Chapter 3
Performance Enhancements for Defined Benefit Pension Plans

John M. Mulvey, Thomas Bauerfeind, Koray D. Simsek, and Mehmet T. Vural

Abstract Over the next several decades, traditional corporate and government pension plans will encounter increasingly severe problems in many countries. Contributing factors include underfunding status, demographic trends, low savings rates, and inefficient investment/saving strategies. This chapter takes up the last point, showing that a systematic forward-looking asset–liability management model can improve performance across many reward and risk measures. The model takes the form of a multi-stage stochastic program. We approximate the stochastic program via a set of state-dependent policy rules. A duration-enhancing overlay rule improves performance during economic contractions. The methodology is evaluated via historical backtests and a highly flexible, forward-looking financial planning tool.

Keywords Asset and liability management · Financial optimization · Pension plans · Risk management · Asset allocation · Surplus optimization

3.1 Introduction

Traditional pension trusts, called defined benefit (DB) plans herein, are threatened by a number of forces. The factors include (1) the loss of funding surpluses occurring over the past 10 years and current underfunded ratios, (2) a demographic nightmare – long-lived retirees and a shrinking workforce, (3) changing regulations, (4) greater emphasis on individual responsibilities for managing personal affairs such as retirement, and (5) inefficient financial planning. The days of someone working for a single organization–IBM for example–for their entire career and then retiring with comfort supported by the company’s contributions are largely gone (except for public sector employees in certain cases).

This chapter takes up the lack of effective risk management and financial planning by DB pension plans. The 2001/2002 economic contraction showed that the ample pension plan surpluses that existed in 1999 could be lost during an equity market downturn and a commensurate drop in interest rates which raises...
the market value of liabilities (Mulvey et al. 2005b; Ryan and Fabozzi 2003). The loss of surplus could have been largely avoided by applying modern asset and liability management models to the problem of DB pension plans. Boender et al. (1998), Bogentoft et al. (2001), Carino et al. (1994), Dempster et al. (2003, 2006), Dert (1995), Hilli et al. (2003), Kouwenberg and Zenios (2001), Mulvey et al. (2000, 2008), Zenios and Ziemba (2006), and Ziemba and Mulvey (1998) describe the methodology and show examples of successful applications. The Kodak pension plan (Olson 2005), for example, implemented an established ALM system for pensions in 1999, protecting its surplus over the subsequent recession. The situation repeated itself during the 2008 crash when most pension plan funding ratios dropped further. Again, systematic risk management via ALM models would have largely protected the pension plans.

Over the past decade, there has been considerable debate regarding the appropriate level of risk for a DB pension plan. On one side, advocates of conservative investments, called liability-driven investing or LDI in this chapter, have proposed a portfolio tilted to fixed income securities, similar to the portfolio of an insurance company. These proponents argue that a pension plan must fulfill its obligations to the retirees over long-time horizons and accordingly should reduce risks to the maximum degree possible.

To minimize risks, pension liabilities are “immunized” by the purchase of assets with known (or predictable) cash flows which are “adequate” to pay future liabilities. The goal is to maintain a surplus for the pension plan: Surplus/deficit = value(assets) − PV(liabilities), where the liability discount rate is prescribed by regulations such as promulgated by the Department of Labor in the United States. To protect the pension surplus requires an analysis of the future liabilities for the pension plan, i.e., expected payments to the plan retirees throughout a long time period – 40 or 50 or even 60 years in the future. Clearly with an ongoing organization, these liabilities are uncertain due to longevity risks, to future inflation, to possible modifications of payments for changing policy, and to other contingencies. Importantly, interest rate uncertainty plays a major role since the value of the liabilities (and many assets) will depend directly on interest rate movements. For these reasons, the asset mix will need to be modified at frequent intervals under LDI, for example, as part of the annual valuation exercises conducted by qualified actuaries. Similar to an insurance company, the duration of assets and the duration of liabilities should be matched (approximately) at least if the pension plan is to ensure that the surplus does not disappear due to interest rate movements.

As an alternative perspective, other experts suggest that a pension plan should be willing and able to accept risk-bearing investments since it has a long horizon with only a small percentage of cash flow payments occurring during the near term. An apt analogy is a university endowment. Here, in fact, there has been a decided shift

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1 We define the term “pension surplus” to indicate the difference between the market value of assets and the present value of liabilities (positive or negative). A related term is the funding ratio: market value of assets/present value of liabilities.
over the past 10–15 years by leading universities, promoted by the efforts of David Swensen (2000) at Yale University and others, from employing primarily market-traded assets to private instruments such as hedge funds, private equity, venture capital, and hard assets such as timber lands. Supporting this shift is the theory that private markets will provide greater returns than publicly traded markets, e.g., due to an illiquidity premium. Until the 2008 crash, the alternative investment domain did indeed provide superior returns. However, it became apparent in the latter part of 2008 that private markets are not immune to dramatic downturns. During this period, the value of the overall portfolio for many university endowments dropped 25–35%. Despite these large draw downs, university administrators state that the previously high returns would not have been possible if they had followed conservative investment strategies. Clearly, time-dependent risks and rewards play a role in the investment decision process.

From the standpoint of a pension plan, there is another issue to consider. All defined benefit pension plans in the USA and many other countries are protected against default by government (or quasi-government) organizations. The Pension Benefit Guarantee Corporation (PBGC) provides a safety net when a US company is no longer able to make adequate contributions typically during a bankruptcy. A fee is assessed of all DB pensions in order to fund the PBGC. Therefore, the risks to most pensioners are largely mitigated. However, there are systemic risks to taxpayers if and when the entire DB pension system is threatened (Parks 2003).

We focus on issues involving the protection of a pension surplus. The investment world has experienced two severe downturns over the past 10 years – the 2001/2002 tech-bubble and the 2008–2009 great recession. Over the same period, interest rates have gradually declined causing the present value of liabilities to increase. As mentioned, the relatively health surpluses for pension plans occurring in 1999 have disappeared today due to these two causes. Any attempt to manage pension plan risk must consider both asset valuation and the risk of interest rate decreases (Mulvey et al. 2006).

Importantly, to address risk mitigation approaches, we must recognize that the complicated nature of pension planning – numerous stakeholders, long time periods, conflicting measures of risk – requires approaches that strive to achieve a number of simultaneous objectives (Arnott and Bernstein 1990; Bader 2003; Black 1995; Mulvey et al. 2008; Muralidhar and van der Wouden 1999). For example, we can claim that a sponsoring organization should increase its contribution to render the pension plan utterly safe and riskless. However, the sponsors will have other productive uses for its capital and may very well be in distress when asked or required to make substantial contributions. A large contribution may cause the pension plan to go bankrupt. Thus, while there is an immediate trade-off between contribution today and risk reduction for the pension plan, the long-term health of the organization must also be considered.

There is unanimity about the long-term joint survivability of the sponsoring organization and the pension plan. A healthy organization will be able to fulfill its promises in the future—in terms of the DB pension plan. Thus, strategies which can reduce future contributions and protect the surplus should be implementable. More will be said about this issue in the empirical tests (Section 3.5). For our purposes,
we aim to please all (or a majority) of stakeholders with our proposed investment strategy.

To highlight the benefits of a method to protect the asset wealth and pension surplus, we must understand the characteristics of a market crash, for instance, as took place in 2000/2001 and in 2008/2009. The first observation is that the equity markets dropped dramatically in short- or mid-term speed (certainly within a year). Thus, any protection must be able to adjust dynamically in weeks or months or the protection must be in place well before the crash occurs. In addition to stock market drops, there are several other common characteristics to a crash, including higher volatility, contagion across asset categories (very high correlation coefficients), and lower government interest rates (in situations when the government is considered safe and sound). Thus, any model with a fixed correlation and single-period structure, such as the traditional Markowitz model, will be unlikely to provide much diversification benefits since the market’s behavior during a crash is very different from behavior during normal times.

An effective ALM model must take into account short time steps – months, weeks, or even days. And the investment strategy must aim to protect both the asset wealth and the pension surplus. We suggest that an efficient approach for dealing with pension-surplus protection is to implement dynamic strategies involving long-term government bonds (or strips during crises). We call our strategy – duration enhancing overlay (DEO) – for defined benefit pension plans. DEO provides the best of both worlds since, as we will demonstrate in Section 3.5, it protects asset wealth and the pension plan’s surplus (which has an impact on future expected contribution).

The basic concept is straightforward: Increase the duration of the assets in a dynamic fashion as conditions in equities and other risk-bearing assets deteriorate (Mulvey et al. 2010). To accomplish this objective, we take positions in long-duration government bonds (or strips) and take an equal amount of short positions in short-term government securities. The strategy is implemented by means of a quasi-protection process. The motivating principle involves the “flight to quality” during stressful economic environments. The strategy is efficiently implemented via the futures/swap markets (Mulvey et al. 2007). Thus, the futures strategy does not impact the investor’s core asset portfolio; optimal asset allocation remains mostly intact. At the strategic level, futures instruments do not take capital, but possess risks and thereby require risk allocation procedures.

The remainder of the chapter is organized as follows. The next section defines the asset–liability management model for a DB pension plan. The structure involves integrating the sponsoring organization with the pension plan as a single entity (enterprise risk management) across a large number of stochastic scenarios. The generic model can be readily specialized for a standalone pension plan. Section 3.3 defines alternative objective functions, depicting the goals of the various stakeholders – retirees, sponsoring company, governments, and so on. A short discussion of solution strategies is included. The DEO overlay strategy appears in Section 3.4, along with several variants. Section 3.5 describes the empirical results of applying the DEO strategy. Both backtests and a forward-looking ALM system are evaluated showing the benefits of a global DEO strategy. Conclusions follow in Section 3.6.
3.2 An Asset–Liability Management Model for DB Pension Plans

This section defines our asset and liability management (ALM) model for a defined benefit pension plan. We follow the framework established in Mulvey et al. (2005a, 2008) via a multi-stage stochastic program. This framework allows for realistic conditions to be modeled such as the requirement for funding contributions when the pension deficit exceeds a specified limit and addressing transaction costs. However, as with any multi-stage stochastic optimization model, the number of decision variables grows exponentially with the number of stages and state variables. To compensate and to reduce the execution time to a manageable amount, we will apply a set of policy rules within a Monte Carlo simulation. The quality of the policy rules can be evaluated by means of an “equivalent” stochastic program. See Mulvey et al. (2008) and Section 3.5 for further details.

To start, we establish a sequence of time stages for the model: \( t = [1, 2, \ldots, T] \). Typically, since a pension plan must maintain solvency and be able to pay its liabilities over long time periods, we generate a long-horizon model – over 10–40 years with annual or quarterly time steps. To defend the pension plan over short time periods, we employ the DEO overlay strategies – which are dynamically adjusted over days or weeks. However, the target level of DEO is set by the strategic ALM model. In effect, the DEO provides a tactical rule for protecting the pension plan during turbulent conditions.

We define a set of generic asset categories \( \{A\} \) for the pension plan. The categories must be well posed so that either a passive index can be invested in, or so that a benchmark can be established for an active manager. In the ALM model, the investment allocation is revised at the end of each time period with possible transaction costs. For convenience, dividends and interest payments are reinvested in the originating asset classes. Also, we assume that the variables depicting asset categories are non-negative. Accordingly, we include “investment strategies” in \( \{A\} \), such as long–short equity or buy–write strategies in the definition of “asset categories.” The need for investment strategies in \( \{A\} \) has become evident as standard long-only securities in 2008 became almost completely correlated (massive contagion). The investment strategies themselves may take action (revise their own investment allocations) more frequently and dynamically than as indicated by the strategy ALM model.

Next, a set of scenarios \( \{S\} \) is generated as the basis of the forward-looking financial planning system. The scenarios should be built along several guiding principles. First, importantly, the time paths of economic variables should be plausible and should to the degree possible depict a comprehensive range of plausible outcomes. Second, the historical data should provide evidence of reasonable statistical properties, for example, the historical volatilities of the stock returns over the scenarios should be consistent with historical volatilities. Third, current market conditions should be considered when calibrating the model’s parameters. As an example, interest rate models ought to begin (time = 0) with the current spot rate or forward rate curves. Third, as appropriate, expert judgment should be taken into account. The expected returns for each asset category should be evaluated by the
institution’s economists. There should be consistency among the various parties in a financial organization or at least the differences should be explainable. A number of scenario generators have been successfully applied over the past 25 years for asset and liability management models (Dempster et al. 2003; Høyland and Wallace 2001; Mulvey 1996).

For each \( i \in \{A\}, t = [1, 2, \ldots, T], s \in \{S\} \), we define the following parameters and decision variables in the basic ALM model:

**Parameters**

- \( r_{i,t,s} = 1 + \rho_{i,t,s} \), where \( \rho_{i,t,s} \) is the rate of return for asset \( i \), in period \( t \), under scenario \( s \)
- \( g_{t,s} = 1 + \gamma_{t,s} \), where \( \gamma_{t,s} \) is the percent growth rate of the organization in period \( t \), under scenario \( s \)
- \( b_{t,s} \) Payments to beneficiaries in period \( t \), under scenario \( s \)
- \( \pi_s \) Probability that scenario \( s \) occurs - \( \sum_{s \in S} \pi_s = 1 \)
- \( x_{i,0,s}^{\rightarrow} \) Amount allocated to asset class \( i \), at the end of period 0, under scenario \( s \), before first rebalancing
- \( y_0^b \) Value of the organization at the end of time period 0
- \( e_{t,s} \) Borrowing costs for period \( t \), under scenario \( s \)
- \( \sigma_{i,t} \) Transaction costs for rebalancing asset \( i \), period \( t \) (symmetric transaction costs are assumed)

**Decision variables:** Except as indicated, these variables are non-negative

- \( x_{i,t,s} \) Amount allocated to asset class \( i \), at the beginning of period \( t \), under scenario \( s \), after rebalancing
- \( x_{i,t,s}^{\rightarrow} \) Amount allocated to asset class \( i \), at the end of period \( t \), under scenario \( s \), before rebalancing
- \( x_{i,t,s}^{BUY} \) Amount of asset class \( i \) purchased for rebalancing in period \( t \), under scenario \( s \)
- \( x_{i,t,s}^{SELL} \) Amount of asset class \( i \) sold for rebalancing in period \( t \), under scenario \( s \)
- \( x_{i,t,s}^{TA} \) Total amount of assets in pension plan at the beginning of time period \( t \), under scenario \( s \)
- \( y_{t,s} \) Value of the organization after a contribution is made in period \( t - 1 \), under scenario \( s \)
- \( y_{t,s}^{\rightarrow} \) Value of the organization at the end of period \( t \), before contribution is made in period \( t \), under scenario \( s \)
- \( y_{t,s}^{CONT} \) Amount of cash contributions made at the end of period \( t \), under scenario \( s \)
- \( x_{i,t,s}^{BORR} \) Amount of borrowing by the organization at the end of period \( t \) for use in pension plan, under scenario \( s \)

Given these decision variables and parameters, we can define the general multi-objective optimization model as follows:
Maximize \( U\{Z_1, Z_2, \ldots, Z_k\} \), [ALM]

where the goals are defined as functions of the decision variables (below): \( Z_k = f_k(x, y) \)

Subject to

\[
\sum_{i \in A} x_{i,t,s} = x_{t,s}^{TA} \quad \forall s \in S, \ t = 1, \ldots, T + 1, \quad (3.1)
\]

\[
x_{i,t,s} = r_{i,t,s} x_{i,t,s} \quad \forall s \in S, \ t = 1, \ldots, T, \ i \in A, \quad (3.2)
\]

\[
y_{t,s} = y_{t-1,s}^{\text{CONT}} - e_{t-1,s} \left(x_{t-2,s}^{\text{BORR}}\right) \quad \forall s \in S, \ t = 1, \ldots, T + 1, \quad (3.3)
\]

\[
x_{i,t,s} = x_{i,t-1,s}^{\text{BUY}} + \sum_{i \neq 1} x_{i,t-1,s}^{\text{SELL}} (1 - \sigma_{i,t-1}) - x_{i,t-1,s}^{\text{BUY}} \quad \forall s \in S, \ i \neq 1, \ t = 1, \ldots, T + 1, \quad (3.5)
\]

\[
x_{1,t,s} = x_{1,t-1,s}^{\text{BUY}} + \sum_{i \neq 1} x_{i,t-1,s}^{\text{SELL}} (1 - \sigma_{i,t-1}) - \sum_{i \neq 1} x_{i,t-1,s}^{\text{BUY}} - b_{t-1,s} + y_{t-1,s}^{\text{CONT}} + x_{t-1,s}^{\text{BORR}} \quad \forall s \in S, \ t = 1, \ldots, T + 1, \quad (3.6)
\]

\[
x_{i,t,s} = x_{i,t,s'} \quad \text{and} \quad y_{t,s} = y_{t,s'}^{\text{CONT}}, \ x_{t,s} = x_{t,s'}^{\text{BUY}}, x_{t,s} = x_{t,s'}^{\text{SELL}}, \ x_{t,s} = x_{t,s'}^{\text{SEL}} \quad \forall s \text{ and } s' \text{ with identical historical path to } t, \text{ and } \forall t, \forall s. \quad (3.7)
\]

Numerous additional constraints are required to manage the pension plan environment. For example, we will limit the amount of risks allowed in the portfolio by constraints:

\[
\text{Risk}\{Z_1, Z_2, \ldots, Z_k\} \leq \text{Risk}_{\text{max}}. \quad (3.8)
\]

A network graph (Fig. 3.1) depicts, for a given scenario, the pertinent cash flows for each asset and the company’s contribution. The graphical form allows managers to readily comprehend the model’s structure for the main cash flow constraints. For simplicity, we have excluded the non-network constraints in our ALM formulation (e.g., Rauh 2006). The non-anticipativity constraints (3.7) depend upon the format of the scenario tree; these conditions are addressed in our tests by means of “policy
rules” over computable state variables. We do not assume any Markov property in our formulation.

3.3 Multi-objective Functions and Solution Strategies

Setting an investment strategy for a DB pension plan is complicated by conflicting requirements and the diverse goals of the stakeholders. Each of the interested groups is served by several of the defined Z-objective functions. Especially relevant is the relationship between the pension plan and the sponsoring organization. In the USA, DB pension plans fall under the auspices of the Departments of Labor and Tax, and the requirement of the 1974 Employee Retirement and Security Act ERISA (with ongoing modifications by changing regulations and Congressional action). Thus, a US-based DB pension plan must undergo annual valuations by certified actuaries, who compute the various ratios including the accumulated benefit obligations (ABO), the projected benefit obligations (PBO), and funding ratios. These valuation exercises help determine the requirements for contributions by the sponsoring organization and the fees to be paid to the quasi-governmental organization PBGC (whose job is to take over pensions from bankrupt companies).

We will employ the following five objective functions (Mulvey et al. 2005a, 2008).
3.3.1 Economic Value

The first function, called economic value, is a combination of the expected risk-adjusted discounted value of future contributions (Black 1995) and the discounted value of the surplus/deficit of the pension plan at the horizon, time = \( T \). The first part of this objective provides a measure for the long-run cost of the pension trust:

\[
Z_{1\_A} = \sum_{s \in S} \pi_{s} \sum_{t \in T} y_{t,s}^{\text{CONT}} / (1 + r_{t,s}),
\]

where the risk-adjusted discount rate equals \( r_{t,s} \) and is based on actuarial and economic judgment. The second part involves the discounted value of the pension’s surplus wealth at the end of the planning horizon:

\[
Z_{1\_B} = \sum_{s \in S} \pi_{s} Sw_{r+1,s}.
\]

This part focuses on the investment strategy and contribution policy of the pension trust so that the highest average surplus value is achieved. Thus, the first objective function is to maximize economic value:

\[
Z_1 = Z_{1\_B} - Z_{1\_A}
\]

3.3.2 Volatility of \( Z_1 \)

The second objective function indicates the volatility of the cost of running the pension plan. It is a risk measure for the most important objective function \( Z_1 \):

\[
Z_2 = \text{Std}(Z_1).
\]

3.3.3 Worst Case of \( Z_1 \)

Next, we compute the probability that the sponsoring organization will make an excess contribution, defined as a second risk-based objective. This function is calculated as follows: \( Z_3 = \sum_{s \in S} \pi_{s} I_{s} \), where the indicator is \( I_{s} = \{1 \text{ if there exists an excess contribution under scenario } s, \text{ and } 0 \text{ otherwise} \} \). An alternative is to employ the more tractable conditional value at risk measure (Bogentoft et al. 2001).

3.3.4 Probability of a Significant Contribution

As a fourth measure, we focus on the likelihood of a large payment, called excess contribution, to the pension trust at any point during the planning period:
\[ Z_4 = E \left[ \left( y_{t,s}^{\text{CONT}} - \alpha \cdot y_{t,s}^{\uparrow\downarrow} \right)^2 \right], \] where \( \alpha \) equals a substantial fraction of the company’s total capital at the time of the contribution (Bogentoft et al. 2001). This function approximates the company’s ability to service its pension trust under severe circumstances. This risk measure highlights situations in which the organization may have difficulty paying its contributions (Ippolito 2002).

### 3.3.5 Volatility of Contribution

For many companies, the volatility of the contribution can be an important factor since it has a direct impact on the volatility of earnings for the sponsoring firm (Peskin 1997): \( Z_5 = \text{Std}(Z_{1,A}) \).

Other objective functions have been applied in practice (see Mulvey et al. 2008, for example). However, to keep the discussion manageable we assume the aforementioned five objective functions. Since these objectives are clearly conflicting, we develop a multi-objective financial planning model in which the trade-offs among the goals are illustrated. The goal of the overall model is to maximize the health of the pension plan and the sponsoring company. We will show that the integrated entity can benefit by applying the developed global DEO strategy (discussed in the next section).

Due to the massive size of the ALM model, we approximate its solution by reference to a set of state-dependent policy rules. These rules have been developed and evaluated by executing a large set of stochastic programming models. It can be shown that for many pension plans (Mulvey et al. 2008), the results of the stochastic programs compare favorably with the performance of the developed policy rules, thereby we apply the policy rules in our empirical tests in Section 3.5.

### 3.4 Advantages of Futures Market Strategies

At the strategic level, the futures markets does not require any direct capital investment and is thereby distinguished from traditional asset variables \( \{A\} \). A prominent example involves commitments made in the futures/forward/swap markets (Mulvey et al. 2007). Here, for example, the investor may engage in a contract to purchase or sell a designated amount of a commodity such as corn at a designated date in the future. The investors (buyer and seller) must, of course, conform to exchange requirements for initial and margin capital and must participate in the mark-to-the-market mechanisms at the end of each trading day. We do not model these tactical issues on our strategic ALM model. Rather, we treat securities in the futures market as adjuncts to the core assets and assume that all margin calls are managed in the standard way to avoid margin calls. These investments are defined via “overlay variables.” Implicitly we assume that the size of the overlay variables is relatively
modest in scale and diverse enough to treat them at the strategic level without the need for tactical issues.

There are several advantages to futures market investments. First, it is straightforward to “go” short or long on a particular contract without the burden and costs of borrowing the security (traditional shorting). Second, long/short investments in commodities, currencies, and fixed income combinations can assist the investor in achieving the goal of achieving wide diversification. For a DB pension plan, there are additional advantages. In particular, a pension plan must maintain a health funding ratio in order to minimize contributions from the sponsoring organization to the pension plan. As mentioned, the funding ratio and pension surplus depend upon not only upon the market value of assets but also on the discounted value of estimated future cash flows (liabilities to pay retirees). The discount rate has a large impact on the funding ratio. During major economic downturns, for instance, the risk-free rate can drop by substantial amounts – with a possible commensurate decrease in the funding ratio. Accordingly, the duration of assets and the duration of liabilities will contribute to the management of a DP pension plan. A duration mismatch can be addressed by engaging in swaps or other futures/forward market operations. Mulvey et al. (2007, 2010) provide further discussions of overlay strategies.

We add futures strategies via a new set \( \{A-O\} \) and associated decision variables – \( x_{j,t,s} \) for \( j \in \{A-O\} \) – to the ALM model:

\[
\sum_{j \in \{A-O\}} x_{j,t,s} \cdot (r_{j,t,s}) = x_{t,s}^{\text{Overlay}} \hspace{1cm} \forall s \in S, t = 1, \ldots, T + 1. \tag{3.9}
\]

The total return of the futures variables in time \( t \) and under scenario \( s \) is defined by \( r_{j,t,s} \). We include the return from these variables in the cash flow constraint (3.6) as follows:

\[
x_{1,t,s} = x_{1,t-1,s}^{\uparrow} + \sum_{i \neq 1} x_{i,t-1,s}^{\text{SELL}} (1 - \sigma_{i,t-1}) - \sum_{i \neq 1} x_{i,t-1,s}^{\text{BUY}} b_{t-1,s} + y_{t-1,s}^{\text{CONT}} + x_{1,t-1,s}^{\text{BRR}} + x_{t-1,s}^{\text{Overlay}} \\
\forall s \in S, t = 1, \ldots, T + 1. \tag{3.10}
\]

The futures variables provide much flexibility to establish a widely diversified and dynamic portfolio for a DB pension plan. A prime example is the global duration-enhancing strategy – called global DEO described in detail in this chapter. This strategy extends a single country (the USA) and fixed-mix version of DEO (Mulvey and Kim 2010) by modeling the process in a dynamic fashion across several sovereign debt markets.

The DEO concept increases the commitment to long-duration government bonds, e.g., strips, during stressful market conditions. Figure 3.2 further motivates the strategy. Here, the correlation between equity returns and government bond returns becomes negative during economic downturns. Why? This relationship is caused by investors seeking the safest investment during high volatility, crash periods. As a consequence, the optimal level of government long-term bonds in a portfolio
becomes much higher than during time periods in which the correlation is positive (normal periods). We can model this process with multiple regimes.

As mentioned, the futures strategies are included in the ALM model as expanded variables in the multi-stage stochastic program. To simplify the process, we apply a non-anticipative policy rule. In particular, the approach for investing in a long/short strategy based on the flight-to-quality condition. The investment is made under a set of three triggers. Whenever the tests are active (engaged), the strategy takes action in the respective countries by “purchasing” a long-duration government bond and by shorting a short-term government security (t-bills in the USA). The long/short strategy can be implemented in several equivalent ways. A swap can be activated. Alternatively, a futures market such as the CME’s ultra-bond index can be employed. In the latter case, a long position in the futures market is the sole investment needed since the costs of the short side is taken care of in the price of the futures contract. For investors who do not have access to futures markets, the DEO strategy can be applied with exchange-traded funds, such as long-government bond funds (e.g., TLT and EDV).

The first trigger involves tracking volatility of equity markets in the respective country. Whenever short-term volatility exceeds a long-term moving average, the volatility trigger is engaged. A second trigger is aimed at short-term indicators. This trigger will be disengaged for a certain time period whenever a sufficiently large loss occurs. The third trigger takes into account the spread in the yield curve between long and short instruments. When the spread exceeds a fixed parameter, this trigger is engaged. The three triggers must all be positive before a position is established. The target amount of underlying securities is a fixed percentage of the investor’s
capital at any time $t$. For the implementation in the next section, we evaluate DEO in three regions: (a) the USA, (b) Japan, and (c) Europe.

The time step for the DEO strategy is much shorter than the annual time periods in the strategic ALM model. We analyze the DEO strategy on a daily and monthly basis, whereas the strategic model renders decisions yearly. In this manner, we combine the strategic ALM model with a tactical policy rule. The combination provides a dynamic and responsive process to protect the pension surplus during crash regimes, while at the same time linking to the strategic ALM model – which is consistent with the decision-making setting for large institutional investors (annual meetings to determine allocation decisions). Other tactical processes can be added in a similar fashion.

### 3.5 Empirical Tests

The empirical tests have been conducted in two ways. First, we evaluate the DEO strategies over historical backtest periods. Then, we apply a forward-looking ALM system.

#### 3.5.1 Historical Backtests

We selected the decade January 1, 2000, – December 31, 2009. This period has had two major downturns with very large drawdown values (almost 60% in the majority equity markets). Also, global co-integration has taken place during this time period. Markets are connected throughout the world as never before. Table 3.1 depicts summary statistics for the three regions tested – the USA, Europe, and Japan. Note that the DEO strategies all display positive returns with modest drawdown in the US version, and much higher drawdown values in Europe and Japan. A combined equal-weighted strategy for the three regions with monthly rebalancing (global DEO 3X) gives excellent returns, but with commensurately high risks in terms of volatility and drawdown values. A less leveraged global DEO strategy has very good returns and very modest volatility and drawdown values. Note the comparison with three traditional assets: The S&P 500 equity index and two commodity indices (AIG and Goldman Sachs). The global DEO strategy outperforms these three benchmarks over the historical decade.

The DEO strategies are based on overlay concepts. Hence, the performance numbers should provide almost additive performance for a traditional portfolio. This issue is made more important when the positive returns of the DEO strategy occurs mostly during downturns in equity and other traditional assets. To this point, the correlations in monthly returns among the seven asset classes in Table 3.1 (excluding global DEO 3X) are given in Table 3.2. We present the correlation coefficients for the full data period as well as for two subsets: S&P500 losing months and winning months. Overall, the DEO strategies have very low correlation with the traditional
Table 3.1 Performance of DEO strategies in three countries and comparison with other assets January 1, 2000–December 31, 2009

<table>
<thead>
<tr>
<th></th>
<th>US DEO</th>
<th>Euro DEO</th>
<th>Japan DEO</th>
<th>Global DEO (1/3 each)</th>
<th>Global DEO (100% each)</th>
<th>DJ AIG commodity index</th>
<th>GS commodity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual geometric return</td>
<td>5.39%</td>
<td>6.85%</td>
<td>4.72%</td>
<td>5.89%</td>
<td>16.65%</td>
<td>−2.68%</td>
<td>4.20%</td>
</tr>
<tr>
<td>Annual volatility</td>
<td>8.71%</td>
<td>11.44%</td>
<td>11.38%</td>
<td>8.05%</td>
<td>24.16%</td>
<td>16.28%</td>
<td>17.34%</td>
</tr>
<tr>
<td>Maximum drawdown (MDD)</td>
<td>7.58%</td>
<td>21.32%</td>
<td>17.75%</td>
<td>9.25%</td>
<td>25.80%</td>
<td>52.80%</td>
<td>54.50%</td>
</tr>
<tr>
<td>Return per volatility</td>
<td>0.62</td>
<td>0.60</td>
<td>0.41</td>
<td>0.73</td>
<td>0.69</td>
<td>−0.16</td>
<td>0.24</td>
</tr>
<tr>
<td>Return per MDD</td>
<td>0.71</td>
<td>0.32</td>
<td>0.27</td>
<td>0.64</td>
<td>0.65</td>
<td>−0.05</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table 3.2 Monthly return correlations: First panel is for the full period of January 2000 to December 2009 and the second and third panels are for S&P500 losing and winning months, respectively

<table>
<thead>
<tr>
<th></th>
<th>US DEO</th>
<th>Euro DEO</th>
<th>Japan DEO</th>
<th>Global DEO</th>
<th>SP500</th>
<th>DJ AIG CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro DEO</td>
<td>0.36</td>
<td>0.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan DEO</td>
<td>0.31</td>
<td>0.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global DEO</td>
<td>0.68</td>
<td>0.81</td>
<td>0.79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP500</td>
<td>−0.08</td>
<td>0.15</td>
<td>0.04</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DJ AIG CI</td>
<td>−0.22</td>
<td>0.30</td>
<td>0.01</td>
<td>0.07</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>GSCI</td>
<td>−0.23</td>
<td>0.17</td>
<td>−0.09</td>
<td>−0.05</td>
<td>0.20</td>
<td>0.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>US DEO</th>
<th>Euro DEO</th>
<th>Japan DEO</th>
<th>Global DEO</th>
<th>SP500</th>
<th>DJ AIG CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro DEO</td>
<td>0.15</td>
<td>0.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan DEO</td>
<td>0.20</td>
<td>0.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global DEO</td>
<td>0.54</td>
<td>0.76</td>
<td>0.81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP500</td>
<td>−0.15</td>
<td>0.13</td>
<td>−0.14</td>
<td>−0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DJ AIG CI</td>
<td>−0.24</td>
<td>0.44</td>
<td>−0.02</td>
<td>0.11</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>GSCI</td>
<td>−0.25</td>
<td>0.35</td>
<td>−0.13</td>
<td>0.01</td>
<td>0.40</td>
<td>0.92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>US DEO</th>
<th>Euro DEO</th>
<th>Japan DEO</th>
<th>Global DEO</th>
<th>SP500</th>
<th>DJ AIG CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro DEO</td>
<td>0.48</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan DEO</td>
<td>0.39</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global DEO</td>
<td>0.75</td>
<td>0.83</td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP500</td>
<td>−0.16</td>
<td>0.05</td>
<td>0.21</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DJ AIG CI</td>
<td>−0.21</td>
<td>0.16</td>
<td>0.03</td>
<td>0.01</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>GSCI</td>
<td>−0.23</td>
<td>0.02</td>
<td>−0.07</td>
<td>−0.10</td>
<td>0.10</td>
<td>0.89</td>
</tr>
</tbody>
</table>

As we take up the issue of optimal asset allocation with respect to various objectives in the next section, our backtesting analyses demonstrate the added benefits asset classes. Furthermore, global DEO has a slightly negative correlation with the S&P500 when the latter is losing and a slightly positive one when the markets are up.
of overlay strategies for investors with traditional asset allocations which are not necessarily optimal. Such an investor may have allocated 60% in S&P500 and 40% in US Treasury Bills with monthly rebalancing during the period January 2000 to December 2009. In Fig. 3.3, we plot how this investor may have fared during this decade without and with global DEO. It is apparent that with the DEO, the investor does not underperform in bull markets and can move in the opposite direction in bear markets (e.g., recent downturn at the end of 2008).

Another hypothetical investor might have picked the best-performing fixed-mix strategy during that decade by allocating about 70% in long-term (25+ years) US government bonds and 30% in GSCI. This strategy would have provided more than 7% annual geometric return with a maximum drawdown of about 20%. Even this performance-concerned fixed-mix investor with perfect foresight would have benefited from DEO strategies. As depicted in Fig. 3.4, given the perfect foresight, the base strategy performs quite well. Nonetheless, a modest amount of global DEO brings a remarkable improvement without increasing the drawdown.

To summarize the performance of some traditional strategies in risk-reward framework and how they are improved by DEOs, we present in Fig. 3.5 annual geometric return and maximum drawdown values in a scatter plot analysis. The unfilled markers correspond to traditional strategies whereas the filled ones with the same geometric shape are for the same strategies with a modest amount of global DEO.
Fig. 3.4 Time series plot of $1 invested with a perfect foresight compared with the added benefits of DEO

Fig. 3.5 Risk-reward plots of various fixed-mix strategies with and without global DEO
3.5.2 Forward-Looking ALM Tests

From a strategic vantage point for an investor or pension sponsor, rule-based simulators are the instruments of choice for ongoing strategic risk control and management. These approaches allow for covering with very high degree of accuracy all aspects of the complex, individual situation in which strategic financial decisions are made. Realistic simulations of an investments vehicle’s stochastic behavior is a rich and reliable source for the information needed in ongoing strategic risk control activities as well for regularly revising decisions on risk optimal strategies allocation.

Most strategic decisions occur across a multi-periodic context, often with complex, path-dependent rules for rebalancing, contribution, and withdrawals. In most cases such conditional rebalancing rules can be found for each single asset; it is necessary to include them in order to represent each asset’s marginal contribution. Such rules are not only an essential aspect of asset allocation, but also the rules offer the opportunity to design and optimize them as an integral part of the strategy. In that sense one has to define strategic asset allocation not only as the composition of a portfolio, which would be sufficient if the world were a static one, but rather as an asset allocation strategy, which includes portfolio compositions and management rules. On the level of the strategy, these rules should not depend on exogenous conditions of single markets, but rather on the overall goal achievement compared to the individual preference structure, e.g., at a certain high funding level, a de-risking of the strategic portfolio happens, since no more risk taking is necessary to achieve the overall goals.

Such management rules always depend on additional sets of evaluation rules, internally or externally given, to evaluate the development of the results of the strategies, for example, under commercial law balance sheet and profit/loss calculations, taxation, or various other aspects. These rules produce incentives to favor one allocation strategy over another. Thus it is a basic requirement in order to find individually optimal strategies, to work with rule simulators, which represent relevant management and evaluation rules adequately and with the least level of simplification. This requirement is matched by modern rule simulators such as the PROTINUS Strategy Cockpit™ – described below and employed for the forward-looking tests.

When the multi-period environment is represented accurately, it becomes possible to design individually specific sets of objectives, constraints, and bounds. This is a major advantage of rule simulators, for which it is a condition qua sine non to have optimization and simulation in a single model setting. The necessity of optimizing strategies based on individual objective functions comes from the fact that any strategic investment is done to serve not a general common goal, but always to fulfill goals depending on individual conditions, rule sets, and preference structure. Systems like the PROTINUS Strategy Cockpit™ allow for setting up any objective functions derived from the variable of the rule set and perform desired calculation on them.
In this context, a policy-rule simulator can be seen as financial laboratory tool, allowing designing, testing, and optimizing strategies in a real-life setting tailored to the investor’s situation and needs and assumptions. Additionally these instruments are perfect to measure regularly and prospectively the development of the strategic risk positions based on updated figures with the same model, with which these positions were developed. This additional application of such simulators has been sparse in the past. Typically they were only employed in allocation studies on a yearly or even longer basis. When used for regular controlling, they give valid information which helps minimize the effect of the possible crises. Ideally, such implementations will increase over time.

Unfortunately, most rule-based optimization problems lead to non-convex models – thus requiring computationally intensive, heuristic algorithms. The length of the vector which is to be optimized is limited since it increases the number of combinations and thus computational time. Therefore, it was standard until recently that one short vector for all \( s, t \) was optimized, which can be interpreted as the best compromise solution over all states of the environment. With advanced systems such as the one briefly described herein, this limitation can be overcome to some degree by optimizing on a small number of short vectors which are each assigned to certain conditions, called regimes. Such regimes can be defined by the time step, e.g., every 3 years a new fixed-mix rebalancing vector is defined, or by some state conditions, e.g., there is a vector for a normal funding range and two additional ones for positive and negative funding situations. These approaches have already been successfully implemented; they give a priori recommendations on what to do when arriving in some specific and maybe critical environmental states. Investor can benefit by this type of information.

3.5.2.1 The PROTINUS Strategy Cockpit™

Protinus Strategy Cockpit is an integrated development environment for modeling multi-period stochastic planning problems in finance. It has been employed successfully as a strategic risk controlling and risk management tool over the past decade. It is a policy-rule simulator and optimizer, working in all MS Windows™ and MS Server™ environments developed by the consulting firm PROTINUS in Munich, Germany. Ziemba and Mulvey (1998) described such systems in general, which they called decision rule approaches in comparison to alternative approaches, at a time when only very small number of implementations of such approaches existed. Predecessors of the PROTINUS Strategy Cockpit™ developed by the former Princeton-based organization Lattice Financial LLC were implemented, for example, as the first and, for several years, primary ALM system employed at the large German corporate Siemens.

The PROTINUS Strategy Cockpit™ generates user-specific rules by assembling a library of building block rules, ranging from simple arithmetic operations to complex accounting standards. The building blocks are put into the desired order via an execution schedule and where necessary a quantitative condition for their execution.
PROTINUS Strategy Cockpit™ includes a powerful meta-heuristic, non-convex optimization algorithm based on early concepts of Glover’s Tabu search (Glover and Laguna 1997). The analyses are updated from past runs by saving solution information as templates and by grouping into reports. PROTINUS Strategy Cockpit™ includes project management tools typically needed when working with large scenario spaces and complex rule sets and performing risk measurement and allocation studies. Figures 3.6 and 3.7 are screenshots from the financial engineers’ version. There is also a configuration available, which provides a fully automatic version, called PROTINUS Strategy Factory™. Over the past several years, this system has been implemented to individually optimize on a quarterly basis, in a fully automatic fashion, several tens of thousands of portfolios for unit-linked insurance contracts provided by the Insurance Company Skandia in several countries in central Europe.

3.5.2.2 Evaluating Several Versions of the Global DEO Strategy

This section has two purposes. First, it provides brief examples of how a rule simulator can help determine the effects of addition-specific investment products to a given asset universe, a question investors as well as providers of such products have

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**Fig. 3.6** Screenshot 1 showing several models with their basic structure. For the highlighted model its variables, with starting values, and a part of the building blocks, with the links to variables are shown.
Fig. 3.7  Screenshot 2: One example for integrated statistical analysis. In the middle an objective function is designed, picking a variable from list on the right and defining the calculation performed thereon with the statistics editor

to answer regularly. Second, we will analyze specifically how the DEO strategies perform in a prospective context.

The overlay strategies are evaluated in PROTINUS Strategy Cockpit™ with three case studies: an asset-only context, a pension plan with IFRS balance sheet calculations, and the same pension plan rule with an added conditional contribution rule. All three cases are based on scenarios for the DEO overlay strategies and a group of broad, standard markets, i.e., US and Euro-equity as well as Euro-government and Euro-corporate bonds. For the pension plan cases, IFRS liability scenarios are produced from the scenarios for inflation and discount rates of the economic model. The basic liability data representing the plan’s population with all its biometric characteristics come from a modified real data set. We choose to generate a 10-year, 1000-scenario space with a quarterly scaling, since all shorter time steps are not of the typical interest for the strategic investor. In addition, we employ a commodity overlay strategy, called the Princeton Index (Mulvey and Vural 2010), to provide additional diversification benefits.

For these analyses, we apply a cascade structure economic model which allows for the generation of consistent scenario spaces for market returns and fundamentals and liabilities. The economic model is again made out of a group of simple building blocks. Early versions of such models are described by Mulvey (1996). The model includes basic equations with mean reverting assumptions and derives most returns processes implicitly from the cascade of fundamental processes. These
return processes are either produced by functional dependencies or via advanced random number drawing techniques. For all processes the first four moments, including skewness and kurtosis, and the interactions among the variables can be defined explicitly. The cascade represents one core macroeconomic environment, typically representing the investor’s home region in order to include the local inflation and the rate, especially discount rate environment. These variables, along with scenarios for the liability variables such as IFRS defined benefit obligation (DBO), service cost, and pension payments are produced, so that a complete and fully consistent set of scenario spaces results, which represents accurately relevant exogenous risk factors.

To calibrate the model means for the fundamentals and the standard markets, we construct estimates based on long-term forecasts available from standard sources in combination with sound, standard forecasting approaches (Mulvey 1996; Høyland and Wallace 2001). Higher moments including skewness and excess kurtosis are solely dependent on historic data. For the overlays all values are taken from the historic simulations as described before.

The rules simulate quarterly fixed-mix rebalancing, which is applied to the long portfolio for the standard markets as well as for the four overlay strategies. More complex conditional rebalancing rules are not chosen in order to have a clearer view on the effects of adding the overlay strategies to a standard long portfolio. The long portfolio represents the total asset wealth of the investor. The derivatives (overlay) portfolio contributes to this wealth only through its quarterly change in its value. The IFRS pension model has additionally built in an IFRS building block, which is executed every fourth quarter and performs a full IFRS balance and P&L calculation with the so-called SORIE approach. For the third case, a contribution rule analogous to the Pension Protection Act rule in the USA is implemented.

In all three cases, we optimize first on a portfolio vector including only the four standard markets and then on a vector including the long portfolio of the four standard markets and the four overlay strategies. This factor is the sum of the fractions of the single overlay positions, given by the user or determined by the optimization. Thus the optimization determines the optimal leverage as well as the composition of the overlay portfolio. For the asset-only case we restrict this leverage factor to 2, for the pensions model it is set to 1, to represent some preferences of various types of investors roughly. Each single position is constrained to 100% of the NAV of the long portfolio.

We compare in our evaluations long-only optimizations and those with the overlay strategies to assess the effects on the total result. Due to the short computing time we ran several dozens of optimizations with various non-convex objective functions. The following represents a selection focussing on typical types of objectives, optimized regularly in the consulting practice during last decade.

### 3.5.2.3 Asset-Only Case

For this case, we work with an objective function and weight therein, which represent a conservative investor, who is not required to obey any institutional legal requirements. The first part of the function calculates in each point in time the
Table 3.3 Allocations for portfolios with and without overlays in the asset-only case

<table>
<thead>
<tr>
<th></th>
<th>Portfolio long only (%)</th>
<th>Portfolio with overlays (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro stocks</td>
<td>8.0</td>
<td>6.0</td>
</tr>
<tr>
<td>US stocks</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Euro gov.</td>
<td>92.0</td>
<td>58.6</td>
</tr>
<tr>
<td>Euro corp.</td>
<td>0.0</td>
<td>35.4</td>
</tr>
<tr>
<td>DEO Euro</td>
<td>na</td>
<td>0.0</td>
</tr>
<tr>
<td>DEO USD</td>
<td>na</td>
<td>3.5</td>
</tr>
<tr>
<td>DEO JPN</td>
<td>na</td>
<td>1.9</td>
</tr>
<tr>
<td>Princeton index</td>
<td>na</td>
<td>5.1</td>
</tr>
</tbody>
</table>

5-percentile of the total portfolio’s profit and loss and arithmetic average of these values along time. The second part calculates the discrete return along each scenario and the arithmetic average thereof at the end of the planning horizon. Examples for a better fit to specific individual investors would be, besides the weight between the two parts, some weighting along time or the introduction of some target return or wealth path of which deviations are minimized. We choose a weight which leads to conservative portfolios in the long positions. The weight remains unchanged for both the long only as well as for the optimization including the derivatives position.

As one finding, including the overlay strategies does not change the distribution among the core portfolio of bonds and equities significantly. When the overlay strategies are added, the long portfolio shifts into corporate bonds to some degree allowing for higher returns and additional diversification (Table 3.3).

Second, the optimal solution in this more risk-averse context does not require high leverage. As expected, an optimum solution when combing the overlay strategies with an existing strategy is not necessarily reached when using the maximum leverage is allowed. In this case, the maximum could have been as high as 200% of the volume of the long portfolio. But already by adding less than 10% overlays clear improvements on development of the portfolios can be observed especially on the level of 5th percentile (Fig. 3.8).

Clearly, a different objective function focussing on higher moments of the result variables would increase the leverage to profit more from the high skewness and kurtosis of the returns of the strategies. But for this quite representative conservative case, low leverage is enough.

3.5.2.4 Pension Plan ALM Example 1

For the pension plan example we optimize on an objective function maximizing the median of funded status across scenarios in each point in time and the arithmetic average thereof and minimizing arithmetic average of the 5-percentile of the funded status along each scenario. With more aggressive weights and a constraint that the Euro component of the portfolio is higher than the US component, which represents the typical local bias, the following fractions result for the two portfolios (Table 3.4).
Performance Enhancements for Defined Benefit Pension Plans

Fig. 3.8 Asset values over time for portfolios with and without overlays in the asset-only case

Table 3.4 Allocations for portfolios with and without overlay variables in ALM case 1

<table>
<thead>
<tr>
<th>Asset Class</th>
<th>Portfolio long only (%)</th>
<th>Portfolio with overlays (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro stocks</td>
<td>24.3</td>
<td>10.1</td>
</tr>
<tr>
<td>US stocks</td>
<td>21.9</td>
<td>9.1</td>
</tr>
<tr>
<td>Euro gov.</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Euro corp.</td>
<td>53.8</td>
<td>80.8</td>
</tr>
<tr>
<td>DEO Euro</td>
<td>na</td>
<td>0.0</td>
</tr>
<tr>
<td>DEO USD</td>
<td>na</td>
<td>22.8</td>
</tr>
<tr>
<td>DEO JPN</td>
<td>na</td>
<td>0.0</td>
</tr>
<tr>
<td>Princeton index</td>
<td>na</td>
<td>73.9</td>
</tr>
</tbody>
</table>

While minimizing what could also be called “funding at risk” (FaR) we try to reduce the deviations of a value that is calculated as the difference of market value of plan assets minus the DBO. In reality both are driven to some degree by local inflation and local discount factor for the DBO. These dependencies are very accurately covered by the economic model which generates the scenarios for both the asset returns and the liabilities. The resulting portfolios are thus not surprising, with a high fraction in local currency corporate bonds. When the overlay strategies are allowed, an alternative skewed source of return is available, resulting in de-risking the long portfolio and increasing the liability hedge.

The long portfolio alone has a proposed equity fraction which is likely the maximum most sponsors would accept nowadays. Nevertheless, this value is inadequate to achieve a solid funding given the liability requirements on average over time. The lower end of the distribution does show quite such dramatic developments. When adding the overlay strategies to the portfolio, the situation changes significantly. This change is caused by the volume of the overlays occurring at the maximum level allowed (i.e., at 100% of the value of the long portfolios (Fig. 3.9)).
When looking at the portfolio returns in a histogram the positive effect of adding the overlays to the portfolio can be seen quite clearly: The shape of the distribution is more skewed with a higher kurtosis (Figs. 3.10 and 3.11).

### 3.5.2.5 Pension Plan ALM Example 2

For the last analyses we engage an additional feature of the software, which encourages the modeler to run series optimizations automatically, for example, in order to change the weights of components of an objective function to generate a set of results – analogously to an efficient frontier. We expand the IFRS model with an additional contribution building block. This step executes whenever the funding...
ratio of plan assets vs. DBO in a scenario falls below 80%. In this case one-seventh of the deficit in the funding status is contributed in cash to the plan. Thus, future contributions in this situation are distributed evenly over the next 7 years; the resulting cash flow vector is discounted with the same rate for discounting the DBOs in this scenario.

We optimize on the objective one $Z_1$ (Section 3.3) with weight leading to more conservative results. The function consists of average of the present values of the contributions in each knot along a scenario and the average thereof across scenarios and time. The second part is the average of the surplus at the end of each scenario discounted again with the according rate.

The results are again evaluated with and without the overlay strategies. In this analysis, we find again the positive effects from the two prior cases. Adding the overlay strategies to the universe leaves the optimal long portfolio only marginally changed as compared to the long-only case (Table 3.5). As in the other cases, strategies with the overlays are clearly superior to one without, as it can be seen in the two graphs (Figs. 3.12 and 3.13).

Had we seen the advantages of adding the overlay strategies in the first two cases either on the risk or on the reward side, now this last example shows a combined effect on both goals. Again the allowed leverage of 100% is fully engaged, which explains the strong improvements achieved by adding the overlays. As with the previous case, adding the overlays allows for de-risking the long portfolio.

Incorporating the overlays increases the average terminal surplus significantly and at the same time reduces the need for average contributions. This case is representative of many pension plans – the input is based on real data, only slightly modified for modeling purposes. Importantly, we see that the pension plan can only fulfill its long-term goals with fairly high fractions of risk-bearing assets, which probably many trustees would not accept. In the median, the strategy with overlays
### Table 3.5 Allocations for portfolios with and without overlays in ALM case 2

<table>
<thead>
<tr>
<th>Maximum weight contributions</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro stocks</td>
<td>17.4%</td>
<td>20.8%</td>
<td>24.0%</td>
<td>28.3%</td>
<td>31.2%</td>
<td>35.8%</td>
<td>52.6%</td>
</tr>
<tr>
<td>US stocks</td>
<td>15.6%</td>
<td>18.8%</td>
<td>21.6%</td>
<td>25.4%</td>
<td>28.0%</td>
<td>32.2%</td>
<td>47.4%</td>
</tr>
<tr>
<td>Euro gov.</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Euro corp.</td>
<td>67.0%</td>
<td>60.4%</td>
<td>54.3%</td>
<td>46.3%</td>
<td>40.8%</td>
<td>32.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum weight surplus</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro stocks</td>
<td>10.3%</td>
<td>9.0%</td>
<td>10.6%</td>
<td>12.5%</td>
<td>31.0%</td>
<td>38.2%</td>
<td>52.6%</td>
</tr>
<tr>
<td>US stocks</td>
<td>9.2%</td>
<td>8.1%</td>
<td>9.5%</td>
<td>11.2%</td>
<td>27.9%</td>
<td>34.4%</td>
<td>47.4%</td>
</tr>
<tr>
<td>Euro gov.</td>
<td>2.2%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Euro corp.</td>
<td>78.3%</td>
<td>83.0%</td>
<td>79.9%</td>
<td>76.3%</td>
<td>41.0%</td>
<td>27.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>DEO Euro</td>
<td>12.5%</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>DEO USD</td>
<td>27.2%</td>
<td>25.4%</td>
<td>24.6%</td>
<td>29.1%</td>
<td>41.0%</td>
<td>34.5%</td>
<td>31.6%</td>
</tr>
<tr>
<td>DEO JPN</td>
<td>0.2%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>4.6%</td>
</tr>
<tr>
<td>Princeton index</td>
<td>60.1%</td>
<td>74.5%</td>
<td>75.4%</td>
<td>70.9%</td>
<td>78.8%</td>
<td>65.5%</td>
<td>63.9%</td>
</tr>
</tbody>
</table>

is already zero contributions in year 2, whereas the long portfolio alone reaches this point only after year 8. When looking at the 5% worst cases, the overlay strategies give impressive results – in 95% of all cases no contribution is required after year 10 (Figs. 3.12 and 3.13).

![Frontier Average Surplus / Average Contributions](image)

**Fig. 3.12** Efficient frontiers with and without overlay variables in ALM case 2
3.6 Conclusions

Defined benefit pension plans will continue to experience severe difficulties in developed countries due to long-term demographic trends, the lack of contribution from sponsoring organizations, and ineffective ALM planning. To address the third issue, we suggest that a systematic forward-looking planning process can assist pension plan administrators. This chapter has shown that a DB pension plan can benefit by applying a duration-enhancing strategy in conjunction with traditional asset allocation and ALM policies. Not only does the strategy improve asset performance but also it enhances economic value in the ALM context. We take advantage of the plan’s ability to increase duration in the assets – thereby improving performance across multiple objective functions. The approach allows the pension plan to continue to invest in higher returning assets such as equity and other risk-bearing instruments so that the long-term costs of managing a plan are reduced. At the same time, the risks to the pension surplus are constrained so that the plan’s future contributions are relatively low. This is relevant during an economic contraction when rendering a substantial contribution can be onerous for the sponsoring organization.

The global duration enhancement strategy provides an effective mechanism for carrying out the basic concepts and extends previous research (Mulvey et al. 2010). A global perspective can be helpful in providing diversification benefits – as compared with a single country system such as developed in the USA. The strategy is pertinent for a worldwide organization possessing pension plans across countries. The issue of balancing the needs of pension plans of subsidiaries in individual countries with the global enterprise remains difficult to resolve – and will continue to be a topic for future research.

The 2008 economic crash showed that traditional approaches to investment planning, such as embodied by the static Markowitz model, possess severe limitations. The assumption of a constant covariance matrix was widely in error during...
the October-December 2008 period as correlation coefficients approached 1. In conjunction, the need for dynamic remedies became evident as markets plunged throughout the world in a short order. Single-period models are generally unable to respond in an appropriate manner to protect the investor’s wealth or surplus for pension plans. Another contributing factor has been the lack of attention to liquidity concerns. Single-period portfolio models do not properly address transaction costs or liquidity constraints. In contrast, a multi-stage ALM model can include realistic issues such as dynamic policy rules (e.g., DEO), transaction costs, conditional liquidity constraints, and related real-world matters directly in the model. Likewise, multi-period ALM systems can evaluate innovative and dynamic investment strategies in a realistic forward-looking context.

References


