

Duration, Systematic Risk, and Employee Valuation of Default-Free Pension Claims

Jihad S. Nader

ABSTRACT

Lifetime-contract theory assigns a riskless discount rate for sponsor valuation of pension obligations, but does not address the appropriate discount rate for employee valuation of pension promises. This puts in question the use of a riskless discount rate assumption in many studies which analyze pension claim valuation by employees. This article presents a method for assessing the employees' discount rate for pension claims. The method involves formulating the beta-duration relationship for these claims and combining this relationship with the capital asset pricing model. Numerical illustrations indicate that even for default-free pension promises, the employees' discount rate includes a systematic risk premium which may be non-negligible for young employees, but diminishes rapidly as employees grow older.

Introduction

The modern economic and financial theory of pensions owes much of its evolution to two distinct but mutually consistent models of the labor market, namely the implicit lifetime contract (LC) model, and the compensating wage differentials (CD) model.¹ Empirical support for both models has been growing in recent years.² Under the LC paradigm, a firm's pension promise is a binding obligation which should be valued by the sponsor at the riskless discount rate, so as to reflect the highest degree of certainty that this promise will be honored at maturity.³ Under the CD model, wages internalize the workers' valuation of pension claims, such that their total compensation equals the value of their lifetime marginal product.⁴

Jihad S. Nader is Assistant Professor of Finance, Concordia University, Montreal, Canada. The author gratefully acknowledges the helpful comments of the Editor and two anonymous referees.

¹The LC model was developed by Azariadis (1975), and discussed by Akerlof and Miyazaki (1980), Holmstrom (1981), Green and Kahn (1983), and many other writers. The CD model, widely attributed to Smith (1937, p. 100), was discussed by Rosen (1974).

²See for example Ehrenberg (1980), Schiller and Weiss (1980), Smith (1981), Brown (1982), Wise and Kotlikoff (1984), and Pesando (1985).

³See Bagehot (1972), Treynor, Regan, and Priest (1976, p. 45), and Pesando and Clarke (1983).

⁴Although this equalization process may be considered to take place on a spot-auction (i.e., period-by-period) basis, as is the case in Sharpe (1976), a lifetime equalization process appears to be much better supported by the Canadian wage-service data used by Pesando (1985), and by

Whereas the LC framework clearly identifies the riskless rate as the appropriate discount rate for valuation of the pension obligation by the sponsor,⁵ considerable ambiguity appears to surround the appropriate discount rate for employee valuation of the pension claim. Skinner (1980, p. 32), for example, expresses doubt that employees factor risk into this valuation, and dismisses risk as irrelevant for pension accounting. In contrast, the empirical evidence on the CD model cited above appears to confirm that employees factor risk into their valuation of pension claims, as reflected by the corresponding wage differentials. In particular, Smith (1981) provides evidence which suggests that employees demand a risk premium on the pension promise itself, distinctly from any default-risk premium on the plan's under-fundedness.⁶ Ippolito (1986, p. 175) also states that underfunding a pension plan entails payment of a risk premium to the employees, and that this premium constitutes a cost to the sponsor. However, he does not address the notion of a distinct risk premium on the pension promise itself. Furthermore, he explicitly ignores risk premium components in his analysis of the sponsor's pension cost.

At the policy level, several studies by Pesando (1982, 1984a, 1984b, and 1985) and by Pesando and Clarke (1983) have invoked the LC-CD framework to analyze recent pension reform initiatives and pension accounting issues, both in Canada and the United States. Invariably, such analyses rest, implicitly or explicitly, on the assumption that the employees share the sponsor's interpretation of the pension contract, and thus value their pension claim by using a riskless discount rate. To the extent that the employees' "true" (but unobservable) discount rate does or should embody a risk premium (as suggested by the evidence on the CD model cited above), the quantitative analyses in these studies may incorporate significant biases,⁷ and reconsideration of their policy implications in this light may be warranted. This, however, would remain largely a matter of conjecture, unless the employees' discount rate for pension promises is assessed in a direct manner.

The main purpose of this article is to present a method for performing such an assessment. To our knowledge, no such method has yet been developed. In the process, it is shown that even if employees considered their pension claims

empirical evidence from the U.S. manufacturing sector, provided by Brown (1982), and Wise and Kotlikoff (1984).

⁵The question as to whether the sponsor should use the nominal or the real riskless rate can be answered by reference to the nature of the pension obligation. To the extent that sponsors' behavior (e.g., granting periodic *ad hoc* inflationary adjustments to pensions in pay) suggests that they recognize a real pension obligation, the real riskless rate appears appropriate. See Pesando and Clarke (1983).

⁶In the regression results provided by Smith (1981, p. 467), the estimated coefficient for the marginal wage-pension tradeoff is for the most part in excess of this coefficient's theoretical value of -1. This suggests that a \$1 enrichment of the present value of the pension promise by the sponsor would result in a wage concession that is less than \$1, with the difference representing a risk premium paid to the employees on the marginal pension promise.

⁷Pesando (1984b) illustrates the potential importance of errors arising from the use of inappropriate discount rates in valuing employee pension claims.

to be entirely free of default risk,⁸ their discount rate, properly determined, would incorporate a premium that compensates them for the systematic risk of this claim. The article is organized as follows:

In the first section, the relationship between systematic risk and duration for default-free bonds is formulated, and numerical estimates of this relationship for Government of Canada (GOC) bonds are presented. The same framework is then applied, in the second section, to formulate the systematic risk of default-free pension claims (viewed as long-term bonds)⁹ as a function of their duration. Application of this function in the framework of the capital asset pricing model (CAPM) shows how the employees' discount rate for pension claims can be assessed. Numerical illustrations are then presented to shed light on the order of magnitude of the systematic risk premium embedded in this rate. These illustrations indicate that this premium is independent of the benefit formula, that it may be non-negligible for young employees, and that it diminishes as employees grow older. The author's conclusions are presented in the last section.

Bond Duration and Systematic Risk

Sharpe (1985, pp. 326–27) describes a single-factor model in which duration is the key determinant of the rate of return on a long-term bond:

$$\tilde{R}_i = \alpha_i - kD_i\tilde{R}_1 + \tilde{\epsilon}_i \quad (1)$$

where $\tilde{R}_i$ = the rate of return on bond i ; α_i = a constant term; $\tilde{R}_1$ = the rate of return on a one-year bond; k = a constant which measures the responsiveness of $\tilde{R}_i$ to a change in $\tilde{R}_1$; D_i = the duration of bond i ; and $\tilde{\epsilon}_i$ = a random error term.

The above model implies that $\tilde{R}_i$ responds to changes in $\tilde{R}_1$ in proportion to $-D_i$. For example, if $k = 0.5$ (as Sharpe suggests), then a 1 percent increase in $\tilde{R}_1$ would lower $\tilde{R}_i$ by 0.5 of 1 percent if $D_i = 1$ year, by 0.5 of 2 percent if $D_i = 2$ years, and so on.

This model appears particularly applicable to default-free bonds, for which the $\tilde{R}_i - \tilde{R}_1$ spread can be attributed entirely to term structure considerations, i.e., to maturity (and hence duration) differences. For such bonds, there are no other factors besides duration (not even unsystematic factors) that would affect the $\tilde{R}_i - \tilde{R}_1$ spread. Thus, one can apply a strict interpretation of (1) which implies that for these bonds $\tilde{\epsilon}_i = 0$.¹⁰

As a result, equation (1) allows the derivation of bond i 's beta as a function of its duration. Denoting the rate of return on the market portfolio by $\tilde{R}_m$, and dropping $\tilde{\epsilon}_i$ from (1):

⁸ This would be the case if, for example, the sponsor's pension obligation (valued at the riskless rate) were fully funded, and the fund's assets consisted entirely of default-free securities.

⁹ It is quite common, in the pension literature, to characterize pension claims as long-term loans, annuities, or bonds. See for example Ippolito (1986, pp. 168–75), and Pesando (1984b; and 1985, p. 928).

¹⁰ See Sharpe (1985, p. 326).

$$\begin{aligned}\text{Cov}(\tilde{R}_i, \tilde{R}_m) &= \text{Cov}[(\alpha_i - kD_i\tilde{R}_1), \tilde{R}_m] \\ &= -kD_i \text{Cov}(\tilde{R}_1, \tilde{R}_m)\end{aligned}\quad (2)$$

Thus,

$$\begin{aligned}\beta_i &= -kD_i \frac{\text{Cov}(\tilde{R}_1, \tilde{R}_m)}{\sigma^2(\tilde{R}_m)} \\ &= -kD_i \rho_{1,m} \frac{\sigma(\tilde{R}_1)}{\sigma(\tilde{R}_m)}\end{aligned}\quad (3)$$

where $\rho_{1,m}$ = the coefficient of correlation between $\tilde{R}_1$ and $\tilde{R}_m$; $\sigma(\tilde{R}_1)$ = the standard deviation of $\tilde{R}_1$; and $\sigma(\tilde{R}_m)$ = the standard deviation of $\tilde{R}_m$.

The role of k in (1) is to adjust for the fact that duration has been found to overstate the responsiveness of $\tilde{R}_i$ to changes in $\tilde{R}_1$. Sharpe (1985) refers to evidence from the Center for Research on Security Prices data base (see Ingersoll, 1983) for the period 1950 through 1979, which shows that bond portfolios with a one-year duration had about half the return variability (measured by the standard deviation) of bond portfolios with a five-year duration.¹¹ Accordingly, Sharpe (1985, pp. 325-26) suggests that $k = \sigma(\tilde{R}_1)/\sigma(\tilde{R}_5) \approx 0.5$.

However, if (3) is to be used for bonds and time periods other than those to which Sharpe (1985) refers, then one must re-estimate k , since it may be inaccurate simply to assume that $k = 0.5$. For example, GOC bond data published in Hatch and White (1985) indicate that over the period 1968 through 1983, k (estimated in the manner used by Sharpe) varied from year to year, and in all years except 1982 was substantially below 0.5, with an average k value of 0.25.¹²

Similarly, annual bond and common stock data in Hatch and White (1985) allow an estimation of $\rho_{1,m}$ and $\sigma(\tilde{R}_1)/\sigma(\tilde{R}_m)$, with average values of -0.1456 and 0.2841 respectively, over the period 1968 through 1983.¹³ This leaves D_i , which can readily be computed from market data on any given GOC bond, published in the Bank of Canada Review. An estimate of β_i can then be obtained from (3) as follows:

$$\begin{aligned}\beta_i &= -(0.25) D_i(-0.1456)(0.2841) \\ &= 0.0103 D_i\end{aligned}\quad (4)$$

Ultimately, this method allows the assessment of bond i 's expected rate of return over a given period, by substituting the β_i estimate from (4) into the security market line equation (SML), as follows:

$$r_i = r_f + \lambda\beta_i \quad (5)$$

¹¹ See the diagram in Ingersoll (1983, p. 175).

¹² For full details on the data and estimation procedure, see Nader (1987, pp. 282-89).

¹³ The market portfolio used in the estimation procedure combines Hatch and White's common stocks and long GOC bonds. The full estimation procedure is described in Nader (1987, pp. 282-89).

where r_i = the expected rate of return on bond i ; r_f = the riskless rate; and λ = the market risk premium. For example, applied to GOC bonds over the period 1968 through 1983, with an estimated average (*ex ante*) λ of 3.65 percent,¹⁴ the SML is:

$$r_i = r_f + 0.0365 \beta_i \quad (6)$$

Substituting the value of β_i from (4), one gets:

$$r_i = r_f + 0.00038 D_i \quad (7)$$

This estimation procedure has been applied to GOC bonds of various maturities, over the period 1968 through 1983.¹⁵ An analysis of the k , β_i , and r_i values obtained in this manner indicates that they are generally consistent with actual developments in the GOC bond market, and that they clearly bear out the observed changes in the relationship between long-term and short-term default-free instruments, over that period.¹⁶

Application to Pension "Bonds"

Determinants of Pension "Bond" Duration

Using the preceding framework, an employee's pension claim is considered as a default-free bond,¹⁷ which promises "coupon" (benefit) payments of \$X in each year of retirement.¹⁸ Thus, for an employee who is expected to reach the normal retirement age in T years, annual payments of \$X are promised from year $T + 1$ to year $T + Z$, where Z is the expected length of the retirement period.

The level of X is determined by the plan's benefit formula, and also by the multiple-decrement probability that an employee in a given age-and-service group will remain in the firm's employ until retirement. However, both of these factors turn out to be irrelevant for the analysis, as indicated by the absence of X from (10) below.¹⁹

A third factor which affects the analysis is the age-specific probability of surviving in each successive year of retirement, a_{v+j} (where v and j take on the values specified for (8) and (9) below). Thus, the mortality-adjusted stream of

¹⁴The market portfolio used in estimating λ is the same one described in footnote 13.

¹⁵For full numerical results, see Nader (1987, pp. 468–69).

¹⁶See Nader (1987, pp. 282–89).

¹⁷See footnotes 8 and 9.

¹⁸In actual practice, pension annuities are more common as a form of paying benefits among defined benefit plans than among defined contribution plans, which more commonly make lump-sum payments to retiring members (McGill, 1984, p. 110). However, the IRS requires (but does not restrict) all qualified plans in the U.S., regardless of plan type, to make their pension promises (as opposed to actual benefit payments) available in the form of annuities (McGill, 1984, pp. 109–10). Thus the fact that the model formulated in this section assumes an annuity does not restrict the model's applicability to a particular type of pension plan, since in all cases the pension promise is offered as an annuity.

¹⁹For this reason, these factors are not discussed. The interested reader is referred to McGill (1984).

promised payments on the pension bond, evaluated at the employee's appropriate discount rate r , has a present value:

$$PV_0 = X \sum_{j=1}^{Z+y} \frac{a_{v+j}}{(1+r)^{v+j}} \quad (8)$$

and its duration is:²⁰

$$\begin{aligned} D_0 &= -\frac{\partial PV_0}{\partial(1+r)} \cdot \frac{(1+r)}{PV_0} \\ &= (1+r) \frac{\sum_{j=1}^{Z+y} (v+j)(a_{v+j})(PVIF_{r,v+j+1})}{\sum_{j=1}^{Z+y} (a_{v+j})(PVIF_{r,v+j})} \end{aligned} \quad (9)$$

where $y = 0$ and $v = T$ for $T \geq 0$; $y = T$ and $v = 0$ for $T < 0$; $Z+y \geq 0$; and PVIF denotes the present value interest factor at r percent. To simplify the notation, (9) is rewritten (for given a_{v+j} and Z values)²¹ as:

$$D_0 = (1+r) F(r, T). \quad (10)$$

The absence of X from (10) is noteworthy. It reflects the fact (illustrated by Keintz and Stickney, 1980; and Nader, 1987) that the duration of pension benefits is insensitive to the various actuarial assumptions used in the benefit formula. This, in turn, indicates that a duration-based method of estimating the discount rate for pension bonds is totally free of "actuarial latitude" biases, which have long been perceived to pose problems for financial research in the pension area.²²

Also noteworthy is the irrelevance of pre-retirement enrichments to the pension promise, for discount rate determination based on (10). Such enrichments may either be built into the benefit formula or negotiated separately through the collective bargaining process (McGill, 1984). The anticipation of such enrichments by plan members translates into a larger expected pension annuity, X . However, the fact that X cancels out of (10) indicates that expected pre-retirement enrichments (and other specifics of plan design or benefit formula which affect the level, not the timing of X)²³

²⁰ See Copeland and Weston (1988, p. 490).

²¹ These values can readily be obtained from industry-specific mortality and life expectancy tables.

²² See Kingsland (1982), and Ezra (1988) for discussions of these problems.

²³ There is a host of qualitative characteristics which vary from one plan to another, and affect the level of an employee's pension expectation. For example, stringent rules as to vesting and portability may interact with employee mobility to increase the probability of unvested withdrawal from the firm's employ. The effect of this increased probability is to reduce the multiple-decrement probability of remaining in service until retirement, in each year prior to the vesting date. (See Winklevoss, 1977.) This, in turn, translates (in the context of (8)) into a lower level of X . However, the *time pattern* (and hence duration) of the pension annuity is totally unaffected by these vesting

have no effect on duration and, ultimately (as shown in (11), (12) and (13) below), on the systematic risk and corresponding discount rate for the pension claim.

Finally, it is important to note that although X is absent from (10), the nature of r in (10) is determined by the nature of X in (8). Thus, if X represents a purely nominal pension annuity, then r should be viewed as a nominal discount rate, whereas if X is defined in real terms, then r should also be viewed as real. This point should be taken into consideration, in the process of using (10) as a basis for estimating the employee's discount rate for the pension claim.

Estimating the Employee's Discount Rate: Numerical Illustrations

Substituting D_0 from (10) for D_i in (3), the systematic risk of pension bond i at the beginning of a given holding period (e.g., the one-year period between two successive valuations) is:

$$\beta_i = -k\rho_{l,m} \frac{\sigma(\bar{R}_1)}{\sigma(\bar{R}_m)} (1+r_i) F(r_i, T) \quad (11)$$

To illustrate, if our 1968 through 1983 estimates of the beta-duration relationship for GOC bonds are used in (11),²⁴ then:

$$\beta_i = 0.0103 (1+r_i) F(r_i, T) \quad (12)$$

Note, however, that while T is known for any given employee, r_i is not. Nevertheless, substituting the value of β_i from (12) into (6), the SML equation for the pension bond is:

$$r_i = r_f + 0.00038 (1+r_i) F(r_i, T) \quad (13)$$

Thus, at the beginning of the holding period, given r_f , T , a_{v+j} , and Z , r_i can be determined through a trial-and-error process which seeks to satisfy (13).

To illustrate, assume that retirement occurs at the normal retirement age of 65, $Z = 45$, $r_f = 8$ percent, and the a_{v+j} values are derived from Winklevoss (1977, pp. 13-15). From (13), one can assess r_i for any given employee age.²⁵ Table 1 shows the results of this trial-and-error process for two widely

and portability considerations, as indicated (not surprisingly) by the absence of X from (9) and (10).

²⁴As stated in the first section, these are $k = 0.25$, $\rho_{l,m} = -0.1456$, and $\sigma(R_1)/\sigma(R_m) = 0.2841$. As shown in Nader (1987, pp. 468-69), the GOC bonds used for obtaining these estimates had maturities of up to 30 years, with durations up to about 15 years. Thus, they appear adequately representative of a long-term default-free pension "bond," and their use in (11) to obtain (12) seems reasonable.

²⁵The r_i determined by using (13) is a nominal discount rate, since the parameter value of 0.00038 was estimated (in (4), (6) and (7)) by using non-indexed GOC bond data. Implicitly, therefore, the results shown in Table 1 are based on a nominal pension annuity. However, (13) can just as readily be applied to the case of a real (fully indexed) pension annuity, provided rate-of-return data for a price-indexed, default-free bond are used to re-estimate the parameter values in (4), (6) and (7).

different active ages, for the retirement age, and for one retired age. These results suggest that employees demand a systematic risk premium on the pension bond, which decreases rapidly with the approach of the first coupon date and becomes negligible thereafter. Over a 50-year age gap (20 to 70), the systematic risk-premium spread is approximately 2 percent. This is quite large in comparison with the basic discount rate component (the long-run real riskless rate) which, in Canada, is generally considered to fall in the range of 2.5 percent to 3.5 percent (Skinner, 1980, p. 31).

Table 1

Discount Rates and Systematic Risk Premiums for Four Employee Ages
($r_f = 0.08$; $Z = 45$)

Attained Age (AA)	$T = 65 - AA$	r_i	$r_i - r_f$
20	45	0.100	0.020
50	15	0.088	0.008
65	0	0.083	0.003
70	-5	0.081	0.001

Note that for young employees, the presence of a significant systematic risk premium is due in the main to the relatively long duration of pension claims. For example, (7) indicates that for a 20-year-old employee, $D_i = (r_i - r_f) / 0.00038 = 0.02 / 0.00038 = 52.63$ years. By contrast, (6) suggests that the systematic risk of these claims for a 20-year-old is not large. That is, $\beta_i = 0.02 / 0.0365 = 0.55$, which indicates that these claims are only about half as volatile as the market portfolio.

The origin of this systematic risk may be explained as follows. Employees may be viewed as engaging in periodic valuations of their pension claims for the purpose of determining the compensating differentials (concessions) they should factor into their next wage settlement. The discrepancy between the horizon (e.g., one year) separating the current valuation from the next one, and the longer horizon to the bond's maturity, entails systematic interest rate risk in the manner described and tested empirically (for default-free U.S. bonds) by Roll (1971), and as formulated theoretically by Boquist, Racette, and Schlarbaum (1975). As an employee ages, this discrepancy diminishes, and so does the systematic risk and the related premium on the pension bond.

Summary and Conclusions

This article presents a duration-based model for assessing the implicit discount rate which employees use in valuing their pension claims. The key result, illustrated numerically, is that even in the absence of default risk, the employees' implicit discount rate for pension promises is not a risk-free rate but a risk-adjusted rate. That is, the pension plan sponsor incurs a systematic risk premium on the pension obligation, whether or not this obligation is subject to default risk. If default risk is present (e.g., due to pension plan underfundedness or to the investment risk characteristics of the pension

portfolio), then any premium this risk might entail should be viewed as a distinct cost to the sponsor, over and above the systematic risk premium. Thus the key result, expressed in finance-theoretic (risk premium) terms, is consistent with evidence from the labor market provided by Smith (1981), regarding the presence, in employee wages, of distinct compensating differentials for pension promises and pension plan underfunding.

Moreover, the paper shows that the systematic risk premium for pension promises is higher the lower the employee's age. This result is also consistent with labor market evidence presented by Schiller and Weiss (1980), which reveals a diminishing marginal rate of wage-pension equalization with younger employee age. That is, the notion that a young employee discounts a \$1 increase in his or her (default-free) pension promise at a higher discount rate than an older employee (Table 1), is consistent with Schiller and Weiss' (1980) empirical finding that a young employee would make a smaller wage concession for a \$1 increase in the pension promise than an older employee.

The numerical illustrations also suggest that quantitative analyses of the effects of pension reform initiatives on employee pension wealth, such as the analyses performed by Pesando (1984a, 1984b, and 1985), should employ a risk-adjusted discount rate. To the extent that (for younger employees at least) the systematic risk premium may be non-negligible (e.g., 2 percent), the use of a riskless discount rate, even for default-free pension promises, may result in potentially significant biases in these analyses and their policy implications.

On the empirical level, the results of this article are subject to the qualification that the systematic risk-duration relationship employed to generate numerical illustrations with the model is based on a GOC bond proxy for pension "bonds." Despite its reasonability (as noted in footnote 24), a question might persist as to the extent to which such a proxy is representative of the systematic risk-duration relationship for "real life" pension claims. This calls for further research aimed at direct empirical verification of the model (equation (11)) for real life pension claims, much in the same way as the model was empirically verified by Nader (1987) for GOC bonds. Such empirical verification deserves a separate study, and is made difficult by the fact that pension claims, unlike bonds, are for the most part not actively traded.

Despite the preceding empirical qualification, this article makes a contribution by formulating a new, theoretically well-founded and actuarially unbiased procedure for pension claim valuation by the employees. Properly modified, this procedure may also prove useful in other contexts, such as discount rate determination for the valuation of property-liability loss reserves, or of claims arising from wrongful death and injury cases.²⁶ As well, the results presented above draw attention, for the first time, to potentially important conceptual links between the financial and labor market settings within which the value of pension claims is determined.

²⁶ See D'Arcy (1988), and Jennings and Phillips (1989).

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