Public Pension Plan Risk-Sharing: Options and Consequences

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Abstract

In traditional public sector defined benefit (DB) plans the employer generally bears nearly all investment risk, longevity risk, and inflation risk during both working years and retirement years. In traditional defined contribution (DC) plans, employees bear nearly all these risks. In this paper, we build on our previous work on risk-sharing policies in public pensions by extending a stochastic simulation model to examine a full spectrum of risk-sharing options. We use stochastic simulations to analyze the impacts of these risk-sharing options on plan members and contributing governments. In this draft we present preliminary analysis of the extent to which contingent cost-of-living adjustments (COLAs) and contingent employee contribution policies can transfer risk from employers to plan members.

Introduction and motivation

In traditional public sector defined benefit (DB) plans the employer generally bears nearly all investment risk, longevity risk, and inflation risk during both working years and retirement years. In traditional defined contribution (DC) plans, employees bear nearly all these risks. With increasing costs and risks in DB plans, state and local governments have sought to share one or more of these risks with employees, during working years or retirement years or both.

In recent years several state pension plans have introduced contingent cost-of-living adjustments (COLAs) and contingent employee contributions. For example, COLAs in the South Dakota Retirement System depend partly on plan funded status, COLAs in the Wisconsin Retirement System depend upon investment performance, and employee contributions in the Pennsylvania State Employees' Retirement System depend partly upon investment performance.[1] Many variants and alternative approaches to risk-sharing are possible.

As governments seek ways to control pension costs and risks while providing competitive compensation to public employees, it will be increasingly important to understand how risk-sharing mechanisms affect costs and risks to pension plans, governmental employers, active employees, and retirees. These costs and risks depend upon uncertain future events and are best analyzed with methods that take their probabilistic nature into account.

In this paper, we build on our previous work on risk-sharing policies in public pensions by extending a stochastic simulation model to examine a full spectrum of risk-sharing options.[2] We use stochastic simulations to analyze the impacts of these risk-sharing options on plan members and contributing governments.

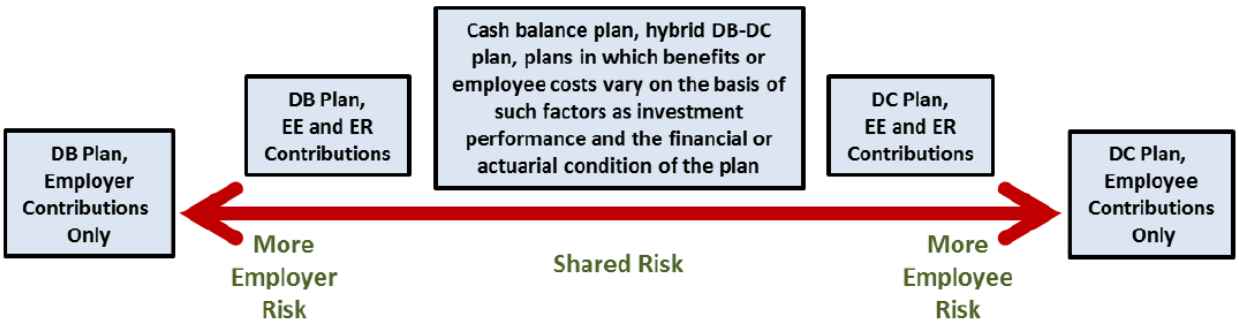
We examine measures of (1) impacts on employers including the level and volatility of employer contribution costs and (2) impacts on plan members including the level and volatility of retirement benefits, and the level and volatility of employee contributions. Policymakers are a crucial audience and we seek to develop measures that are intuitive and useful to audiences not familiar with stochastic analysis.

This paper is organized as follows: (1) description of major kinds of risk-sharing policies, (2) risk measures, (3) our approach to modeling risk-sharing policies, (4) how we evaluate risk-sharing policies, (5) simulation results, and (6) conclusions.

Risk-sharing policies

Risk-sharing policies are used by many state and local pension systems to share investment risk, longevity risk, and inflation risk among employers and employees. In pension systems investment risk refers to the uncertainty of returns from assets invested in capital markets. Longevity risk refers to the uncertainty that retirees will live longer than projected. Inflation risk is the uncertainty that the prices of goods and services will grow faster than pension benefits. Investment risk is the most significant of these three risks for most pension systems.

Depending on the design of a pension plan, the above risks are borne by employers and/or employees. The figure below (developed by NASRA, 2014) shows the spectrum of pension plan risk-sharing designs.



Source: Brainard, Keith, and Alex Brown. "NASRA Issue Brief: Shared-Risk in Public Retirement Plans," June 2014. (EE refers to employee and ER refers to employer.)

At the left end of the spectrum is the traditional defined benefit plan with only employer contributions, in which most risks are borne by employees. At the right end of the spectrum is the traditional defined contribution plan with only employee contributions, in which most risks are borne by employees. Between these two ends lie plan designs that share risks between employers and employees. Many public plans adopt some plan designs that involve risk-sharing. For example, a DC plan can incorporate COLAs that protect against inflation risk, while a DB plan can incorporate variable employee contributions to share risks with the employees. In general, risk-sharing policies fall into three categories: contingent benefits, contingent employee contributions, and hybrid plans.

With contingent benefit policies, defined benefit pension plans can link some portion of pension benefits, usually the cost-of-living adjustments (COLAs), to the plan's performance. When the pension plan's investment performance or funded status falls under a certain threshold, retirees receive lower pension benefits. When performance is above specified thresholds, benefits may be higher.

With contingent employee contributions, active employees are required to increase their contributions when the pension plan's investment performance or funded status falls under specified levels. Pension plans can also share the normal costs or the actuarially determined contributions (ADC) with employees. When performance is above specified thresholds, employee contributions may be lower.

While contingent benefits and contingent contributions are based on traditional defined benefit plans, hybrid plans aim to bring in defined contribution (DC) elements into the plan design. Hybrid plans can be a cash balance (CB) plan or a DB-DC hybrid plan. The CB plan is a defined contribution pension plan with guaranteed investment returns. The guaranteed rate of return is usually lower than the expected rate of return that is used in a traditional DB plan. A DB-DC

hybrid plan consists of a traditional DB plan (usually with a lower benefit level than in a DB-only arrangement) and a supplemental DC plan.

The table below shows several typical policy options for risk sharing and their variations. Policy option 1 is a traditional DB plan; policy option 9 is a traditional DC plan; options 2 to 8 are typical risk-sharing policy options.

Policy options	**Examples and variants**
1. Traditional DB with contributions from employees and employers	Benefits are defined by a formula (e.g. years of service × 2% × 3-year final average salary); Employers' contributions are determined by ADC; Employees may be required to make contributions; COLAs can be linked to CPI.
2. Traditional DB with contingent COLA triggered by investment returns	Same as 1, except COLA varies by investment returns Variations: COLA ranges can be different; COLA can be linked to CPI; investment returns can be smoothed over years; COLAs can have floors and caps.
3. Traditional DB with contingent COLA triggered by the funded ratio	Same as 2, except COLAs are triggered by the funded ratio Variations: COLA ranges can be different; COLA can be linked to CPI; funded ratio trigger can be different; COLAs can have floors and caps.
4. Traditional DB with contingent employee contributions triggered by investment returns	Same as 1, except employee contributions vary by investment returns. Variations: The contribution range can be different; years of low investment returns can be different; employee contributions can have floors and caps.
5. Traditional DB with contingent employee contributions triggered by funded ratio.	Same as 4, except employee contribution changes are triggered by the funded ratio. Variations: Funded ratio triggers can be different; the contribution range can be different; years of low funded ratio; employee contribution rates can be linked to the ADC or normal cost; contributions can have floors and caps.
6. Cash balance plan with guaranteed returns	Retirement benefits are determined by the notional pension account The rate of return is guaranteed. Variations: Guaranteed rate can vary (e.g., 3% to 7%); guaranteed rate can be linked to investment returns; guaranteed rate can be based on U.S. Treasury bond yields

Policy options	Examples and variants
7. Hybrid DB-DC plan with lower DB benefits and supplemental DC benefits	Retirement benefits consist of two plan benefits: -DB plan: (e.g. YOS × 1% × 5-yr FAS) -DC plan: individual retirement account with employee contributions and employer's match Variations: DB multiplier can vary; DB multiplier can be linked to years of services; employer contributions might vary; employee contributions to DC might be mandatory or voluntary; DC return rates might be guaranteed
8. Traditional DC plan with fixed contributions	Retirement benefits are determined by individual tax-deferred accounts; Both employees and employers contribute to the plan; Investment decisions are made by employees with no guaranteed returns.

Risk measurements

In public pension management, uncertainties in investment returns, mortality expectations, and inflation rates create risks for sponsoring governments that pay the required contributions, for pension systems seeking to maintain solvency, and for beneficiaries wishing to receive promised benefits.

Risks can be measured in many ways. How much risk a pension plan is subject to depends on the plan's characteristics, such as its maturity, asset position, and funded ratio. A plan's funding policies, investment policies, and actuarial practices, as well as the capital market environment, also affect the risk levels. Recent developments in the risk measurement and reporting literature in public pensions pay more attention to the use of probability-based risk measurements.

Probability-based risk measurements involve the use of forward-looking simulations to estimate the probabilities of certain values reaching levels that may be concerning. For example, measures may estimate the probability that employers' required contributions will increase by 20% of payroll over 3 years, or that the plan's funded ratio will decrease below 60%, or that retirees' benefits will drop by 10% of the original benefit level within a given period of time. Related risk measurements examine values in the tails of distributions. - For example, if the worst 5% scenario happens, what will happen to required employers' contributions, the plan funded ratio, and retirees' benefits? Investment scenarios can be developed based on plans' capital market assumptions, or hypothetical scenarios such as a low-return environment or an "asset shock" scenario (Pew, 2018)[3].

To evaluate the risks over the long term, simulations usually run over 30 to 40 years (Pew, 2018). The present values of contributions and benefits provide a long-term perspective to look at a pension plan's long-term costs and benefits. To fully evaluate the benefits over an employee's lifetime, the present value of expected lifetime benefits is a proper measurement. Risks can also be evaluated across different cohorts (that is, across employees who join the pension plan at different times). Comparison of contributions and benefits across cohorts can show the intergenerational equity implications of alternative pension policies.

Selected probability-based measurements for contribution risk, solvency risk, and benefit risk are shown in the table below.

	Contribution risk for the employers	**Solvency risk for the plan**	**Benefit risk for the members**
Probability of reaching a certain level **Or** Probability of volatility over a certain level	Probability of the employer's contribution rate increasing above a specified threshold	Probability of funded ratio dropping below a certain level	Probability of benefit decreases of at least a specified amount
Value at the tail	Employer's contribution rate in the worst 5% scenario	Funded ratio in the worst 5% scenario	Benefits in the worst 5% scenario
Long-term impact	Present value of employer's contributions over the long term	-N/A	Present value of benefits over an employee's lifetime
Intergenerational equity	Present value of employer's contributions by cohorts	-N/A	Present value of employee's benefits by cohorts

Modeling method

We examine potential impacts of selected risk-sharing policies on employers and plan members using a model that simulates a pension fund's year-by-year finances taking investment return volatility into account (i.e., a stochastic simulation model). The pension plan we model has demographic characteristics of a stylized typical U.S. public pension plan.

To run the model, we specify (1) benefit policies that determine annual benefit payouts, (2) investment return assumptions that determine annual investment returns and income, and (3) funding and contribution policies that determine contribution inflows. The baseline benefit policy includes a 1.5 percent fixed annual COLA. Inflation is assumed to be 2 percent annually, and thus the baseline policy does not keep up with inflation. We describe asset-return assumptions below. In our baseline runs, employees contribute 5 percent of payroll and the employer pays the remainder of normal cost and amortizes investment gains or losses over 15 years with 5-year asset smoothing. We calculate the plan's funded ratio and other measures each year.

A 40-year run of the model starting from a 75 percent or 100 percent funded ratio constitutes a single "lifetime" for the pension fund. We examine a stochastic scenario in which we run the model for 2,000 lifetimes, with investment returns varying within a single lifetime and across lifetimes.

The key model assumptions are summarized in the table below.

Table Key model assumptions

Demographic data and important actuarial assumptions

Initial demographics of active members and retirees	Based on Arizona SRS
Decrement tables	Mortality based on RP-2014 mortality tables Termination rates and disability rates based on averages of 5 large public plans
Salary table	Based on salary table of Arizona SRS
Annual growth in starting salary of new employees	1.5%
Age distribution of new employees	Based on the age distribution of low year-of-service employees in Arizona SRS
Benefit provisions	- Only service retirement benefit and deferred retirement benefit are modeled - Single retirement age of 60 - Benefit factor: 2.1% - Final average salary: 3 years with the highest salaries
Range of age	20-100
Starting funded ratio	75% or 100%
Valuation method	Entry Age Normal
Asset-smoothing*	5 years
Amortization*	15-year level dollar closed amortization
Employee contribution rate	Base rate: 5% of salary*
Employer contribution rate	No negative contributions (withdrawals)

* Employee contribution rates under contingent employee contribution policies can deviate from the base rate.

Risk-sharing mechanisms modeled

Using the pension simulation model described above, we simulate the following stylized risk-sharing mechanisms:

- Contingent COLA mechanisms. We examine two stylized contingent COLA policies:

- COLAs are granted only when actual investment returns are greater than the assumed return (7.5 percent) of the plan.
- COLAs are granted only when plan funded ratio, based on market value of assets, is above a predetermined threshold (90%).

- Contingent employee contribution mechanisms. We examine two stylized contingent employee contribution (EEC) policies:
  - Employee contribution rate is reduced (increased) when the actual investment returns are greater (lower) than the assumed return (7.5%) of the plan.
  - Employee contribution rate is reduced (increased) when plan funded ratio based on market value of assets is above (below) a predetermined threshold (90%).

The table below summarizes the key features and parameters of the four risk-sharing policies as we have simulated them, and lists example plans that have similar policies.

Policy type		How COLA or employee contribution (EEC) rate is determined	Single COLA rate used in valuation	Example Plan
Baseline		1.5% fixed	1.5%	
Contingent COLA policy	**Contingent on *investment return***	2% COLA if return >= 7.5% 0% COLA if return < 7.5%	1.5%	Maryland MSRPS
	Contingent on *funded ratio*	2% COLA if funded ratio >= 90% 0% COLA if funded ratio < 90%	1.5%	Arizona SRS
Contingent employee contribution policy	**Contingent on *investment return***	EEC rate ranges from 4% to EEC 7% when return in the prior year goes from 11% to 4% (EEC rate = 5% when return = 7.5%)	1.5%	Pennsylvania SERS and PSERS
	Contingent on *funded ratio*	EEC rate ranges from 4% to EEC 7% when the funded ratio in the prior year goes from 100% to 70% (EEC rate = 5% when funded ratio = 85%)	1.5%	Detroit General Retirement System (GRS)

Investment return scenarios

The risk-sharing policies are simulated under the following investment return scenarios:

- **Deterministic asset-shock scenario.** This scenario incorporates a severe adverse shock to investment returns in the second simulation year followed by a short recovery period and then returns equal to the earnings assumption over the long run. We assume that there is a 24 percent investment loss in year 2 followed by a three-year recovery period with annual returns of 12 percent, after which annual returns stay constant at 7.5 percent.
- **Stochastic scenario:** This scenario assumes that the expected long-run compound return is equal to the assumed return of 7.5 percent, with a standard deviation of 12 percent throughout the 40-year simulation period (an arithmetic mean return of 8.22% is used to achieve this). These assumptions are consistent with what other capital market assumptions we have examined. [4]

Evaluating risk-sharing mechanisms

We use the pension simulation described in the previous section to investigate how risks are shared between employers and employees through various risk-sharing mechanisms.

- **Impact on employers.** Pension funds and their sponsoring governments are mainly concerned about how risk-sharing mechanisms would affect the total pension costs and to what extent contribution volatility can be dampened.
- **Impact on employees.** Plan members (active and retired) care about their benefit levels, the protections against inflation risk through COLA arrangements, and stability of their annual benefit payments. In the case of risk-sharing employee contribution, plan members care about how much more employee contributions they will expect to make before retirement.

The table below shows main measures for four aspects of the impact of risk-sharing policies.

Impact on		Measure based on summary values in simulation groups with varying long-term average return	Measure based on probabilities of risk events
Employer	**Overall level of employer pension costs**	Present value of total employer contributions over 40-year period	-
	Volatility of annual employer contribution	Max. 5-year increase in employer contribution rates over 40-year period	Probability of employer contribution rate rising more than 10 percentage points in a 5-year period up to year 20.
Plan members	**Overall level of pension benefits.**	Present value of total pension benefits for a representative member	Probability of PV of total benefit lower than 90% (or 95%) of the level in the baseline policy with no risk-sharing.
	Stability of annual pension benefit	Max. decrease in inflation-adjusted annual benefit a representative member may experience	Probability of inflation-adjusted annual benefit falling below 90% of the starting benefit anytime in the first 10 (or 20) years of retirement.

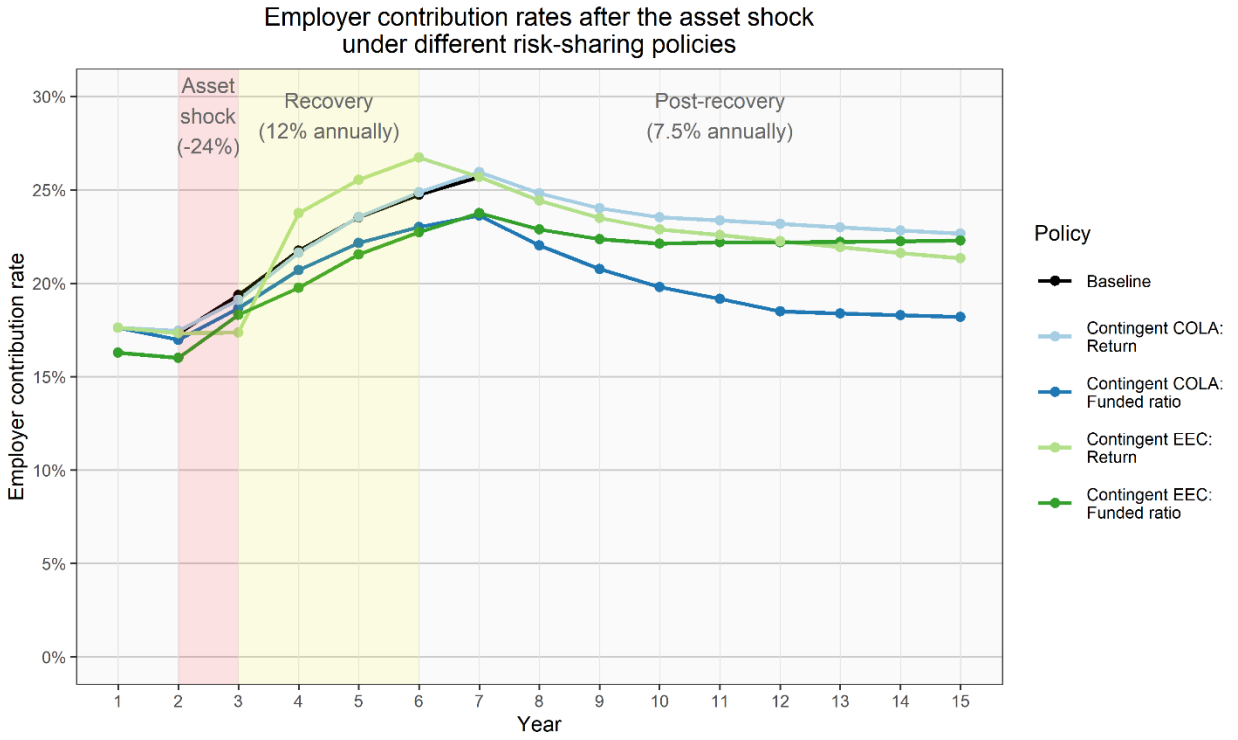
Results of deterministic asset-shock scenario

This section demonstrates how different risk-sharing policies would affect the pension costs and benefit levels under a hypothetical asset-shock scenario similar to the Dodd-Frank stress-testing scenario. Our hypothetical plan has an initial funded ratio of 75 percent, similar to typical public plans today. Our analysis focuses on the first 15 years of the deterministic asset-shock scenario.[5]

Under the two contingent COLA policies, the asset-shock causes a temporary suspension of COLA and reduces pension benefit costs, but in ways that differ depending on the trigger included in the policy. Under the return-based contingent COLA policy, only the COLA in year 2 is affected, after which the COLA resumes. Under the funded-ratio-based COLA policy, even under the scenario in which the plan earns 7.5 percent every year, there is no COLA until plan funding rises from 75 percent to 90 percent, after year 7. In the shock scenario, the plan does not achieve 90 percent funding until after year 11, and thus there is no COLA until then – the cost savings to the employer and the benefit reduction for employees, relative to baseline, do not occur until long after the asset shock.

Under the two contingent employee contribution policies, the asset shock has no impact on total pension benefit costs and only affects how these costs are shared between employers and employees.

We first examine the cost-reducing and volatility-damping effects of our stylized risk-sharing policies under the deterministic asset-shock scenario. The figure below shows the employer contribution rates under these policies during the first 15 simulation years.



Note: The line for Baseline scenario almost overlaps with the line for return-based COLA policy (the light blue line) in year 1 to 7 and overlaps with the line for return-based employee contribution policy (the light green line) in year 8 to year 15.

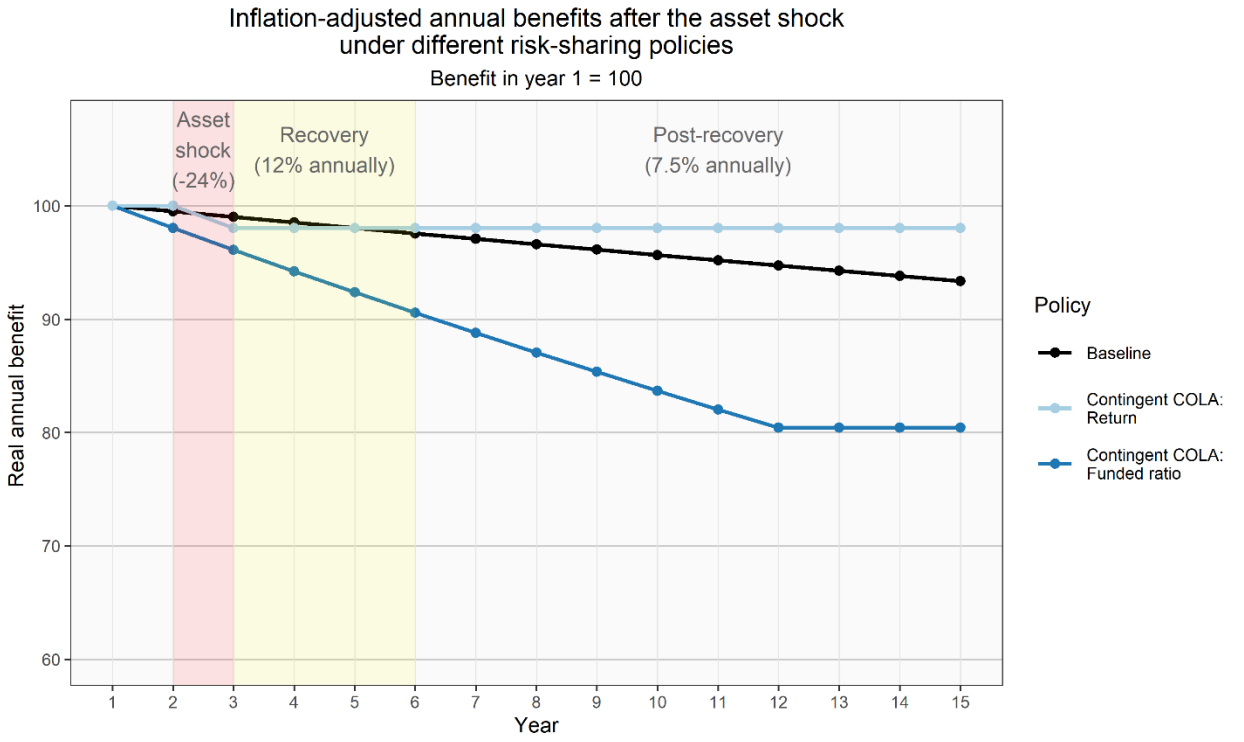
The funded-ratio-based policy has the strongest cost-reducing and volatility-damping effects as it provides zero COLA for 10 years after the asset shock. In year 10, the employer contribution rate is 19.8 percent under the funded-ratio-based COLA policy, which is 3 percentage points lower than that under the baseline of 1.5 percent constant COLA. The present value of employer contributions during the first 15 years under the funded-ratio-based COLA policy is about 9 percent lower than the amount under the 1.5 percent constant COLA.

The COLA contingent upon investment returns shows minimal effect under this asset-shock scenario because only one year's COLA is affected. In fact, the employer contribution under this COLA policy becomes even greater than that of the 1.5 percent constant COLA policy in later

years because of the increasing amortization costs generated by the difference between the 1.5 percent COLA used in the valuation and the 2 percent COLAs realized in all years after the asset shock. The effect of the return-based COLA policy is minimal in this specific deterministic scenario but may be different when returns vary, as we examine further below.

The funded-ratio-based employee contribution policy (the dark green line) shows impacts on employer contributions that are similar to the funded-ratio-based COLA policy in early years after the asset-shock, while it has higher costs afterwards as it only temporarily shifts costs to employees and does not reduce total pension benefit costs. The stylized return-based employee contribution policy (the light blue line) only reduces the employer contribution by about 2 percent in the year right after the asset-shock because the cost-sharing between employers and employees in this particular policy design only depends on the investment return in the prior year.

The risk-sharing policies' volatility-damping and employer-cost-reducing effects come at the cost of reduced benefits for retirees or higher contributions for active members. The impact of risk-sharing policies on individual retirees can be better understood by looking at the stream of inflation-adjusted benefits that reflect the true purchasing power of the payments, for a single cohort. The figure below shows the inflation-adjusted benefits starting at $100 in year 1 over the 15-year period under the two contingent COLA policies. Pension benefits under the contingent employer contribution policies are the same as the baseline and therefore are not shown below. The purchasing power of the benefit declines by 20 percent under the funded-ratio-based COLA policy.



We have demonstrated with the deterministic asset-shock scenario the risk-sharing mechanisms of different risk-sharing policies and illustrated how the additional cost caused by a one-time asset-shock is shared between employer and employees.

One important conclusion from the analysis above is that risk-sharing policies that are contingent on investment returns in a single year provide little protection against a single-year deterministic asset shock, no matter how severe, if it is followed by returns above the threshold. However, when returns can vary from year to year, the story may be different, as each year in which returns are below the threshold will result in a lower COLA or higher employee contributions. By contrast, under this return scenario, policies contingent on the funded ratio have larger impacts and for longer periods of time. The full effect of risk-sharing policies can be only understood in stochastic simulation settings, the focus of the next section.

Results of stochastic simulations

This section examines how variations in the design of our stylized risk-sharing policies translate into variations in overall **plan costs**, **contribution volatility**, **overall benefit level**, and **stability of annual benefit payments**, using metrics constructed based on the results of our simulation model.

To investigate how these policies perform under different investment return levels, we divide the 2,000 simulations into quintiles based on the 40-year compound average investment

return, and in each quintile we calculate the median value of the measures presented in the table above. By examining a 40-year period, this takes a longer-term view of the implications of risk-sharing policies. We provide details in the section on simulation results.

Ranges of 40-year compound average return in each quintile (referred to as a "return group") are:

- Quintile 1: Lower than 20th percentile (average annual return is lower than 6.54%)
- Quintile 2: 20th to 40th percentile (average annual return is between 6.54% and 7.22%)
- Quintile 3: 40th to 60th percentile (average annual return is between 7.22% and 7.89%)
- Quintile 4: 60th to 80th percentile (average annual return is between 7.89% and 8.63%)
- Quintile 5: higher than 80th percentile (average annual return is higher than 8.63%)

Impact on employers

Impact on overall employer pension cost

The overall employer pension cost under each policy is measured by the present value of total employer contributions over a 40-year simulation period.[6] The table below compares the total employer pension contribution costs under the baseline policy, the two contingent COLA policies, and the two contingent employee contribution policies in each of the five long-term average return groups as constructed in the previous section. For each long-term return group, we calculate the median employer pension costs under all policies, with the median result under the baseline over all simulations normalized to 100. The normalized group-wise median costs under the baseline policy are presented in column 1, and the percentage differences from the baseline for the results of the risk-sharing policies in each return group are presented in column 2 to 5.

We illustrate how to read the table by interpreting the first two columns. (Later tables follow the same format, so it is important to understand this one.) Our index of employer cost in the middle (3rd) quintile of returns has a median of 101.6. (The median employer cost under the baseline policy over all simulations is set to be 100.) The median employer cost index rises 32 percent to 134 if 40-year compound returns are in the lowest-return quintile and falls 31 percent to 70.2 if returns are in the highest quintile. The columns to the right show the impact of different policies against this baseline. The COLA contingent on investment returns lowers the median employer cost index by 6.1 percent in the middle quintile, by 6.5 percent in the highest quintile, and by 4.7 percent in the lowest quintile (that is, the index, not shown in the table, is 4.7 percent less than 70.2). This means that the return-contingent COLA as we have modeled it is less costly to the employer than the baseline 1.5 percent COLA in all return quintiles, in the median case, even though it has the potential to be more expensive in some

specific simulations since the maximum COLA is 2 percent. It provides its benefit to the employer mostly through lower average costs rather than through protection from return volatility – the difference between the median 4.7 percent cost reduction in the high-return quintile and the 6.5 percent cost reduction in the low-return quintile is not very great, especially compared to the variation in the baseline (the median cost index of 134 in the high return quintile is almost twice the median cost index of 70.2 in the low-return quintile). The other columns can be read similarly.

Percentage differences in PV employer contribution
from baseline by long-term return quintile
(Median values within groups)

Return quintile	Range of 40-year compound return	PV employer cost in Baseline	Contingent COLA: Return	Contingent COLA: Funded ratio	Contingent EEC: Return	Contingent EEC: Funded ratio
1	< 6.5%	134.0	-6.5%	-10.0%	-0.6%	-2.4%
2	6.5%~7.2%	110.8	-6.4%	-8.6%	-0.2%	-0.9%
3	7.2%~7.9%	101.6	-6.1%	-8.1%	0.4%	-0.1%
4	7.9%~8.6%	87.6	-5.3%	-7.2%	1.1%	0.7%
5	> 8.6%	70.2	-4.7%	-6.1%	2.0%	2.0%

The two contingent COLA policies provide moderate cost reducing-effects (-4% to -10%) compared to the baseline and the effects are stronger in low-return groups. The designs of the contingent COLA policies affect their impacts: the funded-ratio based COLA policy provides greater cost-reducing effects in all long-term return groups and its effect is more responsive to the long-term return environment (greater variation across the return quintiles). In the quintile with the lowest long-term return, the cost-reduction under the funded-ratio based COLA policy is more than 10 percent compared to the baseline, which can be a meaningful amount of pension cost savings for a plan sponsor that may suffer from low government revenues associated with the low return environments.

The two stylized contingent employee contribution policies have quite limited impact on employer pension costs (-2% ~ +2%). Note that these two particular policy designs can lead to higher employer costs in scenarios with high long-term returns as the employee contribution rates can fall below the base level when returns are good. Also, the funded ratio based

employee contribution policy is more responsive to long-term returns, for the same reasons discussed above for contingent COLA policies.

Impact on contribution volatility

We measure employer contribution volatility by the maximum increase in employer contribution as a percentage of payroll within any 5-year period of the 40-year simulation period. We calculate the value of this measure for each of the 2,000 simulations under the five policies, grouping the results into the five long-term return quintiles, and then present the median result in each return quintile for these policies in the table below.

Maximum increase in employer contribution rate in 5 years by long-term return quintile (Median values within groups)

Return quintile	Range of 40-year compound return	Baseline	Contingent COLA: Return	Contingent COLA: Funded ratio	Contingent EEC: Return	Contingent EEC: Funded ratio
1	< 6.5%	20.0%	18.9%	19.2%	21.8%	19.0%
2	6.5%~7.2%	20.1%	18.6%	18.9%	21.8%	18.6%
3	7.2%~7.9%	17.6%	16.2%	17.1%	19.5%	17.1%
4	7.9%~8.6%	16.1%	15.1%	15.0%	18.2%	14.9%
5	> 8.6%	10.9%	9.7%	10.9%	13.4%	11.5%

The results show that none of the four risk-sharing policies examined exhibits strong contribution-volatility-dampening effects measured by the maximum increase in employer contribution rates within 5 years. The two contingent COLA policies and the funded-ratio based employee contribution policies show quite limited volatility-dampening effects (about 1 percentage points lower than under the baseline). The effect of the “Contingent COLA: return” policy is slightly stronger because the annual changes in COLAs and the resulting changes in contributions under this policy are more responsive to the year-to-year fluctuations of investment returns.

The return-based employer contribution policy even leads to greater volatility in employer contributions, because its direct impact on employer and employee contribution rates is tied to annual investment returns without any smoothing mechanism, which can cause great volatility in contributions that can more than offset its volatility dampening effect.

An alternative way of evaluating contribution volatility is to examine the chance that the sponsoring government may experience sharp increases in required pension contributions in a short period of time. To construct a measure, we define "sharp increase" as the employer contribution rate rising more than 10 percent of payroll within 5 years, and use the simulation results to calculate the probabilities of such an event occurring during the first 10 or 20 simulation years under each policy scenario. The results are presented in the table below. Under the baseline policy, the plan faces a 15 percent chance that it may experience a sharp increase in employer contribution in 10 years, and the chance is more than doubled (37 percent) when the horizon is extended to 20 years. The two contingent COLA policies and the funded-ratio based employee contribution policy reduce the chance of sharp contribution increases moderately, lowering the probability to 10 to 12 percent for the 10-year horizon and to 29 to 31 percent for the 20-year horizon.

Probability of employer contribution rate rising more than 10% within a 5-year period in the first 10 or 20 years

Up to year	Baseline	Contingent COLA: Return	Contingent COLA: Funded ratio	Contingent EEC: Return	Contingent EEC: Funded ratio
10	15.2%	12.0%	10.3%	23.5%	12.4%
20	36.6%	30.9%	29.2%	48.5%	31.3%

The volatility-dampening effects shown in the two tables above are relatively small suggesting that the stylized risk-sharing policies we examined can only marginally mitigate investment-related risk for employers across the overall probability distribution of returns. However, these measures do not reveal the potential volatility-dampening effects of these policies during periods with severe asset losses, a topic we are currently analyzing.

Impact on plan members

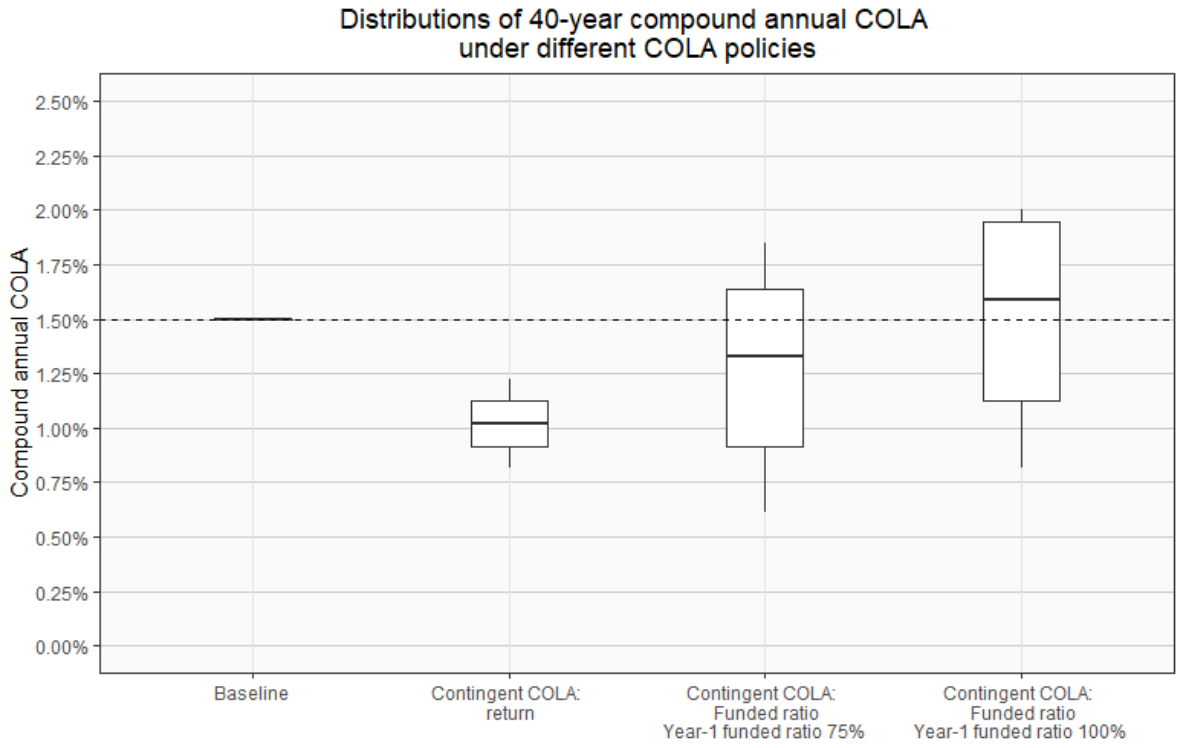
When analyzing how pension benefits are affected by risk-sharing policies, we focus on a single cohort of retirees who retire at age 60 in year 1 and potentially live to age 100 with annual attritions determined by the RP2014 mortality tables. We normalize the year-1 benefit payment to 100 and apply COLA rates generated from the simulations to determine the annual benefit payments in following years.

As the contingent employee contribution policies do not affect benefits and always have the same level of benefit as the baseline policy, we do not present results for these policies in this draft. The impact on plan members will be felt through higher contributions (lower take-home pay); we will present measures of this in a later draft. To demonstrate how the impact of the funded ratio based policy is affected by starting funded ratio, we present the results for an additional simulation scenario in which the plan starts with a 100 percent funded ratio under the funded-ratio based COLA policy.

Impact on overall level of pension benefits

Distribution of 40-year compound average COLA

Before examining benefit levels, we first show the variations in granted COLAs across policies that underlie the differences in benefits. The figure shows the distribution of 40-year compound average COLA under different policy scenarios.



Under the "Contingent COLA: return" policy, the median COLA is close to 1 percent, which is the middle point between the ceiling COLA (2 percent) and floor COLA (0 percent) in this policy, and the distribution is very concentrated around the median.

Under the funded-ratio based COLA policy, if starting with 75 percent funded ratio the median average COLA is about 0.2 percent lower than the baseline of 1.5 percent. If the plan starts with full funding the median average COLA would exceed the baseline by 0.1 percent. The difference

is largely attributable to the fact that no COLA is granted in early years when starting with a 75 percent funded ratio, which is lower than the funded ratio threshold for the COLA of 90 percent. Note that the median compound average COLAs are higher under the funded-ratio based COLA policy than under the return-based COLA policy. Besides the particular design of these stylized policies, another factor contributing to the higher COLAs under the funded-ratio based COLA policies is that the model does not allow negative contributions (withdrawal from the fund) even when a large surplus exists, which pushes upward the distribution of funded ratio over time and in turn the distribution of compound annual COLA.

Although the two funded-ratio based policies offer higher compound average COLAs in the median cases than the investment-return-based COLA policy, they cause much greater variations in average COLAs across simulations, which in turn implies greater uncertainty in benefits.

Present value of total benefit by long-term return group

We now examine how the different COLA policies translate into variations in total pension benefits plan members can expect to receive, measured in our analysis by the total present value of all benefit payments during retirement years evaluated upon retirement. When calculating the present values, the discount factor consists of two components: 1) the regular discount factor that reflects the time value of the payments and the time preferences of individuals; 2) the accumulated probability of survival at each age that reflects the chance the retiree will receive the benefit at that age. The regular discount factors are constructed using the plan's discount rate assumption of 7.5 percent.[7]

For each policy, we calculate the percentage differences in the present value of benefit from the baseline in each simulation, then divide these differences into the five long-term return groups. The table below shows the present value of total benefits under the baseline, which is constant across return groups, and the median values of the percentage differences from the baseline values in each return for the three risk-sharing policy scenarios. For example, among the simulations in the group with the lowest long-term average returns (the first row), the median difference in the present value of total benefit from the baseline under the return-based COLA policy is -5.1 percent ($1,260 compared to $1,328 under the baseline, in normalized dollar values. (Recall that $1,328 is the present value of lifetime expected benefits under the baseline policy for a 60-year old who retires in year 1 with an initial benefit of $100.)

Percentage differences in PV benefit from baseline
by long-term return quintile
(Median values within groups)

Return quintile	Range of 40-year compound return	PV benefit in Baseline	Contingent COLA: return	Contingent COLA: Funded ratio Year-1 funded ratio 75%	Contingent COLA: Funded ratio Year-1 funded ratio 100%
1	< 6.5%	1,328	-5.1%	-8.7%	-2.5%
2	6.5%~7.2%	1,328	-4.7%	-7.0%	-0.4%
3	7.2%~7.9%	1,328	-4.1%	-6.1%	0.5%
4	7.9%~8.6%	1,328	-3.7%	-5.2%	1.6%
5	> 8.6%	1,328	-3.2%	-3.7%	3.5%

Under the return-based COLA policy, the reduction in the present value of benefit ranges from 3.2 percent in the group with the highest return to 5.1 percent in the group with the lowest return, which are equivalent to losing the benefit accrual of half to one year of service for a plan member who entered at age 25.

For the funded-ratio based COLA policy, the greater variation in average COLA observed in the previous section translates into greater variation in the present value of benefit. When starting with a 75 percent funded ratio, the benefit reduction can be substantial in low return groups: the present values of benefit are 7 percent and 8.7 percent lower than the baseline in the median cases, which are equivalent to losing 1.2 to 1.5 years of service. Starting with a 100 percent funded ratio would result in much higher benefits while the variation is still large: the present value of benefit is 3.5 percent higher than baseline in the highest-return group and 2.5 percent lower in the lowest-return group, and the benefit value is similar to the baseline in the medium-return group.

Note that in the medium return group (group 3) the present value of benefit under the funded ratio based policy (75 percent starting funded ratio) is lower than that under the return-based COLA policy, while the previous section shows that that the median compound average COLA is higher under the funded ratio based policy. This is largely caused by the timing of the COLAs and the discounting of future values: because the starting funded ratio of 75 percent does not reach the 90-percent threshold for granting the COLA, benefits under the funded ratio based

COLA policy will remain low in early years, during which the benefit values bear greater weights (are less discounted) in the calculation of total present values.

Risk of low total benefit

Although the analysis in the section above provides useful information about how the impacts of risk-sharing policies vary across long-term return environments, it is not sufficient if we want to fully evaluate the risk that the benefit levels are significantly lower than what the plan members expect: showing only the median differences in benefit from the baseline within return groups ignores the variations inside the groups, which can also contribute to the risk of benefit levels.

To better evaluate the risk of low benefit levels under risk-sharing policies, we calculated the probability under each policy that the present value of benefit is lower than 90 percent or 95 percent of the baseline value. The results are shown in the table below.

Probability of present value of benefit below 90% or 95% of the level in baseline

Measure	Contingent COLA: return	Contingent COLA: Funded ratio Year-1 funded ratio 75%	Contingent COLA: Funded ratio Year-1 funded ratio 100%
Lower than 90% of Baseline	0.2%	18.5%	1.1%
Lower than 95% of Baseline	36.2%	59.2%	17.8%

Probability of present value of benefit below 90% or 95% of the level in baseline

Measure	Contingent COLA: return	Contingent COLA: Funded ratio Year-1 funded ratio 75%	Contingent COLA: Funded ratio Year-1 funded ratio 100%
Lower than 90% of Baseline	0.2%	18.5%	1.1%
Lower than 95% of Baseline	36.2%	59.2%	17.8%

Under the return-based COLA policy, it is very unlikely (0.2 percent chance) that the present value of benefit will be lower than 90 percent of the baseline value, while this would occur with a more than one-in-six chance (18.5 percent) under the funded-ratio based COLA policy with 75 percent starting funded ratio. The chances of the present value of benefit falling below 95% of the baseline level are substantial under these policies (36.2 percent and 59.2 percent). Starting with full funding considerably reduces the probability of low benefit under the funded ratio based COLA policy.

Impact on stability of pension benefits

According to several economic theories, individuals prefer a smooth and predictable path of consumption. Sharp declines in benefits or low benefits in certain time periods may cause welfare losses even if potentially offset by higher benefits in other periods.

Risk of sharp decline in inflation-adjusted annual benefit

Inflation adjusted benefits would decrease when the granted COLA rate falls short of inflation. We examine the risk of large decline in inflation-adjusted annual benefit in a short time period, which is measured by the maximum decrease in inflation-adjusted benefit within 5 years during the 41-year retirement period of the cohort.

The table below shows the median values of the maximum 5-year benefit decreases in each of the five long-term return groups under different policy scenarios. As the year-1 benefit payment is normalized to 100, the values in the table can be understood as percentage changes compared to the year-1 benefit. For example, across the simulations in the group with the lowest long-term average return (row 1), the median amount of 5-year maximum decrease in real benefit under the return-based COLA policy is 7.6 percent of the year-1 benefit. For reference, the largest possible 5-year drop in real benefit is about 9.6 percent of the year-1 benefit with our inflation assumption of 2 percent, which would occur if no COLA is granted for the first five years.

Maximum 5-year decreases in real benefit by long-term return quintile
(Median values within groups)

Return quintile	Range of 40-year compound return	Baseline	Contingent COLA: return	Contingent COLA: Funded ratio Year-1 funded ratio 75%	Contingent COLA: Funded ratio Year-1 funded ratio 100%
1	< 6.5%	-2.4%	-7.6%	-9.4%	-9.2%
2	6.5%~7.2%	-2.4%	-7.6%	-9.4%	-9.1%
3	7.2%~7.9%	-2.4%	-7.5%	-9.4%	-8.7%
4	7.9%~8.6%	-2.4%	-7.4%	-9.2%	-5.8%
5	> 8.6%	-2.4%	-7.3%	-8.5%	-2.0%

Under the baseline policy, the real annual benefit decreases by 2.4 percent every 5 years as the fixed COLA rate of 1.5 percent is half a percent lower than the assumed inflation rate of 2 percent. Under the contingent COLA policies, retirees may face much larger real benefit decreases: the maximum 5-year real benefit decreases can be three to four times as large as the baseline.

Under the return-based COLA policy, the maximum 5-year real benefit decrease only varies slightly around 7.5 across long-term average return groups, implying that large decreases in real benefit under this policy are primarily caused by short-term fluctuation of investment returns. Annual investment returns can be highly volatile in the short term regardless of the long-term market conditions, therefore the short-term benefit volatility under the return-based contingent COLA policy can be large even when the long-term market performance and the plan funded status are good.

Under the funded-ratio based COLA policy, the decreases in real benefits can be affected by long-term investment returns to a greater extent. When starting with a 75 percent funded ratio, the plan would grant no COLA before the funded ratio rises above the policy threshold of 90 percent, causing persistent decreases in real benefits in early years. The maximum 5-year real benefit drop increases slightly when moving toward groups with lower returns, in which it takes longer for the plan to reach the funded ratio threshold for COLA and it is more likely the funded ratio would fall back below the threshold.

When the plan starts with full funding under the funded-ratio based COLA policy, the maximum 5-year decreases of real benefits are substantially lower in the two high-return groups (-2 percent and -5.8 percent), in which the funded ratio is more likely to remain above the 90 percent threshold. In medium and lower-return groups, however, the real benefit decreases are close to those under the 75 percent starting funded ratio, as the impact of low long-term returns outweighs the advantage of a high starting funded ratio.

Risk of low annual benefit

We also construct a measure for the chance that retirees experience low annual benefits in certain years during retirement. “Low annual benefit” is defined as the inflation-adjusted annual benefit falling below 90 percent of the starting benefit (normalized to 100), then we use the simulation results to calculate the probabilities of such an event occurring during the first 10 or 20 simulation years under each policy scenario. “Low annual benefit” defined above results from the lack of COLA for an extended period: with the assumed inflation of 2 percent, the real benefit would fall below 90 percent of the year-1 amount if COLA is not granted for at least six years.

The table below shows that retirees may face a considerable chance of experiencing a real benefit lower than 90 percent of the starting benefit during the first 20 years of retirement.

Probability of real benefit falling below 90% of starting benefit in any year up to year 10 or 20

Up to year	Baseline	Contingent COLA: return	Contingent COLA: Funded ratio Year-1 funded ratio 75%	Contingent COLA: Funded ratio Year-1 funded ratio 100%
10	0.0%	20.3%	58.1%	16.7%
20	0.0%	94.7%	73.9%	44.4%

Probability of real benefit falling below 90% of starting benefit in any year up to year 10 or 20

Up to year	Baseline	Contingent COLA: return	Contingent COLA: Funded ratio Year-1 funded ratio 75%	Contingent COLA: Funded ratio Year-1 funded ratio 100%
10	0.0%	20.3%	58.1%	16.7%
20	0.0%	94.7%	73.9%	44.4%

Under the return-based COLA policy, the chance of experiencing low real benefit is about 20 percent in the first 10 years, and the chance rises to more than 95 percent by year 20, reflecting the great variability in annual benefits under this policy caused by the fluctuation of investment returns.

When starting with a 75 percent funded ratio, the funded-ratio based COLA policy leads to much higher risk of low annual benefits in the first 10 years compared to the return-based COLA policy (58.1 percent compared to 20.3 percent), which is the result of the lack of COLA granting in early years when the funded ratio is below the threshold of 90 percent. The risk increases at a lower rate over time under the funded ratio based COLA policy as the initial unfunded liabilities are paid off: by year 20 the probability of experiencing low annual benefit is 74 percent, which is still substantial but is about 20 percentage points lower than that under the return-based COLA policy.

Starting with a 100 percent funded ratio can greatly reduce the risk of experiencing low real annual benefit, but a probability of 44 percent by year 20 is still by no means low.

Conclusions and next steps

In this research, we use stochastic simulations to examine how risk-sharing policies affect public pension systems. Based on a review of prior studies on risk-sharing policies and risk measurements, we have developed a toolbox for risk-sharing policy options and risk measurements. Our current model focuses on contingent COLA and contingent employee contribution policy options. In upcoming analyses we will examine other risk-sharing options,

such as cash balance plans, DB-DC hybrid plans, and more-complex policies such as those in South Dakota and Wisconsin.

We have constructed several probability-based, forward-looking risk measurements to evaluate how risk-sharing policies affect risks to employers and plan members. For impacts on government employers that contribute to pension systems we measure (1) the present value of employer contributions, (2) the maximum increase in employer contributions in a 5-year period, and (3) the probability of employer contributions rising more than 10 percentage points of payroll within 5 years over the next 20 years. For impacts on plan members, we measure (1) the present value of total pension benefits, (2) the probability of total pension benefits falling below 90% or 95% of the baseline, (3) the maximum 5-year decrease in inflation-adjusted annual benefits, and (4) the probability of inflation-adjusted annual benefits falling below 90% of the initial benefit.

We examine the impacts of risk-sharing policies under both a deterministic asset-shock scenario and a stochastic asset-return scenario. In the deterministic scenario, we assume a 24 percent investment loss in year 2, followed by a three-year recovery period and constant returns afterwards. In the stochastic scenario, we use a 7.5 percent assumed rate of return and 12 percent standard deviation to construct five return groups. In the lowest return group, the long-term average annual return is below 6.54%, which is lower than the 20th percentile of investment returns in our stochastic simulation; in the highest return group, the long-term average annual return is above 8.63%, which is higher than the 80th percentile of investment returns in our stochastic simulation.

Our preliminary simulation results show that:

- The contingent COLA policies we examined, which are stylized versions of policies in current use, can moderately reduce employer pension costs in the long term and provide meaningful cost-reducing effects in persistent low return environments. The contingent employee contribution policies we examined, also styled after policies in use, have a very small impact on total employer pension costs.
- These contingent COLA and contingent employee contribution policies reduce the volatility of employer contributions only marginally.
- These risk-sharing policies could create a significant benefit risk for retirees. Retirees would face sizable variations in pension benefits they can expect to receive and could experience low benefits during retirement in low-return environments.
- The specific design of a risk-sharing policy will have large effects on its impact. For example, the impacts of the funded-ratio based risk-sharing policies vary to a greater extent across different long-term return environments and heavily depend on the plan funded status when these policies are adopted.

One important preliminary conclusion is that if employers wish to achieve significant risk reduction through risk-sharing policies, these policies would have to transfer far more risk to employees that the contingent COLA and contingent employee contribution policies examined here, which are representative of many policies currently in place. Policy makers would need to evaluate carefully the implications of this for plan members and for their attractiveness as employers.

We plan to expand our simulation model in several directions. First, we will examine the full spectrum of risk-sharing policy options, including cash-balance plans and DB-DC hybrid plans. Second, we will construct risk measurements for a pension plan's solvency (for example, the probability of a plan's funded ratio falling below a certain level). We will also examine risk measurements that reflect intergenerational equity. That is, how do risk-sharing policies affect employees who join the systems at different times, or taxpayers receiving services at different times? Finally, we will develop measures that describe the trade-offs between protecting employers from risk and protecting plan members from risk. Our study will provide valuable information to help state and local government policymakers understand potential impacts of risk-sharing options they adopt or consider.

Appendix

Valuing actuarial liability under contingent COLA policy

A single COLA is used in annual actuarial valuations done within the model. In practice, actuaries typically value plan liability with contingent COLA by using a single deterministic COLA rate that is "actuarial equivalent" to the variable future COLA. In this paper, we value plan liabilities every year using the same deterministic COLA rate across all contingent COLA policies to make comparison across policies more straightforward.

For the sponsoring governments, contingent COLAs can potentially reduce pension costs and dampen contribution volatility. Under common contingent COLA arrangements, the liabilities for retirees tend to move in tandem with the corresponding plan assets, resulting in less changes in unfunded liability and therefore smaller swings in required contributions. For example, consider a contingent COLA based on investment returns in which a 2 percent COLA will be granted if the return to the plan assets is greater than 7.5 percent in the previous year and no COLA will be granted otherwise. The plan liability is valued using a 1.5 percent deterministic COLA in each year. Suppose the realized investment return is 5 percent in the current year and therefore no COLA is granted. An actuarial loss will be created due to the investment shortfall for the next valuation year and an amortization cost will be added to the employer contribution. However, the amortization cost will be partly offset by an actuarial gain created by the difference between 1.5 assumed percent COLA used in the valuation and the actual COLA granted, which is 0. Thus, the total increase in contribution caused by the investment shortfall will be lower under the contingent COLA policy compared to under a constant COLA policy. Note that the liabilities of active members are not affected by the variations in annual COLA, as they are always valued based on the single deterministic COLA rate assumed by the plan.

Endnotes

[1] For examples of the former, see "Cost-Sharing Features of State Defined Benefit Pension Plans: Distributing Risk Can Help Preserve Plans' Fiscal Health." and "NASRA Issue Brief: State Hybrid Retirement Plans" (National Association of State Retirement Administrators, December 2017). For an example of the latter, see Dennis Bams, Peter C. Schotman, and Mukul Tyagi, "Optimal Risk Sharing in a Collective Defined Contribution Pension System," SSRN Electronic Journal, 2016, https://doi.org/10.2139/ssrn.2766486.

[2] Boyd, D., Chen, G. & Yin, Y. (2019). "Public Pension Risk-Sharing Mechanisms and Their Potential Impacts." Hutchins Center Working Paper #53. August 2019. Link

[3] Pew (2018) Assessing the Risk of Fiscal Distress for Public Pensions: State Stress Test Analysis. Retrieved from https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/AWP_92_final.pdf.

[4] Our review of a survey of CMAs used by 34 investment advisors (Horizon 2019) suggests that a 7.5 percent assumed return and 12 percent standard deviation can reasonably be achieved by an asset portfolio that allocates 54% to equities, 15% to fixed income, and 31% to alternative investments over a long term. See Horizon (2019) Survey of Capital Market Assumptions. Retrieved from https://www.horizonactuarial.com/blog/2019-survey-of-capital-market-assumptions.

[5] Including longer periods in the model would not provide relevant information about the impact of risk-sharing policies related to the asset shock during the initial years because: 1) the investment losses and gains created by the asset shock and the recovery period will have been mostly recognized and amortized by year 25; second, the assumed constant return of 7.5% after the recovery period will create little variation in COLA and employee contribution rate in longer term.

[6] An alternative measure of plan cost also includes the Unfunded Actuarial Accrued Liability (UAAL) in year 40, which represents the outstanding funding gap that eventually needs to be made up beyond the final simulation year. We did not include the terminal UAAL in our cost measure for the following reasons: 1) our analysis focuses on the realized plan costs to employers during the simulation period; 2) the terminal UAAL could be shared by the employer and employees (through contribution increases and benefit cuts) in the long term and there is great uncertainty in how the UAAL might be apportioned between the employer and employees; 3) as our model does not allow for negative contributions (withdrawal from the fund) even when large surplus exists, a large proportion of the simulations include large negative terminal UAALs (surplus), which can make the comparison across policies more difficult to interpret.

[7] To come: note about choice of discount rate