CREATING A CORPORATE BOND SPOT YIELD CURVE FOR PENSION DISCOUNTING

DEPARTMENT OF THE TREASURY
OFFICE OF ECONOMIC POLICY
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I. Introduction

Plan sponsors, plan participants and financial markets should be able to depend on accurate measurement of pension liabilities. Accuracy requires that the discount rates used in calculation of the present value of a plan's benefit obligations satisfy two criteria: the discount rates must reflect the timing of the future payments, and they should be based on current market-determined interest rates for similar obligations. The Administration proposes[1] to replace the current law method with a schedule of rates drawn from a spot yield curve of high grade corporate bonds.[2] Discounting future benefit cash flows using the rates from the spot yield curve is the most accurate way to measure a plan's liability because, by matching the maturity of the discount rate with the timing of the obligation, it properly computes today's cost of meeting that obligation. Spot yield curves are used routinely by financial market participants to value future cash flows, for example, those of loans, mortgages, bonds, and swaps.

The Administration also proposes to require plans offering lump sum payments to use the same spot yield curve for both measuring pension liabilities and determining the minimum value of the lump sum payments. Changing the interest rate used to determine the lower bound for lump sums to the same market-determined spot yield curve as used in the liability calculations would ensure that the minimum lump sum is the same as the value of the pension annuity. Sponsors would still be free, as they are under current law, to be more generous if they wished. In such cases, it is important that the calculation of liabilities explicitly take into account the probability that future payments will be made in the form of a lump sum.

The purpose of this paper is to describe the methodology that will be used to derive the spot yield curves in the Administration's proposal. The paper begins by describing the proposed methodology for calculating spot yield curves; it then provides illustrative examples of the resulting curves. The results are presented in a series of charts, including a chart illustrating the evolution of a 90-business-day moving average spot yield curve over time. As the charts show, the 90-day average curves are smooth over the maturity range without excessive

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[1] See www.dol.gov/ebsa for a complete description of current law relating to valuing pension liabilities, the reason for change, and the Administration's proposal. See also the General Explanations of the Administration's FY 2006 Revenue Proposals (Blue Book) at http://www.treas.gov/offices/tax-policy/library/bluebk05.pdf. For the underlying rationale for the use of the corporate bond yield curve in pension discounting, see the testimony of Mark J. Warshawsky, Assistant Secretary for Economic Policy, before the Special Committee on Aging, U.S. Senate, October 14, 2003.

[2] A spot yield curve is simply a table or a graph that reports a set of yields at a particular point in time on single payment bonds (zero coupon bonds) of different maturities. A single payment bond (zero coupon bond) provides a single payment at a future time when the bond matures.

fluctuations and evolve smoothly over time without distortion by very short-term market movements. They accurately reflect high grade corporate bond markets, while minimizing the idiosyncratic impact of individual issues and the impact of short-term market volatility.

In order to produce spot yield curves that measure the market as accurately as possible, the estimation methodology should correct for influences on yields due to special characteristics of bonds that are not related to their underlying risk. In particular the presence of embedded options was found to have a significant effect on prices. The estimation methodology incorporates an appropriate correction for this factor. A technical appendix explains the details of the methodology.

Treasury would compute the spot yield curves and would make the calculated curves available on a regular basis for use in pension discounting. Pension plans would apply the spot yields of each maturity to discount the future expected benefit cash flow at that maturity.

II. Implementing the Proposal

The spot yield curve is not directly observable, but must be estimated from data on high quality corporate bonds. This section presents the criteria that guide the choice of estimation methodology for spot yield curves and a description of the methodology.

Criteria for Choice of Methodology

The methodology for estimating spot yield curves for use in pension discounting should meet the following criteria:

- It should be as *transparent* in construction as possible, using accepted, logical, and accurate techniques and assumptions, enabling rates to be accepted by employers, plan beneficiaries, and the investment community.

- It should *accurately reflect high grade corporate bond markets while minimizing idiosyncratic impact* of individual issues and the chance of manipulation by an issuer or source of data, by drawing upon data that are as broad and deep as possible at each maturity.

- It should use *readily and reliably available data* that are updated frequently, and likely to remain available over a reasonably extended period.

- The resulting spot yield curves should be *smooth over the maturity range*. Furthermore, the curves should evolve *smoothly over time*, so that they reflect changing conditions in established financial markets without inducing excessive short-term market volatility.

Methodology

Spot yield curves are estimated directly from data on corporate AA bonds. The process incorporates unbiased adjustments for bonds with embedded call options, and allows for unbiased projections of yields beyond a 30-year maturity.[3]

Estimation. The price of a bond is expressed as the sum of the cash flows discounted to the present, with an added factor adjusting for the price impact of any embedded call options. The discount function is estimated by a nonlinear least squares process, and the spot yield curve is then calculated. The yield curve is projected beyond maturities of 30 years using the estimated discount function. Par yield curves[4] are also presented for comparison with actual market yields. See Appendix 1 for details of the method.

Data. The results in this paper are drawn from data on daily corporate AA bond price and par amount outstanding obtained from Merrill Lynch.[5] The data include only corporate bonds with fixed coupons and no embedded options other than calls, with maturities of 30 years or less, and par amounts outstanding of at least $250 million. To capture behavior at maturities less than a year, the bond price data are augmented with data from the Federal Reserve Board for AA commercial paper.

Averaging over a 90-Day Period. As indicated above, the proposal includes a provision that the spot yields be averaged over a 90-business-day period. The averaging should reduce the impact of day-to-day market volatility in the liability measures and should help make contribution requirements more predictable while not compromising the accuracy of liability measures. The results are presented for both single-day yield curves and curves averaged over a 90-business-day period.

Reflecting Lump Sums in the Liability Calculation. Because the minimum value of lump sum payments would be the same as the present value of the underlying pension annuity, the mechanics of the liability calculation for plans offering the minimum can proceed by discounting all future expected pension annuity cash flows to the present using the current spot yield curve. By contrast, in the case of a more generous sponsor, the calculation of liabilities must explicitly take the lump sum behavior into account. For example, a sponsor may offer an additional cash payment to early retirees taking lump sums, along with the lump sum generated as the present value of the pension annuity. In this example, the liability calculations should

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[3] One other public methodology, familiar to pension analysts, is the Citigroup Pension Discount Curve, originally developed in response to the 1993 SEC guidance on discount rates under SFAS 87 and SFAS 106. The Citigroup approach uses Treasury par curve data to set the shape of the yield curve and calculates the AA corporate spot yields at each maturity by adding to the Treasury par curve an average of the difference between corporate and Treasury par yields within each of five maturity ranges. The Citigroup curves do not extend beyond a maturity of 30 years and thus are not easily usable for discounting pension liabilities which can extend much beyond that maturity. The Citigroup Pension Discount Curve is published at each month end, in tabular form, at 6-month maturities between 0.5 years and 30 years. The month-end curves are available back to September 30, 1995. For further details, see Lawrence Bader, "Discounting Pension Liabilities under the New SEC Rules", *Pension Section News*, June 1994; see also Bader and Ma, "The Salomon Brothers Pension Discount Curve and the Salomon Brothers Pension Liability Index, 1995 Update", Salomon Brothers, January 1995. The Citigroup Pension Discount Curve and the two papers are available on the Society of Actuaries website, at http://www.soa.org.

[4] Par yield curves show the yields to maturity of coupon-paying bonds selling at par, at each maturity.

[5] Price data from several additional sources will be used in the preparation of published yield curves.

include the value of the expected cash payments, discounted to the present using the spot yield curve.

III. Results

The impact of the proposal is illustrated in the charts presented in this section.

Results for a Single Date

Charts 1 and 2 show the results for December 30, 2004. Chart 1 shows the calculated spot yield curve for that date. The curve starts below 3 percent and increases to between 6 and 7 percent over the projection period out to 80 years. The curve is consistent with the typical shape of yield curves.

CHART 1

SPOT YIELD CURVE
CORPORATE AA BONDS
12/30/04, Percent

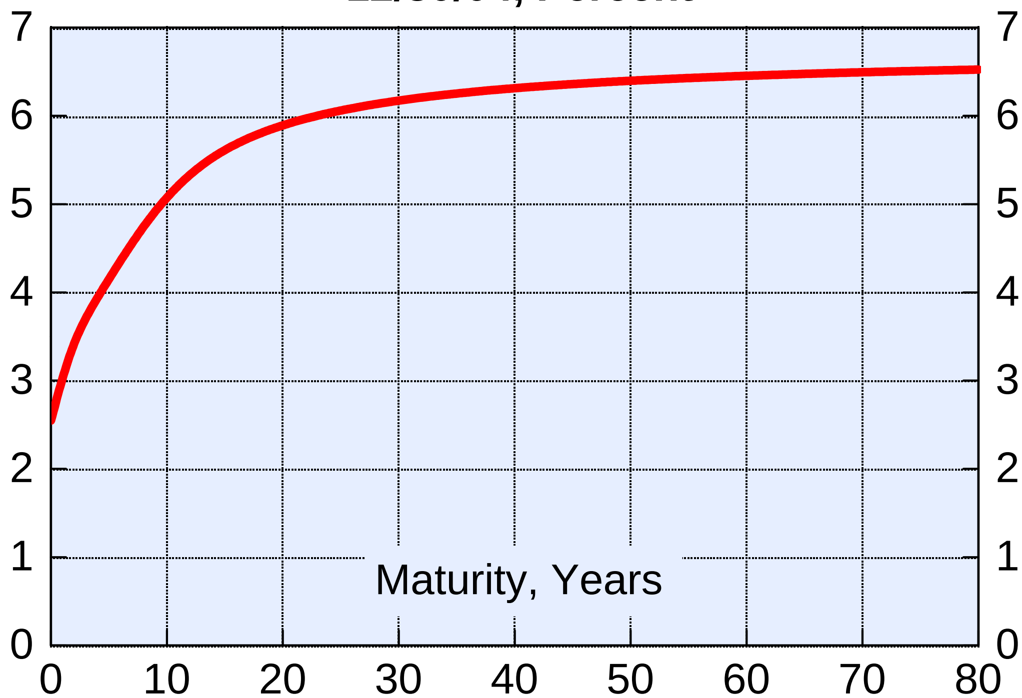
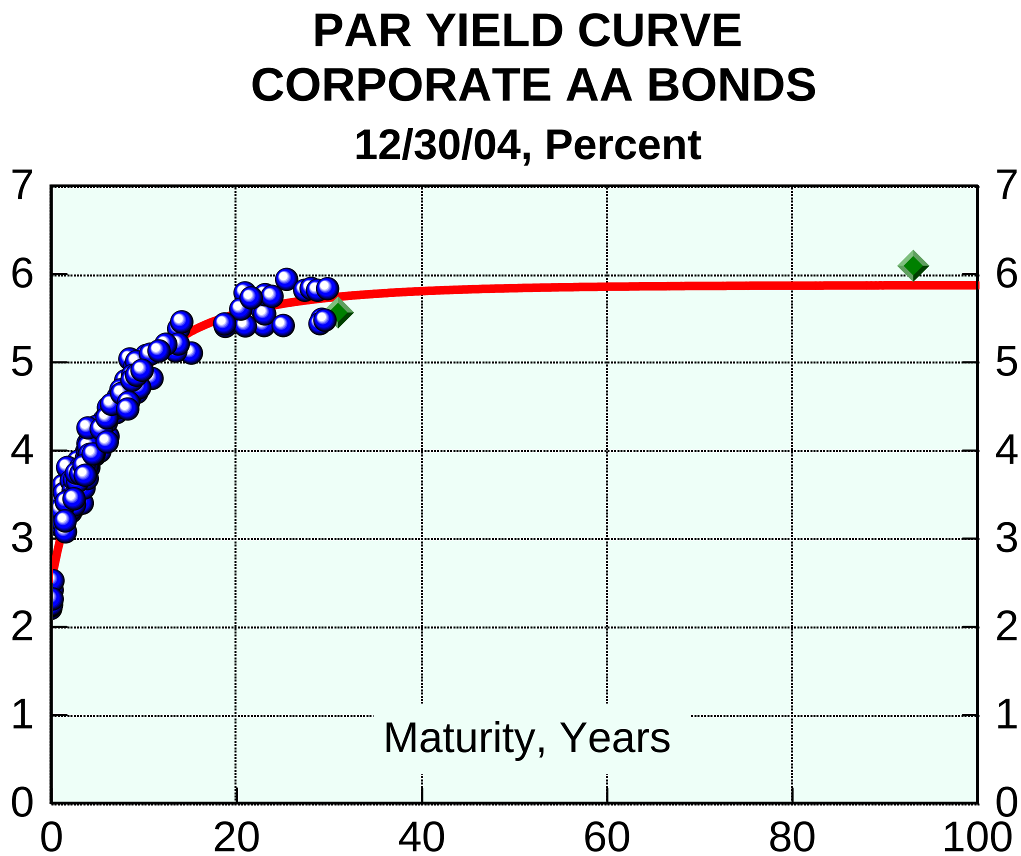


Chart 2 shows the estimated par yield curve, the yields to maturity on coupon-paying bonds selling at par, for the same day, with the actual yields of the securities in the sample plotted as dots around it. The diamonds on the chart are the yields of two securities with maturities beyond 30 years and thus not included in the estimation process. As can be seen, the data are well approximated by the estimation process.

CHART 2

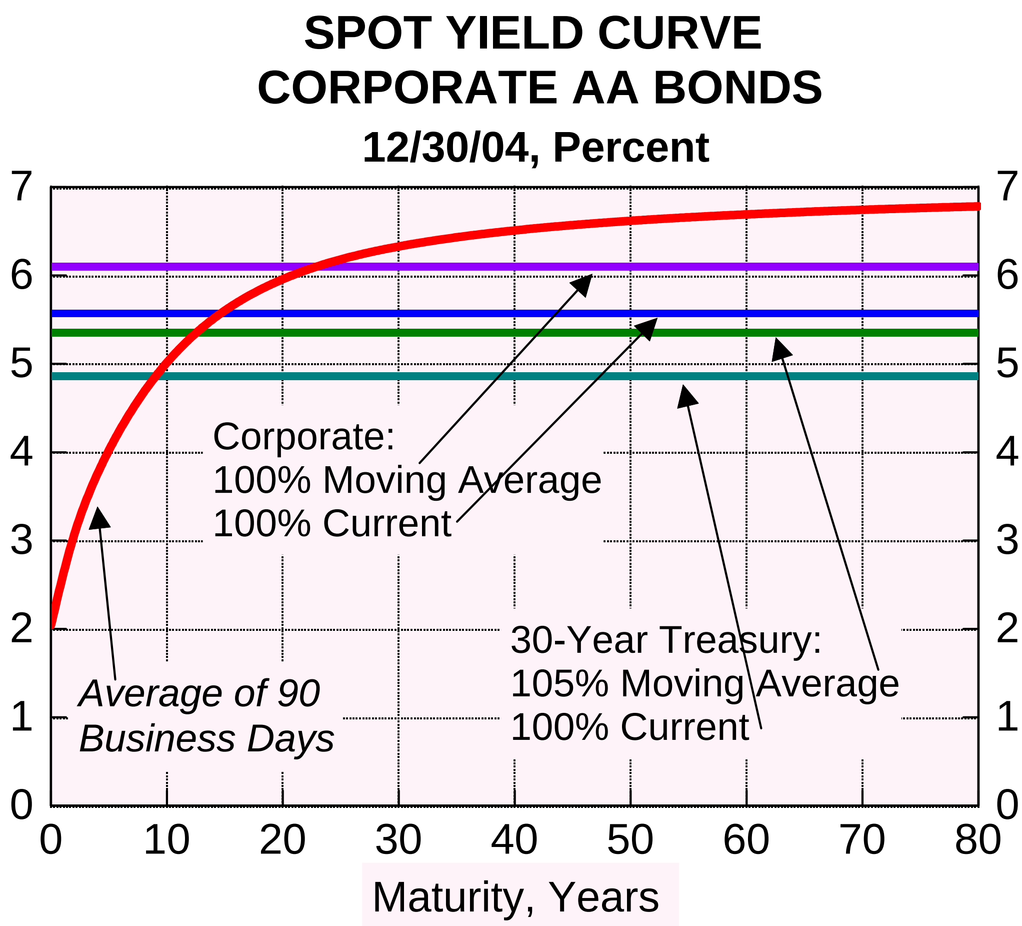


Averaging over a 90-Day Period

Chart 3 shows the 90-business-day average spot yield curve for December 30, 2004. This curve is calculated by averaging the spot yields at each maturity from spot yield curves constructed for the 90 business days up to and including December 30, 2004. The average curve rises smoothly from about 2 percent to between 6 and 7 percent at the longest maturities.

To facilitate comparison with current law for plan years beginning in 2004 or 2005, the chart also shows the current and 4-year weighted average corporate bond rate, and the current and 105 percent of the 4-year weighted average rate on 30-year Treasury securities.[6] The 90-business-day average spot yield curve is presented as a table in Appendix 2.

CHART 3



Evolution over Time

Chart 4 is a three-dimensional chart illustrating the stability of the 90-day average spot yield curves from January 2000 through December 2004. The average spot yield curves at each date are shown as front-to-back slices with interest rates on the vertical axis and maturities on the axis extending into the paper, away from the reader. The average curves are arrayed by date on the axis that runs left to right.

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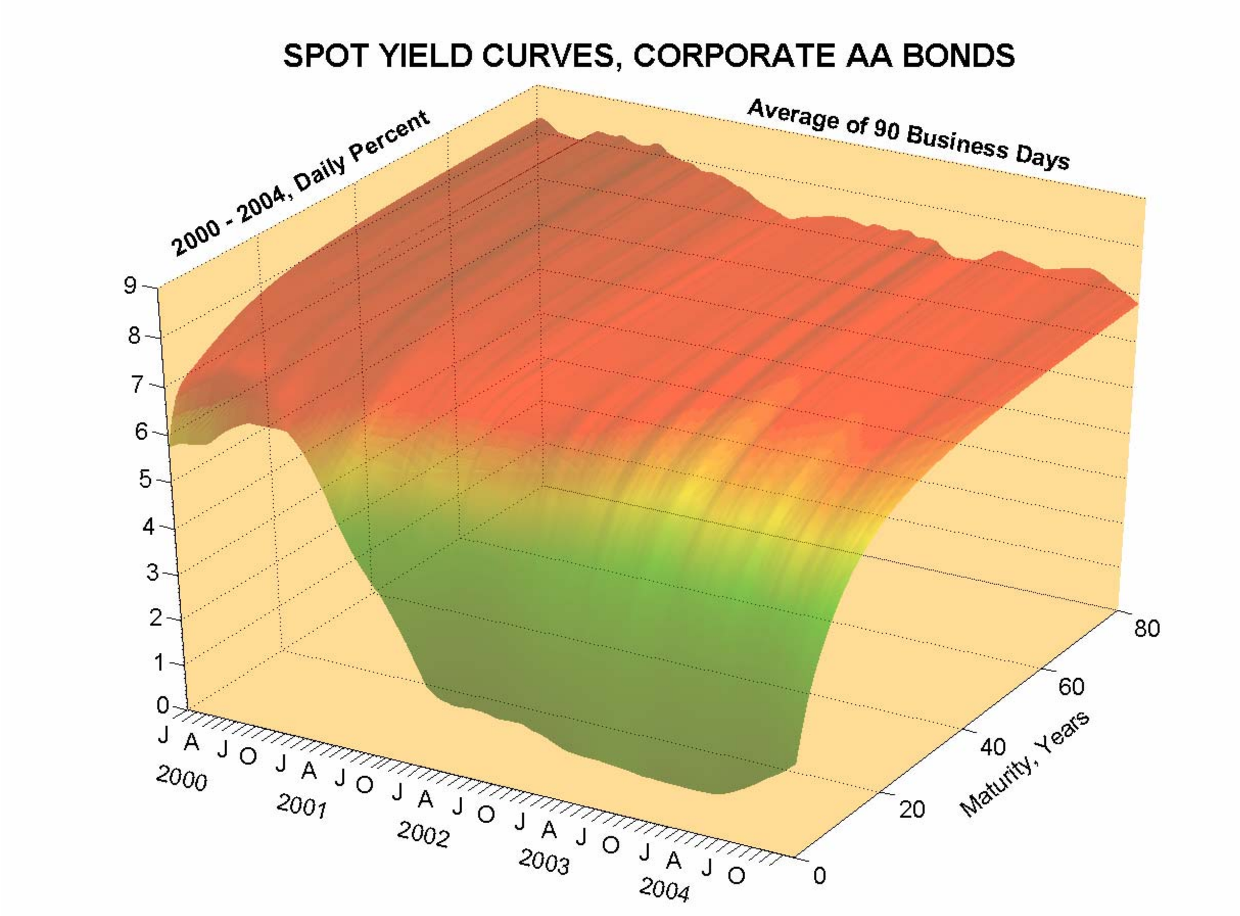
[6] The 4-year Corporate Bond Weighted Average rate for December 2004 is 6.10 percent; 105 percent of the 30-year Treasury Weighted Average rate is 5.35 percent.

The evolution of the 90-day average spot yield curves illustrated in the chart accurately tracks (with a slight lag due to the moving average process) the general pattern of corporate bond markets over this period. The shortest maturity spot yields begin at between 5 and 6 percent in January 2000, rise somewhat through 2000, decline to around 1 percent over most of the following period through mid-year 2004, and increase to about 2 percent by yearend 2004. The long maturity yields begin above 8 percent in January 2000, dip to under 7.5 percent by 2002, and recently are below 7 percent. As the chart indicates, the 90-day average spot yield curves evolve smoothly across these five years, yet still reflect important market movements.

CHART 4



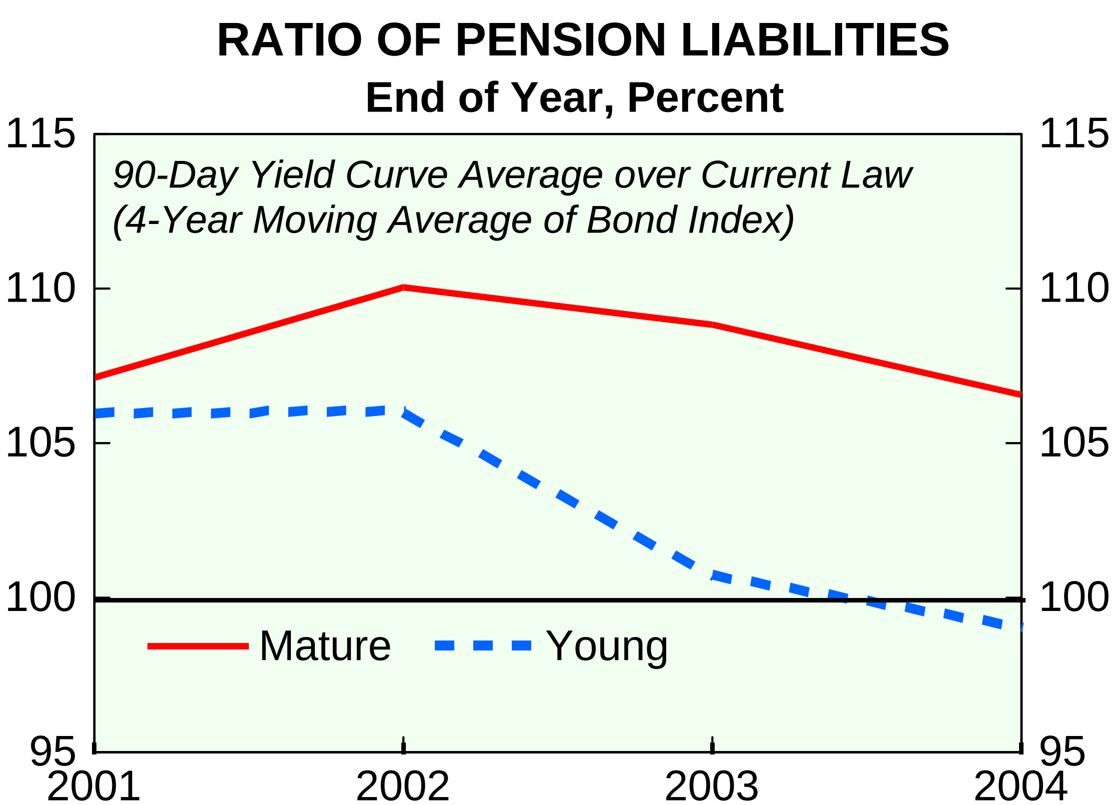
Comparison of Liability Values over Time

Charts 5 and 6 compare pension liabilities using the yield curve to liabilities under current law, for a mature plan (short duration distribution of benefits) and a young plan (long duration distribution of benefits), at yearends 2001-2004. Chart 5 shows the ratio of the liability calculated using the yield curve to that calculated using the 4-year weighted average corporate rate in current law for both plans.

As the chart shows, the mature plan's liabilities calculated using the yield curve are uniformly larger than those using the rates in current law (the ratio is uniformly above 100 percent). This unsurprising result is due to the fact that the bulk of the mature plan's cash outflows occur relatively early and the yield curve shorter-term rates are lower than the current law rate.

The young plan's liabilities under the yield curve are larger than those using current law at the beginning of the period but fall slightly below current law liabilities in 2004. This result is due to the fact that the bulk of the young plan's liabilities occur at long horizons, with the result that the liabilities are primarily determined by the behavior of the long-term spot rates. The long-term rates in the yield curve are below the current law rate in 2001, resulting in higher liabilities compared to those under current law, then gradually rise above it, resulting in lower liabilities.

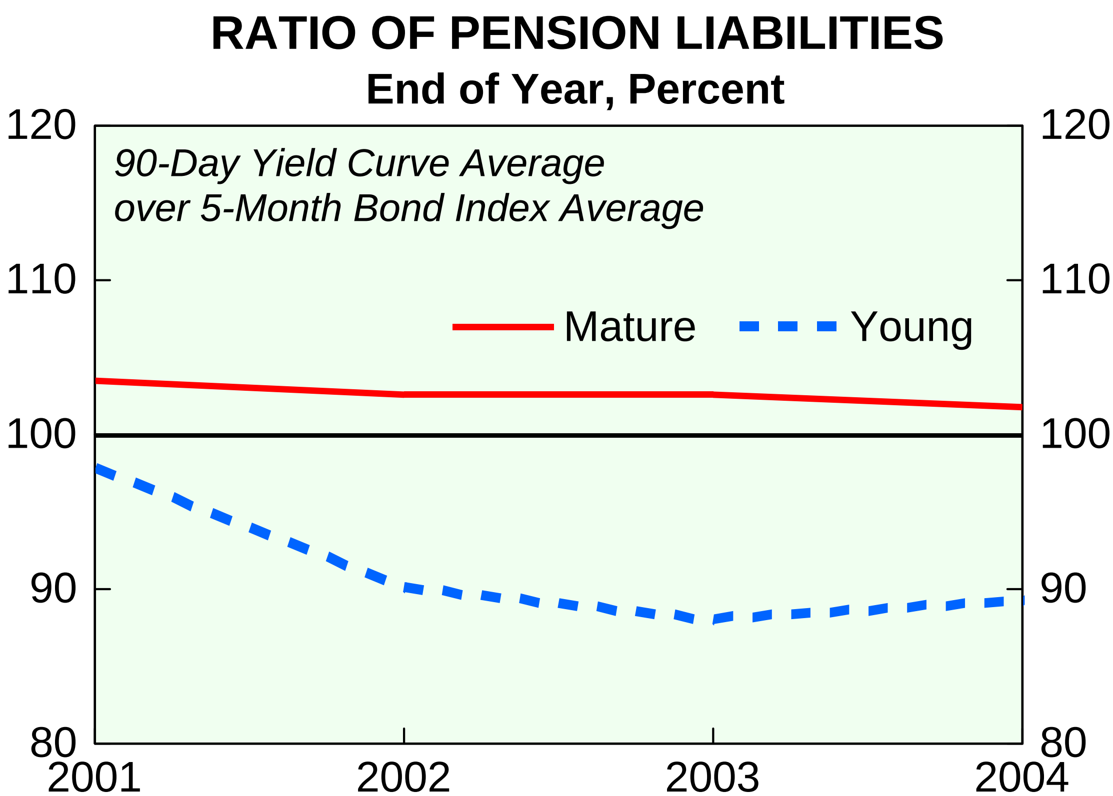
CHART 5



The consecutive ratios are relatively stable. Compared to current law, the liabilities calculated using the yield curve evolve smoothly over time without much variation from year to year, notwithstanding the significant drop in short-term rates over the period.

The comparisons in Chart 5 reflect the fact that the current law interest rate is based on an average of interest rates over the prior 48 months. As a result the current law calculation of liability reflects significantly higher out-of-date rates. It is helpful to focus just on the effects of an upward sloping yield curve (as opposed to the effects of smoothing). Chart 6 presents a comparison of liabilities calculated using the yield curve and using the corporate bond index rate from current law but averaged over the preceding 5 months – similar to the 90-business-day average for the yield curve. This comparison more clearly illustrates the impact from the use of the yield curve versus a single rate.

CHART 6



As Chart 6 shows, the mature plan's liabilities calculated using the yield curve are consistently slightly higher than those using the 5-month average corporate bond index rate. Again these results reflect the fact that the single corporate index rate is higher than the shorter-term rates under the yield curve that are matched to the shorter-term cash flows that are the bulk of the mature plan's cash flows. The young plan's liabilities are uniformly lower using the yield curve than using the 5-month average corporate bond index rate, reflecting the fact that the corporate rate is lower than the long term yield curve rates appropriate to the bulk of the young plan's cash flows.

IV. Conclusion: Choosing Rates for Pension Discounting

The 90-day average spot yield curves constructed as described in this paper can well serve as rates for pension discounting. They are constructed using accurate techniques and assumptions. They are based on readily and reliably available data from known sources. They accurately reflect high grade corporate bond markets, while minimizing the idiosyncratic impact of individual issues and the impact of short-term market volatility. Finally, as can be seen from the charts, they are smooth over the maturity range without excessive fluctuations and evolve smoothly over time without distortion by very short-term market movements.

APPENDIX 1

COMPUTING THE SPOT YIELD CURVE[7]

The following notes sketch out technical details about the data and estimation methodology used to compute the spot yield curves in the proposal.

The spot yield curves used in the proposal are estimated using data on daily corporate AA bond price and par amount outstanding obtained from Merrill Lynch and data on bond characteristics such as coupon and callability. The dataset includes only corporate bonds with semi-annual fixed coupons, maturities of 30 years or less, and amounts outstanding of at least $250 million. Bonds with special characteristics such as floating rate coupons are not included. Bonds with regular embedded call options but no embedded options other than calls are included. To capture behavior at maturities less than a year, the bond price data is augmented with data for AA commercial paper from the Federal Reserve Board. For a small number of days, the absence of a sufficient number of quotes that fulfill these criteria meant that that day was eliminated. Although the total number of quotes in each daily sample has varied over time, recently it has been a little above 200. The number of bonds with regular call options has varied from about 10 in 2001 to around 5 recently.

To estimate the spot yield curve from the bond prices it is first postulated that the prices in the AA market are characterized by a discount function, which for each maturity gives today's price for $1 received at that maturity through investment in AA quality securities. The spot yield curve is calculated from the discount function; in effect, allowing for maturity, the two curves are the inverse of each other, since discounting future payments by the spot rate from the curve is the same as applying the discount function to the future payments. The par yield curve, which shows the yield at each maturity of a bond paying coupons and trading at par, can also be derived from the discount function.

Estimating the Discount Function

A specific functional form of the discount function must first be chosen for estimation. In this methodology the discount function is expressed in terms of the instantaneous forward interest rate, and then the forward rate is modeled as a cubic spline. The knot points for the spline are chosen at maturities of 0, 1.5, 3, 7, 15, and 30 years, because these knots appear to work well in dividing the market into maturity segments. In addition, the spline is constrained to have a zero derivative at the 30-year knot to make it taper off smoothly, and to have a zero second derivative at the zero knot for increased stability at the short end. Finally, the forward rate spline is constrained at the 30-year knot to be equal to its mean value over the range from 15-30 years.

The bond price given by the present value of cash flows is then adjusted for the value of any call option embedded in the bond by expressing the price of the bond as the sum of the

[7] This methodology was developed by James A. Girola, with participation by Lucy Huffman, both of the Office of Economic Policy, under the general supervision of Mark J. Warshawsky, Assistant Secretary for Economic Policy.

discounted cash flows and the value of the call.[8] The value of the call is modeled, in an unbiased way, as a coefficient multiplied by the length of time of call exposure, the time that the investor is exposed to the risk that the bond will be called.[9] For a bond with a nondiscrete call that has not yet reached its first call date (or for bonds with discrete calls that are between call dates), the call exposure time is the time from the next call date to maturity.[10] For a bond with a nondiscrete call that is callable currently, the call exposure time is the time until maturity.

The spline and the call exposure coefficient are jointly estimated by nonlinear least squares, that is, the sum of squared errors between predicted and actual sample prices (including accrued interest) is minimized.[11] The data are weighted by the square root of outstanding par value to assure that the estimated yield curve reflects the movement of the market as a whole. The data are further weighted by the inverse of the square root of duration, to correct for heteroscedasticity. To facilitate the estimation process, the spline is written in terms of B-spline bases. To obtain a more refined estimate of the discount function, the estimation takes account of coupon and principal payment dates that fall on a weekend or holiday.

The yield curve is projected beyond maturities of 30 years using the estimated splines.[12] Because the forward rate spline at 30 years is constrained to be equal to its mean over years 15-30, and its derivative is constrained to be zero at 30 years, the forward rate for maturities longer than 30 years is equal to the forward rate at 30 years. The projected spot rate gradually converges to a constant depending on this forward rate. The final step is to compute a 90-business-day moving average of the spot yield curves.

In general, the estimation proceeds very smoothly over the last several years, and the daily yield curves, as well as the 90-business day average curves, evolve along a stable path. In particular, the projection beyond 30 years produces results that are simple and unbiased, are smooth over the entire maturity range, and are consistent over time. Empirically, the stability

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[8] A number of models for the value of the embedded call option have been proposed in the academic literature, including the exact continuous Black-Scholes formulation, and lattice-computed discrete extensions. The resulting yield curves from the linear regression model appear to be more stable over time. Tao-Hsien Dolly King, "An Empirical Examination of Call Option Values Implicit in U.S. Corporate Bonds", *Journal of Financial and Quantitative Analysis*, Vol. 37, December 2002, also estimates the value of embedded calls using a regression model.

[9] The effects of several variables related to call option values were analyzed, including the exercise price, the call exposure time, and the time until the first call date for those bonds in the call protection period (the period before the first call date). The only variable consistently significant and of the correct sign was the call exposure time. Since all bonds with embedded calls in the data are rated AA, measures of volatility were not analyzed.

[10] A bond with a nondiscrete call is one that is callable at any time after the first call date at the terms specified in the call schedule. A bond with discrete call(s) is callable only on the date(s) specified in the call schedule.

[11] The impact of other factors was examined, including liquidity and tax effects, but only the call exposure time measure was found to be consistently effective over time. Elton *et al*, "Factors Affecting the Valuation of Corporate Bonds", New York University, October, 2000, have examined the impact of different factors.

[12] Some academic research has theorized on the behavior of spot rates for long maturities. Dybvig and Marshall, "Pricing Long Bonds: Pitfalls and Opportunities", *Financial Analysts Journal*, January-February, 1996, suggest influences, including long range default risk, which would tend to increase long term spot rates, and interest rate risk of comparable Treasury bonds, which would result in a negative impact on spot rates related to convexity. They and market practitioners also cite the presence of investors with a strong preference for long-term bonds, which would tend to lower rates. Dybvig, Ingersoll and Ross, "Long Forward and Zero-Coupon Rates Can Never Fall", *Journal of Business*, 1996, vol. 69, No. 1, argue that very long term spot rates should converge to a limit. The proposal's projection beyond 30 years is an unbiased distillation of all these theoretical influences.

appears to be aided by holding the knots fixed over time at reasonable values approximating maturity segmentation in the AA market, and by constraining the spline at 30 years as described.

APPENDIX 2

SPOT YIELD CURVE, CORPORATE AA BONDS

12/30/04, Percent
Average of 90 Business Days

Maturity, Years	Spot Rate	Maturity, Years	Spot Rate	Maturity, Years	Spot Rate	Maturity, Years	Spot Rate
0.5	2.33	20.5	5.99	40.5	6.52	60.5	6.69
1.0	2.59	21.0	6.01	41.0	6.52	61.0	6.70
1.5	2.84	21.5	6.04	41.5	6.53	61.5	6.70
2.0	3.07	22.0	6.06	42.0	6.54	62.0	6.70
2.5	3.27	22.5	6.08	42.5	6.54	62.5	6.71
3.0	3.44	23.0	6.10	43.0	6.55	63.0	6.71
3.5	3.61	23.5	6.13	43.5	6.55	63.5	6.71
4.0	3.76	24.0	6.15	44.0	6.56	64.0	6.71
4.5	3.89	24.5	6.16	44.5	6.57	64.5	6.72
5.0	4.03	25.0	6.18	45.0	6.57	65.0	6.72
5.5	4.15	25.5	6.20	45.5	6.58	65.5	6.72
6.0	4.27	26.0	6.22	46.0	6.58	66.0	6.72
6.5	4.38	26.5	6.23	46.5	6.59	66.5	6.73
7.0	4.48	27.0	6.25	47.0	6.59	67.0	6.73
7.5	4.58	27.5	6.26	47.5	6.60	67.5	6.73
8.0	4.68	28.0	6.28	48.0	6.60	68.0	6.73
8.5	4.77	28.5	6.29	48.5	6.61	68.5	6.74
9.0	4.86	29.0	6.30	49.0	6.61	69.0	6.74
9.5	4.94	29.5	6.32	49.5	6.61	69.5	6.74
10.0	5.02	30.0	6.33	50.0	6.62	70.0	6.74
10.5	5.09	30.5	6.34	50.5	6.62	70.5	6.75
11.0	5.16	31.0	6.35	51.0	6.63	71.0	6.75
11.5	5.23	31.5	6.36	51.5	6.63	71.5	6.75
12.0	5.29	32.0	6.37	52.0	6.64	72.0	6.75
12.5	5.35	32.5	6.38	52.5	6.64	72.5	6.75
13.0	5.41	33.0	6.39	53.0	6.64	73.0	6.76
13.5	5.46	33.5	6.40	53.5	6.65	73.5	6.76
14.0	5.51	34.0	6.41	54.0	6.65	74.0	6.76
14.5	5.56	34.5	6.42	54.5	6.66	74.5	6.76
15.0	5.60	35.0	6.43	55.0	6.66	75.0	6.76
15.5	5.65	35.5	6.44	55.5	6.66	75.5	6.77
16.0	5.69	36.0	6.45	56.0	6.67	76.0	6.77
16.5	5.73	36.5	6.46	56.5	6.67	76.5	6.77
17.0	5.77	37.0	6.47	57.0	6.67	77.0	6.77
17.5	5.80	37.5	6.47	57.5	6.68	77.5	6.77
18.0	5.84	38.0	6.48	58.0	6.68	78.0	6.78
18.5	5.87	38.5	6.49	58.5	6.68	78.5	6.78
19.0	5.90	39.0	6.50	59.0	6.69	79.0	6.78
19.5	5.93	39.5	6.50	59.5	6.69	79.5	6.78
20.0	5.96	40.0	6.51	60.0	6.69	80.0	6.78