A NEW WAY OF LOOKING AT THE RISK IN DEFINED BENEFIT PENSION PLANS

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June 2000

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ABSTRACT

The portability feature of a defined contribution (DC) pension greatly reduces the risk to the accumulation of pension wealth. Conversely, defined benefit (DB) pensions have a variety of default risks that decrease the expected value of DB pension wealth. This paper examines those risks. Accrual of DB pension wealth is characterized in terms of purchases of risky bonds. Changing jobs triggers default on these bonds. Simulations are presented to show the potential loss in pension wealth from default. In addition, a methodology used to price corporate bonds is applied to generate estimates of the implied risk premia of DB pension bonds over comparable riskless bonds.

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At first glance, it might appear that defined contribution (DC) and defined benefit (DB) pension plans that provide identical streams of income in retirement would in fact be identical retirement income regimes. This is not the case. My point here is to demonstrate that DC plans are in many ways a superior means of providing retirement income security. This is true for two primary reasons. First, the portability and investment choice attributes of DC pensions confer substantial advantages on DC plan participants. In particular, the option to rollover the assets in a DC plan to an IRA or 401(k) when changing jobs serves to dramatically reduce the risk level of DC plans. Second, DB pensions have a variety of default risks that decrease their value. As will be shown below, benefit accrual in a DC plan can be characterized in riskless terms. Conversely, the default risks associated with DB pensions means that DB plan benefit accrual is risky, and remains risky up to the date of retirement. The differences in the risk borne by DC and DB plan participants means that the expected present value of the future benefit stream of DC and DB plans with identical benefit accrual rates can differ substantially.

The crucial element defining the difference between DC and DB plans is portability. The portability feature of DC plans allows us to characterize them as relatively riskless vehicles for building pension wealth in comparison to DB plans. Conversely, the lack of portability inherent in DB plans means that the future benefits derived from these plans are subject to a variety of risks. When these risks are taken into account the expected present value of the benefit stream declines significantly. These risks will be detailed below.

The next section of the paper briefly describes the principal differences between DC and DB plans. The third section analyses the default risks associated with DB plans. This section shows how benefit accrual in DB plans can be described in terms of purchases of risky bonds. By comparison, accrual of identical benefits in a DC plan can be exactly replicated with purchases of riskless U.S. Treasury bonds. The fourth section applies the methodology used to price options and corporate bonds to generate estimates of the implied risk premia of these bonds over comparable riskless DC pension bonds. The fifth section offers some concluding remarks.

Principal Differences Between DC and DB Plans

Lack of portability is one of the well-known drawbacks of DB plans. Under a DB regime, workers who stay with the same employer for their entire career retire with larger pensions than similarly compensated workers in similar DB schemes who change employers over the course of their careers. This fact makes DB plans particularly unattractive for younger workers, who face the greatest uncertainty in terms of future job tenure.

The vesting rules of DB plans are another unappealing feature when compared to typical DC plans. Vesting usually occurs after 5 years in DB plans, although many public sector DB plans require 10 years of service for vesting. By contrast, employee contributions vest immediately in DC plans. Employer contributions vest immediately in 34 percent of DC plans. In addition, 27 percent of DC plans have cliff vesting, where employer contributions are vested after a period ranging from one to five years. A further

32 percent of DC plans have graduated vesting, and 2 percent of plans base vesting of employer contributions on the employee's class year.[1] Employees who change jobs and move from one DC plan to another face only the potential loss of pension rights of non-vested employer contributions. Furthermore, DC plans are neutral with respect to job tenure. Workers with vested rights in a DB plan who leave the firm after 5-10 (or more) years see their pension benefits frozen in nominal terms based on their salaries at that time. Similar workers with DC plans continue to accumulate interest income, dividends, and capital gains in their pension portfolio.[2]

Participants in DC plans have flexibility in terms of investment choice, in exchange for which they bear investment risk. This flexibility permits individuals to structure their portfolios in accordance with their time and risk preferences. This has an obvious appeal, however concerns remain that financially unsophisticated participants may choose portfolios either too conservative or too risky, putting retirement income security in jeopardy. In general it appears that DC plan participants make reasonable investment choices. As of the end of 1998, asset allocation in 401(k) plans on average consists of 49.8 percent equity funds, 17.7 percent company stock, 11.4 percent in

[1] Source: *"Employee Benefits in Medium and large Private Establishments, 1997,"* Department of Labor, Bureau of Labor Statistics, Bulletin 2517, September 1999. The above numbers don't add up to 100 because 5 percent of responses were "other" or "not determinable."

[2] This assumes that employees who change jobs either roll their DC balances into new DC vehicles, or else leave their original balances untouched to accumulate over time. Data compiled by the *Employee Benefit Research Institute* from the 1993 Current Population Survey suggest that this is a fair working assumption. Among those who had ever taken a lump-sum distribution (almost all of whom in the sample were age 60 or younger), 41.5 % used some or all for tax-qualified saving; 17.0 % used some or all for non tax-qualified saving; 30.5 % used some or all for housing, business formation or debt reduction; 2.9 % used some or all to finance education; and 38.3 % used some or all for consumption. The median distribution was $3,507 in 1993 dollars. Large distributions were overwhelmingly rolled over into another saving vehicle. For example, 76.7 % of recipients receiving distributions of $50,000 or larger used some or all for tax-qualified saving, while only 12.9 % used some or all for consumption. Conversely, 59.6 % of recipients receiving distributions of less than $500 used some or all for consumption, while 27.2 % used some or all for tax-qualified saving. Source: *"Employment-Based Retirement Income Benefits: Analysis of the April 1993 Current Population Survey,"* EBRI Issue Brief Number 153, September 1994.

guaranteed investment contracts, 8.4 percent in balanced funds, 6.1 percent in bond funds, 4.7 percent in money market funds, and 0.3 percent in other value funds.[3]

DB Pensions Defined as Risky Bonds

In a typical DB plan retirement benefits are calculated as a percentage of final average salary. An employee's final average salary may be based on earnings in the last year of covered employment, or an average of the last several years of employment. The benefit formula takes into consideration years of service and an accrual factor. For example, an employee reaching the normal retirement age with 30 years of service in a DB plan with an accrual factor of 2.0 percent per year would retire with a benefit of 60 percent of final average salary. For a final average salary of $50,000, the pension in the first year of retirement would be $30,000, and the accrual can be thought of as annual increments of $1,000.

This accrual would only be the case for an employee who was vested and worked a full career of 30 years, meeting the age and service requirements to retire with full pension benefits. Benefit accrual in a stylized DB plan can be thought of as annual purchases of risky zero-coupon bonds, maturing at the time of retirement. The face value of these bonds is an amount sufficient to finance the purchase of an annuity paying the annual benefit accrual. For example, consider an annuity paying out $8,000 annually for each $100,000 accumulation. At this price, it would require a $375,000 accumulation to finance pension benefits of $30,000. The $375,000 represents the total face value of the

[3] Source: EBRI/ICI Participant-Directed Retirement Plan Data Collection Project, January 2000. One area of concern in DC plan asset allocation is the reliance on company stock. This implies a dramatic and probably unrecognized increase in risk borne by plan participants. Orthodox finance theory would recommend shorting company stock, not taking large long positions.

zero-coupon bonds "purchased" by a DB plan participant over the course of a full working career.

Thinking of DB benefit accrual as a means of accumulating a stock of pension wealth annuitized at retirement is also a means of comparing DB and DC plans. In the example above, the pension wealth accumulated by the DB participant could be exactly replicated by a participant in a stylized DC plan purchasing zero-coupon bonds each year with face values such that the DC plan participant ended up with the same accumulated assets at age 65. This asset stock could then be annuitized to provide the same income stream in retirement.

Furthermore, in 2000, a younger employee in this stylized DC plan could purchase for $180.23 a U.S. Treasury Strip zero-coupon bond with a face value of $1,000 maturing in February 2029.[4] The bond yields 6.0 percent, and if rolled over into another DC vehicle if and when the employee changes jobs, the DC participant will eventually accumulate $1,000.[5] (U.S. Treasury Strips are zero-coupon bonds formed by taking a U.S. Treasury note or bond and stripping out the semi-annual coupons and the principal portion into separate securities. For example, a 10-year Treasury note could be stripped into 21 zero-coupon bonds, consisting of 20 coupons and the final principal payment.[6] Backed by the full faith and credit of the U.S. government, these securities bear no default risk.)

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[4] Price and yield to maturity from the *Wall Street Journal* of May 17, 2000.
[5] This investment option is chosen for ease of exposition. The percentage of DC plans offering investment options of this type is not known.
[6] In financial publications such as *The Wall Street Journal* U.S. Treasury Strips are listed alongside treasury bills, notes, bonds, and Treasury Inflation Protection Securities (TIPS). Zero-coupon bonds formed from coupons are designated with the symbol ci, principal payments from treasury notes are designated with the symbol np, and bond principal payments with the symbol bp.

Unfortunately for DB plan participants "purchasing" zero-coupon bonds in their pension plans, their bonds are not the equivalent of U.S. Treasury Strips. There are a variety of risks associated with benefit accrual in a DB plan. This means that the associated zero-coupon bonds DB plan participants purchase have a variety of default risks. Furthermore, the types of risks and the severity of the default changes over time. Participants in DB plans are exposed to three broad types of risks, detailed below.

The first type of risk involves the vesting provisions of DB plans. With vesting at the five-year mark, employees who exit the firm before they vest lose all pension benefits. This is the worst default scenario. In this case, employees purchase zero-coupon pension bonds for up to five years, yet receive nothing. This is equivalent to a default where the bondholders receive exactly zero cents on the dollar. In nearly half of state and local government DB plans the vesting threshold is ten years of covered employment, making the default risk significantly higher (Zorn 1997).

Younger workers are particularly susceptible to this default risk. Younger workers are more likely to change jobs and even careers. The average worker holds 9.2 jobs between the ages of 18 and 34.[7] Between ages 18 and 24, workers hold an average of 5.6 jobs. Between ages 25 and 29, workers hold an average of 3.0 jobs. Between ages 30 and 34, workers hold an average of 2.4 jobs. In a world of DB plans, younger and more mobile workers face the prospect of working a substantial part of their careers while accruing no pension rights. (In this analysis no distinction is made between voluntary and involuntary job termination.) In effect, younger workers who leave before vesting subsidize older workers and other workers who remain with the same employer. This transfer of pension wealth is irreplaceable. Furthermore, due to the relentless logic of compound interest, these employees miss out on the opportunity to accrue retirement wealth over a period of decades.

A second form of default occurs when an employee leaves the firm after vesting but before reaching the normal retirement age. This also triggers default on the risky zero-coupon bonds the employee has been purchasing to finance retirement. However, because the employee is vested, the default is not total. The employee receives partial payment on the bonds. As in a corporate bond default, the amount of principal recovered is highly variable. In the case of a corporate bond default where the corporation is subsequently liquidated, the amount recovered by the bondholders is a function of the seniority of their claims and the residual assets of the firm. In the case of a vested employee leaving the firm before the normal retirement age, the amount recovered is also largely a function of the employee's seniority.

Recovery under this default scenario can be illustrated with a simple numerical example where we assume that vesting occurs after five years. Consider an employee who starts with the firm at age 35 with a salary of $30,000, receives annual nominal earnings increases of four percent, and retires at age 65. (These earnings increases may be thought of as two percent annual real increases and two percent inflation.) The employee faces two alternative career path options. On the first path the employee remains with the same firm for 30 years, accruing pension benefits at a rate of two percent per year that are paid as a percentage of final salary. On the second path the

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[7] Source: Department of Labor, Bureau of Labor Statistics, News Release April 25, 2000. The numbers of jobs that span age groups were counted once in each age group. Hence, the sum of jobs across the individual age groups is higher than the overall average number of jobs held.

employee exits the firm after either 10 or 20 years. The pension benefits earned under the two paths are shown in Table 1.

The face value of the zero-coupon pension bonds purchased by the employee each year finances an annuity paying $1,946. Hence remaining with the employer from age 35 until retirement at age 65 would produce a pension benefit corresponding to the first year's service of $1,946, two percent of the final year's salary. Employees who stay with the firm continue to purchase these bonds and eventually receive their full face value, with benefits corresponding to $19,460 for 10 years of service and $38,921 for 20 years of service. The full pension benefit received by an employee who worked 30 years and retired at age 65 consists of 30 of these zero-coupon bonds, financing an annuity paying $58,381 in the first year of retirement. (This is essentially the inflation-adjusted counterpart to the earlier example.)

However, if the employee quits after 10 years, the annual benefit corresponding to the first 10 years of service would be only $8,881. This is only 46 percent ($8,881/$19,460) of the benefit paid to a similar employee who remained with the firm for 30 years. If the employee quits after 20 years, the benefit eventually payable at age 65 from the first employer would be $26,293. This is 68 percent ($26,293/$38,921) of the benefit paid to a similar employee who remained with the original employer until the normal retirement age.

These annuity payouts can be used to calculate the amount of pension wealth earned by DB plan participants. The pension wealth calculation is based on TIAA single life annuity rates for a 65-year old as of June 1998 that pay a monthly amount of $759 per $100,000 accumulation under the standard payment method (Poterba and Warshawsky

1999). Using this annuity rate we can calculate pension wealth under the default and non-default scenarios described above. This calculation is shown in Table 2.

Under the non-default scenario, an employee who works a full 30-year career and retires at the normal retirement age of 65 accrues pension wealth of $640,988. In the first year, the DB benefit accrual was equivalent to a purchase of a deep discount zero-coupon bond with a face value of $21,366.

However, looking at the wealth accumulations under the various default scenarios shows the degree of riskiness inherent in the DB benefit accrual. An employee who leaves before vesting forfeits the entire $21,366 face value bond purchased in the first year of covered employment. A vested employee who leaves the firm after 10 years and eventually receives 46 percent of the face value of the bonds purchased ends up losing more than $100,000 in pension wealth. For an employee who leaves after 20 years of service the recovery from the default is less severe at 68 percent, but this still represents a loss of pension wealth of nearly $150,000 in comparison to the same employee who stayed with the firm until the normal retirement age. In addition, this deterministic example used a constant inflation rate of 2.0 percent. If a higher inflation rate had been used, then the default loss suffered by employees who left before the normal retirement age would have been higher still. In conditions of high inflation, the real value of the eventual benefits earned by employees leaving DB plans could be quite small.[8]

A (stylized) DC plan participant could replicate this amount of pension wealth accrual with purchases of zero-coupon bonds bearing no default risk. For example, our hypothetical 35-year old employee with a salary of $35,000 can accumulate $21,366 of

[8] It is common for DB plans to provide some protection against inflation in retirement, with either statutory or ad hoc cost of living increases in benefits.

certain wealth at retirement by paying $3,852 for U.S. Treasury Strips maturing in February 2029 with a face value of $21,366.[9] This represents a DC plan (employee and employer) contribution rate of 12.8 percent. Hence an extremely risk-averse investor could have all of the investment security of a DB plan with all of the considerable mobility and investment choice advantages of a DC plan. Furthermore, this example used an investment choice in the DC plan yielding only 6.0 percent in nominal terms.

A brief comparison with corporate bond defaults may illustrate the severity of the loss suffered by participants in DB plans who change jobs and lose their DB plan coverage. For example, as of December 1999, Optel Inc., a telecommunications firm, was in default on its long-term debt. The issue, of senior notes paying 11 ½ percent due in 2008 and rated D by Standard & Poor's, ended December trading at 52 ½.[10] Average recovery rates for all defaulted issues, of all seniority categories, were 42 percent of par in 1999. This was approximately equal to the post-1970 average.[11] Looking at default rates across different ratings of corporate bonds also serves to show the riskiness of DB pension plans. Table 3 shows cumulative default rates, five and ten years after issuance, for corporate bonds of varying quality. The table shows that even ten years after issuance, the cumulative default rate for corporate bonds originally rated BBB – the lowest investment grade rating – was only 2.44 percent (Altman, Hukkawala and Kishore 2000). By contrast, the cumulative default rate for bonds originally rated CCC – highly speculative high yield or "junk" bonds – was 48.38 percent. After five years, the cumulative default rate for bonds originally rated CCC was already 36.07 percent.

[9] As in the example above, price is taken from the *Wall Street Journal* of May 17, 2000.
[10] Source: Standard & Poor's *"Bond Guide,"* December 1999.
[11] Source: Moody's Investors Service, *"Historical Default Rates of Corporate Bond Issuers, 1920-1999,"* January 2000.

As of February 1998, the median employee had been with the same employer for 3.6 years.[12] Median tenure for managerial and professional workers was 4.8 years, for technical, sales and administrative support workers it was 3.2 years, and for service workers it was 2.4 years. Overall, approximately a quarter of workers had been with their current employer for less than a year. Hence the probability of an employee remaining with an employer long enough to avoid the types of default risks associated with DB plans was not high. Looked at in this way benefit accrual in a DB plan is more akin to "purchases" of the lowest-rated or "junk" corporate bonds.

There is an additional type of default risk associated with the accrual of pension wealth in DB plans. This risk is of particular relevance to older and long-serving employees covered by DB plans. This is the risk that the benefit formula and accrual rules associated with the plan change, particularly the provisions basing the eventual pension benefit on final average salary.[13] Changes of this nature have been very popular in private sector DB plans in recent years, and this popularity shows no signs of waning. Specifically, changing a DB plan with the pension benefit based on final average salary to a cash balance plan has the potential to significantly reduce the expected pension wealth of older and long-serving employees. Furthermore, this type of default risk is almost entirely beyond the employee's control. The unpredictable nature of this risk adds a large degree of uncertainty to the expected benefits of employees in DB plans. This added risk places a downward bias on the expected present value of the benefits offered under DB plans.

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[12] Source: Bureau of Labor Statistics, Current Population Survey, 1998.

[13] Participants in state and local government DB plans are generally immune to changes in plan provisions that endanger expected benefits.

There are two aspects to the default risk posed by the possibility that a traditional DB plan might convert to a cash balance plan. The first is the loss of the early retirement subsidy common (although by no means universal) in DB plans. The second is the straightforward reduction in pension wealth that may hit an older employee when an employer decides to convert to a cash balance plan. As this risk may be very difficult to foresee, it may also be very difficult if not impossible for an employee to hedge against.

In a cash balance plan an employer typically contributes between 2 and 10 percent of earnings to a notional employee account each year, crediting the account with interest at the Treasury bill or bond rate (Clark and Schieber 2000). The level of earnings contributed to the employee's account may vary with age and years of service. Cash balance plans resemble defined contribution plans with low contribution rates and conservative investment styles. In addition, employers with DB plans may convert them to pension equity plans. In a pension equity plan an employee receives a credit, typically between 7 and 12 percent of earnings, for each year of service. If an employee leaves the firm the credit is valued based on some form of final average salary. Cash balance and pension equity plans are known as hybrid plans. They are called hybrid plans because they combine elements of DB and DC plans. An employee with a hybrid plan who leaves the firm receives the sum in the account balance as a lump sum distribution, thus eliminating the mobility drawbacks of DB plans. However, hybrid plans typically do not allow for investment choice.

In an analysis of 77 firms that converted to hybrid plans, Clark and Schieber found that the reduction in benefits to older employees was largely the consequence of the elimination of early retirement subsidies. However, they did find that in roughly half of the sample workers who left the firm at ages 60 or 62 faced cuts in benefits in addition to the loss of early retirement subsidies. They found that for a 40-year old employee with 10 years with 10 years of service at the time of transition to a hybrid plan, 51 percent of those who retire at age 62 faced cuts in benefits in addition to the loss of the early retirement subsidy. For 26 percent of this employee cohort, the early retirement subsidy represented less than a quarter of the benefit cut. The loss of the early retirement subsidy represented between a quarter and a half of the benefit cut for 23 percent. The loss of the early retirement subsidy represented between a half and three quarters of the benefit cut for 33 percent. The loss of the early retirement subsidy represented between three-quarters and all of the benefit cut for 18 percent of this cohort.

The Risk Premium on DB Pension Bonds

The previous section showed that benefit accrual in a DC plan can be characterized as purchases of riskless discount bonds, paying a known amount at a point in the future. By contrast, benefit accrual in a DB plan was characterized as "purchases" of risky discount bonds, paying much less than face value in the (likely) event of default. This section calculates the risk premium on these DB pension bonds, given a range of parameter values.

Risk premia are calculated using the options pricing methodology originally developed by Black and Scholes (1973) and Merton (1974). The options pricing framework allows us to model the pricing problem in terms of risky and riskless debt. Options are derivative securities: they derive their value from the value of an underlying asset. The holder of an option has the right, but not the obligation, to buy or sell the underlying asset at a fixed price. The right to buy the underlying asset is a call option;

the right to sell is a put option. The holder of a call option profits from an increase in price in the underlying asset; the holder of a put option benefits from a fall in the price of an underlying asset. Conversely, an investor can sell or "write" options. In return for writing an option an investor receives a small payment, or premium. If the option then expires without being exercised the writer of the option pockets the payment. Hence, a writer of call options hopes to benefit from a fall in price in the underlying asset, while a writer of put options hopes to benefit from an increase in price in the underlying asset.

The methodology developed to price options also has direct application for bond pricing. One of the insights of the options pricing literature is that debt and equity securities can be modeled as options on the total value of the firm. In this framework, debt and equity holders have contingent claims on the firm, as they are only paid back in the event that the firm's assets are greater than or equal to the value of their claims. For instance, bondholders are paid back at the time of maturity of their bonds if the value of the firm's assets is greater than the value of the bonds. If the value of the firm's assets is not greater than the face value of the bonds, the firm defaults and the bondholders receive the value of whatever assets remain. Equity holders receive payment only after the bondholders have been paid. This default risk explains why corporate bonds carry a premium in terms of yield over riskless U.S. Treasury bonds. The subordination of equity holders to bondholders in the contingent claims framework also explains why equity carries a risk premium over debt.

To model this, we assume that if assets generate enough value to meet or exceed the face amount of the bond at maturity, then the bondholders receive the promised payment:

D = B if A > B;

Where D is the payment made at maturity, B is the face amount of the bond, and A represents the value of the assets of the firm. If the assets do not generate enough value to make the payment, the firm is declared bankrupt and the bondholders receive what is left:

D = A if A < B

Due to limited liability, the equity holders' stake is a residual claim. Their payoffs are as follows:

E = A – B if A > B

= 0 if A < B;

where E is the value of equity.

Merton extended the options pricing framework originally developed by Black and Scholes for pricing call options on equity and applied it to price corporate bonds. His insight was to model corporate zero-coupon bonds as a portfolio consisting of an equivalent face value zero-coupon Treasury bond plus a short position into a put-to-default on the firm's assets. Merton used this insight to calculate the risk premium on corporate zero-coupon bonds. Put another way, an investor purchasing a zero-coupon corporate bond has purchased a riskless U.S. Treasury zero-coupon bond of the same face amount and written a put option on the assets of the firm. If the firm's assets at the time of maturity have enough value to pay the face amount, then the bondholder is paid back and the put option expires without being exercised. The investor receives the amount of the riskless U.S. Treasury zero-coupon bond plus the premium received for writing the put option. This premium is the risk premium the investor requires for bearing the default risk of investing in corporate debt. Default, however, is equivalent to exercise of the put option. The amount of the loss faced by the bondholder is determined by the value of the put option. In the worst case scenario the value of the put option is equivalent to the full face amount of the bond and the investor receives nothing.

The pricing formula for the risk premium is:

$R(t) – r = -1/tLn\{N[H2(d, \ ^2t)] + 1/dN[H1(d, \ ^2t)]\}$

Where

$H1(d, \ ^2t) = -[1/2 \ ^2t – Ln(d)]/ \quad t$

$H2(d, \ ^2t) = -[1/2 \ ^2t + Ln(d)]/ \quad t$

And $d = Bexp(-rt)/A$

And N is the cumulative normal distribution function. The formula assumes that interest rates are deterministic, not stochastic. The key variables are the maturity of the bond (t), the volatility ( ) of the assets determining the bond's final payout, and the ratio of the discounted present value of the riskless zero-coupon bond (B) to the total value of the firm (A). This ratio is the parameter d.

This methodology is directly applicable to our comparison of the riskiness of DC and DB plans. The previous section shows that benefit accrual in a DB plan could be exactly replicated in a DC plan by purchasing riskless zero-coupon U.S. Treasury Strips. Conversely, the default risks associated with "purchases" of pension bonds in DB plans imply that DB pension bonds are more akin to the lowest rated corporate bonds. Using the options-pricing framework, we can characterize these DB pension bonds as a portfolio consisting of a riskless zero-coupon bond and a short position in a put-to-default on a risky zero-coupon bond. The premium received from the short position on the put option is the risk premium on the DB pension bond. The pricing formula above allows us to calculate this risk premium, given a range of assumptions about parameter values.

For a bond of a given maturity, the risk premium is an increasing function of and d. The parameter d, the ratio of debt-to-firm value, is an indicator of the degree of leverage of the firm.

Two of the variables in the pricing formula take on slightly different interpretations when the formula is applied to the case of DB pensions. First, the parameter A now represents the value of a DB pension bond, relative to the discounted present value of a riskless zero-coupon bond. This means that the parameter d is now the ratio of a riskless bond to a risky DB bond. For example, if A=1, then the parameter d collapses to Bexp(-rt), the discounted present value of a riskless zero-coupon bond. This corresponds to the case of perfect certainty, where the value of the future pension promise is known with complete conviction. In the real world of DB plans, however, employees do not know with perfect certainty that they will remain with the same employer for their entire career. Thus A in this case takes a value less than or equal to 1.0 until the date of retirement. Furthermore, we would expect the value of A to be smaller the farther the employee is from retirement. To see this consider the calculations for benefit accrual in the previous section. Employees vested in a DB plan who leave after 10 years and have 20 years to go until retirement know the nominal value of the future benefits they will receive. In the previous section this was calculated at $8,881. Unfortunately, employees have no idea what the real value of this $8,881 will be in 20 years. Furthermore, employees have no way to hedge against this risk.

The volatility parameter, , also takes on a different interpretation here. Volatility in the case of DB plans represents the volatility of the DB pension promise. In the pricing formula this is multiplied by t, the number of years until retirement. Together, this represents the volatility of the pension promise over the number of years until retirement. Low volatility means that there is a low probability the employee will leave the firm and thus forfeit the full DB pension. High volatility means a high probability the employee will leave the firm before the normal retirement date. Hence, the parameter is likely to be relatively higher for younger workers. In sum, the volatility parameter is a proxy for mobility. A priority for future research is to map data on job mobility to the volatility parameter.

Risk premia are calculated for a variety of parameter values under three scenarios concerning employee mobility and the number of years until retirement. In the first scenario the employee is vested in a DB plan but still has 30 years to go until retirement. In the second scenario the employee has 20 years to go until retirement. In the third scenario the employee has 10 years to go until retirement. The parameter A is given a range of values relative to the discounted present value of riskless bonds ranging from 1.0 to approximately 0.33. The highest values of A are chosen for the scenario where the employee has 10 years to go until retirement. The lowest values are chosen for the scenario where the employee has 30 years to go until retirement. As A declines in value, this is analogous to a decline in the real value of the pension promise. For example, with 10 years to maturity, a riskless zero-coupon bond discounted at 6.0 percent with a face value of $1,000 sells for $550. If we choose the value of A with 10 years to retirement to be 80 percent as valuable as a riskless zero-coupon bond, then we can calculate the parameter d as d=Bexp(-rt)/A=(0.55/0.80)=0.69. This method generates values for the parameter d ranging from 0.55 (A is 100 percent as valuable as a riskless zero-coupon bond, 10 years to retirement) to 3.30 (A is approximately 33 percent as valuable as a riskless zero-coupon bond, 30 years to retirement), similar to that found in the Merton method of pricing corporate bonds. The volatility parameter, , was given a range of 0.1 to 0.3. This also corresponds to volatility values used to price corporate bonds. The nominal riskless rate of interest chosen was 6 percent.

Risk premia for the three scenarios are shown in Charts 1-3, in hundreds of basis points. The lines in each chart show that the risk premium is an increasing function of volatility, our proxy for mobility. The charts suggest that the risk premia on DB pension bonds are very high for any but the lowest levels of volatility. Indeed, as volatility increases beyond the lowest level, the risk premia on DB pension bonds becomes hundreds of basis points. Risk premia are also an increasing function of d and the time to retirement. This illustrates the fact that future DB benefits are frozen in nominal terms for those who change jobs. Hence, early and mid-career employees in DB plans who have anything less than total job security may face tremendous risks to their pension wealth. Because the nominal DB benefit is frozen if they leave, participants in DB plans are at the mercy of macroeconomic forces completely beyond their control. There is no way for them to hedge this risk.

The short position on the put option in the DB pension bond portfolio is potentially very costly. Indeed, the only case where the pricing formula generates risk premia of less than 100 basis points is typically for the very lowest volatility parameter. All other parameter combinations generate risk premia greater than 100 basis points, often significantly greater. Comparing the buildup of pension wealth in this framework shows the significant risk to their retirement income security that DB plan participants face.

Conclusion

This paper has shown how the portability option reduces the risks associated with building pension wealth in a DC pension. Conversely, this paper has demonstrated how the variety of default risks associated with DB pensions increases the risks to an employee's buildup of pension wealth. Thus seemingly identical DC and DB pensions with identical benefit accrual rates and retirement income streams are in fact entirely different sources of retirement income security. The DC pension is not subject to these risks and consequently may be much more valuable.

Benefit accrual in a DB plan can be characterized as purchases of risky bonds. The methodology developed to calculate the risk premium on corporate bonds over U.S. Treasury bonds can be used to calculate the risk premium of DB pension bonds over riskless bonds held in a DC plan portfolio. The calculations suggest that the lack of portability of DB plans results in risk premia on DB pension bonds that may be hundreds of basis points.

Uncertainty with regard to the future confers significant value on the option to retain and rollover the assets in a DC plan. This option is particularly valuable for younger employees, who face the greatest uncertainty in terms of future job tenure. However, the option is also valuable for older employees. Older employees who are already vested in DB plans face significant losses of pension wealth if they change jobs, and also face the possibility that their employers may convert their DB plans to hybrid plans. Exercising the rollover option in a DC plan allows employees of all ages to continue building pension wealth, helping to secure a comfortable retirement.

References

Altman, Edward I., Naeem Hukkawala, and Vellore Kishore, *"Defaults and Returns on High-Yield Bonds: Lessons from 1999 and Outlook for 2000-2002,"* Business Economics, April 2000, pp. 27-38.

Black, Fisher, and Myron Scholes, "*The Pricing of Options and Corporate Liabilities,"* Journal of Political Economy, Vol. 81, May-June 1973, pp. 637-654.

Clark, Robert L., and Sylvester J. Schieber, *"Taking the Subsidy Out of Early Retirement: The Story Behind the Conversion to Hybrid Pensions,"* paper presented at the 2000 Pension Research Council Symposium, May 2000.

Merton, Robert C., *"On the Pricing of Corporate Debt: The Risk Structure of Interest Rates,"* Journal of Finance, Vol. 29, No. 2, May 1974, pp. 449-470.

Poterba, James M, and Mark Warshawsky, *"The Costs of Annuitizing Retirement Payouts from Individual Accounts,"* National Bureau of Economic Research Working Paper 6918, January 1999.

Zorn, Paul, 1997 Survey of State and Local Government Employee Retirement Systems, Chicago: Public Pension Coordinating Council, c/o Government Finance Officers Association, 1997.

Table 1

Impact of Job Changes on Pension Benefits in DB Plans

Amount Recovered in the Event of Default on DB Pension Bonds

Age	**Salary**	**Default**	**Non-Default**	**Ratio**
35	$ 30,000	0	$1,946	NA
45	$ 44,407	$8,881	$19,460	0.46
55	$ 65,734	$26,293	$38,921	0.68
65	$ 97,302	$58,381	$58,381	1.00

Source: Author's Calculation

Note: In the default scenario, the employee changes jobs at age 35, 45, or 55 respectively, and has their eventual DB pension benefit frozen in nominal terms at that time. In the non-default scenario the employee stays with the firm until the normal retirement age of 65.

Table 2

DB Pension Wealth Accrued by Employees who Leave the Firm Versus Employees who Stay 30 Years

Amount of Zero-Coupon Bond Wealth

Age	Salary	Default	Non-Default	Ratio
35	$ 30,000	0	$21,366	NA
45	$ 44,407	$97,513	$213,663	0.46
55	$ 65,734	$288,686	$427,325	0.68
65	$ 97,302	$640,988	$640,988	1.00

Source: Author's Calculation

Note: Pension wealth accrued in the default scenario is based on benefits accrued up to the point at which the employee leaves the firm. In the default scenario the employee leaves at age 35, 45, or 55 respectively. In the non-default scenario the amount of pension wealth accrued is based on a full DB pension valued on the basis of the employee's final aveerage salary at age 65.

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Chart 1: Risk Premia on DB Pension Bonds, 30 Years Until Retirement (hundreds of basis points)

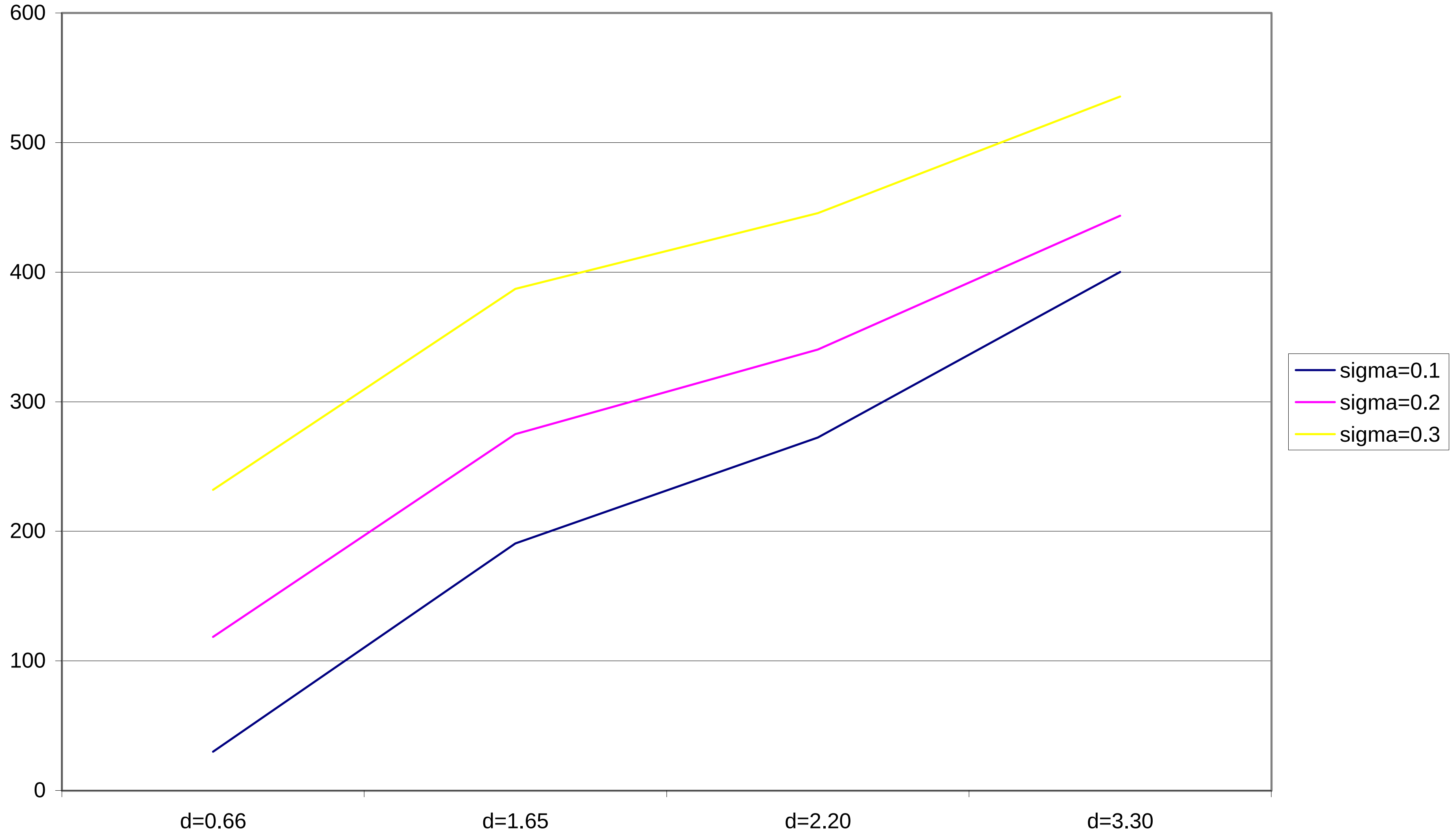


Chart 2: Risk Premia on DB Pesnion Bonds, 20 Years Until Retirement (hundreds of basis points)

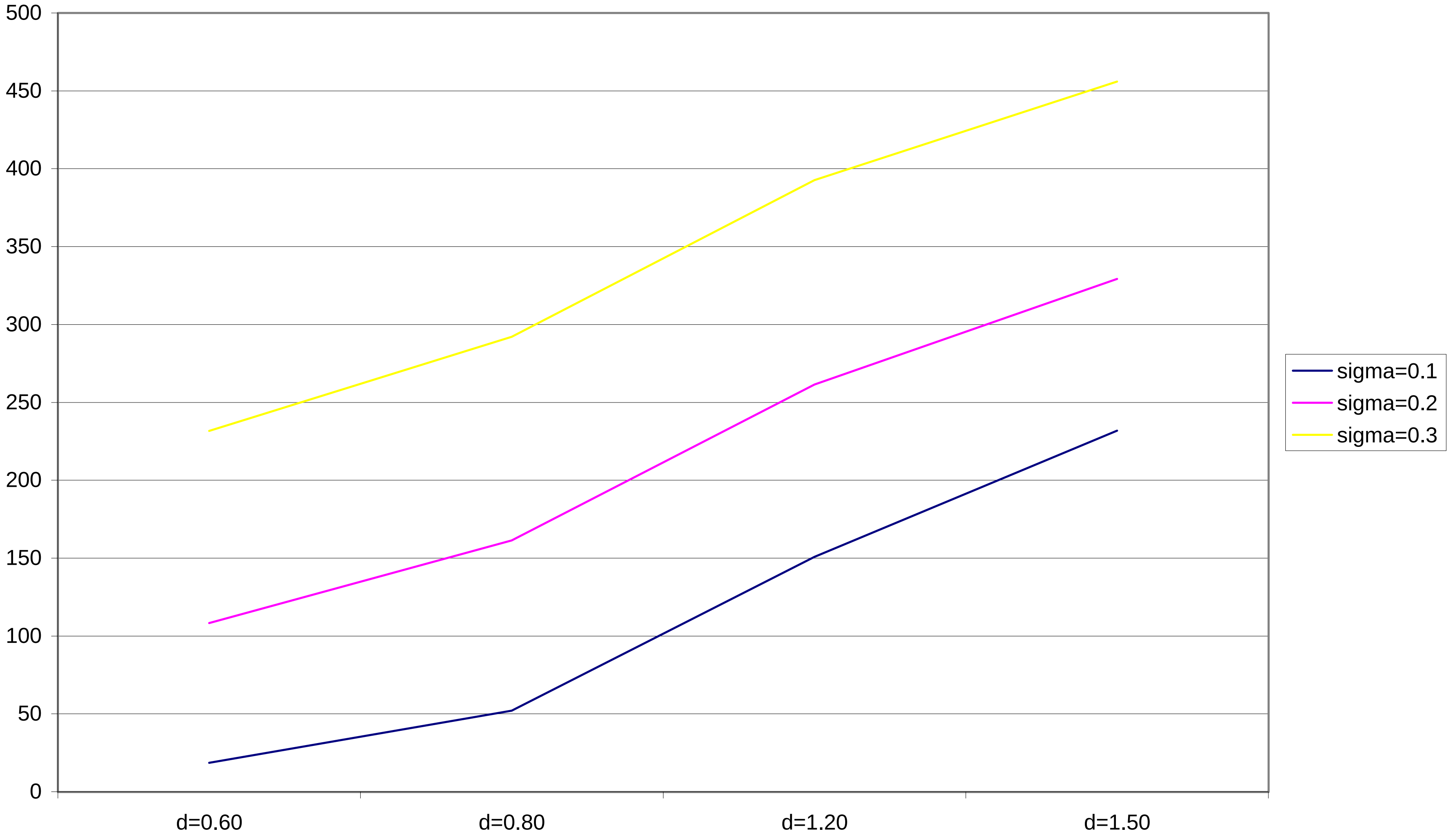
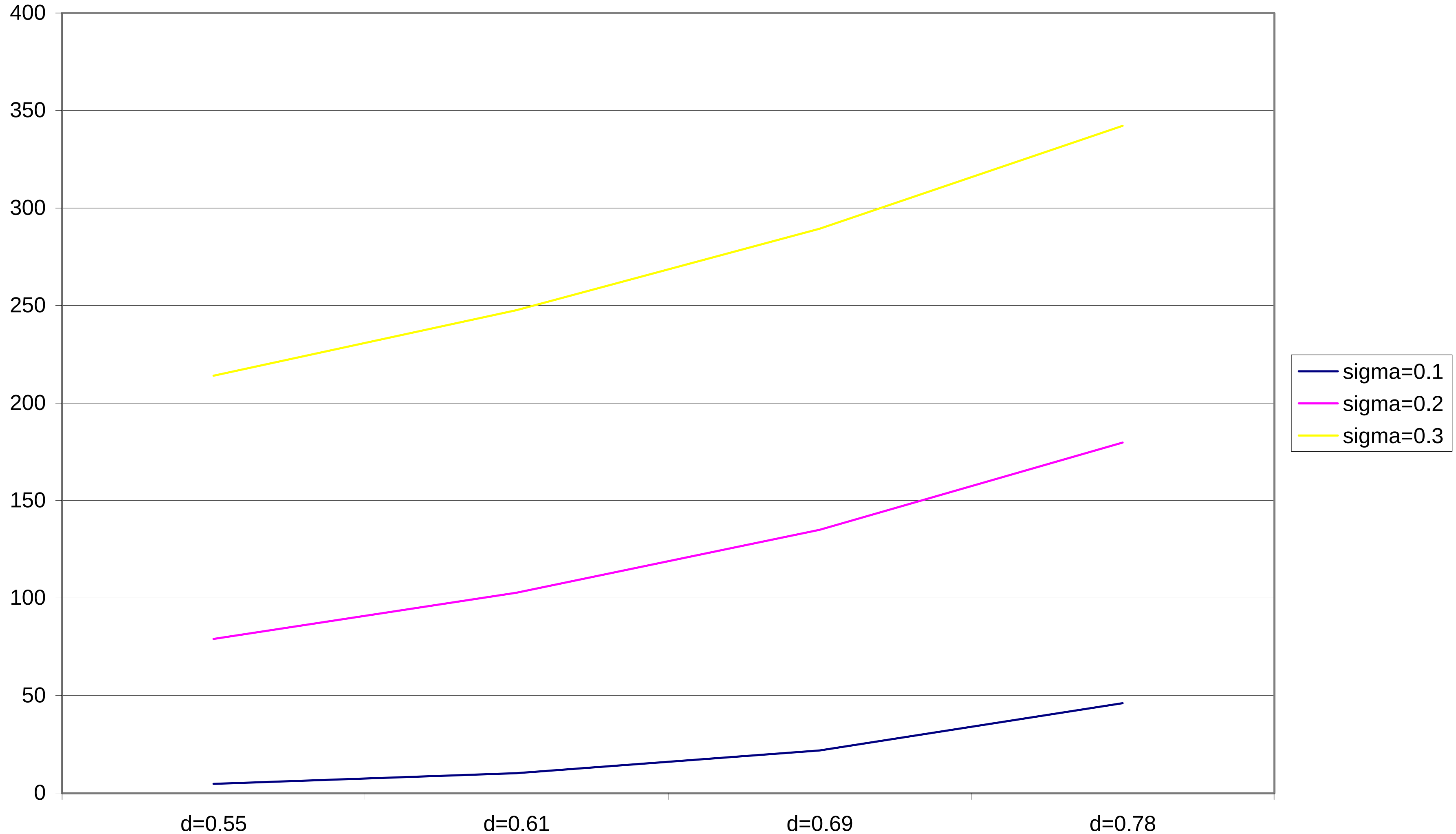


Chart 3: Risk Premia on DB Pension Bonds, 10 Years Until Retirement (hundreds of basis points)



T=30, sigma=0.3	0.0002484	0.0029853	0.0190612	0.027234	0.0400233	0.0629659
T=30, sigma=0.2	0.0050861	0.0118531	0.0275079	0.0340235	0.0443496	0.0644404
T=30, sigma=0.1	0.014609	0.0232055	0.0387082	0.0445527	0.0535505	0.0708386
T=20, sigma=0.3	0.0002644	0.0018536	0.0052113	0.015086	0.0231814	0.0287456
T=20, sigma=0.2	0.0056138	0.0108219	0.0161368	0.0261519	0.0329329	0.0374031
T=20, sigma=0.1	0.016167	0.0231753	0.0292123	0.0392748	0.0455902	0.0496294
T=10, sigma=0.3	0.0001006	0.0004716	0.0010195	0.002184	0.0046004	0.0094314
T=10, sigma=0.2	0.0048129	0.0078994	0.0102671	0.0134949	0.017967	0.0242835
T=10, sigma=0.1	0.0163716	0.0214025	0.0247641	0.0289366	0.0342143	0.0410497

30 years, sigma=0.3	2	30	191	272	400	630
30 years, sigma=0.2	51	119	275	340	443	644
30 years, sigma=0.1	146	232	387	446	536	708
20 years, sigma=0.3	3	19	52	151	232	287
20 years, sigma=0.2	56	108	161	262	329	374
20 years, sigma=0.1	162	232	292	393	456	496
10 years, sigma=0.3	1	5	10	22	46	94
10 years, sigma=0.2	48	79	103	135	180	243
10 years, sigma=0.1	164	214	248	289	342	410

sigma=0.1	30	191	272	400
sigma=0.2	119	275	340	443
sigma=0.3	232	387	446	536
	d=0.66	d=1.65	d=2.20	d=3.30
sigma=0.1	19	52	151	232
sigma=0.2	108	161	262	329
sigma=0.3	232	292	393	456
	d=0.60	d=0.80	d=1.20	d=1.50
sigma=0.1	5	10	22	46
sigma=0.2	79	103	135	180
sigma=0.3	214	248	289	342
	d=0.55	d=0.61	d=0.69	d=0.78