Chapter 18

A SCENARIO APPROACH OF ALM

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Abstract

ALM is very important in the strategic decision making of liability driven organizations, especially pension funds, insurance companies and banks. In this chapter we treat three components of ALM for pension plans: The ALM decision problem, the ALM-methodology, and ALM in practice.

We describe and demonstrate that the quintessence of the full scale ALM decision problem is that risk budgets of all stakeholders and all available policy instruments are taken into account to accomplish adequate pensions at acceptable cost and risk. In practice this implies that ALM leads to an optimal integral pension-, contribution-, and investment policy, recently frequently referred to as the Pension Deal. Also, since the integral approach implies that the strategic asset allocation is evaluated in terms of the costs, benefits and risks of the beneficiaries, ALM can be seen to encompass what in the investment community recently has been introduced as liability driven investing.

In the ALM-methodology to accomplish this objective a central role is played by scenario analysis, sustained by optimization methods.

The section about ALM in practice is based on three pension plans. For these plans we first describe the role of ALM in sustaining the specification of the risk profile of the stakeholders, and in the identification of the basic integral pension-, contribution-, and investment policy. Next we select three possible policy-measures to demonstrate the increase of efficiency of the basic ALM-policies, i.e., currency hedging, state dependent asset allocation, and alternative equity exposure.

Keywords

asset liability management, derivatives, liability driven investing, optimization, pension deal, pension funds, scenarios, simulation, state dependent asset allocation, strategic asset allocation

JEL classification: C15, C22, C32, C44, C61, C88, E37, E43, E47, G10, G11, G23, G31

1. Introduction

Why is ALM so extremely popular in international pension fund markets, and in newer application areas such as insurance companies, endowment funds and housing corporations?

At pension plans the main risk budgets are provided by the sponsors and the (future) beneficiaries. For these stakeholders larger risk budgets imply lower contribution rates and higher pensions, and vice versa. The stakes are high. For example, Dutch pension assets in 2005 amount to about 600 billion US$, which approximates Dutch GDP. Thus, e.g., 2% more return on the assets equals 2% of GDP per year, which in the Netherlands amounts on average to 5% of national salaries per year. Especially in the UK, the US and Switzerland the pension funds have such a large impact on the national economy as well. Therefore governance, justification, transparency, efficiency and accountability of pension management are getting crucially important. This is further enforced by the national pension regulators, and by the international pension accountants. ALM sustains decision makers in these issues by providing insight in the relevant risk-return relationships, and by identifying and communicating optimal ALM-strategies which yield each risk-provider in the pension deal a maximal benefit in return.

We treat ALM for pension plans from three approach routes: the full scale ALM decision problem, the ALM-methodology, and ALM in practice.

In Section 2 we argue that the quintessence of the ALM decision problem is that risk budgets of all stakeholders and all available policy instruments are taken into account in order to accomplish adequate pensions at acceptable cost and risk. In practice this implies that ALM should lead to an optimal integral pension-, contribution-, and investment policy, recently referred to as a fair pension deal.

In Section 3 we describe the applied ALM-models and ALM-methods. A crucial role is played by scenarios to model uncertainty, and by simulation and optimization methods to sustain the identification of efficient integral ALM-policies.

Section 4 treats ALM in practice. The results in this section are based on data of three pension plans. We first describe the scenarios which are used to simulate and optimize ALM-policies, as well as the various ALM-measures which are applied to evaluate the performance of the ALM-strategies. Given the scenarios we first concentrate on the usefulness of ALM to sustain decision makers in determining the basics of the ALM-policies, i.e., the specification of the risk profile of the stakeholders, and the identification of the basic integral pension-, contribution-, and investment policy. Next we select on three possible policy measures to demonstrate the improvement of basic ALM-policies, i.e., currency hedging, state dependent asset allocation and alternative equity exposure. The effects of other measures such as flexible pension schemes, dynamic derivative strategies, matching of interest rate risk, elimination of the "long-only" constraint, and the impact of other alternative investments such as commodities, private equity and hedge funds are the subject of other research papers. This chapter focuses on the integral approach of ALM-problem, and on the use of the available policy measures to accomplish fair and efficient pension deals.

2. Institutional setting and the definition of ALM

Employers and employees negotiate a pension scheme in which employees either earn pension rights (= Defined Benefit scheme) and/or obtain pension contributions (= Defined Contribution scheme). Increasingly, employers and employees agree on a hybrid pension schemes with both DB- and a DC-components. For more information on the development of pension schemes, see Ambachtsheer and Ezra (1998); Davis (1994); Muralidhar (2001); and Modigliani and Muralidhar (2004).

The agreed pension scheme is carried out in the pension plan under the responsibility of the board of trustees. In The Netherlands the board of trustees consists 50% of employers and 50% of employees and retirees. A board of trustees has to take into account the interests and requirements of many pension stakeholders. These concern first of all the sponsor, employees, and beneficiaries (= retired and deferred non-active members of the plan), but also the "indirect" stakeholders consisting of the pension regulators and the pension accountants. We call the employees and beneficiaries the active and non-active members of the plan.

We first consider the interests of the sponsor. On the one hand, sponsors wish to profit by low pension contributions to the plan resulting from high portfolio returns on the pension assets. On the other hand, sponsors set constraints on the extent that pension investment risk and other pension risk drivers are allowed to affect her own Profit & Loss account (P&L) and Balance Sheet (BS) under the rules of IFRS or FAS (= International Financial Reporting Standards and Financial Accounting Standards). The maximum pension risk that a sponsor is willing to bare is referred to as the risk budget provided to the pension plan. The rationale of this risk budget is that it allows the trustees ceteris paribus to create higher returns on the pension assets, thereby enabling to reward the sponsor's risk budget with lower expected contributions to the plan.

The contribution agreement materializes at which low levels of the funded ratio (ratio of the pension assets and the value of the pension liabilities) the sponsor donates additional contributions, thereby specifying her pension risk budget, and which rebates she gets in return at high levels of the funded ratio. Therefore, the contribution agreement is also referred to as the surplus/deficit agreement, and as the risk sharing agreement between the sponsor and the pension fund.

To illustrate the importance of the specification of the contribution agreement, we introduce the frequently used concept of investment-leverage (IL) of pension plans. The investment leverage is defined as the ratio of the pension assets of the pension plan, and the sum of annual salaries of the active members of the plan. In the Netherlands the average IL is about 4, ranging from 1 for very young plans to 20 for very mature plans. The IL-concept is of enormous practical importance. Consider a plan with an IL of 4, and suppose that the risk budget provided by the sponsor enables the investment managers to increase the investment risk so that the plan earns an additional expected return of 1% per year. If these additional returns would be completely allocated to the benefit of the sponsor, this would imply a reduction of the contributions of 4% of salaries per year. However, the sponsors also have to take into account the accompanying risk. Consider, for example, the case where the funded ratio has dropped to a level of 90%, which must immediately be remedied by the sponsor to a level of 100%. For the plan with an IL of 4, this would amount to a contribution of 40% of salaries. A mature pension fund, with a typical IL of 20, would have to provide a huge contribution equaling 200% of salaries. If we also take into account that deficits in the pension plan are likely to coincide with a bad profitability of the sponsor, then it is evident that the risk budget which the sponsor provides to the plan should be constrained to responsible values. Sponsors should make a responsible trade-off of low expected contributions to the pension fund, and Contribution at Risk. Extremes are the full Defined Benefit schemes where the sponsor bares all the pension risk, and Defined Contribution schemes where the sponsor donates a fixed contribution and all pension risk is carried by the members of the plan. Currently, hybrid schemes emerge with both DB- and DC-components where also the sponsor bares pension risk, but in a limited amount.

The second group of stakeholders whose interests boards of trustees have to take into account are the members of the plan, distinguished in the employees and the beneficiaries. The fund can either carry out a DC-scheme, where all members have the responsibility for their own pension investments (personal asset allocation and risk management), or a DB-scheme where members build up pension rights which are covered by collectively held pension assets. The funded ratio in DB schemes is the extent in which the value of the pension assets covers the value of the value of all the liabilities. Recently Collective DC-schemes emerge, where the sponsor carries no pension risk, and the members collectively invest. The methods in this chapter apply to DB and Collective DC (although, of course, individual DC could be viewed as a pension fund of one person, to which the methods in this chapter then would apply as well).

In many DB plans and in all Collective DC plans members bare risk by renouncing from COLA (= Cost Of Living Allowance) once the funded ratio of the plan deteriorates to too low levels. The risk baring of the employees and beneficiaries can even be taken a significant step further by allowing temporary reductions of the pensions and pension rights. The rationale of these risk sharing COLA-arrangements is that these, analogously to the pension risk budget of the sponsor, ceteris paribus allow the pension plan to carry more investment risk, thereby paying higher pensions enabled by the higher expected portfolio returns.

The COLA-agreement materializes at which low levels of the funded ratio the members abstain from full indexation, and which additional indexation they get in return at high levels of the funded ratio. Of course, if the COLA-agreement would enable the plan to create an additional expected portfolio return of 1% as the result of a higher risk profile of the investments, this could be applied to improve the pensions 1% per year. (Also recall the pension rule of thumb that 1% more return on the pension assets approximately yields 30% higher pensions.) On the other hand, missing COLA of, e.g., 2.5% per year over a period of 20 years would reduce the purchasing power of the pensions with about 40%, so that also for these stakeholders an efficient equilibrium should be accomplished between expected pensions and Pension at Risk.

Boards of trustees shape and manage these objectives of the sponsors and the members by specifying and carrying out an integral contribution-, COLA-, and investment policy, also referred to as ALM-policy (= Asset Liability Management) and as Pension Deal. ALM-projects support trustees and their stakeholders in identifying feasible and efficient ALM-policies.

In addition to negotiating and agreeing a contribution- and COLA-agreement with the sponsors and members, the trustees in specifying an ALM-policy also have to specify the maximum risk that the plan encounters a deficit, also referred to as Surplus at Risk. Clearly Surplus at Risk concerns the investment risk which cannot directly be transferred to the sponsors and the members. In many countries local laws limit Surplus at Risk. For example, in The Netherlands pension funds have to create surpluses such that the probability of deficit (i.e., funded ratio $< 100\%$) is at most 2.5% on a 1-year horizon. However, Surplus at Risk should not only be limited by laws, but also by the phenomenon that it becomes disproportional difficult to recover from increasing deficits (see the box and Table 1).

> The nonlinear relationship between funded ratio and required portfolio return
>
> Liability return is defined as the autonomous growth of the liabilities (excluding the growth due to new pension rights of the active members). Given, e.g., a 4% liability return, a funded ratio of 100% would remain at the level of 100% if a portfolio return is achieved of 4%. However, at a funded ratio of 80%, a portfolio return of 5% would have to be achieved to compensate for the growth of the liabilities, increasing to a required portfolio return of 8% in case the funded ratio would drop to a level of 50% (cf. Table 1). Hence, at increasing deficits, the trustees would have to take disproportional larger investment risk to restore the financial health of the plan. At too large deficits, this phenomenon makes complete ruin of the plan not to be averted, unless drastic additional measures are taken with respect to additional funding by the sponsors, or a reduction of the pension rights of the plan members.

Table 1 column 2 depicts the portfolio return $x1$ that is needed to match the growth of 4% of the liabilities in any year given that the fund has a deficit d. Thus $x1$ solves the equation $(1-d) * x1 = 0.04 \Rightarrow x1 = 0.04/(1-d)$.

Column 3 depicts the portfolio return $x2$ that in case of a deficit d is needed to eliminate the deficit in a period of 5 years. Thus, this required return not only has to match the growth of the liabilities, but also eliminates the deficit. Thus $x2$ solves the equation: $(1-d) * (1+x2)^5 = 1.04^5 :\Rightarrow x2 = 1.04/(1-d)^{1/5} - 1$.

Thus, ALM first of all concerns determining the maximum allowable risk with respect to the sponsors, members and deficits, and specifying an optimal integral contribution-, indexation-, and investment policy, whose consequences satisfy the risk limits, and which provides optimal pension contributions and pension benefits in return. As mentioned, the stakes are high. In The Netherlands each 1% additional investment return which can be created as a result of the risk sharing pension deals (currently being equal to 1% of GDP) either leads to a reduction of the contributions of 4% of salaries, or cu-

Table 1
Required portfolio returns in case of deficit

Deficit (% liabilities)	Required return to match the growth of the liabilities	Required return to eliminate deficit in 5 years
0%	4%	
10%	4.4%	6.2%
20%	5%	8.7%
30%	5.7%	11.7%
40%	6.7%	15.2%
50%	8%	19.5%
60%	10%	24.9%
70%	13.3%	32.3%
80%	20%	43.5%
90%	40%	64.8%

mulatively to 30% higher pensions. Therefore ALM-projects to accomplish these deals, and to investigate investment classes and investment strategies to optimize the results of the pension deals have become crucially important. We clearly see this trend worldwide.

3. The ALM approach

In practice we approach the ALM-problem with scenario analysis, combined with simulation- and optimization techniques, see Figure 1. The objectives of this approach are twofold:

- Provide quantitative and graphical insight to the ALM-decision makers;
- Identify efficient integral ALM-strategies.

The quintessence of scenario analysis is that the external uncertainties which ALM-decision makers have to take into account, i.e., inflation, interest rates, risk premiums of equity, as well as transitions of the plan members, etc., are modeled by a set of possible plausible future developments, referred to as scenarios. Using a corporate model of the pension plan, ALM-strategies are evaluated by simulating the consequences of the ALM-strategy in each individual scenario. In practice, usually the "learn-and-react" approach is followed. That is, ALM-strategies are evaluated, analyzed, and in an iterative procedure improved, until an efficient and fair ALM-strategy is obtained, recently also referred to as the Pension Deal, which efficiently balances downside risk and upside potential of all stakeholders. In some cases, especially in ALM-projects with a large research component, this learning process is sustained by applying optimization techniques. We use the same approach, and in a large extent the same models, in ALM for insurance companies, housing corporations and banks.

Before we proceed in describing our scenario analysis approach in more detail we observe beforehand that presently this approach is still in a large extent rooted in the

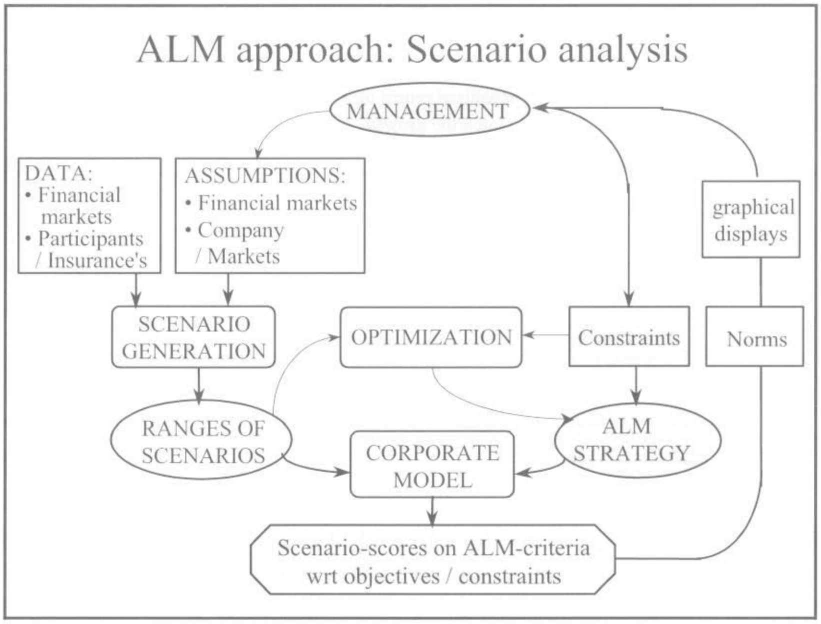

Fig. 1. Scenario approach of ALM.

approach which has been published in the classic ALM-papers by Kingsland (1982) and Winkelvoss (1982). It is interesting and relevant to repeat the following statement in Kingsland (1982):

> "The dynamic behavior of a pension plan is clearly dominated by rules and methodology which are discontinuous and nonlinear functions of its financial condition. The task of developing a closed-form solution to evaluate the potential state of a pension plan following a series of stochastic investment and inflation experiences would be extremely difficult, if not impossible. To date, the only approach that has proven feasible is the application of Monte Carlo Simulation, wherein an investment and inflation scenario is generated by random draws based on the expected probability distribution of year to year investment and inflation behavior. In order to develop an accurate assessment of the range of potential uncertainties, it is necessary to repeat this simulation process by generating dozens or hundreds possible scenarios, consistent with statistical expectations."

Since 1982 science has enormously moved their borders, see the ALM-papers in this two-volume Handbook. This especially concerns approaches for scenario generation, and optimization algorithms. But, as will appear in the remainder of this section, in order to analyze the full scale ALM-problem, taking into account the costs, benefits and risk of all stakeholders, the core of the statement of Kingsland in our practice is still valid. As can be verified from other chapters in this volume, stochastic optimization methods increasingly find their way in ALM-applications as well.

In the sequel of this section we will elaborate on the models of our approach. In Section 3.1 we describe the methodology to generate scenarios of the future economic environment. In Section 3.2 we explain the methodology which is followed to evaluate ALM-strategies with respect to the generated scenarios. In this section we explain how, given a scenario set of the external risk drivers, we simulate what the consequences of an ALM-policy are for the various SaR-, CaR-, and PaR-risk and return measures. Section 3.3 focuses on optimization. Practical cases are reported in Section 4.

3.1. Generating scenarios

The uncertainties that have to be taken into account in ALM-analyses consist of the future economic environment on the one hand, and of the pension liabilities that result from the uncertain development of the current and future active and non-active members on the other. The uncertainties are modeled as a fan of scenarios, and not as a tree, which of course is only responsible since we restrain the use of the scenarios to simulation and non-anticipating optimization. These scenarios are generated in two steps.

The scenarios of the economic environment are generated using a Vector Auto Regressive model (VAR). Denote these scenarios of the vectors of uncertainties as $\{s_{tn} = i_{tn}, r_{tn}, c_{tn}, e_{tn};\ t = 1, \ldots, T,\ n = 1, \ldots, N\}$ (cf. Figure 2), where

i_{tn} = local price- and wage inflation in $\langle t, n\rangle$ (thus, i_{tn} is the value of inflation in node t of scenario n),

r_{tn} = interest rate structures in the distinguished countries in $\langle t, n\rangle$,

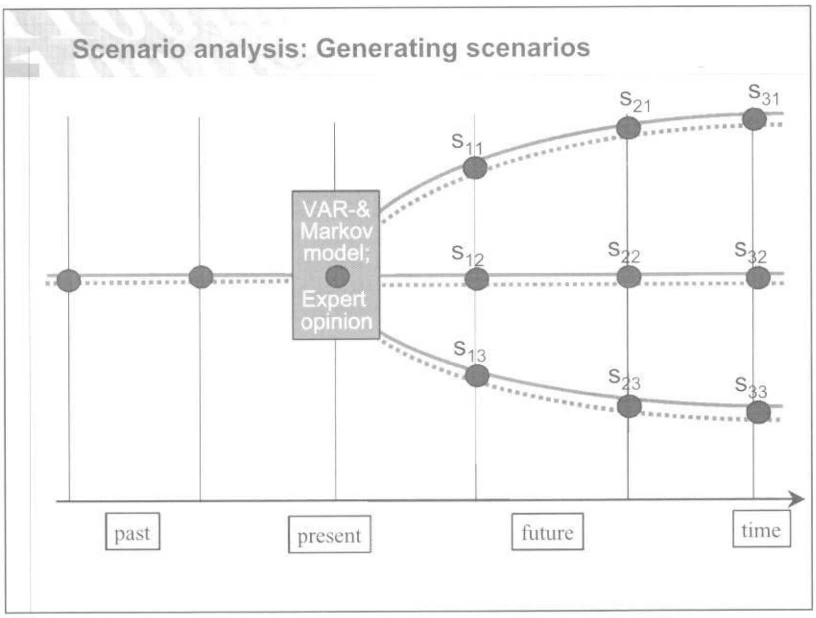

Fig. 2. Scenario generation of the future economic environment, and of the development of the actuarial quantities of the members.

c_{tn} = currency rates between of the distinguished countries in $\langle t, n\rangle$,
e_{tn} = risk premiums of the distinguished asset classes in $\langle t, n\rangle$.

In the next step the relevant actuarial quantities are developed using a Push Pull Markov probability model to determine the status (i.e., active/non-active, age, salary group, ...) of the current and future members in each node $\langle t, n\rangle$ of the scenarios, whereas the pension scheme of the plan is used to determine the corresponding actuarial quantities of the members in $\langle t, n\rangle$. That is, each s_{tn} is extended to $s_{tn} = i_{tn}, r_{tn}, c_{tn}, e_{tn}, a_{tn}, p_{tn}, l_{tn}$ where

a_{tn} = actuarial cost in $\langle t, n\rangle$,
p_{tn} = pension payments in $\langle t, n\rangle$ (excluding COLA),
l_{tn} = value of the liabilities in $\langle t, n\rangle$.

Thus, as a result of the scenario generation process that is further described in this section we know the value of each relevant economic quantity on the one hand, and the resulting actuarial quantities of the plan on the other. In our ALM-projects we typically choose to work with scenario sets of 2500 scenarios with a horizon of 25 years ($T = 25$, $N = 2500$).

The methodology to generate scenarios for the future economic environment is depicted in Figure 3. That is, a time-series model is used to extrapolate the properties of historic time series probabilistically to the future in the form of many scenarios. As illustrated in the picture, in practice some properties of the scenarios are frequently

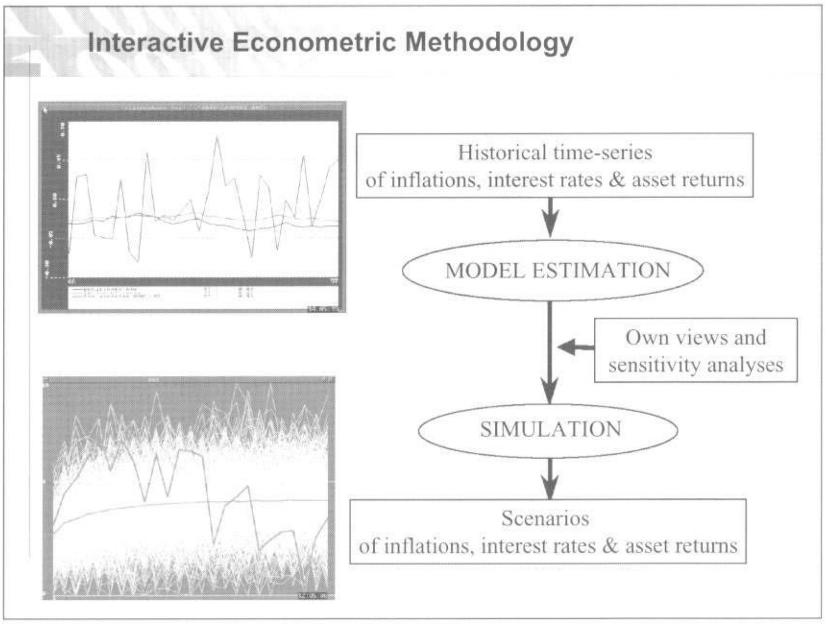

Fig. 3. Probabilistic extrapolation of time series in the form of scenario-sets.

changed by the decision-makers. This typically concerns changes of the expected development of inflation, interest rates and equity risk premiums based on expert opinion of investment advisory committees, and changes of higher moments of the scenarios in the context of sensitivity analyses.

To construct year-frequency scenarios of the future development of the economic time series we apply (log-)Normal Vector AutoRegressive VAR models. In VAR-models, the values of the economic quantities in any year follow a multidimensional (log-)normal probability distribution whose expected values are linear combinations of the realizations of the economic quantities in the previous years:

$$y_{t}. \sim N\big(\mu + \Omega * [y_{t-1} - \mu], \Theta\big).$$

The model assumes stationarity, such that it may be necessary to transform the raw historic data, or that it may be necessary to include dummy variables for periods, such as the oil crisis, which violate stationarity.

The estimation of the model proceeds in two steps. First the sample estimators are determined of the variance- and covariance matrices, denoted as V and W (to preserve stationarity, the denominator of these estimators is the number of sample points, and not the number of sample points minus the number series). In the second step, applying the Yule Walker estimation method Ω and Θ are, respectively,

$$\Omega = V * W^{-1}; \quad \text{and} \quad \Theta = V - W * V^{-1} * W^{T}.$$

An important characteristic of the VAR-model, which is crucial for the quality of the ALM-analyses which are sustained by the model, is that if the parameters are estimated using the Yule Walker method, then also with limited historic data the scenarios which are generated by the model will asymptotically display the same expected values, standard deviations, and (auto-)correlations as observed in the applied historic data set (cf. Boender and Romeijn (1991), and Steehouwer (2005)). Thus, the scenarios are "consistent with statistical expectations", which is of crucial importance from the point of view of interpretation and decision support (cf. Bunn and Salo (1993)).

The VAR-model is continuously extended and improved. In particular:

- Yield curves

  Due to the need to analyze duration strategies, and due to the growing importance to work with mark-to-market valued liabilities, the model generates yield curves $r(t)$. Of course, in ALM this implies that a yield curve has to be generated in each year t of each scenario s, in such a way that the relevant dynamics and correlations are in accordance with statistical expectations. We accomplish this by using the Nelson Siegel model which is characterized by four parameters, i.e.:

$r(t) = \beta_0 + (\beta_2 + \beta_2) * (1 - e^{-t/\tau})/(-t/\tau) - \beta_2 e^{-t/\tau}$	
	Nelson Siegel yield curve
$\lim_{t\to\infty} r(t) = \beta_0$	Long interest rate
$\lim_{t\downarrow 0} r(t) = \beta_0 + \beta_1$	Short interest rate
β_2 and τ	Curvature & scaling parameters

We generate scenarios of Nelson Siegel yield curves by feeding the VAR-model with historic data of the four Nelson Siegel parameters, and, analogously to the other economic quantities, generate the four parameters in each node $\langle t, n\rangle$, which characterizes the yield curve in each $\langle t, n\rangle$. The Yule Walker estimation procedure ensures that the relevant standard deviations and (auto-)correlations coincide with the historic data. Also, the extent in which the curve shifts, tilts and flexes over time is in accordance with past observations.

- Currencies

  In many ALM-projects, hedging currency risk is an important topic. This implies that the scenario generator must be able to produce consistent realizations of currencies and interest rates. We accomplish this by assuming that the covered interest rate parity applies, adding (correlated) error terms which measure the deviations from the interest rate parity in the applied historic data.
- Consistency of simulation and evaluation

  Mainly due to the new international accounting rules and the progress in determining the fair value of the liabilities, scenarios are increasingly also used for the valuation of (embedded) options. Scenarios, which are used for the latter approach, have of course to be arbitrage free. In ALM-projects these two objectives of scenarios are frequently combined. That is, ALM-policies are evaluated by simulating their consequences on a set of scenarios, and within this evaluation process options are evaluated using a scenario-approach, which of course requires these scenarios to be consistent.
- Business cycles

  VAR-models assume stationarity. However, recently theories have revived that the economic environment is not stationary, but moves in compositions of longer term and shorter term business cycles. An important part of our research effort is focused on identifying these cycles, and replicating them in the scenarios (cf. Steehouwer (2005)).

The simulation of the liabilities in each node $\langle t, n\rangle$ is accomplished in three phases. In the first phase a so-called Push Markov model is applied to generate the status of each current active and non-active plan member in each $\langle t, n\rangle$. That is, given characteristics of the members, especially gender, age, salary group and years of service, matrices of transition probabilities are used to simulate future developments of the members with respect to survival, disability, resignation and career. This part of the model is called a Push Markov model since the stochastic behaviors of the members are independent. The survival probabilities are based on public actuarial tables. The probabilities of disablement, resignation and career are based on data in the social annual reports of the sponsors.

The expected future development of the size and structure of the employee force is input of the ALM-model, determined in cooperation of the Human Resource Manager of the company. Given the results of the Push Markov model, in the second phase a so-called Pull Markov model is applied. This model successively fills vacancies by hiring new employees until the number of employees in each category in each $\langle t, n\rangle$ is as much as possible in accordance with specified numbers.

The result of the first two phases of the generation process of the liabilities is that we know the status of each current and future active and non-active member in each node of each scenario. Then the (frequently extensive) pension scheme of the plan is applied to compute all the relevant actuarial quantities in each node $\langle t, n\rangle$, which especially concern the actuarial cost, the pension payments and the value of the pension liabilities. Of special importance is the determination of the pension liabilities in each $\langle t, n\rangle$. These are determined by discounting the future payments of the members in $\langle t, n\rangle$ by the Nelson Siegel interest rate structure in $\langle t, n\rangle$.

3.2. Simulating the consequences of ALM-policies

In the previous section we described how the VaR-model, the Push-Pull Markov model, and the pension scheme of the plan are used to generate scenarios of the economic environment and of the corresponding development of the pension liabilities. These scenarios are used to evaluate the risk-return consequences of ALM-policies in terms of Surplus-, Contribution-, and Pension at Risk and at Gain. To illustrate how this is accomplished we for the sake of simplicity assume:

- The ALM-policy consists of a contribution policy x_c, a COLA policy x_i, and asset allocation policy x_a, summarized in the ALM-policy vector x.
- The fund in each node $\langle t, n\rangle$ is characterized by the asset allocation α_{tn}, the funded ratio ϕ_{tn} (= ratio between the value of the pension asset and the value of the pension liabilities), the contribution rate χ_{tn}, and a possible COLA deficit ι_{tn}, summarized in the plans "state of the world" vector θ_{tn}.

Thus x denotes the set of decision rules which the ALM-decision makers analyze and specify in ALM-projects. For example, a simple choice for the investment policy x_a, might be to rebalance to a fixed strategic asset allocation in each node $\langle t, n\rangle$, whatever the state of the world θ_{tn} in $\langle t, n\rangle$. Another typical example is the specification of a COLA policy x_I where COLA is not fully granted in $\langle t, n\rangle$ if the funded ratio ϕ_{tn} in $\langle t, n\rangle$ attains too low values.

Now, applying an ALM-policy x on the initial state θ_0 will, given the vector of scenarios for year 1 $\{s_{1n},\ n = 1, \ldots, N\}$, yield the status θ_{1n} of the fund in year 1 of every scenario $n = 1, \ldots, N$: $\theta_{1n} = x(\theta_0, s_{1n})$, $n = 1, \ldots, N$. Analogously, applying the ALM-policy x to any θ_{tn}, will yield the state in $\theta_{t+1,n}$ (see Figure 4): $\theta_{t+1,n} = x(\theta_{tn}, s_{t+1,n})$, $t = 1, \ldots, T$; $n = 1, \ldots, N$.

Given the state vectors θ that result from an ALM-policy x on a scenario set s, in practice we usually determine the following ALM-scores:

- Expected contribution rate:

  The ALM-quantity "expected contribution rate" is defined as the average value of the observed contribution rates in all combinations $\langle t, n\rangle$.

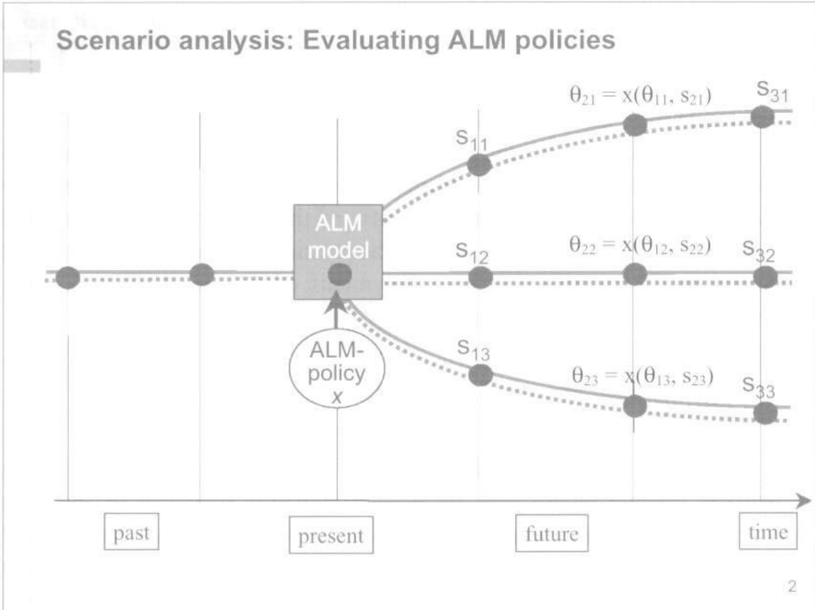

Fig. 4. Evaluation of the "state of the world" of an ALM-policy x in every node $\langle t, n\rangle$.

- Expected funded ratio:

  Analogously to the previous definition the expected funded ratio is defined as the average of the observed funded ratios over all combinations $\langle t, n\rangle$.
- Downside deviation of the funded ratio:

  Following the definition of downside deviation of portfolio return (cf. Sortino and van der Meer (1991)), we define the downside deviation of the funded ratio in year t as the standard deviation of the funded ratios which are smaller than 100% in year t, i.e.,

$$D_t = \left[\sum_{n=1}^{2500} (\mathrm{MIN}(\varphi_{tn} - 100, 0)^2/2500 \right]^{1/2},$$

  where φ_{tn} denotes the funded ratio in $\langle t, n\rangle$. The overall downside deviation of the funded ratio is defined as the average of D_t over all $t = 1, \ldots, 25$.
- Probability of underfunding:

  This risk measure is defined as the percentage of $\langle t, n\rangle$ combinations where a plan is confronted with underfunding. An important alternative definition of underfunding is the percentage of scenarios in which the pension fund is ever over the horizon $t = 1, \ldots, T$ confronted with underfunding.

- 1% 1 year Surplus at Risk (SaR):
  The 1% 1-year Surplus at Risk is defined the amount of underfunding which occurs with 1% probability. For example, if the 1% 1-year SaR is equal to 10, then with a probability of 1% the funded ratio in any year will be smaller than 90%.
- Probability of incomplete COLA:
  This risk measure is defined as the percentage of $\langle t, n\rangle$ combinations where the pension rights of the non-active members will not be fully compensated for the inflation of prices.
- 5% 3-year Pension at Risk (PaR):
  This risk measure quantifies the risks of incomplete COLA over longer periods. The 5% 3-year PaR is defined as the minimal COLA deficit (in percent points) which will occur with 5% probability over a period of 3 years.
- Probability of a contribution rate larger than the basic actuarial contribution:
  This risk measure is defined as the percentage of $\langle t, n\rangle$ combinations where the contribution rate, due to required additional contributions, is larger than the basic actuarial contribution.
- 5% 3-year Contribution at Risk (CaR):
  Analogously, the 5% 3-year CaR is the minimal amount of contributions (expressed as the percentage of salaries in any year) which the sponsor has to pay with 5% probability over a period of 3 years.

3.3. Optimization

Ideally, ALM-optimization models should take into account all available policy instruments. That is, the decision variables of these models should not only concern the asset allocation, but also the contribution- and COLA policy. Secondly, ALM-optimization models should ideally take into account that a current decision can optimally be adapted in future circumstances.

Important examples of ALM-models who optimally adapt current decisions to future circumstances are the dynamic recourse optimization models in: Berkelaar (2002); Carino et al. (1994); Carino and Ziemba (1998); Dert (1995); Geyer et al. (2005); Kouwenberg (2000); Rudolf and Ziemba (2004); Sharpe and Tint (1990); Siegmann (2003); Wallace and Ziemba (2005); and Ziemba (2003), and in the many references on this research area in this two-volume Handbook.

Due to our complex definition of the ALM-problem, in particular, the measures to postpone COLA if the funded ration drops below critical values, in practice we still use the simple hybrid simulation–optimization method described in Boender (1997), Boender, Oldenkamp and Vos (1997) and Boender and Romeijn (1995). That is, the model randomly generates and evaluates tens of thousands random ALM-policies, and selects the ALM-policies which constitute the efficient frontier with respect to the applied ALM-criteria. In principle, any parameter of an ALM-policy can be a decision variable in this search process. A typical example is the search for a state dependent rule which optimally relates the strategic asset allocation (abbreviated SAA), in particular, the amount of equity, to the value of the funded ratio (cf. Section 4.6). However, such an approach is also able to identify jointly optimal investment-contribution policies, which de facto is the core of integral ALM.

Thus, the hybrid simulation–optimization can in principle search for the optimal value of any parameter of ALM-policies, and it guarantees complete consistency between optimization and simulation (actually the interface parameters of the simulation model constitute the decision variables of the random optimization model). However, such a random approach suffers from the "curse of dimensionality". In particular, if an ALM-policy is sought which determines the optimal decision in every year t of every scenario n, the resulting ALM-problem would typically contain tens of thousands of decision variables, in which case the hybrid random method is powerless. Therefore, the need to extend and improve the recourse models such that an optimal integral ALM-decision with respect to all available policy instruments can be identified in every $\langle t, n\rangle$ strongly remains.

4. ALM: Practical results

This section presents ALM-analyses for three pension plans. The characteristics of these plans are described in Section 4.1. In Section 4.2 we describe the scenarios which we apply to evaluate the consequences of ALM-policies. Section 4.3 focuses on the determination of the risk profile of the plans, and on the consequences of the maximum allowable risk for the strategic asset allocation and the basic ALM-policy. In Section 4.4 we proceed to demonstrate the economic power and efficiency of sharing pension risk between the plan sponsor and the members.

The next sections display the efficiency improvements that can be accomplished by alternative investment classes and by alternative investment strategies. In Section 4.5 we quantify the ALM-effectiveness of the policy to hedge strategic currency risks. Section 4.6 treats state-dependent asset allocation. Section 4.7 concludes by analyzing the ALM-improvements that can be accomplished by investing in an asset class that consists of an efficiently constructed portfolio of derivatives.

4.1. *Experimental environment*

The three pension plans which we study all carry out an average pay DB pension scheme, where the active members earn an old-age pension right of 1.75% of pensionable salary (= salary minus state pension) per year. Employees start earning pension rights at the age of 25, and retire at the age of 65, such that a complete pension amounts to 70% of average pay. Widowers pensions amount to 70% of old age pensions. In order to make the results as comparable as possible, we assume that each pension fund starts with the same funded ratio of 120%.

Other characteristics are displayed in Table 2. Plan A can be considered as an "average representative" pension plan. Plan B is a young plan, while plan C is mature. We

Table 2
Characteristics of the pension plans

	Plan A	Plan B	Plan C
No. active members	2.000	11.000	2.000
No. non-active members	6.500	6.500	20.000
Total	8.500	17.000	22.000
Liabilities active members	€175 million	€425 million	€175 million
Liabilities non-active members	€475 million	€475 million	€1450 million
Total liabilities	€650 million	€900 million	€1625 Euro
Maturity (= share of non-actives in the pension liabilities)	73%	53%	89%
Liability leverage (= salaries of the active members expressed as fraction of the total liabilities)	0.22	0.69	0.09
Asset leverage (= pension assets expressed as fraction of the salaries of the active members)	5.5	1.7	13.6
Funded ratio (discount rate liabilities 4%)	120%	120%	120%

emphasize the relevance of the liability leverages and the asset leverages of the plans. The liability leverages implicate that the plans A, B and C with 1% of salaries can improve the funded ratio with, respectively, 0.22 percentpoints (pp), 0.69 pp and 0.09 pp. Thus, from the point of view of the power of additional contributions, plan B is relatively strong, and plan C weak. On the other hand, the asset leverages implicate that 1 pp additional portfolio return for the plans A, B and C is, respectively, equal to 5.5, 1.7, and 13.6% of the salaries of the active members. Thus, the plan that profits most from high portfolio returns suffers hardest from low returns, and vice versa. These characteristics in a large extent determine which ALM-policies are optimal for each of the plans A, B and C.

In our ALM-analyses we assume that the trustees of the plans have already decided on the contribution policy and COLA policy. For reasons of comparison we assume that these core elements of the ALM-policies are equal for each of the plans:

- Contribution policy

  All the plans base their contribution policy on the actuarial contribution, which in any year is equal to the actuarial cost of the new pension rights which have been granted to the active members (excluding the cost of the indexation of the pension rights). Dependent on the value of the funded ratio in any year the plans adapt the basic contribution according to the following surplus-deficit agreement:

  - Deficit agreement

    The deficit agreements, which specifies the risk budgets provided by the sponsors and the amount of risk sharing between the plans and the sponsors, run as follows. If the funded ratio drops below 120%, the contribution is increased, taking into account two restrictions. First of all, the contribution rate, expressed as a percentage of the salaries of the active members, is only allowed to increase 2 pp from one year to the next. Furthermore, the contribution rate is limited to a maximum value of 20% of salaries. These constraints imply that the sponsors only carry part of the risk of the pension plan, with obvious consequences for the ALM-policy, in particular, for the strategic asset allocation.

- Surplus agreement

  The surplus agreements, which specify the benefits which the sponsors get in return for risk budgets they have provided to the plans, run as follows. If the funded ratio exceeds the level of 140%, the contribution is decreased, taking into account two state dependent restrictions. First of all, analogously to the deficit agreement, the contribution rate is only allowed to decrease 2 pp from one year to the next. Secondly, the contribution rate is not further decreased than to the level of 0% (= contribution holiday). However, these restrictions are relaxed if the funded ratio exceeds the level of 180%. In these circumstances all excess assets are refunded to the sponsor.

- COLA policy

  The three plans follow the policy that the pension rights of (only) the non-active members are compensated for the inflation of prices only if the plan is in the situation of a positive surplus (funded ratio > 100%). Indexation deficits are recovered once the funded ratio has recovered to a level above the minimally required 100%. Note that the possibility to postpone COLA of the non-active members defines an important risk budget that the plans can exploit to achieve a higher return on the pension assets. The non-active members are "rewarded" for this risk budget and risk sharing by the intention to use the additional portfolio returns first of all to compensate their pension rights for inflation.

4.2. *Economic scenarios*[1]

In the experiments we use scenarios for the economic quantities and asset classes which are displayed in Tables 3 and 4. Table 3 displays expected values, standard deviations, autocorrelations and Information Ratios (= expected value/standard deviation) which have been observed in the period which has been used to estimate the VAR-model, as well as the values of these statistics in the 2500 scenarios which have been generated by the estimated VAR-model (horizon 25 years).[2] The reader can verify the approximate equality between the historic and future statistics. Exceptions concern the expected values, the Information Ratios, and the standard deviation of the inflation of wages and prices. This is explained as follows:

[1] With respect to the liability scenarios we assume that the number of employees is constant over time. Transition probabilities with respect to survival, career, disablement, etc. are based on national data and on data provided by the sponsoring companies.

[2] The international derivatives fund refers to the alternative asset class which is analyzed in Section 4.7.

Table 3
Historic and scenario statistics of the applied 2500 economic scenarios

	Scenarios 2001–2025					Historic data 1970–2000				
	Avg.	St. dev.	Auto corr. lag1	Auto corr. lag2	IR	Avg.	St. dev.	Auto corr. lag1	Auto corr. lag2	IR
Price inflation	2.75	1.5	0.56	0.25		4.1	3.0	0.86	0.68	–
Wage inflation	3.75	1.8	0.56	0.46		4.9	4.1	0.89	0.76	–
10 year Euro interest rate	5.75	1.3	0.70	0.48		8.1	1.6	0.75	0.53	
Euro bonds (duration 5)	5.9	6.7	−0.22	0.01						–
Equity MSCI Europe	8.75	20.7	−0.17	0.00	0.41	13.5	21.1	−0.19	−0.02	0.64
Equity MSCI USA unhedged	8.9	21.2	0.09	0.01	0.40	13.7	22.5	0.11	0.03	0.61
Equity MSCI UK unhedged	8.6	23.2	0.02	0.11	0.33	13.1	25.5	−0.04	0.11	0.51
Equity MSCI JP unhedged	11.2	34.6	−0.11	−0.12	0.29	16.5	36.3	−0.14	−0.18	0.45
Equity MSCI Emerging markets	12.9	36.1	−0.37	0.02	0.35	19.9	37.0	−0.36	−0.08	0.54
Equity MSCI world unhedged	8.2	20.6	−0.08	−0.09	0.40	12.6	20.7	−0.09	−0.12	0.61
Equity MSCI USA hedged	8.65	15.7	−0.10	−0.09		14.0[a]	16.1	−0.05	−0.21	–
Equity MSCI UK hedged	8.4	19.3	−0.06	−0.03		14.4	20.1	−0.06	0.01	–
Equity MSCI JP hedged	11.0	28.2	−0.08	−0.08		12.0	29.3	−0.06	−0.13	–
International derivatives fund	16.1	34.5	−0.05	−0.04						–

[a]The figures in this block of the table are the locally observed statistics over the period 1970–2000 in the US, UK and Japan.

- Oil crisis

  In the generated scenarios the standard deviations of the inflations are significantly lower than in the past. This is due to the requirement of the VAR-approach that the data should be stationary, which is violated by the values of inflation in the period 1971–1975. Including a dummy variable for the inflations in this period remedies stationarity, but implies of course that the standard deviations in the scenarios deviate from the past.
- Expected values

  In all ALM-projects expected values of the inflations, and the returns on asset classes are not replicated from the past, but separately decided upon, frequently in cooperation with investment advisory committees of the board of trustees.

The risk premium of the several equity asset classes is determined as follows. Starting point is the assumption that the risk premium of European equity, defined as the difference between the expected arithmetic return on European equity and the 10 year Euro interest rate, is equal to 300 basis points (bp). This is substantially lower than we have observed in the past, cf. also the book by Dimson, Marsh and Staunton (2002), who estimate the geometric equity risk premium over the last hundred years to be 450 bp. See Mehra (2006) for further estimates. On the other hand, several economists, see, e.g., Arnott and Bernstein (2002), estimate the forward looking risk premium of equity "nowhere near the 5 percent level of the past", and argue that the

Table 4
Correlations in the applied 2500 economic scenarios

	1	2	3	4	5	6	7	8	9	10	11	12
1. Price inflation												
2. Wage inflation	0.74											
3. Euro bonds (duration 5)	0.11	0.21										
4. Equity MSCI Europe	−0.21	−0.26	0.13									
5. Equity MSCI USA unhedged	0.02	−0.14	0.16	0.80								
6. Equity MSCI UK unhedged	−0.09	−0.19	0.20	0.79	0.69							
7. Equity MSCI JP unhedged	−0.13	−0.11	0.04	0.42	0.32	0.38						
8. Equity MSCI Emerging markets	−0.14	−0.14	0.03	0.56	0.47	0.44	0.78					
9. Equity MSCI world unhedged	−0.10	−0.20	0.17	0.87	0.86	0.76	0.60	0.67				
10. Equity MSCI USA hedged	−0.08	−0.10	0.20	0.62	0.81	0.69	0.24	0.35	0.59			
11. Equity MSCI UK hedged	−0.09	−0.12	0.21	0.74	0.63	0.92	0.43	0.58	0.69	0.58		
12. Equity MSCI JP hedged	−0.17	−0.12	−0.01	0.32	0.25	0.23	0.94	0.78	0.47	0.24	0.34	
13. International derivatives fund	−0.08	−0.15	0.13	0.65	0.65	0.57	0.45	0.50	0.75	0.44	0.52	0.35

forward looking risk premium "may well be near zero, perhaps even negative". Also taking into account that we extrapolate historic standard deviations unchanged to the future,[3] we position ourselves between the very exuberant past, and these very pessimistic views on the future, and proceed with an arithmetic prospective risk premium of 300 basis points (bp) (cf. also Siegel (2003)). For an investment period of 25 years, an arithmetic risk premium of 300 bp for European equity (standard deviation 20.7%) implies a geometric risk premium of only 100 bp, whereas for local US-equity (standard deviation 15.7%), this implies a geometric risk premium of 200 bp.

Given the specification of the prospective risk premium of one of the equity asset classes we determine the expected risk premium of the other equity asset classes as follows. Keeping the volatility of European equity unchanged, the Information ratio of this asset class deteriorates from 0.64 in the past, to 0.41 in the generated scenarios. Given this adaptation, the risk premiums of the other equity asset classes are reduced in such an extent that the IR of these asset classes reduces in accordance with the reduction of the IR of European equity.

In addition to the "classic" asset classes, the tables also mention the characteristics of the "international derivatives fund (IDF)" of ABN-AMRO. The IDF can be seen as a complex call option with an indefinite life, of which the manager seeks to optimize the return profile by buying and selling options (cf. Dert (2002)). Investment decisions are based on the assumption that equity prices are lognormally distributed with an expected return equal to the risk-free rate +6% and a standard deviation that is equal to the

[3] The papers demonstrating low prospective risk premiums of equity never seem to address the consequences of their analysis on the volatilities. Clearly from the point of view of asset allocation low prospective risk premiums of equity would be considerably less problematic (or even not problematic) if the volatilities decline accordingly.

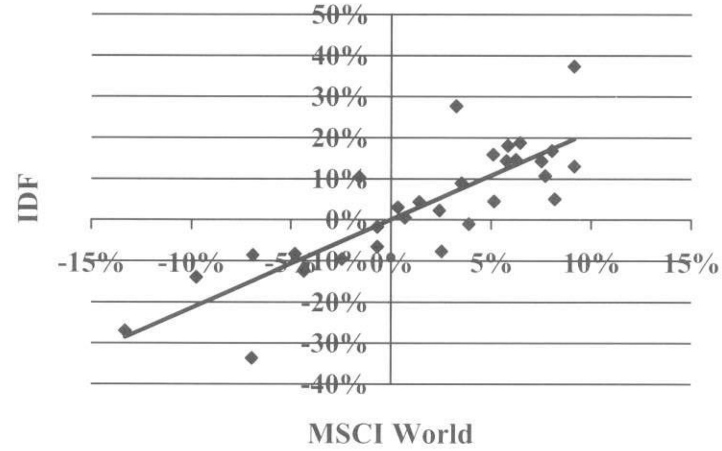

Fig. 5. Gross monthly log returns on the IDF and MSCI, and linear regression line.

implied volatility of at the money options that expire at the investment horizon. The investment policy of the IDF does not allow for stock picking or market timing.

To assess the impact of investing in the IDF, an empirical relationship between the return on the IDF and the return on the MSCI world was established. Figure 5 shows the track record that was used to estimate a relationship between the monthly returns on the IDF and the monthly returns on the MSCI world.

The ALM-model uses annual returns. Therefore, we transform the relationship between the monthly log returns to a relationship between annual log returns. This is straightforward under the assumption that neither the monthly returns on the MSCI World nor the error term in the regression are autocorrelated. We obtain the following relationship:

$$\text{Return IDF} = e^{2.15\ln(\text{Return MSCI})+u},$$

where:

Return MSCI = Gross annual total return on the MSCI World Index,

Return IDF = Gross annual return on the IDF,

u = Random number sampled from a normal distribution with mean 0 and standard deviation 0.319.

In IDF the coefficient of 2.15 reflects substantial leverage to equity returns whilst the functional specification does not allow for returns on the IDF worse than -100%. This is realistic because investors in the IDF only buy a participation in a mutual fund and cannot loose more than their initial investment. This combination of leveraged equity exposure and limited liability can only be attained by the use of options.

Using this relationship we generate returns on the IDF via a 2-step procedure. First, using the approach described in Section 3, we generate scenarios for all economic quantities except the return on the IDF. Then, for each point in time in each scenario the return on the IDF is computed by substituting the associated return on equity and a random number, sampled from the error distribution u, in the equation above. This procedure has two important advantages over using theoretical option pricing models. Firstly, the IDF returns are generated in a way that is fully consistent with the scenario generation of the quantities. And secondly, the returns are based on a historic relationship between real life option returns and the MSCI world which reflects all practical issues that affect returns on option portfolios. The crucial assumption that the decision makers have to make, however, is that this historic relationship is sufficiently representative for the future. But then again, it is straightforward to use the ALM-model to assess the sensitivity of the outcomes of the study to perturbations in this relationship.

4.3. Determination risk profile and strategic asset allocation

Assuming that the pension plans have already decided on the COLA- and contribution part of the ALM-policy, the first ALM-issue that we have to address is the specification of the strategic asset allocation (SAA). Evidently, more investment risk will on the one hand yield higher expected portfolio returns, at the benefit of the contribution rates, the indexations and/or strengthening the buffer, whereas the underfunding-, contribution-, and indexation risk will deteriorate on the other. In deciding on the SAA, and thereby completing the integral ALM-policy, we assume:

(i) The trustees of the boards put an explicit risk constraint on the funded ratio;
(ii) In the basic ALM-policy the SAA will consist of Euro-bonds, and of the equity classes Euro, US, UK, Japan and the emerging markets, where the returns of latter four are unhedged for currency risk. The total amount in equity will be allocated to Euro 25%, US 50%, UK 10%, JP 10% and emerging markets 5%.

Then, the SAA is the mix, structured according to (ii), which satisfies the risk constraint (i).

Thus, it is of crucial importance that the trustees properly determine the maximum allowable downside risk of the funded ratio. In practice, this is supported by the information which is displayed in Figure 6, which for plan A shows how the funded ratios develop in the 2500 scenarios if the plan would, respectively, invest 30, 43, 50 or 60% in equity. In numerous practical ALM-projects the trustees of the plans, thoroughly analyzing and discussing (if not debating) these graphical presentations of the scenario developments of their intended ALM-policies, frequently decide to limit the risk profile of the funded ratio to a downside deviation of at most 2%. For plan A this would imply an SAA with 43% internationally diversified unhedged equity.

Observe from Figure 6 that each extension of the SAA with 10 pp equity would imply that the lower envelop of the scenario developments of the funded ratios would deteriorate approximately 10 pp. Thus, taking into account that the portfolio returns on the pension assets which are required to cover the autonomous growth of the liabilities increases disproportionally with decreasing funded ratios,[4] it cannot be considered un-

[4] Let λ be the liability return, and let f be the funded ratio. Then, in order to meet the liability growth the pension assets have to render a portfolio return of λ/f. For example, if f drops from 100 to 90, 75 and 50%,

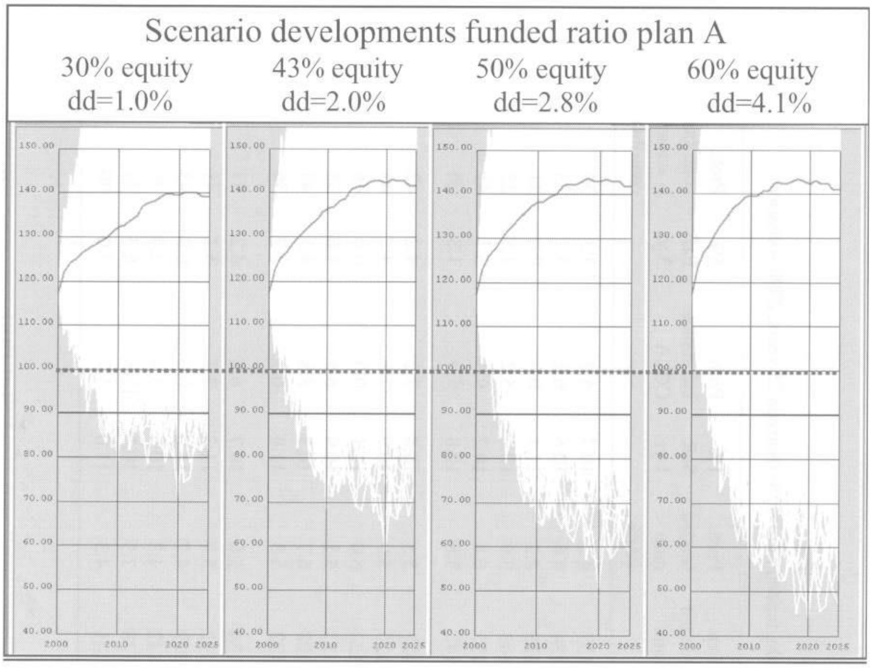

Fig. 6. Scenario developments and scores of the downside deviation (dd) of the funded ratio of plan A with 30, 43, 50 and 60% equity in the strategic asset mix.

wise that the trustees do not authorize a higher risk-profile than a downside deviation of at most 2%.

Applying the risk norm to limit the downside deviation of the funded ratio to 2% also to the plans B and C, these plans can carry a SAA with, respectively, 40 and 33% equity. In combination with the COLA- and contribution policy, which we assume to remain unchanged, the SAA's complete the basic ALM-policies of the plans. The ALM-scores of these policies are depicted in Table 5. We observe that, apparently counter-intuitive, plan B, whose liability leverage is about three times larger than for plan A, and therefore about three times stronger than plan A from the point of view of the impact of additional contributions on the funded ratio, nevertheless contains less equity in the SAA than plan A. This is because the high liability leverage, which makes the plan stronger than plan A at low levels of the funded ratio, also accounts for three times larger deterioration's of the funded ratio if the plan reduces the contributions at high levels of the funded ratio. As a result the expected funded ratio of plan B (127%) is

then the required portfolio returns increase, respectively, 11, 33 and 100%. These required returns only cover the autonomous growth of the liabilities, such that in order to improve the funded ratio, even higher returns have to be achieved.

Table 5
ALM-results for plans A, B and C, given downside deviation of the funded ratio $\leqslant 2\%$ (horizon 25 years, 2500 scenarios)

		Max. perc. equity	Exp. contribution rate	Exp. funded ratio	Prob. funded ratio < 100%	1% SaR 1 yr	Prob. incomplete COLA	5% PaR 3 yr	Prob. contribution > actuarial contribution	5% CaR 3 yr
Plan A	Basic policy	43	5.4	137	4.2	10.7	5.9	3.3	30	59
	Max contribution 15%	37	6.3	134	4.6	10.6	6.2	3.7	33	45
	No risk sharing with non-active members	28	8.2	133	4.2	11.1	0.0	0.0	31	59
	Hedging currency risk	73	1.1	143	3.9	10.7	5.2	1.5	25	57
	State dependent equity exposure (avg)	56	1.4	133	6.4	10.2	9.3	5.1	41	60
	20% alternative equity exposure	58	1.0	143	3.8	10.8	5.0	1.8	26	56
Plan B	Basic policy	40	7.9	127	5.5	10.8	7.2	4.2	42	55
	Max contribution 15%	36	8.0	125	5.9	10.9	7.8	4.7	45	45
	No risk sharing with non-active members	29	8.7	124	6.0	11.1	0.0	0.0	46	54
	Hedging currency risk	69	6.3	132	5.1	10.9	6.5	3.6	35	50
	State dependent equity exposure (avg)	50	6.4	127	6.7	10.3	8.8	4.5	49	57
	20% alternative equity exposure	53	6.3	132	5.3	11.4	6.7	3.9	36	51
Plan C	Basic policy	33	3.7	134	5.0	10.7	6.8	4.2	37	60
	Max contribution 15%	28	5.3	132	5.7	11.3	7.7	5.2	41	45
	No risk sharing with non-active members	17	10.4	127	4.7	11.0	0.0	0.0	43	60
	Hedging currency risk	56	−3.9	142	4.2	10.5	5.4	2.4	30	60
	State dependent equity exposure (avg)	42	−4.4	128	7.5	10.1	10.8	6.3	54	60
	20% alternative equity exposure	46	−4.2	141	4.3	11.0	5.7	3.0	30	60

substantially lower than the expected funded ratio of plan A (137%), which of course reduces the maximum feasible risk exposure of the SAA of plan B. The net result appears that plan B, notwithstanding her contribution power, can invest slightly less in equity than plan A. This phenomenon emphasizes the complexity of integral (COLA-, contribution-, investment-) ALM-policies, as well as the quintessential role of buffers in strategic asset allocation of ALM.

4.4. Risk sharing and integral ALM

In previous sections we described the relevancy of integral ALM, where also the risk budgets provided by the sponsors and the non-active plan members are exploited in order to be able to carry sufficient investment risk, and earn sufficient investment returns to make it feasible to provide adequate pension payments at acceptable pension cost.

In this section this statement is quantified. That is, we analyze the ALM-consequences if the sponsor reduces the risk budget by allowing maximal contribution rates of 15% of salaries, rather than 20%. Secondly, we analyze the ALM-impact if the non-active members would withdraw their risk budget by forcing the plan to fully compensate their pension rights for inflation, whatever the value of the funded ratio. Table 5 shows the importance of the reduction of these risk budgets. That is, if the sponsor is only willing to pay 15% of salaries if the funded ratio deteriorates, then the plans A, B and C would have to reduce the percentage of equity in the SAA's from 43, 40 and 33% to, respectively, 37, 36 and 28% with obvious consequences for the contribution rates.

The risk budget provided by the non-active members appears to be even more important. If this risk budget would be withdrawn, then the percentage of equity in the SAA's would have to be reduced from 43, 40 and 33% to, respectively, 28, 29, and 17%. Taking in mind that an equity risk premium of 3.5% implies that 10% less equity in the SAA of a portfolio of 10 billion reduces investment income with 35 million p.a., the necessary reduction in equity as a result of the withdrawn risk budget can be considered enormous. This is verified by the implications on the expected contribution rates in Table 5: For plan A, the expected contribution rate would increase from 5.4% of salaries to 8.2%. For the younger plan B with the smaller liability leverage, the contribution rate is 8.7% rather than 7.9%. The mature plan C with the relatively large group of non-active members, and the large liability leverage, profits most from the risk budget of the non-active members. For this plan the withdrawal of this risk sharing leads to an expected contribution rate of 10.4% rather than 3.7%.

Finally, the risk budget provided by the non-active members may appear asymmetric to the benefit of the sponsor. Due to this risk budget the expected contribution rates decrease significantly, while the risk providers are confronted with pension risk with apparently no "upside" in return. The (historic) background of this phenomenon is that due to this risk budget the sponsors are able to provide high DB pension rights at reasonable internationally competitive cost, while the non-active plan members are only confronted with reasonably low pension risk.

4.5. Hedging strategic currency risk

An investment outside the home country is a composition of local asset classes and currency exposure. Pension plans increasingly decide to work with hedged strategic benchmarks. That is, they decide to measure their "strategic value added" with respect to benchmarks in which currency risk is eliminated.[5] In this section we give the arguments and counter arguments for this policy, and analyze the potential ALM-efficiency gains for the plans A, B and C.

(a) Risk-return trade-off

The most important argument to hedge strategic currency risk is the assumption that in spite of short time volatility, currencies will not yield an expected long term return. Observe that if pension plans would really in every respect be long term investors, this argument to hedge strategic currency risk would lose a lot of her power: Pension plans could just surf the currency waves without incurring hedging cost. However, also for long term pension plans the short term is extremely relevant. Drops in the funded ratio might trigger additional contributions and postponement of COLA, while also International Accounting Standards (IAS) more-and-more transfer profits and losses of the pension plans to the P&L's of the sponsors. Thus also pension plans have to take into account the short term implications of their long term strategies.

In the scenarios hedged returns are constructed from the local returns by determining expected values according to the interest rate parity (i.e., forward currency returns make up for the differences in the short interest rates between home-countries), and adding correlated error terms which are based on the deviations from the interest rate parity in the applied historic data set (1970–present). The characteristics of the hedged returns, taking into account 20 basis points per annum for the cost of hedging, are displayed in Tables 3 and 4. Clearly the hedged returns provide a much more efficient risk-return trade-off than the unhedged counterparts.

(b) Mean reversion

In addition to the risk-return trade-off, strategic currency hedging also finds its roots in the concept of mean reversion. It can be verified from Table 3 that local equity in all countries displays mean reversion properties. See, for example, Euro equity with a historic mean reversions of -0.19 (lag 1 year), and local US-equity with historic mean reversion of -0.05 and -0.21 (lag 1 year, and lag 2 years). Thus, locally equity returns below the mean with more than 50% probability are followed by returns above the mean, which, in particular, for long term investing pension plans provides a crucially important strong mitigation of risk.

However, we can also verify from Table 3 that unhedged returns, composed of local returns and currency returns, lose the property of mean reversion, especially for US-equity, where the majority of the Dutch international investments are allocated.

[5] A hedged strategic benchmark is not in contradiction with currency bets on the tactical investment level.

Fig. 7.

This is due to the high mean aversion (= positive autocorrelation) of +0.34 of US-dollar-return with respect to the Euro in the historic dataset (cf. also Figure 7), which obviously ruins the mean reversion of local US-equity from the point of view of the unhedged dollar-exposed European investor in US-equity. Clearly, if history would repeat itself, this would provide an additional strong argument to hedge strategic currency risk, especially for long term European investments in the US.

Table 5 displays the ALM-results if the plans would carry out their basic ALM-policy, and hedge the strategic currency risk of their equity investments in the US, UK and Japan. The ALM-results are impressive. Satisfying the risk constraint on the funded ratio plan A can increase the investments in equity form 43 to 73% of the portfolio, with a resulting reduction of the expected contribution rate from 5.4% of salaries to 1.1%. Also, the scores on all other ALM-criteria improve, in particular, the 5% 3-year Pension at Risk for the non-active members, which almost halves from 2.7 to 1.5%. Decomposition of these efficiency gains learns that about 2/3 can be attributed to the risk-return trade-off of hedged returns (a), and 1/3 to the retaining of mean reversion.

Next we address whether there are also counter-arguments for fully hedged benchmarks:

– Forward premium puzzle

A delicate issue is the impact of the forward premium puzzle on the decision to hedge strategic currency risk. That is, that the dollar-return and the forward dollar rate (which is used for hedging the currency risk) in practice are negatively correlated. In the historic period which we apply for scenario generation this correlation is −0.38. In the scenarios the puzzle presents itself in the curious phenomenon that the correlation between the dollar and local US-equity is +0.16, whereas the correlation between the forward dollar rate and local US-equity is −0.31. Thus recalling

$$\begin{aligned}\sigma^2(\text{unhedged}) &= \sigma^2(\text{local equity}) + \sigma^2(\text{dollar})\\ &\quad + 2 * \rho(\text{local equity, dollar}) * \sigma(\text{local equity}) * \sigma(\text{dollar})\\ \sigma^2(\text{hedged}) &= \sigma^2(\text{local equity}) + \sigma^2(\text{forward rater})\\ &\quad + 2 * \rho(\text{local equity, forward rate}) * \sigma(\text{local equity})\\ &\quad * \sigma(\text{forward rate})\end{aligned}$$

we must conclude that the puzzle works out very negative for the volatility of unhedged returns (positive correlation between local US-equity and the dollar), and positively for hedged returns (negative correlation between local US-equity and the forward rate).

– Peer group risk

Also pension plans are sensitive for peer group risk. That is, if a plan realizes a lower portfolio return than the universe (whatever the benchmarks and the liability structure of the plan), this will lead to bad publicity in the press. Thus, in taking the hedge decision also the probability of realizing a lower performance than unhedged benchmarks has to be taken into account. Relevant probabilities are (of course) that a hedged portfolio with 50% probability will generate a lower return than an unhedged portfolio, and that a hedged portfolio with 10% probability generates a 3% lower return as an unhedged portfolio. Taking into account that 3% could be seen as a reasonable estimate for the equity risk premium, these figures again emphasize that the currency exposure strongly matters.

– Long term implementation

Finally, if boards of pension plans abstain from hedging strategic currency risk, the most overriding argument is implementation risk. Currency hedging is implemented using forward contracts. That is, if the currency depreciates, the plan is regularly compensated for the loss. But, if the currency appreciates, the plan is regularly "billed". Figure 7 indicates that currencies tend to move in long waves. Thus, a plan that hedges currency risk may be confronted with a sequence of dozens of months in which the plan repeatedly has to pay to compensate for the appreciating currency. Boards fear the risk that during such a long sequence they might bail out of the hedging policy, thereby incurring a considerable loss, rather than waiting for the recovery which is implicit in the basic assumption that currencies yield no long term return.

4.6. *State dependent asset allocation*

In this section we address the issue of state dependent asset allocation. Intuitively, the more surplus over the liabilities, the more market risk a pension plan could carry in the investment portfolio. A logical consequence of this proposition (not appreciated by many investment managers faithfully acting on the principle of mean reversion) is that the smaller the surplus, the less a pension plan should expose herself to market risk, and

Table 6
State dependent percentages of equity in the strategic asset allocation: Evaluation criteria: Expected contribution rate & downside deviation funded ratio $< 2\%$

Plan A	Plan B	Plan C
Funded ratio: $\leqslant 105:20\%$	$\leqslant 110:20\%$	$\leqslant 115:10\%$
Funded ratio: $120:55\%$	$120:55\%$	$120:55\%$
Funded ratio: $130:65\%$	$130:65\%$	$130:65\%$
Funded ratio: $\geqslant 190:95\%$	$\geqslant 190:95\%$	$\geqslant 190:95\%$

thus reduce equity in the SAA. An important argument underlying this proposition is that the portfolio return that is required to cover the autonomous growth of the liabilities increases exponentially if the funded ratio deteriorates. As a result it would be rational to carry out a policy which aims to prevent underfunding by timely reducing equity in the SAA if the funded ratio deteriorates.

We investigated this proposition by the simple random search algorithm described in Section 3. The (approximate) optimal policies that have been identified by the search for the plans A, B and C are depicted in Table 6.[6] The ALM-consequences of these policies are contained in Table 5.

The structure of the optimal rules is that if the funded ratio drops to 120%, which is also the level at which the contribution rate is increased, the amount of equity is significantly reduced. Clearly this element of the optimal rules guarantees that deficits are efficiently aimed to prevent. If the funded ratio increases above the level of 120%, the optimal amount of equity increases proportionally: up to a funded ratio of 130% with 10% of equity per 10% points more funded ratio, and at funded ratios above 130% with 5% of equity per 10 pp more funded ratio.

Secondly, the ALM-scores in Table 5 indicate that also the ALM-scores of state dependent asset allocation are impressive. In relation to the basic ALM-policy the expected contribution rate for the plans A, B and C reduces from 5.4, 7.9 and 3.7% to 1.4, 6.4 and -4.4% at the same underfunding risk. Hence, given these criteria, state dependent asset allocation is extremely efficient. However, due to the state dependent investment policy the COLA- and contribution risks significantly increase. Hence, in practice pensioners might argue that such an investment policy should be accompanied by appropriate measures to reduce COLA risk.

[6] If the algorithm would randomly generate state dependent rule of arbitrary form, then the optimal rules would be V-shaped. That is, given the applied ALM-criteria, at low funded ratios it is optimal to increase the amount of equity in the SAA if the funded ratio further deteriorates. This result is also sustained by the more sophisticated recourse optimization models (see, e.g., Berkelaar (2002), Dert (1995), and Kouwenberg (2000)). Apparently, if the funded ratio is critically low, the optimal escape is to increase the expected portfolio return, and accept the accompanying higher risk. However, since the regulating authority forbids this conduct, we restricted the random optimizer to generate only rules where the market risk in the SAA increases monotonically with increasing funded ratios.

4.7. *Alternative equity exposure*

The use of derivatives in ALM is still a relatively uninvestigated research area, see, e.g., Boender, Oldenkamp and Vos (1997). In this final section we investigate the ALM consequences of the alternative equity exposure via the IDF derivatives product described in Section 4.2. We carried out the investigation by replacing 20% of the equity exposure of the asset mixes by the IDF product (thus, in an asset allocation with 50% equity, 10% points of equity is replaced by IDF). The results appear in Table 5. The reader can verify that the ALM efficiency gains are very significant. Why should using derivatives produce these improvements? The improvements cannot be explained from the Information Ratio of the derivatives product. The key is asymmetry. Using derivatives ALM-ers can create upside potential, while efficiently protecting downside risk. Therefore, with respect to the strategic use of derivatives in ALM, we expect that we have only seen the very beginning.

5. Conclusion

This paper emphasizes the integral approach of ALM-problems. That is, given a set of assumptions about the relevant uncertainties, for each of the stakeholders a maximum risk limit is specified. This implies that risk limits are specified with respect to pension and indexation/COLA at risk, contribution at risk, and surplus at risk. Given these risk limits an integral indexation/COLA-, contribution-, and investment policy is specified which optimizes return. The ALM-policy which is the result of the integral approach is also referred to as the pension deal.

The empirical Section 4 shows the relevance of this approach. For plan A which can carry 43% of equity and 57% bonds in the base case, the maximum amount of equity decreases to 37 and 28%, respectively, if the sponsor reduces the maximum contribution form 20% of salaries to 15%, and if the non-active members abstain from state-dependent COLA.

The paper also demonstrates the relevance of the structure of the liabilities. In the base case, where plan A can carry 43% of equity in the strategic asset allocation, plans B and C that are, respectively, less and more mature than plan B, the amount of equity in the strategic asset allocation is ceteris paribus equal to 40 and 33%. Recently the relevance of the liabilities to investing is also emphasized in the investment community (cf., e.g., inflection point III in Bernstein (2003), referred to as liability driven investing (LDI)).

The paper also demonstrates the effectiveness of alternative asset categories and alternative asset strategies. We selected to study hedging currency risk, state dependent asset allocation and a high upside/low downside derivatives product. Given the same amount of surplus at risk, for plan A these alternatives imply that the plan can risk neutrally change the strategic asset allocation to 15 and 30% more equity. The effects of other measures such as flexible pension schemes, dynamic derivative strategies, matching of interest rate risk, elimination of the "long-only" constraint, and the impact of other alternative investments such as commodities, private equity and hedge funds are not described here.

Finally, our approach is based on simulation. We look forward to integrating more stochastic optimization in our models (see, e.g., Wallace and Ziemba (2005), and the results of others in this volume), such that ALM projects in the pension-, insurance-, and banking industry both applying new products and new technologies can further improve the efficiency of their strategies.

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