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5 Defined Benefit versus Defined Contribution Pension Plans: What are the Real Trade-offs?

Zvi Bodie, Alan J. Marcus, and Robert C. Merton

Although employer pension programs vary in design, they are usually classified into two broad types: defined contribution and defined benefit. These two categories are distinguished in the law under ERISA. Under a defined contribution (DC) plan each employee has an account into which the employer and, if it is a contributory plan, the employee make regular contributions. Benefit levels depend on the total contributions and investment earnings of the accumulation in the account. Often the employee has some choice regarding the type of assets in which the accumulation is invested and can easily find out what its value is at any time. Defined contribution plans are, in effect, tax-deferred savings accounts in trust for the employees, and they are by definition fully funded. They are therefore not of much concern to government regulators and are not covered by Pension Benefit Guarantee Corporation (PBGC) insurance.

In a defined benefit (DB) plan the employee's pension benefit entitlement is determined by a formula which takes into account years of service for the employer and, in most cases, wages or salary. Many defined benefit formulas also take into account the Social Security benefits to which an employee is entitled. These are the so-called integrated plans. See Merton, Bodie, and Marcus (1987) for a discussion of integration.

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DB and DC plans have significantly different characteristics with respect to the risks faced by employers and employees, the sensitivity of benefits to inflation, the flexibility of funding, and the importance of governmental supervision. Our objective in this paper is to examine the trade-offs involved in the choice between DB and DC plans.

In section 5.1, we briefly review the mechanics governing the determination and valuation of the benefit streams under DB and DC pension plans. Section 5.2 contains an informal discussion of the relative advantages of each type of plan. In section 5.3 we develop a formal model to examine the trade-offs between the two types of plans in the face of both wage and interest rate uncertainty. Our conclusion is that neither plan can be said to wholly dominate the other from the perspective of employee welfare. Section 5.4 summarizes our results and concludes the paper.

5.1 Plan Characteristics and Valuation

5.1.1 Defined Contribution Plans

The DC arrangement is the conceptually simpler retirement plan. The employer, and sometimes also the employee, make regular contributions into the employee's retirement account. The contributions are usually specified as a predetermined fraction of salary, although that fraction need not be constant over the course of a career.[1]

Contributions from both parties are tax-deductible,[2] and investment income accrues tax-free. Often the employee is given a choice as to how his account is to be invested. In principle, contributions may be invested in any security, although in practice most plans limit investment options to various bond, stock, and money-market funds. At retirement, the employee either receives a lump sum or an annuity, the size of which depends upon the accumulated value of the funds in the retirement account. The employee thus bears all of the investment risk; the retirement account is by definition fully funded, and the firm has no obligation beyond making its periodic contribution.

Valuation of the DC plan is straightforward: simply measure the market value of the assets held in the retirement account. However, as a guide for personal financial planning, the DC plan sponsor often provides workers with the indicated size of a life annuity starting at retirement age that could be purchased now with the accumulation in their account under different scenarios. The actual size of the retirement annuity will, of course, depend upon the realized investment performance of the retirement fund, the interest rate at retirement, and the ultimate wage path of the employee.

5.1.2 Defined Benefit Plans

Whereas the DC framework focuses on the *value* of the assets currently endowing a retirement account, the DB plan focuses on the *flow* of benefits which the individual will receive upon retirement.

A typical DB plan determines the employee's benefit as a function of both years of service and wage history. As a representative plan, consider one in which the employee receives 1 percent of average salary (during the last 5 years of service) times the number of years of service. Normal retirement age is 65, there are no early retirement options, death or disability benefits, and no Social Security offset provisions. The actuarially expected life span at retirement is 80 years.

Assuming the worker is fully vested, at any point in time his claim is a deferred nominal life annuity, insured up to certain limits by the Pension Benefit Guarantee Corporation. It is a deferred annuity because the employee cannot start receiving benefits until he reaches age 65. It is nominal because the retirement benefit, which the employer is contractually bound to pay the employee, is fixed in dollar amount at any point in time up to and including retirement age.

Many people think that under final average pay plans of the sort described here, retirement benefits are implicitly indexed to inflation, at least during the employee's active years with the firm, and therefore should not be viewed as a purely nominal asset by the employee and a purely nominal liability by the firm. We examine this issue in detail in section 5.2. For now we focus on the value of the explicit claim only.

Given an interest rate and a wage profile, it is straightforward to compute the present value of accrued benefits under our prototype DB plan. Table 5.1 presents such values for workers at different ages assuming a constant real annual wage of $15,000. The present value of accrued liabilities can increase from continued service because of 3 factors: (1) as years of service increase, so does the defined benefit, (2) if the wage increases, so will the retirement benefit, and (3) as time passes, less time remains until the retirement benefits begin, so that their present value increases at the rate of interest.

To illustrate the separate contributions of each of these factors to the cumulative results reported in table 5.1, consider the case in which the benefit formula calls for 1 percent of final year's salary times years of service and that the worker lives for 15 years after retiring at age 65. The worker is 35 years old, has worked for the firm 10 years, and his current salary is $15,000. The nominal interest rate equals a real rate of 3 percent per year plus the expected rate of inflation.

Under the 7 percent inflation scenario, the sources of the change in the value of the pension benefit from the passage of an additional year are as follows. Prior to this year, the worker had accrued a life annuity

Table 5.1 **Present Value of Accrued Benefits and Marginal Change in Benefits for Hypothetical Worker, No Early Retirement**

Starting Age 25	Present Value of Accrued Benefits in Constant Dollars		Marginal Change in Present Value of Accrued Benefits from an Additional Year's Work			
	0% Inflation 3% Discount Rate	7% Inflation 10% Discount Rate	0% Inflation 3% Discount Rate		7% Inflation 10% Discount Rate	
Current Age			Constant Dollars	% of Salary	Constant Dollars	% of Salary
30	$2,274	$144	$455	3.03	$41	.27
35	$5,271	$463	$527	3.51	$82	.55
40	$9,167	$1,120	$611	4.07	$158	1.05
45	$14,169	$2,404	$708	4.72	$297	1.98
50	$20,532	$4,840	$821	5.47	$546	3.64
55	$28,563	$9,354	$952	6.35	$938	6.25
60	$38,631	$17,575	$1,104	7.36	$1,768	11.79
65	$51,181	$32,329	$1,242*	8.28	$2,794*	18.63

NOTES: Worker currently paid $15,000 per year with no real wage growth.
Worker will retire at age 65.
Pension plan pays 1 percent of average salary in last 5 years times years of service.
Pension plan contains no early retirement provisions or makes correct actuarial adjustment for early retirees.
Benefits are vested after 5 years.
Real interest rate is 3 percent, nominal rate increases one for one with inflation.
*Value calculated for age 64 rather than age 65.
SOURCE: Adapted from Ellwood (1985).

of $1,500 per year (1 percent × 10 years × $15,000) beginning at age 65. With a nominal interest rate of 10% per year, the present value (PV) of this deferred annuity at age 35 is $654. The increase in pension benefits as a result of working an additional year can be broken into three parts:

Factor 1: One additional year of service at a salary of $16,050 ($15,000 × 1.07) entitles him to an additional deferred annuity of $160.50 per year, and

Factor 2: The salary increase of $1050 entitles him to an additional deferred annuity of $105 per year (1 percent × 10 years × $1,050).

The PV of these additional accrued benefits from factors 1 and 2 at the end of the year is $127. This represents the nominal value of the newly earned pension benefits, which is an annuity of $265.50 per year starting at retirement.

Factor 3: The PV of his previously accrued benefits increases by 10 percent from $654 to $719.40 because the date of their eventual receipt has drawn one year closer.

As a result of all three factors, the nominal value of his pension wealth increases from $654 to $846 and its real value to $791.

Now let us refer to table 5.1 to see how these factors manifest themselves in the time pattern of benefit accrual in the no-inflation and in the 7 percent inflation scenarios. The right-hand panel shows the constant dollar present value of benefits attributable to continued work with the same employer; these benefits are represented by factors 1 and 2 only. In the no-inflation case, there is no salary growth and hence only factor 1 is at work. For each additional year of service an additional deferred annuity of $150 per year is earned. Note, however, that the value of the incremental benefits earned at each age increases with age, from $455 (3.03 percent of salary) at age 30 to $1,242 (8.28 percent of salary) at age 64. This is a reflection of the fact that the additional $150 per year deferred life annuity has a higher PV the closer the employee is to age 65. The accrual of benefits under a DB plan is thus inherently "backloaded."

For a fixed real interest rate, this backloading effect is much more pronounced in the 7 percent inflation scenario because of the impact of inflation on the nominal interest rate. In this case the constant-dollar value of additional pension benefits earned increases from $41 (.27 percent of salary) at age 30 to $2,794 (18.63 percent of salary) at age 64. In contrast, backloading or frontloading in DC plans is independent of inflation as well as interest rates.[3] This is because employers can achieve any backloading pattern by simply choosing an appropriate pattern of contribution rates over the course of the employee's career. The left-hand panel of table 5.1 illustrates the effect of inflation on the

PV of total accumulated pension benefits under the DB plan assuming no real salary growth.

5.1.3 Funding

As mentioned before, DC plans are by their nature fully funded, that is, the market value of the plan's assets equals the liability of the sponsor to the plan's beneficiaries. In sharp contrast, the calculation of the funding status of DB plans is complex and controversial. If the plan's assets are invested in traded securities, their market value is relatively easy to ascertain. The source of difficulty is in measuring the sponsor's liability.

From a strictly legal point of view the sponsor's liability is the present value of the accrued vested benefits which would be payable if the plan were immediately terminated. But many pension experts contend that sponsors have an implicit semicontractual obligation which makes it more appropriate to take account of projected future salary growth in the computation of the firm's pension liability. The contention of a further obligation beyond the legal one makes it unclear whether a real or nominal interest rate should be used in discounting future benefits (either with or without salary growth projections) to compute their present value. To evaluate the strict obligation of the sponsor, the DB liabilities could be determined by deriving the cost of an immunized or dedicated bond portfolio using current market prices. While clearly superior to a simple interest rate assumption, this valuation procedure is itself only an approximation because the payment dates of pension liabilities typically extend far beyond the maturity range that is rich enough to extract our discount bond prices from traded coupon bonds. Hence, an exact bond-dedication scheme is not feasible. Immunization techniques that rely on duration measures are not wholly reliable because duration measures are sensitive to the specification of term structure dynamics. (See Bierwag 1977, Bierwag and Kaufman 1977, and Cox, Ingersoll, and Ross 1979). Beyond the term structure, the default risk associated with partially funded pension obligations adds the further problem of choosing equivalent-risk bonds from the securities market.

For the past several years the Financial Accounting Standard Board (FASB) has been grappling with these issues, trying to establish a uniform set of valuation standards for firms to use in their financial statements.

The government guarantees, up to a limit, employer pension benefits through the PBGC. The valuation of guaranteed benefits therefore should utilize the riskless-in-terms-of-default interest rate. However, in practice, only 80 percent of accrued benefits is vested while only 90–95 percent of vested benefits is guaranteed so that roughly one-quarter of accrued benefits is not guaranteed (Amoroso 1982). Thus, the funding status of a plan is important to employees as well as to the PBGC. In effect, adequate funding protects accrued-but-not-yet-vested benefits. See Marcus (1987) for an analysis of PBGC insurance and corporate funding policy.

5.2 Trade-Offs

Our original belief was that defined contribution plans would necessarily dominate defined benefit plans because of the flexibility of DC plan design. We would have guessed that anything that could be accomplished with a DB plan could be replicated in a cleverly constructed DC plan. However, this belief is not borne out. DB plans create implicit securities that can be welfare improving and that are neither currently available in capital markets, nor likely to be created in capital markets in the future. Some examples of these "securities" are factor-share claims, price-indexed claims, and perhaps deferred life annuities at fair interest rates.

Moreover, some of the "real-world" complications in plan design, such as incentive effects, tend to favor DB over DC plans. Thus, the optimal plan design is likely to be firm specific. At this point, all we can do is enumerate the relative advantages of each plan type and describe the circumstances in which one plan might dominate.

5.2.1 Investment Performance and Choice

The most obvious source of risk to an employee in the DC plan is the investment performance of the fund. However, this source of uncertainty can be controlled. For example, the periodic contributions of the DC plan could, in principle, be used to purchase deferred annuities which would generate retirement income streams similar to those provided by DB plans. Alternatively, it is feasible for the plan to select an investment strategy with low variance rates of *real* returns. Bodie (1980) has shown that commodity futures can be added to portfolios to successfully provide an effective hedge against inflation. Therefore, in either nominal or real terms, DC plans do not necessarily impose substantial risk on participants, given the availability of low-variance investment strategies.

There are, however, no strong *a priori* reasons to believe that most individuals would choose to invest accumulated DC funds in the lowest risk asset. DC plans typically offer sufficient flexibility to select a risk-return strategy suited to the employee's individual preferences and circumstances. In contrast, DB plans force individuals to accumulate the pension portion of retirement saving in the form of deferred life annuities and thus limit the risk-return choice.

5.2.2 Accrual Patterns

As noted and illustrated in table 5.1, DB plans are inherently backloaded. DC plans can be backloaded too by choosing a contribution rate that rises with a worker's age and tenure.[4] Therefore, the salient inherent difference in accrual patterns between the two plan designs is that DB backloading is stochastic in the sense that real benefit accruals depend upon the rate of wage inflation. This seems to us an avoidable source of uncertainty which both parties (employer and employee) might benefit by shedding. On this score, DC plans would appear to be superior, although implicit contracting to provide employees with a protective "wage floor" (cf. Diamond and Mirrlees 1985) can be implemented more effectively with DB-type plans.

5.2.3 Termination and Portability

It is commonly asserted that considerations of portability favor DC plans. The typical justification is that the worker in a DB plan who leaves his job for reasons beyond his control forfeits future indexation of benefits already accrued. It is further asserted that there are implicit contracts between employees and firms which require larger total compensation (wage plus pension accrual) for more highly tenured workers. Hence, termination of employment causes a forfeiture of the ability to work for advantageous total compensation rates (and, in particular, indexation of total pension accruals). Under this line of reasoning, DC plans are more portable.

It should be realized, however, that the portability issue is intimately tied to the accrual pattern. For DC plans with contribution rates tied to tenure as well as age, the penalty to early termination can be as great as for any DB plan. In practice, however, contribution rates for DC plans are rarely tied to tenure and are usually not as heavily backloaded as DB plans. Therefore, in practice it would appear that portability considerations do favor DC plans over DB plans.

5.2.4 Incentives

Pension benefits in DC plans depend upon the wage trajectory over the worker's entire career. In contrast, benefits in most DB plans depend on final average salary. For this reason, workers in DB plans should have a greater incentive to sustain a high level of effort over the entire career in order to achieve a high career-end salary. Final salary has greater leverage in DB plans because of its greater effect on pension benefits.

In conclusion, it seems that there is a trade-off between the goals of portability and incentives. Portability dictates low backloading, while incentives require high backloading. While DC plans opt in practice for lower backloading than DB plans, this pattern is not an inherent property of the two plans.

5.2.5 Informational Economies in Plan Design and Implementation

Retirement income planning is one of the most complex areas of personal finance. Many employees would consider it a service to have their employer define and provide an adequate level of savings for them. Since retirement-income goals are typically defined as percentage replacement rates of salary, the benefits of DB plans which are defined in exactly those terms are easier to interpret.

One could in principle achieve the goal of a specific replacement rate with a DC plan of the so-called target benefit type. Under these plans, the contribution rate is adjusted periodically to achieve the target replacement rate, taking into account the discrepancy between actual and assumed investment return. However, such plans are rare.

5.2.6 Wage-Path Risk

The pegging of benefits in DB plans to final average wage would appear to provide employees with a type of income-maintenance insurance not available in DC plans. This observation has been used to support the selection of these plans over DC plans. This conclusion is, however, not robust. If wage paths are unpredictable at the start of a career, then individuals may view it as very risky to have their retirement benefits depend so heavily on final salary. Indeed, employees might prefer a retirement benefit tied to (inflation-adjusted) career-average earnings so as to eliminate excessive dependence on the realized wage in the final years of employment. This time-averaging feature is achieved by a DC plan because benefits will depend on the contribution in each year of service, rather than on a final wage formula. Although inflation-adjusted career-average DB plans would achieve the same goal, in practice these plans are quite rare. In fact, the only major DB plan that pays a benefit computed in such a fashion is the Social Security system. We pursue this issue further in the analysis in section 5.3.

5.2.7 Interest-Rate Risk

As noted earlier, one major source of uncertainty in DC plans concerns the terms under which the stock of retirement wealth can be transformed into a flow of retirement income. DB plans, by offering life annuities, effectively guarantee the interest rate at retirement. It should be noted, however, that without indexation of benefits, this is a guarantee of the nominal rather than the real interest rate. The value to the employee of a nominal-rate guarantee is questionable when inflation over a 10- or 20-year period can be highly unpredictable.

In principle, DC plans can offer at retirement the same nominal interest rate guarantee through the purchase of deferred life annuities as a DB plan. However, in practice, with the notable exception of the Teacher's Insurance and Annuity Association (TIAA), the capitalization rates used to compute benefits in the private annuity market are far below the interest rates available in competitive financial markets. This discrepancy is often attributed to an adverse selection problem and discourages participation in the annuity market by unhealthy individuals.[5] The adverse selection issue is largely avoided in DB plans because workers are precommitted to participation regardless of health status.

5.3 A Model of Wage and Interest Rate Uncertainty

In this section we develop a model to focus on the twin issues of wage and interest rate uncertainty using stylized versions of DB and DC plans. We find that the putative replacement rate advantages of DB plans are not supported by our model, and that the interest rate guarantee is only partially supported: specifically, DB plans do offer welfare-improving opportunities with respect to postretirement interest rate uncertainty, but *not* with respect to preretirement uncertainty.

For the most part, we will concentrate on individual welfare in a model in which all wage uncertainty is employee-specific and, from the firm's perspective, is perfectly diversifiable. This framework is at a polar extreme from Merton's (1983) model of Social Security, in which all uncertainty regarding marginal product derives from uncertainty in the aggregate production function, with no individual-specific effects. In Merton's framework, labor-income uncertainty is perfectly correlated across individuals, and in such an environment, DB plans may offer superior risk-sharing properties that are not captured in our model. Although our model focuses exclusively on uncertainty at the individual worker's level and interest rate risk, we will discuss further the implications of Merton's model for our results. As indicated earlier, interest rate uncertainty emerges as a central determinant of the relative advantages of DB versus DC plans.

5.3.1 Pension Plan Design

We consider a 3-period model in which the individual works in periods 0 and 1 and is retired in period 2. Current wage, W_0 is known, while period-1 wage, W_1, is uncertain until $t = 1$. For simplicity, we will assume that the time 0 expectation of W_1 is W_0. Trends in wage paths could easily be incorporated into the analysis, but would simply clutter the algebra; hence we ignore such trends. Wages are measured in real dollars as of time 0.

Consumption occurs at three points: $t = 0, 1, 2$. A pension benefit, P, is paid at $t = 2$. The real interest rate prevailing between $t = (0, 1)$ is denoted r_0, and is known at time 0. The real rate between $t = (1, 2)$ is r_1 and is not known until time 1. Finally, we assume that individuals have initial nonhuman wealth of A_0. The timing assumptions of the model are presented in figure 5.1.

If financial markets were complete, then, of course, the choice of pension plan would be irrelevant because the employee could use securities to trade to an optimal position. There are two important deviations from complete markets that make pension design crucial from the employee's perspective. First, there are neither markets in which wage uncertainty can be insured, nor ones in which claims to future wages can be sold. This feature of our model precludes employee-initiated risk pooling. Second, because of adverse selection problems, the market for deferred life annuities is assumed to be closed. Although such markets do in fact exist, as discussed, the rates of return typically offered are so low as to discourage widespread participation. In our model, the absence of such annuities will be captured by not allowing individuals to invest at $t = 0$ in two-period bonds which pay specified returns during the retirement period, $t = 2$.

The goal of the firm is to offer a pension plan that maximizes the utility of a "typical" worker, subject to the constraint that all pension plans considered have equal present value of costs to the firm. Subject to the firm's indifference condition, we compare the utility value of DB versus DC plans.

In DB plans, firms typically promise workers a prespecified fraction of career-end wages, possibly averaged over the last several years of working life, and this is the type of plan we model. We will assume that the pension benefit at $t = 2$ equals W_1, so that expected income in each period of life is equal. We assume further that pension benefits are explicitly linked to the price level. While this practice is uncommon in the private sector in the United States, it is true of Social Security and it serves as a useful base case from which to analyze the potential efficacy of competing pension designs.

0	1	2	Time
X ----------------------	X ----------------------	X	
W_0	W_1	P	Income
C_0	C_1	C_2	Consumption
A_0	A_1	A_2	Financial Wealth
----------r_0----------	----------r_1----------		Interest Rate

Fig. 5.1 Timing Assumptions

The present value at $t = 0$ of the firm's time-2 pension obligations is

$$\text{PVDB} = E(W_1)B(0, 2), \tag{1}$$

where $B(0, 2)$ is the present value at $t = 0$ of a claim to an expected payoff of \$1 at $t = 2$, with an uncertainty equivalent to that of the wage distribution. If wage uncertainty were completely diversifiable, then $B(0, 2)$ would equal the present value of a certain dollar to be received in two periods; $B(t, T)$ would be the discount function at t for payments at T. However, for the moment, we will not restrict the nature of wage uncertainty.

In contrast to DB plans, DC plans require firms to contribute a prespecified fraction of wages into the worker's retirement saving account each period. For simplicity we will assume that explicit wages paid in each period are the same for each type of pension plan provided. Hence, the indifference condition for the firm is that the present value of periodic contributions into the DC plan equals the present value of the DB commitment. The prespecified (at $t = 0$) DC contribution schedule is set at time 0 and therefore can depend only on observed variables at $t = 0$. While the contribution rates may depend on expectations of future interest rates, they cannot be updated *ex post facto* to reflect realizations of interest rates or any other factor.

There is an infinite number of DC contribution schedules which have the same PV. Among these, we will select the one which has the same timing pattern as the PV of accruing benefits under the DB plan.

The contribution schedule, k_t, as a fraction of wages is given by:

$$\begin{aligned} k_0 &= \frac{1}{2}B(0, 2); & t &= 0, \\ k_1 &= \frac{1}{2}B(0, 2)/B(0, 1); & t &= 1. \end{aligned} \tag{2}$$

The present value at $t = 0$ of the DC plan contribution equals

$$\begin{aligned} \text{PVDC} &= k_0 W_0 + k_1 E_0(W_1)B(0, 1) \\ &= \frac{1}{2}W_0 B(0, 2) + \frac{1}{2}E_0(W_1)B(0, 2). \end{aligned}$$

Since $E_0(W_1) = W_0$, the present values of the firm's contributions in the DB and DC plans are equal.

Notice that since $B(0, 1)$ is less than 1, the DC plan as specified above embodies some backloading. In fact, any degree of prespecified backloading may be built into the DC plan simply by changing the coefficients in equation (2) from their values of 1/2. Any coefficient pair for

k_1 and k_2 that sums to 1 will ensure that the present value of the DC plan equals the present value of the DB plan.

The pension benefit in the DC plan will accumulate at $t = 2$ to a value that depends on the investment experience of the plan. Call the rate of return on the pension portfolio in each period z_t and let $Z_t = 1 + z_t$. Then the pension benefit paid at $t = 2$ in the DC plan will be

$$P_{DC} = \frac{1}{2}B(0, 2)W_0Z_0Z_1 + \frac{1}{2}[B(0, 2)/B(0, 1)W_1Z_1, \tag{3}$$

whereas in the DB plan,

$$P_{DB} = W_1. \tag{4}$$

Notice that there is no assurance, or even likelihood, that the expected pension benefits will be equal across the two plans, despite the fact that the ex ante present values are equal.

5.3.2 Welfare Analysis

Pension benefits are subject to uncertainty from both stochastic wage paths and stochastic investment returns. Rather than consider these effects jointly, we will examine polar cases in which one or the other source of uncertainty dominates.

Wage Uncertainty

Consider first the case in which all investment returns can be made certain by investing pension assets in default-free bonds. Therefore both r_0 *and* r_1 are known at $t = 0$. Moreover, suppose for the moment, that all wage uncertainty is perfectly diversifiable to the firm, so that $B(t, T)$ is simply the discount function for riskless future cash flows. Under these hypotheses,

$$Z_0 = 1 + r_0 = R_0 \text{ and } z_1 = 1 + r_1 = R_1.$$

Further, with no uncertainty regarding the evolution of future interest rates, $B(0, 1) = 1/R_0$ and $B(0, 2) = 1/R_0R_1$. Thus, equation (3) reduces to

$$P_{DC} = \frac{1}{2}(W_0 + W_1). \tag{3'}$$

In this simple case, it is clear that the DC plan must dominate the DB plan for any risk-averse utility function. With $E_0(W_1) = W_0$, both plans have equal expected benefits, while the DC plan imposes less uncertainty on participants because of the "wage averaging" embodied in equation (3′). Essentially the only uncertainty in this case derives from W_1. The DC plan allows for limited risk pooling of wage uncertainty through the firm (and ultimately the stock market), while the DB plan allows for none. This advantage of DC plans may be thought of as a pure efficiency gain.

The advantage of DC plans in the wage-uncertainty-only scenario does not hinge solely on the diversifiability of wage risk. Suppose that final wage is highly correlated with some marketable security, such as the value of the stock of the firm or the value of a broad market index. In this case, the DB plan implicitly forces the participant to invest a large fraction of wealth in this asset, since the pension benefit essentially duplicates the payoff to the asset. In contrast, the DC plan allows the participant to take the pension contribution each period and invest it in any security. In essence, the DC plan allows participants to get their money out of the (over)investment in W_1 and achieve superior portfolio diversification. This advantage of DC plans is incremental to the pure efficiency gain from the risk pooling opportunity that was noted above.

Interest Rate Uncertainty

In this section, we will assume that wage paths are either given or uncorrelated with the interest rate, and that the only investment vehicles are bonds. However, the future path of interest rates is not known at the time the pension contract is established. Because wages pose no systematic risk, $B(t, T)$ is simply the riskless discount function, and $B(0, 1) = 1/R_0$.

As in Merton (1983), we will assume that the lifetime utility function for the individual at time 0 is

$$U_0 = \log(C_0) + E_0[\log(C_1) + \log(C_2)]. \tag{5}$$

At time 1, all uncertainty is resolved since both W_1 and R_1 (and hence P) are known. Lifetime utility at $t = 1$ is thus

$$U_1 = \log(C_1) + \log(C_2),$$

and at $t = 2$ is

$$U_2 = \log(C_2).$$

Upon arriving at $t = 2$, the individual will consume all of his financial wealth, plus all pension benefits:

$$C_2 = (A_1 + W_1 - C_1)R_1 + P. \tag{6}$$

Thus, at $t = 1$, the optimization problem is

$$\max[\log(C_1) + \log(C_2)],$$

which results in the first-order condition

$$C_1 - C_2/R_1 = 0. \tag{7}$$

Using equation (6), equation (7) can be solved to yield

(8)
$$C_1^* = (A_1 + W_1 + P/R_1)/2,$$
$$C_2^* = R_1C_1^*.$$

Using the expressions for P from equations (3) and (4), we find that

(8-DB) $$C_1^{DB} = (A_1 + W_1 + W_1/R_1)/2,$$

while

(8-DC) $$C_1^{DC} = [A_1 + W_1 + (1/2)(W_0 + W_1)B(0, 2)R_0]/2.$$

As expected, the difference between equations (8-DC) and (8-DB) reflects the "wage diversification" attribute of DC plans, in that consumption depends upon a weighted sum of earnings over the entire career. A perhaps surprising feature of equations (8) is that consumption for individuals in DC plans is not a function of the realized interest rate, R_1, although it is for individuals in DB plans. This is true despite the fact that retirement *wealth* is subject to interest rate risk for DC plans, but not for DB plans.

This feature of the model turns out to be an artifact of the log utility function, but nevertheless highlights an important feature of DB versus DC plan design. Recall the first-order condition (7) for optimal consumption allocation across times 1 and 2, which requires that time-2 consumption be R_1 times time-1 consumption. For an individual in a DC plan, all wealth already is held and can be invested at rate R_1 at $t = 1$. Thus, the simple rule is to consume one-half of wealth at $t = 1$, invest the remainder, and thus consume R_1 times one-half of wealth at $t = 2$. Consumption at $t = 1$ is thus *independent* of R_1. In contrast, in a DB plan, the pension benefit to be received at $t = 2$ already is fixed at $t = 1$. Thus, a large value of R_1 requires a decrease in $t = 1$ consumption in order to satisfy the first-order condition for an optimum. Another way of seeing this is to note that, for the log utility function, consumption at $t = 1$ depends *only* on wealth, not on the interest rate. For DC plans, wealth at $t = 1$ is independent of R_1, since all assets are already in hand. For DB plans, pension benefits are still deferred at $t = 1$, and wealth depends on R_1.

For more general utility functions, consumption at $t = 1$ depends on both wealth *and* R_1. However, DC plans still offer a type of consumption smoothing that is not offered by DB plans. Specifically, the generalized first-order condition at $t = 1$ requires that the ratio of the marginal utility of consumption at $t = 1$ to that at $t = 2$ equals R_1. A larger R_1 thus induces more time-2 consumption. This can be attained with less (or no) sacrifice of current consumption when assets are already in hand since assets currently invested can earn the higher rate of interest. In DB plans, in contrast, there is no offset between income and substitution effects. A larger R_1 *decreases* pension wealth and, simultaneously, requires a reallocation of consumption to the retirement period, $t = 2$. Thus, the consumption stream in DC plans is less sensitive to the interest rate during the accumulation phase, and indeed, in the log utility case, is actually independent of the realization of the interest rate.

Using equations (8), we may now compute the derived or indirect utility function at $t = 1$:

$$\text{(9-DB)} \quad J_{\mathrm{DB}}(A_1, W_1, t = 1) = \log(C_1^*) + \log(C_2^*)$$
$$= 2 \log[1/2(A_1 + W_1 + W_1/R_1)]$$
$$+ \log(R_1);$$

$$\text{(9-DC)} \quad J_{\mathrm{DC}}(A_1, W_1, t = 1) = 2 \log\{1/2[A_1 + W_1 + W'B(0, 2)R_0]\}$$
$$+ \log(R_1);$$

where $W' = (W_0 + W_1)/2$, that is, career-average earnings.

As a base case to compare equations (9), consider the situation in which the expectations hypothesis for the term structure of interest rates holds. Then $B(0, 2) = (1/R_0)E_0(1/R_1)$. In this instance, with $E_0(W') = W_0$ and W_1 uncorrelated with R_1, the expectations of the arguments of the log terms in equations (9) are equal. However, the argument of the log term in (9-DC) is subject to less uncertainty (as of $t = 0$) than in (9-DB). This is due to both the wage diversification embodied in the DC plan and the interest rate risk that appears only in the DB plan.

Using equations (9), we may obtain the derived utility function at $t = 0$:

$$\text{(10)} \quad J(A_0, W_0, t = 0) = \max\{\log(C_0) + E_0\,[J(A_1, W_1, t = 1)]\}.$$

From equation (10), it is easy to show that time-0 utility is higher in the DC plan (still assuming that the expectations hypothesis holds). Consider the optimizing value of time-0 consumption under the DB plan. This consumption choice is also feasible in the DC plan and will result in an identical value for A_1. However, for any given A_1, $E_0[J(A_1, W_1, t = 1)]$ is greater in the DC plan. This last point follows from the equal expected values of the arguments of the log function in equations (9), the greater dispersion of the argument in the DB plan, and the concavity of the log function. Because DC plans offer greater welfare than DB plans at consumption levels that are optimal for DB plans, they must do so *a fortiori* when C_0 is chosen to be optimal for the DC environment.

For the DB plan to dominate the DC plan, it would be necessary for it to offer a *greater* expected pension benefit at $t = 2$. This would require that $B(0, 2)$ be less than $E_0(1/R_0R_1)$, that is, that there be a positive liquidity or risk premium for investing in long-term bonds rather than rolling over shorts.

At this point, it is worth reconsidering the assumptions of our model. It should be apparent that the zero expected growth rate of real wages is not essential to the argument. Our analysis would have been similar even with a positive trend in real wages. The only major modification would involve an adjustment for the fact that a DB plan with a 100 percent replacement rate of final salary would promise retirement-period income greater than career-average wages. The per period contributions to the retirement fund in the equal-present-value DC plan would thus need to be correspondingly increased. In the nomenclature of equation (2), the sum of k_1 and k_2 would need to exceed 1.0. However, aside from this adjustment, the analysis would be similar.

The issue of interest rate uncertainty during the retirement period is more difficult and poses issues not easily treated in the above model. In our 3-period model, the individual simply consumes total retirement wealth in the last period. If, however, retirement itself is viewed as a many-period interval, then real retirement *income* and not *wealth* may be the significant determinant of welfare. Given a stock of wealth at retirement, the real consumption stream that is feasible for the retiree depends on the real long-term interest rate at the time of retirement, when the purchase of a (real) life annuity is contemplated. Even if retirement wealth can be predicted fairly precisely with a low-investment-risk DC retirement fund, the real income stream that can be generated by that wealth is subject to considerable uncertainty.[6] In contrast, by guaranteeing a specified income (and hence, consumption) stream upon retirement, the (price-level-indexed) DB plan eliminates the risk associated with the conversion, at retirement, of a stock of retirement wealth into a flow of equivalent-present-value consumption. DC plans cannot offer a guaranteed capitalization rate at retirement because of our assumption that life annuities and bonds of long- enough maturity do not exist.

In order to examine some potential effects of uncertainty in the interest rate at retirement, we will consider a simple adjustment to our model. Suppose that at $t = 2$, the financial assets of individuals are multiplied by some increasing function of R_2, $f(R_2)$, where R_2 equals one plus the postretirement rate of interest. The multiplication by $f(R_2)$ reflects the increased retirement-income stream that is available to DC participants when interest rates at retirement turn out to be high. In contrast, for DB plans, the retirement-income stream is guaranteed by the firm so that interest-rate risk is not borne by plan participants.

Reconsider now the optimal consumption program for DC plan participants. At $t = 2$,

$$C_2 = [(A_1 + W_1 - C_1)R_1 + P_{DC}]f(R_2), \tag{11}$$

which now is stochastic at $t = 1$ because of the dependence on R_2. Thus, at $t = 1$, the maximization problem becomes

$$\max \log(C_1) + E_1[\log(C_2)],$$

which has first-order condition

$$\frac{1}{C_1} - E\left[\frac{1}{C_2} R_1 f(R_2)\right] = 0. \tag{12}$$

But examination of equations (11) and (12) shows that $f(R_2)$ drops out of the first-order conditions so that (12) results in exactly the same consumption level at $t = 1$ as in the nonstochastic R_2 model. Lifetime utility, however, may change. For example, for an actuarially fair $f(R_2)$ adjustment, such as $f(R_2 = R_2/E_1(R_2)$,[7] consumption at $t = 1$ is unchanged, while consumption at $t = 2$ has the same expected value as in the previous model, but greater uncertainty. In this case, expected time-2 utility falls. If time-2 interest rate uncertainty is sufficiently great relative to wage and time-1 interest rate uncertainty, DC plans could become inferior to DB plans from the viewpoint of plan participants. Thus, retirement-period interest rate uncertainty emerges as a potential advantage of DB relative to DC plans.

5.3.3 Factor-Share Uncertainty

Merton (1983) has examined a model in which labor-income uncertainty derives entirely from an aggregate production function in which income shares accruing to capital and labor are stochastically determined. In contrast to the model above, in which labor-income uncertainty is diversifiable, in Merton's model labor income is perfectly correlated across individuals. Given the nontradeability of human capital, economic inefficiencies arise in this economy, since early in life, individuals hold too much of their wealth in human capital relative to physical capital, while at retirement all wealth is invested in physical capital. These portfolio imbalances preclude optimal sharing of factor-share risk. Merton suggests that a Social Security system which pays retirees a share of current wage income implicitly provides diversification across factor shares and can increase welfare by improving the efficiency of risk bearing in the economy.

A similar argument can be made with regard to DB versus DC plans. In a DC plan, the income of a retired individual depends solely on investment performance and is independent of retirement-period uncertainty in factor shares. Retirees thus have no stake in labor income during their retirement period. In a DB plan, retirement income is also determined upon retirement. However, if factor-share uncertainty is primarily attributable to unforeseeable long-term secular trends (rather than to transitory business-cycle effects) then a final-salary DB plan may provide risk-sharing benefits similar to Merton's Social Security scheme. Such secular uncertainty could arise, for example, from unanticipated changes in labor-augmenting technical progress.

Since the pension benefit under the DB plan is tied to final salary, individuals participating in such a scheme are invested in an implicit security that is tied to the wage share in the neighborhood of the retirement period. To the extent that firms offer ad hoc increases in pension benefits when wages of current employees increase, the retiree's stake in aggregate labor income is further enhanced. Of course DC plan benefits also depend to some extent on end-of-career earnings. However, the career averaging properties of DC plans greatly reduce the magnitude of this dependence. Thus, if labor-income uncertainty is predominantly dependent on economy-wide factors, then this source of risk would favor DB over DC plans.

5.3.4 Inflation

In the preceding model, we assumed that wages and pension benefits were all contracted in real terms. It is clear that the vast majority of DB plans as currently implemented are not contractually indexed during the retirement period. This weakens the case for viewing DB plans as offering income-maintenance or interest-rate insurance.

Moreover, there is controversy surrounding the degree of indexation during the worker's active life. Bulow (1982) has argued that wages in firms administering DB plans should *not* be expected to keep pace with the price level. His argument is based on the notion that labor markets clear as spot markets (with respect to pension issues) and that any implicit contracts between firms and workers are independent of pension issues. In this case, the market-clearing employee compensation will determine the *sum* of wages plus accruing pension benefits. The level of either wages or pension accruals alone, however, is indeterminate.

To illustrate Bulow's point, consider the effects of an unanticipated increase in the price level. The increase imposes a real loss on workers, since their pension benefits are defined in nominal terms. Of course, the worker's loss is the firm's gain. If, however, the employees were to receive a pay raise in the subsequent period which would keep their real wage constant, then the earnings base upon which pension benefits are calculated also would rise at the inflation rate, and the worker's pension loss would be eliminated. Real compensation in the second period would in effect be higher than in the first: real wages are constant, but pension transfers have increased in order to compensate for the effects of the unanticipated inflation. The firm has, in effect, issued insurance against the effect of inflation on the value of pension benefits.

Bulow argues that firms neither behave in this way nor should they be expected to. His competing model holds total real compensation exogenous. Because pension benefits in DB plans increase with the wage level, the wage component of compensation will *not* rise at the inflation rate in the subsequent period. Instead, the sum of the partially indexed wage increase and partially indexed recovery of real pension benefits *together* will provide an increase in nominal compensation which matches the inflation rate. However, the initial loss of pension value due to inflation is borne entirely by the worker.

Under the Bulow model, DB plans pose significant risk to participants. The nominal nature of the pension contract is to be taken quite seriously; workers bear the entire brunt of inflation risk. Thus, while DB plans provide a less variable final-salary replacement rate to workers than do DC plans, the final real salary itself becomes more sensitive to inflation. Whether DB or DC plans are riskier in a utility sense is therefore an open question. Bulow's model is far from universally accepted. Several observers (e.g., Cohn and Modigliani 1983) believe that firms do in fact offer implicit indexation to workers. In this view, the wage decision is made separately from the pension decision, and the effects of wage increases on pension benefits are ignored in the determination of worker compensation.

5.4 Concluding Comments: Is There a Better Way?

The major advantage of DB plans is the potential they offer to provide a stable replacement rate of final income to workers. If the replacement rate is the relevant variable for worker retirement utility, then DB plans offer some degree of insurance against real wage risk. Of course, protection offered to workers is risk borne by the firm. As real wages change, funding rates must correspondingly adjust. However, to the extent that real wage risk is largely diversifiable to employers, and nondiversifiable to employees, the replacement rate stability should be viewed as an advantage of DB plans.

The advantages of DC plans are most apparent during periods of inflation uncertainty. These are: the predictability of the value of pension wealth, the ability to invest in inflation-hedged portfolios rather than nominal DB annuities, and the fully-funded nature of the DC plan. Finally, the DC plan has the advantage that workers can more easily determine the true present value of the pension benefit they earn in any year, although they may have more uncertainty about future pension benefit flows at retirement. Measuring the present value of accruing defined benefits is difficult at best and imposes severe informational requirements on workers. Such difficulties could lead workers to misvalue their total compensation and result in misinformed behavior.[8]

Of interest for future research is the possibility of pension plan designs that combine the best attributes of DB and DC plans. Many firms already offer DB plans supplemented by DC plans. An interesting alternative is the so-called floor plan, which is in essence a DC plan together with a guarantee of a minimum retirement income based on a DB-type formula. Employers and employees can trade off the level of guaranteed floor against the size of the expected DC benefit. These plans offer the downside protection of DB plans, yet still allow employees to take positions in high-expected-return assets. Floor plans already are offered by some firms [9] and allow for a great deal of flexibility and creativity.

Notes

1. It is important to distinguish here between several subcategories of DC plans: money purchase, profit sharing, and thrift plans. For money purchase plans, like TIAA-CREF, contributions are usually based on the employee's compensation, as stated in the text. But in profit-sharing plans employer contributions are based on the sponsor's profitability, and in thrift plans contribution levels are usually determined voluntarily by employees, with employer matching contributions at some prespecified rate. Thrift plans are usually offered as a supplement to a DB or other DC plan.

2. Until the late 1970s, employee contributions to many DC plans were not tax-deductible, the main exception being employees of certain nonprofit organizations (403[b] plans). But recently the government has expanded tax-deductibility of employee contributions to the private for-profit sector through 401(k) plans.

3. There is a separate question of whether the difference in backloading patterns is of importance to workers. Consider a scenario in which the inflation rate is fixed and only the interest rate varies. In this case, the impact of interest rates on accrual patterns would be irrelevant to workers from a welfare standpoint. The real stream of benefits to be paid starting at retirement is independent of the trajectory of the present value of accrued benefits. When inflation rates are stochastic, however, backloading patterns can have important effects on welfare. The real benefit stream during retirement moves inversely with the stochastic price level.

4. The contribution pattern for a DC plan required to match the accrual pattern of a DB plan could run into IRS limits on annual contributions at older ages, particularly for higher paid employees.

5. An alternative explanation is that insurance companies view their annuitants as members of a captive market and try to recoup past losses by offering them below-market rates.

6. As always, it is impossible to tell from first principles of welfare analysis whether an individual would necessarily choose to convert wealth into a riskless stream of retirement benefits.

7. This is an *actuarially* fair adjustment in the sense that the expected value of period-2 income would be unaffected.

8. While workers are more likely to be informationally disadvantaged than employers, the level of complication is such that employers also may make significant mistakes. All of this is perhaps an issue in evaluating the Bulow argument, since that argument turns on accurate perceptions of the "true" pension benefits and costs.

9. Among the companies offering floor plans are Xerox, Hewlett-Packard, and Georgia-Pacific.

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Comment Laurence J. Kotlikoff

This paper provides a very insightful comparison of defined contribution and defined benefit pension plans. While the authors are cautious, one is left with the impression that the defined contribution form of pension plans is superior in many, if not all, respects to the defined benefit form. I certainly concur with that conclusion. Many defined benefit plans appear to subject workers and employers to unnecessary earnings risk by tying the pension payment to the average of earnings at the end of workers' careers; while hedging inflation, such provisions mean that workers' pensions are very sensitive to earnings late in their careers. Such earnings may be unusually low for reasons including poor health, changes in market conditions, and so forth.

Other defined benefit plans relate the pension to longer averages of earnings, which make the initial real pension benefit potentially quite sensitive to inflation. Still other defined benefit pensions are independent of earnings, positing a nominal benefit that depends only on service. The real values of these latter pensions are also very sensitive to inflation.

In contrast to the defined benefit plans, defined contribution plans appear to be riskier with respect to the real rate of return. However, as the authors point out, one can devise close to riskless portfolios that get around this objection. In addition, they make the important point that defined benefit plans also are sensitive to the real rate of return because changes in real rates alter the present value of future defined benefits.

Once workers retire the defined benefit pensions are subject to considerable inflation risk. While many firms do provide cost-of-living increases on an ad hoc basis, these increases do not keep pace with inflation, as Robert Clark has shown in his study of cost-of-living increases in the 1970s. In contrast, defined contribution plans give workers the option of withdrawing their funds and investing them themselves. As mentioned, one can safely hedge inflation and secure a real, if minuscule, rate of return; the problem is, however, that many retirees may not know how to devise such riskless portfolios that involve using future commodity markets. While financial markets could provide such safe assets, they do not appear readily available at the current time.

A problem with defined contribution plans not discussed in detail by the authors is that defined contribution plans that pay off at retirement do not provide retirees with an annuity, and therefore do not provide

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retirees with insurance against life-span uncertainty. Those that do pay off in the form of an annuity provide a stream of nominal retirement benefits that are subject to inflation risk just like the benefits of defined benefit plans.

Another important issue that the authors do not consider is whether defined benefit plans are too complicated for workers—and, indeed, even employers—to understand and properly evaluate. It is not atypical to find a defined benefit plan that has (1) an age- and service-related benefit formula, (2) an average earnings base, (3) age- and service-dependent early retirement reduction formulas, (4) special early retirement supplemental benefits, and (5) actuarial reductions for workers terminating prior to early retirement. To calculate correctly one's accrual of pension benefits in such plans requires actuarial skills which typical workers do not possess. In addition, in many cases even if the workers possessed such skills, the booklets describing the pension plans are so poorly written, if not intentionally misleading, that it is very difficult to figure out what one is actually receiving. Hence, an important advantage of defined contribution plans is that they provide workers with better information about their retirement finances.

My guess is that defined benefit plans emerged because they were attractive to older union members and to employers who thought they could generate strong retirement incentives without being explicit about those incentives. In the process the country has been straddled with a very risky private pension system that provides insufficient information to both workers and employers about the benefits and costs of financing retirement.