The Public Pensions Quadrilemma:

The Intersection of Investment Risk and Contribution Risk

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Abstract

Pension plans for state and local government employees seek to accomplish four main financing goals: maintain sufficient funds to pay benefits as needed; keep contribution costs low for sponsoring governments and employees; stabilize contributions from year to year, to assist in budgeting; and stabilize costs from generation to generation, a precept known as intergenerational equity. Pension trustees, actuaries and other stakeholders generally believe that, with prudent management, a plan can satisfy these goals. However, plan stakeholders appear to take this conclusion as an article of faith rather than the result of quantitative analysis.

I build a stochastic model of pension financing designed to explore the tradeoffs between plan goals. The model shows that, with regard to these financing goals, plan sponsors face a "quadrilemma": a financing strategy can satisfy one goal only at the expense of others. In particular, the level of investment risk taken by public plans today, in search of returns sufficient to lower the cost of such plans to acceptable levels, implies large variations in contributions either from year-to-year or generation-to-generation in order to maintain the ability to pay benefits under all circumstances. A plan that takes a more conservative investment strategy can attain solvency, contribution stability and intergenerational equity, but at the cost of substantially higher contribution levels. This highlights the key trade-off facing public plans between affordability and other considerations, or more broadly between risk and return.

Key words: public sector pensions; state and local government; retirement.
JEL Codes: H55, H75, H83

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1. Introduction

Most employees of state and local governments are enrolled in traditional defined benefit pension plans. A DB pension is designed to pay participant a guaranteed (or "defined") retirement benefit based on a formula, which is generally independent of the investment performance of the plan's assets.[1] By contrast, most private sector employees participate in DC pensions to which the employer may provide a contribution but makes no commitment regarding the ultimate level of retirement income the pension account may provide.

Public DB plans have become a source of policy and political controversy over the past decade as their funding health has declined and the annual budgetary contributions required for these plans have risen. While public DB plans were on average fully-funded around the turn of the century, at least using the accounting rules established by the Governmental Accounting Standards Board, they were in 2012 on average around 73 percent funded.[2] Unfunded benefit liabilities for the median state plan rose from about 25 percent of employee payroll in 2002 to about 150 percent of payroll in 2012.[3] Unfunded liabilities for state and local plans in 2012 were roughly $1 trillion. Using so-called "fair market valuation," which most economists believe provides a fuller view of the economic costs of public plans, state and local plans are on average about half-funded and unfunded liabilities top $4 trillion.[4] Fair market valuation discounts benefit liabilities at an interest rate gauged to match the risk of the liabilities; by contrast, GASB rules

[1] In a number of plans, post-retirement benefit increases or similar supplements are subject to the investment or funding performance of the plan. In very few plans are core benefits subject to alteration.

[2] Munnell et al. (2013).

[3] See Wilshire Consulting (2013).

[4] For background discussion see Biggs (2011) and Novy-Marx and Rauh (2011).

allow plans to discount liabilities using the expected return on pension assets, whose risk is significantly greater than that of the benefits they fund.

Perhaps more important in this context is that annual contributions from plan sponsors calculated under GASB rules, referred to as the Actuarially Required Contributions (ARC), have roughly doubled over the past decade, putting increased budgetary pressure on state and local governments already squeezed by the economic recession. From 2001 to 2012, average Annual Required Contributions for state plans rose from 6.2 to 15.3 percent of payroll. Rising pension costs, in conjunction with depressed revenues due to the economic downturn, have caused many of these payments to prove unaffordable. While plans on average made 100 percent of their ARC payments in 2001, it is estimated that only 80 percent of ARCs were paid in 2012.[5] Changes in budgetary costs for pensions are perhaps more important in a public policy context than summary measures of the present value of a plan's long-term benefit liabilities, as plan sponsors desire that their annual contributions be both low and stable from year to year.

At the same time, many public plan stakeholders view government-run DB pensions as having large efficiencies relative to other modes of pension provision, such that limiting or eliminating them would harm public employees and taxpayers alike. According to this view, the long-run nature of public plans – in terms both of investment holding periods which last from the time an employee is hired until he or she dies, and of the infinitely-lived nature of (most) governments – allows such plans to claim the risk premium built into equities and other investments while shielding plan sponsors from much of that risk. Public plan stakeholders argue that long-term nature of pension plans, combined with policies designed to exploit the long term, such as smoothed investment returns and long amortization periods, largely negate the market risk embedded in public plans investment portfolios. This article examines the degree to which these beliefs are correct.

[5] Munnell, et al. (2013).

Despite rising costs in recent years, many stakeholders believe that public plans can generate relatively generous, guaranteed benefits for participants while levying on sponsors contributions that are both relatively low and stable. A pressing question for pension sponsors is the degree to which this combination is possible. Ordinary investors face a trade-off between risk and return, which in the context of funding a fixed future liability means that the investor must choose between either low contributions or stable contributions but cannot have both. Public plans, by contrast, are believed to benefit from long time horizons. In discussions of state and local employee pensions, the phrase “long term” comes up often: plans rely on “long term” investment returns, whose risk characteristics are believed to differ substantially from the year-to-year fluctuations observed in financial markets. Likewise, public plans themselves are “long term” institutions that, unlike private pensions, need not consider the possibility of their sponsor becoming insolvent. These beliefs about the “long term” are foundational in explaining why public plans take greater investment risk than private pensions, and why public plan accounting standards pay so little attention to that risk.

Public employee pensions share with all retirement plans the goal of helping employees better prepare for retirement, which in a life cycle context means amassing sufficient assets over the course of a working career so as to provide a smooth path of consumption between work and retirement. Financial advisors often summarize this process in terms of replacement rates, which represents retirement as a percentage of pre-retirement earnings. Because the cost of living is generally lower in retirement, financial advisors generally recommend that a replacement rate of 70 percent of pre-retirement earnings is sufficient for an individual to maintain his pre-retirement standard of living.

But public plans share large-scale financing goals that are distinct from those of the DC plans that predominate in the private sector. There are four major financing goals that concern public plan trustees, elected officials and other stakeholders such as public employees, taxpayers and holders of municipal debt. These goals include:

Solvency: For any given time period the plan should maintain sufficient funds to pay benefits owed in that period. Benefits are a promise made to employees over their careers and in many cases are guaranteed by state laws or constitutions. The American Academy of Actuaries states, "The policies established to fund the pension plan should be premised on the assumption that the obligation to provide the promised benefits must be met."[6] Stakeholders are understandably very leery of any scenario in which there is a possibility the plan will be unable to pay benefits as scheduled.

Affordability: Pension contributions constitute a significant portion of government budgets and, like any other budget line-item, must compete against the government's other spending priorities as well as desires to limit the tax burden imposed on the public. While rarely stated overtly, plans aim for affordability by investing pension funds in assets with high expected returns. Pension liabilities and the contributions necessary to fund them rise or fall by around one-fifth for each percentage point change in the assumed return on the plan's investments. Thus, a plan that achieved 8 percent returns on investment – a typical target for public plans in the U.S. – operates at roughly half the contribution cost of a plan that held riskless U.S. Treasury securities. This desire for affordability helps explain public plans' historical shift from fixed income investments to equities and, more recently, the rapid increase in so-called "alternative investments" such as hedge funds and private equity. Of course, higher expected returns are accompanied by higher risk.

Cost stability: Policymakers desire that large items in state and local budgets do not fluctuate in cost from year to year, as this makes budget planning more difficult. As the American Academy of Actuaries put it, "Significant changes in the contribution amount from one year to the next can have significant repercussions on other parts of the budget, particularly if those changes require an increase that is not or

[6] American Academy of Actuaries (2014).

cannot be anticipated."[7] Worse still are costs that rise and fall with the economy, as these can place larger revenue demands on plan sponsors at times when the economy is weak and tax revenues are scarce.

Intergenerational equity: This precept means, in GASB's terms, that "taxpayers of today pay for the services that they receive and the burden of payment for services today is not shifted to taxpayers of the future." GASB illustrates this concept with such terms as "living within our means" and "fairness."[8] Under certain simplifying assumptions, which will hold in our model, perfect intergenerational equity would mean that each generation of taxpayers would pay the same rate of taxation to support plans.[9]

Pension trustees, actuaries and other stakeholders generally appear to believe that, with prudent management, a plan can satisfy these goals. However, plan stakeholders appear to take this conclusion as an article of faith rather than the result of quantitative analysis. Washington's State Actuary has for a number of years conducted an in-depth analysis of plan financing that includes Monte Carlo simulations and other techniques for analyzing funding risk. The California Public Employees Retirement System (CalPERS) this year added a "Risk Analysis" section to its actuarial valuations, and has for several years published a separate report on funding risk. In other states and municipalities, such analysis is more rudimentary or non-existent. And very little emphasis is placed on this material in discussions of pension policy with elected officials or the public.

Moreover, discussions of plan financing often include references that many experts in the field consider dubious, such as a reliance on the "long term" nature of plans as a rationale for downplaying or ignoring the effects of investment risk. For instance, Madland and Bunker (2012) refer to public DB plans' "ability to maximize returns over a long time horizon… When accounts of both older and younger workers are pooled together, the fund manager can shoot for a higher return as the plan has a much longer

[7] American Academy of Actuaries (2014).
[8] GASB (2009).
[9] These simplifications can include the assumption that retirement periods do not rise relative to the length of working careers.

investment time horizon."[10] It is not clear, however, why pooling funds for different cohorts would lead to an investment strategy that differed from an age- and size-weighted average of the strategy that would be appropriate for a single cohort.[11]

Similarly, the AARP states that "because pension plans invest for very long time horizons, they are able to diversify their portfolios across broad time periods, and can better withstand market swings."[12] The National Association of State Budget Officers (2012) states that "Pension plans typically have long time horizons, which allow investment gains or losses to be smoothed out over a period of years and unfunded liabilities to be amortized."[13] Gary Findlay (2009), executive director of the Missouri State Employees Retirement System, states that "the objective that is stipulated by law is to have contribution rates that remain relatively level over decades of time because we are a plan with very long time horizons."[14]

Yet, many experts doubt this notion of "time diversification." [15] While one common measure of investment risk – the standard deviation of annualized investment returns – declines over longer holding periods, the standard deviation of investment wealth increases because the effects of a longer holding period trump the effects of a lower standard deviation of annual returns. Put another way, while the likelihood of falling short of a given goal declines over long time periods, the size of the shortfall contingent on falling short increases.

To provide greater insight into the degree to which public plans can accomplish their four principle financing goals, this paper constructs a simple but flexible model of public pension financing.

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[10] Madland and Bunker (2012).

[11] For instance, imagine that a single individual or cohort of individuals followed an investment rule in which the percentage equity share of their portfolio equaled 100 minus the individual/cohort's age. Pooling individuals or cohorts of different ages together would not necessarily lead to an optimal portfolio that contains a higher equity share than implied by this 100-minus-age rule of thumb.

[12] AARP (undated).

[13] National Association of State Budget Officers (2012).

[14] Keller (2009).

[15] See for instance Samuelson (1997) and Bodie (1995).

The model simulates the effects of investment risk on annual pension contributions, over both the short and the long term. Risk is generated via stochastic investment returns, while the effects of portfolio risk on contributions are muted via stabilization policies that smooth investment returns and amortize unfunded plan liabilities over multiple years.

This type of analysis is particularly useful given the significant changes that have taken place with regard to pension financing over the past several decades. Public plans today are generally far larger relative to the budgets of their sponsors: in 1975 state and local pension assets were equal to only 49 percent of annual government expenditures, according to data from the Federal Reserve's Flow of Funds and the Census Bureau's data set on state and local government finance. Today, pension assets have nearly tripled to 143 percent of government outlays. Moreover, the risk of pension funds has risen significantly: to generate an expected return of 8 percent, a pension fund today must hold a portfolio with a standard deviation of about 14 percentage points; due to higher riskless interest rates, in 1975 a similar 8 percent return could have been achieved with a portfolio standard deviation of around 3.7 percentage points. Thus, what we might term "pension funding risk" – that is, the standard deviation of pension investments measured as a percentage of plan sponsor budgets – has risen significantly over the past four decades.[16] In other words, public plans today are a "different animal" than in the past, and thus inferences based upon past practices or patterns may not apply to the future. Explicit modeling of today's pensions may provide better insights.

This model also generates answers to more general questions such as: To what degree do investment returns "settle down" over the long term, allowing for a relatively stable contribution rate? How much do smoothing and amortization policies allow plans to dampen or eliminate the effects on required contributions of shorter-term fluctuations in portfolio returns? Is a plan that makes its full required contributions each year effectively protected against insolvency? How high might those

[16] Biggs (2013).

contributions go, and how might they affect state or local government budgets? And what are the implications for plan solvency if sponsors cannot or will not make their required contributions each year?

2. Modeling plan finances

Actuaries who conduct valuations of public plans must model a wide range of variables and simulate the plan population in great detail. This may make such models unwieldy in conducting the type of analysis undertaken here. As a result, such analysis – which is more important to the sustainability of public plans – may not be undertaken.

The model presented builds on Hamilton (2007), with improved treatment of amortization methods and investment return smoothing. Relative to the types of models used by plan actuaries, the model presented here makes two major simplifications that allow for more robust analysis of the effects of investment risk on annual contributions. First, the model focuses on a mature pension plan, meaning one which is in a steady state in terms of employees and beneficiaries. This assumption greatly simplifies the modeling of the participant population, as in a mature plan benefits remain constant relative to payroll from year to year. In the absence of market risk, we can easily calculate the contributions, assets and investment returns necessary for the plan to remain adequately funded in perpetuity.

Second, the only risk the model analyzes is investment risk. In reality, plans face variations in a number of factors, such as longevity, retirement ages, the incidence of disability, and so forth. Modeling these risks demands a far greater level of detail. But the model presented here is adequate for the task, as variable investment returns are by far the greatest risk facing public plan finances. If plans are unable to adequately handle investment risk, adding other risks only heightens the burdens on plan sponsors and stakeholders.

We begin with a steady state contribution rate based upon plan attributes, including a constant investment return.[17] Each plan is different, but for illustration we use parameters that are reasonably typical of most public plans, based upon figures from the Public Plans Database maintained by the Center for Retirement Research at Boston College. In our analysis, benefits are assumed to be equal to approximately 28 percent of payroll, assets are 4.3 times payroll, nominal investment returns are 8 percent and nominal payroll growth is 4.1 percent.[18] Given these inputs, an annual contribution rate of 11 percent of payroll would be sufficient to maintain the program's funding such that benefits could be paid while the plan's assets would neither rise nor fall relative to the wage base.

We assume that employees pay 6 percent of wages into the plan while the plan sponsor pays 5 percent. Once returns are allowed to vary, the employer also will be responsible for any additional contributions needed to address unfunded liabilities; the plan sponsor and potentially employees may benefit from reduced contributions if the plan becomes overfunded. [19]

Shifting now to a situation in which asset returns can vary, the steady state contribution rate is supplemented by an amortization payment designed to return the fund's assets relative to payroll to its steady state level. In simple terms, the contribution rate at any given time is equal to the steady state

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[17] Equation 1. $SSC = PGR - \mathrm{A}\, x \left[\frac{R-g}{1+g}\right]$ where *SSC* represents the steady state contribution rate (as a percent of payroll), *PGR* is the pay-as-you-go program rate, meaning the ratio of benefits paid in a year to payroll in that year; *A* is the plan's asset as a percentage of payroll; *R* is the assumed return on the plan's investments; and *g* is the growth rate of payroll.

[18] Payroll growth is composed of price inflation at 2.5 percent and combined individual wage growth and workforce growth of 1.6 percent.

[19] There are some plans, such as Nevada PERS, in which employees share in paying amortization costs; in others, such as Wisconsin, post-retirement benefit increases are contingent upon plan financing. In these cases, risk is shared between employers and employees. In most cases, however, risk is formally borne by the plan sponsor and transmitted to employees only indirectly, such as through lower wage increases.

contribution plus or minus an amortization payment based upon the difference between the fund's actual balance and its steady state balance.[20]

In most cases, public plans today amortize funding discrepancies on a "level percent of payroll" basis, which means that amortization payments rise annually with the growth of the plan's wage base.[21] This produces a lower payment than if amortization were calculated on a "level dollar" basis, in which case the amortization interest rate is equal to the plan's assumed investment return. Some plans do amortize on a level dollar basis, which produces higher initial payments but lower payments in later years.

In all cases, the model calculates amortization payments on a "rolling basis," in which payments are recalculated each year. Most plans follow this practice, though many amortize each year's funding discrepancy over a finite period. Rolling amortization requires slightly lower payments because, in theory, amortization of a given dollar of over- or underfunding extends indefinitely. In practice, however, rolling amortization of a given dollar of funding discrepancy in year 0 restores the fund to very close to its target level by year 30. It also is more manageable from a modeling standpoint, so we assume that all plans follow rolling amortization.

In addition, most plans practice "smoothing" of investment earnings, which creates a distinction between the market value of the plan's investments and an "actuarial value" that is used to determine contribution rates. Investment income attributed to the plan's actuarial investments is a function of average investment returns over a number of prior years, generally five but sometimes as many as fifteen.[22] Since contributions are based upon actuarial assets, this approach serves to smooth contribution

[20] Equation 2. $C = SSC + \frac{A_t - A}{\left\lfloor \frac{1-\frac{1}{(1-i)^N}}{i} \right\rfloor}$. The upper term A_t-A represents the difference between the plan's assets at time t and its steady state assets (both relative to payroll). This different is the funding discrepancy to be amortized. The lower term calculates how that difference is amortized over time; N represents the number of amortization years (generally 30) while i represents the implicit interest rate at which funding discrepancies are amortized.

[21] Thus, in most cases i in Equation 2 will be equal to $(r - g)$, that is, the difference between the plan's assumed return on investment (in the stylized case, 8 percent) and the growth of payroll (4.1 percent).

[22] Discussion of various smoothing methods is available in Winklevoss (1993).

rates as well. Thus, A_t in Equation 3 is the actuarial or smoothed value of plan assets, not the market value. In conducting solvency tests later, however, such tests are calculated using the market value of plan assets.

The model can be extended over any desired period, depending upon what the investigator considers to be the "long term." In most cases we report results over a 100-year period for ease of understandability.

The model simulates investment returns using a Monte Carlo approach in which the computer generates investment returns that are individually random but which collectively are illustrative of the portfolio held by a public plan. In most cases, the plan's average investment return will be 8 percent and the standard deviation of investment returns is 13 percent. This latter figure determines the distribution, or risk, of the plan's investments. Both the mean return and investment risk are broadly typical of assumptions made by U.S. public plans. While each individual investment outcome is random, the distribution of investment returns – and the effects on plan funding and contribution rates that such differences imply – provide information regarding the level of contribution risk faced by plan stakeholders. Typically the model is run 500 times. This is a relatively simply modeling of investment returns, but it appears to be sufficient for the task.[23]

3. Model results

Before analyzing pension financing plans' ability to achieve their goals, we first briefly discuss the model's results with regard to investment returns and risk over the long term. This seems worth touching on, given the role that beliefs about long-run investment returns play in shaping pension

[23] For instance, the risk model used by CalPERS simulates investment returns in greater detail; however, CalPERS's chief actuary represents that this additional modeling detail does not material affect the results. (Personal conversation.)

financing policy. For each model run, we measure the geometric mean investment return, or compound return, which best expresses the effect of investment returns on plan financing.

The median 100-year compound return generated by the model is 7.1 percent. By itself this lower return will have a significant upward effect on average plan contributions. The difference between this model-generated typical return and the assumed return of 8 percent derives from how they are defined. Most pension plans estimate their investment returns as arithmetic means. The arithmetic mean is the sum of annual percentage investment returns, divided by the number of years. For instance, if the return is 20 percent in Year 1, -10 percent Year 2, and 20 percent in Year 3, the arithmetic mean return will be 10 percent. In practice, however, the more important measure for pension financing is the geometric mean, or compound, return. The geometric mean better accounts for the fact that, if a plan loses some given percentage amount in one year, the lower base value of the fund means that it must earn a larger percentage gain in the following year to make up the loss. In our example above, the geometric mean return for the three years is only 9 percent. Pension financing is not concerned with rates of return so much as assets and liabilities, and so the contribution rate adjusts upward to keep assets and liabilities on track. Thus, a contribution rate calculated using an arithmetic mean return is likely to understate the actual contribution rate that plan sponsors must pay. This distinction is one reason why the Society of Actuaries Blue Ribbon Panel on pension financing (2014) recommended that investment return assumptions for pensions be based on geometric rather than arithmetic mean.[24]

Exhibit 1. Distribution of 100-year investment returns and implied average contribution rates

Percentile	Geometric mean return	Average contribution rate
5%	4.6%	25.0%
10%	5.1%	23.0%
25%	6.1%	18.8%
50%	7.1%	14.7%
75%	8.0%	11.0%
90%	9.0%	6.9%
95%	9.4%	5.2%

Based upon annual mean of 8 percent and standard deviation of 14.3 percent.

Exhibit 1 shows that investment risk remains significant even over long holding periods. While the typical long-run return is 7.1 percent, the interquartile

[24] Society of Actuaries Blue Ribbon Panel (2014).

range is from 6.1 to 8.0 percent; this latter figure denotes that plans have only a roughly 25 percent chance achieving the return on which their baseline contribution rates are calculated. Plans have an equal chance of receiving a return nearly two percentage points below their baseline rate. Going further, the model generates returns below 5.1 percent in 10 percent of simulations and below 4.6 percent in 5 percent of simulations. On the opposite side, average 100-year returns are 9.0 and 9.4 percent with the same probabilities.

When these returns are applied, steady state contributions can vary significantly. For instance, at a 6.1 percent average return the baseline contribution would rise from 11.0 percent to 14.7 percent; assuming a 5.1 percent average return, the contribution would increase to 18.8 percent. This type of very simple analysis, which is rarely made public by plans, shows that even over the very long term significant risks to plan sponsors and taxpayers remain. However, such an analysis does not provide any detail regarding other policy goals pursued through pension financing strategies. For this we turn to more details results from the financing model.

The model by itself does not tell us how well public plans' financing strategies are likely to accomplish their goals of Solvency, Affordability, Contribution Stability, and Intergenerational Equity. To do so, we must establish criteria for measuring these goals and set numerical standards for how they may be satisfied. These summary measures include:

- *Solvency probability*: Measures whether the plan's fund becomes insolvent over a given period, generally 100 years. Most plan stakeholders, including trustees, elected officials, public employees and taxpayers, grow uneasy when the plan has *any* chance of becoming insolvent. For that reason, we set the Solvency Probability criterion at 100 percent: this means that in none of the 500 simulations should the plan's fund be exhausted over a 100-year period, implying a probability of insolvency of less than 0.2 percent over 100 years.

- *Affordability*: Affordability in this context reflects the realized cost of the plan in a world with fluctuating asset returns relative to Steady State Costs calculated when returns are assumed to be constant. We deem a plan to be Affordable if its average 100-year cost is in 75 percent of the model simulations within 10 percent of the Steady State Cost calculated when returns are held constant. This measure helps stakeholders determine whether the plan is likely to be financially sustainable by its sponsors. Thus, a plan with a Steady State Cost of 11 percent of payroll, as ours has, would be considered affordable so long as the simulated cost was less than 12.1 percent of payroll in at least 75 percent of modeled outcomes.
- *Annual contribution volatility (ACV)*: Measures the variation in employer contribution rates from year to year, meaning the average absolute value change in required contribution rates from one year to the next. The ACV is measured relative to payroll, so any contribution increase due to a growing workforce or rising wages is excluded. Thus, for instance, an increase in employer contributions from 6 to 7 percent of payroll would have an ACV value of 1, as would a reduction in contributions from 11 to 10 percent. A low ACV value reflects stable contributions from year to year. We assume that plan sponsors would not wish for their contribution rates, relative to payroll, to vary by more than 10 percent from one year to the next. Thus, if the plan's baseline contribution rate is 11 percent of payroll in Year 0, an increase or decrease of less than 1.1 percentage points to Year 1 would satisfy this criterion. While the 10 percent standard is somewhat arbitrary, for context we pay point to the California Public Employees Retirement System (CalPERS). In 2005, CalPERS enacted an actuarial measure intended to reduce contribution volatility; since that time, the ACV as applied to CalPERS contribution rates averaged 5 percent.[25] Thus, 10 percent does not seem an overly restrictive standard.
- *Intergenerational equity:* We measure intergenerational equity through variation in lifetime tax rate, taken as the average employer contribution over rolling 25-year periods. We assume that

[25] See McDaniel (2005).

plan sponsors would not wish for one generation of taxpayers to pay dramatically more than another. However, because intergenerational equity is so infrequently measured, it is difficult to find reference values for what might constitute a reasonable, generationally-fair variation in lifetime tax rates. For these purposes, we assume that intergenerational equity is satisfied if the 75th percentile of taxpayers (those paying the highest lifetime pension tax rates) *on average* pay lifetime tax rates no more than 1.5 times higher than taxpayers at the 25th percentile.[26] For instance, intergenerational equity would be considered satisfied if the 75th percentile paid a lifetime pension tax rate of 15 percent of wages while the 25th percentile paid a lifetime tax rate of 10 percent of wages. This criterion does not mean that in no instance can the ratio of lifetime tax rates for the 75h/90th percentiles exceed 1.5; rather, it states only that the average of these ratios over 500 simulations cannot be greater than 1.5. Moreover, the ratio of lifetime taxes at, say, the 90th and 10th percentiles may be substantially larger. Thus, to the author this appears a relatively forgiving standard for satisfying intergenerational equity.

In addition, we track several other outcome variables. These include average investment returns over 100 years; the average contribution rate over 100 years; the average maximum contribution rate in each 100-year period.

The numerical satisfaction values assigned to each of these criteria are obviously subjective and readers may come to different judgments regarding appropriate values. For that reason, in the following section we report both whether the plan satisfied each criterion as well as the actual value calculated by the model.

[26] For each 100-year period, lifetime tax rates are calculated as the average employer contribution rate over 76 overlapping 25-year periods. For each 100-year period, the model calculates the 75th and 25th percentile lifetime tax rates. The model simulates 100-year periods 500 times, and the 75th and 25th percentile lifetime tax rates are averaged and expressed as a ratio. If the rate exceeds some target value, in this case 1.5, the financing strategy is said not to satisfy intergenerational equity.

Simulation specifications and results

For each simulation, we outline the specifications and the results. In addition, extended discussion is added where appropriate to highlight points of interest raised in the simulation. The model is specified as follows. The Steady State Contribution is equal to 11 percent of employee wages, assuming a constant annual investment return of 8 percent, implying an employer contribution of 5 percent of wages and employee contribution of 6 percent of wages. The employee wage base is assumed to rise at 4.1 percent annually. Once returns are allowed to vary, it is assumed that the standard deviation of annual returns is 14 percent. To achieve an 8 percent expected return today, a pension must build a portfolio with a standard deviation of returns of around 14 percent.[27] Funding surpluses or deficits are calculated based upon actuarial assets, using five-year smoothing of investment returns. Surpluses and deficits are amortized over 30 years on a level percent of payroll basis. For Simulation 1, we assume that both employee and employer contributions are always made, regardless of how well-funded the plan becomes. The model is run 500 times to test the effects of investment risk on the plan's ability to fulfill its stakeholders' financing goals.

In Simulation 1, the plan's fund becomes insolvent in none of the 500 100-year simulations conducted, meeting the goal for solvency. (Exhibit 2.) The average employer contribution rate, however, was 9.6 percent of payroll, nearly double the static employer cost of 5 percent of payroll and the more forgiving affordability goal of averaging less than 6 percent of wages. In other words, in a real world of

Exhibit 2. Results of Simulation 1

	Goal	Actual	Met?
Insolvency probability less than or equal to	0.0%	0.0%	Yes
Average Employer Contribution Rate Below	6.0%	9.6%	No
Annual Contribution Volatility Below	10%	17%	No
Lifetime tax rate ratio (75th/25th percentiles)	1.5	1.6	No

[27] Most plans, to the degree they report investment risk, assume a portfolio standard deviation of 12–13 percent. However, a significant number of investment consultants believe that current public pension portfolios have expected returns significantly below 8 percent. For instance, in a recent survey, eight investment consultants projected that a typical public plan portfolio would return only around 6 percent over the next 15 years. No consultant projected average annual returns in excess of 6.9 percent. See Rizzo and Krekora (2013).

fluctuating asset returns employer contribution costs would on average be 56 percent higher than a standard actuarial forecast that ignored investment risk would conclude.

Second, in Simulation 1 the plan sponsor must always pay a minimum contribution of 5 percent of payroll and can never take contribution holidays, regardless of how well-funded the plan might become. Thus, the plan sponsor can contribute no less than 5 percent of payroll but at times may be required to contribute substantially more. This will produce an average contribution higher than 5 percent, We will relax this assumption in following simulations to allow for reduced contributions should the plan become over-funded.

The Annual Contribution Volatility measure averages 17 percent, meaning that on average contributions rise or fall by 17 percent from one year to the next. This value is above the goal that contributions should vary by no more than 10 percent from year to year.

Intergenerational equity is measured through the ratio of the 75th percentile of lifetime tax rates to the 25th percentile, with the goal that the 75th percentile of taxpayers pay no more than 1.5 time the average lifetime taxes as the 25th percentile. Over the 500 simulations, the average 75th/25th percentile ratio equals 1.6. The average 75th percentile lifetime tax rate is equal to 11.9 percent of wages while the average 25th percentile lifetime tax rate is 7.8 percent.[28]

These results show that defined benefit pensions do not make risk disappear. Rather, that risk is transferred to taxpayers and may in certain cases extend over protracted periods of time. On the other hand, a number of generations of taxpayers pay no more than the Steady State Contribution over their full working lifetimes; indeed, in the absence of requirement that employees and employer always make the minimum contribution, many generations could pay substantially less. We will explore that question in Simulation 2. In summary, however, we can say that the stylized plan explored in Simulation 1 fails to satisfy three of the four financing goals outlined in the opening of this paper.

[28] The average of the 75th/25th ratios exceeds by a small amount the ratio of the average 75th/25th percentile.

In Simulation 2, we relax the requirement that employers make the full 6 percent of payroll contribution to the plan each year, while retaining the customary requirement that employees always pay their mandatory 5 percent contribution. Simulation 2 is thus closer to reality, in that both actuarial practices and actual events allow for plan sponsors to reduce or skip contributions should they become overfunded. The same smoothing and amortization rules are applied when the plan is in surplus as when it becomes underfunded. In other respects, Simulation 2 is identical to Simulation 1.

Exhibit 3 shows the results of Simulation 2. As in Simulation 1, the plan does not become insolvent in any of the 500 simulations. This leads to a more general point which appears to hold throughout a range of specifications: so long as the plan *always* makes its full contribution, as calculated using reasonable rules for amortization and smoothing, it is very unlikely to become insolvent. The importance of this result will be explored in greater detail in Simulation 3.

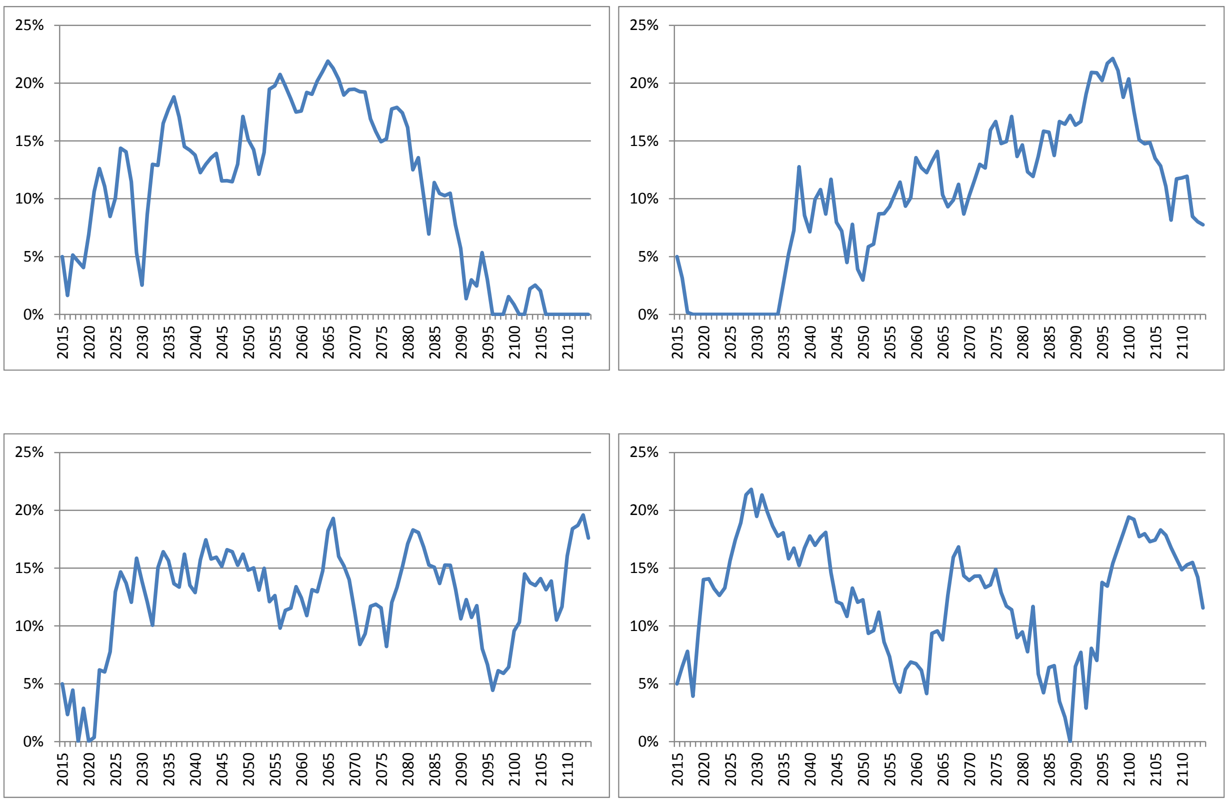
Exhibit 3. Results of Simulation 2			
	Goal	Actual	Met?
Insolvency probability less than or equal to	0.0%	0.0%	Yes
Average Employer Contribution Rate Below	6.0%	9.0%	No
Annual Contribution Volatility Below	10%	25%	No
Lifetime tax rate ratio (75th/25th percentiles)	1.5	1.9	No

The average employer contribution rates in Simulation 2 fall to 9.0 percent, versus 9.6 percent in Simulation 1. This is due to the allowance that employers may reduce contributions when the plan becomes overfunded. Nevertheless, this remains well above the steady state employer contribution rate of 5 percent of payroll, and does not satisfy the Affordability goal of 6 percent of wages.

Average contribution volatility, however, increases significantly relative to Simulation 1 – and for the same reason: allowing for reduced employer contribution rates increases the variation in contributions from year to year. In Simulation 2 the average year-to-year difference in employer contribution rates rises to 25 percent, from 17 percent in Simulation 1. As the threshold value is 10 percent, Simulation 2 does not satisfy this criterion.

To provide a more intuitive view of how contributions may vary from year to year, Exhibit 4 contains four single mode runs based upon Simulation 2. As noted above, no single simulation is by itself meaningful. For instance, one simulation may have a higher average contribution rate than another. But the simulations resemble each other much more closely in terms of the variation in required employer contributions over very short periods of time.

Exhibit 4. Examples of single simulations of employer contribution rates, based upon Simulation 2.



In addition, the provision allowing the plan sponsor to reduce contributions when the plan is overfunded leads to increased differences in lifetime tax rates, undermining the goal of intergenerational equity. In Simulation 2, the 75th percentile lifetime tax rate is 12.1 percent, versus 6.4 percent at the 25th percentile, resulting in a ratio of 1.9. Thus, while allowing for reduced employer contributions lowers the average contribution rate, it also appears to undermine intergenerational equity and increase contribution volatility.

Simulation 3 explores in greater detail the issue of contribution volatility, in particular what happens if annual contributions grow so high that sponsors are unable to make them. This is an important consideration in light of the increase in both the size of public plans and the risk of their investments. As a result of this trend, high contribution years will tend to demand larger contributions relative to the sponsor's tax base than when pensions were smaller and took less investment risk.

For instance, in Simulation 2 the average employer contribution rate is 9.0 percent of payroll. However, on average one out of every 10 years the contribution rate exceeds 13 percent. Moreover, there was one simulation of the 500 – occurring, therefore, with a roughly 0.2 percent likelihood – in which the average contribution rate over the full 100-year period was 22 percent. A sponsor that initiated a plan based upon the expectation of a 5 percent typical employer contribution – which is what would be reported from a typical actuarial analysis – may not be able or willing to support a plan in the event it cost so much more than forecast.

Exhibit 5. Payment of Actuarially Required Contribution, 2010

ARC as % payroll	Percentage paying full ARC	Average percent of ARC paid
10%	62%	95%
20%	44%	81%
30%	24%	81%
40%	33%	88%
All	46%	84%

Source: Author's calculations, from Public Plans Database.

Exhibit 5 is based upon data from the Public Plans Database for 2010 (the most recent year for which complete data were available), detailing how the size of plan ARCs relative to plan payroll corresponds with the plan sponsor making the full ARC. As might be expected, as the ARC rose the percentage of plans making full payments declined. Within these averages, however, were some plans that paid a substantial portion of the ARC, but not the full payment, and others who made no or only a small payment.

We model these dynamics in simple terms to illustrate the effects of plans failing to make large annual pension contributions. Simulation 3 maintains the assumptions of Simulation 2 but introduces a cap on employer contributions at three times the steady state contribution rate. Thus, in our example, the steady state employer rate is 5 percent of payroll so we set the cap at 15 percent. Including the 6 percent employee contribution, total contributions are limited to 21 percent of payroll. Employers will not skip contributions, as some plan sponsors have; however, they will contribute only up to the annual cap but no further.

The results of this contribution cap are apparent in the solvency results: whereas in previous simulations the plan never became insolvent, once employer contributions are capped at 15 percent of payroll the plan becomes insolvent in 32 percent of the simulations. Simulation 3 fails the affordability and contribution volatility tests as well. The cap does bring intergenerational equity very close to the standard. However, given that the plan would become insolvent over nearly one-third of the 100-year scenarios, this measure becomes much less meaningful.

Exhibit 6. Results of Simulation 3

	Goal	Actual	Met?
Insolvency probability less than or equal to	0.0%	32.2%	No
Average Employer Contribution Rate Below	6.0%	7.9%	No
Annual Contribution Volatility Below	10%	17%	No
Lifetime tax rate ratio (75th/25th percentiles)	1.5	1.5	No*

*Due to rounding.

Given these extreme results, we conduct a sensitivity test Simulation 3.b in which the employer contribution cap is raised from 15 to 20 percent of wages, for a total maximum contribution of 26 percent of wages including the employee share. This has a significant impact on solvency result, reducing the probability of insolvency over 100 years from 32 percent to slightly over 2 percent. Thus, the placement of a contribution cap is of great significance (as would be more detailed modeling of contribution holidays in which no payment is made). In Simulation 3.b the financing plan continues to fail the Affordability and Contribution Volatility Tests, and the higher maximum contribution pushes the plan away from intergenerational equity as well.

Exhibit 7. Results of Simulation 3.b			
	Goal	Actual	Met?
Insolvency probability less than or equal to	0.0%	2.4%	No
Average Employer Contribution Rate Below	6.0%	8.7%	No
Annual Contribution Volatility Below	10%	22%	No
Lifetime tax rate ratio (75th/25th percentiles)	1.5	1.8	No

Simulation 4 considers a commonly mentioned reform, shortening of the amortization period from the common period of 30 years. This reform is designed to more rapidly restore plans to financial health and to improve generational equity. Because unfunded liabilities would be amortized more quickly, such a reform is also designed to improve incentives with regard to risk-taking or the enactment of benefit enhancements that are not fully funded. At the same time, a shorter amortization period will increase the volatility of annual contributions.

Simulation 4 is identical to Simulation 2; that is, it does not contain a contribution cap as in Simulation 3. It differs in reducing the amortization period for unfunded liabilities from 30 years to 20 years. As with Simulation 2, the probability of insolvency through 500 simulations is zero percent. The average employer contribution rate is 8.3 percent. This is lower than Simulation 2's 9 percent, and indicates that more rapid amortization of unfunded liabilities can generate lower average contribution rates, presumably by reducing the probability of very high contribution rates in a few years.

However, annual contribution volatility rises significantly, from 25 percent in Simulation 2 to 31 percent in Simulation 4. This reflects the need to repay unfunded liabilities more rapidly. Put another way, because in this model unfunded liabilities arise solely from variations in investment returns, a shorter amortization period transfers market risk more directly into contribution volatility. Interestingly,

Exhibit 8. Results of Simulation 4			
	Goal	Actual	Met?
Insolvency probability less than or equal to	0.0%	0.0%	Yes
Average Employer Contribution Rate Below	6.0%	8.3%	No
Annual Contribution Volatility Below	10%	31%	No
Lifetime tax rate ratio (75th/25th percentiles)	1.5	2.3	No

intergenerational equity does not seem to be improved by more rapid amortization; in fact, the ratio of lifetime tax rates at the $90^{th}/10^{th}$ percentiles rises from 1.9 in Simulation 2 to 2.3 in Simulation 4.

Simulation 5 illustrates the effects of changes in investment policy, to explore the trade-offs between affordability and other financing concerns. In Simulation 5 we reduce the expected return on plan assets to 6 percent, with an accompanying reduction in portfolio risk to a standard deviation of annual returns of 10.3 percent (versus 14.3 percent in the baseline projection with an 8 percent expected return). Simulation 5 otherwise resembles Simulation 3, with no maximum contribution as well as 30-year amortization of unfunded liabilities.

Exhibit 9. Results of Simulation 5			
	Goal	Actual	Met?
Insolvency probability less than or equal to	0.0%	0.0%	Yes
Average Employer Contribution Rate Below	15.8%	14.4%	No
Annual Contribution Volatility Below	10%	8%	Yes
Lifetime tax rate ratio (75th/25th percentiles)	1.5	1.4	Yes

The results of Simulation 5 are of interest, in that it is the first simulation in which the financing plan achieves both low contribution volatility and intergenerational equity. Annual Contribution Volatility averages 8 percent, which is under the 10 percent goal; the lifetime tax rate ratio equals 1.4, versus a 1.5 goal. The system would also remain solvent in 100 percent of 100-year simulations.

Where the system fails is affordability, with the average employer contribution rate equal to 14.4 percent of payroll. This result is simply a function of the lower risk, lower return portfolio: in the steady state, our stylized plan with an assumed investment return of 6 percent has a total contribution cost of slightly over 19 percent, which net of the employee contribution leaves an employer cost of 13 percent of payroll. As in our other simulations, adding the effects of market risk and other factors increases the average contribution rate slightly.

Conclusions

Public employee pensions set for themselves a number of financial goals. These include solvency, the assurance that benefits can always be paid; affordability, the ability to finance benefits at a cost that does not crowd out other government spending priorities or other forms of employee compensation; contribution stability, meaning relatively stable and predictable employer contributions from year to year; and intergenerational equality, which implies that each generation of taxpayers fully funds the compensation of public employees providing service during that generation.

The goals are rarely modeled explicitly, with the result that conflicts between them are poorly understood. Plan stakeholders appear to believe that with prudent and responsible management, which combines making contributions as required and applying various actuarial techniques to smooth costs, all four goals can be accomplished. Here we construct a simple model of a mature pension plan incorporating the effects of portfolio risk on a plan's ability to achieve its financing goals.

Because these goals are rarely quantified, setting standards by which they are considered to be satisfied is inherently subjective. We have done so based upon intuition and cursory examination of plan practices and standards. We find that most common pension financing plans – that is, investment in a portfolio with an expected return of 8 percent, with returns smoothed over 5 years and unfunded liabilities amortized on a level payroll basis over 30 years – produces significantly higher average costs than would be predicted using a standard actuarial model that ignores investment volatility, and fails to stabilize contributions in the short term or establish interperiod equity over the long term.

Simulations utilizing a lower risk, lower return investment portfolio lead to a conclusion that is familiar to almost any other investor but unusual in this context: if public plans wish to achieve both contribution stability and intergenerational equity, they will simply have to pay more and take less investment risk. Despite long time horizons and various contribution smoothing techniques, the risk-return trade-off that is essential to any other investment decision also holds for public plans. Plans may smooth risk in the short term by transferring it to the long term, or vice versa, but risk generated by the plan's investments is ultimately transferred to the plan's contributions.

These issues become more important as plans grow larger relative to their sponsors. A large pension plan investing in risky assets is a "different animal" from the relatively small and less risky plans of the past. Thus, modeling of the sort conducted here may be of benefit to plan trustees, as opposed to relying on historical experience when the allocation of plan assets or returns on assets classes may have been very different.

It is worth noting how the analysis here relates to the so-called "market valuation" debate over how pension liabilities should be valued. Traditional actuarial standards, enshrined in standards set by the Governmental Accounting Standards Board, discount pension liabilities at the expected return on plan investments, generally close to 8 percent.

A next step is to model the correlation between pensions' contribution needs and the ability of plan to meet them. Stock prices are correlated with the state of the economy, meaning that low returns and higher required contributions may occur at times when tax revenues are weak. As Peng puts it, "These two forces reinforce each other and create volatility in the level of pension contribution, funding ration and government operating budget."[29] Washington State's actuary put it more simply with regard to its own plans' experiences: "Weak economic environments were correlated with weak investment returns. Lower investment returns created the need for increased contributions at a time when employers and members could least afford them."[30] Additional dollars are needed when the marginal value of a dollar is highest, while surpluses occur when a marginal dollar is less valuable.

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[29] Pen (2008).
[30] Office of the Washington State Actuary (2010a, b).

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