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# Comparing Costs and Risks of Retirement Plans for Sponsors

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## Abstract

This stochastic simulation analysis compares funding costs and volatilities for private sponsors of traditional defined benefit (DB), pension equity (PE), cash balance (CB), and defined contribution (DC) retirement plans. Plan provisions of equivalent benefit generosity in the different plan types are determined. The modeling includes current funding requirements and practices as well as a comprehensive set of uncertainties in asset and labor markets. The results show that costs and risks for sponsors vary significantly with plan types, investment and funding strategies, and participant demographics. The hybrid PE and CB plans exhibit characteristics of cost efficiency, as in the DB plan, and risk reduction, as in the DC plan, for plan sponsors under conventional investment strategies. These features are more saliently observed in the CB plan, but it is also more difficult to implement effective asset–liability management strategies for it.

## Introduction

Employer-sponsored retirement plans are important for workers, because the plans provide income resources for retirement, and for employers, because the plans can help attract and retain talented workers and support more orderly labor force exit at older ages when worker productivity starts to wane. The landscape for plan sponsorship is evolving with the confluence of changes in demographics, worker preferences, economic and financial events, public opinion, and laws and regulations. For plan sponsors, it is essential to have a good assessment of the cash costs and risks that are associated with retirement plans. Different plan types and designs have varying and sometimes

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competing efficacy in serving various corporate goals and the welfare of participants. This article, through stochastic simulations, intends to provide a quantitative comparison of the prevailing retirement plans and discuss the implications of plan offerings in the context of corporate cash flows.

A traditional defined benefit plan (hereafter DB, denoting *traditional*) automatically provides retired workers with guaranteed lifetime benefits based on the level and duration of earnings with the employer. The sponsor makes contributions to fund the accrued benefits and makes up any funding deficits that may develop. Plan assets are pooled and the sponsor is responsible for investment losses but does not have access to surpluses for general corporate purposes. A defined contribution plan (DC), such as a 401(k) account plan, usually has some contributions by the employer, often matching employee contributions, and plan participants bear all the investment and retirement income risks. Hybrid pension equity (PE) and cash balance (CB) plans combine elements of DB and DC plans. They are designed as individual account plans paying a lump sum benefit but feature principal and return guarantees from the sponsor on the pay credits accrued to the account.

Our analysis focuses on the levels and volatilities of funding costs from the plan sponsor's perspective, given that the benefit generosity to participants is set to be roughly equivalent across the plans. We examine how the plans fare with the most salient plan provisions, operating under the main legal and regulatory requirements and common workforce circumstances. Stochastic simulations of asset returns and interest rates reflect standard market shocks in normal times and low-probability large-magnitude (rare) economic disasters. Simulations of labor earnings for each worker capture the life-cycle age-earnings profile, idiosyncratic (random) individual income variations, and broad correlations of general wage levels with macroeconomic shocks.

The simulation results show that costs and risks vary significantly with plan types, demographics, and investment and funding strategies. The most important results are the higher cost volatility of the DB plan, the higher cost level of the DC plan, and the lower volatility (compared to the DB plan) and the lower cost (compared to the DC plan) of the hybrid plans. Liability-driven investment (LDI) strategies, which are increasingly used to manage and hedge risks in DB plans, however, are difficult to implement in hybrid CB plans. The results highlight the advantages and disadvantages of the different retirement plan types as currently designed and regulated.[1]

The remainder of this article is structured as follows. The following section reviews the literature, especially related to plan funding. The "Assumptions and Simulations" section contains the assumptions of the stochastic simulation analysis, as well as explains the funding rules and how benefit equivalence across plan types is assured. The "Findings from Simulations" section provides the baseline results and alternative specifications. The final section concludes.

[1] Innovations, including legislative reforms, may provide a better alignment of retirement plan design with corporate and workforce goals and preferences. Warshawsky (2010), for example, proposes a flexible structured plan that would share investment risk and returns between employees and employers.

## LITERATURE REVIEW

There is a fairly large literature that seeks to explain how pension plan sponsors fund and invest their plans or how they should do so. In addition, there are a few studies that try to test empirically the theories found in the literature. The results, both theoretical and empirical, are decidedly mixed. Nonetheless, it is useful to do a brisk review as background. Our present study takes a different tack than the literature—it begins, taken as givens, with the observed investment and funding behavior of pension plan sponsors—heavy allocations to equities and less than continual full funding—it then examines the simulated consequences for sponsor cash cost and its volatility, under current law, of different plan types. The study does not address the issue of expense measurement—still controversial among actuaries but settled almost universally among economists to use the risk-free rate to calculate pension liability and expense. Rather, this study compares the (simulated) realizations of cost under current law from sponsoring retirement plans of different types but equivalent benefit generosity.

Early authors in the literature (Sharpe, 1976; Treynor, 1977) posit that the possibility of the sponsor's bankruptcy gives the sponsor a "pension put option" on the difference between promised benefits and pension fund assets. The value of the put option increases with the duration of the pension claim by workers, the uncertainty of the plan sponsor's business prospects, and the riskiness of the pension fund's assets. Funding (sponsor contributions) increases pension assets, leaves liabilities unchanged, and either reduces corporate assets or increases corporate liabilities. Treynor (1977) makes the argument that larger pension contributions increase the value of the pension put option and hence shareholder value because pension assets are usually risky, liabilities are very long-dated, and pension beneficiaries do not demand compensation for increased risk. But, as noted by Sharpe (1976), large contributions (higher funding) do not increase share value if pension claims are due soon (either due to an impending bankruptcy or a mature participant population or if the plan sponsor can easily terminate the plan at any time), or if beneficiaries are powerful (say, through a union), or if pension assets are relatively low risk. In these latter circumstances, the plan sponsor would seek to minimize funding. The introduction in ERISA of cheap pension insurance from the government, through the Pension Benefit Guaranty Corporation (PBGC), has been suggested to influence sponsors to want to further minimize funding and to increase the riskiness of pension assets.[2] Subsequent tightening of funding rules and the restructuring of PBGC premiums to reflect funded status in the Pension Protection Act (PPA) of 2006, however, likely temper these inferences.

Other authors (Black, 1980; Tepper, 1981) demonstrate that tax considerations at both the corporate and personal levels favor bond investment by plan sponsors. The labor relations theory, by contrast, is ambiguous—a desire for good relations would lead a sponsor to generously fund its plan and to invest in equities to allow for future benefit increases, while a tense situation would lead a sponsor to be stingy both with funding and asset risks. Bodie (1990) holds that the pension liability attributed to past service and pay should be fully immunized by bond investments, while other anticipated increases

[2] The most recent authors to express this view forcefully are Love et al. (2011), following Brown (2008).

in pension benefits should be funded by equities. This is essentially a mixed investment strategy dependent on how rapidly the plan liability is growing.

The following are some representative papers in the empirical literature. Rauh (2009) finds that most plan sponsors do not behave in an opportunistic manner; that is, they do not game the PBGC insurance program. Francis and Reiter (1987) find that tax, accounting, labor relations, and capital structure conditions have varied and complex influences on the funding strategies of plan sponsors. Power et al. (2000) find that regulatory actions by the PBGC via publication of a list of severely underfunded plans have some economic and political impact to encourage better funding outcomes. McKillop and Pogue (2009) examine the relationship between funding risk of DB plans and corporate debt ratings and equity risk of large U.K. plans. They find that more pension risk does increase sponsor equity risk, although not necessarily one-for-one, and lower credit ratings.

## ASSUMPTIONS AND SIMULATIONS

### Provisions of Retirement Plans

The retirement plan provisions modeled here largely follow the common practice. Our comparative analysis starts with a traditional DB plan, where 1-year service accrues 1 percent of final 5-year average pay that will be delivered as a fixed nominal annuity in retirement for life. There is no cap on the number of service years to be credited.

Both PE and CB plans are legally treated as a DB plan but have individual account features. They generally pay the benefit as a lump sum to a participant upon retirement. The lump sum amount is determined by the pay credit and interest credit rates as stated in the plan. Interest credit is accrued for all years in the CB plan but only for posttermination years in the PE plan. Pay credit for the CB plan is a certain percentage of current pay, while it is a percentage of the (commonly final 5-year) average pay for the PE plan, as for a traditional DB plan. In the most common practice, the pay credit rate is constant and the crediting interest rate is variable, often linked to yields on long-term Treasury bonds. Pay credit rates in our analysis are endogenously set to ensure benefit equivalence across plans (details below) and the interest credit rates are set to be the variable 30-year Treasury bond yields.

For DC 401(k) plans, the sponsors make matching and/or nonmatching contributions as certain percentages of current pay. Participants own and manage their account balances, which hinge on the performance of their chosen portfolios besides the levels of contribution.

Some examples help illustrate how these plans set benefits (not necessarily equivalent here). For a retiree with 30 years of service and a final 5-year average pay of $100,000, a 1 percent DB plan would provide a fixed payout at the normal retirement age of $30,000 per year for life (1 percent × 30 × $100,000). A 10 percent PE plan would pay a $300,000 lump sum upon retirement (10 percent × 30 × $100,000), assuming uninterrupted service with the same employer and thus ignoring posttermination interest credit in the calculation. For a worker currently making $50,000, a CB plan would give her an employer accrual of $2,750 this period (4 percent ×$50,000 plus 5 percent ×$15,000), assuming a 4 percent pay credit, a 5 percent interest credit related to current Treasury yields, and a current account balance of $15,000. A DC plan with a 6 percent nonmatching contribution rate would give the worker an employer contribution of $3,000 (6 percent × $50,000) in the current period. Future employer accruals or contributions in the CB and DC plans follow the plan rules and economic experience and the worker would get the resulting lump sums upon her retirement.

### Benefit Equivalence Across Plans

For a fair evaluation, we determine and set comparable benefit generosity to participants across the plans. This is achieved by several steps. First, labor earnings, interest rates, and discount rates for plan liability valuations are stochastically simulated (details in later sections) and their averages are calculated. Second, based on the averages, we determine the expected lump sum commuted values at retirement age of the traditional 1 percent DB plan. Third, we search for pay credit rates or employer contribution rates that make the PE, CB, and DC plans deliver lump sum values equivalent to the DB plan. Job separations are simulated and the calculations include the benefits paid to those who leave employment early and those who retire as active participants (see "Demographics of Plan Participants" below).

For the benefit equivalence, the average of the simulated 30-year Treasury yield rates is used as the interest credit rate for the hybrid plans and as the expected investment return for the DC plan. One could argue for a higher investment return for the DC plan via a riskier equity portfolio. But this is hard to justify for this benefit-equivalence purpose, because the DC plan lacks the guarantees by the employer and the PBGC that are featured in the DB (including hybrid) plans. Accounting for the duration risk on plan participants, others could argue for a shorter maturity and hence further lower interest rate than the risk-free 30-year Treasury yield for the DC plan. We settle at the middle ground by implicitly assuming that DC plan participants can hold 30-year Treasury bonds to maturity, with little risk, as in the hybrid plans.

The equivalence operates at the plan level *ex ante*, not necessarily at the level of a single worker. That is, the eventual benefits to individual participants of the PE, CB, and DC plans vary with pay, interest and investment outcomes, and job turnover. The equivalent pay credit or contribution rates will be shown later along with the specific assumptions. Benefits in our simulations are calculated for each worker and then aggregated to produce total costs and liabilities at the plan level.

### Regulatory Funding Rules

For DB (including hybrid) plans, the funding of accrued benefits for a given year can follow one of two legally allowed methods. The traditional unit credit (TUC) method calculates benefit accrual each year as a flat-dollar amount or a percentage of participants' *current* compensation. The projected unit credit (PUC) method uses *final* compensation instead, including projected pay increases in future years.[3] The TUC method tends to underestimate the salary base for benefit accrual, such as the average for the final 5 years, which generally moves upward, and thus leads to an increasing trajectory of contributions for sponsors. The PUC method provides an estimate of liabilities and costs preferred by some as more reflective of anticipated economic expenses, especially for the final-average-pay DB plans. The TUC method is used to guide sponsors for funding

[3] See further discussions in McGill et al. (2010, chap. 22).

their plans as the legal minimum required contribution under the PPA of 2006 and is preferred by some analysts as more reflective of the actual legal commitment of the employer.

The PPA requires that, at the minimum, the DB, PE, and CB plan sponsors contribute normal costs and amortize shortfalls (unfunded liability) if the plan's asset value falls below its liability. The funding target is equal to the present value of all benefits accrued on service and pay *to date*. The normal cost is the present value of benefits earned in the current year. This funding obligation can be offset by excess assets if the plan is overfunded. Plan sponsors may well consider the PUC method, as allowed by the PPA when determining maximum tax deductible contribution levels, for discretionary extra funding to smooth the contribution flow. This precautionary incentive, however, is weakened by the current punitive excise tax on reversions of excess pension assets, which essentially prohibits the withdrawals of excess pension assets for general corporate purposes when plans are overfunded (see Pang and Warshawsky, 2009, for an analysis of possible excise tax reforms and consequences). Our analysis hereafter mainly focuses on the TUC method but will consider a PUC scenario later.

According to the PPA rules, funding shortfalls should be amortized by the general 7-year schedule. A faster 6-year amortization is required if the plan is less than 70 percent funded. No benefit accrual is allowed if the plan is below 60 percent funded. Other benefit restrictions such as a prohibition on plan amendments increasing benefits, the payment of lump sums, and so on that are triggered at various funded levels in current law are ignored in this analysis, as are legislative and administrative relief measures, mostly temporary, passed in response to the financial crisis. Assets, plan liabilities and normal costs are annually revalued in our analysis to account for stochastic asset returns, salary increases, service changes, demographic developments, and interest rate realizations.

### Stochastic Rates and Returns With Normal Shocks and Rare Disasters

We simulate the range of investment outcomes, interest rates, and inflation rates using a stochastic model that allows for standard market randomness (also called "shocks") in normal times and low-probability, large-magnitude (rare) economic disasters ("fat tails"). Rates and returns in normal times are modeled as a vector autoregressive (VAR) system, following Campbell and Viceira (2004, 2005). The VAR specifies current asset returns as a function of lagged returns and current-period shocks. The add-on rare economic disasters are simulated based on the framework of Barro (2006). Utilizing the dynamics and outputs of this enhanced "normal-disaster" VAR system, we additionally simulate corporate and Treasury bond yields and returns that are needed for our analysis. Details of the estimation and simulations are described in the Appendix. As advantages over conventional asset return models, this integrated and comprehensive approach captures the persistence of market shocks and both the contemporaneous and serial correlations of asset classes.[4]

Assets of DB, PE, and CB plans are assumed to be invested in stocks (proxied by S&P500 Total Return index) and bonds (proxied by Barclays Aggregate Bond Index) with a 50–50 mix for a typical investment strategy. Later we consider an alternative strategy that

[4] This integrated model was first implemented in Pang and Warshawsky (2010).

matches the long duration of liabilities by investing in long government/credit assets (proxied by Barclays Long Government/Credit Index). Crediting interest rates in PE and CB plans follow the 30-year Treasury bond yields. Discount rates for liability valuations are proxied by Citi AAA/AA bond yields. Discount rates for DB plans (including hybrid plans) are set by the Internal Revenue Service and the composite corporate bond rate (CCBR) is the most legitimate series to use for our analysis. The CCBR, however, is short in time coverage (since 2003) and we thus opt to use Citi AAA/AA yield, which mimics CCBR very well for the available period.

Table 1 summarizes the simulated rates and returns, with and without consideration of economic disasters. Historical statistics are also provided as reference. Compared to a no-disaster environment, the incorporation of rare economic disasters significantly lowers the expected asset returns and increases their volatilities. Plan comparisons hereafter are mainly based on rates and returns with consideration of economic disasters but we will consider the no-disaster case later for a robustness check. The equity premium, that is, the difference between average equity and risk-free 90-day T-bill returns, is about 4.8 percent from our simulations based on the 1985–2010 data. The equity premium is lower than traditionally found in the literature (for instance, the 6 percent in Mehra and Prescott, 1985, is based on an earlier and longer 1889–1978 period). Bond returns and yields are also generally higher in this period than in the past. This 1985–2010 period is used because of the belief that monetary policy has been largely in a new regime since the end of high inflation in the late 1970s and early 1980s.

### Stochastic Labor Earnings

Labor earnings are simulated based on the model in Campbell et al. (2001) and Cocco et al. (2005). Individual labor income exhibits a life-cycle age-earnings profile and is also simultaneously affected by aggregate economic shocks. The life-cycle component in logarithm form is modeled as a deterministic age polynomial plus idiosyncratic permanent and transitory shocks. Aggregate shocks are represented by excess equity returns and their (lagged) variations affect current period labor earnings. Excess equity returns are defined as the difference between equity return and the rate on money market instruments (nearly risk-free T-bills).

We utilize the baseline parameter values from Campbell et al. (2001) and Cocco et al. (2005) and generate earnings for workers with a high school education. Specifically, the variances of permanent and transitory (log) earnings shocks are 0.0106 and 0.0738, respectively. The correlation coefficient between (log) earnings and excess equity return is 0.3709. The simulated real earnings exhibit the well-documented hump shape: they average about $40,000 at age 30 and reach a peak around $52,000 in the worker's 50s. Labor earnings are first simulated in real terms and then converted to nominal terms, given that plan benefit formulae are defined in nominal terms. Inflation rates are simulated in the VAR system using the CPI-U index as the measure of general prices.

### Demographics of Plan Participants

Survival of participants after retirement is simulated according to the unisex general population mortality table. For simplicity, we ignore the probabilities of disability and set preretirement mortality to zero. We model and simulate job separations, based on the termination rates reported in McGill et al. (2010, appendix table A1, p. 784). In line

**Table 1**
Summary Statistics of Simulated Rates and Returns (%)

| | Equity Return | Aggregate Bond Return | 90-Day T-Bill Return | 5-Year T-Note Return | 10-Year T-Note Return | Long Government/ Credit | Citi AAA/AA Yield | 30-Year T-Bond Yield | Inflation |
|---|---|---|---|---|---|---|---|---|---|
| Real | | | | | | | | | |
| No disasters | | | | | | | | | |
| Mean | 7.1 | 4.9 | 1.3 | 4.2 | 5.3 | 6.1 | 4.6 | 3.4 | – |
| Std. dev. | 17.1 | 4.6 | 1.8 | 5.7 | 8.0 | 8.8 | 1.4 | 1.4 | – |
| With disasters | | | | | | | | | |
| Mean | 5.6 | 4.4 | 0.8 | 3.4 | 4.4 | 5.4 | 4.2 | 3.1 | – |
| Std. dev. | 19.1 | 6.4 | 4.5 | 9.4 | 12.1 | 11.7 | 4.2 | 4.2 | – |
| Historical | | | | | | | | | |
| Mean | 9.3 | 4.9 | 1.4 | 4.2 | 5.3 | 6.3 | 4.7 | 3.6 | – |
| Std. dev. | 18.4 | 5.9 | 1.9 | 6.9 | 10.0 | 9.7 | 1.6 | 1.6 | – |
| Nominal | | | | | | | | | |
| No disasters | | | | | | | | | |
| Mean | 9.9 | 7.8 | 4.2 | 7.0 | 8.2 | 9.0 | 7.4 | 6.2 | 2.8 |
| Std. dev. | 17.3 | 4.3 | 2.1 | 5.4 | 7.8 | 7.8 | 1.3 | 1.2 | 1.3 |
| With disasters | | | | | | | | | |
| Mean | 8.6 | 7.4 | 3.8 | 6.4 | 7.4 | 8.4 | 7.2 | 6.1 | 3.0 |
| Std. dev. | 18.6 | 4.4 | 2.3 | 6.8 | 9.7 | 9.0 | 1.3 | 1.3 | 4.2 |
| Historical | | | | | | | | | |
| Mean | 10.2 | 7.7 | 4.3 | 6.9 | 8.1 | 9.1 | 7.6 | 6.5 | 2.8 |
| Std. dev. | 17.1 | 5. 8 | 2.3 | 6.1 | 8.6 | 9.5 | 1.7 | 1.8 | 1.3 |

Source: Authors' simulations based on historical data 1985–2010.

with law and common practice, we assume that benefits are vested once the workers have been employed with the firm for 5 years for the DB plan, 3 years for the PE and CB plans, and 1 year for the DC plan.

We first consider a baseline population scenario (POP0) of plan participants. They are assumed to be initially uniformly distributed in the age range of 26–60 and to retire at age 65. Further, in order to get a more typical age composition, we duplicate the workers aged 26–40. The average initial age of plan participants is thus 40. A fixed number of new workers, in the distribution of 26–60 as amended by the 26–40 doubling, are assumed to enroll in the plan every year. The fixed number is set to be 5 percent of the number of first-period plan participants. This scenario reflects a common workforce demographic pattern that is expanding with a certain pace of aging. The plan population is intended not to be overly young so the funding cost would be underestimated for DB pension plans or overly mature so the pension's cost would be unfairly overstated.

Payment options have an effect on plan demographics. Participants in PE, CB, and DC plans get lump sum payments and exit the plans upon retirement. Terminated vested workers are assumed to leave their benefits in the plans and claim them upon attainment of a normal retirement age. The plan populations expand as new employees enroll. Over time, however, the number of workers exiting the plans will be larger than the number of new entrants. These plan demographics are confined to workers. These dynamics also hold for a traditional DB plan with a lump sum payment. Population size and average age are otherwise both larger for a DB plan with annuity payout because retirees remain in the plan for their entire lifetimes.

## FINDINGS FROM SIMULATIONS

### Results With Baseline Assumptions

Our baseline case considers plan population POP0, job turnover, and economic disasters in the asset markets. Equivalence to the 1 percent accrual final average pay DB plan, as discussed earlier, requires the following: a 9.6 percent pay credit of final average pay for each year of service in the PE plan, a 5.9 percent pay credit plus interest credit linked to 30-year Treasury yields in the CB plan, and a 5.9 percent of pay as employer nonmatching contribution in the DC plan (or 100 percent match up to 5.9 percent of pay). Employee contributions are ignored because our analysis focuses on employer costs. The PE pay credit rate can be largely viewed as the average annuity factor for POP0: a $9.6 premium is needed for a $1 fixed life annuity. The pay credit rate for the PE plan is higher than for the CB plan because the PE plan has no interest credit for active workers.[5] These equivalent pay credit rates are generally within the range empirically observed (see the analysis of prevalent plan provisions by Hill et al., 2010). Pay credit rates vary widely when the plan benefit formulae are graded for age, service, or points (age + service) or are fixed.

We run a large number of simulations and report the summary statistics for a 40-year horizon. This time horizon is somewhat arbitrary but covers a complete career of workers starting at age 26 until retirement at 65. We use three measures to compare average cost

[5] With a substantially lower interest credit rate, the CB pay credit rate would be higher so as to provide benefits equivalent to the PE plan.

**TABLE 2**
Funding Costs and Volatilities per Worker With Baseline Assumptions

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| DB | 5.0 | 5.6 | 42.7 | 11.0 | 4.8 | 4.1 |
| PE | 5.1 | 4.7 | 48.8 | 10.5 | 5.1 | 3.4 |
| CB | 4.5 | 4.0 | 44.7 | 9.2 | 4.7 | 3.1 |
| DC | 5.9 | 2.9 | 59.1 | 6.8 | 5.9 | 0.0 |

Source: Authors' simulations.

levels on a per worker basis: annual nominal cost, real total 40-year cost (present value), and annual contributions as a percent of payroll. Funding risks are reflected by the standard deviations of these three measures. The annual measures focus on immediate cash flows while the present values reveal the long-run cost for each worker on average.

The DC plan has the lowest year-to-year fluctuations in funding costs while the traditional DB plan tends to experience significantly larger swings, as shown in Table 2. The PE and CB plans are in between. The employer contributions are a constant percent of payroll for the DC plan, and annual nominal costs have a smaller standard deviation of about $2,900 versus $4,000 for the CB plan, $4,700 for the PE plan, and $5,600 for the DB plan.

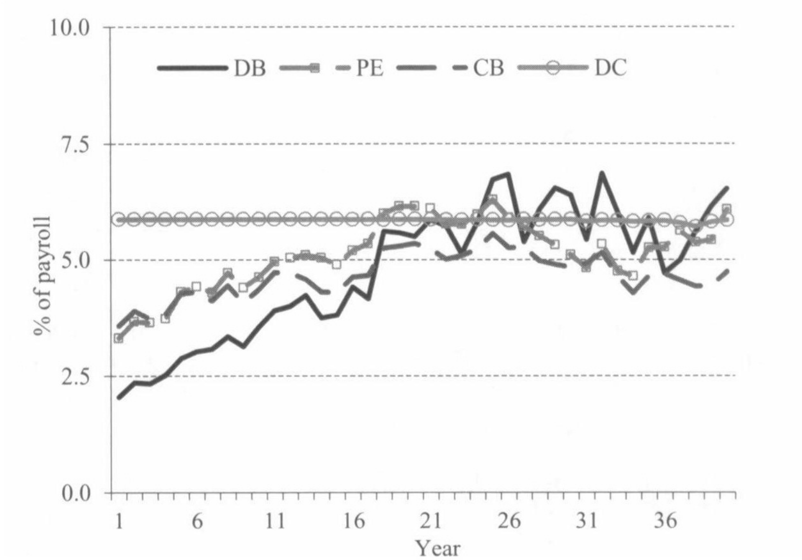
Employer contributions for the DB plan are more volatile than for other plans. As plotted in Figure 1, the DB plan costs as percentages of payroll exhibit a generally upward trend because the population is aging and the funding of benefit accruals by the TUC method is concentrated in the years leading to retirement. Most importantly, the figure shows big variations from year to year. This uncertainty forms a management burden for the traditional DB plan sponsor under the assumed investment strategy.

The DC plan is the most costly on average among the plans. Funding costs account for 4.8 percent, 5.1 percent, 4.7 percent, and 5.9 percent of payroll for the DB, PE, CB, and DC plans, respectively. Total real costs per worker over the 40-year period (present value) are about $42,700, $48,800, $44,700, and $59,100 for these plans, respectively. The results for the PE and CB plans show the hybrid nature of these plans. Their funding volatilities are often lower than those for the DB plan. Their average costs are lower but volatilities are higher than for the DC plan.

The differences in costs and risks are explained by the sources of uncertainties in these retirement plans. The DC plan sponsor contributes a fixed percentage of pay. Investment strategies and outcomes are the participants' own responsibilities. Volatilities of nominal and real costs for sponsors are caused by the stochastic changes in labor earnings.

For DB, PE, and CB plans, by contrast, the sponsors are responsible for investing assets. This is beneficial to the participants because their retirement benefits are insulated from market fluctuations. It may also benefit the sponsors in that they have the potential

**FIGURE 1**
Average Annual Funding Costs as a Percentage of Payrolls




Source: Authors' simulations.

opportunities to realize higher investment returns that will eventually reduce funding costs. As indicated by results in Table 2, contributions are locked as a percentage of pay for the DC plan sponsor, while the eventual contributions for the other plans depend on, and gain advantage from, the outcomes of collective investing in a mixed portfolio. The lower annual cost and fluctuation of the CB plan is particularly attributable to the long-run asset accumulation because the plan is "front loaded," while the DB and PE plans are "back loaded." That is, funding contributions are more proportionally allocated to younger ages in the CB plan but tend to be concentrated in the near-retirement years in the DB and PE plans, owing to the ever-increasing average of final wages.

In addition, DB, PE, and CB plans face differential uncertainties in the liability valuations. DB plan liabilities grow and fluctuate with salary raises and service years. Calculated as present values of future benefits over a typically long duration (including over the entire remaining lifetimes of retired workers), the DB liabilities are also highly sensitive to changes in interest rates. Liability variations are mitigated in PE and CB plans by their accrual formulae. Their benefits are expressed as account balances upon retirement and the liability durations are shorter than for the DB plan. Their accruals vary with new realizations of crediting interest rates, besides stochastic labor earnings, but are less sensitive to discount rate changes compared to DB plans. The lower volatility in liabilities is an important factor distinguishing hybrid plans from DB plans. By the plan provisions, the CB plan liability has a shorter duration than the PE plan because the (variable) interest credit rate in the CB plan is also responsive to changes in discount rates. This leads to lower cost volatilities for the CB plan than for the PE plan.

The PE plan is closer to the DB plan in nature because both types accrue benefits as a percentage of final average pay regardless of capital market conditions, except when

**TABLE 3**
Probabilities of Funded Ratios With Baseline Assumptions

| | Asset–Liability Ratio | | | | | |
|---|---|---|---|---|---|---|
| | <0.60 | <0.80 | <0.90 | <1.00 | <1.10 | <1.20 |
| DB | 0.3 | 2.9 | 15.0 | 47.7 | 83.0 | 95.1 |
| PE | 0.2 | 3.5 | 20.5 | 55.1 | 85.3 | 94.8 |
| CB | 0.0 | 2.0 | 15.7 | 50.6 | 83.3 | 93.5 |

Source: Authors' simulations.

(stochastic) interest credits are provided to the terminated (vested) workers in the PE plan. The CB plan is closer to the DC plan because employers contribute a percentage of current pay, the terminal account balances depend on market outcomes, and only the value of pay credits is guaranteed in the CB plan.

We here note the impact of job turnover on plan costs. Assuming no turnover would lead to a slightly higher average cost for the DB plan, by 0.3 percent of payroll (results not shown), because more workers and/or more years of work would be vested. In contrast, the average costs for PE and CB plans are marginally lower, by 0.1 percent of payroll, because fewer years in these plans would require interest credit, which is higher than pay credit rate on average in the simulations. The cost for the DC plan is largely the same, with or without turnover. The consideration of job turnover thus makes a generally small difference, because the job termination rate is zero after age 52 in the baseline assumptions, based on McGill et al. (2010).

We next look at the stochastic funded statuses of plans. They indicate how the plans fare in meeting the regulatory and funding requirements. The distribution of funded ratios, as reported in Table 3, has some differences across the DB, PE, and CB plans, given the same investment strategy. All plans are set to be 100 percent funded initially in the simulations. Relative to the DB plan, the PE and CB plans have a larger likelihood of asset–liability ratio exceeding 1.2 but also a higher risk of being underfunded (below 0.9). The CB plan has the smallest chance of being significantly underfunded (below 0.8). This results from dynamics of both assets and liabilities. When the interest rate (discount rate) decreases, plan liabilities increase. For the CB plan, however, the interest credit rate also drops, offsetting the increase in liabilities. This self-adjustment is weaker in the PE plan and nonexistent in the DB plan. On the asset side, lump sum payments coincidental with asset value drops, when markets perform poorly, constitute a larger drain of PE and CB plan assets, while the DB plan with annuity payouts has more opportunities to recover the loss over time. The liability-side dynamics lead to more volatile funding ratios for the DB plan while the asset-side dynamics lead to greater volatility for the PE and CB plans.

### Results With Same Asset Returns Across Plans

Investment strategies, tactics, and outcomes are often different for pension plans with collective investing versus for 401(k) participants with individual management of assets. They eventually affect funding costs and risks, which is important for firms pondering

**TABLE 4**
Funding Costs and Volatilities per Worker With Alternative Assumptions for Interest Rates and Asset Returns

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| | 30-Year Treasury Yield Rates for All Plans | | | | | |
| DB | 7.0 | 5.3 | 69.1 | 13.6 | 6.1 | 2.4 |
| PE | 6.9 | 4.5 | 77.0 | 14.6 | 6.5 | 1.6 |
| CB | 6.6 | 3.2 | 77.2 | 11.4 | 6.4 | 0.5 |
| DC | 6.6 | 3.1 | 78.0 | 12.1 | 6.4 | 0.0 |
| | Citi AAA/AA Corporate Bond Yields as Discount Rates | | | | | |
| DB | 6.3 | 4.9 | 49.7 | 7.9 | 5.7 | 2.3 |
| PE | 6.0 | 4.0 | 54.9 | 7.6 | 5.8 | 1.5 |
| CB | 6.0 | 3.5 | 54.3 | 6.4 | 5.8 | 0.8 |
| DC | 5.8 | 2.8 | 58.5 | 7.5 | 5.9 | 0.0 |

Source: Authors' simulations.

which type of plans to sponsor. Some researchers, however, may postulate that the economic costs of the promised benefits should be valued uniformly, on a risk-neutral basis, by a certain interest rate and that whether the benefits are funded by equity versus bond assets is a separate decision.

We therefore examine the sensitivity of plan funding costs to investment outcomes. We here remove the differentials in investment and set all interest rates and asset returns equal to 30-year Treasury yield rates. For further clarity, we also drop the consideration of job turnover that slightly favors plans requiring more years for benefit vesting. Other assumptions are the same as in the baseline case. Table 4 shows the results.

Funding costs are higher for all plans than in the baseline, as expected. CB and DC plans have quite similar funding costs and risks—6.4 percent of payroll on average or $6,600 per worker a year. The CB plan sponsor manages the assets and accumulates returns on investments but also credits the participant's account with the same return. Given the same investment returns, and some stochastic disturbances aside, the CB plan has no obvious advantage to the sponsor versus just giving the participants the money directly and immediately.

Assuming a uniform rate of return (Treasury yield) is controversial in the pension community. First, it is inconsistent with common practice of pension investment. And second, it is said that pension liabilities are corporate promises and thus should be valued or discounted by high-quality corporate bond interest rates, as regulated by current law. For additional reference, the lower panel of Table 4 reports results when plans are assumed to use Citi AAA/AA for liability valuation (as well as the determination of benefit equivalence). The corporate bond yields are higher than 30-year Treasury rates and lead to lower plan liabilities, by 0.4–0.7 percent of payroll annually on average or $19,400–$22,800 in real dollars over 40 years. Again, the comparative costs and risks across plans continue to hold.

### Results With Alternative Demographics

We now come back to the baseline assumptions. Our baseline demographic scenario (POP0) assumes a roughly balanced age composition—younger participants account for a slightly larger fraction initially but new enrollment is later outpaced by the aging of the work force. This is necessary for a fair evaluation of the plans, in particular the DB plan. Benefit accrual for a single worker in a final-average-pay DB plan rises nonlinearly as the worker ages and approaches retirement. The funding cost would be lower in earlier years for an immature population with a larger proportion of younger workers. The reverse is true for a more mature population mainly composed of older workers.

We consider two alternative population scenarios. POP1 assumes that new entrants are all aged 26 and the number of them in each year is equal to the number of participants who retire at age 65. The total number of participants and their average age remain constant for the PE, CB, and DC plans but are both increasing for the DB plan. POP2 assumes no new entrants, causing the number of participants to shrink and the average age to rise rapidly. For comparable benefit generosity at the plan level, the pay credit rate (largely) remains at 9.6 percent for both POP1 and POP2 for the PE plan because benefits are still defined as a percentage of final average pay. As for the DB plan, the PE plan does not have the avenue of interest accrual (except for the minority of terminated (vested) workers) to alter funding cost when the length of plan maturity changes with demographics, in contrast to a CB plan. The benefit-equivalent pay credit is 5.4 percent of current pay for the CB and DC plans for POP1 and 5.8 percent for POP2. More of the CB and DC benefits are in the form of interest credit, rather than pay credit, for the longer time horizon of POP1. With a shorter horizon for POP2, interest credit plays a smaller role and the required pay credit is quite close to the baseline case.

Table 5 summarizes the simulated costs and volatilities. Funding costs decrease by all measures for the traditional DB and DC plans in the POP1 scenario relative to the baseline POP0. For instance, the real 40-year cost per worker is lower by $800 for the DB plan, $1,000 for the PE plan, $4,900 for the CB plan, and $6,400 for the DC plan. This is because the average level of earnings is lower for the plans with the addition of younger workers. The longer service careers also mean opportunities to gain investment returns for the DB. This is also true for the PE and CB plans but they need to grant more interest credit at the same time (for the terminated and vested workers in the case of PE plan).

For POP2, the DC plan experiences roughly similar costs to the baseline case. This suggests that the DC plan is generally age neutral in the distribution of accruals; that is, funding costs are linearly allocated to the career years. Most noticeable are the considerably higher funding cost and volatility for the DB plan—average funding cost is higher by 4.9 percent of payroll than for POP0. The results reveal that the demographic evolution is a particular source of funding volatilities for the traditional DB plan. DB plans are back-loaded and recognize accruals at an increasing pace in the near-retirement years. The demographic impact also shows up significantly in the PE and CB plans, with average funding cost being higher by 1.5 percent and 1.4 percent of payroll, respectively.

**TABLE 5**
Funding Costs and Volatilities per Worker With Alternative Demographics

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| A Relatively Steady Plan Population (POP1) | | | | | | |
| DB | 4.8 | 6.6 | 41.8 | 15.1 | 4.9 | 5.2 |
| PE | 5.0 | 5.4 | 47.8 | 14.1 | 5.3 | 4.2 |
| CB | 3.8 | 4.0 | 39.9 | 11.2 | 4.3 | 3.5 |
| DC | 5.1 | 2.4 | 52.7 | 6.4 | 5.4 | 0.0 |
| A Shrinking Plan Population with Rapid Aging (POP2) | | | | | | |
| DB | 11.6 | 41.7 | 71.5 | 45.8 | 9.7 | 23.0 |
| PE | 6.9 | 17.2 | 59.5 | 22.7 | 6.6 | 8.6 |
| CB | 5.8 | 12.3 | 52.0 | 19.5 | 6.0 | 8.2 |
| DC | 5.5 | 3.0 | 56.9 | 5.7 | 5.8 | 0.0 |

Source: Authors' simulations.

Labor earnings are higher on average for POP2. The average investment horizon with POP2 is much shorter for the DB, PE, and CB plans before paying out benefits, and the plans are funded more through direct contributions than from asset accumulations over time. Relative to the DB plan, contributions by the PE and CB sponsors increase less steeply with workers' ages because of the lump sum payouts.

### Results With Alternative Funding Approach

We examine variations of results with alternative funding approaches and plan provisions. It is possible that some of the funding costs for the DB plan, particularly those late-career contributions ("back-loaded") for newer and younger entrants, could fall outside our 40-year horizon and thus be not well funded in the baseline TUC method. We rerun the simulations using the PUC funding method. The PUC method includes projected increases in future earnings and allocates more of the normal costs, liabilities, and thus funding contributions to a worker's earlier years. Table 6 reports the results, whereby the results for the PE, CB, and DC plans are identical to the baseline case. Total 40-year real cost is found to be higher by $3,400 per worker when the DB plan sponsor somewhat front-loads its contributions than in the baseline TUC case. Lower volatilities of annual contributions emerge as well in this PUC case relative to the TUC case because the asset build-up forms a cushion for funding shortfalls. The standard deviation of annual contributions is lower by $500 per worker compared to the baseline TUC results. The DB plan with this alternative funding approach maintains its significantly lower average funding cost than the DC plan by all the three cost measures.

**TABLE 6**
Funding Costs and Volatilities per Worker With PUC Method for the DB Plan

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| DB | 4.5 | 5.1 | 46.0 | 14.7 | 4.9 | 4.3 |
| PE | 5.1 | 4.7 | 48.8 | 10.5 | 5.1 | 3.4 |
| CB | 4.5 | 4.0 | 44.7 | 9.2 | 4.7 | 3.1 |
| DC | 5.9 | 2.9 | 59.1 | 6.8 | 5.9 | 0.0 |

Source: Authors' simulations.

**TABLE 7**
Funding Costs and Volatilities per Worker With a 65–35 Equity–Bond Portfolio

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| DB | 4.7 | 6.5 | 41.1 | 12.4 | 4.8 | 5.1 |
| PE | 4.8 | 4.8 | 47.3 | 12.0 | 5.1 | 4.0 |
| CB | 4.0 | 4.2 | 41.8 | 10.7 | 4.5 | 3.6 |
| DC | 5.9 | 2.9 | 59.1 | 6.8 | 5.9 | 0.0 |

Source: Authors' simulations.

### Results With Alternative Investment Strategies and Economic Conditions

With regard to investment strategy, we first assume an even more aggressive higher risk 65–35 equity–bond mix for plan investments (irrelevant for the DC plan). As shown in Table 7, this strategy reduces annual nominal contributions on average, compared to the baseline results. Over the 40-year horizon, real funding cost is lower by $1,400–$2,900 on average per worker for the DB, PE, and CB plans. The more aggressive portfolio, however, imposes greater funding risks for these plans. The standard deviation of annual nominal contributions is higher by $100–$900 per worker or 0.5–1.0 percent of payroll and the standard deviation of 40-year real cost is higher by $1,400–$1,500 per worker, compared to the baseline results. Recall that our stochastic asset model includes disasters, which lower expected returns on risky assets.

We also consider an investment strategy akin to LDI. The rationale is that investment portfolios should ideally match plan liabilities in duration in order to manage and hedge interest rate risks. Long bonds work better to match the long-duration liabilities and shorter bonds to match short-duration liabilities. The conventional equity–bond mix has the problem of risk mismatch between assets and liabilities.

**TABLE 8**
Funding Costs and Volatilities per Worker With Liability-Matching Investment

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| DB | 4.3 | 6.3 | 38.9 | 10.5 | 4.2 | 4.0 |
| PE | 4.4 | 4.3 | 45.1 | 9.6 | 4.6 | 3.0 |
| CB | 5.4 | 3.6 | 50.1 | 7.8 | 5.4 | 2.0 |
| DC | 5.9 | 2.9 | 59.1 | 6.8 | 5.9 | 0.0 |

Source: Authors' simulations.

For our baseline POP0, the average duration of liabilities gradually declines over the 40-year time horizon. With the demographic aging, more and more workers approach retirement and receive payments of benefits, resulting in shorter durations. The average duration decreases from about 20 to 10 years for the DB plan and from about 15 to 5 years for the PE plan. The DB plan duration is typically longer than the PE duration because the former plan offers life annuity payments, which have longer maturity and are more sensitive to changes in discount rates than lump sum payments in the PE plan. For the CB plan, the interest credit on existing account balances responds to changes in discount rate in the model. A rise in discount rate reduces the plan liabilities but the simultaneous rise in interest credit increases liabilities. A drop in discount rate is accompanied by a drop in the interest credit rate. These moves offset each other, mostly, and lead to nearly zero duration for the CB plan.

We consider a rough but simple LDI strategy: assets are invested in 5-year Treasury notes for liability durations shorter than 4 years, in 10-year T-notes for durations of 4–8 years, and in long government/credit for durations of 8+ years.[6] By this strategy, the DB plan assets are mainly invested in long bonds, the PE plan investment starts with long bonds and reallocates to medium-term bonds over time, while the CB plan assets are in relatively short 5-year T-notes.

Results in Table 8 show that this LDI strategy reduces the cost volatility for all pension plans (irrelevant for the DC plan). Relative to the baseline case, annual nominal contributions across the DB, PE, and CB plans have smaller standard deviations, by $500–$700 per worker or 0.1–1.1 percent of payroll, and the total real cost over 40 years is also less volatile by $500–$1,400 per worker. The LDI strategy favors the DB and PE plans in particular because, besides lowering the funding volatility, it leads to drops in average costs by 0.5 percentage points of payroll than in the base case. In contrast, the strategy raises funding cost for the CB plan, by 0.8 percentage points of payroll. In real terms

[6] This simple strategy only provides an illustration of liability-matching investments and it utilizes far fewer asset classes than are available and used in practice. It is directionally correct but does not fully portray the sophisticated and customized portfolios that can match liabilities more effectively or even perfectly, particularly for the DB plan.

**TABLE 9**
Funding Costs and Volatilities per Worker Without Economic Disasters

| | Annual Nominal Cost, $000 | | 40-Year Real Cost, $000 | | Contributions as % of Payroll | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| DB | 4.2 | 4.6 | 36.9 | 8.0 | 4.4 | 3.9 |
| PE | 4.0 | 3.6 | 41.2 | 7.2 | 4.5 | 3.2 |
| CB | 3.2 | 3.0 | 35.2 | 5.9 | 3.8 | 2.8 |
| DC | 5.2 | 2.5 | 51.5 | 5.0 | 5.5 | 0.0 |

Source: Authors' simulations.

over the 40-year horizon, the LDI strategy reduces funding costs by $3,600–$3,800 per worker for the DB and PE plans but adds $5,400 for the CB plan.

The LDI strategy apparently has differential implications across the plans. Significantly higher returns are expected from longer bonds for the DB and PE plans and lower expected returns from shorter bonds for the CB plan. In other words, the LDI strategy aiming to minimize risk is more costly to implement for the CB plan. The CB plan could as well invest in the long bonds but this would work against the rationale of tracking the (short) durations of liabilities and hedging against fluctuations in the interest rate.[7]

Finally, we examine the impacts of economic and financial weaknesses. Table 9 reports the funding costs and volatilities in more benign economic conditions, that is, where there are no possible large economic disasters. Compared to the no-disaster scenario, occurrences of rare but large-magnitude economic disasters add about $800–$1,300 to the annual nominal cost or about $5,800–$9,500 to the long-run 40-year real cost per worker for the DB, PE, and CB plans. The extra funding cost is in the range of 0.3–0.9 percent of total employee salaries. Employer contributions to the DC plan also fluctuate, by about $700 annually or 0.4 percent of payroll, because macroeconomic shocks affect workers' earnings but the impact is smaller than on other plans.

## CONCLUSIONS

From the plan sponsor's perspective, this simulation analysis compares the levels and volatilities of funding costs for the prototype plans. Our model incorporates the important plan provisions and legal regulations, usual fluctuations and rare disasters in asset markets, and individual worker-specific and macroeconomic shocks to labor earnings.

The results show that the DC plan has the lowest volatility in yearly funding costs but is not necessarily the lowest cost option for sponsors in the long run for a given level of retirement benefit. The DC plan's uncertainty lies mainly in the stochastic labor

[7] Some CB plans in practice have a floor of interest credit. The risk-hedging strategy is more complicated and difficult to implement in this case because the duration is nearly zero when the interest rate goes up but is long when the interest rate falls below the floor.

earnings. Traditional DB plans tend to experience more volatile funding costs. Sponsors of all DB plans bear the risks of investment losses and fluctuations in liabilities. Hybrid PE plans are closer to DB plans in nature, while CB plans are closer to DC plans. Relative to traditional DB plans, these hybrid plans follow more stable cost trajectories primarily because their liabilities are less sensitive to interest rate changes. Also different than DC plans, hybrid plans provide certain guarantees of retirement benefits to workers while the collective investing likely reduces funding costs. The greater resilience of hybrid plans to financial market risks, however, should be qualified. The traditional DB plans could hedge interest rate risks through LDI; this is more difficult to implement for the hybrid plans.

Some have claimed that the PPA worsens the environment in which DB plans are sponsored by employers and benefits are earned by workers. Warshawsky (2007), however, shows that the PPA should improve benefit security, reduce contribution volatility, and encourage responsible funding management, compared to a very volatile funding mechanism in prior law. Many employers, nevertheless, are sensitive to the risks and fiduciary duties associated with pension plans. They may lack the management capacity and be reluctant to take the actuarial, accounting, and other responsibilities. Many employers therefore opt for DC plans for their simplicity of administration.

The overall challenge for sponsors is to establish a plan that shares financial risks among stakeholders, meets corporate needs, including cost and volatility, and helps workers financially prepare for a smooth and comfortable retirement. DB plans with lifetime annuity payouts provide retirees with retirement security and sponsors with a tool for orderly labor force management. Individual account plans have the appeal of portability and transparency to workers. The probability and timing of retirement for DC plan participants, however, are susceptible to the influence of business cycles (see Pang et al., 2010). DC plan participants may retire in booms just when companies need to add workers or stay at work during busts when companies desire a smaller workforce. Ideally, the advantages of DB and DC plans should be preserved and disadvantages mitigated by using innovative plan designs and funding and investment policies. In this direction, hybrid plans are a natural route to commingle the DC-type benefit portability and DB-type guarantees, experiencing some cost efficiency and relatively lower risk. Hybrid plans, however, have their own obstacle to more effective asset–liability management strategies and also, in practice, encourage participants to avoid an income solution that protects against longevity risk in retirement.

While financial accounting expenses and economic costs matter, cash is "king" for most organizations. The results of our stochastic analysis therefore should be helpful to plan sponsors in choosing a retirement plan type for their workers and in design. Some sponsors, owing to union demands or to the view that it is most conducive to the firm's productivity to reward long-service employees, offer a traditional DB plan. The implied higher cash cost volatility, quantified here, might need to be offset through changes in corporate capital structure, plan investments, funding policy, or other aspects of the compensation package. Some other plan sponsors, by contrast, might currently have a traditional plan but would prefer to better accommodate worker mobility and know that their workers like return guarantees. The results here should assure these sponsors that a move to a hybrid plan would lower volatility while not changing the expected level of cash costs much. Still other sponsors might not consider worker risk preferences much but want a good retirement plan for their workers and are quite concerned about the volatility of cash costs because they are in a cyclical business or in quite competitive international product markets. Their best choice, despite the higher expected cash cost, would likely therefore be a DC plan. And yet still other sponsors might be long-sighted and concerned about demographic risk, and so would choose either a hybrid or DC plan.

The actual choice of retirement plan type clearly will depend on the particular circumstances of the sponsor, its workforce, and current law. It is always good to know, with some analytical accuracy, the range of possible cost outcomes in choosing a retirement plan for an organization's workers.

## APPENDIX: SIMULATIONS OF RATES AND RETURNS

### Dynamics of Asset Returns in Normal Times

Asset returns in normal times are simulated as a VAR process. The VAR coefficients and variance matrix are first empirically estimated and then embedded in the simulations with stochastic shocks. Technically, let $V$ be a vector containing the variables. The vector evolves in an autoregressive pattern:

$$V_t = \beta_0 + \sum_{k=1}^{K} \beta_k V_{t-k} + \mu_t,$$

where $\mu \sim (0, \Sigma)$ denotes a vector of serially uncorrelated normal errors with $E\mu_t\mu_s = 0$, for $t \neq s$. The contemporaneous correlations of shocks are incorporated via the variance–covariance matrix $\Sigma$ and serial correlations of the variables via the coefficients $\beta$. The econometric regression on historical data yields estimates of the coefficients, $\hat{\beta}'s$ and the variance–covariance matrix $\hat{\Sigma}$. The simulations follow several steps: First, a Cholesky factorization decomposes the variance–covariance matrix to a triangle matrix. That is, the factorization finds a triangle matrix W so that $W'W = \hat{\Sigma}$. Second, a vector of random values is generated according to i.i.d. $N(0, 1)$. Multiplying this vector by the Cholesky factor matrix generates correlated shocks to rates and returns. Third, multiplying the VAR coefficients by previous period returns, plus the shocks, gives current period returns. The procedure is repeated forward until the end of time horizon under consideration.

Following the specification in Campbell and Viceira (2005), asset classes include money market (90-day T-bills), stocks (proxied by S&P500 Total Return index), and bonds (proxied by 5-year U.S. Government Bond Total Return Index). These rates and returns in the VAR estimation are expressed in logarithm real terms (after adjusting for inflation that is measured by the change in the CPI-U index), using quarterly data. Additionally, three forecasting variables (state variables), which help form expectations of future rates and returns, include short-term nominal interest rate (nominal T-bills), equity dividend yield, and the slope of the yield curve (yield spread as the difference between U.S. 5-year T-note zero-coupon yield and the yield on 90-day T-bills).

### Asset Contraction and Default in Rare Economic Disasters

The simulations consider low-probability large-magnitude disasters, such as depressions and wars. Expected returns on assets decrease with increases in the likelihood of a disaster. Negative skewness (fat tails) is thus featured in the distribution of asset returns.

The framework is based on Barro (2006) who demonstrates that the possibility of rare disasters can explain the equity premium puzzle and "risk-free" interest rate behavior (e.g., why expected real interest rates were low in major wars) that are not well explained by conventional models.

Rare disasters are assumed to occur with a probability of $p$ per unit of time. With a probability of $\exp(-p)$, the equity market is not affected by the disaster, but with the remaining probability of $1-\exp(-p)$, the equity value shrinks by size $b$. Conditional on the economic disaster, government bonds default with a probability of $q$ but otherwise deliver the specified face value with the remaining probability of $1-q$. A default reduces the bond value by size $d$. Simultaneously with the default of government bonds, cash rate (T-bills) is assumed to decline by size $c$ (a "flight to quality" scenario).

The baseline parameters in Barro (2006) are calibrated based on 60 economic events (15+ percent declines in real per capita GDP during World Wars I and II, Great Depression, postwar depressions, etc.) in the 20th century in 20 OECD, 8 Latin American and 7 Asian countries. Specifically, $p$ is estimated to be 0.017 and $q$ is 0.4. Sizes of loss and default ($b$, $d$, and $c$) are randomly simulated (with necessary interpolations), based on the distribution of per capita GDP contractions in table 1 and figure 1 of Barro (2006). Specifically, the distribution is in the range of 15–64 percent in the raw data and roughly 0.15–0.70 percent if adjusted for trend growth. Realized values may differ for $b$, $d$, and $c$.

### Investment Returns With Normal Shocks and Rare Economic Disasters

In normal times, asset returns follow the stochastic VAR process. When disasters strike, the simulated shrinkages of $b$, $d$, and $c$ are applied to money market, stocks, and bonds, while leaving the same-period state variables intact. Impacts of these disasters carry forward in the VAR through the autocorrelation of each asset class with its own lagged value, and more significantly, through the highly persistent autoregressive coefficients on the state variables (nominal interest rate, dividend yield, and yield spread). Disasters are simulated on an annual frequency and the shrinkages are divided into four equal values for the quarterly VAR simulations. Asset returns are reported below on an annual basis.

### Extending the VAR System: Simulations of Bond Yield Rates and Returns

Utilizing the dynamics and outputs of the enhanced "normal-disaster" VAR system, we simulate corporate and Treasury bond yields and returns as follows. Take the 30-year Treasury yields as an example. First, we run an ordinary least square (OLS) regression of 30-year T-bond yields on 90-day, 5-year, 10-year, and 20-year Treasury yields as well as a constant term. Second, stochastic 30-year T-bond yields are generated by applying the OLS coefficients and adding random shocks (with variance estimated from the OLS residuals) to these explanatory variables. Intermediate inputs in the second step are either from the VAR simulations (e.g., 90-day and 5-year Treasury yields) or additionally simulated based on empirical regression coefficients plus random market shocks (e.g., 10- and 20-year bond yields).

Similar approaches are used to simulate other T-bond yields and returns, discount rates (proxied by Citi AAA/AA bond yields), corporate bond returns (proxied by Barclays Aggregate Bond Index), and long government/credit returns (proxied by Barclays Long

Government/Credit Index). Discount rates used by plan sponsors in valuing plan liabilities should follow various corporate bond yields, related closely to those published by the IRS for regulatory purposes. The IRS time series, however, is very short (2001–2010). We therefore use Citi AAA/AA bond yields instead, which are close to the published IRS composite corporate bond rates.

## References


Barro, R., 2006, Rare Disasters and Asset Markets in the Twentieth Century, *Quarterly Journal of Economics*, 121(3): 823-866.

Black, F., 1980, The Tax Consequences of Long-Run Pension Policy, *Financial Analysts Journal*, 36(4): 21-28.

Bodie, Z., 1990, The ABO, the PBO and Pension Investment Policy, *Financial Analysts Journal*, 46(5): 27-34.

Brown, J. R., 2008, Guaranteed Trouble: The Economic Effects of the Pension Benefit Guaranty Corporation, *Journal of Economic Perspectives*, 22(1): 177-198.

Campbell, J., J. Cocco, F. Gomes, and P. Maenhout, 2001, Investing Retirement Wealth: A Life-Cycle Model, in: J. Campbell and M. Feldstein, eds., *Risk Aspects of Investment-Based Social Security Reform* (Chicago, IL: University of Chicago Press), pp. 439-473.

Campbell, J., and L. Viceira, 2004, Long-Horizon Mean-Variance Analysis: A User Guide [Appendix for "The Term Structure of the Risk-Return Tradeoff"]. Unpublished manuscript, Harvard University. World Wide Web: http://scholar.harvard.edu/files/campbell/files/long-horizon_appendix_2005.pdf.

Campbell, J., and L. Viceira, 2005, The Term Structure of the Risk-Return Trade-Off, *Financial Analysts Journal*, 61(1): 34-44.

Cocco, J., F. Gomes, and P. J. Maenhout, 2005, Consumption and Portfolio Choice Over the Life Cycle, *Review of Financial Studies*, 18(2): 491-533.

Francis, J. R., and S. A. Reiter, 1987, Determinants of Corporate Pension Funding Strategy, *Journal of Accounting and Economics*, 9(1): 35-59.

Hill, T., G. Pang, and M. Warshawsky, 2010, Hybrid Pension Plans: A Comprehensive Look at Their History, Economics and Features, A Towers Watson Perspectives Paper.

Love, D. A., P. A. Smith, and D. W. Wilcox, 2011, The Effect of Regulation on Optimal Corporate Pension Risk, *Journal of Financial Economics*, 101(1): 18-35.

McGill, D. M., K. N. Brown, J. J. Haley, S. J. Schieber, and M. J. Warshawsky, 2010, *Fundamentals of Private Pensions*, 9th edition (New York: Oxford University Press).

McHillop, D., and M. Pogue, 2009, The Influence of Pension Plan Risk on Equity Risk and Credit Ratings: A Study of FTSE 100 Companies, *Journal of Pension Economics and Finance*, 8(4), 405-428.

Mehra, R., and E. C. Prescott, 1985, The Equity Premium: A Puzzle, *Journal of Monetary Economics*, 15(2): 145-161.

Pang, G., and M. J. Warshawsky, 2009, Reform of the Tax on Reversions of Excess Pension Assets, *Journal of Pension Economics and Finance*, 8(1): 107-130.

Pang, G., and M. J. Warshawsky, 2010, Asset Allocations and Risk-Return Tradeoffs of Target-Date Funds, *Journal of Pension Benefits*, 17(3): 24-35.

Pang, G., M. J. Warshawsky, and B. Weitzer, 2010, Retirement Decision: Current Influences on the Timing of Retirement Among Older Workers, in: M. Micocci, G. N. Gregoriou, and G. B. Masala, eds., *Pension Fund Risk Management: Financial and Actuarial Modeling* (New York: Chapman and Hall/CRC Press), pp. 287-314.

Power, M. L., F. H. Dark, and A. K. Singh, 2000, Politics, Insurance Regulation, and Unfunded Pension Liabilities, *Risk Management and Insurance Review*, 3(1): 29-40.

Rauh, J. 2009, Risk Shifting Versus Risk Management: Investment Policy in Corporate Pension Plans, *Review of Financial Studies*, 22(7): 2687-2734.

Sharpe, W. F. 1976, Corporate Pension Funding Policy, *Journal of Financial Economics*, 3: 183-193.

Tepper, I., 1981, Taxation and Corporate Pension Policy, *Journal of Finance*, 36(1): 1-13.

Treynor, J. L. 1977, The Principles of Corporate Pension Finance, *Journal of Finance*, 32(2): 627-638.

Warshawsky, M. J. 2007, The New Pension Law and Defined Benefit Plans: A Surprisingly Good Match, *Journal of Pension Benefits*, 14(3): 14-27.

Warshawsky, M. J., 2010, A Proposal for Retirement Plan Reform, *Tax Notes*, 128(10): 1041-1058.