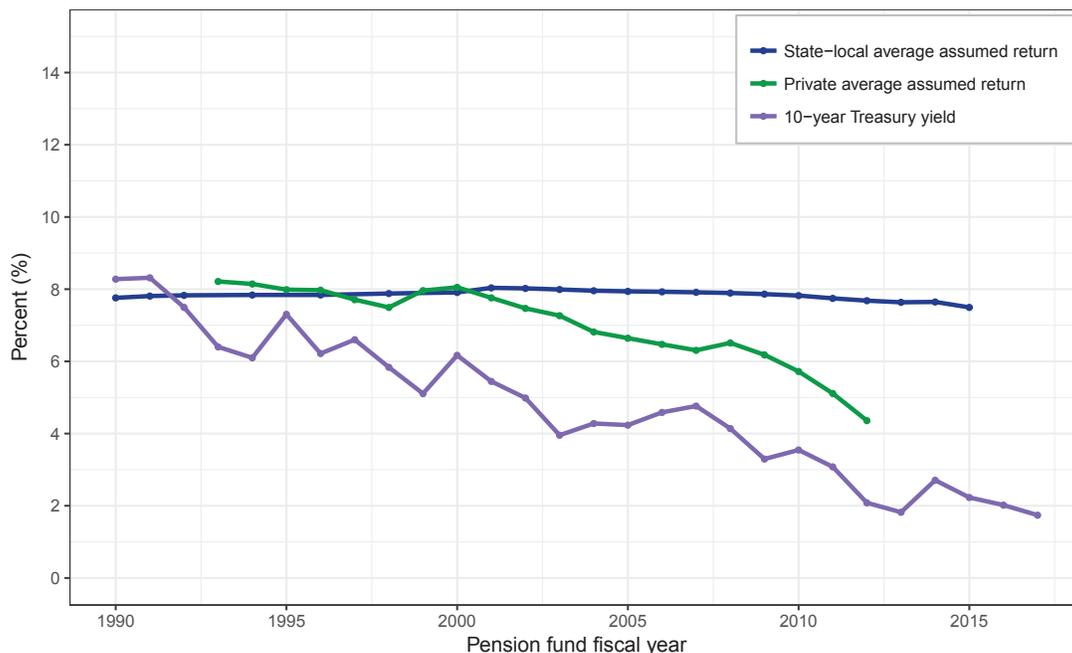
Source: Authors' analysis of Z.1 Financial Accounts of the United States, Federal Reserve Board, Tables L.118.b, L.120.b, and L.122

One likely reason for the increasing allocation of assets by public pension plans to equities is that nominal risk-free returns have declined substantially, but public pension funds' earnings assumptions have been "sticky," barely falling at all (see Figure 2<sup>3</sup>). In contrast, private sector plans have been reducing earnings assumptions along with the declining risk-free returns. Several economists have argued that assumed returns have not followed risk-free returns downward in part because pension fund boards and sponsors prefer high discount rates, which keep the reported actuarial value of pension liabilities and actuarially determined contributions lower, all else equal. Their research suggests that the move toward riskier assets reflects the unique nature of the regulatory and standards-setting environment for public pension funds, particularly the accounting standards and actuarial practices that value liabilities with discount rates equal to earnings assumptions generally selected by the plans themselves. These standards and practices used by public plans in the United States are different than the standards, practices, and rules for private plans and for public plans in other countries.<sup>4</sup>

The decline in risk-free rates created difficult choices for public pension funds. In 1990, after a multiyear drop from unprecedented inflation-induced heights, ten-year Treasuries were still above 8 percent and public pension plans were assuming they would earn just under 8 percent; pension funds could achieve

**Figure 2. Public Pension Fund Earnings Assumptions Barely Fell, Despite Substantial Declines in Risk-Free Rates**

Assumed investment returns of public and private retirement systems and risk-free returns



Sources:

State-local assumed return from Public Plans Database

Private assumed returns provided by Andonov, Bauer, and Cremers

10-Year Treasury yield from Federal Reserve Bank of St. Louis (FRED)

their assumptions while taking very little risk. At the time plan funds were only about 40 percent invested in equity-like assets. From 1990 through the present, risk-free rates fell significantly and ten-year Treasuries are now yielding under 2 percent. Public pension plans could have chosen to reduce their earnings assumptions as risk-free rates fell. Reducing assumptions would have led to large increases in actuarially determined contributions, causing potential stress for employers. For the most part, public pension funds did not do this, presumably believing that they could achieve their long-term earnings assumptions while taking reasonable risks, and perhaps believing that the fall in risk-free rates was temporary. Between 1990 and 2014, risk-free rates fell by about 6 percentage points and the share of assets in equity-like investments rose by about 25 percentage points. In any event, in the current environment, commonly used discount rates of 7 percent to 8 percent can only be justified by investing in asset classes that might be expected to earn substantially more, on average, than risk-free assets, but that are likely to have volatile returns.

### **How We Model the Impact of Public Pension Fund Investment Risks**

We examine the impact of changing investment risk using a simulation model that calculates the year-by-year finances of a public pension fund, allowing investment returns to vary from year to year. A single simulation of the model, constituting one “lifetime” for a pension plan, calculates the year-by-year finances of the plan for fifty years or more. Among other things, the model calculates opening assets, benefit payments, contributions to the plan, and investment income, as well as measures such as the plan funded ratio and employer contributions as a percentage of payroll.

A single scenario typically includes 1,000 such runs, or 1,000 “lifetimes” of the pension plan. In a full scenario, investment returns vary not only from year to year, but also from simulation to simulation, with returns following the same general distribution in each simulation, such as an expected long-term compound return<sup>5</sup> of 7.5 percent with a standard deviation of 12 percent. By summarizing results for 1,000 simulations, we can estimate measures such as the expected funded ratio after thirty years, and the 25th percentile for the funded ratio. We can also estimate probabilities, such as the probability that the funded ratio will fall below 40 percent, or that employer contributions will exceed 30 percent of payroll, or that contributions will rise sharply in a short period of time. (For details, see Appendix: The Stochastic Simulation Model.)

We apply this approach to a plan with fairly typical demographic characteristics that hires enough new workers to make up for workers who leave due to retirement or other terminations. The plan initially is 75 percent funded, broadly consistent with the typical plan, and is amortizing its unfunded liability over a thirty-

year open period as a constant percentage of payroll. It smooths asset gains and losses over five years.<sup>6</sup>

We use this model to examine pension plan funding and contribution risks, as described below.

### How We Measure Funding Risk and Contribution Risk

We examine how changes in the investment environment and in investment practices affect plan funding risk and contribution risk using our stochastic simulation model. We are primarily concerned about two kinds of risks:

- Extremely low funded ratios, which create a risk to pension plans and their beneficiaries, and create political risks that could lead to benefit cuts; and
- Extremely high contributions, or large increases in contributions in short periods of time, which pose direct risks to governments and their stakeholders, and in turn could pose risks to pension plans and their beneficiaries.

There usually are trade-offs between these two kinds of risks. If a pension plan has a contribution policy designed to pay down unfunded liabilities very quickly, it is unlikely to have low funded ratios but it may have high contributions. If a pension plan has a contribution policy designed to keep contributions stable and low, there is greater risk that funded ratios may become very low because contributions may not increase rapidly in response to adverse experience.

We use several measures to evaluate these risks.

### Probability That the Funded Ratio Will Fall Below 40 Percent at Some Point in the First Thirty Years

When returns are stochastic (random), many outcomes are possible, including very extreme outcomes, so it does not make sense to focus on the worst outcomes or the best outcomes. We are particularly concerned about the risk of bad outcomes, and one useful measure is the probability that the funded ratio, using the market value of assets, will fall below 40 percent at some point in a given time period.

We choose 40 percent because it is a good indicator of a deeply troubled pension fund. In 2013, only four plans out of 150 in the Public Plans Database<sup>7</sup> had a funded ratio below 40 percent – the Chicago Municipal Employees and Chicago Police plans, the Illinois State Employees Retirement System, and the Kentucky Employees Retirement System. Each plan is widely recognized as being in deep trouble, with the likelihood of either substantial tax increases, service cuts, or benefit cuts yet to come.

In the scenarios that follow, plans start out with a 75 percent funded ratio. Falling to 40 percent funded would require an investment shortfall of well over 40 percent, which is not likely in a single year. But as the time period extends, there is a chance of an

extended period of low returns, leading to a low funded ratio. This measure evaluates the likelihood of this occurring.

### **Probability That Employer Contributions Will Rise Above 30 Percent of Payroll in the First Thirty Years**

Extremely high contributions can create great political and financial pressure on plan sponsors and may lead to benefit cuts, tax increases, and crowding out of expenditures on other public services. We use the probability that the employer contribution will rise above 30 percent of payroll as of a given year to evaluate how likely it is that the plan sponsor may face the pressure of high contributions.

In the analysis below, the normal cost rate in the first year is 11.5 percent and the employer contribution rate in the first year, including amortization of unfunded liability, is 13.4 percent. Thus, an employer contribution rate of 30 percent would be more than twice the initial contribution rate.

### **Probability That Employer Contributions Will Rise by More Than 10 Percent of Payroll in a Five-Year Period**

Making contributions stable and predictable is one of the most important goals of funding policies from the perspective of the employer. Sharp increases in employer contributions, even if not large enough to threaten affordability, can cause trouble in budget planning. We use the probability that the employer contribution will rise by more than 10 percentage points of payroll in a five-year period to measure this possibility. Highly smoothed policies will keep this risk low, but that tends to exacerbate the risk that the plan will become severely underfunded.

## **Analysis and Results for Different Investment Return Scenarios**

In the analysis that follows, we use the Rockefeller Institute's pension simulation model to examine three sets of investment-return scenarios:

- *The "pure" impact of volatility:* To isolate the role of investment return volatility, we examine scenarios in which the only thing that changes from scenario to scenario is the volatility of investment returns, while the expected investment return is held constant. (In the real world, higher risk is often accompanied by higher expected returns. We address that trade-off in other scenarios.)
- *Policy response to a decline over time in risk-free returns:* Here we consider the trade-off that pension funds faced over time as risk-free returns fell, when they faced a choice between investing in riskier assets to maintain an assumed rate of return, or maintaining the same level of portfolio risk by lowering assumed returns and raising contribution requirements. (In practice, they could have chosen between these extremes.) While it is clear in retrospect that

plans faced this choice, at the time, as risk-free rates were falling, it may not have been clear that the investing environment was changing fundamentally.

- *The true expected rate of return is less than the assumed return:* Our examination of publicly available recent capital market assumptions suggests that the assumed investment returns of public pension plans, which are mostly in the range of 7 percent to 8 percent, are difficult to achieve with their current portfolios even though the share of risky assets has been increased greatly.<sup>8</sup> In this scenario, we examine the implications for plan funded status and required employer contributions if the true expected compound return is lower than the assumed return by 1.5 percentage points, in a manner consistent with publicly available capital market assumptions.

In the following sections, we describe each set of scenarios in more detail and then present results of our analysis.

### The Pure Impact of Volatility

To analyze the pure impact of volatility, we examine three scenarios, each of which has an expected compound return of 7.5 percent, but with different degrees of volatility: an 8 percent standard deviation (least volatile), a 12 percent standard deviation (consistent with assumptions that several plans have used), and a 16 percent standard deviation (most volatile).<sup>9</sup>

Figure 3 shows the median funded ratio and the 25th percentile and 75th percentile under each scenario. Within a given scenario (any single panel) the range of funded ratios increases over time (the gap between the 75th percentile and the 25th percentile increases). As we move from left to right across the scenarios, the standard deviation increases and with it the range of likely funded ratios increases (the 75th-25th percentile gap is greater in the right panel than in the panels to the left). In other words, as investment risk increases funded ratios are likely to become more volatile.

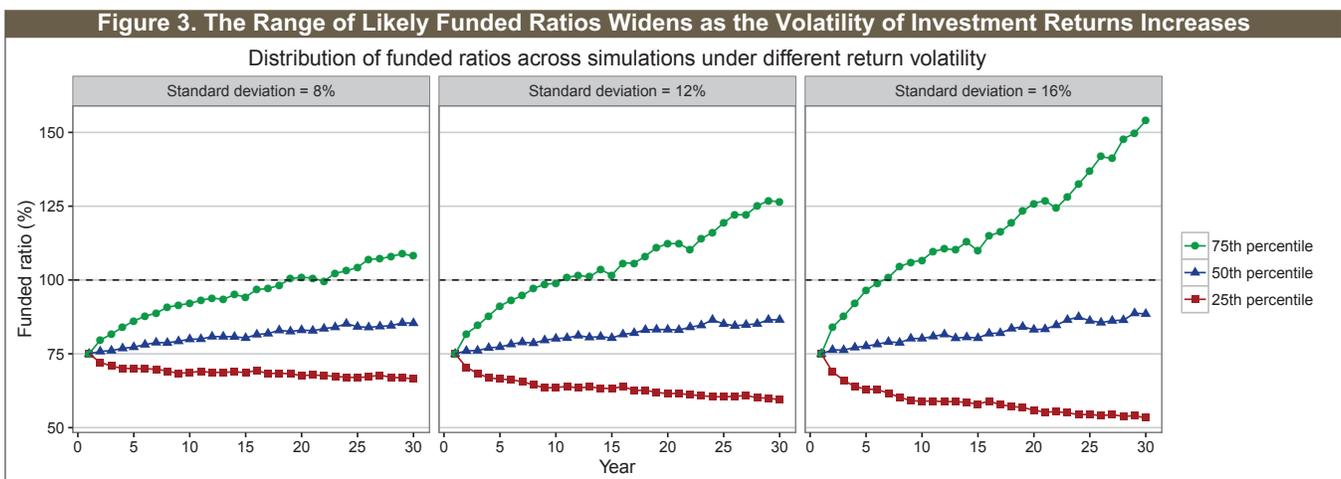


Figure 4 shows the probability that the pension plan will become severely underfunded under each of the scenarios. The impact of volatility is quite clear: The probability that the plan will become less than 40 percent funded sometime in the first thirty years is about 32 percent when the standard deviation is 16 percent, eight times as large as the probability when the standard deviation is only 8 percent.

**Figure 4. The Probability of Severe Underfunding Is Much Greater When Volatility Is High Than When It Is Low. If the Expected Return Is Held Constant**

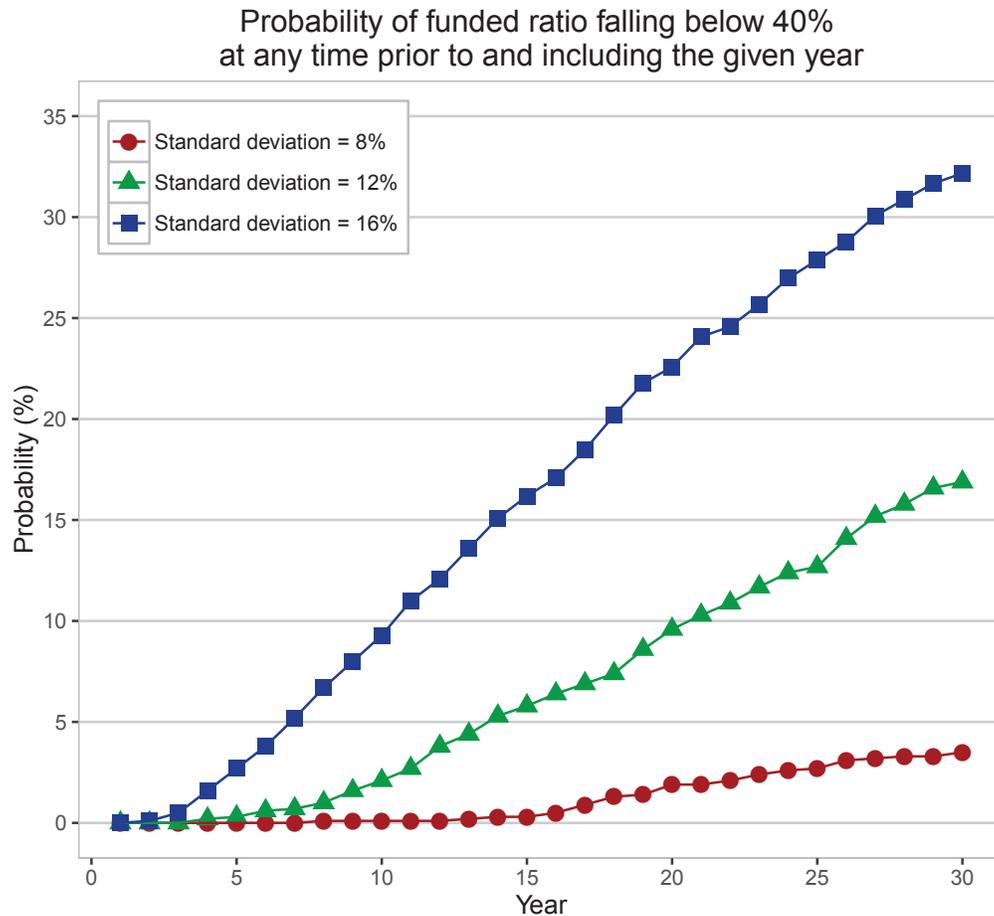
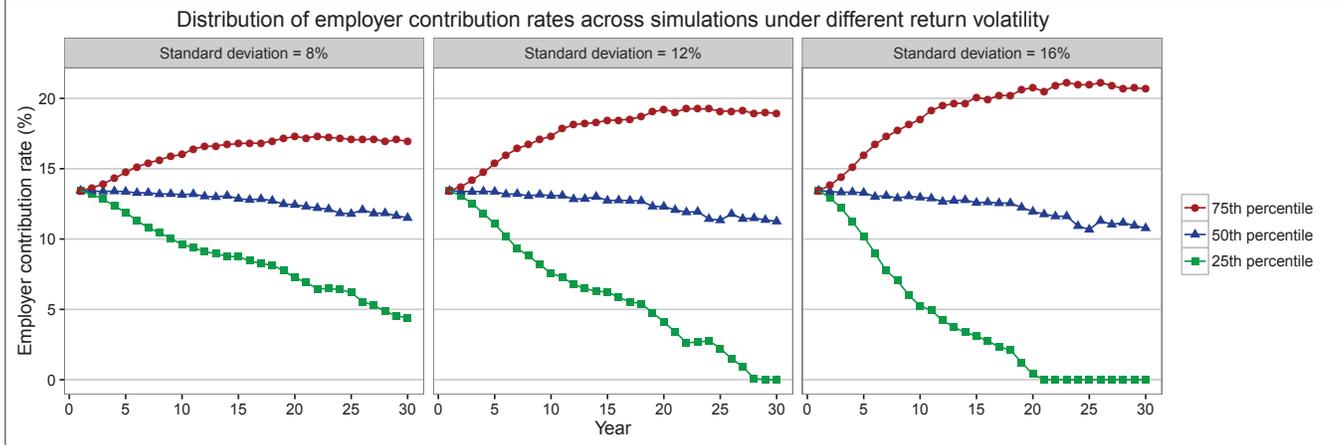


Figure 5 shows the median employer contribution rate and the 25th percentile and 75th percentile under each scenario. Within a given scenario (any single panel), the range of employer contribution rates increases over time (the gap between the 75th percentile and the 25th percentile increases). As we move from left to right across the scenarios, the standard deviation increases and with it the range of likely employer contribution rates increases (the 75th-25th percentile gap is greater in the right panel than in the panels to the left). In other words, as investment risk increases, employer contributions are likely to become more volatile.

**Figure 5. The Range of Likely Employer Contribution Rates Widens as the Volatility of Investment Returns Increases**

As the range of likely employer contribution rates widens, the chance that employer contribution rates will become extremely high also increases. We do not provide a separate figure showing the probability that the employer contribution will rise above 30 percent of payroll. But the probability is essentially zero by year thirty under the scenario with 8 percent standard deviation, while the probability rises to about 2.5 percent when the standard deviation is 12 percent, and to about 8 percent when the standard deviation is 16 percent.

Figure 6 shows the probability that the employer will face a contribution increase of 10 percent or more of payroll within a five-year period under each of the scenarios. Again, the impact of investment-return volatility is clear: The probability of a significant employer contribution increase sometime in the first 30 years is about 36 percent when the standard deviation is 16 percent, more than 10 times as large as the probability when the standard deviation is only eight percent.

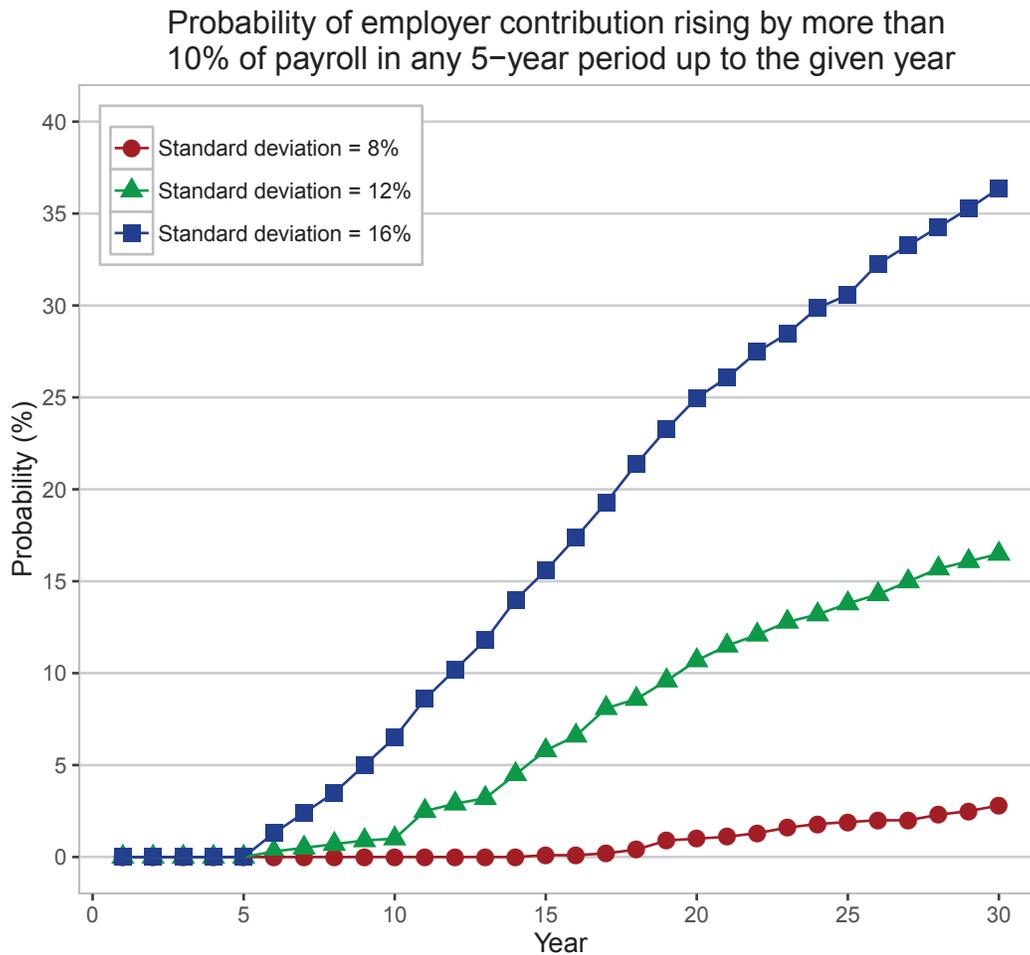
As the figures show, the impact of a “pure” change in volatility on funded ratio and employer contribution risks is substantial. These are not real-world trade-offs because they assume the expected compound return remains a constant 7.5 percent in all three scenarios: in the real world, plans generally can only reduce volatility by accepting a lower expected return. Still, the scenarios illustrate the important impacts that investment-return volatility has on plan and employer finances.

### Scenarios for Plan Responses to a Decline Over Time in Risk-Free Returns

#### Three Scenarios

Next we examine trade-offs that arise when investment-return volatility and expected returns both change, similar in concept to what happened over the last two decades. In this analysis, a substantial decline in risk-free returns presents the plan with the choice between investing in riskier assets to maintain the expected rate of return, or maintaining its asset allocation and overall risk

Figure 6. The Probability of a Substantial Increase in Employer Contributions Is Much Greater When Volatility Is High Than When It Is Low, If Expected Return Is Held Constant



profile, forcing it to accept a lower expected return and also raise requested employer contributions to make up for lower expected investment income.

We constructed three scenarios: the “good old days,” with a high risk-free rate of 6.7 percent; and two scenarios in which the risk-free rate has fallen by 4 percentage points to 2.7 percent. (This is about as much as ten-year Treasuries fell between 2000 and the present, and about as much as thirty-year Treasuries fell between the mid-1990s and the present.) We constructed these scenarios so that the relationship between the risk premium and volatility is the same across the scenarios:<sup>10</sup>

- *The “good old days”:* The risk-free rate of return is 6.7 percent and the plan takes on only a little bit of risk: It has an expected compound return of 7.5 percent with a standard deviation of 1.8 percent. It discounts liabilities at 7.5 percent, consistent with its expected earnings.
- *Invest in riskier assets, justifying high assumed return:* Faced with a risk-free rate that has fallen to 2.7 percent, the plan shifts into riskier assets allowing it to maintain the same

7.5 percent expected compound return, but with more volatility – the standard deviation increases from 1.8 percent to 12 percent. The plan continues to discount liabilities at 7.5 percent, consistent with its assumed earnings. This scenario is similar to how many plans behaved as risk-free rates fell.

- *Lower assumed return and maintain asset allocation:* In this alternative, the plan also is faced with a risk-free rate that has fallen to 2.7 percent, but instead of shifting into riskier assets, it maintains its asset allocation and lowers its assumed compound return to 3.5 percent, so that its standard deviation is 1.8 percent – the same as in the “good old days.” The plan discounts liabilities at 3.5 percent, consistent with the expected return of its portfolio, and therefore must request substantially higher contributions from employers. This scenario is a sort of counter-reality: What plans might have done if they had been willing to raise employer contributions dramatically.

Table 1 summarizes the key characteristics of the three scenarios.<sup>11</sup>

	Risk-free rate	Expected Compound Return	Return volatility (Standard deviation)	Assumed return (Discount rate)
The “good old days” (High risk-free rate)	6.7	7.5	1.8	7.5
Invest in riskier assets, justifying high expected return	2.7	8.2	<b>12.0</b>	7.5
Maintain allocation and lower expected return	2.7	<b>3.5</b>	1.8	<b>3.5</b>

Note:

1. All values are percentage (%).
2. These are simulated scenarios that are intended to reflect main features of investment practices in certain return environments, they are not directly based on historical data.
3. It is assumed that all portfolios have the same Sharpe ratio of 0.46, and the Sharpe ratio does not change across risk-free rate regimes.

### Results – Funded Ratios

The choice to invest in riskier assets entails much more risk to the funded ratio than either the “good old days” scenario or the “lower discount rate” scenarios. Figure 7 shows the median funded ratios and the 25th percentiles and 75th percentiles, calculated over 1,000 simulations of each of the three scenarios (3,000 simulations in all).<sup>12</sup> The range of likely funded ratios is much

greater under the “invest in riskier assets” scenario than under either the “good old days” scenario or the “lower assumed return” scenario. The median funded ratio rises much more rapidly in the “lower assumed return” scenario (rightmost panel). This occurs because the pension fund lowered its earnings assumption and requested much higher contributions from employers, as we will see in the next section. This allowed plan funding to rise quite rapidly relative to the other scenarios.

Figure 8 shows the probability of severe underfunding for each scenario. Under the “good old days” and the “lower assumed return” scenarios, there is essentially zero chance of severe underfunding. In both scenarios the standard deviation is only 1.8 percent, so there is very little investment return volatility – the plan almost always comes very close to achieving its assumed return and there is little risk. By contrast, in the “invest in riskier assets” scenario (green line), there is about a one in six (17 percent) chance that the plan will be severely underfunded within thirty years. By taking on risk, the plan kept employer contributions low, at the expense of funding risk.

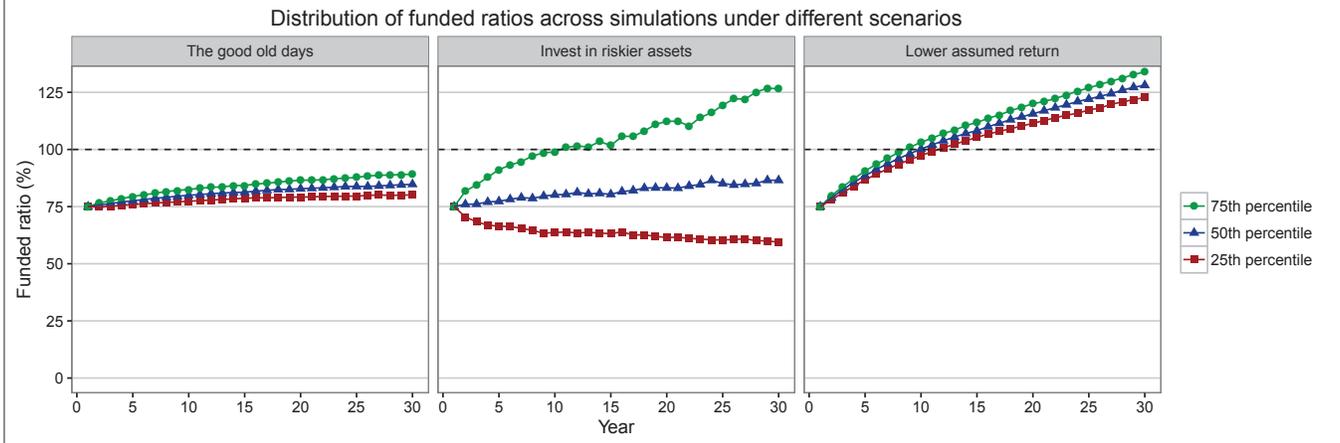
### Results – Contributions

Figure 9 shows the median employer contribution rates and the 25th percentiles and 75th percentiles under each scenario. Under the “invest in riskier assets” scenario the contributions are much lower than if the plan were to lower the discount rate and increase requested contributions, but they are subject to much greater volatility due to the more-volatile investment portfolio. The median employer contribution under the “lower assumed return” scenario is about triple what the contribution was before risk-free rates dropped (“good old days”) and about triple the contribution that was required when the plan invested in riskier assets. This dramatic increase in contributions that would be required by lowered investment return assumptions may help to explain why plans moved into riskier assets.

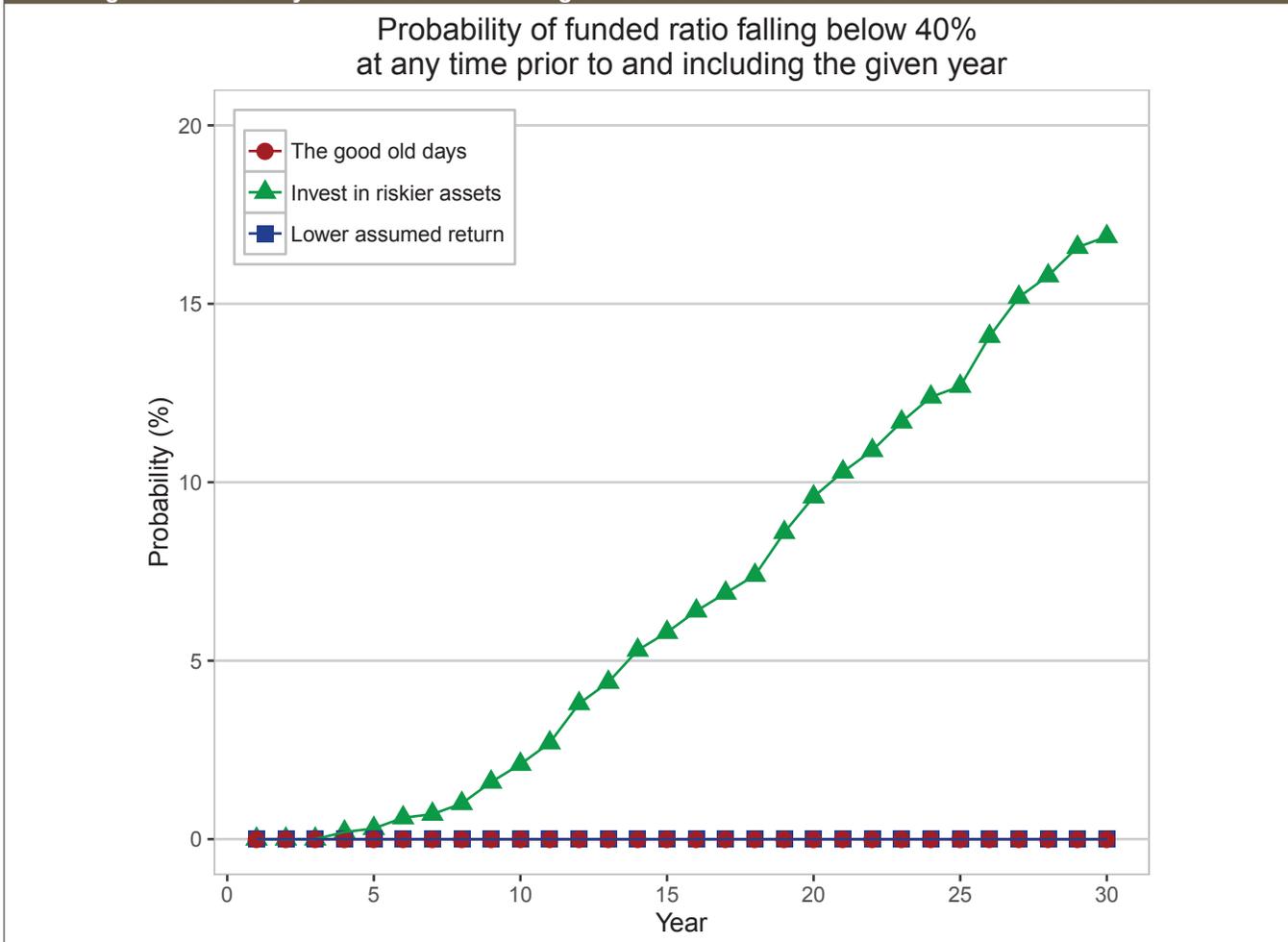
For these scenarios, we do not present our measure of the probability that employer contributions will rise above 30 percent of payroll because in this case it does not provide meaningful information.<sup>13</sup>

Figure 10 shows the probability that employer contributions will rise by more than 10 percent of payroll in any five-year period under the three scenarios. The “invest in riskier assets” scenario, with its much greater chance of large investment-return shortfalls, carries a much greater risk that contributions will have to rise substantially in a relatively short period of time than do either of the other scenarios. However, that increase generally will be from a lower level of contributions than would be required under the “lower assumed return” scenario.

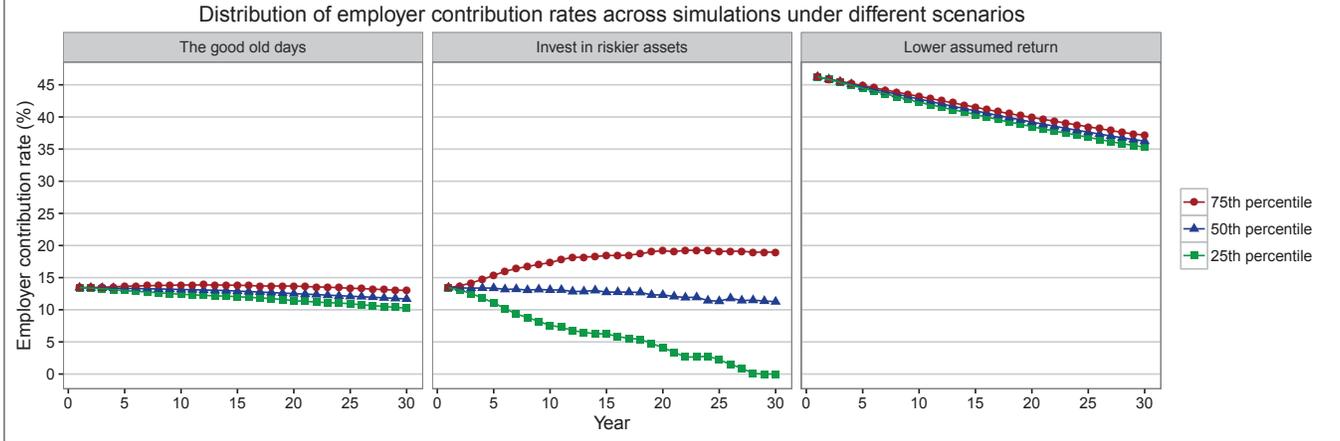
**Figure 7. The Choice to Invest in Riskier Assets Entails Much More Risk to the Funded Ratio Than Either the “Good Old Days” Scenario or the “Lower Discount Rate” Scenario**



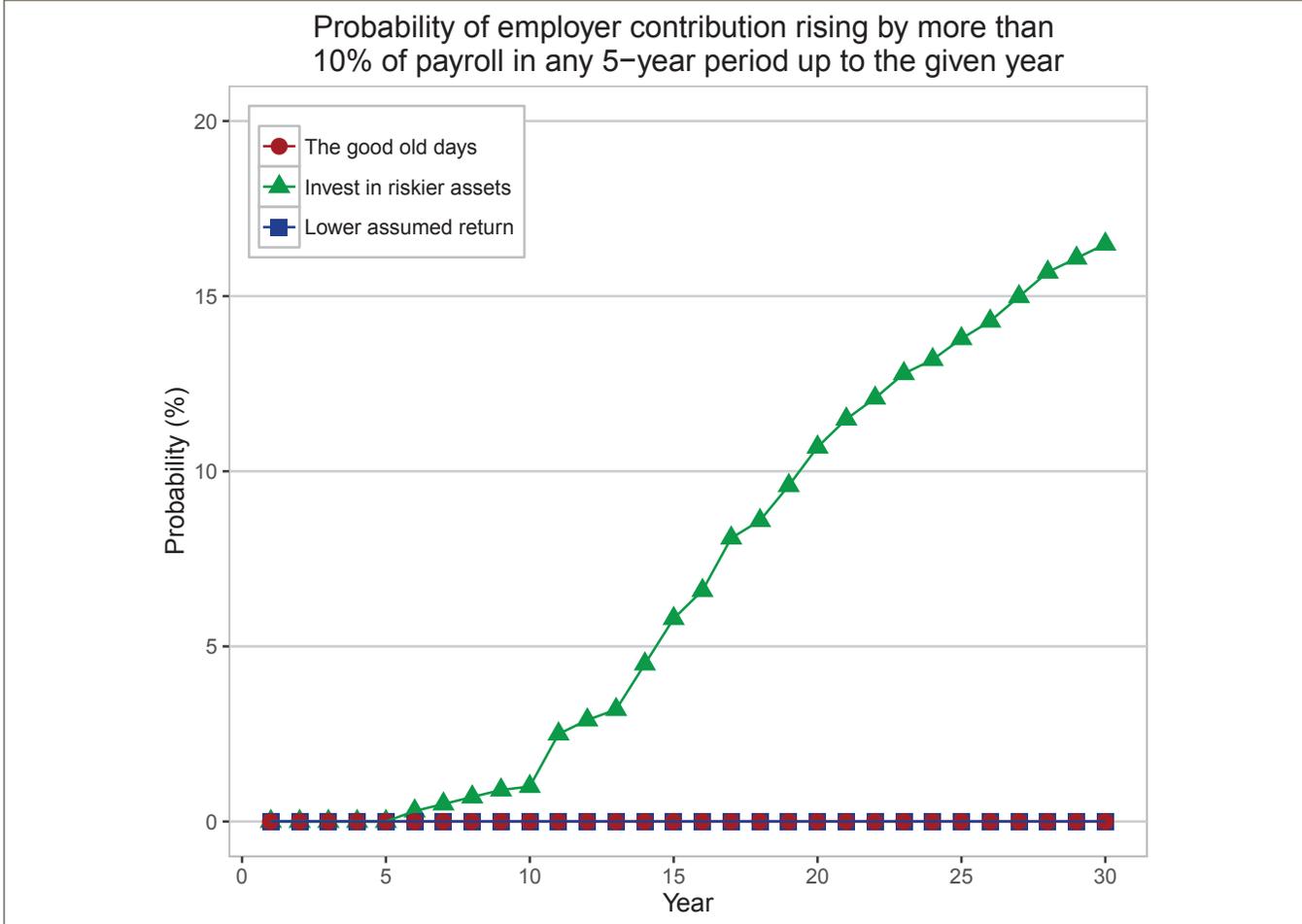
**Figure 8. Probability of Severe Underfunding Is Much Greater in the “Invest in Riskier Assets” Scenario**



**Figure 9. The Employer Contribution Rate Is Much Lower Under the “Invest in Riskier Assets” Scenario, But Is Much More Variable**



**Figure 10. The Probability of Employer Contributions Rising by More Than 10 Percent of Payroll in a Five-Year Period Is Greatest In the “Invest in Riskier Assets” Scenario**



### Summary of Impacts of Responses to a Sustained Decline in Risk-Free Interest Rates

Our analysis shows that plans faced a fundamental trade-off in response to a sustained decline in risk-free interest rates, as summarized in Table 2: If they invested in riskier assets, the risk to the pension fund would increase significantly but government contributions would remain low. The riskier-assets scenario resulted in a 16.9 percent probability for our prototypical plan that plan funding would fall below 40 percent sometime during the thirty years — a level that has been associated with crises in several states. If instead the plan lowered assumed investment returns, the risk to the pension fund would remain minimal, but employer contributions would have to triple, and would remain high for all thirty years of the simulation period.<sup>14</sup> This dramatic increase in required contributions may go a long way toward explaining why plans have taken on increased investment risk.

**Table 2. Plans Faced a Trade-Off When Risk-Free Rates Fell: Increase Risk to the Pension Fund, or Lower Return Assumptions and Increase Government Contributions**

	Plan funding and employer contributions under three investment-return scenarios					
	Funded-ratio measures			Employer contribution measures		
	Probability (percent) of falling below 40% at any time within 30 years	Median funded ratio:		Probability of rising by more than 10% of payroll in any 5-year period (within first 30 years)	Median % of payroll:	
Year 1		Year 30	Year 1		Year 30	
Good old days (7.5% expected return, low volatility)	0	75.0	84.8	0	13.4	11.7
Invest in riskier assets (7.5% expected return, high volatility)	16.9	75.0	86.6	16.5	13.4	11.3
Lower assumed return (3.5% expected return, low volatility)	0	75.0	128.1	0	46.2	36.2

### Scenario in Which the True Expected Rate of Return Is Less Than the Assumed Return

While public pension funds generally have increased investments in risky assets and maintained assumed rates of return as risk-free rates declined, some current market forecasts suggest that it remains very difficult for public pension funds to achieve their assumed returns in the current market environment. To examine the consequences of using earnings assumptions that may be higher than true expected returns (which are unknowable), we constructed a scenario based on our analysis of publicly available capital market assumptions. In this scenario, the standard deviation of returns is 12 percent, the same as in the “invest in riskier assets” scenario, but the expected long-term compound return consistent with this volatility level is only 6 percent, 1.5 percentage points below the assumed investment return.

Figure 11 compares the median funded ratios, and the 25th percentiles and 75th percentiles under a base-case scenario where the true expected compound return equals the 7.5 percent

earnings assumption (left panel), and our lower-return scenario in which true expected compound return is only 6 percent but the pension plan assumes it is 7.5 percent (right panel). In this scenario (the right panel), investment returns tend to fall short on average, and the median funded ratio declines over time, falling to about 60 percent by year thirty. By contrast, when the earnings assumption is met (left panel), the median funded ratio rises gradually and reaches almost 90 percent after thirty years.

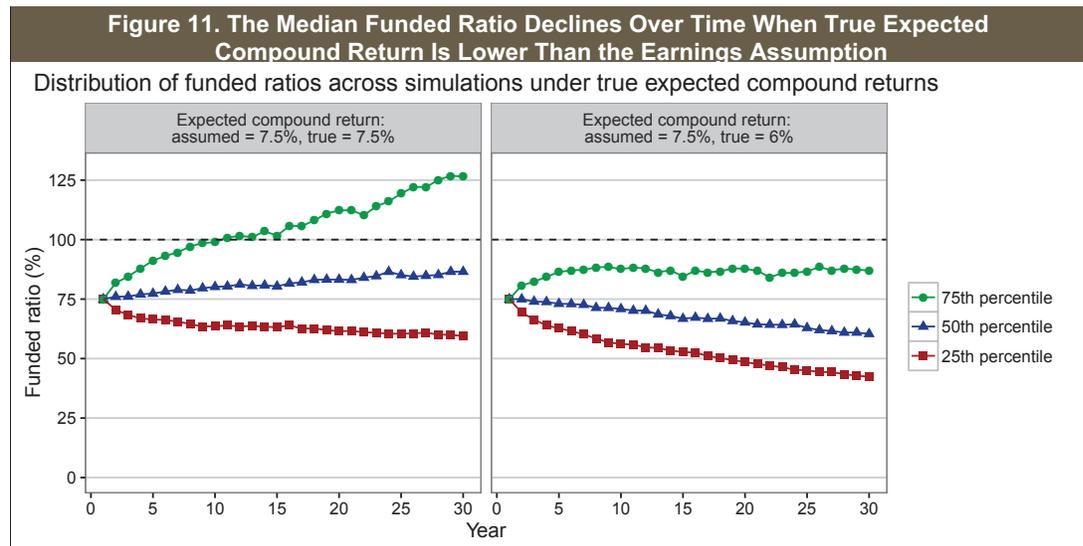
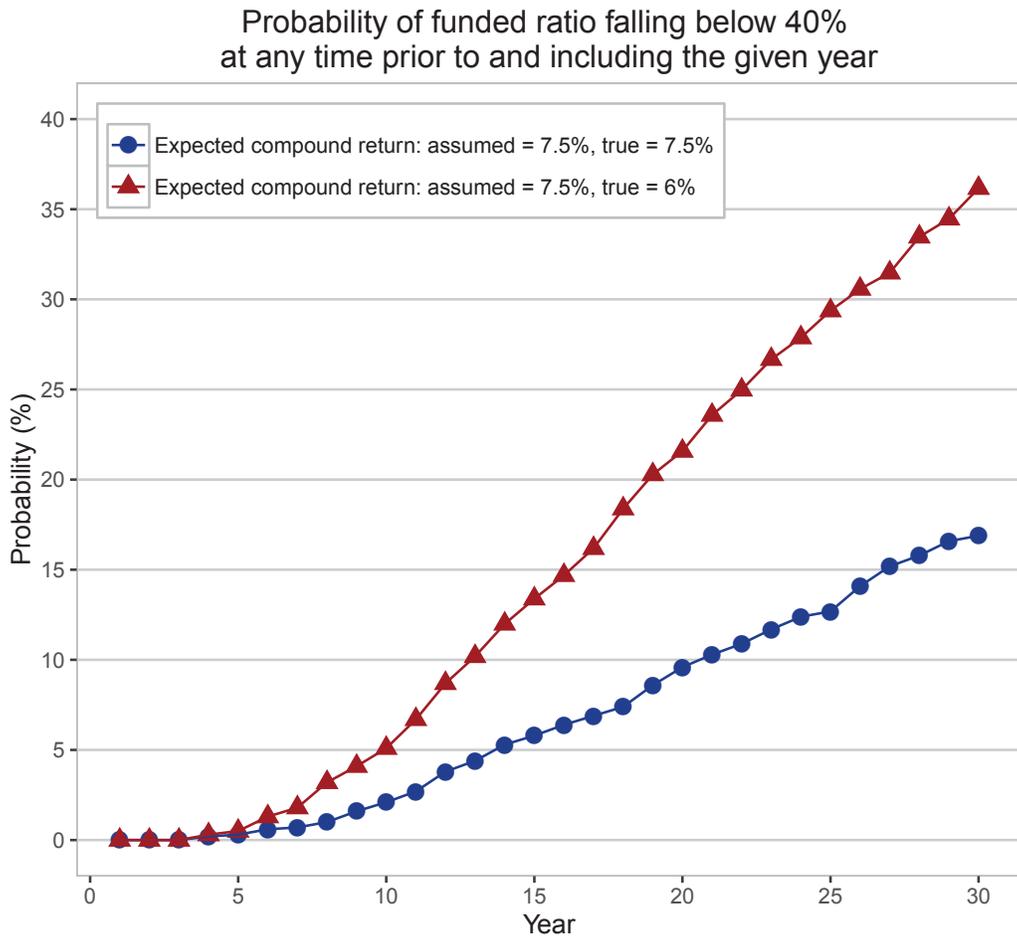


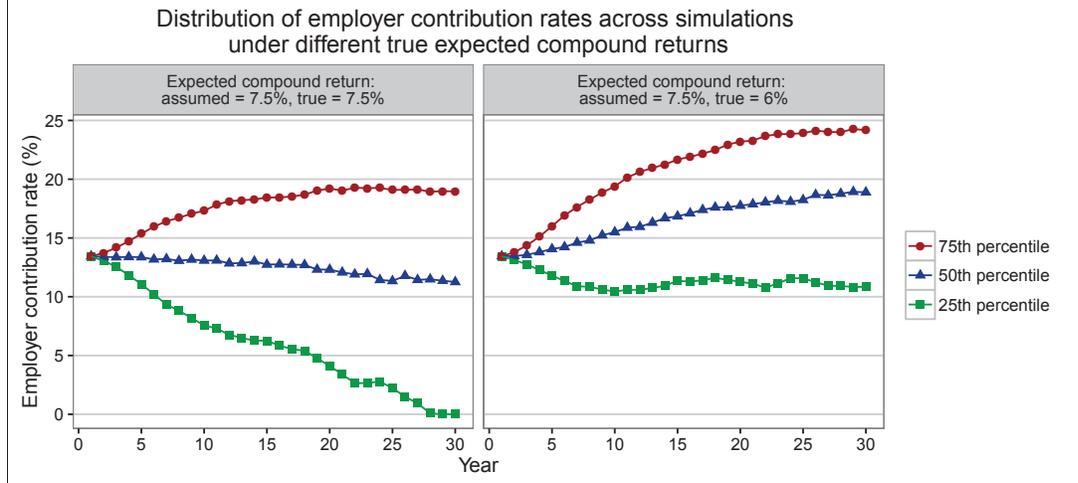
Figure 12 shows that when the earnings assumption is higher than the true return, it greatly increases the risk of the funded ratio falling into crisis territory. The blue line and red line show the probability of the funded ratio falling below 40 percent under the two scenarios. When the true expected compound return falls short of the assumption by 1.5 percent, there is a more than one in three chance that the funded ratio will fall into what we consider crisis territory at some point in the thirty-year period. This risk is more than twice as high as it is if the earnings assumption equals the true expected return.

When the true expected compound return is lower than the earnings assumption, actual investment returns are likely to fall short of the assumed return in any given year. When that occurs, employer contributions will have to rise to make up the shortfall. Figure 13 shows the median, 25th percentile, and 75th percentile employer contribution as a percentage of payroll when the true expected compound return and assumed return are both 7.5 percent (left panel) and when the true expected return is 6 percent but is assumed to be 7.5 percent (right panel). The median employer contribution in the first year is about 14 percent in both scenarios. In the overly optimistic assumption scenario (right panel) it rises continually, reaching about 19 percent by year thirty – approximately 9 percentage points higher than when the 7.5 percent earnings assumption is met.

**Figure 12. The Probability of Extremely Low Funding More Than Doubles When the True Expected Compound Return Falls Short of the Earnings Assumption**



**Figure 13. The Median Employer Contribution Rises Over Time When the True Expected Compound Return Falls Short of the Earnings Assumption**

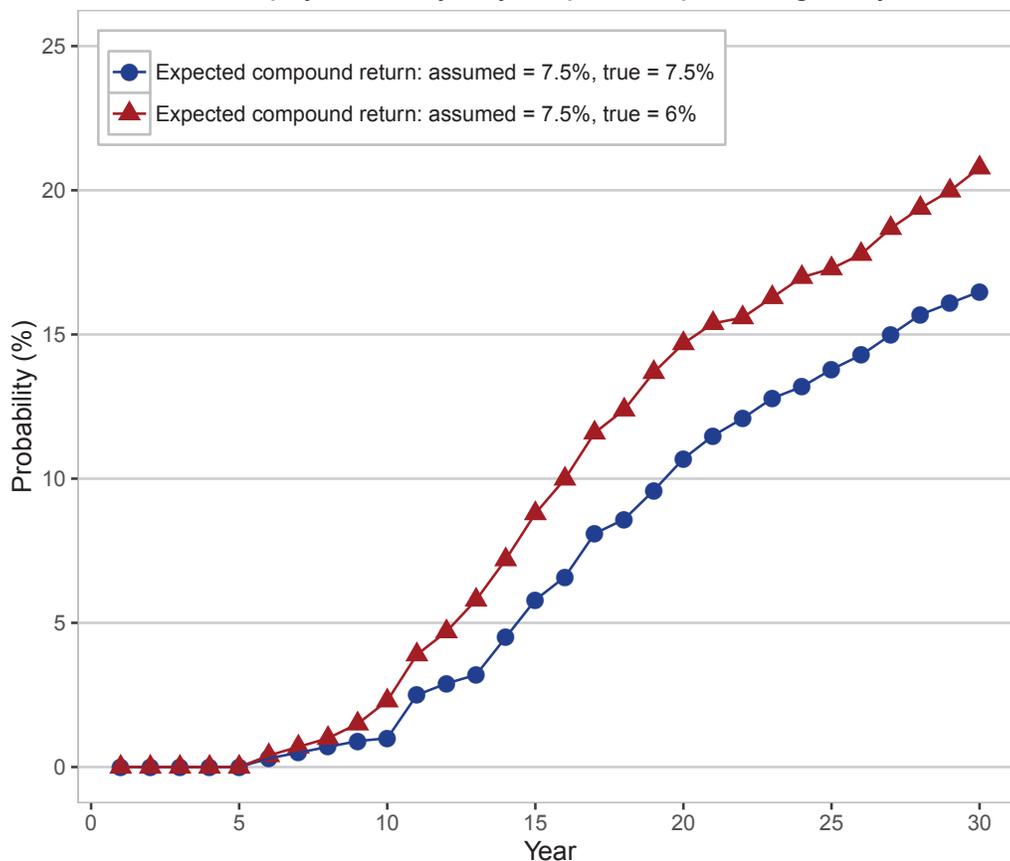


We do not present a separate figure showing the probability that the employer contribution will rise above 30 percent of payroll at some point during thirty years. However, this probability is about 7.5 percent when the assumed return is too optimistic, compared to only 2.5 percent when the expected compound return and assumed return are both 7.5 percent.

Finally, although the two scenarios have the same investment-return volatility, the overly optimistic scenario has a greater risk that employer contributions will rise by more than 10 percent of payroll in a five-year period, as Figure 14 shows.

**Figure 14. Sharp Employer Contribution Increases Are Likely If Assumed Returns Are Higher Than “True” Expected Returns**

Probability of employer contribution rising by more than 10% of payroll in any 5-year period up to the given year



### Conclusions

The decline in risk-free interest rates since the 1980s and 1990s has created a very difficult investing environment for public pension plans. Before the decline, the typical plan could have achieved its investment-return assumptions while taking very little risk. As rates declined, public plans faced a choice: Either reduce investment-return assumptions and request much higher contributions from governments, or maintain assumptions, avoid

increasing contributions from governments, and take on much greater risk.

For the most part, public pension funds have maintained their investment-return assumptions, perhaps in the belief that interest rate declines were temporary and that in the longer run high investment returns could again be obtained at low levels of risk. But maintaining their assumptions implicitly required them to invest in riskier assets.

We modeled the implications of a sustained reduction in risk-free interest rates by examining a prototypical pension plan under three scenarios:

- *The good old days*: The pension plan can expect to earn a 7.5 percent return with very little investment-return volatility, or risk. This is similar to what plans might have been able to achieve two or three decades ago. As the name implies, pension plans no longer have this beneficial choice available.
- *Invest in riskier assets*: In response to declining risk-free rates, the pension plan maintains a 7.5 percent earnings assumption, but invests in riskier assets. Even though it can expect a long-run compound return of 7.5 percent, some years will be much higher and some will be much lower. Our measure of investment-return volatility, the standard deviation, is 12 percent in this scenario. This is similar to what many public pension plans did as risk-free rates fell.
- *Lower assumed return*: In this scenario, instead of investing in riskier assets in response to declining risk-free rates, the pension plan lowers its earnings assumption to 3.5 percent and remains invested in relatively low-risk assets, with a standard deviation of 1.8 percent. This forces the plan to raise contributions from governments. For the most part, public pension plans have not done this (although they have raised contributions in response to investment shortfalls). Lowering risk and raising contributions remains an option.

Pension plans were not limited to one response or the other — they could have chosen to be in-between.

We modeled the finances of our prototypical pension fund over thirty years, assuming that employers pay full actuarially determined contributions. Our analysis shows that plans faced a fundamental trade-off: If they invested in riskier assets, the risk to the pension fund would increase significantly but government contributions would remain low. The riskier-assets scenario resulted in a 16.9 percent probability for our prototypical plan that plan funding would fall below 40 percent sometime during the thirty years — a level that has been associated with crises in several states. If, instead, the plan lowered assumed investment returns, the risk to the pension fund would remain minimal, but employer contributions would have to triple, and would stay high

for all thirty years of the simulation period. This dramatic increase in required contributions may go a long way toward explaining why plans have taken on increased investment risk.

We also examined what would happen if plan earnings assumptions, which are in the range of 7 to 8 percent for most plans, are too optimistic, as some professional market forecasts suggest. We simulated a scenario in which the true expected compound return is 1.5 percentage points lower than the assumed return of 7.5 percent. In that scenario, the plan has more than a one in three chance of experiencing severe underfunding at some point over the next thirty years, which is more than twice as high as when the investment earnings assumption is met. Employer contributions as a percentage of payroll would be expected to rise substantially over time, whereas if the return assumption is met they would fall over time; by the end of thirty years, the median employer contributions in this scenario are almost 50 percent higher than when investment return assumptions are met.

Reducing risk remains an option for plans today, but only at the expense of raising employer contributions. As unpalatable as this may be, given the risk of severe underfunding at today's current level of risk taking, moving in this direction may be advisable.

## ACKNOWLEDGMENTS

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## Appendix: The Stochastic Simulation Model

To examine the interplay between stochastic investment returns and plan demographic characteristics, we use a stochastic simulation model of public pension plans. The model allows us to examine the year-by-year dynamics of pension fund finances for plans with real-world characteristics, under different investment return scenarios and different funding policies. Starting from an initial position (e.g., 75 percent funded), it projects the future annual assets and cash flows, including benefit payments, employer and employee contributions, and investment income, based upon given model inputs.

The most important model inputs include:

- Retirement benefit rules, including the benefit multiplier per year of service; vesting rules; allowable retirement ages; and annual benefit percentage increase, if any (we do not call this a COLA, or cost-of-living-adjustment, because it does not depend on economic conditions).
- Plan demographics in the initial year including number of workers by age and entry age and their average salaries, number of retirees by age and their average benefit, and projected annual growth in the workforce.
- Decrement tables with mortality rates, retirement rates, and separation rates.
- Salary schedules that define how worker salaries change over time and with experience.
- Inflation and aggregate payroll growth assumptions.
- Actuarial rules and methods for determining actuarial liability, normal cost, and an actuarially determined contribution. These include the actuarial cost method (e.g., entry age normal); discount rate (which can be different from assumed and actual investment returns); asset-smoothing rules if any; and amortization rules (open or closed, level percent or level dollar, and length of amortization period).
- Information to determine employee and employer contributions. For employee contributions, this is a fixed percentage of payroll. For employer contributions, this defines whether the employer pays the actuarially determined contribution, or pays according to some other rule such as a fixed percentage of payroll.
- Rules or data specifying investment returns: Investment returns can be deterministic or stochastic.
  - A deterministic run might have a single investment return applicable to all years (e.g., 7.5 percent per year) or it might have a set of deterministic returns, one per year (e.g., 10 percent for each of the first twenty years, followed by 5 percent for each of the next twenty years). When investment returns are deterministic, we

only run a single simulation since results will not vary from run to run.

- A stochastic run generally will draw investment returns randomly each year from a probability distribution — for example, from a normal distribution with an 8.22 percent mean return and a 12 percent standard deviation.<sup>14</sup> (More complex investment return scenarios are possible, too.) When we run the model with stochastic investment returns, typically we conduct 1,000 simulations for a given set of inputs, so that we can examine the distribution of results.

The model can be used to examine prototypical pension funds, or can be used with data for actual pension funds.

We assume that investment returns follow the normal distribution, with a mean long-run compound return of 7.5 percent and a standard deviation of 12 percent. The mean is consistent with what the typical plan assumes today. The standard deviation is broadly consistent with our review of simulations and investment return analyses performed elsewhere: CalPERS used a 12.96 percent standard deviation,<sup>15</sup> Biggs assumed a 14 percent standard deviation,<sup>16</sup> and Bonafede et al. estimated a 12.5 percent standard deviation.<sup>17</sup> A normal distribution with a standard deviation of 12 percent means that in a typical year, the pension fund has a one in six chance of falling at least 12 percentage points short of its investment return assumption and a one in six chance of exceeding its investment return assumption by at least 12 percentage points — the chance of rolling any single number with a fair six-sided die. With approximately \$3.7 trillion of public pension defined benefit plan assets under investment, a 12 percent single-year investment return shortfall is equivalent to more than \$425 billion for the United States as a whole.

Investment returns are assumed to be independent of each other from year to year — bad investment years are not necessarily followed by good investment years, and vice versa. Because investment returns are random in the model, we might obtain virtually any sequence of returns in a single run of the model (which we call an individual simulation), but if we run enough simulations, on average the results will reflect our assumed distribution of returns (i.e., a mean compound annual return of 7.5 percent and a standard deviation of 12 percent). We run the model 1,000 times to gain insight into the likely distribution of outcomes.

## Endnotes

- 1 Donald J. Boyd and Yimeng Yin, *Public Pension Funding Practices: How These Practices Can Lead to Significant Underfunding or Significant Contribution Increases When Plans Invest in Risky Assets* (Albany: Nelson A. Rockefeller Institute of Government, June 2016), [http://www.rockinst.org/pdf/government\\_finance/2016-06-02-Pension\\_Funding\\_Practices.pdf](http://www.rockinst.org/pdf/government_finance/2016-06-02-Pension_Funding_Practices.pdf).
- 2 The source is the Financial Accounts of the United States from the Federal Reserve Board, March 10, 2016 release. We define equity-like investments to include corporate equities, directly owned real property, and an allocated share of mutual funds and certain other assets (Financial Accounts code FL223093043); we allocated the latter using the share that corporate equities are of mutual fund assets for the economy as a whole. We do not include cash and short-term assets such as time deposits, money market funds, checkable deposits, or repurchase agreements, and we do not include debt securities or mortgage loans. Calculations by other analysts sometimes result in higher equity shares than we report here, and can vary depending on the definitions used and on data sources and methods.
- 3 In the figure, the Treasury yield is the ten-year constant maturity yield, averaged over the typical public pension plan fiscal year (ending in June) from the daily rate available as variable DGS10 from the Federal Reserve Economic Data (FRED) website of the Federal Reserve Bank of St. Louis (<https://research.stlouisfed.org/fred2/>). The assumed investment returns are from several sources: (1) 2001-14 values are the unweighted mean of assumed returns, computed by the authors from Public Plans Data website, 2001-14, Center for Retirement Research at Boston College, Center for State and Local Government Excellence, and National Association of State Retirement Administrators, (<http://publicplansdata.org/>); and (2) 1990-92, 1994, 1996, 1998, and 2000 are from Paul Zorn, "Surveys of State and Local Government Employee Retirement Systems," *Government Finance Review* 9 (August 1993), <https://www.questia.com/magazine/1G1-14379961/surveys-of-state-and-local-government-employee-retirement>.
- 4 For example, see Aleksandar Andonov, Rob Bauer, and Martijn Cremers, "Pension Fund Asset Allocation and Liability Discount Rates: Camouflage and Reckless Risk Taking by U.S. Public Plans?," Unpublished Paper, May 2012, <https://fisher.osu.edu/supplements/10/12706/Andonov%20Bauer%20and%20Cremers%20-%20Pension%20Fund%20Asset%20Allocation%20and%20Liability%20Discount%20Rates%20-%202012%2024%2005.pdf>. The longer term move toward riskier assets also reflected responses to laws allowing "prudent person" approaches to investing and laws explicitly allowing investments in a broader range of assets.
- 5 When we use the term "expected long-term compound return," we mean it in a statistical sense, where investment return is a "random variable" — we do not know what the return will be in any given year or even over a long period of time, but we know what it is likely to be. We are not referring to what a pension plan actuary expects or assumes. In fact, the statistical or true "expected return" could be different from what the actuary expects, and we model such a scenario later in this report. It is important to understand that the "expectation" is taken across simulations, meaning in any single simulation the realized compound return can be higher or lower than the "expected long-term compound return," but the mean compound return of a large number of simulations will be close to the "expected long-term compound return." That is one of the reasons we typically run at least 1,000 simulations of any particular analysis.
- 6 For plans in the Public Plans Database in 2013, 30 percent of the plans, with 46 percent of unfunded liabilities, used level percent open amortization. About two-thirds of the unfunded liability of public pension funds is being repaid using methods that stretch repayments out for thirty years or more.
- 7 The Public Plans Data (PPD) website is maintained through a partnership between The Center for Retirement Research at Boston College (CRR) and the Center for State and Local Government Excellence (SLGE). The National Association of State Retirement Administrators (NASRA), supports the partnership by providing review and assistance on the development of data models, validation of data, and development and administration of surveys, <http://publicplansdata.org/>.
- 8 See assumptions in: *Asset/Liability Study: Los Angeles Fire and Police Pension System* (Portland: RVK, Inc., October 2015) and *Michigan State Employee's Retirement System: Asset/Liability Study* (Portland: RVK, Inc., September 2012). Also see assumptions of Callan Associates reported in Timothy W. Martin, "Pension Funds Pile on Risk Just to Get a Reasonable Return," *Wall Street Journal*, May 31, 2016, Markets section, <http://www.wsj.com/articles/pension-funds-pile-on-the-risk-just-to-get-a-reasonable-return-1464713013>.

Callan Associates has noted that it sympathizes with public pension funds given the challenges that professionals face in achieving assumed returns in the current interest rate environment.

- 9 The 16 percent scenario is quite consistent with assumptions of Callan Associates reported in Martin, "Pension Funds Pile on Risk Just to Get a Reasonable Return."
- 10 The portfolio mean return and standard deviation at 6.7 percent risk-free rate are derived in such a way that each portfolio has a Sharpe ratio of 0.46. This is broadly consistent with what a typical plan today appears to assume: It is consistent with an arithmetic mean return of 8.22 percent and standard deviation of 12 percent (generating a long-run compound return of about 7.5 percent), and a risk free rate of 2.7 percent. The Sharpe ratio of 0.46 is higher than what is used or implied in many recent studies, reflecting the optimistic views of public pension plans about the return they can achieve with their current portfolio. For example, Novy-Marx and Rauh use a Sharpe ratio of 0.4 for the stock market in "The Liabilities and Risks of State-Sponsored Pension Plans," *The Journal of Economic Perspectives* 23 (2009): 191-210, <http://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.23.4.191>. We will examine in the next section a scenario in which the expected long-run compound return is only 6 percent and the implied Sharpe ratio is 0.335, which is consistent with current capital market assumptions discussed earlier and lower than what is implied by public pension fund assumptions.
- 11 When investment returns are variable, the long-run compound return (which we show in the table) will be lower than the expected annual arithmetic return. In the model, we draw expected arithmetic returns. We determine the appropriate expected arithmetic mean by a widely used approximation formula under which the long-run compound return equals the annual expected return minus one half of the annual variance.
- 12 To ensure comparability for purposes of the figure, liabilities and the funded ratio in each scenario are discounted using a 7.5 percent discount rate for each graph line.
- 13 Under the "lower assumed return" scenario, the employer contribution rates need to be approximately 46 percent of payroll in the first year, and therefore the probability that the employer contribution rate will rise above 30 percent of payroll at some point during the thirty-year period is 100 percent. Under the scenario "invest in riskier assets," in which the contributions are generally much lower, the probability is only 2.5 percent even though investment returns are much more volatile. The pension fund under the "good old days" scenario has no exposure to this type of risk at all.
- 14 The plan would be likely to become overfunded under this scenario.
- 15 An arithmetic mean of 8.22 percent and standard deviation of 12 percent generate a long-run compound return of about 7.5 percent.
- 16 Alan Milligan, "Annual Review of Funding Levels and Risks, 2012," *Report for Finance and Administration Committee, March 18, 2013* (Sacramento: California Public Employees' Retirement System, March 2013).
- 17 Andrew G. Biggs, "The Public Pension Quadrilemma: The Intersection of Investment Risk and Contribution Risk," *The Journal of Retirement* 2 (2014): 115-27.
- 18 Julia K. Bonafede, Steven J. Foresti, and Russell J. Walker, *2015 Report on State Retirement Systems: Funding Levels and Asset Allocation* (Santa Monica: Wilshire Consulting, February 25, 2015), [https://www.wilshire.com/media/38890/wilshire\\_2015\\_state\\_funding\\_report.pdf](https://www.wilshire.com/media/38890/wilshire_2015_state_funding_report.pdf).

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