Asset/Liability-Management for Pension Funds: Some General Remarks

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Abstract

First the adequacy of asset/liability-management-concepts for driving the strategic asset allocation of pension funds is discussed from an economic point of view: From the main objectives of a pension fund a general investment principle can be derived which justifies the application of asset/liability-management-concepts. Then an overview of those asset/liability-models which are (at the present time) of practical importance is given. In this paper we do not restrict ourselves to British or American funds. Asset/liability-models can also be developed (and adequately applied) for funds in Germany and Switzerland paying regard to the special regulatory framework in those countries.

Résumé

D'abord la conformité des conceptions d'asset/liability-management pour la commande de l'asset allocation stratégique des fond de retraite est discutée d'un point-de-vue économique: A partir des principaux fonds de retraite, on est capable de dériver un principe général pour le placement de capitaux, qui justifie l'usage des conceptions d'asset/liability-management. Puis on donne un exposé de ces modèles des actifs/des passifs, qui ont (en ce moment) une importance pratique. Nous ne nous limitons pas aux fonds anglais ou americains dans cette rédaction. Pour des fonds en Allemagne ou en Suisse on peut aussi développer (et appliquer convenablement) des modèles des actifs/des passifs, qui prennent en considération les conditions spéciales et réglementées dans ces pays-là.

Keywords

Pension fund, valuation of assets, investment management, asset/liability-management, asset/liability-modelling.

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1. The investment management process of pension funds

The investment management process of pension funds can be structured as follows.[1]
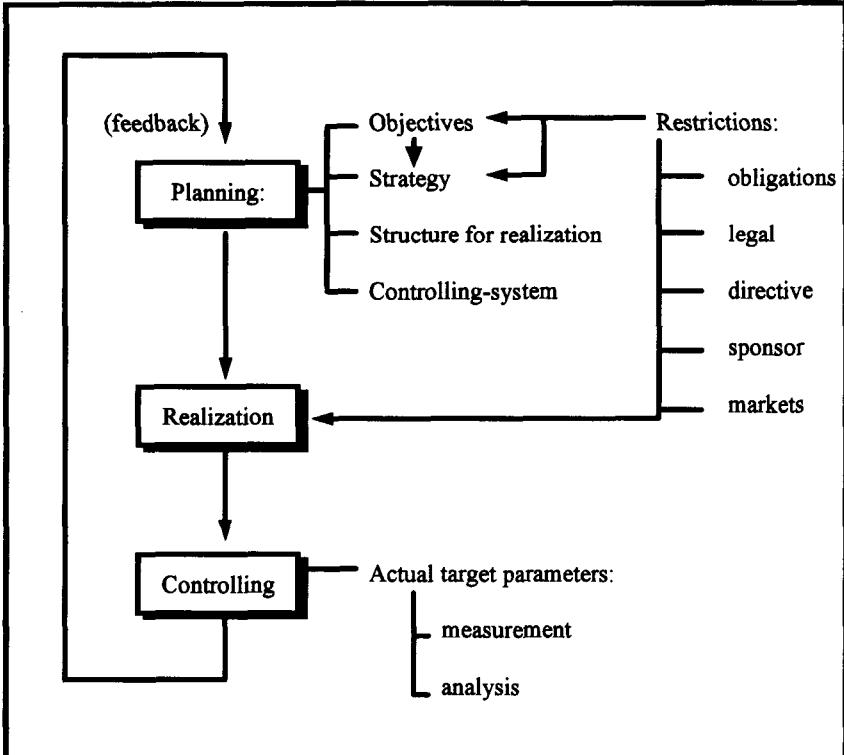

Fig .1: The investment management process of pension funds.

The planning-phase includes the formulation of investment-objectives and the determination of an objective-orientated investment strategy. A structure for realizing the strategy (e.g. decision between external and internal management for subportfolios, choice of investment managers and definition of their competences) and a controlling-system must also be generated. In this paper we concentrate on the first two elements of the planning-phase: The formulation of the objectives and their transformation in an investment-strategy are subject to several restrictions. Usually legal or directive restrictions exist (e.g. a frame for the funding level, solvability directives, limitations for certain asset classes). Sponsoring companies can also influence the investment decisions of the

fund. The realization of investment concepts depends on the investment opportunities which the markets offer. The pension obligations restrict objectives and strategy in so far as they determine the development and commitment of capital, the contribution-stream and the pension-payments-stream.

2. Valuation of assets for purposes of investment management

The adequacy of selected asset valuation methods for purposes of investment management shall be discussed.[2] We consider the risk/return-profile of assets (*merely asset-orientated approach*) and the value of assets relative to the value of liabilities (*asset-liability-orientated approach*) as the target parameters. We discuss the following valuation methods: *historic cost, discounted income value, market (related) value* and *book value*.

Historic cost is the buying-in price of an asset allowing for transaction costs and eventually reduced by systematic depreciations in time.

Discounted income value is the present value of the (expected) future investment income. Usually discounting is realized with a flat yield curve.

A *market related* valuation can be based on buying-in or selling prices (*fair value*). For smoothing the short term volatility of market values one can consider average values, for instance a 200-day moving average.

Book value is a value admissible for accounting purposes and a function of primary valuation methods as the ones above. For instance, book value might be the fair value or the minimum of historic cost and selling price (depending on the specific legal accounting principles).

A historic cost valuation does not show (unrealized) hidden gains or losses of an asset and would cause an incorrect measurement of yearly returns and risks (resp. chances) of asset classes. Such a valuation is also inappropriate for evaluating the financial strength relative to the liabilities.

The valuation of pension obligations is based on present values. Thus a valuation of assets by discounted income values satisfies the *principle of consistency* in valuating assets and liabilities. The discounted income value depends on the (expected) future inflows an asset produces. Therefore *methodically* the discounted income value is appropriate for evaluating the financial strength relative to the liabilities. *Practically* the estimation of future inflows and the choice of an adequate interest rate for discounting can become difficult (espicially for stocks). Due to the severe dependance on subjective assumptions the discounted income value seems to be inappropriate for determining an objective risk/return-profile of an asset.

A market value can be based on buying-in or selling prices. If these prices are significantly different for an asset in possession, one should orientate on the selling price which shows the actual utility of the asset to finance the liabilities. Short term variations of market values are irrelevant for a strategic investment management of pension funds. As a result one should consider smoothed values, e.g. a one-year or 200-days moving average. By a *market related value* we mean a smoothed fair value of an asset. For some asset classes it might be difficult to determine a market (related) value (possibly for real estate or non-marketable bonds). A market related valuation can be viewed as the best of the discussed methods for the merely asset-orientated approach: The yearly risk/return-profile of assets can objectively and appropriately be measured. Above we regarded the discounted income value as methodically adequate for an asset-liability orientated approach but sometimes difficult to determine. A market related value can be viewed as an estimation of the discounted income value and therefore also considered appropriate for an asset-liability orientated approach.

The adequacy of book values depends on their definition and thus in general cannot be discussed.

As a result we favour a market related valuation for the purposes of investment management. In some countries (e.g. Germany and Switzerland) the admissible book values significantly differ from market related values. Such a discrepancy does not necessarily lead us to postulate a modification of accounting principles in those countries. We are

free to choose a valuation method for the purposes of investment management. However, the admissible book values of assets also have to be considered, since usually legal control of the fund's financial situation is based upon book values.

3.   Formulation of an investment principle

We assume that the fund is financing defined benefit pension plans and that the investment management is not restricted by sponsoring companies. At first the main general objectives of pension funds shall be stated.[3]

The primary objective of the fund is to guarantee that the pension obligations can be met permanently (*objective of safety*).[4] The objective of safety can be subdivided into a *short-term* and a *long-term* component: In every year of a planning-period the fund has to possess enough liquidable assets to meet the pension payments already due (*objective of liquidity*). Furthermore, the evaluated obligations (liabilities) have to be sufficiently covered by the assets (*objective of a sufficient funding level*). If the book values of the assets differ from market related values one has to consider a book-value-orientated as well as a market-value-orientated funding level. As a secondary restriction of the objective of safety the fund has to achieve a lowest possible and stable level of contributions (*contribution aim*). Those funds who can be regarded as competitive insurance companies (e.g. funds that offer pension products to companies of a certain industrial sector) will also formulate a *growth aim*.

Below we concentrate on the objective of safety, the risks that endanger its achievement and implications for the investment management.

The objective of safety can be endangered by the *insurance risk*. For our purposes one might define insurance risk as the *danger that in a planning-period the actual pension payments exceed the payments assumed* (within the framework of the funding method) *inasmuch as these deviations have biological reasons*. Examples of the insurance risk are the possibility of increasing expectation of life for "retired lives" or the possibility of

overestimating the number of new entrants within an open funding method. The insurance risk is managed by techniques of pure *Liability-Management*.[5)]

Furthermore, the actual payments can exceed the assumed payments because of the dynamics of wages (if the plan is salary-related) or pension payments (if an inflation adjustment is guaranteed by the plan or demanded by law). The *dynamical* (financing) *risk* is the *danger that the actual dynamics* of relevant quantities *exceed the* explicitly or implicitly (by a net interest rate) *assumed dynamics*. In principle sponsoring companies have to bear the dynamical risk. However, one can postulate an investment *return target* to avoid an endangering of the safety aim: Roughly speaking the fund has to achieve a return that exceeds the sum of the technical discount rate and the difference between actual and explicitly assumed dynamics (*return target*).

From this return objective, however, we must not deduce an unrestricted return maximization as investment principle. Thereby we would ignore potential endangering of the safety aim by *financial risks* (e.g. return shortfall below the target return or market value shortfall below historic cost). The investment principle should be to *maximize the rate of return under consideration of the financial risk capacity of the fund and the regulatory restrictions*. Primarily the financial risk capacity of the fund is determined by *liquidity requirements, development* and *commitment of capital induced by pension obligations (liabilities)* and *free* parts of the *risk reserves*.

Market related value of assets	Book value of assets	Book value of liabilities	"Market value" of liabilities	purpose of risk reserves:
			risk reserve 3	actuarial
		risk reserve 2		
	risk reserve 1			financial

Fig. 2: Types of risk reserves

In Fig. 2 the risk reserves are divided into three components: *Risk reserve 1* denotes the difference between a market related value and the book value of assets. *Risk reserve 2* is defined as the difference between the book values of assets and liabilities. Usually actuaries evaluate pension obligations cautiously. As a result *risk reserve 3* is created by the difference between the book value of liabilities and a (less cautiously but still prudently calculated) "market value" of liabilities.

Usually one will view risk reserve 3 and parts of risk reserve 2 as reserves to protect against the insurance risk (*actuarial risk reserve*). Risk reserve 1 and the remaining part of risk reserve 2 can be considered as *free* risk reserves to protect against financial risks (*financial risk reserve*). If the book value of assets coincides with a market related value of assets, the difference between the market related value of assets and the book value of liabilities has to be separated in an actuarial and a financial risk reserve.[6]

Finally, the three elements of financial risk capacity shall be elucidated a little. For a given planning horizon the *liquidity requirements* LR(t) in the period]t,t+1] can be determined as $LR(t) = X(t) + E(t) - B(t)$,   (1)

        where X(t) denotes the *pension payments* in period]t,t+1] discounted at t,

                E(t) denotes the *administration cost* in period]t,t+1] discounted at t and

                B(t) denotes the *contribution payments* in period]t,t+1] discounted at t.

In the case of a negative LR(t) over the whole planning period the objective of liquidity can be met automatically, since $B(t) \geq X(t) + E(t)$. Also in the case of a positive LR(t) it should, in general, cause no problems to reach the liquidity aim. But if LR(t) exceeds the investment income from dividends, interest-, redemption- and rental payments, assets have to be sold to meet the liquidity requirements. If the selling takes place in a low-price-phase the objective of a sufficient funding level (resp. the contribution aim) could be endangered.

The *development* and *commitment of the liabilities* together with the available *free risk reserves* provide information about the amount of capital that can be invested in asset classes with higher return expectation and volatility: Medium term committed capital

can be invested in such asset classes, if the financial risk reserve is large enough to guarantee a sufficient funding level.

The liquidity requirements and the commitment of capital do not necessarily give homogeneous information for investment management. For instance, over a planning period of ten years there might be yearly liquidity requirements of 5% of the initial liabilities and more than 50% of the initial liabilities might be committed until the end of the planning period.

4. Supporting the transformation of the investment principle in a strategy by asset-liability-modelling

4.1 Preliminaries

In this section it shall be demonstrated how *asset-liability-models*[7] can support the transformation of the investment principle in a strategy. We consider the total asset portfolio of the fund, for whom we want to formulate an investment strategy. Here we disregard models based on matching-techniques.[8] Usually asset-liability-models on the total-fund-level have a structure similar to Figure 3.[9] The model (stochastically) simulates relevant target parameters (e.g. funding level, rate of return) over a planning period and consists of three submodels. The *Asset-Model* forecasts the development of relevant macroeconomic parameters (e.g. rate of inflation) and asset classes. The *Liability-Model* simulates the development of liquidity-requirements and liabilities. Asset-Model and Liability-Model pass their results to a *Fund-Model* which describes the integrating, functional relations between the model parameters and calculates further target parameters.

One might use the following approach[10] in three steps to determine the strategy:

    Step 1: Application of a *risk-capacity-model*,

    Step 2: *Preselection* of candidate-strategies and

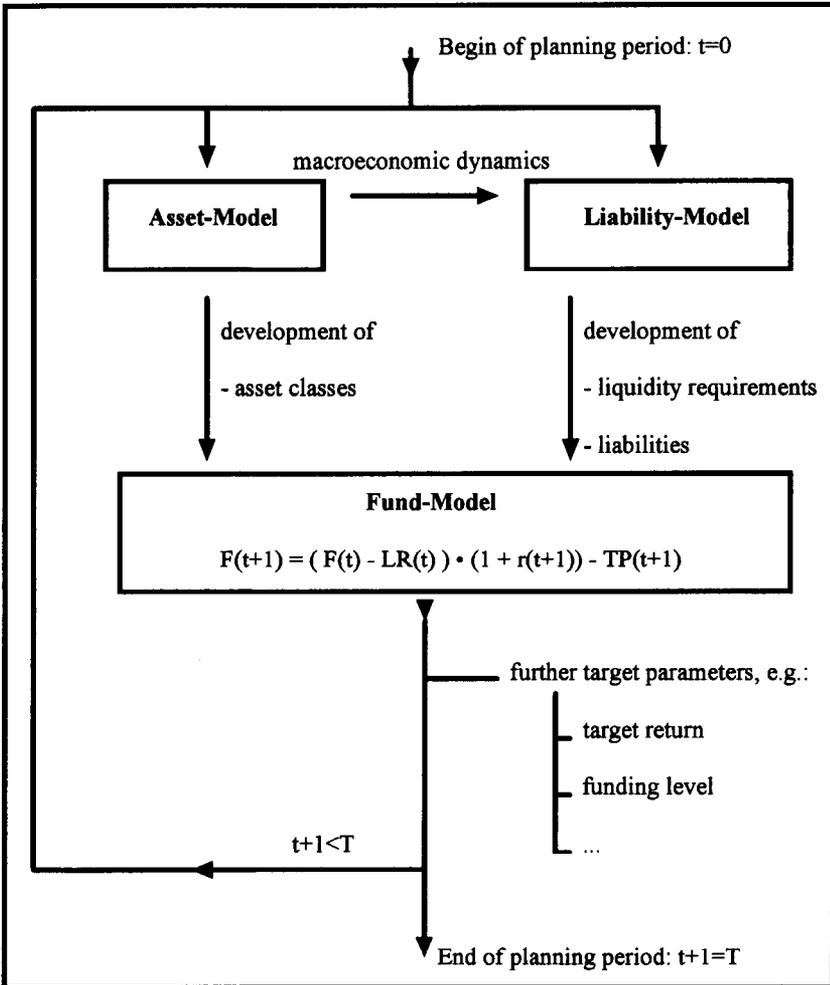   *Step 3*: Testing preselected candidates with a *strategy-test-model*.

Fig. 3: General structure of a Total-Fund-Model

4.2 Risk-capacity-models

The *risk-capacity-model*[11] has the structure of Figure 3. Target parameters are the liquidity requirements, the development of liabilities and the formulation of a return target.

We consider a planning period [0,T] and for a point of time $t \in [0,T]$ we denote by

LR(t)		the *liquidity requirements* in period $]t,t+1]$, see formula (1),
V(t)		the sum of the evaluated pension obligations (*liabilities*) at time t,
F(t)		a market related value of the fund's *assets* at time t,
fl(t)	:=	F(t)/V(t) the market value based *funding level* at time t,
r(t+1)		the *annual total return* (i.e. change of market value plus investment income) for investments over period $]t,t+1]$ and by
TP(t+1)		*tax payments* for the period $]t,t+1]$ at time t+1.

Here the Asset-Model only consists of a submodel to describe the dynamics of salaries and pension payments for the planning period (inflation model). The Liability-Model simulates liquidity requirements LR(t) and liabilities V(t) for the planning period based on a *Markov*-chain population model. Hereto the total population of persons entitled to pension payments is structured in subpopulations (e.g. active and internal persons, active and external persons, pensioners, widows, widowers). Probabilities for a transition from one population into another within one year are estimated.[12] With the results of the population model and the inflation model LR(t) and V(t) can be estimated.

The integrating Fund-Model has to determine the return target. For the planning period a desired market-value based funding level fl(t), $t \in [0,T]$ is fixed. We assume that F(t) and TP(t+1) are known and that LR(t), V(t+1) are calculated with the Liability-Model. Then the necessary value for the market value of assets at time t+1 is

$$F(t+1) := fl(t+1) \cdot V(t+1) \tag{2}$$

On the other hand the development of the fund's assets between t and t+1 can be described as

$$F(t+1) = (F(t) - LR(t)) \cdot (1 + r(t+1)) - TP(t+1) \tag{3}$$

Solving Equation (3) for a return target $r_\tau(t+1)$ yields

$$r_\tau(t+1) = r(t+1) = (F(t+1) + TP(t+1)) / (F(t) - LR(t)) - 1 \tag{4}$$

4.3   Preselection of strategies

A preselection can be based on the (standard deviation, expected value) return profiles of feasible portfolios. In a first step one selects those allocations that are efficient under consideration of the regulatory restrictions (portfolios on the *restricted efficient frontier line*).[13]

Further, the restricted efficient portfolios can be characterized through shortfall approaches. For instance, one might postulate that the strategy should achieve the actuarily assumed rate of return every year with a certain probability or that the return target (identified in the risk-capacity-model) should be reached on average over a fixed period of time with a certain probability. Shortfall approaches will not be discussed here in detail.[14] The following simple model, however, will elucidate them a little.

The fund must achieve at least the actuarily assumed rate of return. A choosen investment strategy, in general, cannot guarantee the actuarial rate of return for certain. Therefore the fund needs financial risk reserves to protect against the shortfall of the rate of return below the actuarial rate. The necessary financial reserves dependent upon accepted shortfall-levels shall be determined.

We denote by a the (known) *actuarily* assumed *rate of return*,

                  ϕ a factor for the relative *financial risk reserve* and by

                  r the random *rate of total return* with expected value μ_r and standard deviation σ_r for a choosen investment strategy.

One wishes that the following condition is satisfied:

$$(1+a) \leq (1+\phi) \cdot (1+r) \tag{5}$$

If we accept a shortfall-probability $\varepsilon \in]0,1[$ and consider the random variable $R := \ln(1+r)$, condition (5) can be replaced by:

$$P(R \geq \ln(1+a) - \ln(1+\phi)) = 1-\varepsilon$$

$$\Leftrightarrow \quad P(R \leq \ln(1+a) - \ln(1+\phi)) = \varepsilon$$

$$\Leftrightarrow \quad \ln(1+a) - \ln(1+\varphi) = R_\varepsilon, \tag{6}$$

where R_ε denotes the ε-percentile of R characterized through $P(R \leq R_\varepsilon) = \varepsilon$.

We furthermore assume that R is normally distributed (i.e. $(1+r)$ is lognormally distributed) with expected value μ and standard deviation σ. If we want to preserve expected value and standard deviation of r, we have to choose:[15]

$$\sigma^2 := \ln\left(1 + (\sigma_r/(1+\mu_r))^2\right)$$

$$\mu := \ln(1 + \mu_r) - \tfrac{1}{2}\cdot\sigma^2$$

The ε-percentile of R can be written as

$$R_\varepsilon = \mu + \sigma\cdot N_\varepsilon ,$$

where N_ε denotes the ε-percentile of the standard normal distribution $N(0;1)$. Now equation (6) can be solved for φ and we finally get:

$$\varphi = (1+a) / \exp(\mu + \sigma\cdot N_\varepsilon) - 1 \tag{7}$$

As an example we assume a=4%, μ_r=7% and σ_r=6%. The necessary risk reserves φ dependent upon several shortfall levels ε calculated by (7) are shown in Table 1.

ε	1%	2.5%	5%	10%	20%	30%
φ	10.9%	8.6%	6.7%	4.6%	2.0%	0.3%

Table 1: Relative financial risk reserves φ dependent upon shortfall-level ε.

At the end of the preselection procedure one can identify strategies that

- are restrictedly efficient,
- achieve the actuarily assumed rate of return with a specified probability (alternatively with or without consideration of the existing financial reserves) and
- reach the return target (on average) with a certain probability.

A selection of these strategies can be used as alternative input strategies for the strategy-test-model.

4.4   Strategy-test-models

A strategy-test-model has the structure of Figure 3. The primary purpose of the model is to simulate the funding level for a planning period dependent upon a fixed investment strategy, e.g. an asset allocation strategy with time-dependent allocation factors. In countries where the book values of assets differ from market related values both a book-value- and a market-value-based funding level will be considered. Further target parameters can be the rate of return, directive solvency margins or parameters that rule the exemption from taxation.

The Liability-Model will be the same as in a risk-capacity-model. In addition to relevant macroeconomic indices, the Asset-Model has to simulate the development of asset classes.[16] Such a simulation can refer to the annual total return of selected asset classes, as, for instance, in the model of *Ibbotson/Sinquefield* (1976). Alternatively, the total return can be split into its two components and the development of market value and investment income is described separately for stock- and real-estate-classes, as, for example, in the models of *Wilkie* (1986)[17], *Bonsdorff* (1991) and *FIM-GROUP* (1994).

A detailed Fund-Model may be formed in the following four steps. In the first step, investment (resp. desinvestment) decisions for the several asset classes are derived from the liquidity requirements and the market values at the beginning of a year according to the defined strategy.[18] Then classwise the development of market values (and book values, if necessary) within the year and the investment income at the end of the year are described. In a third step the results are aggregated to values at the total-fund-level. From these values the target parameters can be determined in the final step. Eventually a reserves-dependent readjustment of the pension-payments-stream or the contribution-stream for the next year can follow. An extensive Model that can be used as Fund-Model for British or American Funds was published by *Daykin/Hey* (1990). A Fund-Model for German Funds can be found in *Baum* (1996, p. 93 f.).

The strategy-test-model will be applied for preselected strategies. The simulated results for the target parameters will be analysed stochastically. Thereby the strategies become

comparable in their influence on the target parameters. At least one selects the strategy that has performed best over all (according to a subjective weighting of target parameters).

Finally, we shall make some brief remarks on the quality of a prognosis with a strategy-test-model. The description of the Fund in the Fund-Model (investment decisions according to the strategy, valuation of assets, balance sheet, gains and losses account, determination of target parameters) can be managed precisely enough.[19] Liability-Models have a relatively long actuarial tradition. If the personnel political input parameters of the Liability-Model (e.g. dynamics of new entrants, salaries and rental payments) are estimated correctly, the simulated results of liquidity requirements and liabilities will be satisfying. The crucial point for the quality of a prognosis consists in the Asset-Model. We can stochastically analyse an Asset-Model and compare its results with real historical data. But even if the results of such an analysis suggest a good model, we cannot be sure that the model produces good estimates for the future. At this point let us remember that no model can forecast a selected random variable or its distribution with certainty. So we should not expect this from an Asset-Model. For the time being it might be appropriate to restrict oneself on a scenario-analysis or to Asset-Models with only a few parameters. For example, one might assume a *random walk* for the total return of a test strategy. The type of distribution function, mean value and standard deviation can be identified from historical data (*back testing*).

As an example for an Asset-Model with split returns we consider a simplified version of "the" *Wilkie*-Model.[20] We denote by:

I(t)   a *consumer price index* at time t,

$\delta_I(t) := \ln(I(t)/I(t-1))$ the *intensity* of the rate of *inflation* at time t,

P(t)   the *price* index of a *stock* index portfolio at time t,

D(t)   the *dividend* index of the *stock* portfolio at time t,

C(t)   the rate of return on *long-term* government *bonds* at time t

and have the following model equations with the four parameters dμ, yw, cμ and cw:

$$P(t+1) = \exp(\ d\mu + yw \cdot \delta_I(t) + (1-yw) \cdot \delta_I(t+1)\ ) \cdot P(t) \qquad (8)$$

$$D(t+1) = \exp(\ d\mu + \delta_I(t+1)\ ) \cdot D(t) \qquad (9)$$

$$C(t+1) = c\mu + cw \cdot \delta_I(t+1) \qquad (10)$$

The inflation index I(t) might be driven stochastically, for instance, with the *Wilkie*-Inflation-Model or with the approach of *Clarkson* (1991).

5.   Conclusion

The investment management of pension funds should be guided along a market related valuation of assets.

For defined benefit plans and in the absence of restrictions by sponsoring companies the investment policy should follow the principle of return maximization under consideration of the financial risk capacity and regulatory restrictions. Primarily, the financial risk capacity is determined by the liquidity requirements, the development and commitment of capital induced by pension obligations and free risk reserves.

Asset-liability-modelling can support the transformation of this principle into an investment strategy. For instance, one might use a three-step-approach consisting of a risk-capacity-model, a preselection of strategies and the application of a strategy-test-model for preselected strategies.

Notes

1. See for instance Albrecht (1995, p. 42 f.), Baum (1996, p. 45 f..) and the references cited there.

2. See Baum (1996, p. 50 f.) and the references cited there.

3. See Ammann (1992), Baum (1996, p. 74 f.) and the references cited there.

4. " 'Elimination of risk' does not refer to variability as such but to the risk of having insufficient assets to meet the obligations as they come due.", Arnott/Bernstein/Hall (1991, p. 10).

5. An overview of Liability-Management-Techniques gives for instance Albrecht (1995, p. 42 f.).

6. At the present time in Switzerland a modification of accounting principles towards a market related valuation of assets is thought about. Ammann/Strebel (1993) discuss the requirements of financial risk reserves in dependance of a choosen investment strategy.

7. See Wise/Annable (1990), van der Meer/Smink (1993) for a structured introduction to asset-liability-modelling.

8. For instance, Baum (1996, p. 191 f.) gives an overview of matching-techniques and references to them.

9. See Daykin/Hey (1990), Thurnes (1992), Albrecht (1995, p. 188 f.).

10. See Baum (1996, p. 80 f.).

11. See Baum (1996, p. 92 f.).

12. See Neuburger (1983) for a detailed discussion.

13. See, for instance, Arnott/Bernstein/Hall (1991, p. 6), Thurnes (1992), Albrecht (1995, p. 85 f., p. 184 f.).

14. See Jaeger/Zimmermann (1992), Albrecht (1993, 1994) and the references cited there for a general discussion of shortfall approaches.

15. See, for instance, Albrecht (1993).

16. A survey of Asset-Models give, for instance, Daykin/Pentikäinen/Pesonen (1994, p. 226 f.).

17. See Wilkie (1986), Daykin/Hey (1990) and Wilkie (1994) for the extended version of "the" *Wilkie*-Model.

18. It shall be remarked that because of market value volatility a strategy with constant asset class weights can cause (implicite) investment decisions, even if the investment income exactly equals the liquidity requirements.

19. See Daykin/Pentikäinen/Pesonen (1994, p. 3 f.).

20. See Baum (1996, p. 153) for a derivation of the equations (8), ..., (10) from the *Wilkie*-Model.

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