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Valuing and Hedging Defined Benefit Pension Obligations – The Role of Stocks Revisited

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I. Introduction

Defined benefit (DB) pension plans cover about 44 million U.S. workers and retirees, and represent a significant liability for many corporations.¹ The total number of participants in defined benefit plans has increased modestly in the last decade, although the number of single- and multi-employer plans declined from more than 73,000 in 1992 to about 31,000 in 2003, with most of the decline occurring among smaller plans with fewer than 1000 participants. This decline has been accompanied by marked increase in defined contribution plans, which now comprise the majority of private pension assets and are the dominant choice among smaller and younger firms that offer pension benefits.

This study revisits the related questions of how a firm should value and hedge its DB pension plan obligations, when earnings growth and stock returns are positively correlated over long horizons. The model, which takes an options pricing approach, provides testable predictions about how pension plan portfolios would vary with differences in firm and worker characteristics if the investment goal of management is to hedge projected future benefit obligations. The framework is used to analyze several important but unresolved issues including: (1) what is the appropriate discount rate for assessing the present value of projected benefit obligations in financial statements; (2) to what extent a hedging demand can explain the high level of stock holdings in DB pension plans; and (3) whether proposed limitations on stock holdings in DB pension funds to reduce the risk to the Pension Benefit Guarantee Corporation (PBGC) could significantly reduce the ability of plan sponsors to effectively manage their liabilities.

A DB pension is deferred compensation that takes the form of a retirement annuity, with payments linked by formula to the number of years of employment and earnings in the final year(s) of employment. The choice of whether to provide a DB plan is influenced by

¹ At year-end 2004, DB pension plan under-funding reached \$450 billion dollars (Congressional Budget Office (2005)). Rauh (2006) provides evidence that the obligation to close funding gaps by increasing investments in pension assets significantly crowds out productive corporate investment.

considerations such as the bargaining and regulatory environment, tax laws, incentives for employees, and risk-sharing. In fact, how such plans are structured, financed, and accounted for is heavily constrained by employment laws (ERISA), Internal Revenue Service regulations, and standards set by the Financial Accounting Standards Board (FASB). The complexity of employment contracts and the regulatory environment, as well as the lack of general results on what and when firms should hedge, also makes it difficult to definitively answer whether it is optimal for firms to hedge projected DB pension liabilities. Section 6 has a discussion of why corporations might want to hedge this obligation, but the main analysis takes this objective as given.²

What would a hedge portfolio for anticipated DB obligations look like? A significant portion of many companies' obligations, including the benefits owed to retirees and separated workers, can be match-funded or delta hedged with a bond portfolio. If, however, future earnings growth and stock returns are positively correlated, stocks can serve as a hedge against earnings-linked pension benefits. The share of stocks in an optimal hedge portfolio changes over time with firm and worker characteristics such as the probability of bankruptcy, worker separation, and mortality; and the relation between earnings growth and stock returns.

Under the assumption that the priced component of earnings risk is driven by the same factor as stock returns, pension obligation can be valued as a contingent claim on the stock market using standard risk-neutral option pricing methods. The results are sensitive to the assumed linkage between earnings growth and stock returns over different horizons. Sensitivity analysis illustrates the effects of different correlation assumptions.

The question of the best investment policy for DB plan assets received considerable attention in the early 1980s, when widespread over-funding to capture the then-available tax advantage was the primary concern of policymakers. That literature provides several reasons for

² This is in contrast to Bulow (1982) Bulow and Scholes (1983), who argue that in many instances the focus should be on accrued pension liabilities rather than projected liabilities.

investing pension plan assets primarily in bonds, including the tax exemption for income earned on plan assets (Black 1980), and the bond-like nature of accrued pension liabilities (Bulow and Scholes (1983) and references therein.) Further, several of the explanations for why stocks might be preferred -- to increase the value of the put option implicit in PBGC insurance or due to the fallacious belief that stocks always outperform bonds in the long-term (Bodie (1990)) -- suggest reasons for regulatory limits on the share of pension plan assets invested in stocks. This paper appears to be the first to quantify the potential hedging demand for stocks by modeling the joint statistical properties of stock returns and earnings growth for covered workers.

To summarize the main results, the model predicts that a large share of a hedge portfolio for active workers would be invested in stocks, with the share in stocks declining as employees age. For companies with relatively few retirees and separated workers, the observed investment practice appears roughly consistent with a hedging strategy. For the many firms with a high proportion of retirees and separated workers, however, a hedge portfolio would be invested almost entirely in bonds, a prediction sharply at odds with observed behavior. A related implication is that the financial accounting standard that allows discounting liabilities at a rate based on the average expected return on pension assets may be a reasonable approximation for firms with predominantly active workers, but understates the true value of liabilities for firms with a large proportion of retired and separated workers. Empirical evidence on how pension investment policy varies with the share of active relative to total participants supports the prediction that firms with a greater percentage of active workers invest more heavily in stocks. Stock holdings also appear to increase in the firm's expected return on assets. Asset allocation appears to be unaffected by the extent of under-funding, firm asset volatility, or leverage.

The remainder of the paper is organized as follows: The valuation model is developed in Section 2. Section 3 illustrates its implications for the optimal hedging strategy and how it varies with firm and worker characteristics, including a detailed example based on Alcoa. The implications of the options pricing model for the debate over the correct discount rate for pension

liabilities are explored in Section 4. Section 5 presents some empirical results on pension investment policy and how firm investment behavior correlates with employee demographics. Section 6 discusses why there may be a demand for hedging projected pension liabilities. Section 7 concludes with a further discussion of the implications for policy.

2. Valuation Model

A worker at a firm with a defined benefit pension has a contingent claim on future retirement income. The value of the claim tends to increase with tenure, and varies with factors such as separation probability, the future path of earnings (which in turn is affected by pension accruals), and life expectancy. The contingent claim is an asset for the worker and a liability for the firm, with PBGC insurance creating a wedge between worker and firm valuations.

The valuation model is from the perspective of the firm. The model projects future pension liabilities for a given worker, taking into account demographics, the possibility of separation and bankruptcy, and using a stochastic model that links future earnings growth to stock returns. The liabilities are valued by projecting them onto the space of traded assets; the component of liability risk orthogonal to the market is assumed to have zero price. A standard risk neutral option pricing framework and Monte Carlo simulation are used to derive the value of the liability. The corresponding hedge portfolio is dynamic. It is identified by solving for the sensitivity of the liability value to the stock price (the liability δ) in each year, and setting the share of stock in the hedge portfolio equal to δ .

2.1 Contract Value at Retirement

The pension benefit is a life annuity with a level payment each year in retirement, starting at age 65.³ It is based on an earnings replacement rate that increases linearly with years of

³ In practice benefits can be more complex, with special provisions for early retirement, inflation indexation, and survivorship benefits. None of these features, whose first order effect would be to increase the lump sum value of benefits at retirement, are explicitly considered here.

service, and on the last few years of earnings. A firm's total pension liabilities are calculated by summing across the present value of obligations to individual workers of different vintages.

The value of benefits at age 65, conditional on the firm avoiding bankruptcy and the worker staying alive until that time, is found with a simple annuity calculation:

$$(1) \quad B_{65} = \sum_{j=65}^{\infty} q_j \exp(-r(j-65)) \left[\rho_T \sum_{i=0}^{T-i} W_{T-i} / I \right]$$

where T is the year of retirement or separation, I is the number of years over which earnings are averaged, W_j is earnings in year j , ρ_T is the terminal replacement rate, q_j is the probability of living to age j , conditional on having lived to age $j-1$, and r is the discount rate, which is constant by assumption. Notice that the formula applies to the vested benefits of workers that separate from the firm prior to reaching retirement age as well as to workers who remain with the firm until age 65. In the calibrations, benefits accrue at 2 percent per year worked, and are based on earnings in the final year of work.

The appropriate discount rate, r , for the equation (1) calculation depends on the security of the benefit payments. If a firm defeases its obligations by purchasing an annuity from an insurance company at the date of separation or retirement, the effective interest rate for discounting is likely to be below the maturity matched Treasury rate because of adverse selection in annuity markets, administrative expenses, etc.. On the other hand, if the firm self-insures its obligations, the discount rate should be similar to that on other long-term liabilities, e.g., the rate on its long-term debt. For the purpose of this analysis, what matters is that this obligation is fixed and known for retirees and separated workers. Hence the choice of discount rate only affects the size of obligations. More importantly, the liabilities for retired and separated workers are essentially fixed income obligations. Thus they can be hedged with maturity matched bonds or delta hedged, and valued using a discount rate appropriate to the long-term liabilities of the firm.

2.2 Benefit Accruals for Current Workers

For current workers, the value of the obligation at retirement (1) is a random variable that depends on the joint probabilities of separation, bankruptcy and death, and the path of future wages.⁴ The year t benefit accrual is:

$$(2) \quad E_t[PV(B_{65})] - E_{t-1}[PV(B_{65})].$$

Equation (2) does not correspond to the accrual measure used for determining required funding levels. In fact, the regulatory formula for accrued liabilities only incorporates wages already received and a contractual replacement rate based on completed years of service. Bulow (1982) shows that the narrower measure is a better representation of the incremental liability to the firm if total compensation always equals the current marginal product of labor so that no compensation is ever deferred. Nevertheless, the broader measure is informative about benefit accruals. Whether and when this measure is relevant, as assumed throughout this analysis, is discussed in Section 6.

2.3 Separation, Mortality and Bankruptcy

In most of the analysis, the probabilities of separation, mortality and bankruptcy are fixed at typical values for the U.S.. Separation probabilities, broken into several broad age groups, are taken from Poterba, Venti and Weiss (200?), and are reported in Table 1. In the event of a separation, the future benefit is a function of the wage in the year of separation. For firms that subsequently go bankrupt, however, the liability goes to zero. The probability of bankruptcy reduces expected future benefit payments, and can be varied to correspond to the credit rating of the firm under consideration. In the base case, it is taken to be a modest .5 percent per year. The

⁴ The possibility of changes in contractual benefits – for instance, conversion to a cash balance plan – also affect the expected value, but are not considered here.

mortality rate, approximated from information in the Social Security Administration Trustee’s Report, is set to .3 percent per year for workers less than 65, and 5 percent per year for workers after 65.

Table 1: Annual Separation Rates	
separation rate $x < \text{age } 35$	0.06
separation rate $\text{age } 34 < x < \text{age } 46$	0.045
separation rate $\text{age } 45 < x < \text{age } 56$	0.04
separation rate $\text{age } 55 < x$	0.05

2.4 Earnings and asset returns

The specification governing the joint distribution of future earnings growth and stock returns is critical to the role of stocks in pricing and hedging pension obligations. The specification chosen is motivated by a number of empirical observations and economic considerations, and also by the need for tractability.

The specification is consistent with several key empirical observations. First, the annual correlation between aggregate wage growth and stock returns is small (e.g., Goetzman (2005)). While little direct evidence appears to be available about the longer run relation between earnings growth and stock returns, there is a growing literature suggesting that there is time-variation in the correlation between consumption growth and dividend growth, and accumulating evidence that long-run growth between these series is much more closely linked than short-term growth (e.g., Bansal and Yaron (2004), Hansen, Heaton and Li (2005), and Julliard and Parker (2005)). Since earnings and consumption also are highly correlated over medium and long horizons, it seems reasonable to use a specification for aggregate earnings growth motivated by evidence on the joint distribution of consumption growth and dividend growth. Finally, earnings are sticky, with a growth rate that is far less volatile than stock returns.

In order to employ a standard risk neutral pricing framework, it is convenient to model stock returns as a lognormal diffusion process, and to induce cointegration through the specification of the earnings process. The aggregate value of stock evolves according to:

$$(3) \quad S_{t+h} = S_t \exp\left((r_s - div - .5\sigma_s^2)h + \sigma_s \sqrt{h}(dz_s)\right)$$

where dz_s is a draw from a standard normal distribution. The expected return on stocks is r_s , the dividend yield is div , and the standard deviation is σ_s . The time step is h , taken in the calibrations to be one year.

The process for earnings captures the properties of low short run correlation between earnings growth and stock returns but higher long-term correlation, and earnings growth that is much smoother than stock returns. To motivate the earnings process, I assume that human capital is also a log-normal diffusion, where dz_w is its (idiosyncratic) risk, and α is its average drift. Human capital slowly adjusts towards the long-run human capital to stock ratio, T^* , at an annual rate of γ . The stock of human capital is reduced by earnings at time t , W_t , which is analogous to a dividend. Specifically, the aggregate value of human capital evolves according to:

$$(4) \quad H_{t+h} = H_t \exp\left((\alpha - .5\sigma_w^2)h + \sigma_w \sqrt{h}(dz_w)\right) + \gamma h \left(T^* - \frac{H_t}{S_t}\right) S_t - W_t$$

Earnings are sticky, and based on human capital. Next-period earnings equals current earnings plus a term that pulls earnings towards a target fraction of current human capital, r_w at an annual rate of β . Earnings evolve according to:

$$(5) \quad W_{t+h} = W_t + \beta(r_w H_t h - W_t)h$$

Since earnings depend on human capital, which in turn depends on the value of the stock market, a contract that depends on earnings can be valued as a derivative. The risk-neutral representation

(3), (4) and (5) have identical functional forms with the drift in (3), r_s , replaced by r_f and a change of probability measure.

Implicit in this specification is the assumption that the earnings (and benefit accruals) of individual workers will move with aggregate earnings and stock returns, rather than following a process that is specific to the individual or the firm. A rationale for this assumption is that over the relatively long time periods relevant to these calculations, competitive forces will tend to keep individual compensation growth in line with aggregate growth. That is, even if wage earnings are lower when benefit accruals are higher, total compensation will tend to move with the aggregate marginal product of labor. If total compensation moves with the aggregate, so too should its components – benefits and salaries.

To the extent that human capital is firm specific and for various reasons it is costly for workers to switch jobs, wage growth may also be correlated with own-firm performance. This raises the possibility that some employer stock belongs in the optimal hedge portfolio, but dependence on own-firm performance is not considered here.

A shortcoming of using aggregate earnings to proxy for individual earnings is that aggregate earnings mask the hump shape typical of age-earnings profiles. It should be straightforward to overlay a typical age-earnings profile on the aggregate earnings model, but this also has not been implemented in this draft.

2.5 Pricing Algorithm

A Monte Carlo simulation of wage and stock price histories is used to compute the present value of benefits for a given worker. The initial conditions include the current wage and the number of years worked. Each year, random numbers determine the innovations to stocks and earnings. Further draws from the random number generator determine whether the worker separates from the firm or dies. In the event of death, the present value of the benefit along that path is zero. In the event of a separation (or ultimately, separation due to retirement), the current

wage is multiplied by the current replacement rate and the annuity factor to calculate the (risk neutral) future value of benefits at retirement. The future value is discounted to the present at the risk free rate. The present value reported is the average across Monte Carlo simulations.

To find the share of stocks in the hedge portfolio, the sensitivity of the present value of benefits to a change in the initial stock value (the δ) is computed. This is accomplished with a parallel Monte Carlo simulation run using the same shocks. Since by assumption the firm sets aside the present value of the liability, investing a share in the stock market equal to δ equates the sensitivity of the hedge portfolio and the sensitivity of the liability to a change in the stock price.

Traditional measures of pension obligations discount the expected future value of liabilities at a fixed discount rate. The analysis demonstrates that the assumption of a single fixed discount rate is theoretically incorrect. Nevertheless, is possible to solve for the discount rate that equates the expected future value generated by the model under the true probability measure discounted at that rate to the present value implied by the model. The illustrative discount rates calculated in Section 5 below use this procedure.

3. Parameterization and Results

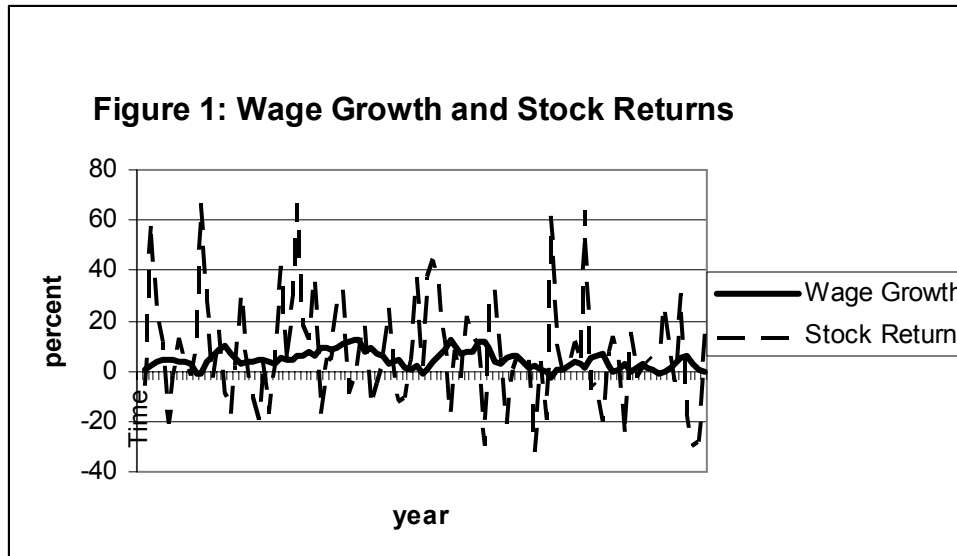
The model of the joint distribution of earnings growth and stock returns described by (3), (4) and (5) has a number of free parameters that are chosen to produce distributions that are broadly consistent with historical data. All growth rates are in real terms. Table 2 contains a list of variables and their values in the base case. The annuity multiplier per dollar of annual retirement benefit is 13, based on a maximum retirement period of 35 years, and a discount rate equal to the risk-free rate plus the mortality rate.

Table 2: Earnings Model Parameters	
mean stock return (r_s)	0.05
payout rate on human capital (r_w)	0.02
dividend yield (div)	0.02
std dev stock return σ_s	0.18
std dev idiosyncratic human capital return (σ_w)	0.04
risk free rate (r_f)	0.02
mean growth human capital (α)	0.02
speed of reversion of human capital to target (γ)	0.10
speed of reversion in earnings (β)	0.33

The model reproduces the low correlation between earnings growth and stock returns at an annual frequency, and produces a higher correlation over longer horizons. Simulating the model for 10,000 years yields the correlations between earnings growth and stock returns reported in Table 3.

Table 3: Earnings Growth and Stock Returns	
1-year correlation	-0.009
3-year correlation	0.11
5-year correlation	0.22

Figure 1 shows a simulated 100-year time series of annual earnings growth and stock returns from the calibrated model. It illustrates the much lower volatility of earnings, and low correlation between earnings growth and stock returns at an annual frequency.



To preview the main findings, simulations reveal that for active workers, stocks comprise a large share of the optimal hedge portfolio. The optimal hedge portfolio is dynamic, with the share of stocks decreasing in age. Separation triggers portfolio rebalancing, with stocks sold and replaced by bonds.

3.1 The Example of Alcoa

Data from the large aluminum manufacturer, Alcoa, provides a quantitative example of the valuation and investment policy implied by the model. Firms with DB plans report information on the earnings, age, and tenure of employees on an attachment to Form 5500. Alcoa has multiple plans covering different groups of employees. The data used in this example is from Plan 1 for the year 2000, which covers 6,178 relatively highly paid workers. Statistics are reported in 4-year windows for age and tenure; the midpoints are used in the estimates. Table A1 shows the present value of liabilities (the pension benefit obligation) and share of stocks in the hedge portfolio, for each age/tenure category in the data. Under the base case parameters, the share of stock for active workers ranges from 86 percent for young workers with short tenures, to 8 percent for workers aged 62 with tenure ranging from 12 to 37 years. The value of future

pension benefits range from less than two times current salary for young workers with short tenures, to almost 10 times current salary for long-time workers near retirement age.

The Pensions and Investments database on pension asset allocation indicates that Alcoa had an overall allocation of 52 percent in stocks (44 percent domestic, 4 percent in international equity, and 4 percent in private equity) in 2000. How does this compare with model predictions? A weighted average for the active participants in Plan 1 yields a stock share of 57 percent. This provides an approximate upper bound on the share of stock attributable to a hedging motive, as liabilities for separated and retired workers would be hedged with fixed income securities. (It is approximate because the demographic characteristics in other plans may differ from Plan 1.)

To take into account separated and retired workers, several approximations are necessary. Data on the number of active, retired, and separated workers and dependents receiving benefits is available for 2003 for all plans combined. The company reports 22,500 active participants, 34,500 retirees, 14,000 separated workers and 9,600 beneficiaries of retired workers, for a total of 80,700 participants. If the ratio of active workers to total workers is the same for Plan 1 as for the firm overall two years later, then active participants represent approximately 28 percent plan participants. To impute the effect of separated and retired workers and their dependents, it is necessary to estimate the portion of liabilities attributable to this group. To get a ballpark estimate, I assume that separated workers left the firm on average 10 years ago with 10 years remaining until retirement, with average earnings equal to average current earnings discounted at 3 percent per year, and with a replacement rate of 20 percent. Surviving beneficiaries are treated similarly. Retirees are assumed to have left the firm on average 7 years ago, and retired with earnings equal to average current earnings discounted at 3 percent, and with a replacement rate of 30 percent. Under these assumptions, obligations to current workers account for just less than 16 percent of liabilities, implying that no more than $.16(57) = 9.1$ percent of stocks could be accounted for by a hedging demand.

This example shows that for firms like Alcoa with many more retirees and separated workers than active participants, a hedging demand cannot justify the typical allocation of over 50 percent of pension assets to stocks. For firms with a higher percentage of active participants, however, a significant allocation to stocks is perhaps justifiable.

For active participants, the share of stocks in the hedge portfolio is sensitive to the parameterization, and especially to the rate, γ , at which human capital growth pulls toward its target ratio with the stock market. In the base case, to keep the correlation between stock returns and earnings growth moderate in the medium term, γ is set to .1. Increasing γ to .2 increases the share of stock in the hedge portfolio considerably. Table A2 shows the results for the various cohorts of Alcoa workers assuming the higher rate of convergence between human and physical capital. For active participants the weighted average share of stocks increases from 57 percent in the base case to 74 percent with more rapid convergence. The weighted average stock weight that includes retirees and separated workers, however, remains much lower than that observed.

4. Discounting Pension Liabilities

What rate firms should be required to use to discount pension liabilities is a topic of current policy interest, as policymakers contemplate imposing tighter funding rules to reduce PBGC's exposure, and FASB revisits its rules for pension accounting.

ERISA requires DB plan sponsors to fund to a level determined by actuarial measures of accrued liabilities (the current liability, or accumulated benefit obligation (ABO)). The accrued liability includes the vested benefits of employees and retirees. It is systematically lower than the present value of expected pension benefit payments, which also includes the effects of anticipated future earnings growth adjusted for separations, bankruptcy and mortality. An actuarial measure that takes future earnings growth into account is called the pension benefit obligation (PBO). Note that the present value of obligations computed in the model is a broader

measure than the PBO, as it includes projected future increases in the replacement rate, whereas the PBO does not.

Whether the ABO or PBO is a better measure of liabilities depends on how the information will be used. At any point in time the PBGC's risk exposure is to accrued liabilities in excess of pension assets. Correspondingly, the ABO is the basis for ERISA funding requirements. The account rule FAS87 requires firms to base the accrual adjustment to earnings from pension activity on the PBO, which FASB views as a more accurate and comprehensive measure of the pension liabilities that accrue in a given year. However, like other balance sheet items that are essentially backward looking, the accrued liability reported on balance sheet is based on the ABO (FASB, 1985).

The various actuarial liability measures are present values in the sense that they are calculated by taking expected future cash flows and discounting them to the present. The discount rate, however, is set by regulation or chosen by the firm, not based on valuation principles. Thus these actuarial measures of liabilities only roughly approximate market values. PBGC funding rules currently require firms to use a discount rate based on a smoothed long-term high grade corporate bond yield, whereas in the past it required discounting at a long-term Treasury bond rate. FASB specifies a rate based on expected returns on pension assets, and firms have considerable discretion in choosing that rate.

Neither the ERISA nor the FASB discount rate is theoretically correct.⁵ Basic finance theory teaches that the value of any stream of cash flows reflects the market risk inherent in those cash flows. The FASB rule of discounting at the expected return on assets tends to systematically understate the present value of liabilities, since pension assets are generally much riskier than

⁵ Clearly, the rules mandating smoothing rates over time rather than using the current market term structure also distort valuations, but the size of that distortion is not assessed here since the term structure is taken as flat and fixed.

pension liabilities. At the same time, using a Treasury rate tend to overstate the present value to the extent that an obligation is sensitive to market risk.

The options pricing model developed in Sections 2 and 3 operationalizes the idea of valuing pension obligations based on the market risk reflected in pension benefits. The analysis implies that no single discount rate is appropriate for all liabilities. Rather, the risk and value of liabilities varies over time and with macroeconomic, firm and worker characteristics. It is this time-varying feature that makes an options pricing approach a more reliable valuation technique than a simple discounting method.

Even if no single discount rate is theoretically correct, the model can be used to assess different simple rules for selecting a discount rate in actuarial calculations. The procedure used is to solve for the premium over the risk-free rate that results in the same present value of expected cash flows as the value implied by the options pricing model. That is, identical cash flows are valued using the options pricing model, and assuming a fixed discount rate. The fixed discount rate that yields the same present value of liabilities as the options pricing model is taken to be the best discount rate.

4.1 Discount Rates for Alcoa

The example of Alcoa Plan 1 is used to illustrate the range of implied discount rates for active participants of different ages and tenures, and the relation between discount rates and the optimal hedge portfolio. Recall that the model uses a risk-free rate of 2 percent and a mean stock return of 5 percent. The discount rate, which is a weighted average of the mean return on stocks and bonds, can be described by the share of stock corresponding to that rate. For instance, a 50 percent stock share corresponds to a discount rate of 3.5 percent. Table A3 reports the implied share of stock in the discount rate for active workers as a function of age and tenure, as well as the share of stock in the hedge portfolio, and the share of workers in that cohort remaining with

the firm until age 65. The weighted average discount rate is 2.9 percent, based on a weighted average stock share of 30.8 percent.

For each cohort and overall, the implied discount rate involves a smaller share of stocks than does the hedge portfolio. The reason is that as long as an employee remains with the firm, the correlation between earnings growth and stock growth imply a heavy weighting towards stocks. Upon separation, however, the hedge portfolio is converted entirely to bonds. For instance, for a 27 year old worker has only a 14 percent chance of retiring with the firm at 65, and a 52 year old workers has only a 52 percent chance. The discount rate is an unequally weighted average of rates relevant to periods with high and low allocations to stock in the hedge portfolio. The averaging underlying the choice of a single discount rate also has the effect of compressing the range of discount rates relative to the range of stock shares in the hedge portfolio.

How does the discount rate used by Alcoa compare to the rate implied by the model? Using the share of liabilities estimated for retired and separated workers and their dependents of 84 percent, the weighted average discount rate for Alcoa overall is $.16(.035) + (1-.16)(.02) = 2.24$ percent, or the equivalent of placing a weight on stocks of $(.16)(.308) = .049$ or 4.9 percent. This modest weighting of stocks in the discount rate is in contrast with the discount rates assumed by Alcoa in computing the pension liability for their financial statements. Alcoa's 2001 Annual Report indicates an expected 9 percent long-term return on plan assets in 2000, presumably based on their pension asset allocation of 52 percent to stocks and 48 percent to relatively safe assets (primarily bonds, and some real estate). Pension liabilities are discounted at 7.75 percent. In 2001, long-term Treasury rates were around 5.5 percent. Assuming an expected return on risky assets of 10 percent, the model implies that liabilities should be discounted at approximately 5.7 percent $(.049(.1) + .951(.055))$, more than 2 percent lower than the rate used by Alcoa for financial reporting.

A conclusion that can be drawn from this analysis is that for companies like Alcoa with a high proportion of retirees and separated workers, the typical practice of discounting liabilities

at the expected rate of return on pension assets significantly understates pension liabilities. For firms with predominantly active workers, however, the current practice may result in estimates of pension liabilities that are close to their true value.

5. Empirical Evidence

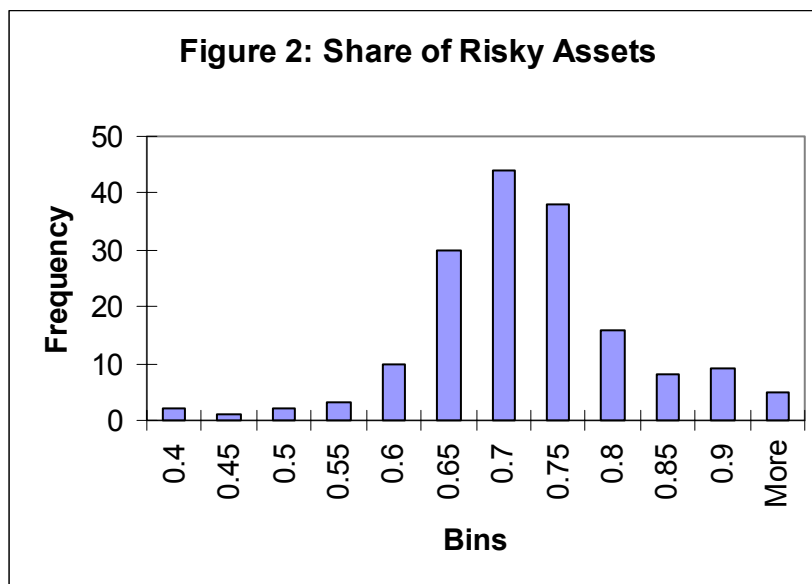
Data on the investment practices of the 1,000 largest pension plans is available from Pensions and Investments, an organization that gathers and sells this data and other pension-related information. Only a subset of the data is for public firms with defined benefit plans, as many of the largest pension providers offer only a defined contribution plan, or are non-public entities such as state governments and unions.⁶ The data on DB pension asset allocation is matched with Compustat information on corporate assets and liabilities and pension plan assets and liabilities, and with information from the Department of Labor's Form 5500 on the number of active participants, retirees and their dependents, and separated workers. Firm asset volatility and the expected return on firm assets are imputed using the approach of Merton (1974).

The matched sample includes 168 firms with pension benefit obligations totaling \$900 billion. Figure 2 summarizes the cross-section of investment policy. Risky assets are the sum of domestic equities, international equities, private equity, own-firm stock, and other. Assets included in the low-risk category include domestic and international fixed income, mortgages, real estate, and cash. An equally weighted average across firms gives an average allocation to risky assets of 70 percent, with a standard deviation of 11 percent.

A straightforward prediction of the model developed in Section 3 is that if asset allocation is influenced by a hedging motive, then firms with a higher proportion of active workers will have a higher percentage invested in risky assets. Several alternative hypotheses are

⁶ Rauh (2005) uses the same data to investigate the relation between pension investment policy, managerial incentives, and credit quality. For some firms the Pensions and Investments data is supplemented here with hand-collected asset allocation data from firm financial disclosures.

also examined. The first is that moral hazard arising from PBGC insurance would cause firms with more under-funded plans and riskier firms to shade their portfolios toward risky assets. The second is that riskier firms cut back on pension asset risk. The third, which is consistent with anecdotal evidence but not with standard theory, is that managers that require a relatively high rate of return on firm assets are reluctant to make investments that have a lower return, even if on a risk adjusted basis the return is fair.



Ordinary least squares is used to investigate to what extent the cross-section of investment policy is correlated with observable characteristics related to the various hypotheses. First, the share of risky assets is regressed on a constant and the following variables in univariate regressions.: (1) the ratio of retirees, separated workers and dependents to total plan participants; (2) under-funding as a percentage of ABO; (3) the estimated volatility of firm assets; (4) firm leverage as measured by book value debt over estimated market value of assets; and (5) the estimated expected rate of return on firm assets. The results are reported in Table 4.

Table 4: Univariate Regressions Of Risky Asset Share On Firm Characteristics

Characteristic	Intercept	t statistic	Coefficient	t statistic	Adj. R²
share retired	.759	30.5	-.119	-2.6	.032
under-funding	.694	76.9	.047	1.2	.003
asset vol	.691	63.4	.025	1.0	.000
leverage	.703	42.2	-.008	-0.3	.001
asset return	.613	20.1	1.06	2.9	.041

The findings are consistent with the hypothesis that firms with more separated and retired workers invest less in risky assets, and also with the idea that firms with higher expected rates of return on firm assets are less inclined to make low-risk investments. In a regression that includes both of these variables (not reported here) the coefficients on both are similar and remain significant, and the adjusted R² increases to .069. The variables associated with moral hazard (under-funding, leverage and asset volatility), do not appear to influence portfolio allocation, either individually nor in unreported regressions including a combination of independent variables.

6. Why Hedge and What to Hedge?

For a firm with a DB pension plan, there are two related but distinct decisions to be made with respect to funding. First, to what extent should the plan be pre-funded? Second, how should pension assets be allocated across various investment categories?

Legally, firms are obligated to meet minimum funding levels based on an ABO measure of liabilities, and assets in excess of 120 percent of full funding do not receive preferential tax treatment. Nevertheless, firms have considerable discretion over the speed with which they close funding gaps, and the extent to which funding exceeds the minimum required. In principle a firm could hold financial assets in excess of legal funding requirements outside of the plan, in anticipation of obligations that exceed the ABO. The funding and location decision is complicated by the illiquidity of assets held in pension accounts – effectively firms pay a high tax to extract funds from over-funded plans. Further, ambiguity about who owns plan assets in excess of explicit liabilities may discourage over-funding. For instance, Bulow and Scholes

(1983) cite examples of unions successfully blocking firms from using excess funds for corporate purposes.

The usual starting point for a discussion of hedging is to point out that in a frictionless market, firms have no incentive to hedge contractual obligations, as the total value of claims held against a firm's assets is invariant to the allocation of risk. Frictions such as bankruptcy costs, taxes and asymmetric information must be present for financial structure to matter. In the case of pensions, tax effects, moral hazard arising from PBGC insurance, the gaming of accounting rules, and managers' beliefs about the appropriate policy are the most often-cited influences on asset allocation. Labor contracts, which are the focus of the discussion here, also affect the incentive to hedge.

In an important paper, Bulow (1982) argues that pension accruals should be based on the ABO rather than on a more forward-looking measure. Accrual accounting aims to record obligations at the time they are incurred. If each year a worker's total compensation – the sum of salary and benefits – approximately equals his or her marginal product, then only the irrevocable portion of benefits earned should be attributed to current compensation. Although the benefit formula may cause accruals to increase as a fraction of compensation over time, lower future salary increases will offset the increased value of benefits so as to maintain total compensation at its competitive level.

Bulow's observation has important implications for financial reporting, as it suggests that using the more comprehensive PBO measure for accruals in combination with wages in many instances overstates total current compensation expense. It does not, however, preclude the possibility that a firm might want to hedge its projected benefit obligations, nor does it invalidate the pricing model in Section 3. The model estimates the present value of the projected future ABO for the firm. The future ABO, like other liabilities, must be taken into consideration for financial planning purposes. If total compensation is a return on human capital, if human capital is co-integrated with the stock market, and if ABO accruals are a fairly stable fraction of a

worker's total compensation (Bulow suggests this is likely), then the assumptions of the valuation model are satisfied.

To the extent that pensions are part of optimally deferred compensation, there may be contractual reasons for the firm to hedge and fund broadly defined pension obligations. Imagine that there is a high return on the development of firm specific human capital, but that performance is not verifiable and so a complete and enforceable contract cannot be written. If the worker pays for human capital investment, there is the risk that the firm will be able to expropriate the return later on. If the employer pays, it risks losing its investment if the worker leaves the firm sooner than expected.

Deferred compensation has the potential to mitigate this problem. It provides workers with a return on their investments in firm-specific human capital, and an incentive remain with the firm long enough for the firm to recoup its investments. The deferral also allows firms to pay less to employees that separate early, reducing investment losses. For a DB pension plan to serve this function, it must be possible to prevent employers from cutting salaries to offset benefit increases, for instance by publishing binding minimum salary levels for specific job descriptions. If the firm funds and hedges pension obligations, the credibility of its promises, and hence their ex ante value to workers, is enhanced. The fund effectively serves as collateral against the partially implicit contract. Further, competitive pressures are less likely to cause a firm with a funded plan to renege than if it has to meet its obligations entirely out of current revenues. The present situation in the auto industry illustrates this phenomenon. U.S. manufacturers, facing foreign competitors with lower labor costs, lament that unfunded obligations to retirees (primarily health benefits) have saddled the industry with unsustainably high costs. Had those obligations been fully funded it seems likely that they would be paid in full, even as the salaries and benefits of current workers were cut to respond to competitive pressure going forward.

7. Policy Implications and Conclusions

This paper develops a framework for estimating a risk-adjusted discount rate for discounting projected benefit obligations, and uses it to assess to what extent a hedging demand might explain the high level of stock holdings in DB pension plans. The analysis demonstrates that the appropriate discount rate, and also the portfolio allocation to stocks consistent with a hedging motive, varies significantly with participant demographics. Stocks play a much larger role for “young firms” -- firms with mostly active workers and relatively few retirees -- than for “old firms” with many separated and retired workers.

These findings are relevant to the ongoing discussion of how to improve the accuracy and transparency of pension accounting in financial statements. The practice of allowing companies to base the discount rate on expected pension asset returns clearly leads to an understatement of liabilities, especially for old firms. It also may provide an incentive to invest plan assets in riskier securities than if the discount rate were unrelated to investment policy, a practice that has the undesirable side effect of increasing the risk exposure of the PBGC. Proposals that call for mandating a maturity-matched Treasury rate for discounting, however, could result in young firms being forced to significantly overstate the value of pension liabilities in PBO calculations.

A similar distinction between young and old firms applies to the question of whether proposed limitations on stock and other risky investments in DB pension funds to reduce the risk to the Pension Benefit Guarantee Corporation (PBGC) could significantly reduce the ability of plan sponsors to effectively manage their liabilities. While the analysis suggests reasons that firms might want to hedge, and the empirical evidence is mildly supportive of a hedging demand, the analysis does not measure the strength of that demand. Nevertheless, restricting investments would be another factor potentially discouraging young firms from adopting or maintaining a DB pension plan.⁷

⁷ PBGC assesses a per capita premium, rather than a charge based on accrued liabilities. This results in young firms paying a much higher premium for a given level of coverage than old firms (CBO (2005)).

The analysis also suggests that even in the absence of moral hazard, the PBGC and the firm might not agree on how assets should be allocated. This is because they are responsible for pension liabilities in distinctly different states of the world. It has been suggested that PBGC's reduction in stockholdings in its own portfolio could serve as a model for corporate pension asset allocation guidelines. The obligations already assumed by the PBGC, however, are entirely for retired workers and effectively separated workers, and are unaffected by subsequent wage appreciation. Thus PBGC's investment policy may not reduce risk from the perspective of young firms.

Finally, while recent commentators have stressed the need to reduce the risk in the DB pension system, the analysis suggests that caution should be taken to avoid imposing overly restrictive regulations that discourage the provision of DB plans for non-economic reasons. The model may be helpful in this regard, as it suggests how investment guidelines and discount rates for financial reporting could be based on participant demographics. Extension of the model to include a stochastic term structure and additional asset classes, as well as further investigation of the empirical relation between earnings and asset returns would be useful for a more complete analysis, but for now are left for future research.

**Table A1: Pension Benefits and Share of Stock in Hedge Portfolio for Alcoa Plan 1 Workers
by Age and Tenure, Base Case Parameters**

# workers	Current age	Years worked	Current salary (\$)	PV (\$)	Stock %
91	22	0	34,722	49,163	86
55	22	2	32,810	51,180	83
108	27	0	38,289	64,202	86
208	27	2	40,413	74,191	83
41	27	7	44,062	99,829	78
97	32	0	47,813	86,276	85
228	32	2	49,620	100,821	82
188	32	7	60,345	154,586	77
90	32	12	66,414	204,282	75
83	37	0	56,870	113,868	83
222	37	2	58,405	129,448	80
178	37	7	64,252	181,088	76
262	37	12	69,805	247,057	74
83	37	17	72,713	299,574	72
57	42	0	64,736	134,440	79
151	42	2	51,633	125,751	77
139	42	7	62,710	196,853	73
266	42	12	69,065	262,501	70
309	42	17	82,276	368,656	69
299	42	22	79,418	407,940	67
23	42	27	58,702	350,613	67
47	47	0	58,106	119,164	71
82	47	2	65,076	155,471	69
90	47	7	64,493	206,624	66
200	47	12	67,781	270,047	65
180	47	17	72,193	350,525	63
303	47	22	76,549	436,409	63
332	47	27	69,203	447,613	62
29	52	0	67,836	123,685	58
59	52	2	63,648	139,616	57
57	52	7	63,919	197,388	53
124	52	12	64,867	262,767	53
97	52	17	69,075	348,616	52
173	52	22	73,072	432,469	51
274	52	27	78,678	537,739	50
288	52	32	77,295	608,916	51
27	57	2	64,351	116,162	36
64	57	12	67,227	265,330	34
44	57	17	54,163	269,105	33
84	57	22	67,977	413,307	33
93	57	27	76,752	545,130	33
214	57	32	85,997	699,528	33
61	57	37	82,801	764,553	32
20	62	12	64,252	228,337	8
34	62	32	71,451	599,670	8
24	62	37	89,897	860,155	8

Table A2: Pension Benefits and Share of Stock in Hedge Portfolio for Alcoa Plan 1 Workers by Age and Tenure, $\gamma=2$

# workers	Current age	Years worked	Current salary (\$)	PV (\$)	Stock %
91	22	0	34,722	46,272	93
55	22	2	32,810	50,283	91
108	27	0	38,289	59,746	93
208	27	2	40,413	71,943	91
41	27	7	44,062	98,656	86
97	32	0	47,813	86,365	94
228	32	2	49,620	101,301	92
188	32	7	60,345	158,591	88
90	32	12	66,414	206,056	84
83	37	0	56,870	116,253	94
222	37	2	58,405	132,343	91
178	37	7	64,252	187,289	88
262	37	12	69,805	246,041	86
83	37	17	72,713	289,121	82
57	42	0	64,736	136,104	92
151	42	2	51,633	120,089	90
139	42	7	62,710	200,190	87
266	42	12	69,065	262,506	84
309	42	17	82,276	371,246	83
299	42	22	79,418	412,162	81
23	42	27	58,702	351,566	82
47	47	0	58,106	121,893	89
82	47	2	65,076	156,439	87
90	47	7	64,493	205,146	83
200	47	12	67,781	272,822	82
180	47	17	72,193	351,578	80
303	47	22	76,549	438,738	80
332	47	27	69,203	445,907	79
29	52	0	67,836	124,370	81
59	52	2	63,648	140,864	79
57	52	7	63,919	199,080	75
124	52	12	64,867	266,331	74
97	52	17	69,075	343,746	72
173	52	22	73,072	434,219	72
274	52	27	78,678	546,034	71
288	52	32	77,295	612,061	71
27	57	2	64,351	115,606	58
64	57	12	67,227	263,415	54
44	57	17	54,163	270,356	53
84	57	22	67,977	412,888	53
93	57	27	76,752	549,285	53
214	57	32	85,997	702,998	52
61	57	37	82,801	766,528	52
20	62	12	64,252	227,911	15
34	62	32	71,451	598,819	14
24	62	37	89,897	861,859	14

Table A3: Share of Stock for Discount Rate, Share of Stock in Hedge Portfolio, and Share Not Separating Before Retirement for Alcoa Plan 1 Workers, Base Case Parameters

# workers	Current age	Years worked	Current salary (\$)	Share stock in discount rate	Share stock in hedge port.	Share not separating
91	22	0	34,722	0.53	0.86	0.11
55	22	2	32,810	0.50	0.83	0.10
108	27	0	38,289	0.53	0.86	0.14
208	27	2	40,413	0.51	0.83	0.14
41	27	7	44,062	0.47	0.78	0.14
97	32	0	47,813	0.52	0.85	0.20
228	32	2	49,620	0.49	0.82	0.19
188	32	7	60,345	0.47	0.77	0.19
90	32	12	66,414	0.44	0.75	0.19
83	37	0	56,870	0.49	0.83	0.25
222	37	2	58,405	0.47	0.80	0.25
178	37	7	64,252	0.44	0.76	0.24
262	37	12	69,805	0.43	0.74	0.25
83	37	17	72,713	0.42	0.72	0.26
57	42	0	64,736	0.45	0.79	0.33
151	42	2	51,633	0.45	0.77	0.34
139	42	7	62,710	0.42	0.73	0.34
266	42	12	69,065	0.40	0.70	0.32
309	42	17	82,276	0.38	0.69	0.32
299	42	22	79,418	0.37	0.67	0.32
23	42	27	58,702	0.37	0.67	0.33
47	47	0	58,106	0.39	0.71	0.41
82	47	2	65,076	0.38	0.69	0.41
90	47	7	64,493	0.36	0.66	0.41
200	47	12	67,781	0.35	0.65	0.40
180	47	17	72,193	0.34	0.63	0.42
303	47	22	76,549	0.33	0.63	0.41
332	47	27	69,203	0.33	0.62	0.41
29	52	0	67,836	0.30	0.58	0.52
59	52	2	63,648	0.29	0.57	0.51
57	52	7	63,919	0.27	0.53	0.51
124	52	12	64,867	0.27	0.53	0.53
97	52	17	69,075	0.26	0.52	0.52
173	52	22	73,072	0.26	0.51	0.52
274	52	27	78,678	0.25	0.50	0.52
288	52	32	77,295	0.26	0.51	0.53
27	57	2	64,351	0.17	0.36	0.65
64	57	12	67,227	0.16	0.34	0.66
44	57	17	54,163	0.15	0.33	0.64
84	57	22	67,977	0.15	0.33	0.65
93	57	27	76,752	0.15	0.33	0.65
214	57	32	85,997	0.15	0.33	0.64
61	57	37	82,801	0.15	0.32	0.64
20	62	12	64,252	0.04	0.08	0.85
34	62	32	71,451	0.04	0.08	0.85
24	62	37	89,897	0.04	0.08	0.85

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