

**Defined Benefit Pension Plans:
A Stochastic Dynamic Programming Approach**

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The research reported herein was performed pursuant to a grant from the U.S. Social Security Administration (SSA), and the Michigan Retirement Research Center (MRRC). The author would like to thank the Social Security Administration for financial support in writing this paper, and Neil Doherty, Andrew Metrick, Olivia Mitchell, Alexander Muermann, John Piggott, Nicholas Souleles and the members of the Risk and Insurance Seminar at the Wharton School for comments on earlier drafts of this paper. The usual disclaimer applies.

Abstract

This paper uses the strategic asset allocation model developed by Campbell *et al.* (1999) to examine the tradeoffs between defined benefit and defined contribution pension plans, extending results by Bodie *et al.* (1988). The effects of varying risk aversion, varying initial income and financial wealth and varying wage processes (that may be correlated with returns on the risky asset) are examined.

1. Introduction

Two sources of risk faced by almost everyone are wage instability and asset return variability. The relative importance of these, and individuals' responses to them, has occupied a great deal of the economics literature. The relevance of this issue in the context of retirement planning is reflected in the design of retirement plans themselves, of which two major types exist: defined benefit, or DB, plans, and defined contribution, or DC, plans.

A DB plan pays an individual a benefit that is defined by formula, usually without reference either to the amount of contributions an individual has made to the plan or to the level of investment returns that the pension plan has earned on its assets. A typical DB plan pays benefits that are linked only to an individual's final salary (possibly averaged) and the length of service that the individual has with the employer that sponsors the plan. Prominent examples of DB plans include the US Social Security system and final salary occupational pension plans, which larger US corporations and federal, state and local governments commonly provide to their employees.

DC plans, on the other hand, usually have fixed contributions but variable benefits. The benefits often depend on the level of contributions made by the employee and the investment return earned by the assets over the employee's lifetime. A common type of DC plan in the US is 401(k) plan, where contributions are paid into an individual member's account, often by both the employer and the employee, returns accrue over the employee's working life and the employee can access the accumulated balance after retirement.

The balance of pension provision between DC and DB plans has changed dramatically in the United States in the last two decades. As recently as 1985, Ippolito [1985] was able to report that "most pension-covered workers in the United States are covered solely or primarily by defined benefit plans". In contrast, the US Department of Labor [2001] reported that of the 59% of employees covered by pension plans in 1996-1998, only 59%

were members of DB plans. Many of these individuals were also members of DC plans. Large differences in pension plan provision has also emerged between public and private sector workers – only 32% of full-time private sector workers were covered by DB plans in 1996-1998, while 90% of full-time public-sector workers were members of DB plans.

Although the balance between DB and DC pension coverage has shifted, the number of workers that are members of both DB and DC plans, as well as the stability of DB pension coverage in some sectors of the economy suggests that both types of plan play an important role in providing retirement security to workers.

Until the late 1980's, the traditional view was that DB plans protected individuals from investment risk (as investment risk was borne by plan sponsors) and from retirement income risk, as pension payments are explicitly linked to the final level of wages in most DB plans. However, an analysis by Bodie *et al.* [1988] revealed that the dependence of the retirement benefit stream on final wages actually *increased* an individual's exposure to wage risks. This was shown by their conclusion that if wage risks dominated investment risks, risk-averse individuals would prefer DC pension plans over DB plans. However, when they included income risk in retirement by recognizing that members of DC plans only have the option to annuitize their wealth at random interest rates, and recognized that members of DC plans bear investment risks not borne by members of DB plans, they were unable to reach a conclusion about which plan type a risk-averse individual would prefer.

This paper extends the analysis of Bodie *et al.* [1988] in order to understand better the conditions under which risk-averse individuals prefer one type of pension plan over another. In an environment where many individuals have a mix of pension types, knowing the determinants of the optimal mix between DB and DC pensions for different individuals is important. It is a first step on the road towards the ultimate goal of designing and fitting a model that explains the wide diversity of the pension environment in the United States. Such a model will be useful in designing pension systems for future

generations in both the United States and other countries, and in understanding more fully the economic role played by different types of retirement benefit.

In order to achieve these goals, this paper applies the strategic asset allocation framework used by Campbell and Viceira (2002) to the DB/DC pension problem. Unlike the original Bodie analysis, the Campbell-Viceira approach allows wage and investment processes to be explicit (and possibly correlated), allows wage uncertainty and investment uncertainty to accumulate over time, models mortality both before and after retirement, and allows investment choice to change dynamically and endogenously over time. This is achieved at the expense of analytical tractability which forces reliance on numerical solutions. The approach of Carroll (1992,1997a,1997b) for numerically solving stochastic dynamic programming problems is used.

2. Defined Benefit Pension Plan

The individual contributes to a defined benefit pension plan over his working life and receives benefits from the plan when he is retired. The date of retirement, and labor supply in general, is assumed to be exogenous.

The benefit of the defined benefit pension is an annual pension of constant real proportion k of final wages for each year of employment. The individual chooses k at the beginning of his working career, and cannot change it thereafter.

Consistent with theoretical models of the labor market, individuals are assumed to pay for defined benefit pensions in the form of lower cash wages. When the individual joins the plan, the expected discounted present value of an individual's pension contributions is set equal to the expected discounted present value of pension benefits for that person. Cross-subsidies common in DB plans (such as from males to females and short-stayers to long-stayers) can be modeled by changing the rate of interest at which this identity holds.

It was decided to model the level of contributions as a constant fraction of wages. This assumption probably overestimates the extent to which DB pension plans expose members to wage risk. This is because with an increasing contribution schedule, more contributions are made later when more is known about the final level of wages and hence benefits. Thus, contributions and benefits are more likely to be closer together than if the contribution schedule is flat or negatively sloping.

3. Model Description

A utility maximizing individual works for t periods, and then is retired for s periods. At the beginning of each period, the individual earns a real risky wage W_j , consumes C_j and has assets on hand of A_j . Between period $j-1$ and period j , the individual earns a return on assets of R_j . All variables with subscript j are revealed at time j .

Wages have both permanent and temporary error components. The permanent error follows some process that is either a random walk, or close to a random walk.

At the beginning of each period the consumer has a stock of assets that can be allocated between the risky and the risk-free asset. He cannot borrow against future income to finance current consumption, implying that the stock of assets is constrained to be positive. The individual is not permitted to short either the risky or the risk-free asset.

The model permits the permanent portion of an individual's income shocks and the returns on the risky asset to be correlated.

The individual can purchase a life annuity when he retires, although this annuity is not priced actuarially fairly to model the effects of adverse selection in the annuities market.

At time 0, the consumer maximizes a time-separable discounted expected utility function of the following form:

$$\max_k \max_{\{Y, C_i, a_i\}} E_0 \sum_{i=1}^{t+s} b^i p_i u(C_i)$$

where p represents mortality, C is consumption, a is the proportion in the risky asset and b is the individual's impatience factor. Subscripts indicate the time at which decisions are made. At time 0, the individual also chooses the level of DB pension, k .

4. Preliminary Conclusions

Preliminary results indicate that two major factors affect the desirability of defined benefit plans. The first is the variability of the defined benefit relative to its expected rate of return, viewed in the context of the other investment options available to the individual. The risk aversion of the individual, which affects the importance of the cheaper access to the life annuity market provided by the defined benefit plan, is the other important factor.

For workers in governments and large corporations, and especially if these workers are near retirement, it is likely that the implicit returns offered by defined benefit plans are fairly large, while wages (and hence retirement benefits) are probably quite stable. Hence, these workers (who are also likely to be relatively risk averse), probably prefer defined benefit plans. For most other workers, wage risks dominate investment risks, implying that defined benefit plans are less optimal than defined contribution plans.

An aspect of defined benefit plans not included in this model that may make them more attractive is their inherent cross-subsidies – usually in favor of lower-paid and longer-service workers. In an environment with asymmetric information, this makes defined benefit plans more attractive to younger workers who expect to stay with one employer for a long time or who anticipate retiring with low wages.

One aspect of defined benefit plans that makes them attractive to employers is the greater control they permit over employee retirement behavior and wage-service profiles than

defined-contribution pension plans. In addition, employers have more flexibility in funding defined benefit plans than they do in funding defined contribution plans. However, defined benefit plans expose employers to investment risks that in defined contribution plans are passed on to individual employees, which may make them less attractive to employers.

Finally, an important economic role played by defined benefit pension plans is that they give individuals access to the market for life annuities without exposing them to interest rate risk. This aspect is extremely important if individuals have high risk aversion and annuity rates are very variable. The final version of this model will include this aspect of defined contribution plans.

5. References

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