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PENSION SIMULATION PROJECT

HOW PUBLIC PENSION PLAN DEMOGRAPHIC CHARACTERISTICS AFFECT FUNDING AND CONTRIBUTION RISK

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Executive Summary

How do demographic characteristics of public pension plans affect the risks that pension funds and their sponsoring governments face? As pension funds mature, relatively more workers retire, leading to more beneficiaries relative to the number of active workers, greater payments of retirement benefits, and increasing assets relative to payroll of active workers. Approximately two-thirds of public pension funds' $3.7 trillion of assets are in investments other than cash and fixed income, and have volatile investment returns. Investment gains and losses become larger relative to payroll and government contributions, which generally are calculated as a percentage of payroll, can become more variable and plan funded ratios can become more volatile.

We examined the year-by-year finances of prototypical public pension funds with a model that allows investment returns to vary in plausible ways, rather than meeting actuaries' assumptions every year. We describe our key conclusions below.

Growing Plans With Increasing Numbers of Workers Are Less Susceptible to Investment Risk Than Are Shrinking Plans

A prototypical pension plan with average characteristics that starts out 75 percent funded, with a workforce that grows 2 percent annually, would have a one in eight chance (13 percent) of falling below a 40 percent funded ratio in a thity-year period — a funded ratio that has been associated with fiscal crises in several pension systems. As the growth in the workforce slows or declines, the risk rises to more than one in five (21.4 percent) for a plan with a 2 percent annual decline in the number of workers.

The plan with a shrinking workforce would have a 27.5 percent chance that actuarially determined contributions will exceed 30 percent of payroll sometime during thirty years, and a 42.4 percent chance that the employer contribution will increase by more than 10 percent of payroll sometime during thirty years, while the plan with a growing workforce has little exposure to these risks.

Very Mature Plans With High Assets Relative to Payroll and High Cash Outflows Face Greater Funding Risk, All Else Equal

A prototypical mature plan with the same characteristics as the growing plan described above has a nearly one in three (31 percent) chance of falling below 40 percent funding in a thirty-year period. There would be a fifty-fifty chance of actuarially determined employer contributions exceeding 30 percent of payroll sometime in those thirty years, even though the plan's initial employer contribution is only about 20 percent, and a nearly 60 percent chance that the employer contribution will increase by more than 10 percent of payroll sometime during thirty years. By contrast, a prototypical "immature" plan (with relatively fewer retirees), with a low asset-payroll ratio and low cash outflows before investment returns, has substantially lower exposure to these risks.

Public pension plans are much more mature now than they were ten or twenty years ago, with lower numbers of active workers per beneficiaries, higher net cash outflows, and higher asset-payroll ratios. Many will mature further as the population continues to age, and as government workforces age. This maturation will lead to higher risks of pension plan underfunding, all else equal, unless pension funds invest in less volatile assets.

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How Public Pension Plan Demographic Characteristics Affect 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 has been worse than expected, or reducing requirements if experience has been better than expected.

The biggest uncertainty is how well the pension fund's investments will do. Funds used to be able to earn 7 to 8 percent a year without taking much risk, back when U.S. Treasuries paid that much. Now, funds can only earn about 1 to 3 percent without taking much risk. However, because they still assume they'll earn about 7.5 percent, they must invest in riskier assets. 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 risk 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.

These issues are important because if contributions rise sharply, governments may have to raise taxes significantly, or cut services sharply. If governments are unwilling to pay requested contributions, they may seek to cut benefits for new workers, existing workers, or even for beneficiaries.

In a previous report we examined how plan funding policies and practices affect the risks of underfunding and of sharp contribution increases.[1] 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 plan demographic characteristics.

Pension Plan Demographics and Pension Fund Risks

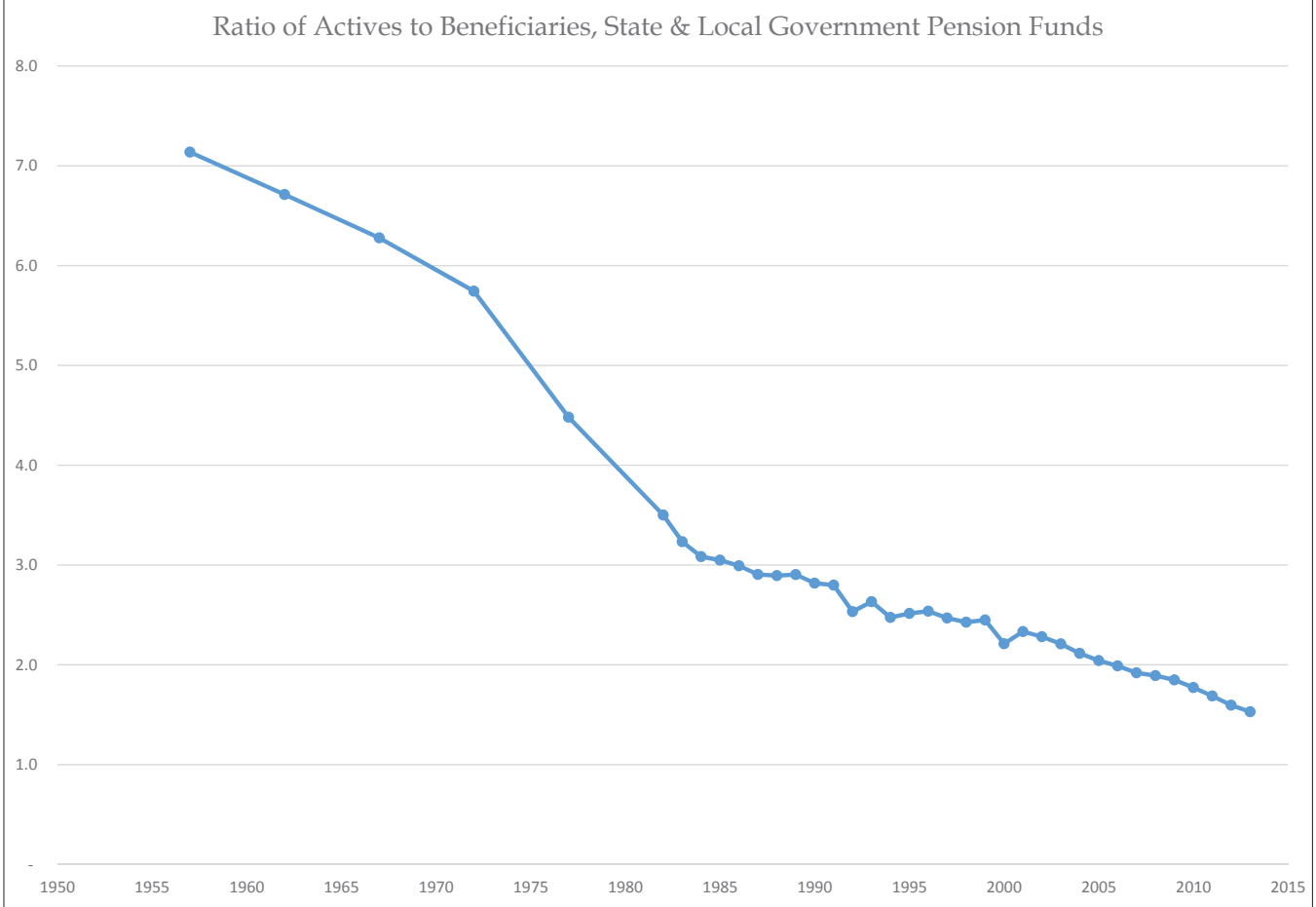
Demographics play an important role in determining pension fund risks in large part through their impact on the ratio of plan assets to payroll. The higher this ratio, the more volatile contributions will be relative to payroll, all else equal. Public pension funds often examine this in their actuarial valuations or other documents. As the California Public Employees' Retirement System (CalPERS), the nation's largest public pension fund, has explained:

> Rate volatility is heavily influenced by the ratio of plan assets to active member payroll. Higher asset to payroll ratios produce more volatile employer rates. To understand this, consider two plans, one with assets that are 4 times active member payroll, and the other with assets that are 8 times active member payroll. In a given year, let's see what happens when assets rise or fall 10 percent above or below the actuarial assumption. For the plan with a ratio of 4, this 10 percent gain or loss in assets is the same in dollars as 40 percent of payroll. For the plan with a ratio of 8, this is equivalent to 80 percent of payroll. If this gain or loss is spread over 20 years (and we oversimplify by ignoring interest on the gain or loss), then the first plan's rate changes by 2 percent of payroll while the second plan's rate changes by 4 percent of payroll.[2]

Maturing Pension Plans Create the Potential for Greater Volatility

As pension funds mature the number of beneficiaries[3] increases relative to the number of active workers. The United States population has been aging, and governmental workforces have been aging along with it, as more governmental workers near or reach retirement age. As a result, most public pension funds are maturing and the ratio of the actives to beneficiaries has been declining for decades (see Figure 1).

Figure 1. The Ratio of the Number of Actives to the Number of Beneficiaries Is Declining for Public Pension Funds

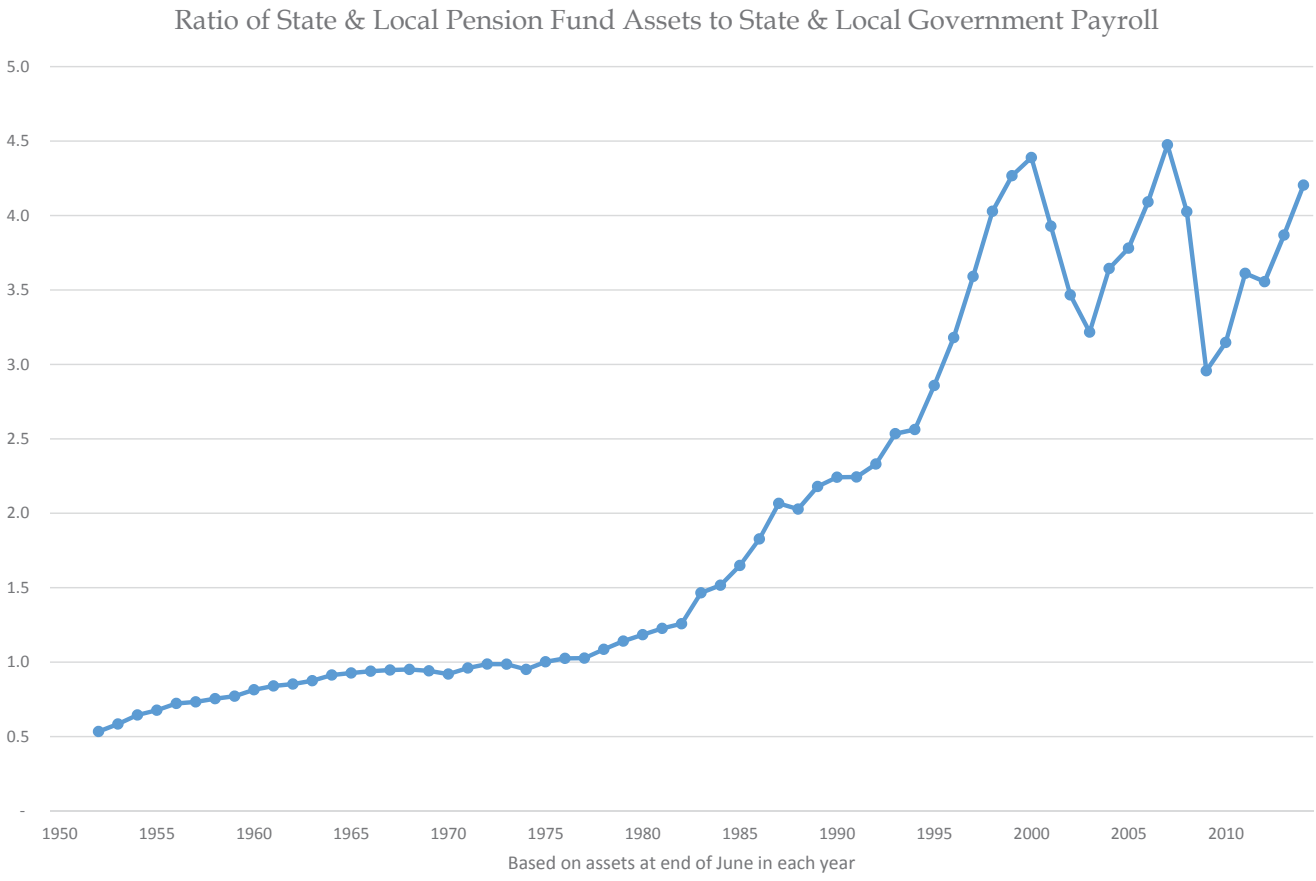


Source: Authors' analysis of the Census Bureau's Annual Survey of Public Pensions (recent years at http://www.census.gov/govs/retire/)

The Asset-Payroll Ratio Tends to Rise as Plans Mature

As the ratio of actives to beneficiaries declines, the ratio of assets to payroll tends to rise because assets must be built up to provide for beneficiaries and because, with relatively fewer actives, payroll is relatively less. As Figure 2 shows, the ratio of assets to payroll for state and local government pension plans has been increasing for decades, although it has fluctuated substantially in recent years due to large swings in investment returns.

Figure 2. The Ratio of Assets to Payroll Is Much Higher Than It Was Twenty or Thirty Years Ago



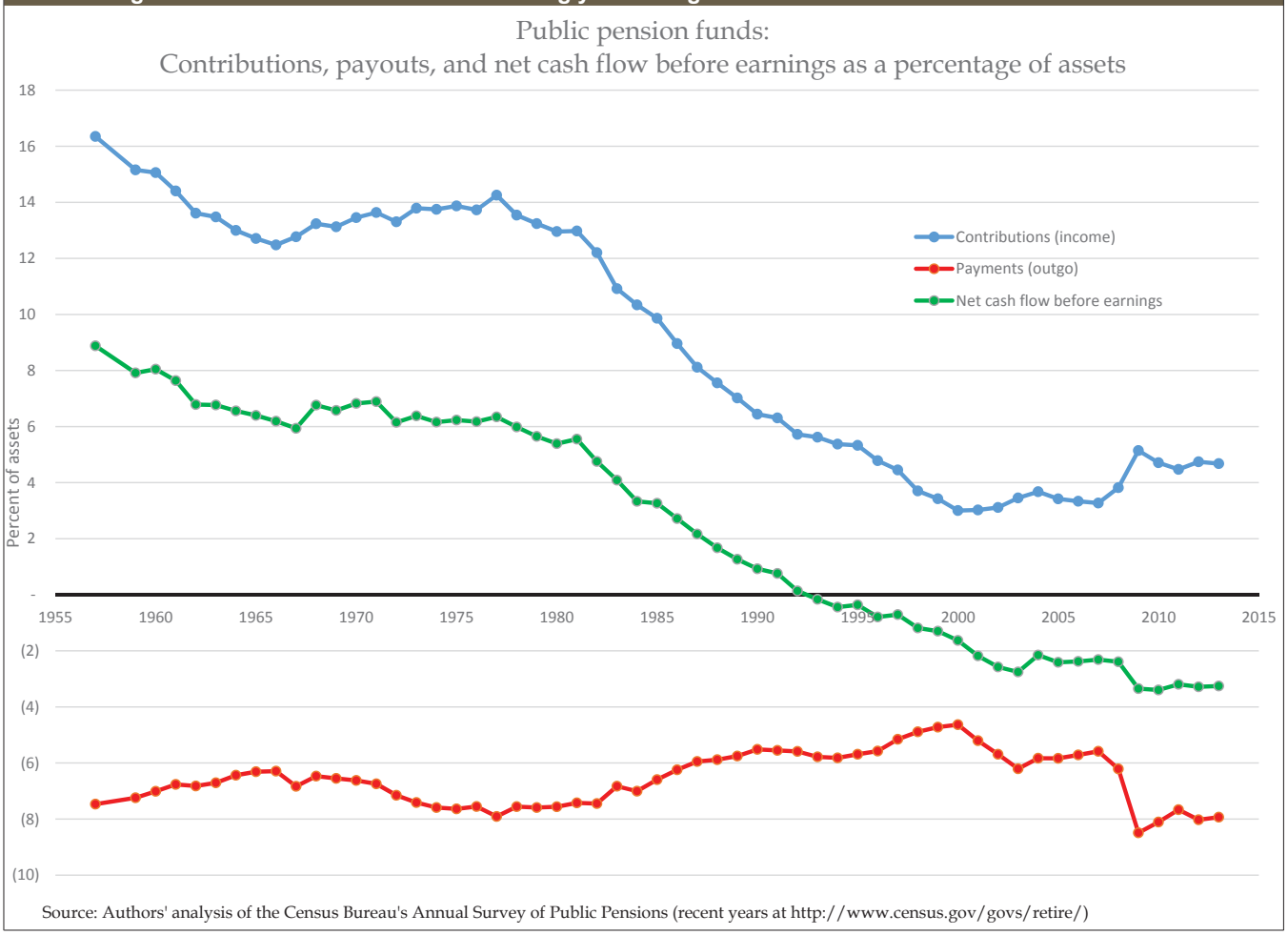
Source: Authors' analysis of Z.1 Financial Accounts of the United States, Federal Reserve Board, March 2015 release.
Note: Denominator is total payroll of state and local governments. Pension fund covered payroll is somewhat less than total state & local government wages, so ratios based on pension fund covered payroll, if data were available for all years, would be slightly higher than shown here.

Maturing Plans Generally Have Negative Cash Flow Before Investment Income

As a plan matures, its benefit payments for a growing retiree population often grow more rapidly than cash contributions for a slower-growing population of active workers. Thus, cash flow before investment income (receipts from contributions minus disbursements for benefits) can become increasingly negative. Cash flows before investment income for state and local government pension plans in the United States have been declining for decades and have been negative since 1993 (see Figure 3). According to the Public Plans Database,[4] in 2013 half of the pension plans had net cash *outflows* before investment income of 2.8 percent or more, 25 percent had negative net cash outflows of 3.9 percent or more, and 10 percent had negative net cash outflows of 6.2 percent or more.[5] These negative cash flows could affect funded status and liquidity needs of plans.

One important factor influencing the asset-payroll ratio and the net cash flow of a plan (before considering investment income) is the growth rate of the plan workforce, which we examine in simulations below. In general, the faster the workforce grows the lower the ratio of assets to payroll, in part because plan

Figure 3. Public Pension Funds Increasingly Have Negative Cash Flows Before Investment Income



Source: Authors' analysis of the Census Bureau's Annual Survey of Public Pensions (recent years at http://www.census.gov/govs/retire/)

payroll is increasing more rapidly. In addition, when the workforce is growing rapidly, net outflows are lower, all else equal, largely because of an influx of new contributions.

CalPERS has expressed concern about increased volatility resulting from a declining ratio of actives to beneficiaries and increasingly negative cash flows before investment earnings. The chief actuary has noted that, "The concern that I have is that the volatility we have built into the funding system is such that it may cause such severe strain on the employers that they may not be able to make the contributions."[6]

Other Demographic Characteristics Can Influence the Asset-Payroll Ratio and Volatility

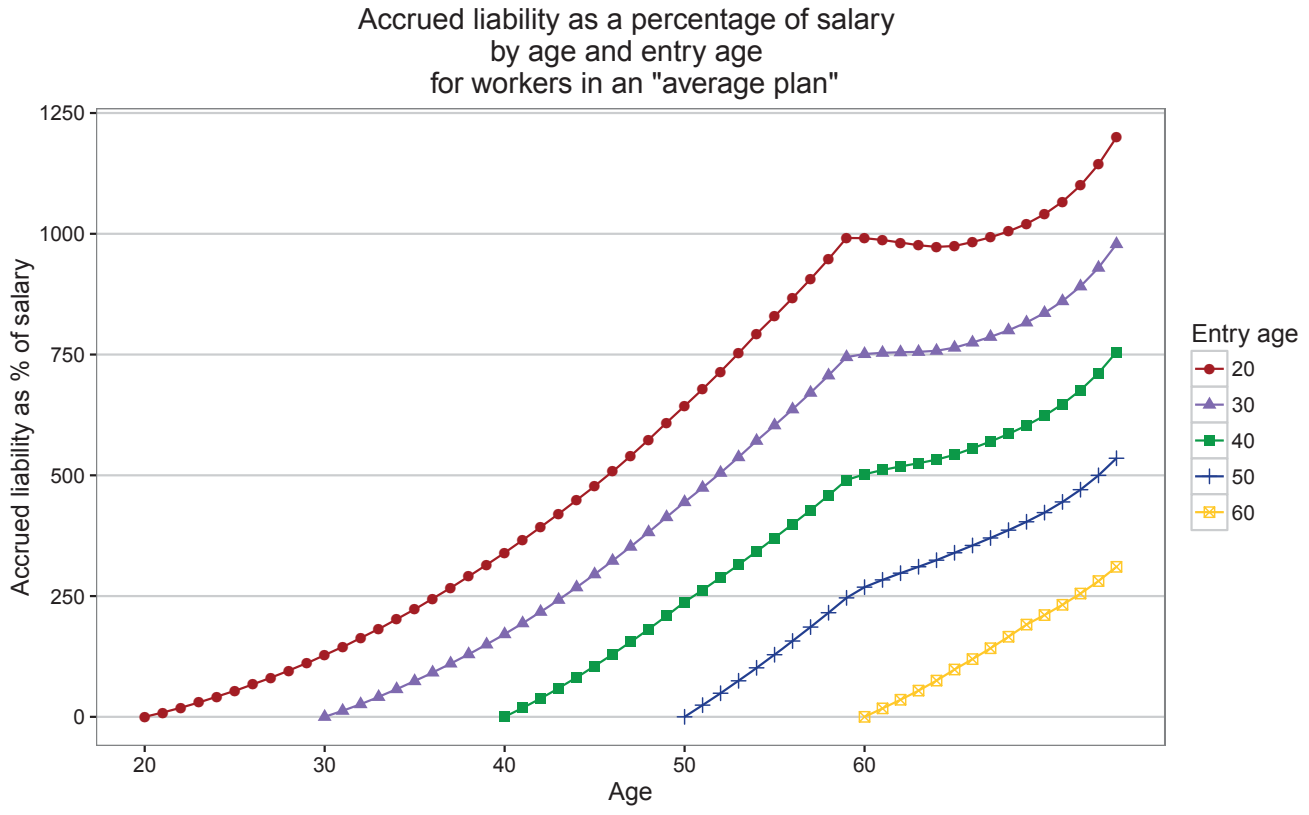
Other factors also affect the asset-payroll ratio, such as the age and years-of-service distribution of workers and beneficiaries, benefit levels, the age distribution of new entrants, and decrement rates such as mortality rates, retirement rates, and the rates at which workers separate from service.[7]

The age and years–of-service distribution of a workforce affects accrued liabilities relative to payroll. Figure 4 shows accrued liability as a percentage of payroll by age for workers in an

average plan (the details of the plan are described in a later section), by entry age. Young workers with low years of service usually have low accrued benefit relative to their salary, and thus a low accrued liability for the sponsor. Liabilities accumulate as years of service increase and can eventually rise to several times salary; thus, each line in the figure slopes upward. The lines for workers who entered at earlier ages are higher than those for later entrants because early entrants have had more years of service over which to accumulate liability. Therefore, a plan with large proportion of older employees and employees with high years of service generally has a high liability-to-payroll ratio.

An older workforce and high years of service can result from low rates of decrement (mortality, retirement, and separation), low or even negative workforce growth, and new entrants that are skewed toward higher ages (see Appendix: How the Distribution of Entry Ages Can Affect Plan Normal Costs).

Figure 4. Accrued Liability Increases as a Percentage of Salary as Workers' Years of Service Increase



A plan with a higher liability-to-payroll ratio will have a higher asset-to-payroll ratio if the liabilities are being funded. Other factors also can affect the ratio of assets to payroll. For example, higher benefits for a given level of pay lead to a higher asset-to-payroll ratio, all else equal.

How We Model the Impact of Demographic Characteristics

We examine the impact of demographic characteristics using a simulation model that calculates the year-by-year finances of a public pension fund under different investment-return scenarios and different funding policies. (For details, see Appendix: The Stochastic Simulation Model.)

We simulate five plans with distinct demographic characteristics, based on our analysis of variation among plans in the Public Plans Database:[8]

- Three average plans with different workforce growth rates. All three plans have the same average initial workforce, and the same initial actives-to-beneficiaries ratio of 2. To investigate the impact of workforce growth on fund risks, we examine three workforce-growth scenarios: negative 2 percent, 0 percent (constant workforce size), and positive 2 percent.
- Mature plan. This plan has an older and shrinking workforce, and a relatively lower actives-to-beneficiaries ratio of 1.7. It has a very high initial asset-payroll ratio and high cash outflow before investment income (about 4 percent of assets) due to high retirement benefit payments and a low actives-to-beneficiaries ratio.
- Immature plan. This plan has a young and growing workforce, and a high actives-to-beneficiaries ratio of 3.3. It has a low initial cash outflow before investment income, due to low retirement benefit payments and the high actives-to-beneficiaries ratio.

The five plans share the following common features:

- retirement benefits are 2.2 percentage points per year of service multiplied by the average of the final three years of salary, increased by two percent in each retirement year;[9,10]
- plan sponsor contributions are made each year that, when added to a 5 percent employee contribution, satisfies the actuarially determined contribution;
- gains and losses amortized with thirty-year open level percent amortization and five-year asset smoothing, a common set of policies;[11]
- a funded ratio of 75 percent[12] and have an expected compound annual return of 7.5 percent with a standard deviation of 12 percent.

Table 1 summarizes characteristics of these prototypical plans in year one and year thirty and shows quartile values for corresponding variables in the Public Plans Database. Appendix Figure 4 and Appendix Figure 5 present distributions of the age of actives, years of service, entry age, and age of new entrants (see Appendix: Distributions of Key Characteristics of Prototypical Plans).

Table 1. Summary of Plans With Different Demographic Profiles[13]

Plan name	Growth of workforce	Average age of actives		Average age of retirees		Active-to-beneficiary ratio		Normal cost as % of payroll		Median Asset-to-payroll (across 1k sims)		Median Net cash flow as % of assets (across 1k sims)	
		Year		Year		Year		Year		Year		Year	
		1	30	1	30	1	30	1	30	1	30	1	30
Average Plan; -2% workforce growth	-2%	45.8	47.1	69.5	78.8	2	0.42	11.5	11.5	4.1	7.6	-1.3	-5.6
Average Plan; Constant workforce	0%	45.8	46.0	69.5	78.1	2	0.63	11.5	11.8	4.1	5.3	-1.3	-3.7
Average Plan; 2% workforce growth	2%	45.8	45.2	69.5	77.4	2	0.92	11.5	12.0	4.1	3.8	-1.3	-2.1
Mature Plan	-1%	47.1	44.3	72.6	78.5	1.67	0.58	11.7	12.3	7.8	6.2	-4.1	-5.6
Immature Plan	1%	48.8	45.9	71.6	77.6	3.33	0.76	12.6	13.4	3.4	4.8	2.5	-2.6

Public Plans Database in 2013

	Growth of workforce	Average age of actives	Average age of retirees	Active-to-beneficiary ratio	Normal cost as % of payroll	Asset-to-payroll	Net cash flow as % of assets
PPD 25th percentile	-1.3%	44.1	68.9	1.1	10.2	3.7	-3.9
PPD 50th percentile	0%	45.8	70.0	1.4	12.4	4.4	-2.8
PPD 75th percentile	1.0%	47.0	71.7	1.7	17.4	6.1	-1.5

Demographic trends for these prototypical plans are consistent with trends in the real world. The actives-to-beneficiaries ratio declines dramatically over time — all plans end up with an actives-to-beneficiaries ratio lower than one in year thirty. As a result, by year thirty most prototypical plans have a significantly higher asset-to-payroll ratio and much larger negative cash flow before investment income in the median case, both of which are associated with higher funding risk.

How We Measure Pension Plan Funding Risk and Contribution Risk

We examine how demographic characteristics 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 employer 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 variable, 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 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 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 first year, this probability is near zero. 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 for 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 rates in the first year range from about 11.5 to 12.6 percent and the employer contribution in the first year, including amortization of unfunded liability, ranges from about 13.5 to 20 percent. Thus, an employer contribution of 30 percent is a substantial increase from the initial contribution level for all plans.

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 percent 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.

Results: Analysis of Demographics and Pension Fund Risk

In the sections that follow, we summarize results from 1,000 simulations of each scenario, with investment returns varying from one simulation to the next.[14] (Some readers may find it helpful to see results from selected individual simulations before reading about the summary results. A section in the appendix presents results for two individual simulations for each of four plans: Appendix: Illustrative Individual Simulations for Plans With Different Demographic Characteristics.)

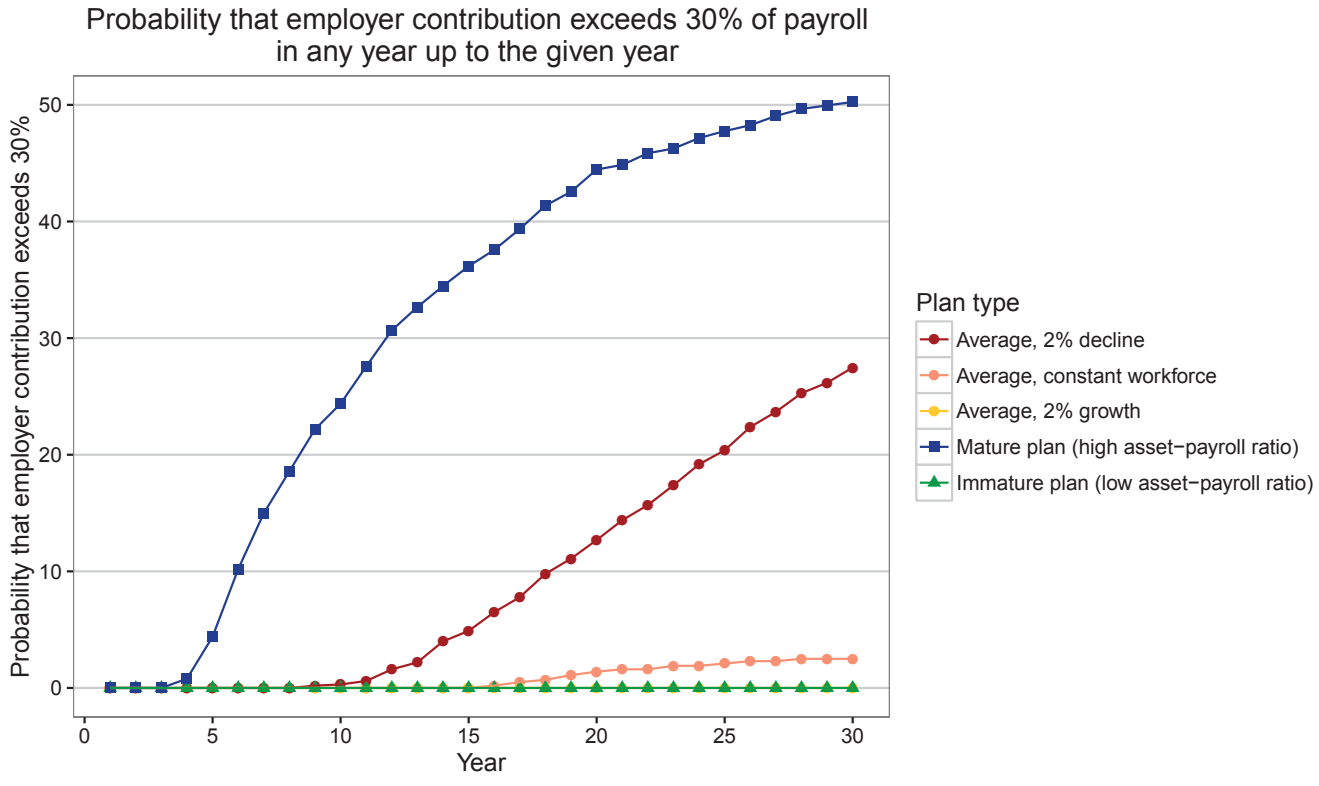
Risk of a High Employer Contribution Rate

The plans with the highest asset-payroll ratios have the greatest risk of a high employer contribution rate and the greatest risk

of a large increase in contribution rate in a short time period. The mature plan has high asset-payroll ratio throughout the simulations. In addition, the average plan with a 2 percent annual decline in the workforce has a substantial increase in its asset-payroll ratio, rising from 4.1 in year one to 7.6 in year thirty. By contrast, the asset-payroll ratio for the same plan with 2 percent annual workforce growth actually declines slightly over the simulation period, and by year thirty its asset-payroll ratio is 3.8, only one-half that of the plan with an annual 2 percent decline in its workforce.

As a consequence of their high asset-payroll ratios, the average plan with a shrinking workforce and the mature plan have the greatest risk of high employer contribution rate, as shown in Figure 5, and the greatest risk of a large increase in contribution rate in a short period of time, as shown in Figure 6.

Figure 5. The Mature Plans and the Plan With a 2 Percent Annual Workforce Decline Have the Greatest Risk of a High Employer Contribution Rate

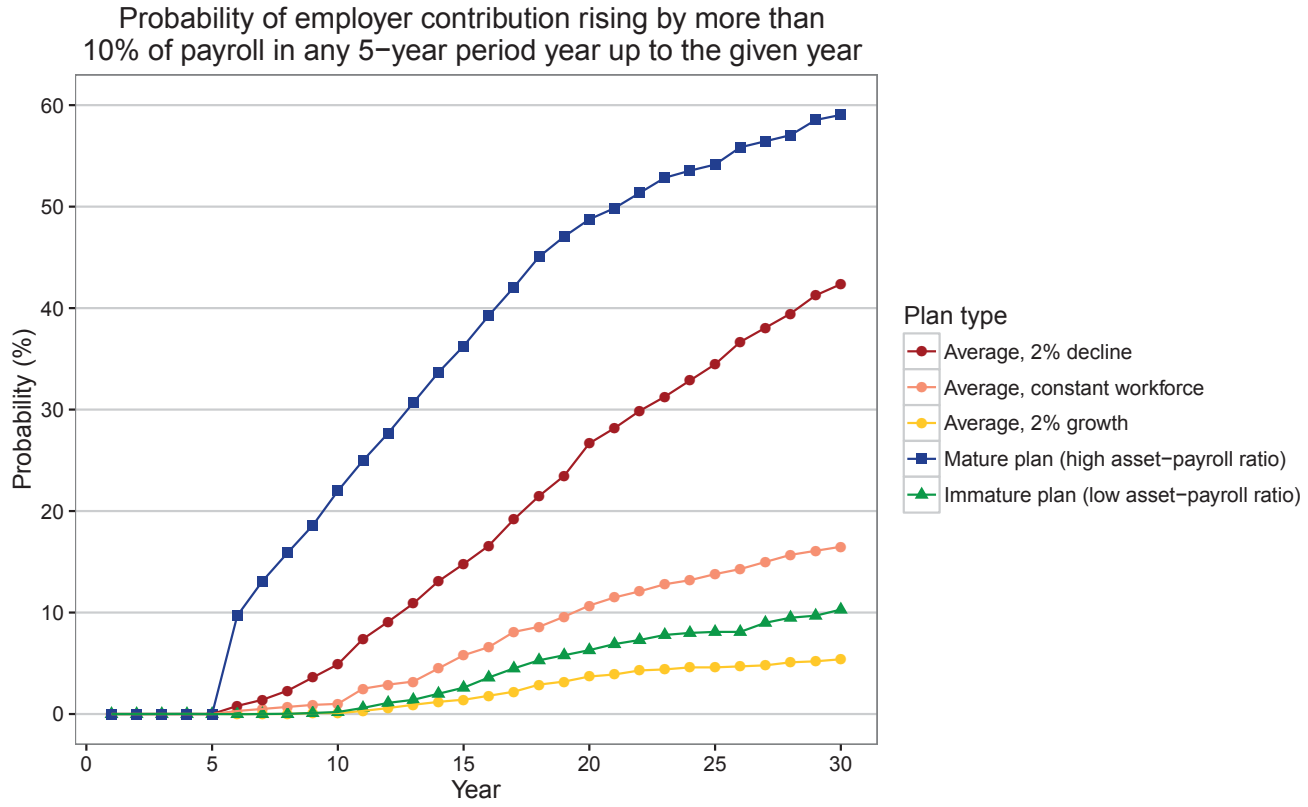


Note: The lines for "Average, 2% growth" and "Immature plan" are overlapped.

Risk of Severe Underfunding

A rapidly growing workforce raises the ratio of active members to beneficiaries and keeps payroll-based contributions high relative to retirement benefit payments. This has a positive impact on net cash flows of pension funds. Shrinking plans, by contrast, can have increasingly negative cash flows. Our average plans all start with net cash outflows before investment income of 1.3 percent in year 1, but by year thirty the plan with a 2 percent annual

Figure 6. The Mature Plans and the Plan With a 2 Percent Annual Workforce Decline Have the Greatest Risk of Large Increase in Contribution in a Short Period of Time



decline in its workforce has a net cash outflow of 5.6 percent while the plan with 2 percent annual workforce growth has a net cash outflow of only 2.1 percent.

The net cash flow and low funded ratio risk differ significantly between the mature plan and the immature plan. The mature plan has a very high initial asset-to-payroll ratio and a high benefits payout relative to payroll and, thus, a large initial net cash outflow before investment income, of 4.1 percent of assets. The large negative net cash flows reduce investible assets of the plan and lower the investment income. As a result, the mature plan suffers a much higher risk of a low funded ratio than the other plans, and has a nearly one in three chance of the funded ratio falling below 40 percent within thirty years. By contrast, the immature plan, which has the least generous benefits for initial retirees and a low actives-to-beneficiaries ratio, has the lowest net cash outflow before investment income, and the lowest risk of severe underfunding.

As a consequence of their large cash outflows, average plan with 2 percent annual declines in the workforce and mature plan with a high initial asset-payroll ratio and high benefit payouts have the greatest chance of severe underfunding (see Figure 7).

Moreover, it is more difficult for plans with large negative net cash outflows to recover toward full funding. Starting off 75 percent funded, the mature plan, which has large negative cash flows, ends up with a funded ratio less than 75 percent by year

Figure 7. Plans With High Initial Asset-Payroll Ratios and Plans With Declining Workforces Have Greatest Risk of Severe Underfunding

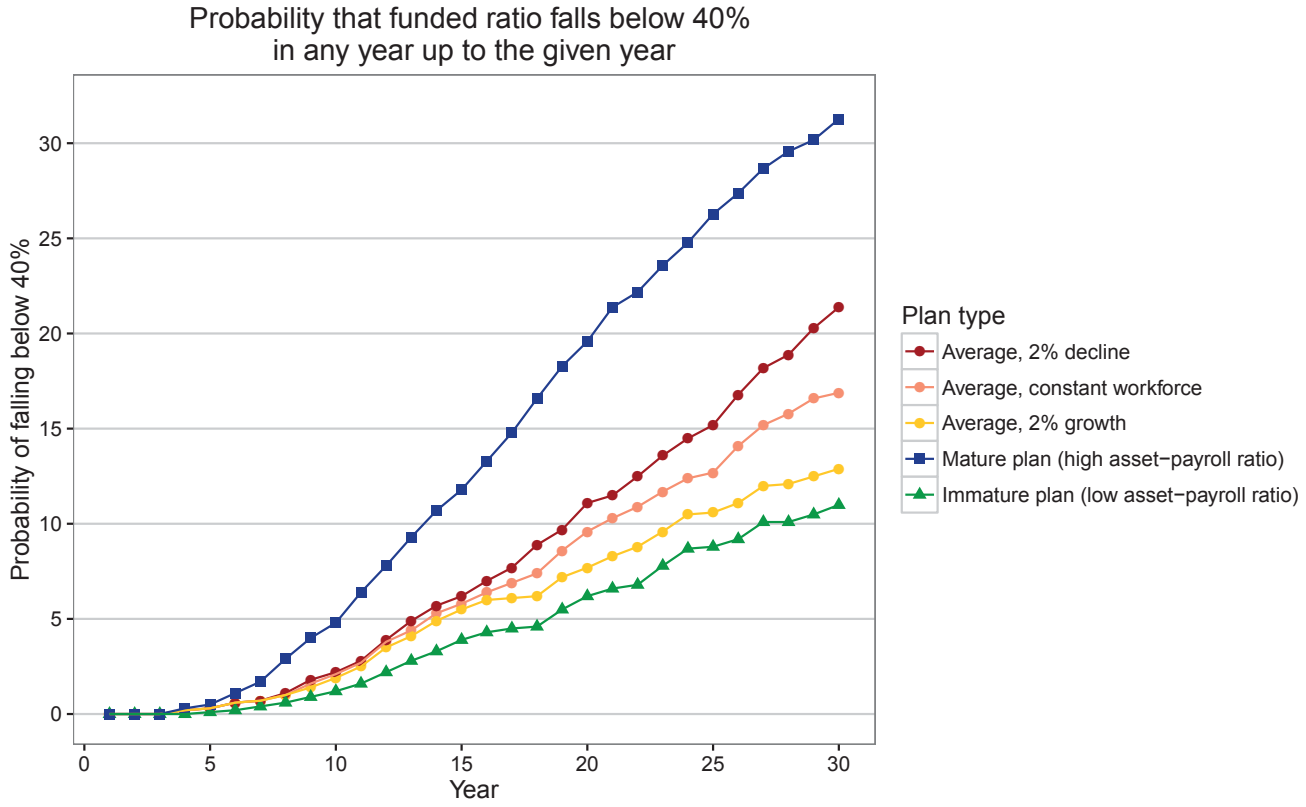
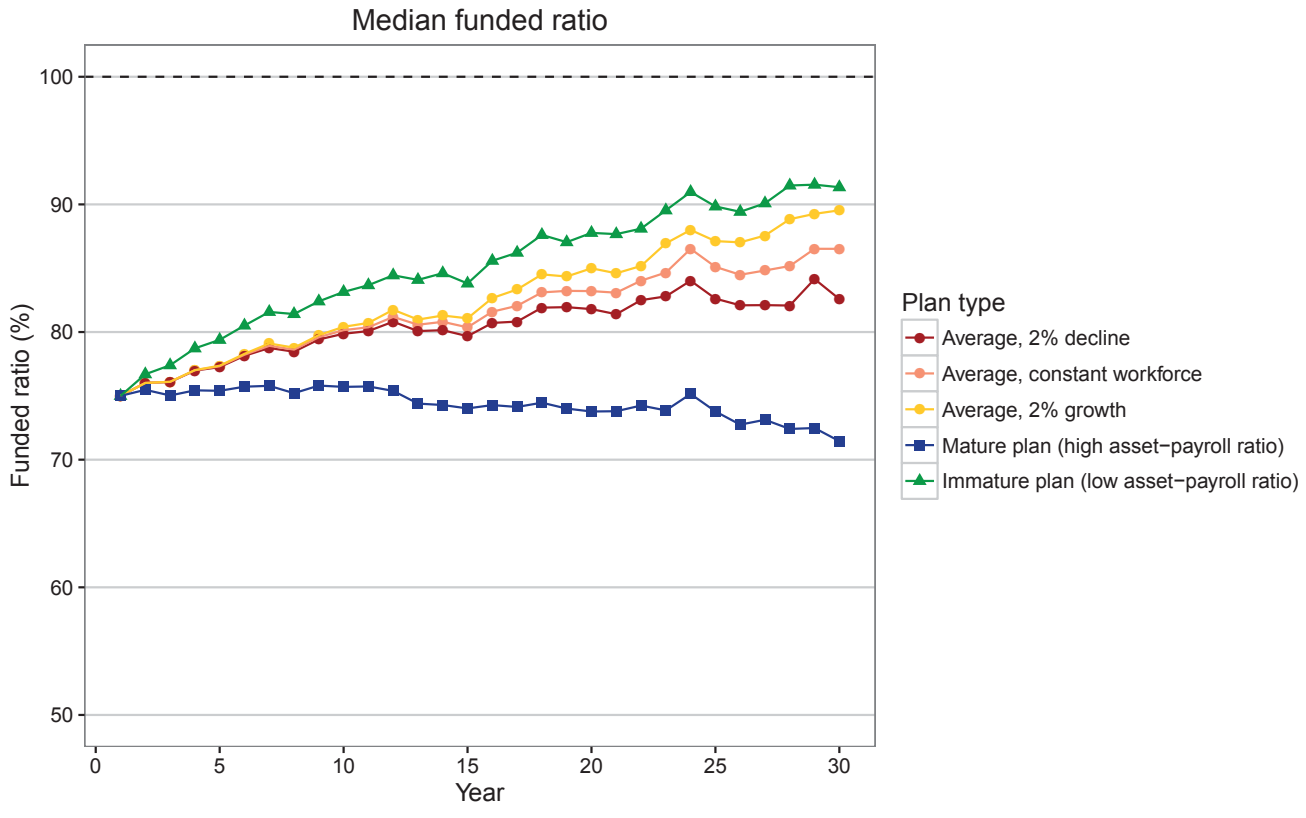


Figure 8. Funded Ratios of Plans With High Initial Asset-Payroll Ratios and Plans With Declining Workforces Recover More Slowly[15]



thirty in the median case, while the median funded ratio of the immature plan, which has positive cash flows in early years, slowly moves upward and reaches over 90 percent by year thirty (see Figure 8).

Overall Summary of Results

Table 2 summarizes the key results. Each row provides the results for a specific demographic scenario — five scenarios for our average plan, reflecting different workforce growth rates, followed by plans with different maturity structures. The columns are organized in three blocks: (1) key characteristics of the plan, (2) the asset-payroll ratio and net cash flow before investment income in years one and 30, and (3) results for our risk measures.

The results for the three average plans show clearly how growth rate of workforce will affect funding risks of pension funds. For the average plan with a workforce shrinking by 2 percent annually, the probability that the funded ratio will fall below 40 percent at some point during the thirty-year period is 21.4 percent, which is more than 8 percentage points higher than the average plan with a growing workforce. The average plan with a shrinking workforce also has a 27.5 percent chance that the plan will experience very high employer contribution rate, and a 42.4 percent chance that the employer contribution will rise sharply in a five-year period, while the average plan with a growing workforce has very little exposure to these two types of risks.

The results for the mature plan and the immature plan show the combination of shrinking workforce, high asset-to-payroll ratio, and large benefit payments relatively to contributions can substantially increase the funding risks of a pension fund. The mature plan has a nearly one in three chance that it will become severely underfunded at some point in thirty years, which is almost three times as high as that for the immature plan. The probability of very high employer contribution and the probability of sharp increases in employer contribution both exceed 50 percent for the mature plan, while the immature plan is much less susceptible to these risks.

Table 2. Plans With Declining Workforces and Increasing Maturity Have Greatest Risk of Severe Underfunding and High Employer Contributions

Plan demographic characteristics and risks of underfunding and of high employer contributions

Plan name	Key plan characteristics			Asset-to-payroll ratio and net cash flow (Median across 1,000 simulations)				Probability (%) that, anytime in 30 years, there will be		
	Annual workforce growth	Active-to-beneficiary ratio in year 1	Normal cost as % of payroll	Asset-to-payroll ratio in year 1	Asset-to-payroll ratio in year 30	Net cash flow before investment income as % of assets in year 1	Net cash flow before investment income as % of assets in year 30	Severe underfunding (40% funded ratio or less)	Very high employer contributions (30% of payroll or more)	Large Contribution rise in at least one 5 year period (increase of 10% of payroll or more)
Average Plan scenarios annual workforce growth:										
2% decline	-2%	2	11.45	4.1	7.6	-1.3	-5.6	21.4	27.5	42.4
Constant workforce	0%	2	11.45	4.1	5.3	-1.3	-3.7	16.9	2.5	16.5
2% growth	2%	2	11.45	4.1	3.8	-1.3	-2.1	12.9	0.0	5.4
Mature Plan (high asset-to-payroll ratio, high net cash outflows)	-1%	1.67	11.71	7.8	6.2	-4.1	-5.6	31.3	50.2	59.0
Immature Plan (low asset-to-payroll ratio, low net cash outflows)	1%	3.33	12.57	3.4	4.8	2.5	-2.6	11.0	0.0	10.3

Conclusions

How do demographic characteristics of public pension plans affect the risks that pension funds and their sponsoring governments face? As pension funds mature, relatively more workers retire, leading to more beneficiaries relative to the number of active workers, greater payments of retirement benefits, and increasing assets relative to payroll of active workers. Approximately two-thirds of public pension funds' $3.7 trillion of assets are in investments other than cash and fixed income, and have volatile investment returns. Investment gains and losses become larger relative to payroll and government contributions, which generally are calculated as a percentage of payroll, can become more variable, and plan funded ratios can become more volatile.

We examined the year-by-year finances of prototypical public pension funds with a model that allows investment returns to vary in plausible ways, rather than meeting actuaries' assumptions every year. We describe our key conclusions below.

Growing Plans With Increasing Numbers of Workers Are Less Susceptible to Investment Risk Than Are Shrinking Plans

A prototypical pension plan with average characteristics that starts out 75 percent funded, with a workforce that grows 2 percent annually, would have a one in eight chance (13 percent) of falling below a 40 percent funded ratio in a thirty-year period — a funded ratio that has been associated with fiscal crises in several pension systems. As the growth in the workforce slows or declines, the risk rises to more than one in five (21.4 percent) for a plan with a 2 percent annual decline in the number of workers.

The plan with a shrinking workforce would have a 27.5 percent chance that actuarially determined contributions will exceed 30 percent of payroll sometime during thirty years, and a 42.4 percent chance that the employer contribution will increase by more than 10 percent of payroll sometime during thirty years, while the plan with a growing workforce has little exposure to these risks.

Very Mature Plans With High Assets Relative to Payroll and High Cash Outflows Face Greater Funding Risk, All Else Equal

A prototypical mature plan with the same characteristics as the growing plan described above has a nearly one in three (31 percent) chance of falling below 40 percent funding in a thirty-year period. There would be a fifty-fifty chance of actuarially determined employer contributions exceeding 30 percent of payroll sometime in those thirty years, even though the plan's initial employer contribution is only about 20 percent, and a nearly 60 percent chance that the employer contribution will increase by more than 10 percent of payroll sometime during thirty years. By contrast, a prototypical immature plan (with relatively fewer retirees), with a low asset-payroll ratio and low cash outflows before investment returns, has substantially lower exposure to these risks.

Public pension plans are much more mature now than they were ten or twenty years ago, with lower numbers of active workers per beneficiaries, higher net cash outflows, and higher asset-payroll ratios. Many will mature further as the population continues to age, and as government workforces age. This maturation will lead to higher risks of pension plan underfunding, all else equal, unless pension funds invest in less volatile assets.

ACKNOWLEDGMENTS

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Appendices

Appendix: The Stochastic Simulation Model

To examine the interplay between stochastic investment returns and plan demographic characteristics, we developed a stochastic simulation model for 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 draws investment returns randomly each year from a probability distribution — for example, from a normal distribution with a 7.5 percent mean return and a 12 percent standard deviation. (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,[16] Biggs assumed a 14 percent standard deviation,[17] and Bonafede et al. estimated a 12.5 percent standard deviation.[18] 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.

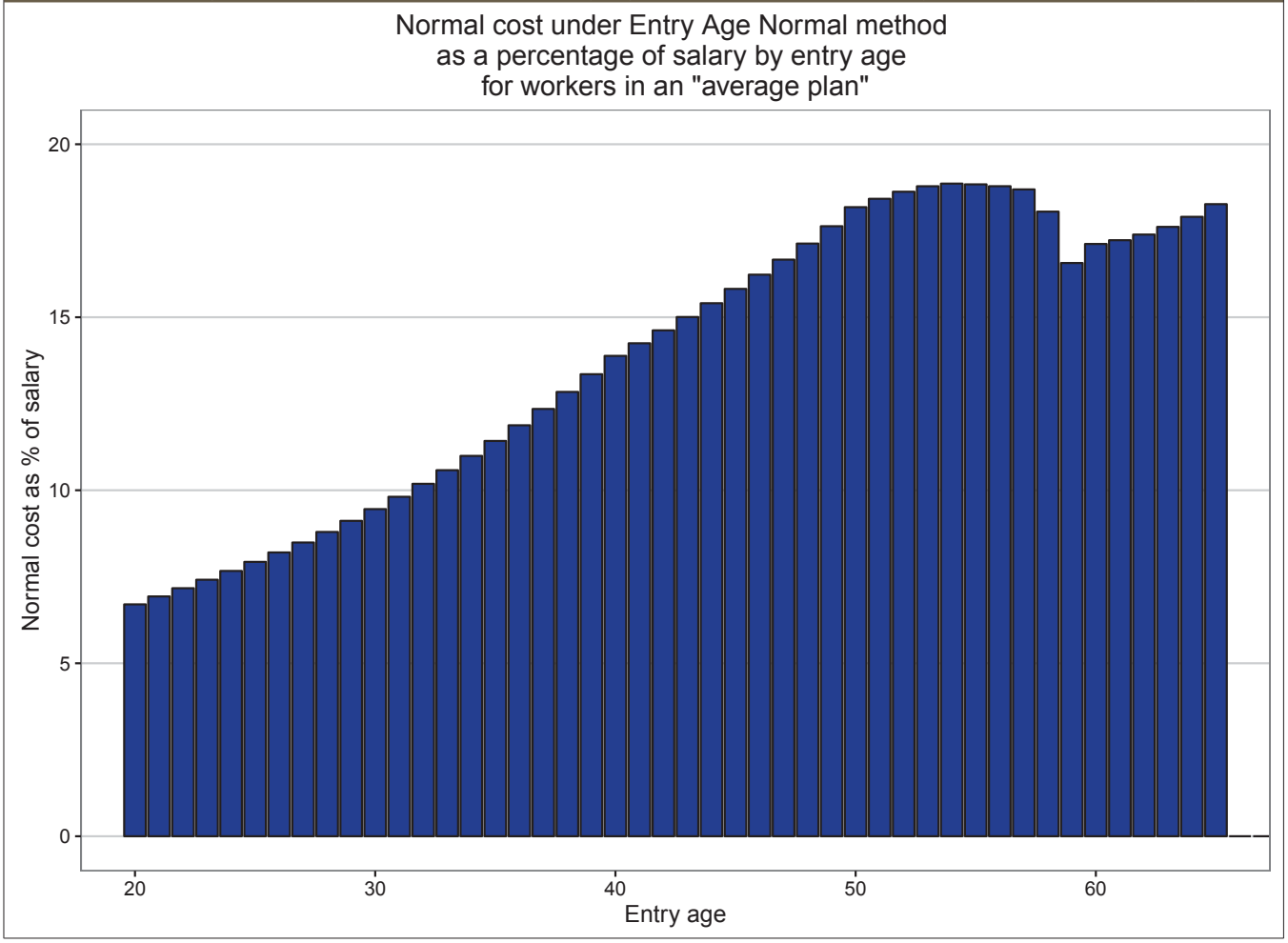
Investment returns are assumed to be independent of each other from year to year — bad investment years are not necessarily followed by good investment years, and vice versa. Because investment returns are random in the model, we might obtain virtually any sequence of returns in a single run of the model (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.

Appendix: How the Distribution of Entry Ages Can Affect Plan Normal Costs

The normal cost rate under the Entry Age Normal (EAN) cost method (the most commonly used method among public pension plans) varies by entry age, and thus the distribution of employees' entry ages affects the plan's overall average normal cost. Appendix Figure 1 shows the normal cost as percentage of salary under

EAN by entry age for workers in an "average plan." Under EAN, the normal cost for any individual employee is always a fixed percentage of one's salary, and this percentage is generally greater for employees entering the workforce at a higher age, because the liability associated with their prospective benefits has to be spread over a shorter career period. Therefore, normal costs generally will be higher for plans in which the new entrants are older than for plans with younger new entrants.[19]

Appendix Figure 1. Normal Cost Under the Entry Age Normal Method Generally Increases With Entry Age



Appendix: Illustrative Individual Simulations for Plans With Different Demographic Characteristics

Appendix Figure 2 and Appendix Figure 3 present the results for two simulations, both of which achieve a 7.5 percent compound annual return over thirty years, albeit with different time patterns. (The first simulation has higher investment returns early and the second has higher investment returns later, although many different time patterns are possible.)

Each simulation has four panels:

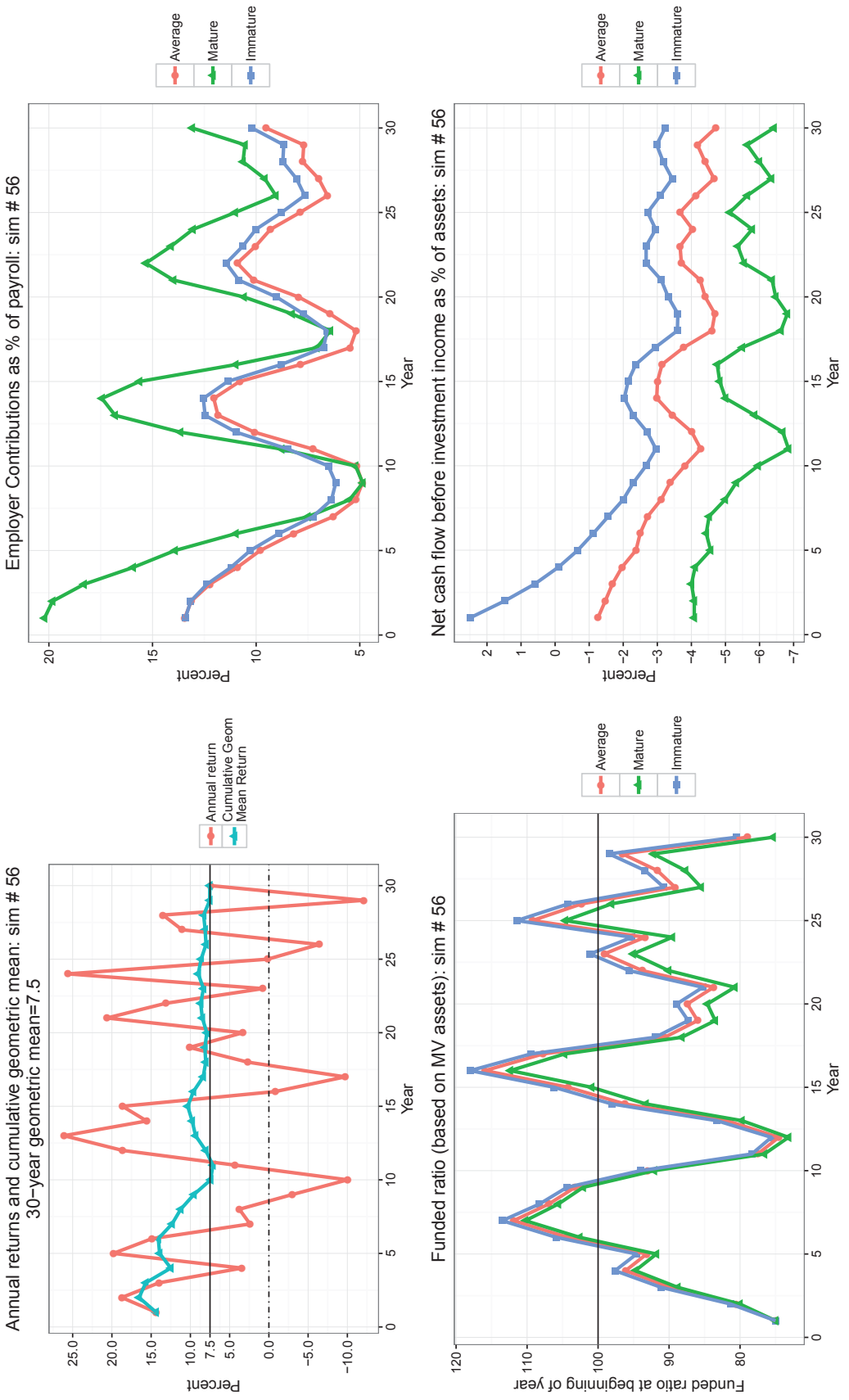
- The upper left panel shows the annual investment return and the cumulative geometric mean return. A horizontal line at 7.5 percent shows the investment return assumption and a dashed line at 0 percent makes it easy to distinguish investment-loss years from investment-gain years. The title notes the geometric mean at thirty years.
- The upper right panel shows employer contributions as a percentage of payroll under each demographic scenario.
- The lower left panel shows the funded ratio under each scenario, using the market value of assets.
- Finally, the lower right panel shows net cash flow before investment income as a percentage of assets.

We have several key observations from the individual simulations:

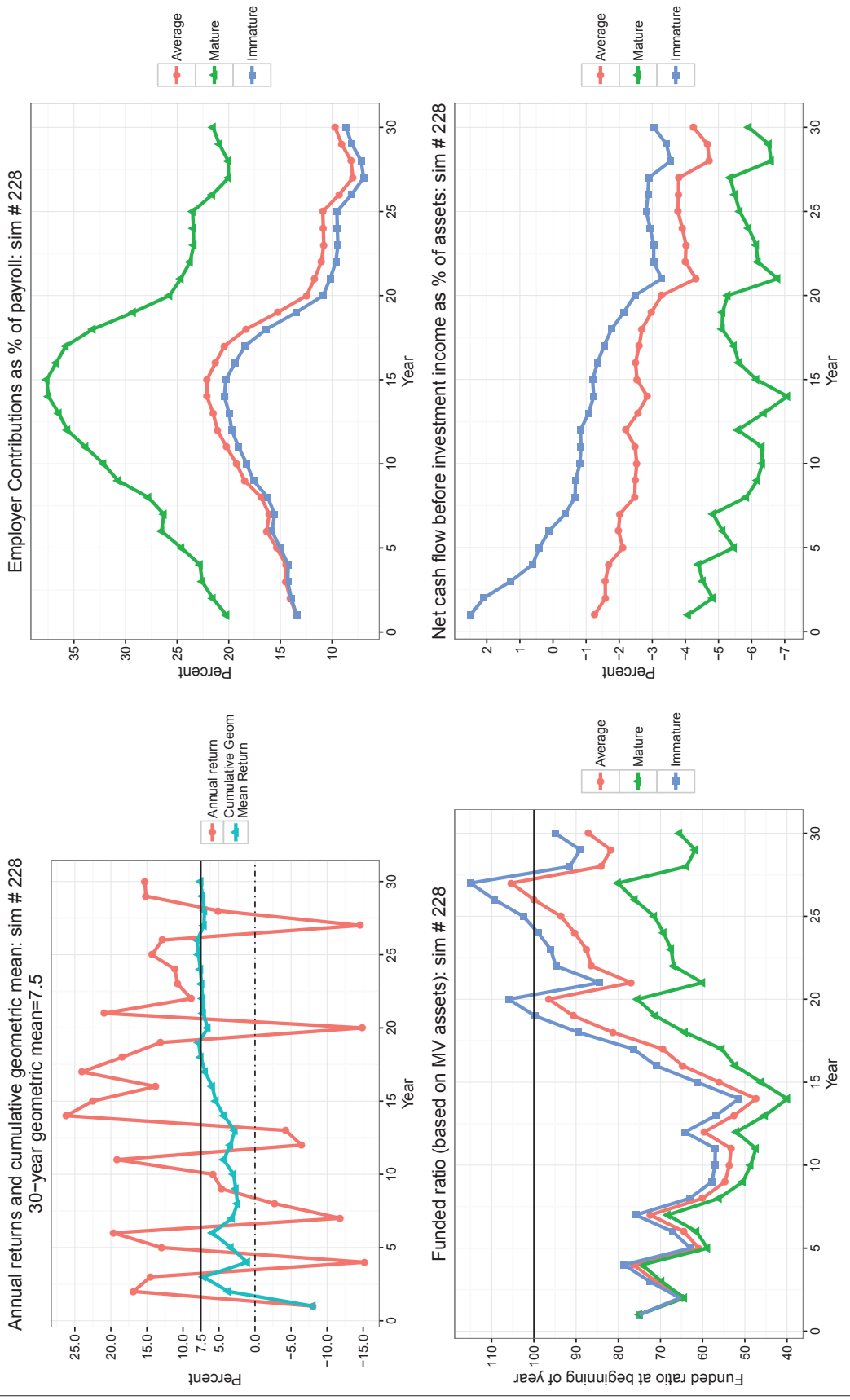
- The time pattern of investment returns has a large impact on the funded status of all three plans. Plans end up with a much higher funded ratio under the first simulation (#56) than under the second simulation (#228). The plans with the more negative net cash flows before investment income in simulation #228 have the lowest funded ratios in that simulation.
- The mature plan, which has the largest net cash outflow before investment income, has the lowest funded ratio among the four plans in all years.
- The mature plan, which starts with the highest asset-to-payroll ratio, has a more volatile contribution rate compared to other plans.

Other simulations we have conducted suggest that the relationship between the time pattern of returns and funded ratio is complex. For example, it is not related simply to whether higher returns come early or late — in many other simulations the funded ratio can be even higher when higher returns come late. The relationship between the time pattern of returns and funded ratio requires more research, but it is clear that this can have an important impact on plan funded status.

Appendix Figure 2. Results of a Single Simulation (#56 — Higher Returns Later) Where Investment Assumption Was Met

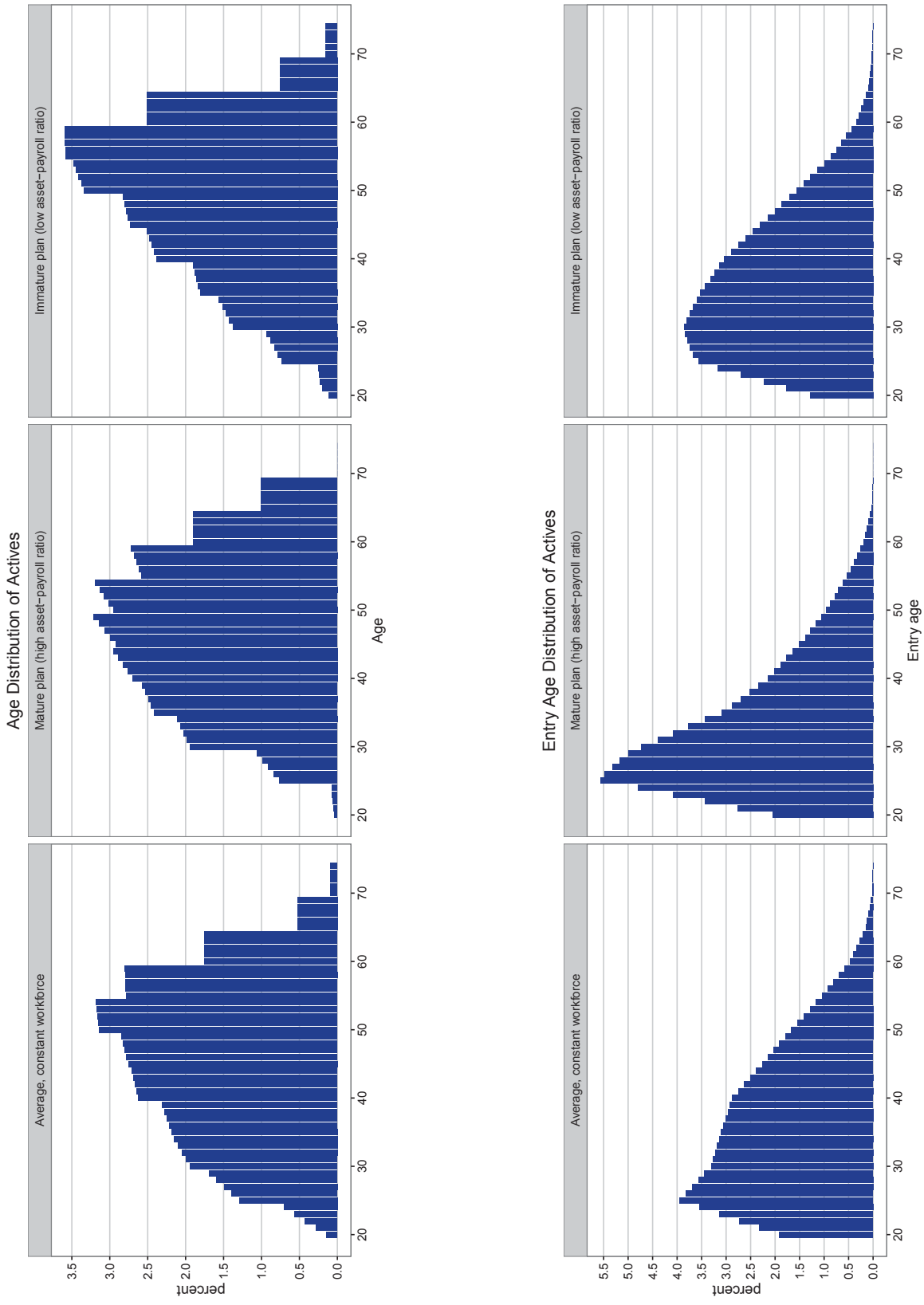


Appendix Figure 3. Results of a Single Simulation (#228 — Higher Returns Later) Where Investment Assumption Was Met

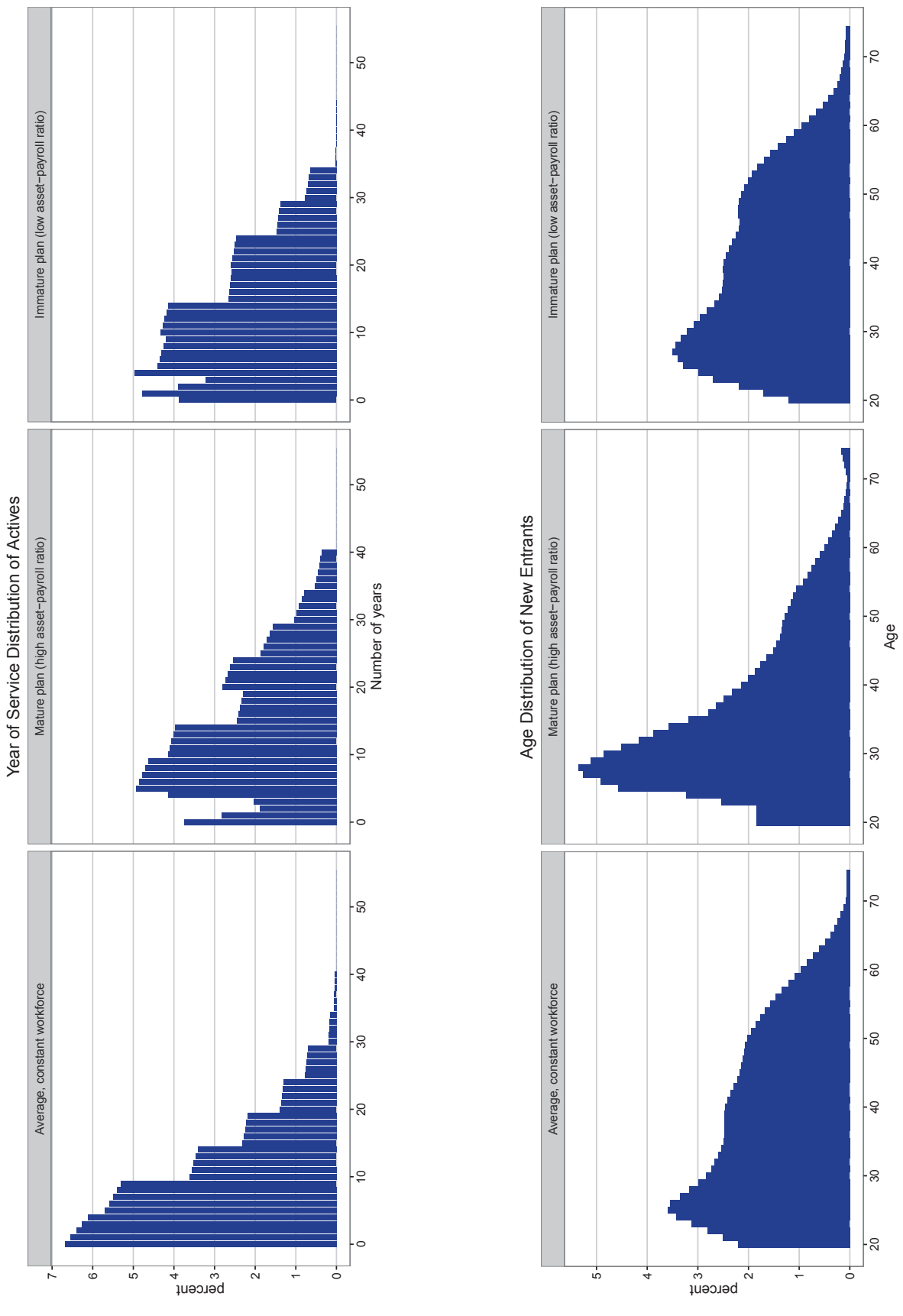


Appendix: Distributions of Key Characteristics of Prototypical Plans

Appendix Figure 4. Distribution of Age and Entry Age of the Simulated Plans



Appendix Figure 5. Distribution of Years of Service and Age of New Entrants of Simulated Plans



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.

2 *CalPERS: Annual Review of Funding Levels and Risks* (Sacramento: California Public Employees' Retirement System, November 18, 2014), https://www.calpers.ca.gov/docs/forms-publications/annual-review-funding-2014.pdf.

3 In this report, the term "beneficiaries" refers to all types of inactive plan members who are receiving benefit payments, including service retirees, deferred retirees, disability retirees, and beneficiaries of death benefit and contingent retirement benefits. In the simulation of prototypical plans, only service retirees and deferred retirees are modeled, therefore "beneficiaries" only include these two types in the discussion of simulation results.

4 The Public Plans Data (PPD) website is maintained through a partnership between The Center for Retirement Research (CRR) at Boston College 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. See: http://publicplansdata.org/.

5 The median PPD net outflow of 2.8 percent in 2013 is slightly smaller than the aggregate net outflow on the graph of 3.3 percent, suggesting that large plans may have slightly greater net outflows as a percentage of assets than does the median plan.

6 Ed Mendel, "CalPERS Looks at Long-Term Rate Hike to Cut Risk," *PublicCEO*, June 1, 2015, http://www.publicceo.com/2015/06/calpers-looks-at-long-term-rate-hike-to-cut-risk/.

7 Gender composition is another important demographic factor. While currently our simulation model does not treat males and females separately, we do use hybrid decrement tables that reflect gender compositions in pension plans.

8 See Public Plans Data, Downloadable Data, http://publicplansdata.org/public-plans-database/download-full-data-set/.

9 The age structure of the plan population is based on our analysis of data in the Public Plans Database, and is similar to the population of the Arizona Public Employees Retirement System, which we found to be fairly typical in many ways.

10 While annual benefit increases are sometimes called COLAs, for cost of living adjustments, we do not use that term here as the increase is unrelated to cost of living.

11 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.

12 Near the 2014 Public Plans Database median of 73 percent.

13 For "average age of retirees," "retirees" only include service retirees and do not include terminated employees who are receiving benefit payments. Including terminated employees receiving benefits will not affect the average age of retirees a lot because vested terminated workers are assumed to start receiving benefits at age sixty in the model and their age structure is therefore similar to that of the service retirees.

14 Each scenario is based on the exact same set of 1,000 investment returns for each simulated year.

15 The y axis in Figure 8 starts with 50 percent rather than 0 to better show the difference between scenarios. However, readers should keep in mind that this rescaling may visually exaggerate the difference.

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.

19 The model assumes that workers will not terminate (leave) after reaching normal retirement age of sixty, and therefore the normal costs of termination benefits are zero for a worker entering at age fifty-nine or later.

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