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

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1. **Introduction**

Despite a significant decline in the prevalence of defined benefit (DB) pension plans relative to defined contribution (DC) plans in the U.S. over the last twenty-five years, DB plans remain an important part of the pension landscape. There are currently about 31,000 single and multi-employer DB pension plans that together cover about 44 million U.S. workers and retirees.[1] Aggregate DB pension assets currently total about $ 2 trillion.

A series of recent events has generated renewed academic and policy interest in the DB pension system. A spike up in bankruptcies of large sponsors with severely under-funded plans (e.g., United Airlines, U.S Air, and Bethlehem Steel) caused the transfer of billions of dollars of pension liabilities to the Pension Benefit Guarantee Corporation (PBGC), the Federal agency that insures DB pension plans. This in turn has led to new legislation intended to contain the risk to taxpayers by tightening funding rules. Partly in anticipation of such rule changes, a growing number of apparently healthy companies (e.g., IBM and Alcoa) have announced a partial or full freeze of their DB plans. At the same time, FASB continues to debate whether the provisions of FAS 87, which govern how pensions are accounted for in financial statements, should be modified. Also looming in the background is the broader question of the best way to structure the private pension system and coordinate it with changes to Social Security.

This paper revisits two basic questions that are critical for understanding and controlling DB pension risk: How should the value of DB pension liabilities be computed; and how should pension assets be allocated? In particular, we reexamine the role of stocks in valuing and hedging pension obligations.[2] Our approach differs from others in the literature in at least two ways. First, it is one of the few that focuses on market value, and does so by using a derivative pricing approach.[3] Second, it is novel in incorporating new evidence on the time-varying correlation between labor earnings growth and asset returns.

A DB pension is deferred compensation that takes the form of a retirement annuity, with

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[1] 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 a 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.

[2] Black (1989) suggests a role for stocks, but does not quantify the effect.

[3] Sundaresan and Zapatero (1997) also takes a derivatives pricing approach, but assumes a constant correlation structure.

payments linked by formula to the number of years of employment and earnings in the final year(s) of employment. Although the short-run correlation between earnings growth and stock returns is negligible, economic theory suggests that there should be a long-run positive correlation between labor earnings and stock returns, and there is some recent empirical evidence supporting this (see, e.g. Benzoni et. al. 2006). We posit a model of the joint process for earnings and stock returns that takes this long-run relationship into account. The derivatives pricing model, which is used to value pension liabilities and characterize the hedge portfolio, incorporates the assumption that the priced component of employee earnings risk is driven by the same factor as stock returns. Risk-neutral derivative pricing methods are then used to value the pension obligation as a contingent claim on the stock market. Determining the value of various liability measures requires assumptions about the stochastic processes for labor earnings, job separations, and stock returns. Particularly important is the correlation over different horizons between employee earnings growth and stock returns. Sensitivity analysis illustrates the effects of different assumptions about this correlation.

The model can be used to value a variety of liability measures, ranging from the narrowest (accrued benefit obligation or ABO) that is based on current years of employment and earnings to date for each former and current worker, to the broadest that is based on projected future years of employment and earnings for all former, current, and future workers. We focus, however, on two intermediate measures that are based on projected future earnings (projected benefit obligation or PBO) and projected future earnings and years of employment (broad PBO) for former and current workers only. The former is consistent with the current accounting definition of the PBO used in financial statements, whereas the latter seems most relevant to managing the current and future obligations associated with the current workforce. Our approach treats the pension cash flows in isolation, for the most part ignoring other cash flows of the firm.[4] In effect, we are asking what the market value of pension liabilities would be if they were traded as stand-alone entities.

In addition to computing the present value of the pension obligation, we compute the internal rate of return, i.e., the average discount rate consistent with the present value of pension liabilities. Representing the valuation rule in terms of a discount rate is useful for evaluating the

[4] Other firm cash flows do matter indirectly, as the assumed probability of firm bankruptcy affects liability value, which we measure from the perspective of the firm.

biases that arise from statutorily set discount rates, which determine the liabilities reported in financial statements and minimum regulatory funding levels.

Our valuation model implies a corresponding hedge portfolio that answers the question of what the firm would invest in if it wanted to hedge the market risk of its pension liabilities. This hedge portfolio has a number of interesting characteristics. First, in light of the long-run relation between stock returns and earnings, we find that stocks are a part of this portfolio, and in some cases an important part. Second, we show how the share of stocks in this hedge portfolio changes over time with firm and worker characteristics such as the probability of bankruptcy, worker separation, and mortality.[5] A large share of the hedge portfolio for young active workers is invested in stocks, with the share in stocks declining as employees age.

We then consider the broader question of the optimal dynamic asset allocation for a firm's DB pension assets, and how it relates to the hedge portfolio for valuation that we focus on? Answering this question in general is difficult.. First, there are obviously many other factors that enter the asset allocation decision in addition to the hedging demand, including taxes, PBGC insurance and the moral hazard that could result, IRS, ERISA and FASB regulations, corporate liquidity needs, and labor contracting considerations. Second, even if the optimal policy is to hedge the pension obligation, there is still the question of *which* measure of pension obligations should be hedged? In a future draft, we hope to suggest a plausible objective function consistent with using the hedge portfolio for valuation as the basis for investment policy.

Bodie (1990, 2006) and others have argued in favor of hedging the current accrued benefit obligation (ABO). They conclude that pension plans should invest 100 percent in bonds that match, exactly or in duration, the cash flows represented by the current ABO.[6] By contrast, our analysis suggests that the dynamic nature of the obligation in many instances requires taking into account not just the current ABO, but obligations associated with expected future accruals as well. We show that stocks typically comprise a portion of the hedge portfolio for the PBO

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[5] For simplicity, we assume that both employee separations and aggregate mortality are uncorrelated with the stock market and that these risks have zero price in financial markets.

[6] In addition, the tax exemption for income earned on plan assets should provide an incentive for firms to invest pension assets in bonds (Black, 1980). For other arguments in favor of pension funds holding a 100% bond portfolio, see, for example, Gold and Hudson (2003) and Wilcox (2006). The most notable example of a company that followed this advice is the U.K. pharmaceutical firm Boots, which shifted completely out of equities in 2001 (they partially shifted back in 2005); see Jolliffe (2005) and Ralfe (2005).

liability, even taking into account that future wages may be reduced by the value of current pension accruals, as suggested by Bulow (1982).

In the final part of the paper, we examine survey data on actual asset allocations by large pension plans. The model 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 stand-alone pension liabilities. We ask 1) whether our model can explain the large average allocation to stocks found in the data (over 60% of aggregate DB pension assets are invested in stocks) and 2) whether the data are consistent with the cross sectional implication that firms with a greater percentage of active workers invest more heavily in stocks. We find that 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. Thus, while we disagree with the recommendation that firms shift pension assets completely to bonds, our results imply that for many firms, a hedging demand is unlikely to explain the propensity to invest the bulk of assets in stocks.

The remainder of the paper is organized as follows: The valuation model is developed in Section 2. Section 3 describes the corresponding hedging strategy, and shows how it varies with firm and worker characteristics. We also compute the constant discount rate at which the present discounted value of the liabilities equals the market price. To illustrate the results, we focus on the example of a single firm: Alcoa. Section 4 discusses the broader issue of when the hedge portfolio used in pricing pension obligations is also the optimal asset allocation for a firm's pension plan. Section 5 presents our empirical results on the relationship between pension asset allocation and employee demographics. Section 6 concludes with a discussion of the implications for policy and extensions for future research.

2. Valuation Model

In this section, we develop a model for valuing pension obligations, based on the market risk reflected in pension benefits.

2.1 Measures of liabilities

A participant in a typical defined benefit pension plan is entitled to a life annuity with a level payment each year, generally starting at age 65.[7] The annual payment is set according to a formula such as:

$$b_{iR} = k \cdot N_{iT} \cdot W_{iT} \tag{1}$$

where b_{iR} equals the annual benefits throughout retirement, k is a fixed percentage (e.g. 2%), T is the year preceding separation, retirement, or plan freezing, N_{iT} is the number of years worked through T, and W_{iT} equals the worker's wage earnings in year T. Thus, the benefits replace a percentage of the workers final earnings, with the replacement rate increasing linearly with years of service. In the event of separation prior to retirement, the future benefit is a function of earnings in the year prior to separation.

A variety of liability measures are used in practice for a variety of purposes, including financial reporting, determining minimum funding levels, and determining maximum tax preferred funding levels. These measures differ in how comprehensively the obligation is defined. We consider four possible definitions of claims, ranging from narrowest to broadest.

i) $\Sigma_{\text{current workers}}\, b_{iR}(k, N_{it}, W_{it})$ (ABO)

ii) $\Sigma_{\text{current workers}}\, b_{iR}(k, N_{it}, W_{iT})$ (PBO)

iii) $\Sigma_{\text{current workers}}\, b_{iR}(k, N_{iT}, W_{iT})$ (Broad PBO)

iv) $\Sigma_{\text{current + future workers}}\, b_{iR}(k, N_{iT}, W_{iT})$ (All-inclusive PBO)

The narrowest of these measures holds constant at current levels both the number of years of

[7] In practice benefits can be more complex, with special provisions for early retirement, inflation indexation, and spousal survivorship. Firms may also voluntarily increase benefits, although that practice appears less common than in the past. None of these features, whose first order effect would be to increase the present value of benefits at retirement, are explicitly considered here.

service and wage earnings, and sums these benefits across all current and retired [8] workers. The present value of the future stream of these benefits is referred to as the ABO. The second measure holds constant years of service, but is based on wage earnings at the separation date. The third (whose present value we refer to as the "broad PBO"), is based on both on years of service and wage earnings at the time of separation. Even broad PBO does not provide an all-inclusive measure of pension liability, however, as it takes into account future separations by current workers, but not the effect of new hires. Our broadest measure also takes into account future hiring decisions by summing benefits (based on the future years of service and future wage earnings) across *both* current *and* future workers at the firm. We refer to the present value of this measure as "all-inclusive PBO."

What constitutes the relevant liability measure depends on the question being asked. The ABO represents a legal obligation of the firm that can be avoided only by bankruptcy. From the perspective of the worker, the ABO is largely a safe asset due to PBGC insurance.[9] FAS 87 requires that firms use the PBO measure to compute the effect of changes in pension liabilities on reported earnings. From the perspective of a manager wishing to assess the future expense associated with the current workforce, however, the PBO understates liabilities because it does not take into account increases due to predictable future "service cost" increases – increases in ultimate benefits based on the number of years with the company. The all-inclusive PBO may be relevant to managers wishing to assess the comprehensive cost of DB obligations.

Each of these four sets of claims can be valued. From the perspective of the firm, the value at any date will depend on known variables such as years of service and current earnings, as well as on the joint probability distribution for future earnings, job tenure, worker lifespan, bankruptcy and stock returns. In this version of the paper, we focus primarily on the broad PBO measure, but similar considerations apply to the other measures, which we plan to consider in more detail in future drafts.

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[8] Throughout we use "retired workers" as shorthand for "retired workers and beneficiaries," since many plans extend benefits to surviving spouses and minor dependents.

[9] The PBGC insures benefits up to a legally mandated maximum amount.

2.2 Contract Value at Retirement

We define B_R as the present value of benefits as of the retirement age R, conditional on the firm having avoided bankruptcy and the worker staying alive until that time (for notational simplicity, we drop the individual i subscript).Assuming a constant discount rate, we can compute B_R by multiplying annual benefits in each year by the corresponding probability of survivorship and then discounting back to the retirement age at rate r. Thus,

$$B_R = \sum_{j=R}^{\infty} q_j e^{-r(j-R)} b_R \quad (2)$$

where b_R is the annual benefit defined in equation (1), q_j is the probability of living to age j, conditional on having lived to age R, and r is the discount rate.

The liabilities for retired and separated workers are essentially fixed income obligations, and can be valued and hedged as such. In the absence of firm bankruptcy risk, the appropriate discount rate, r, for equation (2) is the riskless rate of interest. With bankruptcy risk, the discount rate should be similar to the yield on other long-term liabilities, e.g., the rate on the firm's long-term debt. The liabilities for retired and separated workers can be hedged with maturity matched bonds, or delta hedged.

For current workers, B_R is a random variable that depends on future realizations of wages, separations, etc. Valuing that random variable requires a model relating future wage earnings to priced factors in the capital market.

2.3 Earnings and asset returns

The specification governing the joint distribution of future wage earnings growth and stock returns is critical to the role of stocks in pricing and hedging pension obligations. In this section, we specify a stochastic process that links labor earnings to the value of the stock market over the long run, but allows for deviations in the short run. The specification chosen is motivated by a number of empirical observations and economic considerations, and also by the need for tractability.

Our 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). Second, the volatility of the growth rate of labor earnings is far less than the volatility of stock returns. Finally, there is some evidence that labor earnings and stock prices are positively related in the long run (see, for example, Cardinale, 2004, and the references therein). Benzoni, Colin-Defresne, and Goldstein (2006) assume a positive long run correlation of wages and stock prices, and present some summary evidence supporting their assumption.[10] In addition, 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)). The observation that earnings and consumption also are highly correlated over medium and long horizons provides additional support for our assumption of a positive long-run correlation between labor earnings and the stock market.

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

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

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 below 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, we assume that human capital is also a log-normal diffusion, where dz_w is its (non-priced or 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:

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[10] For a dissenting view, see Lustig and van Nieuwerburgh (2006).

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

Earnings are based on human capital, but they do not adjust instantly to changes in human capital, i.e. they are "sticky." 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. Specifically, earnings evolve according to:

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

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 (4), (5) and (6) have identical functional forms with the drift in (4), r_s, replaced by r_f, and a change of probability measure.

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 in this draft.

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.

Finally, implicit in this specification is the assumption that the total labor earnings 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. The possibility that the wage component of earnings is offset by pension benefit accruals is considered in section 2.8 below.

2.4 Mortality, separation, and bankruptcy

Equations (3) - (5) describe the path of future earnings of a typical worker, which terminate (from the perspective of the firm or pension insurer) in the event of death, voluntary or involuntary separation (including retirement), or firm bankruptcy. In the calibrations, triggers for these termination events are chosen to reproduce typical outcomes for U.S. workers and firms, as described below. In applying the model to specific firms, the parameters could be adjusted to match its characteristics. For instance, the expected bankruptcy rate and typical worker tenure vary considerably across firms.

In the calibrations, the annual separation rate varies with a worker's age, and retirement is imposed uniformly at age 65. The annual mortality rate also is based on historical data. The bankruptcy rate is held constant, effectively increasing the rate at which the firm discounts projected liabilities. If the model were used to value liabilities form the perspective of the pension insurer, the bankruptcy rate would of course increase the value of liabilities rather than decrease it.[11]

The assumption that mortality, separation and bankruptcy risk are orthogonal to priced risks is made for convenience, and because we do not have reliable estimates of the strength of such correlations. It is likely, however, that separation and bankruptcy rates increase in market downturns. That would increase the correlation between future liabilities and the market. Hence it would increase the rate at which future liabilities are discounted and the share of stock in the corresponding hedge portfolio.

2.5 Algorithm for computing liability value and hedge portfolio

We value the liabilities by projection onto the space of traded assets as represented by the stock market; the component of liability risk orthogonal to the market is assumed to have zero price. A standard risk neutral derivatives pricing framework and Monte Carlo simulation are used to compute the present value of benefits for a given worker, as a function of the worker's age, current labor earnings, and current years of tenure with the firm. The values of the stock market and the human capital stock are initialized at the target ratio of the two variables. A firm's total pension liabilities are calculated by summing individual liabilities across all current

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[11] CBO (2005) uses a related options pricing framework to value pension guarantees, but under the assumption that pension liabilities are bond-like.

and past workers.

We perform the Monte Carlo simulations of labor earnings and stock price histories as follows. Each year, random draws from a normal distribution determine the innovations to stocks under the risk-neutral and actual representations, human capital, and earnings. Further draws from a uniform distribution 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), current earnings are multiplied by the current replacement rate and the annuity factor to calculate the future value of benefits at retirement. The future value is discounted to the present at the risk free rate; the price of risk is implicitly incorporated by the risk-neutral representation of the evolution of stock value.[12] The present value reported is the average under the risk-neutral measure across Monte Carlo simulations.

The corresponding hedge portfolio implied by the model is dynamic. To find the share of stocks in the hedge portfolio in the initial year, we compute the δ: the sensitivity of the present value of benefits to a change in the initial stock price. This is accomplished with a parallel Monte Carlo simulation that uses identical shocks. Under the assumption that 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.

When the value of pension assets, A, is not equal to that of liabilities, L, the hedge portfolio must also be adjusted.. In general this is accomplished by using the idea of a hedge ratio, where the share of stock in the hedge portfolio is found by setting the delta of the assets, δ_A equal to $\delta_L L/A$.

2.6 Computing an average discount rate

Standard measures of pension obligations rely on a fixed discount rate (or set of fixed rates reflecting the term structure). Our analysis demonstrates that the assumption of fixed rates is theoretically incorrect. Because the risk of liabilities varies over time, and with macroeconomic, firm, and worker characteristics, so does the appropriate discount rate. It is this time-varying feature that makes a derivatives pricing approach a more reliable valuation

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[12] See McDonald (2006) for a clear explanation of risk-neutral pricing.

technique than a simple discounting method.

Nevertheless, to gauge the size of the error from ignoring risk-adjustment using an interest rate metric, we solve for the discount rate such that the expected future value generated by the model under the true probability measure is equal to the present value implied by the model. That is, identical cash flows are valued using the derivative pricing model, and assuming a fixed discount rate. The fixed discount rate that yields the same present value of liabilities as the derivatives pricing model is reported in Section 3 below.

2.7 Parameterizing the model

In most of the analysis, the probabilities of separation, mortality and bankruptcy are fixed at typical values for the U.S.. Separation probabilities, divided into several broad age groups, are taken from Poterba, Venti, and Wise (2005), and are reported in Table 1. The mortality rate, approximated from information in the 2005 Social Security Administration Trustees' Report, is set to 0.3 percent per year for workers younger than 65, and 5.0 percent per year for workers after 65. The probability of bankruptcy is set to 0.5 percent per year. The benefit accrual rate, k, is fixed at 2.0 percent per year worked.

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, and inflation is neglected. The effect of inflation will be considered in subsequent drafts. 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.

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 at various horizons reported in Table 3. 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 the low correlation between earnings growth and stock returns at an annual frequency.

2.8 Incorporating the effect of pension accruals on wage earnings.

So far, we have not distinguished between wage earnings and total labor compensation, which include wages but also the value of benefits such as pension accruals and health insurance. Bulow (1982) observes that in a competitive labor market, total compensation will equal the marginal product of labor each period. He argues that for companies with DB pension plans, the sum of current wages and current ABO pension accruals should equal the marginal product of labor. Hence, all else equal, a worker's pension accrual is offset by a reduction in wage income.[13] A question that arises is how Bulow's proposition affects the role of stocks in valuing and hedging DB liabilities. The idea that pension accruals reduce contemporaneous wages and that total compensation is the marginal product of labor can be incorporated into the more complicated model described by equations (3) – (5). Taking the offset into account simply requires reinterpreting W_t in equations (4) and (5) as total compensation, and then separately tracking the accrual and wage components of compensation over time. Simulations confirm that the long-run correlation between total compensation and the return on capital implies that pension accruals and the return on capital are positively correlated. That is, even under the assumption that there is a one-for-one offset between wage compensation and pension accruals at a point in time, the common shock to capital and labor compensation induces a positive relation between the change in the pension liability and the change in the stock price, implying that stocks still are a relevant to pricing, and comprise a share of the hedge portfolio. Simulation results demonstrating this will be included in a future draft.

3. Results on valuation and discounting

We present quantitative results for valuation and the discount rate based on the example of Alcoa. To preview the main findings, simulations reveal that for young 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.

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[13] To the extent that pensions represent deferred compensation, however, the offset will only be partial.

3.1 Valuation: 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 current tenure of employees on an attachment to Form 5500. Alcoa has multiple plans covering different groups of employees. The data used is 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 under the "broad PBO" measure, and the corresponding 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 (described in the next section) 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? To answer this, requires separate consideration of active participants, and retirees, separated workers, and dependents.

A value weighted average for the active participants in Plan 1 yields a stock share of 57 percent if the plan were fully funded. This provides an approximate upper bound on the share of stock attributable to a broad-PBO-linked hedging motive, as liabilities for separated and retired workers would be hedged with fixed income securities. It is only approximate, however, because the demographic characteristics in other plans may differ from Plan 1, and because pension assets may not equal the target measure of liabilities. We do not have data on individual plan under-funding, but aggregate data for Alcoa indicates that the company is 18 percent under-funded in 2003 relative to the narrow PBO measure reported. Using a hedge ratio to scale up the allocation to stock to reflect this under-funding would increase the upper bound to 57/.82 = 69.5 percent.

To take into account the effect of separated and retired workers on asset allocation, several approximations are necessary. Data on the number of active, retired, and separated workers and dependents receiving benefits is available for 2003 for all Alcoa 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, we 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) to .16(69.5) = 9.1 to 11 percent of stocks could be accounted for by a simple 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 0.1. Increasing γ to 0.2 increases the share of stock in the hedge portfolio considerably. The last two columns in Table A1 show the results for the various cohorts of Alcoa workers assuming this 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 the observed asset allocation.

3.2 Discount rate: example of 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 real risk-free rate of 2 percent and a mean stock return of 5 percent. The implied discount rate, which always falls between the expected return on stocks and bonds, can be described by the share of stock corresponding to that rate. For instance, under our assumptions a 50 percent stock share corresponds to a discount rate of 3.5 percent. Table A2 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 age 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? Answering this requires taking into account the effect of retired and separated workers, and scaling up rates to match market conditions in 2003. Using the share of liabilities estimated above 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, as measured by the narrow PBO, 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 FASB rule allows firms too much latitude in selecting the discount rate for reporting liabilities. That is, although the rules require firms to use an economically correct rate -- one that reflects the rate implicit in the current price of an annuity contract that would effectively defease the obligation -- common practice is to assume a significantly higher rate for discounting. pension liabilities

4. Optimal Pension Fund Asset Allocation: 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? As pointed out in the introduction, answering these questions is more difficult than determining the hedge portfolio for valuation. Funding levels are only partially a matter of individual firm choice. Legally, firms are obligated to meet minimum funding levels based on an ABO measure of liabilities, and additional contributions when assets are 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, 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 further discussion here, also affect the incentive to hedge.

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, for instance, 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. Credible deferred compensation has the potential to mitigate this two-sided risk. It provides workers with a return on their investments in firm-specific human capital, and an incentive to 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 incentive 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 (for instance by unexpectedly freezing its plan) 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, even as the salaries and benefits of current workers are cut to respond to competitive pressure going forward.

One way to determine how the hedging demand should influence pension asset allocation would be to write down a firm's objective function, and then solve for the optimal pension funding and asset allocation decisions. Van Binsbergen and Brandt (2006) for example, posit an objective function for firms that yields a hedging motive for pension asset allocation. Their analysis, however, does not model the accrual of liabilities, and simply assumes that the liabilities are bond-like. We plan to pursue the objective function approach in a future draft of this paper. In the meantime, we have used the share of stocks in the hedge portfolio as a suggestive proxy for the share that would arise under a more broadly defined optimization problem.

5. Empirical Evidence

5.1 Aggregate trends in DB assets and liabilities (TBA)

5.2 Firm level data

We obtained data on the investment practices of the 1,000 largest pension plans from Pensions and Investments (P&I), a private organization that gathers and sells this data and other pension-related information. P&I administers a survey to large pension plans in which they ask questions on liabilities, total assets, and asset allocation. We use data from calendar year 2004. We restrict the sample to public firms with defined benefit plans, thus excluding firms with only a defined contribution plan and non-public entities such as state governments and unions.[14]

We match these data on DB pension asset allocation with data from Compustat on corporate assets and liabilities and pension plan assets and liabilities, and with data from the Department of Labor's Form 5500 on the number of active participants, retirees and their dependents, and separated workers. The approach of Merton (1974) is used to impute firm asset volatility and the expected return on firm assets, which are also considered as explanatory

[14] Rauh (2006b) uses the same data to investigate the relation between pension investment policy, managerial incentives, and credit quality. For some firms, we supplement the Pensions and Investments data with hand-collected asset allocation data from firm financial disclosures.

variables.[15] Specifically, using Compustat data on the book value and average maturity of firm liabilities and the market value of equity, and estimates of equity volatility from Damodaran Online,[16] the market value of firm assets and their volatility are estimated. The matched sample includes 168 firms with pension benefit obligations totaling $900 billion.

Figure 2 summarizes the cross-section of pension asset allocation. 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.

5.3 Empirical results on the relationship between demographics and asset allocation

If asset allocation is influenced by a hedging motive, then a testable implication of our model is that firms with a higher proportion of active workers will have a higher percentage of pension assets invested in risky assets. In this section, we use the firm data described above to directly test this implication. In addition, we also examine the importance of several alternative factors that might influence asset allocation. 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 to avoid having to contribute additional capital. 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

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[15] We thank Wendy Kiska for these estimates.

[16] http://pages.stern.nyu.edu/~adamodar/

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.

The findings are consistent with the prediction of the model that firms with more separated and retired workers invest less in risky assets. Separately, they are also consistent 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 R^2 increases to .069. Consistent with the findings of Rauh (2006b), 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. Conclusions and Policy Implications

This paper develops a framework for estimating a risk-adjusted discount rate for discounting pension liabilities, 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. Assuming that the results are indicative of the equity share that firms should hold in pension plan assets, our model can only explain a part of the large equity holdings observed in the data. It remains an open question, then, as to why firms hold as much equity as they do.

6.1 Implications for regulated discount and accrual rates

What rate firms should be required to use to discount pension liabilities is a topic of current interest, as policymakers contemplate imposing tighter funding rules to reduce PBGC's exposure, and as FASB revisits its rules for pension accounting. As we have emphasized, the appropriate discount rate depends on the definition of liabilities, which varies depending on the application at hand. The various actuarial liability measures used in practice 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 for financial reporting within regulatory limits, and is often not based on financial valuation principles. Thus in general, these actuarial measures of liabilities are not consistent with market values.

ERISA funding rules, which control the risk exposure of the PBGC, 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 smoothed a long-term Treasury bond rate.[17] Plan sponsors are then required to fund the "current liability," which is an accrual measure similar to the ABO. For funding purposes, under- or over-funding is measured by a comparison of current liabilities to the market value of assets. Since at any point in time the PBGC's risk exposure is only to accrued liabilities (plans of bankrupt sponsors are immediately frozen), accrued liabilities are a reasonable reference point for minimum funding requirements to protect the PBGC.[18] For these known cash flows, however, and from the perspective of the PBGC, the correct discount rates are current, maturity-matched Treasury rates. The rule that allows discounting at a low-risk corporate rate implies that under-funding relative to the current liability is systematically under-reported.

Financial accounting standards require firms to use both the ABO and PBO concepts in financial statements. Specifically, 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).[19]

The principal under FAS87 for computing PBO liabilities – that discount rate that reflect the rate implicit in the current price of an annuity contract that would effectively defease the obligation -- is consistent with the valuation principles emphasized here. However, the way pension accruals affect reported earnings creates a bias that favors equity investment. To see why requires understanding the details of the earnings calculation. Annual earnings are reduced

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[17] Smoothing is also problematic, but does not create a systematic bias in funding levels. Van Bisbergen and Brandt (2006) point out that smoothing the discount rate make it more difficult to hedge the ABO through asset allocation.

[18] A shortcoming of the current liability measure is that it does not take into account the higher costs associated with terminated plans (CBO (2005)).

[19] For a clear explanation of these rules and their implications, see Revsine, Collins and Johnson (2005).

by the amount that year-to-year increases in the PBO exceed earnings from pension assets. The change in the PBO is based on actuarial projections, and the interest charge is based on the assumed discount rate (e.g., 7.75% in for Alcoa in 2003). The change in pension assets, by contrast, is based on an assumed rate of return on assets that is largely independent of actual investment outcomes. In fact, firms typically assume a rate of return on assets that is significantly higher than the discount rate used to compute the PBO, presumably because of the higher returns expected on equity and other risky investments. A small amount of discipline is imposed by the rule that if actual cumulative experience differs by more than a threshold amount from assumed experience, firms are forced to amortize the error over the remaining average service life of employees and include the amortized amount in earnings. The effect, however, is to allow very smooth adjustments to earnings, no matter how risky the pension investment policy. In other words, by investing pension assets in equity, firms can book the equity premium, without bearing the consequence of the added volatility in reported earnings.

6.2 Implications for regulating pension investments

Recognizing the bond-like nature of its liabilities, in recent years the PBGC has reduced the allocation in stocks in its own portfolio. Some have suggested that PBGC's reduction in stockholdings could serve as a model for corporate pension asset allocation guidelines. Our analysis suggests that it is incorrect to infer the correct asset allocation policy for firms from the situation of the PBGC. Firms are responsible for pension liabilities in distinctly different states of the world than is the PBGC. The obligations already assumed by the PBGC are exclusively for retired workers and effectively separated workers, and are unaffected by subsequent wage appreciation. Thus adopting PBGC's investment policy for pension assets does not necessarily minimize risk from the perspective of young firms.

The risk to the PBGC, and ultimately to taxpayers, from apparently excessive investments in equity by some DB sponsors have led to proposals for legal limits on pension asset allocation. Our analysis suggests reasons that some firms, particularly those with a young and active workforce, might want to use stocks to hedge. While our analysis does not measure the strength of this hedging demand, it is possible that such restrictions could further the trend away from offering DB plans.[20] More generally, the analysis suggests that heterogeneity could be important, and 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 and other firm characteristics.

[20] PBGC assesses a per capita premium, rather than a charge based on the overall size of a firm's liabilities. This results in young firms paying a much higher premium for a given level of coverage than old firms (CBO, 2005).

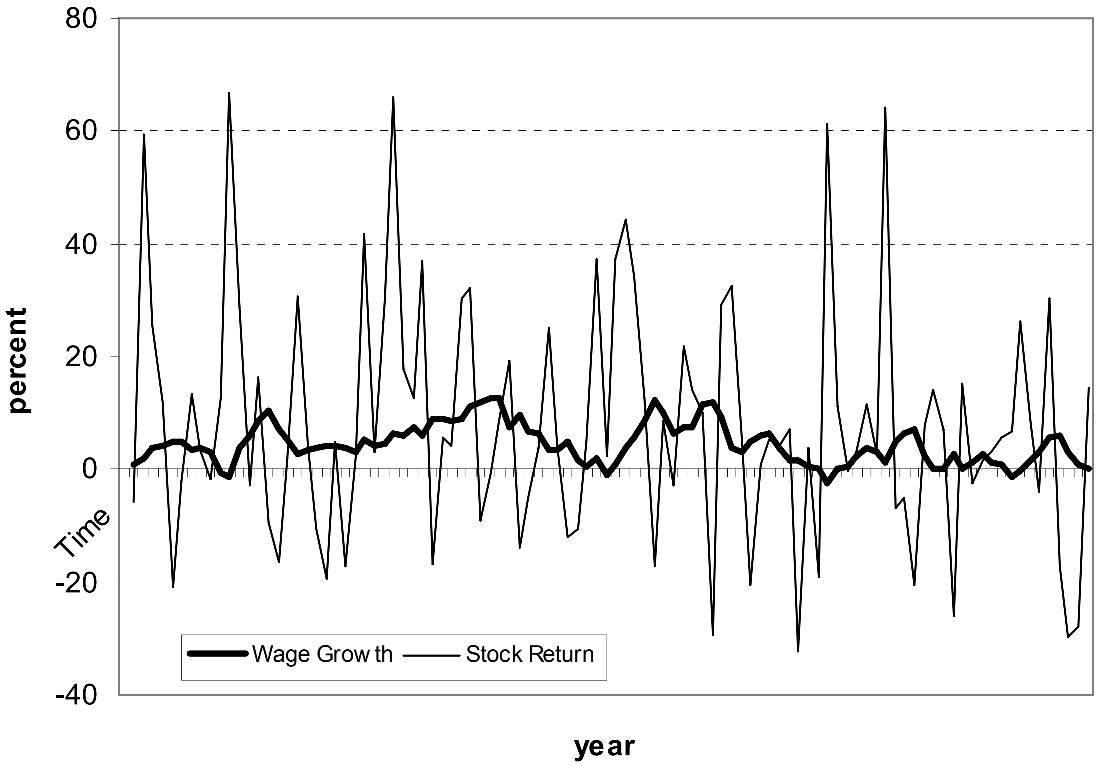
Table 1: Annual Separation Rates	
separation rate x < age 35	0.060
separation rate age 34 < x < age 46	0.045
separation rate age 45 < x < age 56	0.040
separation rate age 55 < x	0.050

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

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

Table 4: Univariate Regressions Of Risky Asset Share On Firm Characteristics			
Characteristic	**Coefficient**	**t-statistic**	**Adj. R^2**
share retired	-.119	-2.6	.032
under-funding	.047	1.2	.003
asset vol	.025	1.0	.000
leverage	-.008	-0.3	.001
asset return	1.06	2.9	.041

Figure 1: Wage Growth and Stock Returns



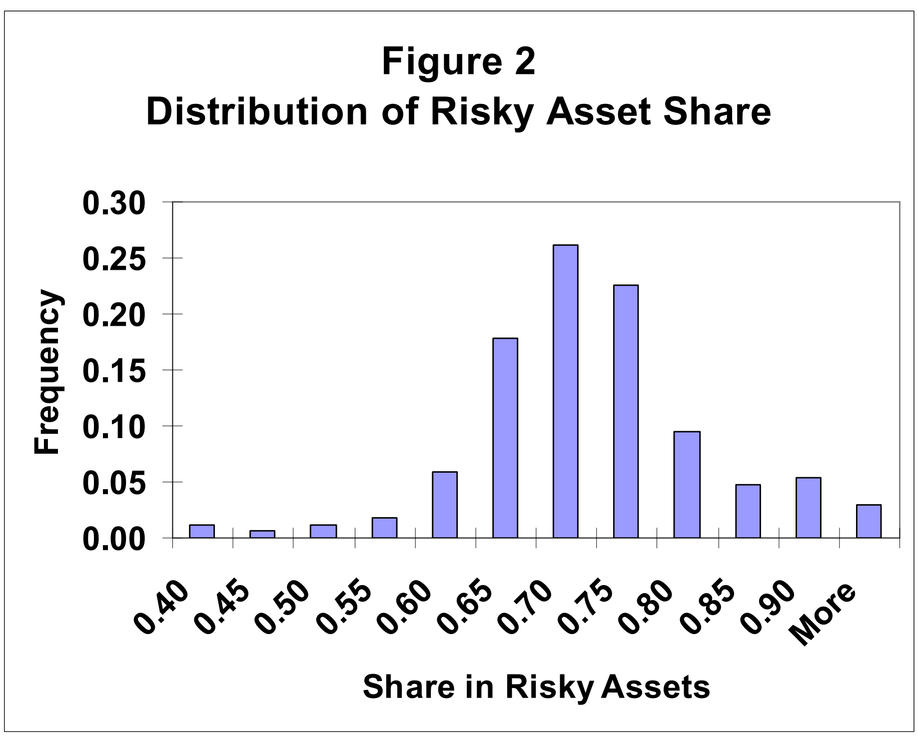


Table A1
Pension Benefits and Share of Stock in Hedge Portfolio for Alcoa Plan 1 Workers by Age and Tenure, Base Case Parameters

				Base Case Parameters		γ=.2	
# workers	Current age	Years worked	Current salary ($)	PV ($)	Stock %	PV ($)	Stock %
91	22	0	34,722	49,163	86	46,272	93
55	22	2	32,810	51,180	83	50,283	91
108	27	0	38,289	64,202	86	59,746	93
208	27	2	40,413	74,191	83	71,943	91
41	27	7	44,062	99,829	78	98,656	86
97	32	0	47,813	86,276	85	86,365	94
228	32	2	49,620	100,821	82	101,301	92
188	32	7	60,345	154,586	77	158,591	88
90	32	12	66,414	204,282	75	206,056	84
83	37	0	56,870	113,868	83	116,253	94
222	37	2	58,405	129,448	80	132,343	91
178	37	7	64,252	181,088	76	187,289	88
262	37	12	69,805	247,057	74	246,041	86
83	37	17	72,713	299,574	72	289,121	82
57	42	0	64,736	134,440	79	136,104	92
151	42	2	51,633	125,751	77	120,089	90
139	42	7	62,710	196,853	73	200,190	87
266	42	12	69,065	262,501	70	262,506	84
309	42	17	82,276	368,656	69	371,246	83
299	42	22	79,418	407,940	67	412,162	81
23	42	27	58,702	350,613	67	351,566	82
47	47	0	58,106	119,164	71	121,893	89
82	47	2	65,076	155,471	69	156,439	87
90	47	7	64,493	206,624	66	205,146	83
200	47	12	67,781	270,047	65	272,822	82
180	47	17	72,193	350,525	63	351,578	80
303	47	22	76,549	436,409	63	438,738	80
332	47	27	69,203	447,613	62	445,907	79
29	52	0	67,836	123,685	58	124,370	81
59	52	2	63,648	139,616	57	140,864	79
57	52	7	63,919	197,388	53	199,080	75
124	52	12	64,867	262,767	53	266,331	74
97	52	17	69,075	348,616	52	343,746	72
173	52	22	73,072	432,469	51	434,219	72
274	52	27	78,678	537,739	50	546,034	71
288	52	32	77,295	608,916	51	612,061	71
27	57	2	64,351	116,162	36	115,606	58
64	57	12	67,227	265,330	34	263,415	54
44	57	17	54,163	269,105	33	270,356	53
84	57	22	67,977	413,307	33	412,888	53
93	57	27	76,752	545,130	33	549,285	53
214	57	32	85,997	699,528	33	702,998	52
61	57	37	82,801	764,553	32	766,528	52
20	62	12	64,252	228,337	8	227,911	15
34	62	32	71,451	599,670	8	598,819	14
24	62	37	89,897	860,155	8	861,859	14

Table A2
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

References

Bansal, Ravi and Amir Yaron (2004), "Risks For the Long Run: A Potential Resolution of Asset Pricing Puzzles," *Journal of Finance*

Benzoni, L, P. Collin Dufresne, and R. Goldstein (2006), "Portfolio Choice over the Life-cycle when the Stock and Labor Markets are Cointegrated," manuscript, University of Minnesota.

van Binsbergen, Jules H., and Michael W. Brandt (2006), "Optimal Asset Allocation in Asset Liability Management," working paper, Duke University, May.

Black, Fischer (1980), "The Tax Consequences of Long-Run Pension Policy," *Financial Analysts Journal*, 21-28.

____________ (1989), "Should You Use Stocks to Hedge Your Pension Liability?" *Financial Analysts Journal*, January/February 1989, 10-12.

Bodie, Zvi (1990), "The ABO, the PBO, and Pension Investment Policy," *Financial Analysts Journal*

_________ (2006), "On Asset-Liability Matching and Federal Deposit and Pension Insurance," proceedings of the Federal Reserve Bank of St. Louis, 30th Annual Economic Policy Conference, Federal Credit And Insurance Programs, forthcoming.

Bulow, Jeremy (1982), "What are Corporate Pension Liabilities? *The Quarterly Journal of Economics*, Vol. 97, No. 3. (Aug., 1982), pp. 435-452.

Bulow, Jeremy, and Myron Scholes (1983), "Who Owns the Assets in a Defined-Benefit Pension Plan?" Chapter 1 in Bodie and Shoven, eds., *Financial Aspects of the U.S. Pension System*, Chicago: University of Chicago Press, 1983.

Cardinale, Mirko (2004), "The Long-run Relationship Between Pension Liabilities and Asset Prices: a Cointegration Approach," unpublished manuscript, Watson Wyatt.

Congressional Budget Office (2005), "The Risk Exposure of the Pension Benefit Guarantee Corporation," available at http://www.cbo.gov/showdoc.cfm?index=6646&sequence=0

Financial Accounting Standards Board (1985), Statement of Financial Accounting Standards No. 87, Employers' Accounting for Pensions, available at http://www.fasb.org/pdf/fas87.pdf

Goetzman, William N., "More Social Security, Not Less" (2005). Yale ICF Working Paper No. 05-05.

Gold, Jeremy and Nick Hudson (2003), "Creating Value in Pension Plans (or, Gentlemen Prefer Bonds) ," *Journal of Applied Corporate Finance 15(4), 51-57.*

Hansen, Lars, John Heaton and Nan Li (2005), "Consumption Strikes Back?: Measuring Long-Run Risk," NBER working paper 11476.

Harrison, J. and William Sharpe (1983), "Optimal Funding and Asset Allocation Rules for Defined Benefit Pension Plans," *Financial Aspects of the U.S. Pension System*, Zvi Bodie and John Shoven, eds., Chicago, University of Chicago Press, 92-106.

Jolliffe, Alexander (2005), "Ex-Boots Executive Challenges Pension Trustees," *Financial Times*, February 12, 2.

Lustig, Hanno, and Stijn Van Nieuwerburgh (2006), "The Returns on Human Capital: Good News on Wall Street is Bad News on Main Street," Working Paper. Forthcoming, *Review of Financial Studies*.

McDonald, Robert (2006), *Derivatives Markets*, 2nd Edition, Addison Wesley.

Merton, Robert C. (1974), "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance*, 29 (2), 1974, 449—470.

Parker, Jonathan and Christian Julliard (2005), "Consumption Risk and the Cross-Section of Expected Returns," *Journal of Political Economy*, 113(1), February 2005, 185-222.

Poterba, James, Steven Venti, and David Wise (2005), "Demographic Change, Retirement Saving, and Financial Market Returns, working paper

Ralfe, John, (2005), "U.K. Firms Taking Risks with Equities," *Financial Times*, Sept 19, 2.

Rauh, Joshua (2006a), "Investment and Financing Constraints: Evidence from the Funding of Corporate Pension Plans," *Journal of Finance* 61, 33-71.

Rauh, Joshua (2006b), "Risk Shifting versus Risk Management: Investment Policy in Corporate Pension Plans," Working paper, Graduate School of Business, University of Chicago.

Revsine, Lawrence, Daniel W. Collins, and W. Bruce Johnson (2005), *Financial reporting and analysis*, 3rd edition, Upper Saddle River, NJ: Pearson/Prentice Hall.

Smith, Andrew (1998), "Salary Related Cash Flows: Market Based Valuation," unpublished manuscript, Bacon and Woodrow, prepared for Conference on Actuarial Valuations, Accounting Standards and Financial Economics, The Royal Society, January 20, 1998.

Sundaresan, Suresh, and Fernando Zapatero (1997), "Valuation, Optimal Asset Allocation, and Retirement Incentives of Pension Plans," *The Review of Financial Studies,* Vol 10, No. 3, 631-660.

Wilcox, David (2006), “Reforming the Defined-Benefit Pension System in the United States,” working paper, Federal Reserve Board. Forthcoming, Brookings Papers on Economic Activity.