Oxford Handbook of Pensions and Retirement Income

Strategic Asset Allocation for Pension Plans

John Y. Campbell and Luis M. Viceira

Abstract

This chapter asks how portfolio choice theory can be used to improve the investment strategies of pension plans. The chapter begins by asking how one should formulate the investment objectives of a defined-benefit pension plan. One view is that the pension plan assets are held on behalf of the plan sponsors (shareholders or taxpayers), who have an obligation to pay pension benefits to beneficiaries. In this case the assets should be invested to maximize tax benefits, to exploit investment opportunities that plan sponsors have difficulty accessing on their own account, and possibly to exploit limited liability and government pension guarantees. An alternative view is that the assets are invested on behalf of beneficiaries, who should value protection of their promised claims along with upside potential in the realistic case where benefits may be adjusted upward when investment results are good. The second part of the chapter discusses how portfolio choice for pension plans is affected by two key considerations that are ignored in the standard mean-variance analysis: the existence of liabilities as well as financial assets, and the need to measure financial risks over the long run rather than the short run.

JEL classification: G12.

1   Introduction

Academic research on asset allocation has had a strong influence on the investment policies of large institutional investors, particularly endowments and pension funds. This chapter summarizes recent research on asset allocation, and discusses its implications for the management of pension plans.

A basic question about pension investing is who controls the asset allocation decision. One view is that the asset allocation decision for a pension fund is made by those responsible for funding the plan liabilities ("plan sponsors"), or agents acting on their behalf. An alternative view is that the decision is made by the beneficiaries of the plan, or fiduciaries acting on their behalf. In defined contribution (DC) pension plans, there is no conflict between these two views because the same individuals are plan sponsors and beneficiaries. In defined benefit (DB) pension plans, however, plan sponsors are the shareholders of corporations (in corporate plans) and taxpayers (in public plans), while the beneficiaries of the plan are employees. The fiduciaries who manage the fund have a legal obligation to respect the interests of the employees, even though they report to and are paid by the plan sponsors.

We begin this chapter by considering the corporate DB asset allocation problem from the plan sponsor's perspective, assuming that the plan sponsor must fully cover the promised benefits to employees. We then introduce the possibility that the corporate plan sponsor may default on some portion of those benefits, and consider the problem from the point of view both of the plan sponsor and of a fiduciary acting in the interests of employees. Finally we consider public DB plans, and DC plans where there are no fixed benefits at all.

Before going further, it is important to ask why pension fund investment decisions have relevance for plan sponsors. Pension fund investing is irrelevant in a hypothetical world with no taxes or transaction costs and where all investors have perfect information, identical investment expertise and opportunities, and unlimited liability. In such a world, those responsible for funding the plan-shareholders and taxpayers in the case of DB plans, and individuals saving for retirement in the case of DC plans - can use their own portfolios to undo whatever asset allocation the pension plan decides upon, to obtain the exposure to risk and return they deem optimal, given their resources and

risk preferences. This is the well-known Miller-Modigliani capital structure irrelevance theorem, applied to pension fund investing. Of course, taxes, transaction costs, and differences in information and expertise are facts of life, and not all investors have the same access to all asset classes. These imperfections have the potential to justify the existence of pension funds, and make pension fund investment policies relevant for pension fund sponsors.

2 Imperfections and the Pension Investment Problem

Taxation

In most countries, asset return taxation differs across assets: Typically the tax burden on assets whose return comes mostly in the form of income, such as fixed-income securities, is higher than the tax burden on assets whose return comes mostly from capital gains, such as equities. Additionally, contributions and returns in retirement accounts of DC plans and in corporate DB plans are often tax-exempt. Investors can minimize their tax burden by locating their most heavily taxed assets in their tax-exempt accounts and their lightly taxed assets in their taxable accounts.

Black (1980) and Tepper (1981) were among the first to make this point in the context of optimal asset allocation for corporate pension plans. They note that a pension fund is economically an integral part of the balance sheet of a corporation, since the corporation is responsible for funding the plan on behalf of the shareholders. Within the corporation, the pension fund works effectively as a tax-exempt investment account. Tax optimization makes it optimal for corporations to contribute as much to the plan as regulations allow, to place fixed-income assets in the pension fund, and to hold equities in the taxable part of the balance sheet. This can be achieved by investing pension assets in bonds, and simultaneously implementing a share buy-back program. This location of assets creates shareholder value in the form of interest tax shields. It also makes future contributions to the plan less volatile; in fact, if there is no uncertainty about the average longevity of the group of pension beneficiaries, and if no new benefits accrue, this policy requires no additional contributions after the initial funding of the plan.[1] Viceira (2003) studies the implementation of a Black-Tepper investment strategy by the British retailer Boots PLC.

Transactions costs and portfolio constraints

From a shareholder risk perspective, a shift into bonds in the pension fund combined with a share repurchase program is not necessarily equivalent to a simple swap or change of location of assets in the balance sheet. This is particularly true in the realistic case where risky assets in the pension plan are held in the form of a well-diversified portfolio of equities. By moving those assets into bonds, the corporation effectively delivers the balance sheet and consequently reduces systematic equity risk. By repurchasing shares, the corporation relevers the balance sheet and increases equity risk. But this increase affects total equity risk, both idiosyncratic and market risk, because the corporation buys back its own shares instead of a portfolio of well diversified equities. Ail increase in idiosyncratic risk is inconsequential for shareholders who can offset it by trading in their own portfolios, but can be material for shareholders who face binding short-sales constraints or employees who contractually must hold a large fraction of their wealth in company stock.

More generally, there are many reasons why individual investors may have a limited ability to optimally diversify their portfolios on their own. These reasons, which may be described as "transactions costs", include investors' limited information or financial expertise, lack of self-discipline, limited access to certain asset classes, transaction fees, and short-sales and borrowing constraints. DB pension funds can be cost-efficient vehicles for corporate shareholders, particularly those of modest net worth, to implement their optimal asset allocation.

DB plans tend to be large relative to almost any individual investors. They also have predictable inflows and outflows. These attributes make them well suited to hold asset classes where large investments are required and where liquidity is limited, such as private equity and alternative investments. These asset classes are not generally available to individuals, unless they have high net worth. DB pension plans can take short positions and use leverage at a fraction of the cost a small investor would have to pay, if he could do it at all. They can hire investment professionals whose information and expertise is not available to most individual investors. These professionals can also provide investors with disciplined investing, which may be important in light of the empirical evidence that individuals tend to sell equities to institutions when

expected stock returns are highest, and conversely buy stocks when their expected return is lowest (Cohen, 2003).

There are two objections to the idea that corporate DB plans should provide investment services to shareholders. First, alternative institutions could provide such services on a stand-alone basis without any connection to a non-financial corporation. Second, corporate pension plans lack transparency; pension accounting rules are complex and do not make it easy for shareholders to understand the impact of pension plan investments on the financial health of the parent corporation.[2] As we discuss below, the case that pension plans should provide general investment services may be stronger for public DB and DC plans than for corporate DB plans.

Limited liability: shareholder perspective

So far we have assumed that shareholders have an absolute obligation to pay the benefits promised by a corporate DB pension plan. In fact, however, shareholders have limited liability and this can have an important effect on the optimal pension plan investment strategy.

Building on the work of Merton (1974, 1977) on the structure and valuation of corporate liabilities, Sharpe (1976) and Treynor (1977) note that the pension liabilities in a corporate DB plan are not intrinsically different from the rest of the liabilities in the corporate balance sheet: Shareholders are responsible for funding them only to the extent that there are assets in the corporation. Limited liability makes it optimal for shareholders to hold risky assets in a pension fund, because they may lower future contributions to the plan if realized returns are positive, and shareholders are not liable beyond the assets of the firm if those returns are negative and as a result firm assets are not enough to fund the plan liabilities. That is, limited liability gives shareholders an option to default on the payment of pension fund benefits, which of course is valuable to them.

Functionally the shareholder position with respect to the pension plan is akin to holding simultaneously a put option on the assets of the plan, with strike price equal to the value of the plan liabilities, and a short position in default-free bonds with value equal to the plan liabilities. Of course, this option is most valuable to shareholders when the plan assets are most volatile, and also when the option is most in the money, i.e., when the

plan is severely underfunded. Investing in risky assets increases the volatility of the plan assets and the value of the put option to shareholders.[3] Taxes on the one hand, and limited liability on the other hand, create an asset allocation tradeoff for corporate DB plans which must be evaluated in each particular case.

The incentive to invest pension plan assets in risky assets is exacerbated in countries whose governments insure failed pension plans. In the United States the Pension Benefit Guaranty Corporation (PBGC), a government-sponsored agency, collects insurance premia from pension plans in exchange for taking over the assets and liabilities of those that fail. The United Kingdom is considering the creation of a Pension Protective Fund (PPF), a pension agency similar to the PBGC. Even in countries without formal pension-protection agencies, there may be implicit government guarantees if governments tend to take over failed plans.

A pension insurance program gives a corporation an option to sell its pension assets to the pension agency at a price equal to its pension liabilities. This put option becomes more valuable as pension plan assets become riskier. If the agency collects a pension insurance premium based on a fair valuation of the put option, the incentive to hold risky assets in the pension plan is offset. However, in practice pension insurance premia are the same for all corporations, regardless of their credit risk, and are relatively low. Thus underfunded pension plans, which are most likely to fail, have a strong incentive to undertake risky investments.

An additional effect of limited liability is that the tax minimization strategy for a corporate pension plan makes existing bondholder claims riskier. This is so because pension claims typically have much lower priority than senior debt on assets outside the pension plan. By funding the pension plan and investing the pension plan assets in bonds, the corporation is effectively making pension liabilities senior to on-balance sheet debt, thus shifting risk from pension beneficiaries to bondholders.

Limited liability: fiduciary perspective

In the presence of limited liability, pension beneficiaries share in the downside risk of the pension fund investment results. Fiduciaries acting on their behalf should limit this risk. In addition, fiduciaries should consider the effect of pension fund asset allocation on the behavior of the plan sponsor. For example, a Black-Tepper investment policy of

placing bonds in the pension fund is riskfree if no further contributions are required from the sponsor, but not if the pension plan is underfunded. In this case there is even a possibility that the reduction of risk in the pension plan assets actually increases the risk to plan beneficiaries, if the plan sponsor responds with a share buyback plan that greatly increases idiosyncratic risk and thus increases the probability of corporate bankruptcy (Oberhofer 2003).

We have assumed so far that pension beneficiaries hold a fixed claim against the sponsor, and that sponsors have the right to appropriate fund surpluses for example, through "contribution holidays." In practice, however, many DB plans involve some flexibility to adjust benefits over time. Workers are in effect offered a combination of a fixed benefit and a benefit that is linked to the overall performance of the fund. In this context, beneficiaries may share to some extent in the upside as well as the downside results of the fund investment decisions. Thus pension beneficiaries will be as interested as plan sponsors to use the pension fund as an efficient vehicle to optimally diversify their portfolios, and pension fund investment in risky assets makes some sense for them too.

Asset allocation for public DB pension plans

Many of the considerations that are relevant for corporate pension plans do not apply to publicly sponsored DB plans. These are tax exempt institutions whose ability to default on their pension obligations is probably very limited-though they may have the power to reduce pension benefits through legislation.

Asset allocation for public DB plans is relevant largely because they may be able to invest oil behalf of taxpayers in illiquid asset classes, and to provide investment expertise at low cost. This role may be more important for public DB plans than for corporate DB plans. The ultimate sponsors of corporate DB plans are corporate shareholders, who by definition are participants in equity markets; they are likely to have at least some financial expertise and access to alternative investment vehicles. The ultimate sponsors of public DB plans are taxpayers, some of whom may have no other exposure to the diversified investment opportunities available in financial markets.

Some of the same considerations that we have discussed for DB plans also apply to DC plans. First, the returns on DC pension plans are untaxed until the assets are withdrawn from the plan. Dammon, Spatt and Zhang (2004) have argued that this should lead individuals with DC pension plans to hold bonds in their retirement accounts, and equities in their taxable accounts, following a strategy that is analogous to the Black-Tepper strategy for DB plans.[4] Second, DC plans can in principle offer individual investors access to otherwise unavailable asset classes. In practice, however, DC plans have built in liquidity requirements which make them unsuitable for investments requiring lockup periods. They tend to be offered as simple tax-exempt vehicles for mutual fund or company stock investing.

3   Asset Allocation for Long-Term Investors

The arguments we have laid out so far imply that pension fund investment decisions are relevant to sponsors and beneficiaries alike. We now assume that the pension fund investment problem can be written as an optimization problem of maximizing expected utility subject to constraints. The utility function captures the notion that there is diminishing marginal benefit of a pension surplus and increasing marginal cost of a pension shortfall. The constraints of the problem reflect the influences of investment returns, pension contributions, and pension benefits on the value of the pension fund.

The academic model which has been most influential in the practice of asset management is Markowitz's (1952) mean-variance analysis. The success of the mean-variance model derives from its simplicity, with a clear and intuitive connection between inputs   investors' expectations of future returns, volatilities, and correlations and the output-a recommended portfolio-and its useful emphasis on portfolio diversification to control risk. This has made the model the basic paradigm in asset allocation, upon which academics and practitioners alike have built numerous refinements and extensions.[5]

The model suffers, however, from two important limitations in its practical application to pension fund investing. First, it focuses only on the financial assets in a portfolio, abstracting both from liabilities and from non-financial income. Second, it assumes

that all investors have a short-term investment horizon. For a given set of expectations of future returns and their variances and correlations, the model recommends the same portfolio of risky assets for all investors.

Pension fund liabilities

By their very nature, pension funds have important liabilities. A DB pension plan, for example, must finance a promised stream of benefits. One way to handle this, while preserving the simplicity of the mean-variance approach, is to specify the objective function in terms of the pension plan surplus, the value of assets less the value of liabilities, at some future date. One can write $S_T = A_T - L_T$, where A_T is the value of assets at future date T and L_T is the value of liabilities at date T, and define a utility function over S_T to capture the idea that the marginal benefit of a surplus is diminishing in the level of the surplus. Mean-variance analysis then seeks to maximize a linear function of the mean and variance of S_T.[6]

This approach implies that the risk of any individual investment with return R_{iT} to horizon T should be measured by its covariance with the surplus:

$$Cov(R_{iT}, S_T) = Cov(R_{iT}, A_T) - Cov(R_{iT}, L_T).$$

In standard mean-variance analysis, an asset's risk is measured by its covariance with the value of the total portfolio of assets, but here one must also take account of covariance with the value of liabilities. An asset that covaries positively with the value of liabilities hedges those liabilities and should be given credit for this. For example, if liabilities take the form of long streams of fixed nominal payments to retirees, then they increase in value when nominal interest rates decline. Long-term nominal bonds also move inversely with nominal interest rates, so they hedge long-term nominal liabilities. Similarly, inflation-indexed bonds hedge liabilities that require long streams of real (inflation-adjusted) payments.

A variant of this approach assumes that there is an infinite utility cost to a pension shortfall, that is, a negative value of S_T. In this case it is optimal first to find a portfolio of assets that perfectly hedges liabilities, and then to invest the remainder of the portfolio trading off risk and return in the usual manner. This approach requires that

liabilities be perfectly hedgeable, and at a cost less than the value of the total portfolio. That is, the pension plan must be overfunded.[7]

In practice, many pension plans are underfunded and have some ability to reduce benefits in bad states of the world (perhaps by threatening bankruptcy). This suggests that one should allow for the possibility of a pension shortfall, and should invest with due regard to the cost of a shortfall, but without assuming that the cost is infinitely negative. One popular approach is to impose a constraint that there is only a small probability (often chosen to be 5%) that a shortfall exceeds some given amount (the "value at risk"). The weakness of this approach is that it treats all shortfalls greater than the value at risk as equivalent, whereas it seems likely that the cost of a shortfall is increasing in the size of the shortfall. This makes it preferable to specify a utility function that penalizes large shortfalls more than smaller ones.

An even more sophisticated approach recognizes that surpluses may be more welcome, and shortfalls may be more painful, in some states of the world than in others. For example, the marginal cost of a shortfall in a corporate DB plan may be greater when the corporate sponsor is currently unprofitable, because then the sponsor must rely on costly external finance to fund the plan; the marginal cost of a shortfall in a public DB plan may be greater when the local economy is weak, because then the local government sponsor of the plan has a reduced tax base. Effects of this sort can be modelled using state-dependent utility, or by treating the condition of the sponsor as an implicit asset of the pension plan whose risks can be hedged by the financial assets of the plan. In either case the lesson is that the financial portfolio should be used to hedge these additional risks. For example, public DB plans should avoid holding local stocks whose value will be correlated with the local tax base.[8]

Long-term investment horizon

Pension funds are distinctive not only because they have liabilities, but because they must invest over a long period of time. The investment horizon T discussed above is likely to be more than one year from the present; indeed, the fund may need to consider multiple horizons rather than just a single horizon. Financial economists have understood at least since the work of Samuelson (1969) and Merton (1969, 1971, 1973) that long-term investing may differ from short-term investing when investment

opportunities vary over time. In this situation long-term investors will care about shocks to investment opportunities - the productivity of wealth - as well as shocks to wealth itself. As Merton emphasized, long-term investors may wish to hedge their exposures to wealth productivity shocks, giving rise to intertemporal hedging demands for financial assets. Brennan, Schwartz, and Lagnado (1997) have coined the phrase "strategic asset allocation" to describe this farsighted response to time-varying investment opportunities.

Unfortunately, in contrast to the appealing simplicity of mean-variance analysis, strategic asset allocation models can be difficult to solve in practice: Investors' risk preferences, spending needs, and investment horizons interact in complex ways with investment opportunities and risk. For many years, practically usable solutions to strategic asset allocation models were unavailable. As a result, the Merton model did not become a usable empirical paradigm, and did not displace the Markowitz model as the leading model in the practice of asset management. A contributing factor to this situation may have been the view that prevailed in academic and applied finance until the late 1980's that investment opportunities were approximately constant. Under this view, one might see Merton's model as an important conceptual advance, but much less important in practice.

Since the 1980's this situation has changed as a result of several related developments. First, a large body of research in empirical finance has established not only that investment opportunities change over time, but also that changes in expected returns on bonds and equities and in real interest rates are highly persistent (e.g. Campbell and Shiller 1988, Fama and French 1988, Hodrick 1992, Campbell, Lo, and MacKinlay 1997). Second, this shift in perception has motivated new research into long-term investing, and financial theorists have discovered some new closed-form solutions to the Merton model. These solutions, while still based on stylized models, offer important analytical insights into the importance for long-term asset allocation of long-term risk (e.g. Kim and Omberg 1996, Campbell and Viceira 1999, 2001, Schroder and Skiadas 1999, Wachter 2002). Third, computing power and numerical methods have advanced to the point at which realistic multiperiod portfolio choice problems can be solved numerically. One particularly appealing approach is to combine approximate analytical solution methods with numerical methods; this

greatly increases the realism of the investment problems that can be solved numerically, while also making the solutions easier to interpret. Campbell and Viceira (2002) provide a book-length survey and integration of this literature, and Campbell, Chan, and Viceira (2003) is an extensive empirical application to the problem of optimal asset allocation across US stocks, bonds, and Treasury bills.

One particularly simple approach to long-term investing modifies the mean-variance analysis only by replacing short-term means and covariances with long-term means and covariances. This approach, which is discussed by Barberis (2000) and Campbell and Viceira (2005), is appropriate for a long-term "buy-and-hold" investor who must make a single portfolio decision today and then must hold the portfolio without further rebalancing. Assets that offer temporarily high returns are less attractive to such an investor than assets that are expected to deliver high returns over the long term. Assets with mean-reverting returns are relatively more attractive to such an investor. For these assets, short-term risks will tend to cancel out over the longer term as unusually high initial returns are offset by lower average subsequent returns. Empirically, stock returns appear to be mean-reverting, as are inflation-indexed bond returns and nominal bond returns in periods of relatively stable inflation; bill returns, on the other hand, exhibit persistent fluctuations so bills are riskier in the long term than the short term. Campbell and Viceira (2005) show how these effects lead a buy-and-hold investor to hold more bonds and stocks than an equally risk-averse short-term investor.

Of course, even investors with a long horizon have frequent opportunities to rebalance their portfolios. An asset with a temporarily high expected return is attractive to an investor who can exploit the short-term opportunity and then rebalance when normal conditions resume. "Tactical asset allocation" strategies use mean-variance analysis with time-varying expected returns derived from some return forecasting model, and short-term risk estimates. But these strategies ignore the difference between short-term and long-term risks. The correct investment approach for a long-term investor who can rebalance frequently is to respond to short-term expected returns, while measuring the risk of each asset using not only its covariance with the total portfolio return, but also its covariance with changes in investment opportunities. A conservative long-term investor should favor assets that do well when investment opportunities deteriorate -

that is, when expected returns decline - for such assets protect the portfolio against the effects of prolonged periods of poor returns.

This "strategic asset allocation" strategy leads conservative long-term investors to increase their average allocations to mean-reverting assets. A mean-reverting asset is one whose expected return tends to decline when its price increases; thus it hedges the variations in its own expected return. Equities, inflation-indexed bonds, and nominal bonds in periods of stable inflation all appear to be mean-reverting, and so they play a major role in strategic asset allocation just as they do in long-term mean-variance portfolios.

Strategic asset allocation investors should value assets not only for hedging their own expected returns, but also for hedging the variations in the expected returns of other attractive assets. Growth stocks, for example, appear to be good hedges against low returns on the aggregate stock market, and may be attractive to strategic asset allocation investors despite their low average returns (Campbell and Vuolteenaho 2004).

4   Conclusion

Much work remains to be done to make strategic asset allocation usable for pension funds and other long-term institutional investors. The goal is to build practical tools to derive optimal strategic portfolio weights given an investor's beliefs about investment opportunities. The challenge is that strategic asset allocation requires an investor to specify beliefs not only about investment opportunities today, but also about how those opportunities may evolve in the future. The reward is that given such beliefs, a strategic asset allocation portfolio can have much better long-run properties than a mean-variance portfolio (Campbell and Viceira 1999, 2002).

One promising approach is the use of Bayesian methods to model investors' uncertainty about the process governing investment opportunities. Uncertainty about the mean return on a risky asset increases its long-term risk relative to its short-term risk and reduces the portfolio allocation of a conservative long-term investor (Brennan 1998). Bayesian methods can also be used to impose prior beliefs about the validity of asset pricing models (Pastor and Stambaugh 2000) or about the unpredictability of stock returns (Xia 2001).

Another important task is to integrate the analysis of liabilities with the analysis of time-varying investment opportunities. If interest rates are constant, fixed nominal liabilities can be hedged using either short-term bills or long-term nominal bonds. If interest rates are arbitrarily time-varying, fixed nominal liabilities at a given future date can only be hedged by nominal bonds that mature at the same date. If interest rates are time-varying in a manner that can be captured by a parsimonious term structure model, then such liabilities can be hedged using a small number of short-term and long-term bonds. Indexation of benefits to wages or prices and uncertain lifetimes of pension beneficiaries further complicate the management of liabilities. The integration of liability management with strategic asset allocation is a leading investment challenge for pension plans.

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[1] In practice longevity risk is a significant issue (Blake and Burrows 2001, King 2004). A recent financial innovation that will help pension plans to manage this risk is the creation of "longevity bonds", whose payoffs depend on the longevity of a large demographic group. The European Investment Bank and BNP Paribas, for example, have announced a 25-year issue linked to the longevity of senior citizens in England and Wales.

[2] Jin, Merton, and Bodie (2004), however, present evidence that corporate stock prices do reflect information about the investment risks of corporate pension plans.

[3] Equivalently, we can interpret the plan beneficiary position as equivalent to holding the assets of the plan while giving shareholders the option to buy them at a strike price equal to the value of the plan liabilities. Increasing the volatility of the plan assets makes this option more valuable to shareholders.

[4] This view has been challenged by Poterba, Shoven and Sialm (2004) for the case of high-income taxable investors who save in actively-managed equity funds. They argue that it might be optimal for those investors to hold these funds in their retirement (non-taxable) account, because they tend to impose substantial tax burdens on their investors, while at the same time it is possible to hold forms of fixed-income investments with low tax burdens such as municipal bonds in the U.S.

[5] Much work by practitioners has sought to address the problem that arises when a mean-variance optimization falsely identifies some combination of risky assets as almost riskless, based on the historical pattern of returns. In this circumstance the optimization will often place excessive weight on what it perceives to be a near arbitrage opportunity. One

approach is to constrain portfolio weights (e.g. Frost and Savarino 1988, Jagannathan and Ma 2002); another is to use prior information to influence the mean-variance estimates (e.g. Treynor and Black 1973, Black and Litterman 1992, Pastor and Stambaugh 2000). Brandt (2004) surveys this literature.

[6] In implementing this approach, an important question is whether to measure only those pension liabilities that have been incurred to date (accumulated benefit obligation, or ABO, in US terminology), or whether to include also liabilities that will be incurred by the ongoing operations of the plan sponsor in the future (projected benefit obligation, or PBO). One view is that future ongoing liabilities will be covered by future contributions from the plan sponsor, in which case plan assets need only be matched to ABO in calculating the plan surplus. An alternative view is that plan assets must cover both past and future accumulated benefits, in which case the PBO may become relevant. Viceira (2004) discusses these issues and the related US accounting rules in the context of the General Motors pension plan.

[7] See Rubinstein (1976a,b) for the theory of optimal investment with fixed liabilities and an infinite shortfall cost. Dybvig (1999) considers the case of an endowment that can increase discretionary spending but never reduce it; such an endowment has variable, endogenous liabilities but again an infinite shortfall cost.

[8] These points are related to the large literature on optimal investment in the presence of non-financial income, for example labor income for individuals or donations for universities. See for example Bodie, Merton, and Samuelson (1992), Merton (1983, 1993), and Campbell and Viceira (2002, Chapter 6).

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