Pension fund risk and return management

From ALM to day-to-day investment decisions

Masters thesis

Business mathematics and informatics

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Preface

Before you lies a final report of a 10 month internship at ORTEC-finance bv. The internship served as a conclusion to my masters programme Business Mathematics and Informatics at the Vrije Universiteit of Amsterdam.

During my 10 month internship I combined my research for this thesis with a job as pension fund consultant at ORTEC-finance. This combination gave me the opportunity to explore both the practical and theoretical aspects of pension fund risk and return management. First of all I would like to thank Annemieke van Goor, coordinator of internships at the Vrije Universiteit, for granting me this opportunity to combine work and internship.

This thesis covers several aspects of pension fund risk and return management. The world of pension funds was completely new to me when I started this internship at May 1, 2007. I would like to express special thanks to Loranne van Lieshout and Jitske van Londen, my supervisors at ORTEC-finance, for guiding me through this new world. Both Loranne and Jitske provided me with useful input, and helped me getting to this interesting final result.

The progress of my internship was warranted by René Bekker, my supervisor from the department of mathematics and informatics of the Vrije Universiteit. During our monthly meetings René provided me with very useful feedback. As it was for me, the world of pension funds was completely new to René. His great interest and involvement were of great help when exploring this new world. I would like to show gratitude and render special thanks to René for his great input and help during the internship.

My thanks also go out to Sandjai Bhulai, secondary supervisor from the Vrije Universiteit, who followed my progress from a distance. His great involvement was a great motivator, especially in the final stage of the internship.

Last but not least I want to show my gratitude to my colleagues at ORTEC-finance, who were always interested and helpful during both internship and work. And besides that, they simply were major ingredients for a pleasant and entertaining period at ORTEC-finance.

Niels Horst, Rotterdam, July 7, 2008.

Executive Summary

In this thesis we describe several aspects of pension fund risk and return management. ORTEC-Finance offers a wide range of services in this area. ORTEC guides pension funds along the path from long-term Assets and Liabilities Management (ALM) to day-to-day investment decisions. This thesis describes issues arising during the different phases of risk and return management for pension funds.

Modeling the pension fund

For both long-term ALM analysis and day-to-day investment decisions, ORTEC utilizes advanced models and software to properly and efficiently model the pension fund. ORTEC uses the Assets and Liabilities Scenario system (ALS) when performing ALM studies for pension funds. ALS is capable of fully modeling the pension fund with all its policy instruments. With ALS, ORTEC created a model of both an economic and demographic environment in which a model of the pension fund can be simulated into the future. The core of the pension fund model is formed by the modules used to model the pension fund's liability structure and its policy instruments. ALS uses the actuarial module to create a detailed model of the liability structure of the pension plan. The contribution policy and the indexation policy of the fund are modeled in the Financing module.

The downside of the detailed and sophisticated model used by ALS, is the fact that it is rather complicated and that it requires a significant level of knowledge to operate the model. Instead of a detailed model, like ALS, one might prefer a less complicated approximation of the pension fund obligations. Both in the literature and in practice, many different methods of modeling the pension fund form a major point of discussion. A common approach used by investment managers is to create a projection of future cash flows. Investment decisions founded by such projections are often summarized in the term Liability Driven Investing, or LDI in short. Throughout this thesis we use the phrase Termination Driven Investing (TDI), since the approach virtually closes the pension fund. The participants of the pension plan will no longer accrue new pension rights and there are no new participants entering the plan.

Modeling the pension fund in a liquidation setting, as in TDI, causes a severe overestimation of the ALM risks. The mismatch is severe enough to conclude that the liquidation setting is useless for supporting the long term strategic investment decision making process. The cause of the overestimation of the risks in a termination driven context is threefold. First of all, the risk-sharing contract between the pension fund and the sponsor is neglected in a TDI approach. A non-closed fund receives additional contributions from the sponsor when the fund finds itself in a state of low funding ratio. The additional contributions help to assure the financial health of the fund. The same holds for the second shortcoming of TDI: the lack of conditional compensation mechanisms that many pension funds use as a risk reducing instrument. Compensation for inflation can be postponed if the fund's solvability is below some critical level. The final shortcoming of TDI is the lack of accrual of new pension rights. In a non-closed fund new rights enter the plan every year. These new rights are purchased at the actuarial price. This price often includes an additional contribution for preservation of required buffers. This implies that new rights enter the plan at a healthy funded ratio and thus cause a partial recovery of weak solvability values.

TDI neglects three essential risk-reducing policy instruments. This makes the TDI approach unsuitable for supporting the ALM decision making process. Each shortcoming of the TDI approach has its effect on the overestimation of the solvency risks. Eliminating a shortcoming results in a far better approximation of the true situation of the fund. However, eliminating one shortcoming still is insufficient to consider the liability model to be accurate enough. ORTEC has recently developed a piece of software that might resolve this issue. A new module for the Assets and Liabilities Scenario system creates the possibility to model the liabilities in a TDI-like way, without having to cope with the shortcomings. That is, we combine the simplicity of the liquidation setting with all dynamics of ALS. This new module is called the Expected Cash Flow (ECF) module.

Several test cases pointed out that ORTEC's ECF module can be a good alternative for the detailed and complicated liability model. The module combines the simplicity of the liquidation setting with the ability to model the different policy instruments of the pension fund. The ALM consultant can save lots of time by using the less complicated model. Hence, we conclude that the ECF module can be very useful. However, the ALM analyst utilizing the ECF module should be aware of several technical and practical issues and shortcomings of the module.

The ECF module might be used in situations in which liability data on individual level is not available. ORTEC often faces such situations when performing analysis for foreign clients. Another situation in which the ECF module might come in handy is when the focus of the research is on the investments of the client, or when only a quick scan is required. However, to get the most realistic dynamics in liabilities and cash flows, the normal actuarial module remains indispensable. Especially when actuarial analysis on the course of life assumptions and the pension regulations is needed.

ALM implementation

Modeling the pension fund is the foundation for the analysis performed during all phases of pension fund risk and return management. In this thesis we highlight several aspects of the important ALM implementation (ALMi) phase. This phase forms the connection between long-term strategic management and day-to-day investment decisions. The pension deal resulting from the ALM study includes a strategic asset allocation. The composition of this asset mix is driven by the ambitions of the fund and is agreed upon because of the corresponding acceptable ALM risks. During the ALMi phase we zoom in on the investments and try to improve the performance of the fund by improving the investment policy. An important aspect of the ALM implementation phase is optimization of the asset portfolio. In this thesis we analyzed techniques based on the Modern Portfolio Theory of Markowitz.

Portfolio optimization can be a very powerful tool to improve the ALM performance of the pension fund. However, Markowitz optimization in an asset-only context can have undesired effects. Several test cases pointed out that the results for the pension fund's performance might give some reason for concern. Especially the short-term performance may be affected negatively by the optimization in an asset-only context. For that reason we advise pension fund managers to include the liabilities in any portfolio optimization routine. The Markowitz funded ratio optimization keeps track of the correlation between asset returns and the liabilities. This optimization routine should be preferred over the asset-only Markowitz optimization. Conclusion is that portfolio optimization can be a very powerful tool to improve the ALM performance of the fund, as long as the liabilities are taken into account at all times.

Once the optimal asset mix has been determined we enter the next stage of the ALM implementation phase: constructing mandates for the asset managers of the pension fund. The mandates should satisfy a very important criterion: the behavior of the asset manager, resulting from the mandate, should affect the ALM results exactly as agreed upon during the ALM study or at least within acceptable boundaries. In order to achieve the desirable correlation between the asset portfolio and the liability structure of the pension fund, the mandate for the asset manager should be sufficiently tight. The traditional mandate, restricting the manager to benchmarks and maximum tracking errors, does not create the possibility of divergence from the ALM results. Any less restrictive mandate, like a Value at Risk requirement, offers the asset manager too much freedom. This freedom can affect the ALM results both negatively and positively. Either way, the possibly large deviations from the results of the pension deal are reason for concern. That is why we conclude that mandates for the asset managers should be constructed as tight as possible, in order to guarantee the ALM performance agreed upon in the pension deal.

Scenario generation

All analysis ORTEC performs in the area of pension fund risk management is based on scenario generation. In the Assets and Liabilities Scenario system scenarios are generated using a Vector Auto Regression model, or VAR model in short. Besides the VAR model embedded in ALS, ORTEC uses another scenario generator in a different phase of pension fund risk and return management. This risk management tool is called PRISMA. The generator is based on drawings from a historical set of macro-economic scenarios. Both scenario generators have their own specific characteristics.

Both models for generating economic scenarios are flexible and provide opportunities to include the user's view on the future. The VAR model is capable of modeling more characteristics of the real economy than the PRISMA generator. The VAR model captures auto-correlations and cross-correlations. The PRISMA generator does not. Problems arising when using the VAR model, like overfitting and high probabilities of negative values, can be solved or dodged using smart techniques.

The advantage of PRISMA is the fact that it is very suitable for short-term analysis. The model can estimate scenarios based on weekly or monthly data, whereas the VAR model of ALS is based on annual data. The main conclusion is that the scenario generators discussed in this thesis are very sophisticated and form a great contribution to well-founded pension fund risk and return management.

Contents

Chapter 1

Problem statement and institutional setting

Pension fund risk and return management includes several routines, which are all interrelated. From long-term strategic assets and liabilities management (ALM), to day-to-day investment decisions, and on to performance evaluation and attribution. ORTEC offers a wide range of services in the area of pension fund risk and return management. In this thesis we highlight several issues concerning the many routines in the field of risk and return analysis for pension funds.

The issues dealt with in this thesis are divided into three headlines. The first headline concerns the modeling of a pension fund. ORTEC uses the Assets and Liabilities Scenario system (ALS) for this purpose. ALS is a sophisticated tool suitable for creating a detailed model of the pension fund. With this model ORTEC is able to perform well founded ALM analysis. However, the model is rather complicated and fully utilizing its functionality is time-consuming and requires extensive knowledge. Although the detailed model is often irreplaceable for its capability of analyzing impacts of several course of life assumptions (mortality rates, career, marital status, etc.), one might prefer a less complicated model for some parts of the research. Both in the literature and in practice, several less complicated methods exist to model the pension fund. The first headline of this thesis consists of the analysis of several models for the pension fund.

Headline 1 described above applies to several routines in the field of pension fund risk and return management. The pension fund models serve as foundation for almost every analysis performed on pension funds. The second headline of this thesis aims at a more specific area of pension fund risk management. This headline focuses on the phase succeeding the long-term strategic ALM study. We refer to this phase as the ALM implementation (ALMi) phase. In this phase we tempt to put the long-term strategic planning into practice. Activities in the ALMi phase include portfolio optimization, constructing mandates for the asset manager, interest-, currency- and inflation hedging, benchmark selection, credit default risks analysis, sensitivity analysis for economic assumptions, etcetera. The purpose of headline 2 in this thesis is to emphasize the significant importance of pension risks in the ALM implementation phase. We identify the pitfalls of managing pension fund risks in an asset-only context, and we show that the liabilities should be taken into account at all times.

The final headline of this thesis contains an evaluation of the ORTEC methods of generating economic scenarios. We consider two different methods used in two different analytical tools developed for the purpose of risk and return management. Besides a technical description of the models, we present an overview of the modeling capacities of both methods. We describe to which extent the model is able to capture characteristics of both past and future developments of the economy. The generators that will be addressed in headline 3 are the so-called Vector Auto Regressive (VAR) scenario generation method integrated in ALS, and a bootstrapping scenario generation procedure used by another risk management tool called PRISMA.

Before we start the analysis of each of the three headlines we first give a brief introduction to the Dutch pension scheme in Chapter 2. In Chapter 3 we describe an important aspect of pension fund risk and return management: long term strategic ALM. In this chapter we also describe the scenario approach to ALM applied by ORTEC. In Chapter 4 the reader can get further acquainted with ALM by means of an example of an ALM study for an artificial pension fund named Hollandia. The Hollandia fund and its ALM results will serve as a test case throughout the remainder of the thesis.

In Chapter 5 we get started with the first headline of our research. In this chapter we describe our findings on pension fund modeling techniques. Headline 1 is directly followed by headline 2 in Chapter 6 about the ALM implementation phase and the importance of pension risks in this phase. Finally, the economic scenario generators of headline 3 will be addressed in Chapter 7.

Chapter 2

The Dutch pension scheme

The pension system in the Netherlands is very sophisticated and serves as an example for many other European countries. In this chapter we provide a brief description of the Dutch pension scheme. The Dutch pension system is divided into three pillars. The first pillar represents the pensions arranged by the state. The second pillar concerns the occupational pensions and, finally, in the third pillar we find the private pension arrangements. The first three sections of this chapter contain a description of the pensions in each of the three pillars. In Section 2.4 we describe some issues concerning the pensions in the second pillar. In that section we introduce some terminology required to understand the remainder of this thesis.

Pensions in the second pillar are often managed by pension funds. Section 2.5 describes the role of the pension fund and its stakeholders. One of these stakeholders is the regulatory entity of the Dutch government. Section 2.6 describes the pension regulations relevant for the pension funds management.

2.1 The first pillar: state pensions

After reaching the pensionable age of 65 each individual that lived and/or worked in the Netherlands receives payments originated from the General Old Age Pensions Act, or AOW in Dutch. Whether or not the individual has an employment history is not important. Besides this governmental addition to the old age pension the state also made an arrangement for disability. If an individual becomes disabled, he or she might no longer be able to generate income. The Dutch government provides compensation by means of a disability pension (WAO). A second cause of termination of the income flow is the death of the individual. The direct relatives to the deceased receive a compensation by means of the General Surviving Relative Act (ANW). All these forms of government initiated pensions are joined in the first pillar of the Dutch pension system.

2.2 The second pillar: occupational pensions

Pensions in the second pillar originate from an employment history. These pensions can be seen as continuation of salary payments after retirement. An individual accrues rights during his or her active career. The most common old age pensions from the second pillar aim at an annual pension of 70% of the average career salary. Besides old age pensions, the second pillar also includes surviving relative arrangements, disability pensions and all other arrangements between employer and employee. There is no common standard for the occupational pensions in the second pillar. The arrangements can differ in many details, like the way the contributions are shared between employer and employee. The pensions in the second pillar are the main subject of this thesis and will be discussed in further detail.

2.3 The third pillar: private pension arrangements

The third pillar contains all voluntarily accrued pension rights. An individual might find his or her total state- and occupational pensions insufficient. In that case the individual has several possibilities to create additional capital for the old days. Common examples of third pillar pensions are annuities, savings and other forms of capacity like a house or a company. Ever since the market clash in the early twenty-first century many employers also offer a form of third pillar pensions. In the modern world of pensions one might come across a hybrid 'defined benefit - defined contribution' system, in which the employer decides to apply second pillar pensions up to a salary of (say) €40000 and create a defined contribution scheme for the excess salary. This gives the employee the opportunity to invest an amount of his or her choice in the future pensions. The pensions in the third pillar can be summarized as all voluntarily accrued additional facilities for the old days.

2.4 Issues of occupational pensions

The occupational pensions from the second pillar are the main concern of this thesis. This section briefly discusses the most important issues and characteristics of occupational pensions.

2.4.1 Final pay versus average pay systems

Many variations exist in the way pension entitlements are accrued. Up until the early twenty-first century most pension schemes were final pay systems aiming at an old age pension of 70% of the last earned salary. We refer to a scheme that aims at a percentage of the last earned salary as a final pay scheme. Partly due to the situation on the financial markets, many Dutch companies recently moved from a final pay scheme to an average pay scheme. An average pay scheme aims at a percentage (often 70%) of the average career salary.

2.4.2 Defined benefit versus defined contribution

Defined benefit and defined contribution are the two major types of retirement pensions. Which type should be preferred is beyond the scope of this thesis. This issue is point of discussion in a huge amount of literature. For more information on the issue, see for example Boender [2] or Yang [8].

The Internal Revenue Code (IRC), the main body of domestic statutory tax law of the United States, gives the following definition of a defined contribution plan: *"a plan providing for an individual account for each participant, and for benefits based solely on the amount contributed to the account, plus or minus income, gains, expenses and losses allocated to the account"*. The most important characteristics of a defined contribution plan are the individuality and the fact that the contributions are defined by the employee. The contributions can be invested in, for example, the stock market. The returns on the investment are credited to the individual's account. At retirement the account is used to provide the individual with pension payments. Result of this construction is the fact that the benefits are subject to a lot of uncertainty. The *contributions* are *defined*, but the benefits are not. The pension risk in a defined contribution plan is fully carried by the employee.

The opposite of defined contribution is defined benefit. A defined benefit aims for a certain amount of pension at retirement. The *benefit* is *defined*. A defined benefit plan creates security of a guaranteed retirement income. The sponsor, or employer, carries the pension risk in the defined benefit plan.

2.5 Pension funds

Pension funds and the way they are managed are major points of interest throughout this thesis. The pension fund is an entity with a lot of stakeholders. Figure 2.1 gives a schematic overview of all these stakeholders. At the top of the figure we find the The regulatory authorities, like De Nederlandsche Bank (DNB). DNB controls the pension fund by means of the new financial regulatory framework (nFTK). Just above the pension fund we see the management entity. The management is responsible for the pension policy. The management and the pension fund agree upon the Actuarial and Operating Memorandum (AOM) in which the policy regarding the financial structure of the pension fund is stated. The pension fund communicates its mechanics through the pension regulations. The pension regulations serve as an encyclopedia for the employees. It contains information about the size of the pension entitlements, about the entitlements that remain if the participant leaves the fund, about the conditions that are required to participate in the fund, about the arrangements concerning accrual of new rights, etcetera. In the agreement between the pension fund and the employer, the rights and obligations of both parties are anchored. This agreement includes a consent about the contribution policy.

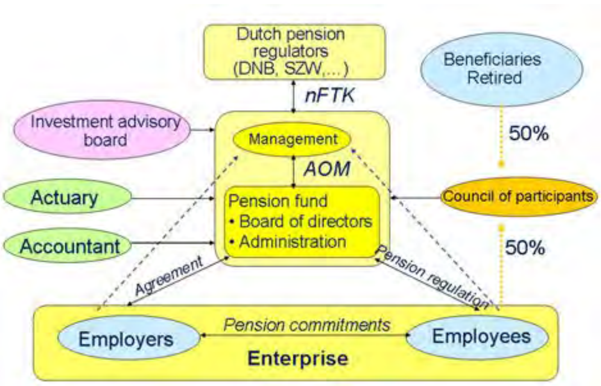

Figure 2.1: The pension fund and its stakeholders

At the right side of Figure 2.1 the council of participants is situated. This entity consists of representatives of both the active participants and the beneficiaries. The council gives advise about important pension fund issues like changes in the regulations, decisions about compensation for inflation, the annual account and the balance sheet. The actuary is the mathematical adviser of the pension fund. He or she provides input concerning changes in rights and obligations of both the employer and the employees. The actuary also has a controlling role. He or she evaluates the financial condition of the fund and reports his or her findings in an actuarial report. The accountant is responsible for the annual account and ensures its fidelity. Last but not least there is the investment advisory board. This committee shares its knowledge about future economic prospects and helps defining the investment strategy.

2.6 Pension regulators and nFTK

In the early twenty first century a market turmoil forced many pension funds into situations of limited solvability. These alarming situations initiated a radical intervention of pension fund managers. Contribution levels were raised and many plans switched from a final pay scheme to an average pay scheme. Many pension plans also took measures concerning compensation for inflation. Up until the financial market turmoil accrued benefits for both active and non-active participants of most pension plans were unconditionally compensated for inflation. Nowadays most pension plans condition the amount of compensation on the financial health of the fund.

All these interventions of the fund managers, in combination with the recovering stock markets, caused the health of the Dutch pension funds to recover to acceptable levels. However, the difficult period alerted the controlling entities in the Netherlands. The Pensions- & Insurance Supervisory Board (PVK, currently part of DNB) introduced the new financial regulatory framework (nFTK). This new set of regulatory rules contains four major headlines.

The first headline concerns the valuation of provisions for pension obligations. The provisions for pension obligations are determined by calculating the net present value of all estimated future pension payments. In the past, these payments were discounted at a fixed interest rate (usually 4%). The nFTK demands a valuation of pension obligations using a (zero-coupon) yieldcurve. Figure 2.2 shows the yieldcurve determined by De Nederlandsche Bank (DNB) at the end of November 2007. Cashflows of different maturities are discounted at different rates, resulting in a so-called fair value of provisions for pension obligations. Besides the fair value determination, the provisions should also take into account the future mortality tenor.

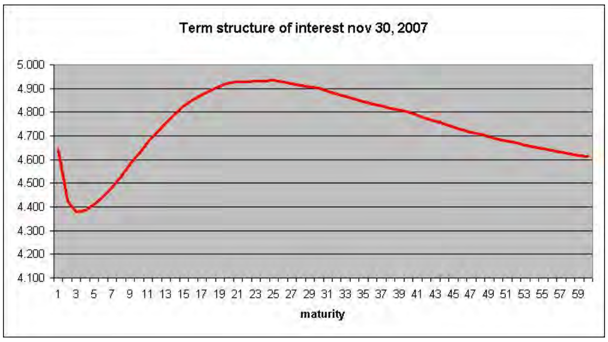

Figure 2.2: Term structure of interest

The second important headline of the nFTK is about solvability demands. The pension fund has the obligation to attain certain buffers to reduce the probability of a deficit. The minimal required buffer can be computed using a complex formula based on European guidelines. The minimal required buffer is approximately 4.5% of the total provision for pension obligations. The minimal required buffer is often rounded to 5% of the total provisons. If the pension fund does not possess the minimal required buffer the fund is in a situation of funding shortfall. In that case the fund has to present a plan to recover within 3 years.

Besides the minimal required buffer, the regulatory framework contains a second issue concerning the fund's buffers. Depending on several policy characteristics, the fund gets assigned a certain target solvency level. This target solvency level is designed to assure that the year-to-year probability of a deficit is at most 2.5%. The pension fund policy should be determined in such a way that the target solvability is present at least within 15 years from now. The size of the target buffer depends on several characteristics of the fund and its policy, and can be determined by the so-called S-formula or square-root formula. The formula takes 6 sources of pension fund risk as input:

S1: **Interest rate risk**: measures the impact of a change in the term structure of interest at the amount of 1 percentage point over all maturities. Interest rate risk highly depends on the duration of the liabilities;

S2: **Equity risk**: Measures the impact of a devaluation of the equity portfolio of the pension fund. The equity risk buffer hedges the fund against a 25% decline of the mature markets portfolio, 30% of private equity, 35% of the emerging martkets portfolio and 25% in the real estate investments. Correlation among these groups is assumed to be 0.75.

S3: **Currency risk**: Measures the impact of a 20% currency devaluation relative to the Euro;

S4: **Commodities risk**: Measures the impact of a 30% decline in the value of the commodities portfolio of the fund;

S5: **Credit risk**: Measures the impact of a 40% increase in credit risk;

S6: **Actuarial risk**: This form of risk is caused by uncertainty about mortality and other transition probabilities. The amount of actuarial risk depends on the the number of participants in the plan, the pension regulations, and on the average age of the plan's participants.

All these sources of risk are combined in the square root- or S-formula:

$$\sqrt{(S1^2 + S2^2 + 2 \times 0.5 \times S1 \times S2 + S3^2 + S4^2 + S5^2 + S6^2)}$$

The square root formula determines the target buffer. If the pension fund does not possess the desired buffer, the deficit should be recovered within 15 years.

The third headline of the nFTK sets a minimum on the contributions. The pension fund has to charge the sponsor at least the 'cost covering contribution'. This contribution consists of the following components:

- The actuarial contribution for the purchase of unconditional commitments;
- Additional contributions for the establishment and preservation of desired and required buffers;
- Execution costs;
- The actuarial contribution for conditional commitments, taking into account the formulated ambitions and the financing methods agreed upon.

The cost covering contribution should be determined at fair value. However, the pension fund is not obliged to use the term structure of interest as a discount factor. The fund may also choose to utilize a more stable discount factor (i.e. 4% fixed) as long as this discount factor meets the conditions of DNB.

The final important aspect of the nFTK is the so-called indexation matrix. This matrix gives information about the agreements concerning compensation for inflation. Depending on the fund's ambition (no commitments, conditional or unconditional commitments, benchmarks), decision-making process (incidentally, annual board meeting, indexation table, unconditional compensation), and financing method (additional contributions, excess returns) the fund gets assigned to a category. The categories are summarized in Figure 2.3. In 2008 the indexationmatrix will be replaced by an indexation label, providing

	Ambition	Decisionmaking	Financing
A.	No commitments	Incidental decisions	No financing Compensation if funded ratio > desired.
B.	No explicit indexation policy	Annual boardmeetings	No financiing. Compensation if Funded ratio > required .
C.	Conditional compensation not linked to an ex-ante benchmark	Contribution -> compensation 1/x buffer -> compensation	Additional contributions.
D.	Conditional compensation not linked to an ex-ante benchmark	Explicit rules for commitments	D1. excess return D2. additional contributions D3. D2 + sponsor guarantee D4. Owner's capital D5. borrowed capital
E.	Combination of conditional & unconditional commitments	Unconditional commitments + A-D	Unconditionally part of cost covering contribution
F.	Unconditional compensation	Unconditional commitments	Cost covering contribution

Figure 2.3: DNB indexationmatrix

the participants of the plan with more insight into the indexation quality of the pension fund.

The consequences of the Dutch pension regulations will play a role in Chapter 4, where we apply ALM to a real pension fund.

Chapter 3

ALM for pension funds

Assets and Liabilities Management (ALM) is a term that could be interchanged with the phrase Balance Sheet Management. The balance sheet of a pension fund can be summarized in three major elements. Assets, provisions for pension obligations and owner's equity. This simple balance sheet is displayed in Figure 3.1.

Assets	Provision Pension Obligations
	Owners Equity

Figure 3.1: Balance sheet of a pension fund

The information in this simplified balance sheet provides us with a measure for the financial health of the pension fund. This health is measured by means of the funded ratio, which equals the ratio of assets over provisions for pension obligations. A pension fund is in deficit if the funding ratio is below 100%. A funding ratio below 105% is defined by the Dutch pension regulators as a situation of funding shortfall. These measures are used to evaluate the financial health of the fund.

ALM for pension funds goes beyond matching assets to liabilities. As mentioned in Paragraph 2.5, a pension fund has many stakeholders. That is why Boender, Dert and Hoek [5] define ALM for pension funds as *"determining an efficient integral pension-, funding- and investment policy which satisfies the objectives and (risk budget) constraints of the active members, the pensioners, the sponsors and the regulating authorities"*. This policy is often referred to as the pension deal. In order to establish a fair pension deal, the management of the pension fund has to take into account the demands of all stakeholders. In Section 3.1 we describe the objectives and demands of the many different stakeholders of a pension fund. Section 3.2 describes the major issues concerning the optimization of the performance of the pension fund and Section 3.3 describes the role of ORTEC in managing the fund's risk and return. Finally, in Section 3.4 we describe ORTEC's scenario approach to ALM for pension funds

3.1 Stakeholders and their objectives

Let us first consider the stakes of the sponsor. The sponsor is responsible for financing the pension plan by means of contributions. Obviously the sponsor wishes these contributions to be as low as possible. On the other hand, the sponsor wants to limit the extent to which the pension risk drivers affect the balance sheet of the corporation. The maximum pension risk that a sponsor is willing to take is often referred to as the risk budget for the pension plan. This risk budget can be controlled by means of the contribution agreement between the sponsor and the pension fund. This contribution agreement contains a consensus about additional contributions and contribution rebates. At certain low levels of the funding ratio the sponsor agrees to perform additional payments in order to restore the financial health of the fund. If the funding ratio exceeds a certain upper level the sponsor gets rebates in return. This contribution agreement can be seen as a risk sharing agreement between the sponsor and the pension fund.

Before continuing to the second group of stakeholders we address a possible additional issue concerning the stakes of the employer. If the pension arrangements are not situated outside the company in a pension fund, the pension risks are present on the balance sheet of the corporation. In this corporate pension setting, the employer faces the requirements and demands of an the International Financial Reporting Standards (IFRS), and the accompanying risks. Corporate pensions and IFRS are beyond the scope of this thesis and will be left out of consideration.

The second group of stakeholders is represented by active and non-active participants of the plan, being the employees and the beneficiaries. The main concern of the participants of the plan is the amount of pension entitlements available for the old days. This amount depends on the growth of the accrued benefits during both the active career of the participant and the retirement period. During the active career the accrued benefits increase by means of annual accrual and compensation for inflation. The annual accrual of benefits stops as soon as the participant reaches the pensionable age. From that moment on, the participant becomes a non-active member of the plan. His or her benefits only increase by means of compensation for inflation.

For both active and non-active participants compensation for inflation can either by unconditional or conditional. The conditionality of compensation often depends on the health of the pension fund. Members of the plan agree to abstain from full compensation for inflation at certain low levels of the funding ratio. On the other hand, the participants might receive additional compensation if the funding ratio is high. This agreement is often referred to as a COLA-agreement. COLA is an abbreviation for Cost Of Living Allowance. Missing Cost Of Living Allowance causes the purchase power of participants to diminish. The risk budget for the participants of the plan should be defined in terms of expected pensions or Pensions at Risk.

Besides negotiating an acceptable contribution- and COLA-agreement with members and sponsors, the pension fund management has to specify a risk-budget concerning the solvability of the plan. This risk budget is often defined by the probability of deficit, also referred to as the Surplus at Risk. Demands concerning the Surplus at Risk are often forced by regulatory institutions. In the Netherlands, pension funds have to strive for sufficient surplus to ensure that the probability of a deficit (i.e. funding ratio $<$ 100%) on a 1-year horizon is at most 2.5%.

3.2 ALM performance optimization

During an ALM study we try to optimize the performance of the pension fund. Figure 3.2 gives an overview of the issues concerning performance optimization for pension funds. At the bottom of the picture we find the four available policy instruments. The pension regulations, the indexation policy, the contribution policy, and the investment policy serve as tools to achieve acceptable performance of the fund. The performance of the fund depends on several criteria. Each performance measure is related to a different group of stakeholders, as described in the previous section. The performance measures can be divided into three categories: pension entitlements, contributions and solvability. The participants of the plan desire a sufficient amount of entitlements at their pensionable age. Some informative performance measures for this category are the expected purchase power of the participants, the amount of compensation for inflation granted, and the probability of compensation delay. Performance in the contribution category can be measured by average net contributions and more importantly by the corresponding risks. A possible risk measure is the 10% Value at Risk (VaR) of the contribution level. The performance in terms of solvability can be measured by the average funding ratio, the probability of a deficit (funding ratio $<$ 100%), the probability of funding shortfall (funding ratio $<$ 105%) and by the Surplus at Risk (SaR). ALM for pension funds is all about finding

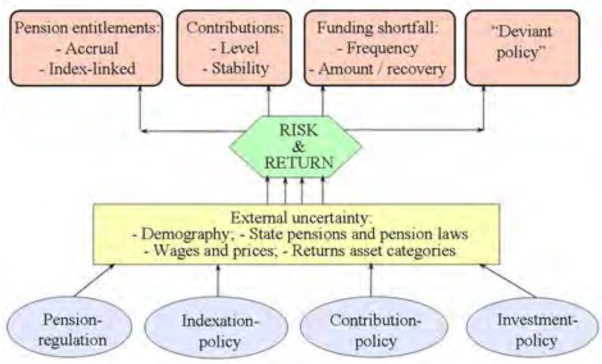

Figure 3.2: Policy instruments

an integral contribution-, indexation- and investmentpolicy such that the performance measures for all categories are within acceptable boundaries.

3.3 ORTEC and Pension Fund Risk- and Return Management

ORTEC offers a wide range of services for pension fund risk and return management. Figure 3.3 gives a schematic overview of the different phases in pension fund management supported by ORTEC. From left to right the phases are sorted by time horizon. On the far left we find Assets and Liabilities Management on a horizon of approximately 20 years. The next step is the ALM implementation phase. The ALM implementation phase focuses on a mid term horizon of 3 to 5 years and deals with the realization of the investment policy. The ALM implementation (or ALMi) phase is a major issue throughout this thesis and will be discussed in detail in Chapter 6. Especially the link between ALM and ALMi is one of the core points of interest.

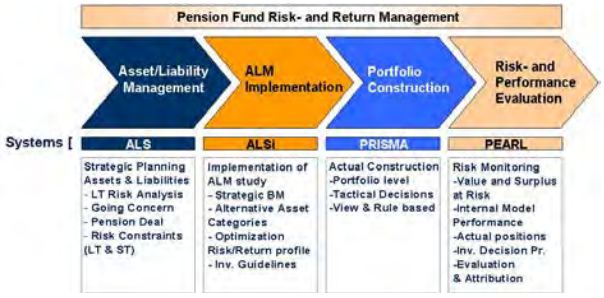

Figure 3.3: ORTEC and pension funds

The next phase, the portfolio construction phase, concerns a horizon of less than 1 year. ORTEC uses the PRISMA risk management system to bridge the gap between strategic plan and the day-to-day business of investment management. The final step is the Attribution or performance evaluation phase. This phase does not concern the future, but rather measures performance over a past period. The most important steps throughout this thesis are the ALM study and the ALM implementation phase. Especially the translation from the long-term recommendations resulting from the ALM study to the day-to-day investment management.

3.4 A scenario approach of ALM

ORTEC's ALM-methodology is based on scenario analysis. Scenarios are very suitable to model uncertainty. The objectives of the scenario approach are twofold (see Boender, Dert, Heemskerk and Hoek [4]):

- provide quantitative and graphical insight to the ALM decision makers;
- identify efficient integral ALM-strategies.

We define a scenario as a set of possible plausible future events. Relevant future events for an ALM decision maker can be market related, like inflation, interest rates, and risk premiums of equity, or pension plan related, like transitions of the plan members. ORTEC's Assets and Liabilities Scenario system (ALS) provides us with a tool to generate a sufficient amount of economic scenarios. The models used for scenario generation will be discussed in further detail in Chapter 7. ALS makes it possible to create a corporate model of the pension fund with all its dynamics. The system simulates the situation of the fund for each of the generated scenarios. The result is a series of possible future developments of the pension fund. These developments are often summarized in what

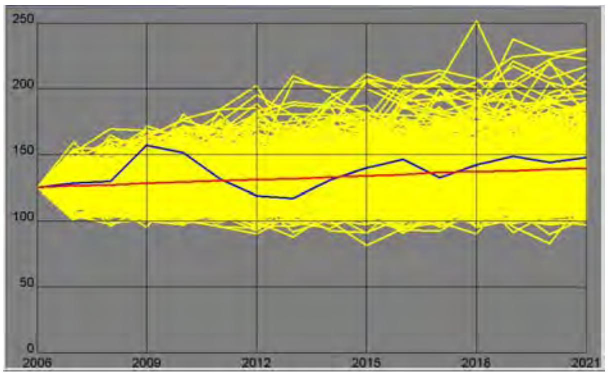

Figure 3.4: Example of a scenario diagram

we call a scenario diagram. An example of such a diagram is displayed in Figure 3.4. The yellow lines represent 500 developments of the funded ratio (nominal market value), over a horizon of 15 years, of a pension fund, given 500 generated scenarios. The red line represents the average development of the funded ratio. The blue line represents an arbitrary development. The scenario diagrams provide us with insight into the quality of the pension policy and feeds a "learn-and-react" approach. It creates the possibility to evaluate ALM-strategies and to improve them in an iterative procedure until an efficient and fair ALM-strategy is obtained.

ALS is capable of calculating several scores, like averages, standard deviations and VaRs, from the scenario diagrams. These ALM scores can be plotted in a so-called ALM field. The ALM field makes it possible to compare several policy alternatives based on a wide variety of ALM scores. An example of an ALM field is displayed in Figure 3.5. What we see is a series of pie charts. Each pie represents a different pension policy. In this case each pie represents a different investment policy. Each variant has a different strategic asset allocation. From left to right the proportion of fixed income instruments decreases from 90% to 10%. The red part of the pie chart represents the risky equity portfolio and the green fraction represents the fixed income portfolio. The diagram of Figure 3.5 shows two effects of the policy alternatives. On the horizontal axis we measure the expected return on the asset portfolio which increases as the amount of risky equity increases. On the vertical axis we see the probability of funding shortfall, a very important measure for the performance of the pension fund. Both the scenario diagrams and the ALM fields will be present throughout the entire thesis, since they are very suitable for giving a quick insight in results.

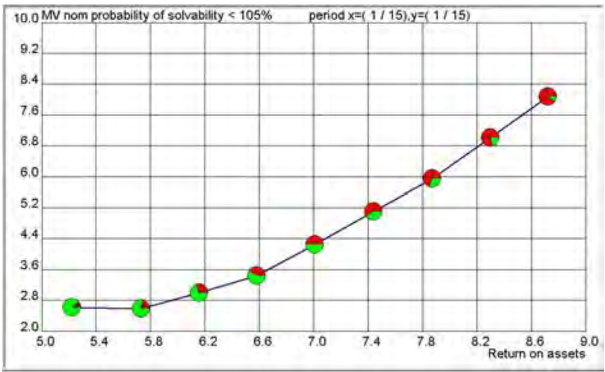

Figure 3.5: Example of an ALM field

3.5 Performance measures for pension funds

Since all stakeholders of a pension fund have different stakes, the health and quality of a pension fund should be evaluated on several criteria. The regulating authorities are interested in a safe and healthy solvability of the fund. The employer desires low and stable contribution levels, and the participants of the pension plan require index-linked pensions. For an ALM analysis of a pension fund we define performance measures in three categories: solvability, contributions, and indexation. In all categories we are interested in both average values and risk measures. We introduce the following performance measures.

Solvability	
Average funded ratio (percentage)	The ratio assets over liabilities
Probability of solvability $<$ 105% (percentage)	The probability of a situation of funding shortfall
Probability of solvability $<$ 100% (percentage)	The probility of a deficit
Average nFTK required buffer (% provisions)	The buffer required by the Dutch regulatory authority as a percentage of the provisions for pension obligations
Probability funded ratio $<$ nFTK required (percentage)	The probability of a situation in which the fund does not possess the buffer required by the Dutch regulatory authority
Contributions	
Average net Contributions (% Salary sum)	The contributions due for the employer as a percentage of the total sum of salaries
90% VaR net Contributions (% Salary sum)	The contribution level exceeds this value in 10% of the cases
Indexation	
Probability of incomplete indexation (percentage)	All accrued benefits are compensated for inflation. The fund has a certain ambition for the amount of compensation granted. This measure gives the probability that the fund is not able to fulfill its ambition
Average realized indexation (% ambition)	The average amount of compensation granted as a percentage of the ambition level
10% VaR realized indexation (% ambition)	The average amount of compensation granted exceeds this level in 90% of the cases
Average purchase power (percentage)	The expected purchase power of currently non-active members of the plan
10% VaR purchase power (percentage)	The expected purchase power of currently non-active members of the plan exceeds this value in 90% of the cases

Table 3.1: Performance measures for pension funds

Chapter 4

ALM applied

In this thesis the Hollandia pension fund serves as a test case for most of our research. The Hollandia fund is an artificial fund created by ORTEC for research and analysis. The fund is designed to represent the average Dutch pension fund. This chapter describes the results of the first step in pension fund risk and return management: the ALM study. After a description of the most important characteristics of the fund we will describe the 'pension deal'. The pension deal is a very important result of an ALM study. It describes an integrated contribution-, COLA- and investment policy that satisfies the needs of all stakeholders as good as possible. This chapter is a summary of the ALM study performed for the Hollandia pension fund. Section 4.1 describes the characteristics of the participants file of the fund. Section 4.2 gives an overview of the pension types availably in the Hollandia pension plan. Section 4.3 describes the results of the first phase of the ALM study: the course of life of the participants file. This course of life is the foundation for the thorough ALM study. We will give a description of the most important results of the study, summarized in the pension deal, in Section 4.4. In Section 4.5 we describe to what extent the needs of all stakeholders are satisfied. That is, we measure the performance of the pension fund given the pension deal.

4.1 Members of the Hollandia Pension plan

Pension funds in the Netherlands exist in many flavors. From very small corporate pension funds with around 600 or 700 members to very large industry wide pension funds like PGGM (health care) with 2 million participants and ABP (government officials) with 2.6 million participants. Hollandia is a medium sized pension fund with a total of 42691 participants. These participants are distributed over different categories as described in Table 4.1. A commonly used value to summarize the composition

Active members (FTE)	23301
Deferred members	12094
Disabled	589
Retired	4966
Surviving Relatives	1741
TOTAL:	*42691*

Table 4.1: Participants of Hollandia

of the participants file of a pension fund is the maturity ratio ('rijpingsgraad' in Dutch). It is defined as the fraction of the total provision for pension obligations that is reserved for non-active participants. Hollandia has a maturity ratio of 45.7%. The Hollandia pension fund is in healthy condition with an initial nominal funded ratio of 125%.

4.2 Pension Regulations

The pension regulations of the Hollandia pension fund are intentionally kept simple. The plan only contains the most significant pension arrangements: an old-age retirement pension and a surviving dependents pension.

4.2.1 Old-age retirement pension

The old-age retirement pension provides the participants of Hollandia with what can be seen as salary after the pensionable age. An active participant starts accruing benefits for the old-age pension at the age of 25. Pension payments commence at the pensionable age of 65. With an annual accrual of 1.75% of the pensionable salary (salary minus franchise) the plan aims at an old-age retirement pension of 70% of the average pensionable salary. The Hollandia old-age pension is an average pay system. If an active member becomes disabled the accrual of new entitlements is terminated. Accrued benefits of the disabled will be compensated for inflation according to the general indexation policy. If an active participant resigns from employment he or she does not transfer the accrued benefits to a new pension fund. The accrual of benefits gets terminated and entitlements will only be compensated for inflation according to the general indexation policy for non-actives.

4.2.2 Surviving dependents pension

The surviving dependents pension arrangement provides in a security for surviving relatives of a deceased member of the plan. At the moment a (married) participant dies the widow(er) receives surviving dependents pension payments. Benefits are accrued during the active service of the employee. With an annual accrual of 1.225%, the Hollandia pension plan aims at a surviving dependents pension of 70% of the old-age retirement pension (49% of pensionable salary). Payments start at the moment the participant dies and continue until the surviving spouse dies.

4.3 Development of the participants file

In the early stages of an ALM-study we make several assumptions about the expected future developments of the participants file. These assumptions can be based on statistical numbers and personal insights. Relevant transition data are mortality rates, marriage frequencies, probabilities of disability and resignation, company growth, age and gender of new employees, career, etcetera. The assumptions made for this ALM study can be found in Appendix A. The assumptions lead to a development of the participants file as described in Figures 4.1 and 4.2. The size of the active population remains constant

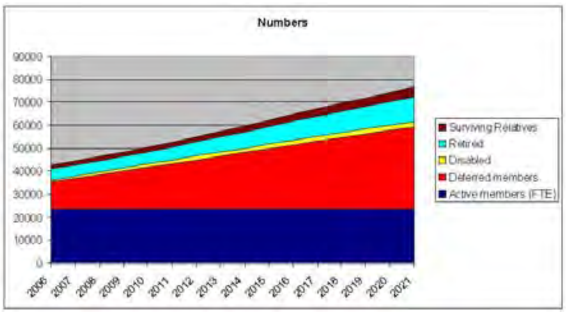

Figure 4.1: Development participants file

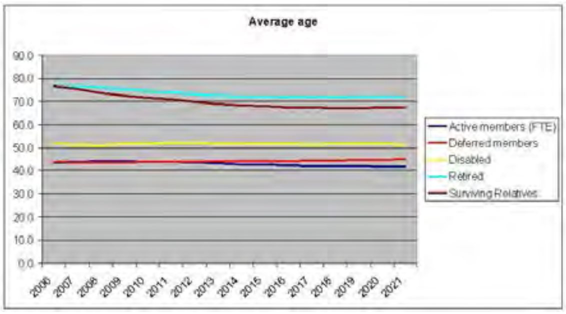

Figure 4.2: Average age of participants

(in FTE) over time. The number of deferred members strongly increases. This is due to the assumption that no value is transferred out of the pension fund. A leaving employee does not disappear from the plan but becomes a deferred member of the plan. Because of an aging population, the number of pensioners and surviving relatives slightly increases. The average age of the active participants is approximately 42 over the entire horizon. The average age of the retired and the surviving relatives declines.

The development of the participants file is a preparation for the ALM-study. The exact procedure of completing an ALM study is beyond the scope of this thesis. It is sufficient to mention that the ALM-study is a learn-and-react process during which several policy alternatives will be analyzed in order to get to a pension deal that satisfies the demands of all stakeholders. In the following section we describe the pension deal resulting from the ALM-study for the Hollandia pension fund.

4.4 The pension deal

The pension deal is an optimal integral contribution-, indexation- and investment policy, whose consequences satisfy the demands of all stakeholders best. After each policy element is described we will report on the ALM-performance of the pension fund (given the pension deal) in Section 4.5.

4.4.1 Contribution Policy

The gross contribution equals the actuarial price including back service indexation. This premium is determined at the nominal market value.

The net contribution is the gross contribution plus or minus the result of the risk sharing contribution contract between the sponsor and the pension fund. If the funded ratio of the fund is below 105% the sponsor pays additional contributions sufficient to recover the deficit within 3 years. If the funded ratio of the fund is below 130% (an approximation for the nFTK desired buffer) the sponsor pays additional contributions sufficient to recover the deficit within 15 years. If the funded ratio exceeds 150% the sponser receives a contribution discount equal to 10% of the surplus.

4.4.2 Indexation Policy

The indexation ambition for active members of the plan is the wage inflation. The wage inflation in the model has a long term expected value of 3%. The indexation ambition for non-active members of the plan is the Dutch Consumer Price Index (CPI) which has a long term expectation of 2%. Accrued benefits of active participants of the plan are unconditionally compensated for inflation. Compensation of the accrued benefits of non-active members is conditional and depends on the financial health of the pension fund. If the funded ratio is below 120%, no compensation will be granted. At higher values of the funded ratio maximal compensation will be granted (while keeping the funded ratio above 120%). Possible indexation lags will be cought up at a funded ratio above 140%.

4.4.3 Investment Policy

The strategic asset allocation of the fund is described in Table 4.2. Each asset category has a bandwidth

EUR Bonds	70%
EUR Equity	10%
US Equity	10%
JP Equity	10%

Table 4.2: Strategic Asset Allocation of Hollandia

of 5%. The currency risk for both non-Euro categories is fully hedged. Interest rate risk is partly hedged by means of a duration strategy. The provisions for pension obligations have an initial duration of 15.7. That is, the weighted average maturity of the fund's cash flows equals 15.7 years. The fixed income portfolio (EUR Bonds) has an initial duration of 4.5. The duration of the fixed income portfolio is strategically increased using a swap overlay. This overlay closes 50% of the duration gap between assets and liabilities.

4.5 Performance measures of the Hollandia Pension Fund

The pension deal described in the previous sections is a result of a thorough analysis of several policy alternatives. The alternative described in the pension deal satisfies the demands of all stakeholders and is assumed to be accepted by the board of the pension fund. Table 4.3 contains numerical performance measures of the pension fund given the pension deal. All measures are based on nominal fair values. For an explanation of the performance measures, see Section 3.5. The probability of a deficit is acceptable

	Hollandia Pension Deal	
years	1-15	1-5
Average funded ratio (percentage)	129	126
Probability of solvability < 105% (percentage)	3.4	2.0
Probability of solvability < 100% (percentage)	0.9	0.4
Average nFTK required buffer (% provisions)	12.8	13.2
Probability funded ratio < nFTK required (percentage)	10.3	8.8
Average net Contributions (% Salary sum)	13.9	13.8
90% VaR net Contributions (% Salary sum)	25.0	21.5
Probability of incomplete indexation NA (percentage)	31.5	32.0
Average realized indexation NA (% ambition)	80.1	80.0
10% VaR realized indexation NA (% ambition)	46.0	42.4
	15-15	5-5
Average purchase power A (percentage)	109.1	103.9
10% VaR purchase power A (percentage)	102.1	101.4
Average purchase power NA (percentage)	95.0	97.4
10% VaR purchase power NA (percentage)	86.5	93.3

Table 4.3: Performance measures of Hollandia

on both the short term (0.4%) and the long term (0.9%). These probabilities imply that the 97.5% Funded Ratio at Risk is higher than the desired 100%. Hence, The demands of the pension regulators are satisfied in terms of solvability.

The average net contribution is approximately 13.9% of the total sum of salaries. The contribution level is rather volatile with a 90% Contribution-at-Risk of 25% over the next 15 years. Whether this value is acceptable depends on the judgement of the pension fund management, and is different for each pension fund. We assume that the board of the Hollandia pension fund has agreed upon the risk budget of the pension deal.

The expected purchase power for active members of the plan is larger than 100%. This is caused by the fact that accrued benefits of active members are unconditionally adjusted for wage inflation. The long term expectation of the wage inflation is 3%. This is higher than the expected price increase of 2%. Hence, the benefits of active members increase at a higher rate than the prices. And thus the purchase power of active members exceeds 100%. The accrued benefits of non-active members are compensated with exactly the price inflation. The purchase power of this group of participants does not reach 100%, since the compensation is conditional. Performance of the fund in terms of purchase power for non-active participants could be further improved. However, we choose not to optimize the performance any further since this is no primary demand for the purpose of this thesis and we assumed the board of the pension fund has accepted the current values.

In the remainder of this thesis we will often refer to the characteristics of the pension deal and the corresponding performance measures.

Chapter 5

Modeling the pension fund

The liabilities, or more specifically the provisions for future pension obligations, form a major element of the financial structure of a pension fund. When analyzing a pension fund, like in an ALM study, it is of crucial importance to have a decent model of the liabilities at one's disposal. Both in the literature and in practice, the many different methods of modeling the pension fund form a major point of discussion. This chapter will discuss the modeling of the pension fund, and especially the liabilities, in detail.

ORTEC uses the Assets and Liabilities Scenario system (ALS) when performing ALM studies for pension funds. ALS is capable of fully modeling the pension fund with all its policy instruments. ALS has its own sophisticated method for modeling the liabilities. This so-called actuarial module will be discussed in Section 5.1.

Utilizing the sophisticated actuarial module results in a detailed and realistic model of the pension fund's liabilities. However, the modeling process is very time-consuming and rather complicated. For that reason it might be desirable to use a less sophisticated model for the liabilities. Especially for pension fund asset managers, who often lack the desired knowledge and time to employ the extensive actuarial module, a less complicated model is preferable. Section 5.2 discusses a model based on a future cash flow projection. Investment decision-making based on such an estimation of cash flows is often referred to as Liability Driven Investment (LDI) or Termination Driven Investment. Both terms will be explained in detail in Section 5.2.

LDI-like models neglect several important characteristics of the true development of the pension liabilities. Section 5.3 discusses the impact of these shortcomings of the simplified models. Finally, Section 5.4 reports on ORTEC's attempt to steer a middle course. ORTEC created a module to combine the advantages of both the simplified model and the detailed version in a so-called Expected Cash Flow (ECF) module. The performance of the new model will be evaluated by comparing results of the approach with outcomes of analysis using the original actuarial module.

5.1 The ORTEC pension fund model

Assets and Liabilities Management for pension funds mainly concerns monitoring future developments of the health of the pension plan. The future situation of the fund depends on a wide range of economic and demographic influences. With the Assets and Liabilities Scenario system (ALS) ORTEC created a model of both an economic and demographic environment in which a model of the pension fund can be simulated into the future. ALS consists of four important modules. The core of this chapter is formed by the modules used to model the pension fund's liability structure and its policy instruments. ALS uses the actuarial module to create a detailed model of the liability structure of the pension plan. The contribution policy and the indexation policy of the fund are modeled in the Financing module. The third module is used to replicate the investment policy of the pension fund. The last module, the economy module, is used to generate the required set of plausible economic scenarios in which the future development of the pension fund will be simulated. The underlying mathematical models of the economy module will be discussed in further detail in Chapter 7.

5.1.1 The actuarial module

ORTEC's Assets and Liabilities Scenario system uses a detailed model of the fund's liabilities. Each participant is modeled individually as well as each pension type in the pension regulations. This detailed liability model is part of ALS and is called the actuarial module. The actuarial module generates liability scenarios. The participants file of the pension plan serves as input for the actuarial module. Each individual is modeled in detail. Properties like gender, age, marital status, salary, part time percentage, etcetera are all taken into consideration. The participants file is the starting point of the simulation of the liability structure. The next step is to define several transition probabilities. Mortality rates, probability of disability, probability of departure, company growth, gender and age of new participants, and marriage frequencies are examples of assumptions to be entered by the user.

The participants file and the transition probabilities form the basis for a so-called Push-Pull Markov process that is used for simulating the future development of the population. Assumptions about mortality, resignation, disability and career push participants out of the plan or to different function categories (career). After this process, each function category is evaluated on its composition. The next step is a Pull Markov methodology to rebalance the participants file. Based on the assumptions about the growth or shrinkage of the population and the gender and age distributions, the system creates new participants for the plan. These new participants become part of the participants file and one (simulated) year later the process starts all over again. Figure 5.1 gives a schematic overview of this recurring series of events.

Figure 5.1: Development of the population

Besides the detailed model of the population, the actuarial module also provides us with a tool suitable to model a great spectrum of different pension types. Old age retirement pensions, temporary old age retirement pensions, (temporary) spouses pensions, and disability pensions are just a few examples of the possibilities. Besides, each pension type can be used more than once in order to model identical pension types with differing accrual percentages. Result of the detailed models is the fact that the estimated future developments of the pension obligations is close to reality. This opens doors for a well-founded analysis of the pension fund. Besides, the detailed model creates the possibility of a thorough analysis of the assumptions underlying the course of life of the participants. The impacts of different mortality rates, marriage frequencies, and other basic actuarial assumptions can be monitored and analyzed in a detailed manner.

The only thresholds of the actuarial module might be the complexity and the large amount of time necessary to adequately model each aspect of the plan.

5.1.2 The financing module

The actuarial module described in the previous section results in a detailed model of the liability structure of the fund. The financing module adds even more detail to the model of the fund. In this module all dynamic policy instruments can be defined. It is possible to define a risk-sharing contribution contract between the fund and the sponsor. Net contributions can be adjusted in case of low levels of the funded ratio. High levels of the funded ratio could result in contribution discounts.

A second important risk-reducing policy instrument is the compensation mechanism. In the financing module one can define several rules concerning the amount of compensation for inflation granted to the participants at a given health of the fund.

The actuarial module and the financing module are linked. Together they form an accurate model of the dynamic pension fund.

5.2 Termination Driven Investment

Instead of a detailed model like the one described in the previous sections, one might prefer a less complicated approximation of the pension fund obligations. A common approach of investment managers is to create a projection of future cash flows. Investment decisions founded by such cash flow projections are often summarized in the term Liability Driven Investment, or LDI in short. Most LDI implementations approximate the pension liabilities through the cash flows resulting from the current pension rights. This approach is referred to by Dimitry Mindlin [6] as Termination Driven Investing (TDI), since this methodology virtually closes the pension fund. The participants of the pension plan will no longer accrue new pension rights and there are no new participants entering the plan. The fund just starts performing payments at the pensionable age of the participants. Payments continue until the participant dies. Mortality rates are assumed to equal those of the 1995-2000 mortality tables, published by the Actuarial Society (AG) of the Netherlands. This results in a projection of future cash flows that might serve as an approximation for the true liabilities of the fund. One can question whether this approximation is accurate enough.

In the Termination Driven Investing environment the pension fund is virtually closed. It is assumed that pension entitlements of current participants are frozen until retirement of the participants. That is, pension accrual is left out of consideration. This assumption makes it easy to estimate future cash flows. Figure 5.2 displays such an estimation. The picture contains the cash flow projection of the Hollandia pension fund. Its shape is very characteristic for a projection of future payments of a pension plan. In the first few years the amount of pension payments increases with the number of retiring active participants. The curve flattens out as soon as all participants are retired. From that point on the amount of pension payments decreases due to deaths of participants until the pension plan is empty.

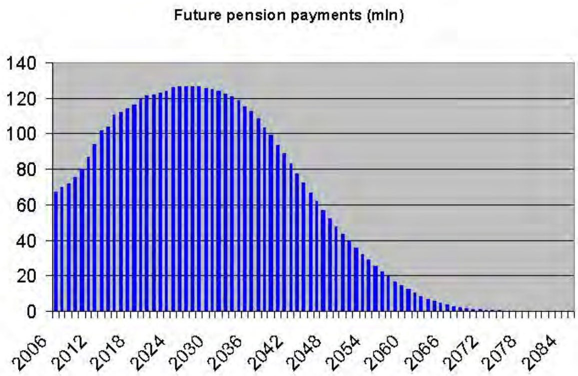

Figure 5.2: Projection of future cash flows

5.2.1 TDI and the strategic asset allocation

The Termination Driven Investing approach uses a projection of future cash flows as an approximation for the true liabilities of the fund. The question is whether this approximation is close enough to reality to serve as foundation for the investment decision-making process. In order to provide insight in the quality of the approximation we present results of a comparison between the results of both the detailed liability model and the TDI approximation. The comparison will be based on how well the solvency risks of the fund are approximated by the TDI approach. The Hollandia fund will once again serve as a test case. Figure 5.3 shows that results of a risk analysis highly depend on the choice of the liability model. The horizontal axis measures the average return on the asset portfolio. The vertical axis measures the solvency risk of the fund. It is obvious that the risks are highly overestimated if the fund is analyzed in a liquidation scenario. This overestimation will have a negative impact on the long term strategic investment decisions. During the procedure of finding a suitable strategic asset allocation the ALM analyst usually tempts to find a portfolio satisfying the risk budget of

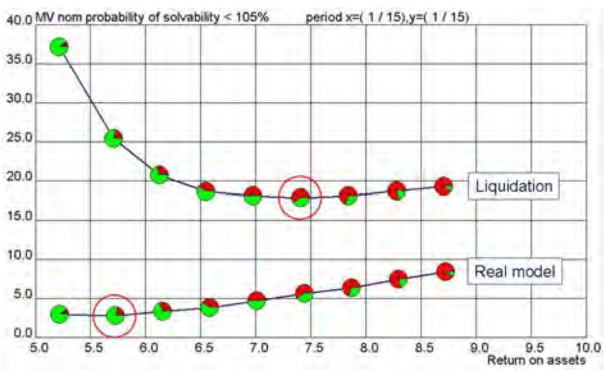

Figure 5.3: Liquidation or going concern

the pension fund. The risk budget is often defined as the maximum probability of funding shortfall. Now look again at Figure 5.3 and suppose that the pension fund management requires a maximum probability of funding shortfall of 5%. The liquidation setting does not present any strategic mix satisfying the risk budget. Hence, investment decisions based on the risk budget are impossible in the liquidation setting.

Another option to find the most suitable strategic asset allocation is to select the mix corresponding to the minimal solvency risk. That is, we select the asset allocation resulting in the lowest probability of funding shortfall. Using this methodology we end up with the portfolios marked with a red circle in Figure 5.3. The figure shows that the liquidation model might result in a completely different strategic asset allocation if we base our investment decision solely on the minimal solvency risk of the fund. In the liquidation scenario we would opt for a mix consisting of 40% fixed income and 60% total return. The going-concern model will lead to a more conservative mix with 70% fixed income and 30% total return. It are these differences that make us conclude that the liquidation cash flow projection is not a very good approximation for the true long-term development of the liability structure of the fund. Therefore we state that TDI is not suitable for supporting the decision process concerning the long-term strategic asset allocation.

In order to further verify this presumption, two other pension funds with different characteristics have been analyzed. The Hollandia pension fund represents the average Dutch pension plan with an average number of participants and an average maturity ratio (provisions non-active members / total provisions). A pension fund with a low maturity ratio is referred to as a young fund. If the ratio is high the fund will be labeled as old. The additional analysis has been performed on both a young fund and an old fund. The results are displayed in Figures 5.4 and 5.5

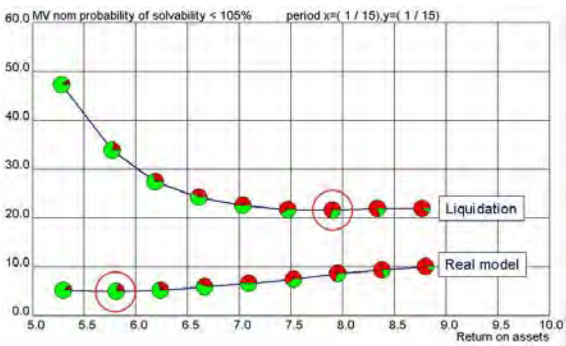

Figure 5.4: TDI for a young fund

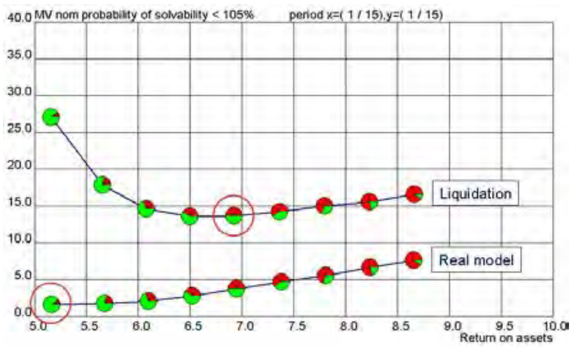

Figure 5.5: TDI for an old fund

Again we observe severe overestimation of the solvency risk and a different choice of strategic asset allocation. This confirms the presumption that a TDI cash flow pattern is not a good approximation for the true long term development of the liabilities and thus can be considered not suitable for supporting the long-term investment decision process.

5.2.2 TDI and mid-term investment decisions

Although the TDI modeling method appeared useless for the long-term investment decisions, the liquidation setting might be of use for other purposes. Instead of the long term strategic asset allocation we try to utilize the TDI model for the mid-term. Again we look at investment decisions, but this time we analyze a horizon of 3 to 5 years.

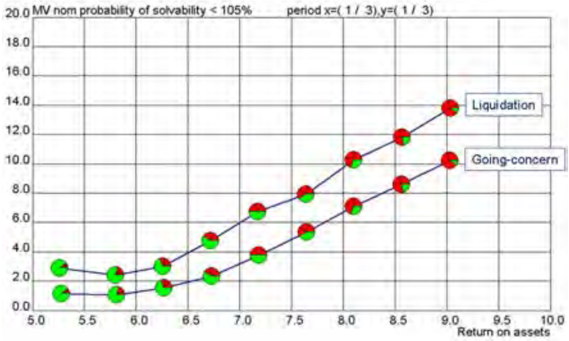

Figure 5.6: TDI on a horizon of 3 years

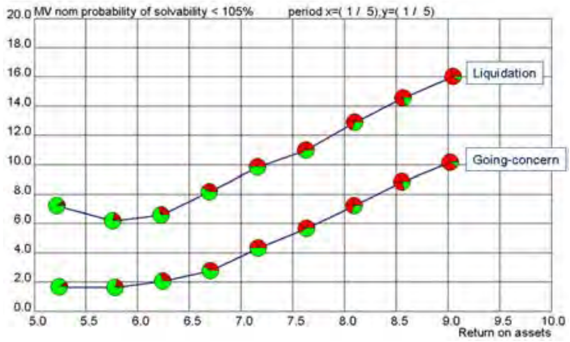

Figure 5.7: TDI on a horizon of 5 years

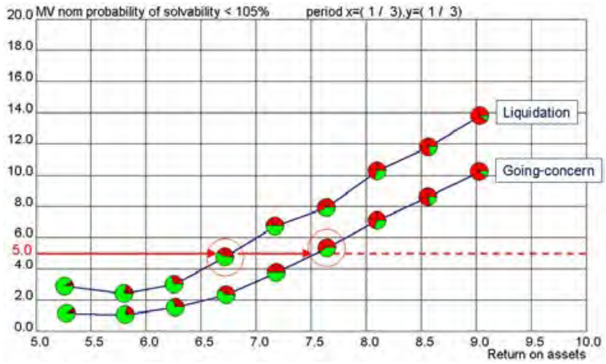

Figure 5.8: Investment decisions in a liquidation setting

From Figures 5.6 and 5.7 we can conclude that the overestimation of solvency risks in a liquidation setting decreases as the horizon gets shorter. However, even on these shorter horizons, the utilization of TDI for investment decision making has some disturbing impacts on the performance of the fund. We show this impact on the basis of Figure 5.8. Suppose again that the board of the pension fund has defined a maximum probability of funding shortfall of 5%. In Figure 5.8 we see the result of the search for the most suitable asset allocation. In the liquidation setting we end up with a portfolio with 40% equity. According to the going-concern model we can increase this amount of equity up to 60% while still keeping the solvency risks at an accaptable level. The additional return achieved by an increased amount of equity can be of use for increasing, for example, the amount of compensation for inflation granted to the participants of the plan. In general we can conclude that the liquidation setting forces the ALM analyst to opt for a portfolio composition that is unnecessarily cautious. With that, the pension fund misses the opportunity of useful additional asset returns.

The overall conclusion of this section is that the liquidation setting is not suitable for supporting any investment decisions. Neither long-term nor mid-term are correctly modeled by TDI. In the next section we explain why the results of TDI diverge from the true results.

5.3 The shortcomings of TDI

In the previous sections we showed that modeling the pension fund in a liquidation setting causes a severe overestimation of the ALM risks. The mismatch is severe enough to conclude that the liquidation setting is useless for supporting the long term strategic investment decision making process. In this section we explain why the liquidation setting wrongly estimates the ALM performance of the fund.

The cause of the overestimation of the solvency risks in a termination driven context is threefold. Boender [1] mentions three shortcomings of TDI. First of all, the risk-sharing contract between the pension fund and the sponsor is neglected in a TDI approach. A non-closed fund receives additional contributions from the sponsor when the fund finds itself in a state of low funding ratio. These additional contributions help to assure the financial health of the fund. The same holds for the second shortcoming of TDI: the lack of conditional compensation mechanisms that many pension funds use as a risk reducing instrument. Compensation for inflation can be postponed if the fund's solvability is below some critical level.

The final shortcoming of TDI is the lack of accrual of new pension rights. In a non-closed fund new rights enter the plan every year. These new rights are purchased at the actuarial price. This price often includes an additional contribution for preservation of required buffers. This implies that new rights enter the plan at a healthy funded ratio and thus cause a partial recovery of weak solvability values.

An important conclusion is that a termination driven approach to pension fund management causes the long-term risks to be highly overestimated. This conclusion can be supported by Boender, Van Lieshout, and Vos [7], who draw a similar conclusion. They also mention the three major shortcomings of TDI. In the following sections we will provide insight in the magnitude of the impact of each of the shortcomings separately.

5.3.1 The impact of conditional compensation for inflation

One of the shortcomings of the TDI approach is the fact that conditional compensation for inflation is completely neglected. The mechanism of conditional compensation is developed to reduce the solvency risks of a pension fund. In case of low solvability the fund management can decide to postpone (or even cancel) compensation of the accrued benefits for inflation. This provides the fund management with a tool to reduce risk. This tool is completely neglected by TDI. The result is an overestimation of the solvency risks. The ORTEC Assets and Liabilities Scenario system provides us with a tool to investigate the impact of the conditional compensation mechanism.

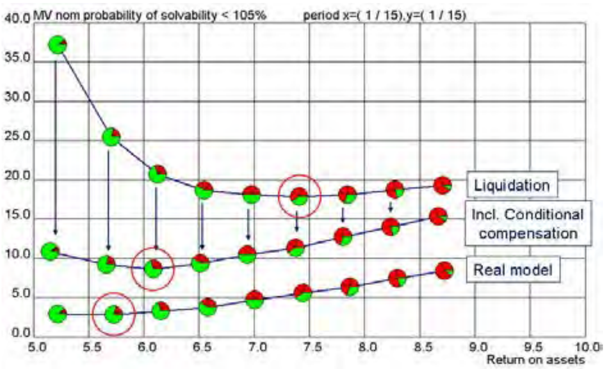

Figure 5.9: The impact of conditional compensation

While still using the TDI expected cash flow as an approximation for the true liabilities we now include the original conditional compensation mechanism of the Hollandia pension fund. The Hollandia mechanism is described in Section 4.4.2. If the solvability is below a threshold, compensation is postponed. The effect of the mechanism is displayed in Figure 5.9. We see that the overestimation of risk is subdued. We also see a shift in the shape of the figure. This causes the investment decision to change again. The circled pie charts represent the minimum risk portfolio for each of the approaches. Including the conditional compensation mechanism brings the SAA closer to the optimal mix resulting from the true liability model. However, the lack of a risk-sharing contribution contract with the sponsor and the ignorance concerning accrual of new pension rights still make the risks appear too high.

The impact of the compensation dynamics highly depends on the policy of the pension fund. If the compensation mechanism is unconditional, there is no such thing as compensation dynamics. In that case the lack of conditional compensation will have no impact on the ALM results at all. From experience in the field we learn that pension funds outside the Netherlands often compensate accrued benefits unconditionally at a certain rate. Hence, TDI might be sufficient for the analysis of foreign funds. However, foreign pension fund managers still have to be cautious, since TDI has two more major shortcomings.

5.3.2 The impact of the risk-sharing contribution contract

The second shortcoming of TDI is the fact that the approach ignores the risk-sharing contribution contract between the pension fund and the sponsor. With the contribution contract the sponsor agrees to grant extra contributions in situations of low solvability (see Section 4.4.1). The contract often also includes an agreement about contribution discounts if the status of the fund is healthy. The additional contributions aid the fund in recovering from low solvability and help to reduce the solvency risk. Including the contribution contract in the model of the fund will also cause the overestimation of risks to diminish. This effect is displayed in Figure 5.10. The estimated solvency risks get closer to the true risks. If we compare the results with Figure 5.9 we notice that the impact of the contribution contract is even larger than the impact of the conditional compensation mechanism.

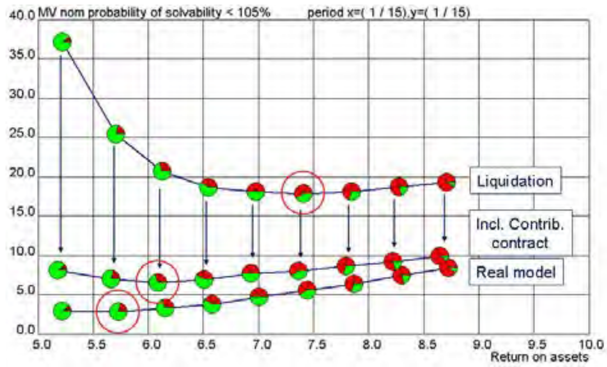

Figure 5.10: The impact of the risk-sharing contribution contract

The impact of the contribution dynamics highly depends on the policy of the pension fund. If the fund does not have a risk-sharing contribution contract with the sponsor, the impact described in this section will not be present. The regulatory institutions in the Netherlands oblige the pension funds to present a recovery plan in case of funding shortfall. The funded ratio has to be recovered to an acceptable level within 3 years. Hence, the impact of the lack of a contribution mechanism is hardly variable for Dutch pension funds. However, pension funds from outside the Netherlands barely face any regulations concerning risk-sharing contribution agreements. Hence, whereas the impact of the missing contribution instrument is equally severe for all Dutch pension funds, foreign funds with a low-volume contribution mechanism (or none at all) might consider the use of TDI. However, they still have to be aware of the impact of the other policy instruments.

In the next section we measure the impact of the last shortcoming of TDI: the lack of accrual of new pension benefits.

5.3.3 The impact of accrual of new pension rights

A very important issue concerning the modeling capacity of TDI is the accrual of new pension rights, or actually the lack of it. The accrual of new pension rights creates a completely new situation for the fund. New rights are purchased against the actuarial price, often including a premium for the preservation of reserves. Hence, new rights enter the plan at a healthy funding ratio and will cause partial recovery of low funded ratios. We again ignore the conditional compensation for inflation and the risk-sharing contribution agreement to measure the effect of including the accrual of new pension rights. In this case we do not include a premium for the preservation of required buffers. The results are displayed in Figure 5.11. Again we observe a reduction in the overestimation of risks. The reduction is not as big as that resulting from the conditional indexation mechanism or the contribution contract, but still it has a considerable impact.

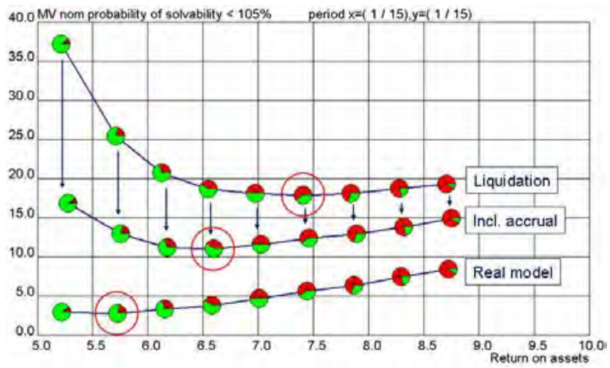

Figure 5.11: The impact of accrual of new benefits

The impact of the accrual of new pension benefits depends on the maturity of the pension fund. The larger the number of active participants, the more accrual of new benefits. Very mature pension fund with little accrual of new benefits might consider the use of TDI. However, pension fund managers should still be aware of the other two shortcomings of TDI.

5.3.4 Conclusions about the shortcomings of TDI

The three major shortcomings of the termination driven model each have significant impact on the estimation of solvency risks of the pension fund. Including any of the missing policy instruments improves the estimation of the solvency risks. However, including only one policy instrument does not lead to a correct strategic asset allocation. Table 5.1 quantifies this observation.

Mix fixed income_equity	Prob. funded ratio < 105				
	Real	Liquidation	Liquidation + cond. compensation	Liquidation + contribution contract	Liquidation + accrual
90_10	2.87	37.09	10.85	8.09	16.77
80_20	2.77	25.37	9.19	6.97	12.91
70_30	3.27	20.69	8.61	6.52	11.12
60_40	3.75	18.6	9.29	6.85	10.97
50_50	4.68	18.04	10.44	7.68	11.57
40_60	5.56	17.83	11.33	8.01	12.32
30_70	6.35	18.05	12.71	8.64	12.87
20_80	7.43	18.67	13.96	9.2	13.76
10_90	8.35	19.24	15.82	9.91	14.85

Table 5.1: The impact of risk-reducing policy instruments

The table shows that the risk-sharing contribution contract has the greatest impact. This can be explained by the fact that the contributions can become as high as necessary. Unlike the conditional compensation mechanism, the contribution mechanism is not just a cost saving mechanism. No matter how large the deficit, the compensation mechanism makes sure that a fixed percentage of the deficit will be eliminated. The conditional compensation mechanism is just a way to save costs. Accrual of new rights has a significant effect on the solvability of the fund. Although the impact is not as big as that of the other policy instruments, we still observe a strong decline in the overestimation of solvency risks.

The magnitude of the impact of each of the policy instruments depends on the characteristics and the policy of the pension fund. A very mature fund does not suffer from the lack of accrual of new pension benefits, since there is only a relatively mall number of active participants that actually reduce the risks by purchasing new benefits. A pension fund that is not bound to regulations concerning a risk-sharing contribution contract, might choose not to increase the contribution level in case of funding shortfall. A fund without a recovery mechanism will not suffer from the missing contribution dynamics in the TDI environment.

The compensation mechanism will do no harm if the pension fund compensates the accrued benefits unconditionally. That is, a pension fund without a risk reducing compensation policy does not suffer from the lack of one in the TDI environment.

In short, a mature fund without a risk sharing contribution contract, and without conditionality in the compensation mechanism, might consider the use of TDI. All other pension fund managers should be very cautious when utilizing the TDI approach.

After having analyzed the impact of each of the missing policy instruments the question rises whether it is possible to add all policy instruments to a termination driven modeling approach, in order to create a simple yet accurate model of the pension fund. The next section describes ORTEC's attempt to create such a model.

5.4 ORTEC's ECF module

From the analysis in the previous sections we can conclude that each shortcoming of the TDI approach has its effect on the overestimation of the solvency risks. Eliminating a shortcoming results in a far better approximation of the true situation of the fund. However, eliminating 1 shortcoming still is insufficient to consider the liability model accurate enough. ORTEC has recently developed a piece of software that might resolve this issue. A new module for the Assets and Liabilities Scenario system creates the possibility to model the liabilities in a TDI-like way, without having to cope with the shortcomings. This module is called the Expected Cash Flow (ECF) module. In this section we will give a short description of the module and analyze its performance by comparing the ALM results of the new approach with the original results.

The ECF module takes three expected cash flow vectors as input. Based on the current participants file we estimate two vectors, representing the future payments for the active members and the non-active members respectively. We make a distinction between active and non-active members because many pension plans use different levels of compensation for both groups of participants. The Hollandia pension fund (conditionally) grants compensation for price inflation to non-active members. Accrued benefits of active members of the plan are compensated according to wage inflation. The third input vector for the ECF module represents the purchase of new pension rights. These three vectors form the basis for the liability structure. This structure is simulated into the future based on three more assumptions: a contribution nominator that increases in time according to some index (i.e. wage inflation), the percentage of active members that mutates to the non-active status each year, and a compensation index for each of the participant groups (actives and non-actives). With only three vectors and some assumptions the ECF module is far less complex than the original actuarial module which requires a significant amount of knowledge about the many different pension types.

The simple liability structure created by means of the ECF module can be linked to an original financing module. This option creates the possibility to include compensation and contribution mechanisms to the model of the pension fund. The following sections report on the analysis of the performance of the new model. We will evaluate the quality of an ALM analysis performed by means of the simplified model and compare it with the original model.

5.4.1 ECF in practice

The first test case for the ECF module is the average Hollandia pension fund. The Hollandia fund is a relatively simple pension fund with only a few pension types and an average participants file. In order to evaluate the quality of the ECF module we will perform a simple ALM analysis for the Hollandia pension fund. We will make a decision about the composition of the asset portfolio based on the solvency risks. We choose the portfolio which results in the smallest probability of funding shortfall (funded ratio $<$ 105%). Figure 5.12 shows the results of the analysis for both the ECF module and the original model. Each pie chart represents an asset mix. A wide range of assset mixes has been evaluated, varying from very conservative (90% fixed income) to very aggressive (90% equity). The preferred portfolio based on the solvability risks is marked with a circle in the figure.

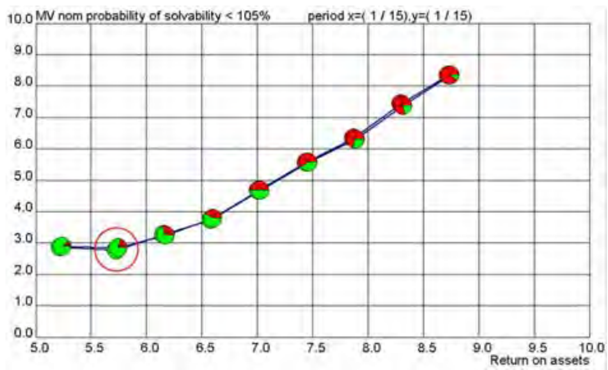

Figure 5.12: ECF for Hollandia

The ECF module certainly survived the first test case. The risks are estimated correctly for the entire range of asset mixes. Moreover, the investment decision-making process results in the correct strategic asset allocation. Table 5.2 shows us that the ECF module also correctly estimates the risks for the contributions and the purchase power.

Mix fixed income_equity	90% VaR net contribution		10% VaR purchase power	
	Real	ECF	Real	ECF
90_10	21.7	21.9	88.6	89.1
80_20	21.3	21.5	90.2	90.7
70_30	21.0	21.1	91.0	91.4
60_40	20.9	20.9	91.6	92.0
50_50	***20.9***	***20.9***	92.0	92.5
40_60	20.9	20.9	92.4	92.9
30_70	21.0	21.0	92.7	93.0
20_80	21.3	21.3	92.9	93.3
10_90	21.5	21.5	***93.2***	***93.4***

Table 5.2: Contributions and purchase power

Before testing the ECF module on some more exotic pension plans we first mention that the quality of the module does not depend on the maturity of the participants file. A test with both the mature Hollandia fund and the young Hollandia fund showed the same soothing results. See Appendix B for a graphical report on the results of the tests.

In the remainder of this section we evaluate the performance of the ECF module for three real pension funds. Again we try to find the optimal portfolio in terms of solvability risks. Each of the three pension funds has its own special characteristics. They can serve as a tool to reveal the possible shortcomings of the ECF modeling method.

Test case 1
The first real test case is a large pension fund with more than 50000 members. The pension regulations contain several pension types. Old-age retirement pensions, temporary old-age retirement pensions, surviving dependents pensions, disability pensions, and defined contribution arrangements are among them. All pension types are average-pay systems. The maturity of the participants file is 64.4%, slightly older than the average Hollandia fund. The participants file is stable: there will be no growth in the number of fulltime equivalents. The results of the ALM analysis are rather impressive. In Figure 5.13 we see that the ALM results of the ECF model are almost exactly the same as those of the real model. More importantly, the ALM analysis results in the correct decision about the strategic asset allocation.

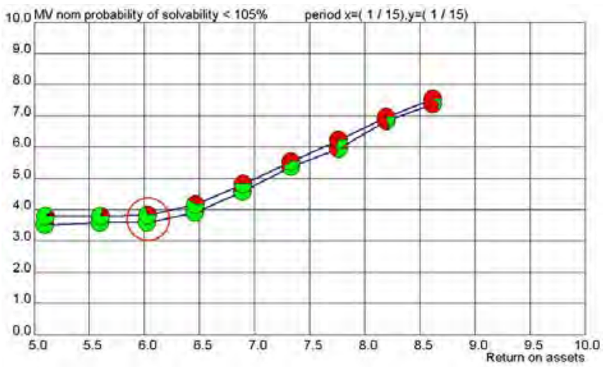

Figure 5.13: ECF for a large real fund

Test case 2
The second test case is a somewhat more exotic pension fund. The pension fund has two different pension regulations with some essential differences. The pension plan consists of two arrangements: an old final pay arrangement and a new average pay arrangement. The pension fund is very young with a maturity of 28.8%. As can be seen in Figure 5.14, the ECF module does not perform very well with this small hybrid pension fund. The cause of the mismatch is in the reason why we called this fund a hybrid pension fund. The pension plan consists of two different pension arrangements. Each having its own contribution policy. The composition of the contributions in the old final pay arrangement is different from that of the new average pay arrangement. The two types of contribution composition are both supported by the ECF modeling approach. However, they can not be implemented both at the same time. Only one contribution composition can be selected.

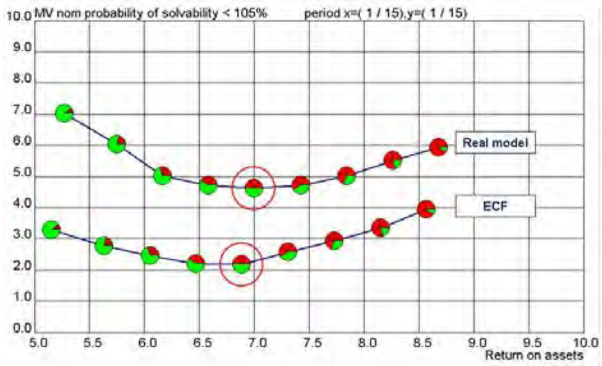

Figure 5.14: ECF for a small hybrid fund

Figure 5.15 shows that the mismatch between the original model and the ECF model can be completely explained by the contribution components. The figure contains the ALM results of the young hybrid pension fund. However, we slightly altered the contribution policy. Both the old arrangement and the new arrangement now contain the same contribution components. The results no longer differ from those of the ECF model. This observation leads to the conclusion that the hybrid contribution arrangement is the only cause of the mismatch between the ECF model and the real model. Since this young hybrid fund contains both final pay arrangements and average pay arrangements we can conclude that such a combination is not necessarily a problem for the ECF model.

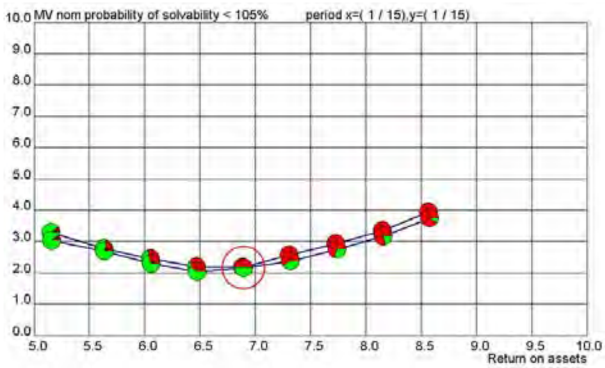

Figure 5.15: Explaining the difference: contribution composition

The example of the hybrid pension fund makes us aware of a difficulty of the ECF module. The cash flow patterns will be provided by the client. It is of crucial importance to gather all necessary information about the cash flow patterns. The composition of the contribution is definitely part of this necessary information. As long as the proper knowledge is available we can detect situations like the one of the hybrid pension fund.

Test case 3
The final test case for the ECF module is an average sized pension fund with both final pay and average pay arrangements. An interesting characteristic of this fund is the fact that the company expects a growth of 60 full time equivalents per year. Figure 5.16 shows the results of the ALM analysis. The mismatch is rather disturbing. However, as can be seen in Figure 5.17, the growth does not seem to be the cause of the mismatch. In search of a cause of the mismatch we encountered a difficulty in the composition of the contribution. The contribution of the fund consists of 14% of the sum of salaries, plus 7.5% of the sum of pensionable salaries (salary - franchise) below €43800, plus 9.5% of the sum of pensionable salaries between €43800 and €116800. Hence, for the determination of the contribution we need three contribution nominators. The ECF module takes only one contribution nominator as input. In this case this leads to an overestimation of the contribution level, and thus to an underestimation of the solvability risks of the fund.

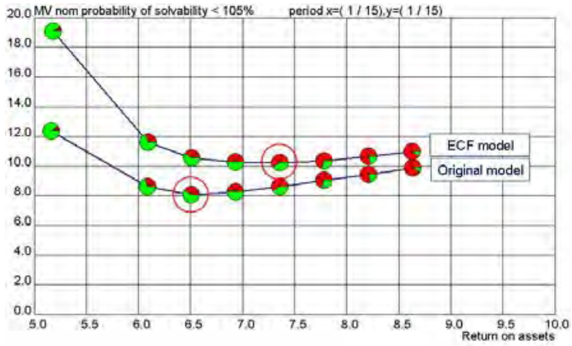

Figure 5.16: ECF and an average growing fund

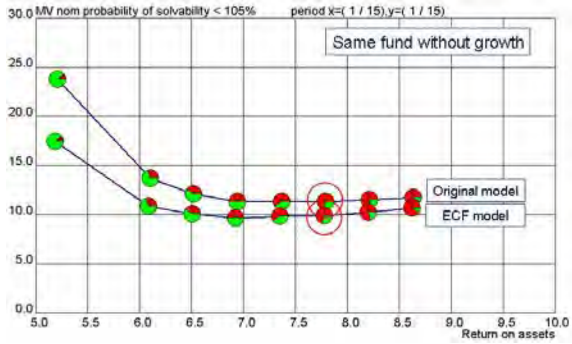

Figure 5.17: The growth is not the cause of the mismatch

The issues concerning the contribution nominators in the ECF module cannot be resolved easily. This leads to the conclusion that the simple modeling method of the ECF module is a problem for a pension fund with a contribution definition that is too complicated to describe with only one contribution nominator.

The ECF module can be very suitable for modeling a pension fund. The simplicity of the module is a great advantage. It is easy to understand and utilizing it takes only a small amount of time. However, the ALM analyst considering the option to use the ECF module should be aware of the fact that there are some pitfalls. The analysis in this section has revealed some issues and shortcomings of the ECF module. In the next sections we summarize the issues revealed during the analysis of the test cases. Besides, we mention several other technical and practical issues related to the utilization of the ECF module.

5.4.2 Technical issues of the ECF module

In this section we summarize several technical issues concerning the ECF module. Some of the issues in this section have been encountered during the analysis of the test cases. Others were identified based on experience from the field. We divide the technical issues into three categories: issues related to the development of the participants file, issues related to the pension regulations, and technical modeling issues.

Development of the participants file

- *Growing participants file*
  If the number of active participants in a pension plan increases, the annual accrual of new pension benefits will grow. The ECF module estimates the accrual of new rights by means of a service cost vector in relation to a contribution nominator. The only growth that is captured by the ECF module is the (often inflation related) growth of the contribution nominator. A contribution nominator defined as the total sum of salaries, for example, will often increase according to the wage inflation. Other types of growth are not included in the estimation of the future cash flows. Hence, the results of the ECF module might diverge from the true results when a pension fund faces a strong growth in the number of active participants.

  The issue of growth is not necessarily a problem for the ECF module. Although it cannot be modeled explicitly, we can capture the growth by manipulating the index for the contribution nominator. Instead of the growth according to (say) wage inflation, we can add the growth of the participants file to the index. With that, the accrual of new pension benefits will increase approximately with the same trend as in the real model.

- *Aging population*
  The contribution nominator often depends on the sum of (pensionable) salaries of the active participants of the plan. The salary of an individual usually partly depends on the individual's age. If the average age of the active population increases, the sum of salaries will increase accordingly. Again this results in an increasing contribution nominator beyond the regular index.ends on the individual's age. If the average age of the active population increases, the sum of salaries will increase accordingly. Again this results in an increasing contribution nominator beyond the regular index.

  As with the previous issue, the growth caused by an aging population can be captured by adding some extra growth to the index for the contribution nominator.

- *Longevity*
  The cash flow vectors serving as input for the ECF module have been determined based on assumptions regarding the longevity of the participants. People are expected to live longer every year. This development is not captured by the ECF module. This might have some impact on the ALM results. Especially on the long-term horizon the impact of longevity might be present.

  This issue cannot be resolved within the ECF module. The increasing longevity should be taken into account when constructing the initial cash flow patterns. One might consider an intentional overestimation of the expected life span of the population. The amount of overestimation depends on the horizon on which the analysis is performed.

Difficulties in the pension regulations

- *Risk-based surviving dependents pensions*
  Most pension plans provide pensions for surviving dependents of deceased participants. Benefits for these pensions are not always accrued according to some annual accrual percentage, like with the old-age pensions. An often used construction is the risk-based surviving dependents pension. This risk-based arrangement can be interpreted as an insurance for the pensions of the surviving relatives of the participant. If the participant dies, the widow or widower receives a certain percentage of the accrued old-age pension benefits of the deceased. In exchange for this privilege, the participant pays an annual insurance premium during his active career. Future cash flows resulting from the risk-based surviving dependents pensions are hard to predict. The cash flows depend on several things like the moment of death and the marital status of the participant at the moment he or she dies.

  The risk-based surviving dependents pensions cannot be captured by the ECF module. The analyst responsible for the construction of the cash flow patterns should make some assumptions about mortality rates, marital frequencies and marriage probabilities, in order to make a well founded estimate of the future cash flows resulting from the risk-based surviving dependents pensions.

- *Defined contribution arrangements*
  A similar problem arises when a pension plan offers a defined contribution (DC) arrangement. As with the surviving dependents pensions, the cash flows of a DC arrangement are hard to predict. In a DC arrangement the participant deposits a defined amount of contributions on a DC savings account. At the retirement date the participant purchases all benefits he can afford using this savings account. Result is that the benefits from the DC arrangement are unknown until the retirement date.

  The ECF module does not provide a functionality for modeling a DC arrangement. In order to take the DC benefits into account, the analyst should make a well founded estimate of the future cash flows resulting from the DC arrangements.

- *Variable pensionable age*
  A pension plan often offers the opportunity to retire before the pensionable age. In exchange the participant renounces from a part of his or her accrued benefits. Due to the variable pensionable

age the payments might differ from the initial estimate used for the construction of the cash flow vectors.

The possible variability of the pensionable age cannot be modeled by the ECF module. The possibility of early retirement should be taken into account when constructing the cash flow vectors.

Technical modeling issues

- *Contribution nominator*
  During the analysis of the test cases we encountered an example of a pension fund with a rather complicated definition of the contribution nominator. The ECF module only takes one contribution nominator as input. Hence, the simple modeling method of the ECF module is a problem for a pension fund with a contribution definition that is too complicated to describe with just that single contribution nominator.

- *Indexation groups*
  A second technical issue concerns the compensation mechanism. The ECF module is able to distinguish two separate groups of participants, each having its own indexation ambition. If the pension fund has more than two indexation groups (disabled, deferred members, early-leavers, etc.), the ECF module will not be able to model the mechanism properly.

Both technical issues could be resolved by adding some tailor made functionalities to the ECF module. However, adding additional features will have a negative impact on the power of the ECF module: its simplicity. The ECF module currently forms a balanced trade-off between simplicity and functionality. One should be cautious not to disturb this balance by making the module too complicated when adding functionalities.

5.4.3 Practical issues of the ECF module

Besides the technical issues described in the previous section, we can think of some practical issues concerning the ECF module.

Input of the module

- *Acquiring the cash flows*
  The main ingredient of the input for the ECF module is a set of three cash flow patterns. For our analysis of the test cases we constructed the cash flow patterns by completely modeling the pension funds using the original actuarial module. Most pension funds do not have a sophisticated model at their disposal to construct these patterns.

- *Interpreting the cash flows*
  If the pension fund management is able to deliver the desired cash flows, the ALM analyst should be very cautious when interpreting the cash flows. As described in the previous sections, many issues concerning the pension regulations and the participants file might affect the way the cash flows should be interpreted. In Section 5.4.1 we already encountered the possibility of differing contribution components. Besides this issue, one can think of several other things that might affect the interpretation of the cash flows. Among them is the possible presence of DC arrangements or risk-based surviving dependents arrangements in the cash flow estimates, and issues concerning the participants file.

Actuarial analysis

- Besides all technical and practical issues mentioned before, there is one important reason why the original actuarial module remains indispensable. The ECF module lacks several useful features of the actuarial module. An ALM study often includes a phase in which analysis is performed on the course of life of the participants. This kind of analysis is impossible with the ECF module.

Without the actuarial module the ALM analyst is unable to provide insight in the impact of the assumptions about things like mortality rates, marital frequencies, career estimates, etcetera. Longevity risks cannot be analyzed and the impact of changes in the pension regulations, like a switch from final-pay to average-pay, cannot be measured.

5.5 Conclusions about modeling the pension fund

In search for a simplified method to model the pension fund, we first analyzed a liquidation setting. This so-called TDI modeling approach appeared unsuitable for supporting both long-term and mid-term investment decisions. A good alternative is ORTEC's ECF module. This module combines the simplicity of the liquidation setting with the ability to model the different policy instruments of the pension fund.

The ECF module reduces the complexity of the pension fund model. The ALM consultant can save lots of time by using the less complicated model. Hence, we conclude that the ECF module can be very useful. However, the ALM analyst utilizing the ECF module should be aware of several issues and shortcomings of the module. We distinguish technical issues and practical issues.

Technical issues

- Development of the participants file;
  - Growing/shrinking participants file;
  - Aging population;
  - Longevity;
- Difficulties in the pension regulations;
  - DC arrangements;
  - Risk-based surviving dependents arrangements;
  - Variable pensionable age;
- Technical modeling issues;
  - Contribution nominator;
  - Indexation groups;

Practical issues

- Input for the module;
  - Acquiring the cash flow patterns;
  - Interpreting the cash flows;
- Actuarial analysis;

We conclude that the ECF module is very useful if the pension fund is able to deliver the desired cash flows and if the contribution- and indexation mechanisms are not too complicated. If a thorough analysis of the course of life assumptions is not required, the ECF module can provide an ALM consultant with a relatively simple model of the pension fund. The quality of the ALM analysis can be guaranteed. However, one should be very cautious when interpreting the delivered cash flow patterns in order to detect possible difficulties.

The ECF module might be used in situations in which liability data on individual level is not available. ORTEC often faces such situations when performing analysis for foreign clients. Another situation in which the ECF module might come in handy is when the focus of the research is on the investments of the client or when only a quick scan is required. However, to get the most realistic dynamics in liabilities and cash flows, the normal actuarial module remains indispensable.

Chapter 6

ALM implementation

The focus of this chapter is on the ALM implementation (ALMi) phase in pension fund management. The ALMi phase succeeds the ALM study. The pension deal resulting from the ALM study includes a strategic asset allocation. The composition of this asset mix is driven by the ambitions of the fund and is agreed upon because of the corresponding acceptable ALM risks. During the ALMi phase we zoom in on the investments and try to improve the performance of the fund by improving the investment policy. The goals of the ALMi phase can be achieved by means of three core investment policy instruments. First of all we can expand the strategic asset allocation. A large scope of available asset categories can be used to find an optimal mix satisfying the demands of the pension fund best. Several portfolio optimization techniques can be used to find the optimal mix. In this chapter we evaluate two of these optimization techniques. We show that a pension fund should be very cautious when optimizing a portfolio in asset-only terms. The liabilities of a pension fund form an important risk driver and should be taken into account when optimizing the asset portfolio.

The second aspect of the ALMi phase concerns the translation of the investment policy into mandates for the asset managers of the fund. This part of ALMi is covered in Section 6.2. We show that the mandate for the asset manager should be sufficiently tight in order to warrant the ALM performance agreed upon in the pension deal.

The third investment policy instrument subject of the ALMi phase is the duration matching strategy. Instruments like swaps and swaptions can be utilized to hedge the fund against interest rate risk. In Section 6.3 we emphasize the importance of such a strategy.

Besides these three core components, the ALM implementation phase consists of several additional investments related issues. Examples are inflation- and currency hedging strategies, credit default risks analysis, active portfolio management, benchmark selection, sensitivity for economic assumptions, etcetera. These additional issues of the ALM implementation phase are beyond the scope of this thesis.

In this section we use a functionality of ALS to perform several optimization routines. Due too some technical issues concerning the optimization algorithm we slightly adjust the duration strategy of the pension deal. The essence of the strategy remains the same. We still use a swap overlay strategy to close 50% of the duration gap between assets and liabilities. However, the method used to determine the duration gap slightly differs from that of the original strategy. Figure 6.1 proves that the impact on the ALM results is only marginal.

6.1 Portfolio optimization

An important aspect of the ALM implementation phase is optimization of the asset portfolio. During the ALM study the board of directors has agreed upon a certain risk profile for the pension fund. The result of the ALM study is a pension deal. The pension deal is an integral contribution-, indexation and investment policy that satisfies the risk profile. One of the main goals of the ALM implementation phase is to further improve the performance of the fund by optimizing the asset portfolio.

	Pension Deal		Pension Deal (alternative duration strategy)	
years	1-15	1-5	1-15	1-5
Average funded ratio (percentage)	129	126	129	126
Probability of solvability < 105% (percentage)	3.2	2.0	3.7	2.4
Probability of solvability < 100% (percentage)	0.9	0.4	1.4	0.8
Average nFTK required buffer (% provisions)	12.3	12.8	13.4	14.0
Probability funded ratio < nFTK required (percentage)	10.3	9.0	11.7	10.8
Average net Contributions (% Salary sum)	13.9	13.8	14.0	13.8
90% VaR net Contributions (% Salary sum)	21.0	18.8	21.0	19.0
Probability of incomplete indexation NA (percentage)	29.5	30.6	28.7	30.8
Average realized indexation NA (% ambition)	81.3	81.0	81.9	80.7
10% VaR realized indexation NA (% ambition)	48.5	43.5	48.8	43.3
	15-15	5-5	15-15	5-5
Average purchase power NA (percentage)	95.4	97.6	95.9	97.6
10% VaR purchase power NA (percentage)	86.0	92.4	86.0	92.4

Figure 6.1: ALM results with the new duration strategy

This section describes a commonly used technique called Markowitz portfolio optimization. This technique is very suitable for asset-only optimization of the portfolio. However, we show that pension funds should be very careful when optimizing the investment portfolio in asset-only terms. The liabilities of the fund should always be taken into account. For that reason we adapt the Markowitz optimization model in such a way that we can can optimize the funded ratio return instead of asset-only portfolio return. For both optimization methods we use a wide range of asset categories. A list of available asset categories and the assumptions about their risk/return profile can be found in Appendix C.

6.1.1 Markowitz asset-only optimization

A commonly used technique to optimize an asset portfolio is Markowitz portfolio optimization. The Markowitz optimization model minimizes the portfolio risk at a given amount of return. The Markowitz portfolio theory is based on several assumptions.

1. Investors always seek for the highest return at a given level of risk;

2. Investors are risk-averse. A less risky asset category is preferred over a riskier asset with the same expected return;

3. Risk of an asset is defined as the variability of its expected returns;

4. Investors base their decisions solely on expected return and risk;

5. Markets are perfectly efficient. There is no such thing as taxes or transaction costs.

Before we describe the optimization model we first introduce several variables.

- w_i = the proportion of asset i in the portfolio;
- μ_i = the expected return of asset i;
- σ_i = the standard deviation of asset i;
- ρ_{ij} = the correlation between asset i and asset; j
- θ = the desired return of the portfolio.

The Markowitz optimization model for a portfolio of N available asset categories is defined as follows.

$$\begin{aligned} min \quad & \sum_{i=1}^{N}\sum_{j=1}^{N} w_i w_j \sigma_i \sigma_j \rho_{ij} \\ s.t. \quad & \sum_{i=1}^{N} w_i = 1; \\ & \sum_{i=1}^{N} w_i \mu_i = \theta; \\ & 0 \leq w_i \leq 1 \quad \forall i; \end{aligned}$$

The procedure of portfolio optimization in the ALM implementation phase consists of two steps. The first step consists of constructing an efficient frontier. This is achieved by first finding the minimum risk portfolio with a corresponding minimal return r. We increase the return with small steps and solve the Markowitz model for each step. The result is a range of minimum risk portfolios for each value of the expected return. These portfolios form an efficient frontier as displayed in Figure 6.2.

The next step in the optimization process is to find the portfolio with the maximal return at the same (asset-only) risk as that of the pension deal. This portfolio can be found on the efficient frontier, exactly above the pie chart of the pension deal. See Figure 6.3 for a graphical representation of this procedure. The risk of the portfolio is displayed on the x-axis in terms of the standard deviation of the portfolio return.

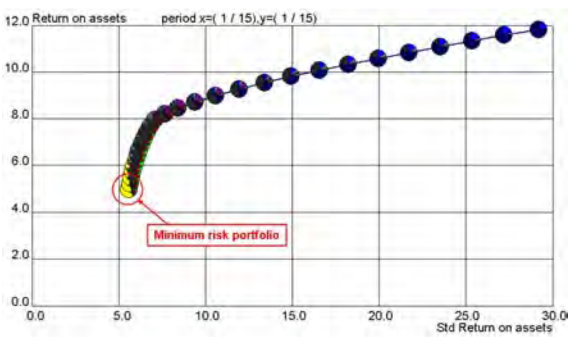

Figure 6.2: The efficient frontier

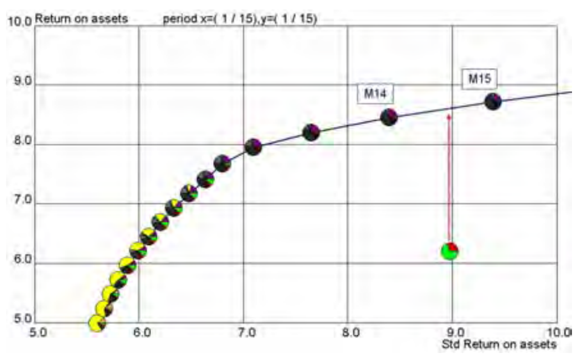

Figure 6.3: The strategic asset portfolio is inefficient in asset-only terms

Figure 6.4 contains an overview of the portfolios on the efficient frontier. The most defensive portfolio (M0) on the efficient frontier consists mainly of cash. Cash alone already has a very low standard deviation of returns. Because of some interesting correlations, risk is even further reduced by adding some bonds (index-linked and European government), real estate, and a small amount of equity to the portfolio. The most aggressive portfolio (M27) contains a large amount of emerging market equity. The portfolio is completed with some private equity (venture capital).

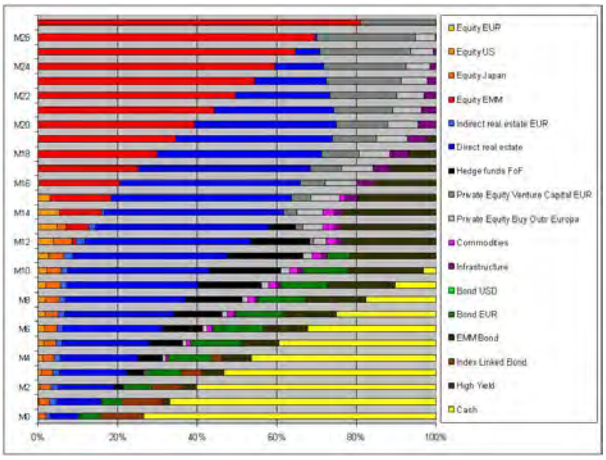

Figure 6.4: The efficient frontier: from defensive (M0) to aggressive (M27)

The efficient portfolio with the same asset-only risks as the portfolio of the pension deal is situated between portfolios M14 and M15 on the efficient frontier. Additional optimization with smaller step sizes between M14 and M15 leads us to a portfolio on the efficient frontier with exactly the same asset-only risks (standard deviation of returns) as the portfolio of the pension deal. The new portfolio consists of 18% equity (mainly emerging markets), 45% direct real estate, 21% high yield bonds, and 16% alternative investment categories like infrastructure, commodities, and private equity. The expected return of the portfolio is approximately 7.9%. The standard deviation of the portfolio return equals that of the strategic portfolio: 7.4%. The portfolio has been improved in asset-only terms. We increased the expected return while maintaining the same amount of risk. The question is whether this improvement also holds for the ALM results of the fund. Figure 6.5 shows the numerical ALM results for both the original policy (See paragraph 4.4.3) and the new optimal portfolio. The new asset mix has a huge impact on the nFTK required buffer. As mentioned in Section 2.6, the required buffer is determined using the square root- or S-formula. Increasing the amount of equity, private equity, and real estate in the portfolio causes the S2 component to rise. With that, the

	Pension Deal (alternative duration strategy)		Asset-only optimization	
years	1-15	1-5	1-15	1-5
Average funded ratio (percentage)	129	126	151	136
Probability of solvability < 105% (percentage)	3.7	2.4	1.7	2.6
Probability of solvability < 100% (percentage)	1.4	0.8	0.6	0.8
Average nFTK required buffer (% provisions)	13.4	14.0	22.7	23.1
Probability funded ratio < nFTK required (percentage)	11.7	10.8	14.2	25.7
Average net Contributions (% Salary sum)	14.0	13.8	11.0	13.3
90% VaR net Contributions (% Salary sum)	21.0	19.0	18.6	18.4
Probability of incomplete indexation NA (percentage)	28.7	30.8	12.6	21.8
Average realized indexation NA (% ambition)	81.9	80.7	91.9	85.7
10% VaR realized indexation NA (% ambition)	48.8	43.3	63.3	46.3
	15-15	5-5	15-15	5-5
Average purchase power NA (percentage)	95.9	97.6	99.4	98.6
10% VaR purchase power NA (percentage)	86.0	92.4	94.9	93.0

Figure 6.5: ALM results with the (asset-only) optimal portfolio

required buffer increases. The higher this buffer, the bigger the probability for the funded ratio to drop below this threshold. The effects on the required buffer and on the probability of a reserve smaller than this buffer are visible on both the short term and the long term.

Besides the issues concerning the nFTK buffer, the pension fund seems to perform better on the long term horizon of 15 years. However, the short term results show some additional concerning issues. The solvability risks are increased. The probability of funding shortfall (funded ratio < 105%) went up from 2.4% to 2.6%. Not a drastic increase, but certainly a reason for caution.

The difference between long term and short term is caused by the effect of the new portfolio on the return and volatility of the funded ratio. The funded ratio return increases impressively because of the high asset returns. The volatility of the asset return remains the same. However, other sources of risk, like interest rate risk, are completely neglected in this optimization process. The new portfolio apparently forces these other risks to increase, yielding an increased volatility of the funded ratio. This increased volatility can do no harm on the long term since the expected funded ratio increases to a sufficiently high level. However, in the early years of the simulation, the funded ratio is not high enough to resist the increased volatility. This results in a higher probability of funding shortfall or even deficit. An illustration of this fact is displayed in Figure 6.6. The planes in the lower left corners of the graphs

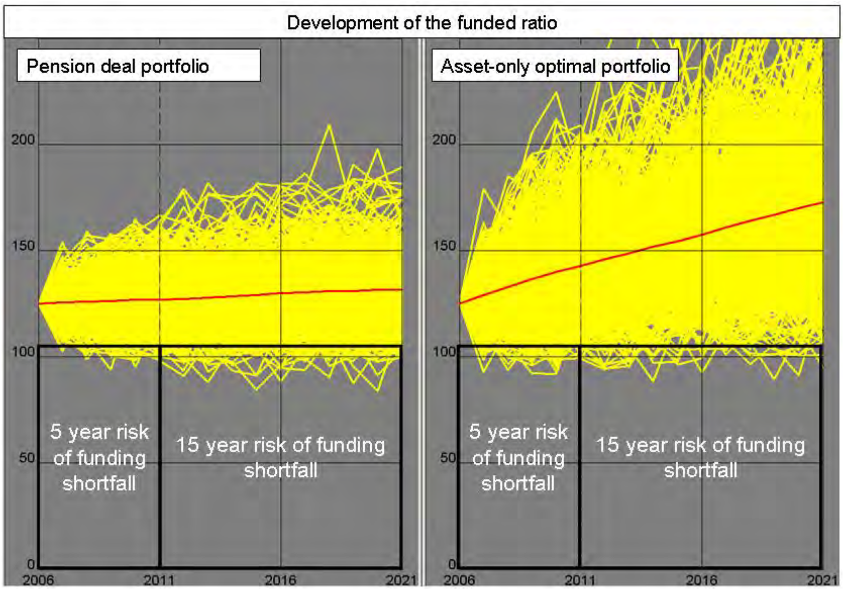

Figure 6.6: Short term risks vs. long term risks

contain the scenarios that cross the threshold of funding shortfall (105%) in the first 5 years. In the situation with the asset-only optimal portfolio we see a higher density of scenarios in the concerning plane. Over the full horizon of 15 years we observe a lower density of scenarios below the threshold.

The numbers in Figure 6.5 justify the conclusion that pension fund managers should be very cautious when analyzing the investment strategy in an asset-only context. Especially the short term ALM results of the fund can be negatively affected by an optimization in asset-only terms. In the following section we describe a method to include the liabilities of the pension fund in the portfolio optimization process.

6.1.2 Markowitz funded ratio optimization

In the previous section it became clear that asset-only optimization can have a negative impact on the short term ALM results of the pension fund. In this section we tempt to include the liabilities in the optimization process by optimizing the funded ratio return instead of the return on the asset portfolio. This goal can be achieved by means of a simulation procedure with ALS.

First we define the return on the funded ratio. Let f denote the funded ratio and R the annual return on the funded ratio. We define a as the value of the asset portfolio, r_a as the annual return on the asset portfolio, l as the nominal value of the provisions for pension obligations, and r_l as the annual return on the nominal provisions. The funded ratio one year from now can be written as $f(1+R)$. This new funded ratio equals the ratio of the new assets over the new provisions, defined as $a(1+r_a)$ and $l(1+r_l)$ respectively. This leads us to an expression for the funded ratio return R.

$$\begin{aligned} f\,(1+R) &= \frac{a\,(1+r_a)}{l\,(1+r_l)} \\ &= f\frac{(1+r_a)}{(1+r_l)} \\ 1+R &= \frac{(1+r_a)}{(1+r_l)} \\ R &= \frac{(1+r_a)}{(1+r_l)} - \frac{(1+r_l)}{(1+r_l)} \\ &= \frac{r_a - r_l}{1+r_l}. \end{aligned}$$

In the simulation procedure of ALS we analyze the funded ratio return for each of the asset categories separately. Before we describe the simulation procedure, we first introduce several variables.

T = simulation horizon in years;

S = number of simulation runs;

N = number of asset categories;

r_{its} = the return of asset category i at time t in scenario s;

r_{lts} = the return on the nominal provisions at time t in scenario s;

R_{its} = the return on the funded ratio for asset category i at time t in scenario s;

For each scenario s and each time t ALS measures and stores the funded ratio return for each asset i.

$$R_{its} = \frac{r_{its} - r_{lts}}{1 + r_{lts}}$$

With these $S \times T$ realizations of the funded ratio return ALS approximates the expected funded ratio return $\mathbb{E}[R_i]$ by means of the sample average.

$$\mathbb{E}[R_i] = \frac{1}{S}\sum_{s=1}^{S}\frac{1}{T}\sum_{t=1}^{T} R_{its}.$$

In a similar way ALS approximates $\mathbb{E}[R_i R_j]$, for $i, j = 1, \ldots, N$, from the sample.

$$\mathbb{E}[R_i R_j] = \frac{1}{S}\sum_{s=1}^{S}\frac{1}{T}\sum_{t=1}^{T} r_{its} r_{jts}.$$

Note that this expression equals $\mathbb{E}[R_i^2]$ if $j = i$. Now, using that

$$Var(X) = \mathbb{E}[X^2] - \mathbb{E}^2[X],$$

and

$$Cov(XY) = \mathbb{E}[XY] - \mathbb{E}[X]\mathbb{E}[Y],$$

ALS approximates the variance $\sigma^2_{R_i}$ of the funded ratio return for each asset category i, and the covariance of the funded ratio return $Cov(R_iR_j)$ for each pair (i, j) of asset categories.

At this point ALS has acquired all necessary statistics to perform Markowitz optimization. The target function is the variance σ_R of the overall funded ratio return R.

$$\begin{aligned}
\sigma_R &= \sum_i \sum_j w_i w_j \sigma_{R_i} \sigma_{R_j} \rho_{R_i R_j} \\
&= \sum_i \sum_j w_i w_j \sigma_{R_i} \sigma_{R_j} \frac{Cov(R_i, R_j)}{\sigma_{R_i} \sigma_{R_j}} \\
&= \sum_i \sum_j w_i w_j Cov(R_i, R_j).
\end{aligned}$$

What remains is the following Markowitz optimization problem.

$$\begin{aligned}
min \quad & \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j Cov(R_i, R_j) \\
s.t. \quad & \sum_{i=1}^{N} w_i = 1; \\
& \sum_{i=1}^{N} w_i R_i = \theta; \\
& 0 \leq w_i \leq 1 \quad \forall i \in \{1, \ldots, N\}.
\end{aligned}$$

The new Markowitz model helps us to deal with an essential difference between the asset portfolio and the liabilities. The risk of an asset portfolio can be reduced by means of diversification. Risk is being reduced by selecting assets with negative mutual correlation. Negative correlation between assets and liabilities results in the exact opposite: an increased amount of risk. If an asset category, which is positively correlated with the liabilities, is added to the portfolio, the total funded ratio risk will decline. This characteristic is caught by the optimization model because asset returns and returns on the liabilities are observed together for each time t in each simulation run s. The behavior of the funded ratio return reflects the behavior of the concerning asset category relative to the behavior of the liabilities.

With the results of the simulation in ALS we can construct an efficient frontier in the risk/return plane of the funded ratio. The resulting frontier is displayed in Figure 6.7. In Figure 6.8 we again search for the portfolio with the maximum expected return at the same risk as the original portfolio.

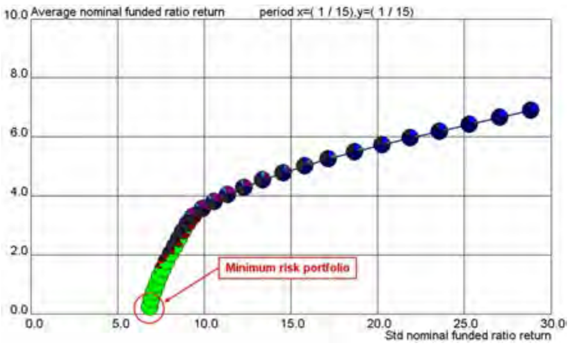

Figure 6.7: The efficient frontier in the funded ratio plane

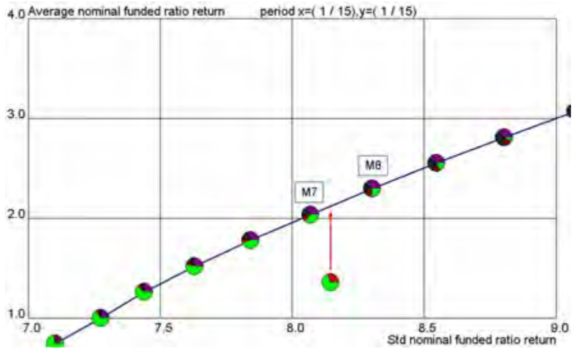

Figure 6.8: The strategic asset portfolio is inefficient

Figure 6.9 contains a bar chart displaying the portfolios on the efficient frontier. From defensive (M0) to aggressive (M27). An interesting observation is the fact that the composition of the minimum risk portfolio (M0) of the efficient frontier in the funded ratio plane is completely different from the asset-only minimum risk portfolio. Instead of the cash in the asset-only case, we now see that fixed income instruments are dominating the low risk portfolios. This effect is caused by the risk reducing correlation between fixed income instruments and the liabilities of the fund.

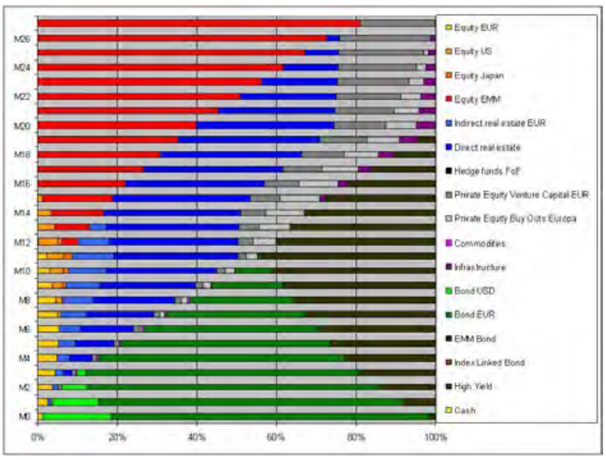

Figure 6.9: The efficient frontier in the funded ratio plane: from defensive (M0) to aggressive (M27)

The portfolio with the highest return at the same funded ratio risk as the original portfolio is situated between portfolios M7 and M8. Additional optimization with smaller step sizes between M7 and M8 leads us to a portfolio on the efficient frontier with exactly the same funded ratio risks (standard deviation of funded ratio returns) as the portfolio of the pension deal. The new portfolio contains a large amount of fixed income instruments: 33% European government bonds and 33% high yield bonds. Real estate is also an important part of the portfolio with 25% (18% direct + 7% indirect) of the total value. Approximately 6% of the portfolio is reserved for equity from Europe and the US. The rest of the portfolio should be invested in private equity, equally divided over venture capital and buy outs, and a small amount of commodities.

The 6.9% expected return of the new portfolio is 1.1 percentage points lower than the return of the asset-only optimal portfolio. Its standard deviation of 7.7% is slightly lower than that of the asset-only optimum. The question is whether the funded ratio optimization has caused an improvement in the ALM results of the fund. Figure 6.10 contains the numerical ALM results for the pension fund.

The funded ratio optimization has the desired effect. On both long term and short term the ALM results can be improved with this technique. We conclude that portfolio optimization is a very useful tool to improve the performance of the pension fund. During the optimization process, the liabilities of the fund should be taken into account. Asset-only optimization can have a negative impact on the ALM results of the fund. Especially the short term performance measures may suffer from the increased volatility of the funded ratio caused by the asset-only optimization.

	Pension Deal (alternative duration strategy)		Funded ratio optimization	
years	1-15	1-5	1-15	1-5
Average funded ratio (percentage)	129	126	136	129
Probability of solvability < 105% (percentage)	3.7	2.4	2.8	2.3
Probability of solvability < 100% (percentage)	1.4	0.8	1.0	0.8
Average nFTK required buffer (% provisions)	13.4	14.0	11.5	12.2
Probability funded ratio < nFTK required (percentage)	11.7	10.8	6.0	6.2
Average net Contributions (% Salary sum)	14.0	13.8	13.3	13.7
90% VaR net Contributions (% Salary sum)	21.0	19.0	20.3	18.7
Probability of incomplete indexation NA (percentage)	28.7	30.8	20.5	25.8
Average realized indexation NA (% ambition)	81.9	80.7	87.2	84.7
10% VaR realized indexation NA (% ambition)	48.8	43.3	54.6	49.8
	15-15	5-5	15-15	5-5
Average purchase power NA (percentage)	95.9	97.6	97.6	98.3
10% VaR purchase power NA (percentage)	86.0	92.4	86.7	93.5

Figure 6.10: ALM results with the optimal portfolio

6.2 Mandates for the asset manager

In the previous sections we described techniques that can be used to find the optimal composition of the asset portfolio. Once the optimal mix has been determined we enter the final stage of the ALM implementation phase: constructing mandates for the asset managers of the pension fund.

In this section we make an assumption about the duration strategy. We assume that the duration overlay strategy is performed by a third party which has insight in both the liabilities and the bond portfolio. With this assumption we consider the duration match as given. In real life the duration strategy is often the responsibility of the board of the pension fund and not of the asset manager. In Section 6.3 we describe the significant impact of duration matching on the performance of the pension fund, and with that, the importance of a correct implementation of the strategy.

A typical mandate for the asset mix consists of a benchmark and a tracking error, often accompanied by out performance goals and demands concerning the duration of the portfolio. An example of a benchmark is the MSCI-Europe index for European equity. The tracking error is defined as the standard deviation of the difference between the realized return and the benchmark return. In this thesis we define the mandate with a benchmark and (possibly) a tracking error as a traditional mandate. The traditional mandate is a very restrictive guideline for the asset manager. In this chapter we show that this restriction is necessary to warrant the desired ALM results. Any amount of additional freedom can have a negative impact on the pension fund's performance. In Section 6.2.1 we first show that even a tight traditional mandate can result in some deviation from the performance agreed upon in the pension deal. In the next sections we show the effect of giving the asset manager some more freedom, by means of some less restrictive asset-only mandates. The following asset-only mandates will come up for discussion.

- The Value at Risk (VaR) mandate;

- The Value at Risk (VaR) plus mandate;

These asset-only mandates can be seen as risk budgets. With the VaR mandate we require the asset manager to construct a portfolio that will generate a given amount of return with a given amount of certainty. A 5% VaR mandate of 2% means that the return of the portfolio should be at least 2% in 95% of the cases. This mandate does not put any restrictions on the composition of the portfolio, and leaves the asset manager with a great amount of freedom.

The VaR plus mandate is somewhat more restrictive. Besides the required VaR of the portfolio, the VaR plus mandate includes a requirement concerning the amount of fixed income instruments in the portfolio. In Sections 6.2.2 and 6.2.3 we show that both VaR related mandates provide the asset manager with too much freedom. ALM results may strongly diverge from those agreed upon in the pension deal due to the less restrictive mandates.

A mandate is considered successful if the performance of the fund with the new portfolio resembles the performance agreed upon during the ALM study. The performance of the pension fund can be evaluated using the three most important performance measures for a pension plan: solvability, contributions and purchase power of the participants.

6.2.1 The traditional mandate

The traditional mandate can be derived from the ALM results by simply writing down the strategic asset allocation, accompanied by the benchmarks used during the ALM analysis. The Strategic Asset Allocation described in the pension deal of the Hollandia pension fund has been summarized in Table 6.1. This table could serve as a traditional mandate for the asset manager. As in the ALM analysis the

Asset category	Percentage	Bandwidth
European Bonds	70%	5%
US equity	10%	5%
European Equity	10%	5%
Japanese Equity	10%	5%

Table 6.1: SAA of the pension deal

benchmarks for the equity classes should be the MSCI-North America, MSCI-Europe and MSCI-Japan respectively. The GBI-EMU could serve as a benchmark for the European government bonds. Recall that, for the analysis of the mandates, we assume the duration overlay strategy as given.

The traditional mandate leaves the asset manager with little freedom. The only option is to move along the given bandwidth. The effect of this freedom can be measured by moving the asset allocation toward the edges of the bandwidth. Especially a switch from the fixed income bonds to equity classes might have some effect on the results of the fund. Within the boundaries of the bandwidths one can increase either the amount of fixed income instruments or the amount of equity. Here we analyze four mixes which are mentioned in Table 6.2. It should be clear that these mixes are kept fixed during this

	More fixed income		More equity	
	Mix 1	Mix 2	Mix 3	Mix 4
European Bonds	65%	65%	75%	75%
US Equity	11.7%	10%	8.3%	10%
European Equity	11.7%	10%	8.3%	10%
Japanese Equity	11.6%	15%	8.4%	5%

Table 6.2: Four mixes satisfying the traditional mandate

analysis. That is, the asset allocation will not vary within the boundaries of some bandwidth.

ALS makes it possible to measure the effects of the given investment strategies. With the bandwidths turned off and the asset allocation defined as in Table 6.2 the system is able to replicate the investment strategies. The health of the pension fund should be measured using the three major performance categories: solvability, contributions and purchase power of the pension plan's participants. These criteria have been used to measure the impact of the four investment strategies. Starting with the solvability criterion, Figure 6.11 displays two characteristics of the fund's funding ratio. The horizontal axis measures the average nominal solvability over a period of 15 years. The vertical axis measures the risk of getting in a situation of funding shortfall. The probability of funding shortfall is a matter of great importance because of the pressure of the Dutch pension regulators.

Looking at Figure 6.11 we can conclude that the restrictive traditional mandate leaves no room for any negative impact on the solvability of the fund. The probability of funding shortfall is approximately equal to the 3.7% of the pension deal policy. The marginal deviation from the risks of the pension deal leads to the conclusion that the traditional mandate is sufficiently restrictive to guarantee an acceptable amount of solvability risk. The next step is to check the impact on the contributions and on the purchase power of the participants of the plan. Figures 6.12 and 6.13 show that the impact on both the contributions and the purchase power is negligible. Both the risks and the average values remain close to the values of the pension deal.

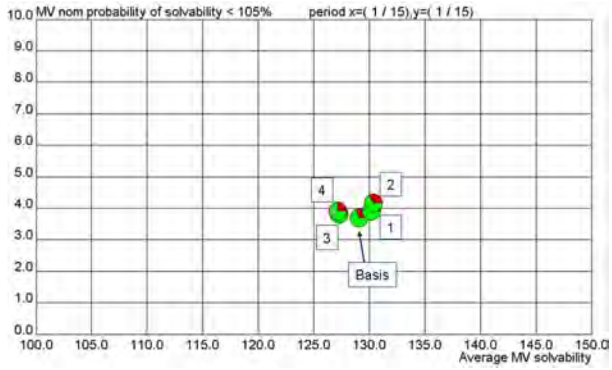

Figure 6.11: Traditional mandate and solvability

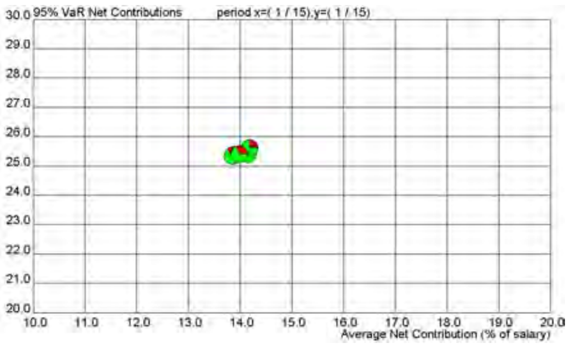

Figure 6.12: Traditional mandate and contributions

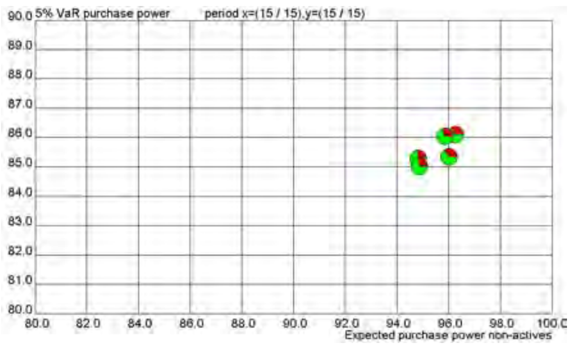

Figure 6.13: Traditional mandate and purchase power

The restrictive traditional mandate has the desired effect on the ALM results of the pension fund. In the remainder of this chapter we try to emphasize the importance of a tight mandate. We analyze the effect of two theoretical asset-only mandates with a lot of freedom for the asset manager. We are interested in the possible impact on the ALM results given the different mandates.

6.2.2 The VaR mandate

The traditional mandate described in the previous section left the asset manager with little freedom in his choice for different asset categories. The mandate discussed in this section provides the asset manager with a greater amount of freedom. The VaR mandate consists of one single asset-only performance measure: the required Value at Risk of the portfolio return. The VaR mandate tells the asset manager to construct a portfolio with an asset-only risk profile similar to that of the portfolio in the pension deal. The risk profile of a portfolio can be described in several ways. Value at Risk is one of them. During our analysis we will use the 1 year 5% VaR. The 5% Value at Risk can be defined as the value that will be exceeded in 95% of the cases. Hence, if the return on a portfolio has a Value at Risk of 2%, then the return of this portfolio will be above 2% in 95% of the cases.

The return of the portfolio in the pension deal has an average 1 year 5% Value at Risk of -5.4%. In the previous section 4 asset mixes have been discussed. The Values at Risk of each of these mixes are mentioned in Table 6.3.

Mix	VaR
Mix 1	-5.8%
Mix 2	-5.9%
Mix 3	-4.3%
Mix 4	-4.3%

Table 6.3: Four mixes and their VaR

It appears that mixes 3 and 4 from the previous section satisfy the VaR mandate. The VaR mandate might lead to acceptable portfolios, like mixes 3 and 4 from the previous section. However, before jumping to conclusions, we have to check whether results with the VaR mandate can get any worse. In order to do so we analyze several mixes matching the VaR mandate. A first interesting portfolio is the optimal portfolio (in asset-only terms). This optimal portfolio can be determined by means of a variation on the Markowitz optimization model. The goal of the optimization is to maximize the expected return of the portfolio, given its 1 year 5% VaR. As we did with the Markowitz optimization model, we assume normally distributed asset returns. This assumption provides us with an approximation for the risk σ_p of the portfolio:

$$\sigma_p = \sum_i \sum_j w_i w_j \sigma_i \sigma_j \rho_{i,j},$$

where w_i denotes the weight of asset i, σ_i denotes the standard deviation of the return on asset i and ρ_{ij} denotes the correlation between asset i and asset j. The 5% Value at Risk of the portfolio can be determined using the lower 5% percentile of the normal distribution. This can be obtained using the inverse cumulative density function:

$$VaR = \Phi^{-1}(5\%, \mu_p, \sigma_p).$$

The portfolio optimization model can be described as follows:

$$\begin{array}{lrcll} \max & \mu_p & = & \sum_{i=1}^{N} w_i \mu_i & \\ \text{s.t.} & \Phi^{-1}(5\%, \mu_p, \sigma_p) & \geq & \theta & \\ & \sum_{i=1}^{N} w_i & = & 1 & \\ & w_i & \in & \{0, 1\} & \forall i. \end{array}$$

The θ in the first restriction represents the required Value at Risk from the mandate. This value can be obtained from the simulated returns on assets from ALS, and equals -5.4%. Given a rather wide variety of different asset categories, the optimization results in an asset allocation as described in Table 6.4. The assumptions about expected return and standard deviation of the different asset categories have been summarized in Appendix C.

Asset category	Weight
US equity	1.1%
EMM equity	18.3%
Direct real estate	44.3%
Commodities	0.4%
Private Equity Venture Capital EUR	5.9%
Private Equity Buy Outs Europa	7.6%
High Yield	18.5%
Infrastructure	3.9%

Table 6.4: Optimal asset allocation at a VaR of -5.4%

We are interested in the ALM results with an asset mix as described in Table 6.4. The results of a simulation with the new asset mix are displayed in Figure 6.14. We observe an impressive improvement of the solvability risk and return. However, the large difference between the new results and the pension deal is reason for concern. The board of the pension fund has agreed upon the performance measures of the pension deal. If the results appear to differ this much from the pension deal, the participants or the board of the pension fund might want to revise their goals. Besides, a different choice of asset allocation might as well have the exact opposite effect. The board of the pension fund wants to prevent this by constructing a sufficiently tight mandate. The VaR mandate is certainly not a tight mandate. Figure 6.15 gives an impression[1] of the additional freedom for the asset manager.

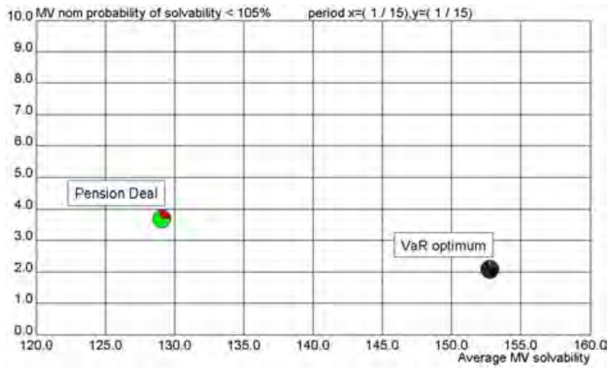

Figure 6.14: VaR mandate and solvability

All pie charts in the figure represent portfolios that satisfy the VaR mandate. As mentioned before, the solvability risks might as well go sky high. A good example is the yellow pie charts in the upper left corner of the figure. The pie chart represents a 100% cash portfolio. The VaR of this portfolio is 0.6%, well within the boundaries of the mandate. Nevertheless, the portfolio results in a probability of funding shortfall that reaches well over 10%. The same holds for the yellow and green pie chart (cash and commodities) with a probability of funding shortfall of 13%.

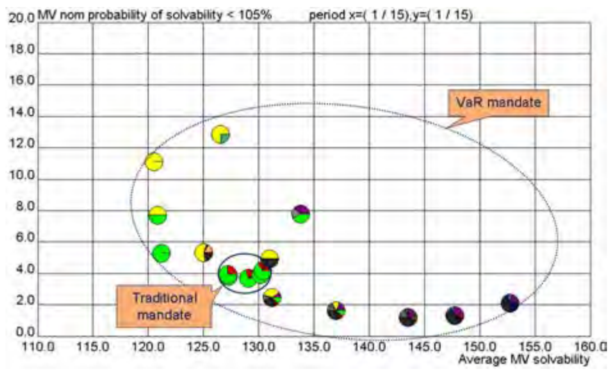

Figure 6.15: The VaR mandate offers additional freedom

The conclusion of this section is that the VaR mandate provides too much freedom to the asset manager. With that, the uncertainty about the ALM results increases dramatically. This holds for the solvability of the fund as well as for the contributions and the purchase power. Figures 6.16 and 6.17 illustrate the effect on the contributions and the purchase power.

[1]Remark: an arbitrary portfolio, that falls within the outer circle in the figure, does not necessarily satisfy the VaR mandate. The circle only gives an impression of the wide variety of results that might occur given the VaR mandate.

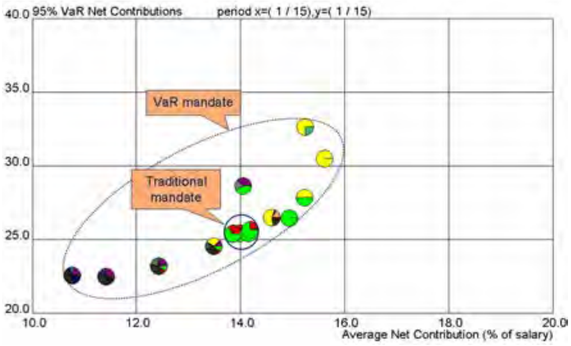

Figure 6.16: VaR mandate and contributions

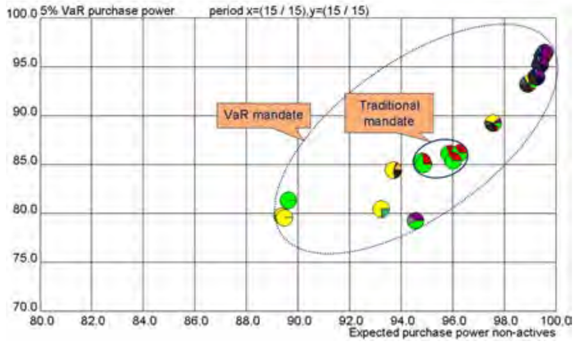

Figure 6.17: VaR mandate and purchase power

6.2.3 The VaR-plus mandate

In the previous section it became clear that the VaR mandate provides too much freedom for the asset manager. The accompanying uncertainty about the ALM results is an undesirable effect. In this section we add an extra restriction to the VaR mandate. Besides the Value at Risk of the original portfolio, we now add the required amount of fixed income instruments to the mandate. We define this new mandate as the VaR-plus mandate. In the pension deal the strategic asset allocation contains 70% fixed income instruments. The asset manager still has a reasonable amount of freedom, since we do not specify the desired type of fixed income instruments. In this example the availability of fixed income instruments is restricted to goverment bonds (European, US and emerging markets), or high yield bonds. In practice the range of instruments is even broader. Think of credit bonds, zero-coupon bonds, convertible bonds, etcetera. With the new restriction added to the Markowitz portfolio optimization model we find the following optimal asset mix.

Asset category	**Weight**
EMM Bond	13.4%
EMM Equity	5.3%
Direct Real Estate	14.9%
Commodities	2.3%
Private Equity Venture Capital	4.8%
Private Equity Buy Outs Europa	2.7%
High yield bonds	56.6%

Table 6.5: Optimal asset allocation at a VaR of -5.4% with at least 70% fixed income

Restricting the amount of fixed income instruments in the asset portfolio seems like a rather tightening restriction. However, Figure 6.18 proves otherwise. Within the VaR-plus mandate the asset manager still has a considerable amount of freedom. This amount of freedom is too large to guarantee the ALM results. The probability of funding shortfall can vary from 2.5% to almost 8%. The average funded ratio of the fund can attain values between 120% and 147%. This high variability leads to the conclusion that the VaR-plus mandate does not restrict the asset manager sufficiently to guarantee the solvability characteristics agreed upon in the pension deal. Figures 6.19 and 6.20 show that the same holds for the other performance measures of the pension fund: contributions and purchase power.

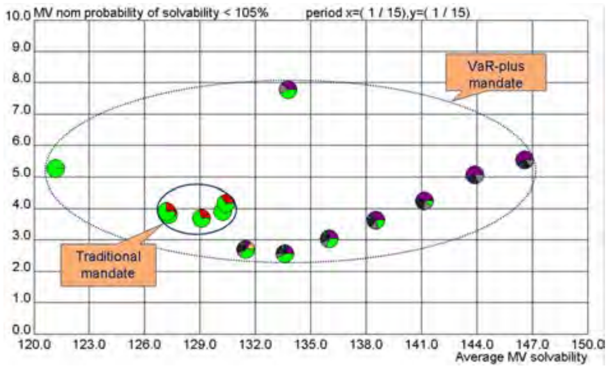

Figure 6.18: The VaR-plus mandate still offers too much freedom

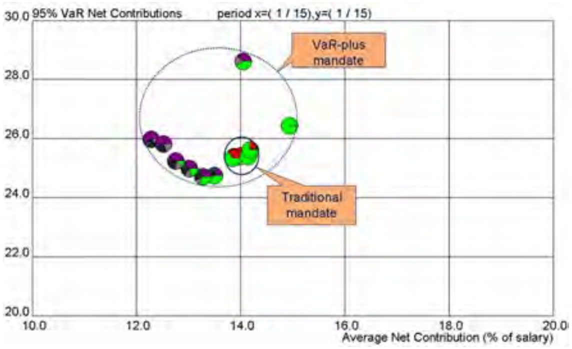

Figure 6.19: VaR-plus mandate and contributions

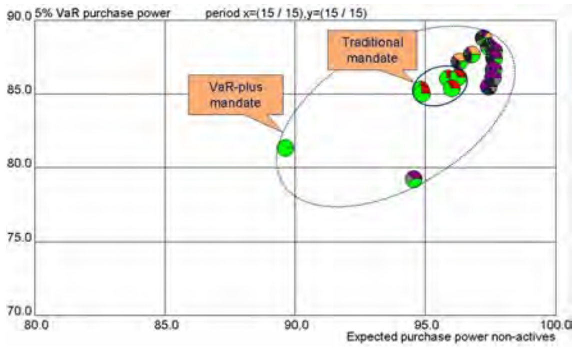

Figure 6.20: VaR-plus mandate and purchase power

6.3 The importance of the duration strategy

At the beginning of this chapter we assumed that the duration strategy was implemented correctly by a third party which has insight in both assets and liabilities. In real life the duration strategy is often the responsibility of the pension fund management. In this section we emphasize the importance of the implementation of the duration strategy.

In the previous sections we have shown that the performance of the pension fund does not solely depend on the asset-only risk/return profile of the investment portfolio. A pension fund faces several other sources of risk. An important risk driver for the pension fund is the correlation between the asset portfolio and the pension fund's liabilities. This correlation depends mainly on the interest rate sensitivity of both the assets and the liabilities. A measure for the interest rate sensitivity is the duration. Duration is defined as the weighted average maturity of future cash flows. In order to control the interest rate sensitivity, the pension fund often defines a duration strategy, like the one described in Section 4.4.3. By adjusting the duration of the asset portfolio, we actually change the correlation between the assets and the liabilities. In this section we emphasize the impact of the correlation between assets and liabilities by creating some artificial asset categories. Each category has the same expected return μ and the same standard deviation σ as the portfolio in the pension deal. We vary the correlation between the new asset category and the liabilities, moving from strongly positive correlation ($\rho \approx 1$) to strongly negative correlation ($\rho \approx -1$).

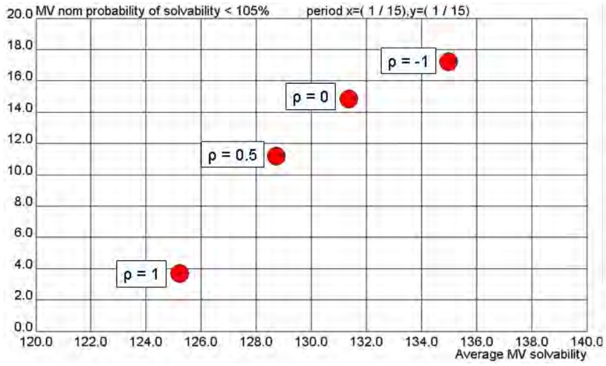

Figure 6.21: Correlation and solvability

Strong correlation between assets and liabilities can be obtained by creating a comparable amount of interest rate sensitivity for both the assets and the liabilities. The provisions for pension obligations are negatively correlated with interest rate changes. If interest rates increase, the value of the provisions decreases, and vice versa. Hence, to create positive correlation between the artificial asset category and the liabilities, we demand negative correlation between the asset category and the interest rate changes.

Figure 6.21 shows the huge impact of correlation between assets and liabilities. High correlation will lead to low solvability risks. No correlation, or negative correlation causes the risks to increase severely. Perfectly positive correlation with the liabilities makes it possible for the assets to exactly track the movements of the liabilities. This completely eliminates the interest rate risk.

A situation with zero interest rate risk is hard to achieve. Zero interest rate risk can only be obtained if the asset portfolio has the same interest rate sensitivity, or duration, as the provisions for pension obligations. The provisions of a pension fund of average maturity, like the Hollandia fund, have a duration of approximately 15 years. Constructing an asset portfolio with a duration of 15 years is only possible with bonds of very high maturity. Even for a 100% fixed income portfolio it requires bonds with a maturity of at least 30 years (depending on the coupon value) to obtain the desired duration of 15 years. These long duration bonds are not widely available. Besides, the liquidity of the available long duration bonds is limited.

A commonly used technique to overcome the difficulties of long duration bonds is a so-called swap(tion) duration overlay strategy. This strategy tempts to increase the duration of the asset portfolio in order to create a greater correlation between assets and liabilities. The difference in duration between the assets and the liabilities is referred to as the duration gap. In the pension deal of the Hollandia fund we compare the duration of 75% of the assets with the duration of the liabilities. The resulting duration gap is closed for 50%. A correct implementation of the overlay strategy is of essential importance. Figure 6.22 illustrates the impact of the duration match.

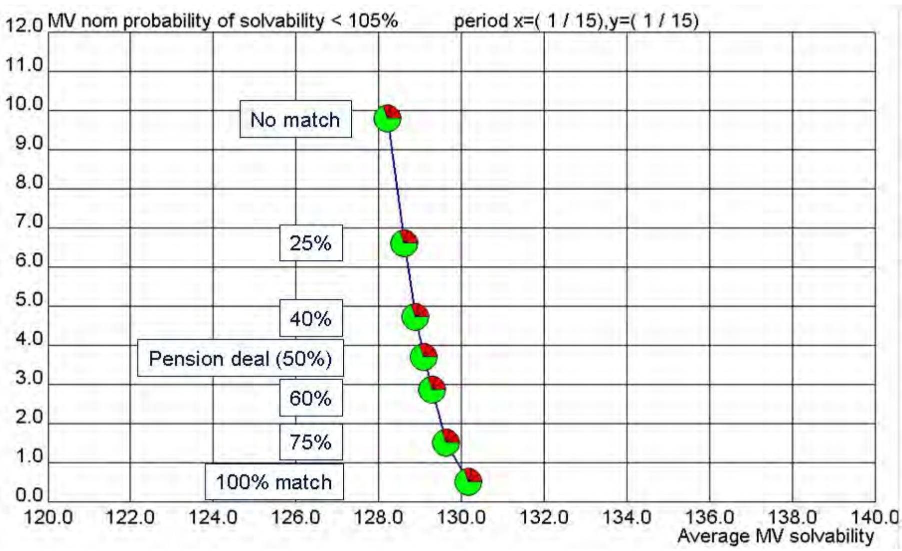

Figure 6.22: The impact of duration matching

The percentages indicate the part of the duration gap that is closed by means of the duration overlay. We see that the risk of funding shortfall can vary from almost zero at a full match to over 10% if the duration is not matched at all. An interesting observation is the difference in ALM performance if the duration match differs slightly from that agreed upon in the pension deal. In the pension deal we closed 50% of the duration gap between the assets and the liabilities. If, for some reason, the implementation of the strategy only closes 40% of the gap we see an immediate and rather severe increase of the probability of a funding shortfall. A possible cause of a differing matching percentage might be insufficient insight into the duration of either the assets or the liabilities.

6.4 Conclusions ALMi: assets, liabilities and the mandate

The analysis in this chapter once again emphasizes the importance of the liability structure of the pension fund. We have shown that portfolio optimization can be a very powerful tool to improve the ALM performance of the pension fund. However, in Section 6.1.1 we have shown the impact of a Markowitz optimization in an asset-only context. The results for the pension fund's performance gave some reason for concern. Especially the short term performance may be affected negatively by the optimization in an asset-only context. For that reason we advise pension fund managers to include the liabilities in any portfolio optimization routine. The Markowitz funded ratio optimization described in Section 6.1.2 keeps track of the correlation between asset returns and the liabilities. This optimization routine should be preferred over the asset-only Markowitz optimization. Portfolio optimization can be a very powerful tool to improve the ALM performance of the fund, as long as the liabilities are taken into account at all times.

When constructing a mandate for the asset manager the liabilities also play an important role. In order to achieve the desirable correlation between the asset portfolio and the liability structure of the pension fund, the mandate for the asset manager should be sufficiently tight. The traditional mandate described in Section 6.2.1 is sufficiently tight and does not create the possibility of diverging ALM results. Any less restrictive mandate, like a Value at Risk requirement, offers the asset manager too much freedom. This freedom can affect the ALM results both negatively and positively. Either way, the possibly large deviations from the results of the pension deal are reason for concern. That is why we conclude that mandates for the asset managers should be constructed as tight as possible, in order to guarantee the ALM performance agreed upon in the pension deal.

The composition of the asset mix is not the only part of the investment policy that should be implemented strictly according to the pension deal. The duration overlay strategy is also very sensitive for deviations from the policy agreed upon. Sufficient insight in the duration of both assets and liabilities is of crucial importance to warrant the correct duration matching percentage, and with that, the ALM results agreed upon in the pension deal.

Chapter 7

Economic Scenario Generation

The models ORTEC uses to perform ALM analysis are based on scenario generation. An advanced scenario generator generates a large amount of plausible macro-economic scenarios. The scenarios are generated using a Vector Auto Regression model, or VAR model in short. A VAR model is a multivariate generalization of an Auto Regression (AR) model. In this chapter we briefly discuss the AR model and continue with the generalization to the VAR model used by ORTEC for macro-economic scenario generation.

Besides the VAR model embedded in ALS, ORTEC uses another scenario generator. This second generator is used in a different phase of pension fund risk and return management. The generator is based on drawings from a historical set of macro-economic scenarios. Both scenario generators have their own specific characteristics.

Once the mathematics and mechanics behind both models are clear we continue with a short analysis of the quality of the models. The quality of the model depends on two characteristics: the ability to capture the characteristics of the real economy, and the flexibility of the model. Examples of characteristics of the real economy are means and standard deviations of economic quantities, (cross-)correlations between quantities, and auto-correlations. An important aspect of the flexibility of the model is the possibility to include user's views on the future in the scenarios.

7.1 Auto Regression

The scenario generator of ALS is based on a Vector Auto Regression model (VAR model). A VAR model is a multivariate version of an Auto Regression model (AR model). In this section we describe the AR model. The section serves as a first step toward the description of the complicated scenario generator of ALS.

The AR model estimates a variable by regression on itself. This explains the term auto regression. An AR(p) model is an auto regression model of the order p. That is, an AR(p) model estimates a variable by regression on the previous p observations of itself. The mathematical definition of the AR(p) model is as follows:

$$x_t = c + \sum_{i=1}^{p} \phi_i x_{t-i} + \epsilon_t,$$

where $\phi_1, \ldots, \phi_p$ are the parameters of the AR(p) model, c is a constant and ϵ_t is an error term. This error term is a stochastic variable with mean 0, constant variance, and no inter-temporal correlation. A stochastic process with these characteristics is called a white noise process. Mathematically, a white noise process ϵ_t has the following characteristics.

$$\begin{aligned} \mathbb{E}[\epsilon_t] &= 0 \\ \mathbb{E}[\epsilon_t^2] &= \sigma_\epsilon^2 \\ \mathbb{E}[\epsilon_t \epsilon_{t-k}] &= 0 \quad \text{for} \quad k \neq 0 \end{aligned}$$

The parameters ϕ_i of the AR(p) model can be calculated using the Yule-Walker equations:

$$\gamma_m = \sum_{k=1}^{p} \phi_k \gamma_{m-k} + \sigma_\epsilon^2 \delta_m, \qquad m = 0, \ldots, p,$$

where $\gamma_m = \mathbb{E}[x_t x_{t-m}]$ is the autocorrelation function of x_t. δ_m is the so-called Kronecker delta function, which equals 1 if $m = 0$ and 0 otherwise. This results in $p+1$ Yule Walker equations which allow us to write the set of equations as a matrix equation for $m > 0$:

$$\begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \vdots \end{bmatrix} = \begin{bmatrix} \gamma_0 & \gamma_{-1} & \gamma_{-2} & \cdots \\ \gamma_1 & \gamma_0 & \gamma_{-1} & \cdots \\ \gamma_2 & \gamma_1 & \gamma_0 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix} \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \vdots \end{bmatrix}.$$

Note that $\gamma_k = \gamma_{-k}$. Assuming that the matrix is invertible[1], this matrix equation can be solved to obtain $\phi_1, \ldots, \phi_p$:

$$\begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \vdots \end{bmatrix} = \begin{bmatrix} \gamma_0 & \gamma_{-1} & \gamma_{-2} & \cdots \\ \gamma_1 & \gamma_0 & \gamma_{-1} & \cdots \\ \gamma_2 & \gamma_1 & \gamma_0 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}^{-1} \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \vdots \end{bmatrix}.$$

What remains is one equation for $m = 0$,

$$\gamma_0 = \sum_{k=1}^{p} \phi_k \gamma_{-k} + \sigma_\epsilon^2,$$

from which we can obtain the variance of the error term σ_ϵ^2.

7.2 Vector Auto Regression

Vector Auto Regression is exactly what it says: auto regression for a vector of variables. A VAR model can be used to model the development of a set of interdependent variables. Suppose we have a set of k variables. We collect these k variables in a $k \times 1$ vector $\mathbf{X}$. Now let $\mathbf{X}_t$ denote the status of the vector at time t. Then $x_{i,t}$ denotes the value of variable i at time t. The VAR(p) model has a lot in common with the AR(p) model as described in the previous section. In particular,

$$\mathbf{X}_t = \mathbf{c} + \sum_{i=1}^{p} \mathbf{A}_i \mathbf{X}_{t-i} + \epsilon_t,$$

where $\mathbf{c}$ is a $k \times 1$ vector of constants, $\mathbf{A}_i$ are $k \times k$ matrices ($i = 1, \ldots, p$), and ϵ is a $k \times 1$ vector of white noise error terms. Each element of the white noise vector ϵ_t has mean 0, constant variance, and there exists no inter-temporal correlation between consecutive error terms. In order to provide some additional insight into the structure of the VAR model, we write out the set of equations for a 2-variable VAR(2) model.

$$\begin{aligned} x_{1,t} &= c_1 + a_{11}^{(1)} x_{1,t-1} + a_{12}^{(1)} x_{2,t-1} + a_{11}^{(2)} x_{1,t-2} + a_{12}^{(2)} x_{2,t-2} + \epsilon_t \\ x_{2,t} &= c_2 + a_{21}^{(1)} x_{1,t-1} + a_{22}^{(1)} x_{2,t-1} + a_{21}^{(2)} x_{1,t-2} + a_{22}^{(2)} x_{2,t-2} + \epsilon_t, \end{aligned}$$

[1]This is very likely the case since almost all square matrices are invertible. That is, the set of singular $n \times n$ matrices is a null-set, i.e., has Lebesgue measure zero.

where $a_{ij}^{(k)}$ denotes the element in row i and column j of parameter matrix A_k. We see that variable $x_{1,t}$ at time t is explained in terms of two lags of itself ($x_{1,t-1}$ and $x_{1,t-2}$) and by two lags of the other variable ($x_{2,t-1}$ and $x_{2,t-2}$). In general, in an n-variable VAR(p) model, each variable i at time t is explained by p lags of itself and by p lags of each of the other $n-1$ variables in the model.

As with the AR(p) model, we can use the Yule-Walker equations to estimate each of the parameter matrices $\mathbf{A}_i$. First we define $\Gamma_i = \mathbb{E}[\mathbf{X}_t \mathbf{X}_{t-i}]$ as the cross-correlation function of $\mathbf{X}_t$. The parameter matrices $\mathbf{A}_i$ are the solutions to the following system of Yule-Walker equations:

$$\Gamma_i = \sum_{i=1}^{p} \mathbf{A}_i \Gamma_{i-1} \quad \text{for} \quad i = 1, \ldots, p;$$
$$\Gamma_0 = \mathbf{A}_1 \Gamma_{-1} + \Sigma,$$

where Σ denotes the vector of variances of the white noise error terms.

7.3 Historical scenario generation in PRISMA

PRISMA is a scenario based risk management tool used for measuring and analyzing solvency risk up to a horizon of one year. As in ALS, the analysis consists of a simulation of the pension fund into the future, given a set of plausible macroeconomic scenarios. The scenario generator of PRISMA is not based on a VAR model like the generator in ALS. Instead, PRISMA randomly draws historical economic scenarios from a database containing daily data of several risk drivers for pension funds and other institutional investors. The most important risk drivers are market indices, exchange rates, yields, and active returns. Based on these risk drivers, the user can define several measures of interest as a function of these risk drivers. For example, the return on the asset portfolio of a pension fund can be defined as a function of market index returns and foreign exchange returns.

The generation of scenarios by means of drawings from the historical database is a procedure of three subsequent steps.

1. Observations of the different risk-drivers over a user-defined period are converted to daily or weekly returns and stored in a database.

2. Each periodic return gets assigned an index number. Each risk driver in the same observation period gets assigned the same index number. Hence, each index number represents a vector containing a series of instantaneous risk driver returns.

3. A large number of random integers is drawn from a uniform distribution with size equal to the number of observations. Scenarios are constructed by placing the randomly drawn observations in a row. This results in a scenario matrix in which each row represents a scenario and each column represents a period.

PRISMA performs analysis based on monthly periods. The weekly or daily returns from the database are converted to monthly returns by means of geometric linking. That is, a vector of weekly returns r_i ($i = 1, \ldots, 4$) is linked through $(1 + r_1) \times (1 + r_2) \times (1 + r_3) \times (1 + r_4) - 1$.

The next step in the PRISMA scenario generation routine is normalization of the returns. The average and the standard deviation are suppressed using the following equation:

$$\tilde{X}(s,t) = \left(X(s,t) - \frac{1}{S} \sum_{z=1}^{S} X(z,t) \right) \times \left(\frac{1}{S-1} \sum_{k=1}^{S} \left(X(k,t) - \frac{1}{S} \sum_{z=1}^{S} X(z,t) \right)^2 \right)^{-\frac{1}{2}} \qquad \forall \quad s,t,$$

where S denotes the number of scenario's. This normalization results in return distributions with zero mean and unit standard deviation. This routine is performed to create the possibility of including user defined expectations and standard deviations for the future. This functionality will be described in further detail in Section 7.4.

7.4 Scenario generators: flexibility and reality

Both ALS and PRISMA tempt to capture the reality as good as possible when generating economic scenarios. In this section we describe the (modeling) quality of both models. That is, we identify the characteristics of the real economy that can or cannot be modeled by the different generators.

Before we judge the generators on their modeling capacity, we first address the flexibility of the models. In general, historical data does not contain all relevant information for the future return distributions. Results achieved in the past are no warrant for the future. That is why we discuss the possibility of integrating view and expectations of the future development of the market into the scenario generator.

7.4.1 User's view on the future

The scenario generators of both ALS and PRISMA give the user the opportunity to include his or her view into the generated scenarios. In this section we describe the methodologies used for the implementation of this functionality.

ALS: regimes
The scenario generator of ALS provides the user with a tool to overrule the historical averages of the past. A so-called regime represents the annual scenario average for each series. The regimes are created by means of the following simple autoregressive model:

$$regime_t = LTexpectation + \phi(regime_{t-1} - LTexpectation),$$

where $regime_0$ is equal to the last observed value in the historical data and $LTexpectation$ is the user's view on the long term average. The autoregressive parameter ϕ is a constant representing the autocorrelation of the variable. This constant should be high for inflations and interest rates (0.7 in the ORTEC economy), and low (0 in the ORTEC economy) for equity returns. The latter reflects the fact that equity returns in any given year do not depend on the returns of previous years. The simple autoregressive model causes the regimes to grow gradually toward the long term expectation.

Besides the long term expectation, the user is also able to include his or her view on the standard deviations. The volatility of returns can be increased or declined manually. The view on both expected return and volatility can be expressed using the VAR model, while maintaining all other historically observed characteristics of the series.

PRISMA: return views for simulated risk drivers
The scenario generator of PRISMA offers the functionality to enter user's views on expectations and standard deviations of risk drivers. These views are inputted as annual measures. The annual views are transformed to monthly measures. The annual view on the mean is converted to a monthly number using the inverse geometric average. That is, the monthly mean μ can be obtained from the annual view M through

$$\mu = (1 + M)^{1/12} - 1.$$

The annual view on the standard deviation Σ is converted to the monthly standard deviation σ by dividing through the square root of the number of months in a year:

$$\sigma = \frac{\Sigma}{\sqrt{12}}.$$

Recall from Section 7.3 that PRISMA generates a set of normalized return distributions $\tilde{X}(s,t)$, each having zero expectation and unit variance. On these normalized returns, views about mean μ and volatility σ can be applied using the following equation:

$$\hat{X}(s,t) = \mu + \sigma\tilde{X}(s,t) \qquad \forall \quad s,t.$$

The advantage of this procedure is that the user can express his or her view on the first and second moments of the return distributions (like mean and standard deviation), while maintaining the historical higher moments (skewness and kurtosis).

Both the VAR model of ALS and the PRISMA bootstrapping method provide the functionality of expressing the user's view on first and second moments of return distributions, while maintaining other historically observed characteristics of the distributions. Both modeling methods are flexible and do not rely solely on historical observations.

7.4.2 Correlation, auto-correlation, and cross-correlation

In the previous section we showed that both modeling approaches considered in this thesis provide sufficient flexibility to express the user's view on the future. In this section we discuss the capability of both methods to model inter-relational dependencies between risk drivers. We discuss three measures of inter-relational dependencies: correlation, auto-correlation, and cross-correlation. Correlation describes the strength and direction of the dependency between simultaneous observations of two random variables. Auto-correlation indicates the strength of the dependency between an observation of a random variable and the previous observations of that same variable. A second order auto-correlation describes the dependency between the current observation and the observation two periods ago. Cross-correlation also describes the relation to previous observations. However, instead of previous observations of the variable itself, cross-correlation describes the relation to previous observations of other variables.

The VAR model of ALS
The VAR model captures all correlation types by definition. That is, if the model is used with a dimension greater than 1. A VAR(p) model estimates a variable based on p predecessors of itself and of the other variables in the model. This automatically warrants all correlation structures mentioned in this section.

PRISMA
The scenario generator of PRISMA is based on drawings from a historical database. Each draw is associated with a vector of instantaneous returns of all risk drivers. That is, each draw consists of a set of observations of returns that actually occurred simultaneously somewhere in the past. This methodology makes sure that inter-relational dependencies between risk drivers is maintained in the generated scenarios. Hence, the PRISMA scenario generator captures the historically observed correlations between risk drivers.

The PRISMA scenario generator does not capture auto-correlation and cross-correlation. A generated scenario consists of a randomly drawn event. Each event describes a vector of instantaneous returns. Since each event is drawn at random, subsequent events are not related to each other. The composition of an event does not depend on any of the event's predecessors.

The VAR model of ALS captures all imaginable correlation structures. The PRISMA bootstrapping method is only capable of capturing the correlations between risk drivers. Subsequent events in a generated scenario of PRISMA are not interrelated and do not reflect any cross- or auto-correlation structure.

7.5 Difficulties of scenario generation

In the previous sections we showed that especially the VAR model of ALS provides us with an accurate, realistic and flexible model for generating economic scenarios. Unfortunately the VAR model has some drawbacks. In this section we describe several issues that arise when we utilize the VAR model. For each shortcoming we also present one or more possible solutions that are actually applied in the field.

7.5.1 Negative inflations and interest rates

If the VAR model is directly applied to variables like interest rates or inflations, the generated scenarios will contain many negative values for these variables. In Figure 7.1 we see 500 generated scenarios of the price inflation in The Netherlands. Indeed, we observe a great amount of scenarios dropping below the threshold of 0% inflation. In fact, the probability of a negative inflation rate in any given year is approximately 6.5%. In real life, we hardly ever observe negative inflation rates. In ALS we can manipulate the inflation scenarios in two ways. The first option is to put a minimum on the value of the price inflation. This procedure cuts of all scenarios at zero. Result is that negative inflation does no longer occur. However, the scenario set will contain many scenarios in which the inflation rate is exactly 0. This is undesirable as well.

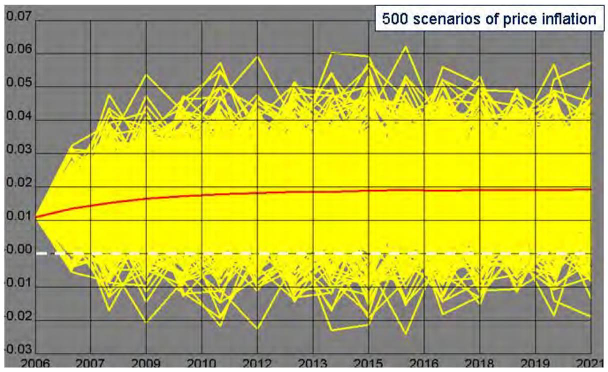

Figure 7.1: The VAR model directly applied to inflation

A more elegant method to prevent negative inflation rates is a log transformation. Instead of modeling the random variable X for the inflation rate, we can model a new random variable $Y = \ln(X)$. The resulting scenarios of $Z = e^Y$ will never become negative. However, this log transformation has another undesirable side-effect. Scenarios will not even get close to 0, whereas negative inflation might occur every now and then in reality. Moreover, the scenarios resulting from the transformation contain many high peaks, with inflation rates up to over 12%. To prevent this fom happening, we choose to apply a transformation of the form $Y = \ln(a + X)$. The resulting scenarios of $Z = e^Y - a$ have a lower boundary at $-a$. In search of a suitable value of a, resulting in an acceptable amount of negative inflation scenarios and high peaks, the ORTEC scenario set is initiated with $a = 0.05$. In Figure 7.2 we see the results of the three transformation procedures.

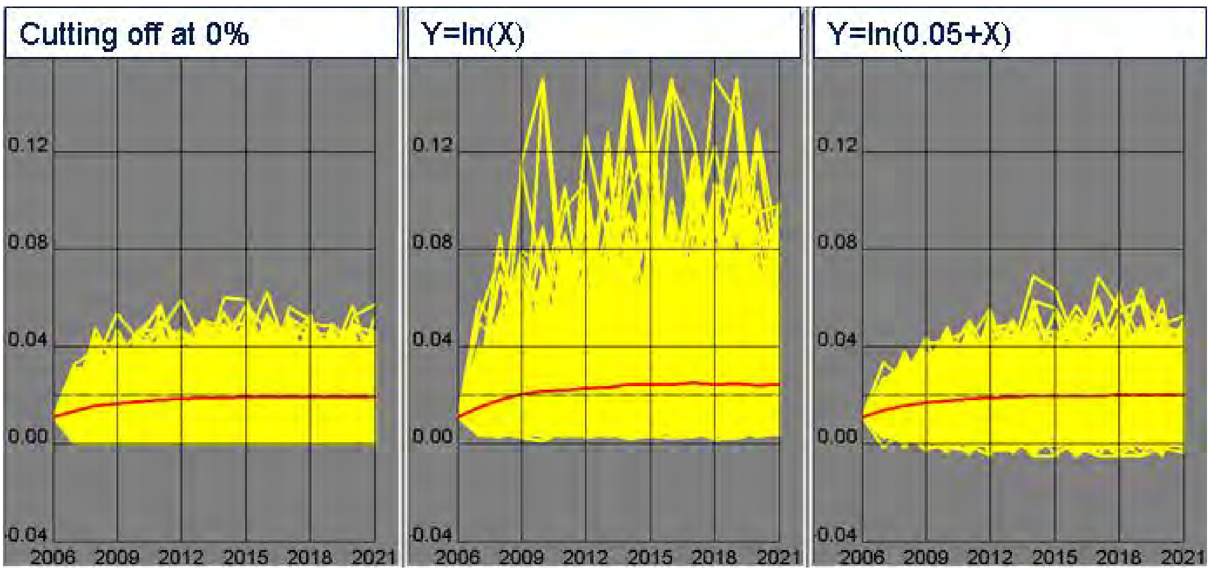

Figure 7.2: Transformations to obtain realistic scenarios

The result of the adjusted log transformation, displayed in the figure on the right hand side, leads to the most realistic scenarios. In the ORTEC scenario set the adjusted log transformation is applied to inflations and short interest rates.

7.5.2 Overfitting

An undesirable side-effect of the VAR model of ALS is a phenomenon referred to as over fitting. Over fitting occurs in a VAR model if the number of variables is too large relative to the number of historical observations. As the number of explanatory variables increases, the uncertainty of predictions becomes smaller. The result is that the variables are hardly volatile in the first years of the simulation. This phenomenon can be explained mathematically. Recall the multivariate VAR model:

$$\mathbf{X}_t = \mathbf{c} + \sum_{i=1}^{p} \mathbf{A}_i \mathbf{X}_{t-i} + \epsilon_t.$$

Remember that ϵ_t denotes the vector of error terms. The error terms are $N(0, \Sigma)$ distributed. Now, if the number of explanatory variables becomes large, there will be hardly any error. It will appear if the variables in $\mathbf{X}_t$ can be fully explained by $\sum_{i=1}^{p} \mathbf{A}_i \mathbf{X}_{t-i}$. In that case the volatility Σ of the error terms becomes very small. With that, the variance of the realization of $\mathbf{X}_{t+1}$ given the realization of $\mathbf{X}_t$ will be small. Mathematically: $Var(\mathbf{X}_{t+1}|X_t)$ will be small.

The solution to the problem of over fitting is what we call the "restricted Yule-Walker" estimation method. When estimating the VAR model, we restrict the number of explanatory variables for each series. With this methodology we create blocks of Yule-Walker estimations. For example, all US series in the model are regressed solely on predecessors of other US series. Hence, the economic model contains a US block of Yule-Walker estimations. The result of the restricted Yule-Walker estimation method is visible in Figure 7.3.

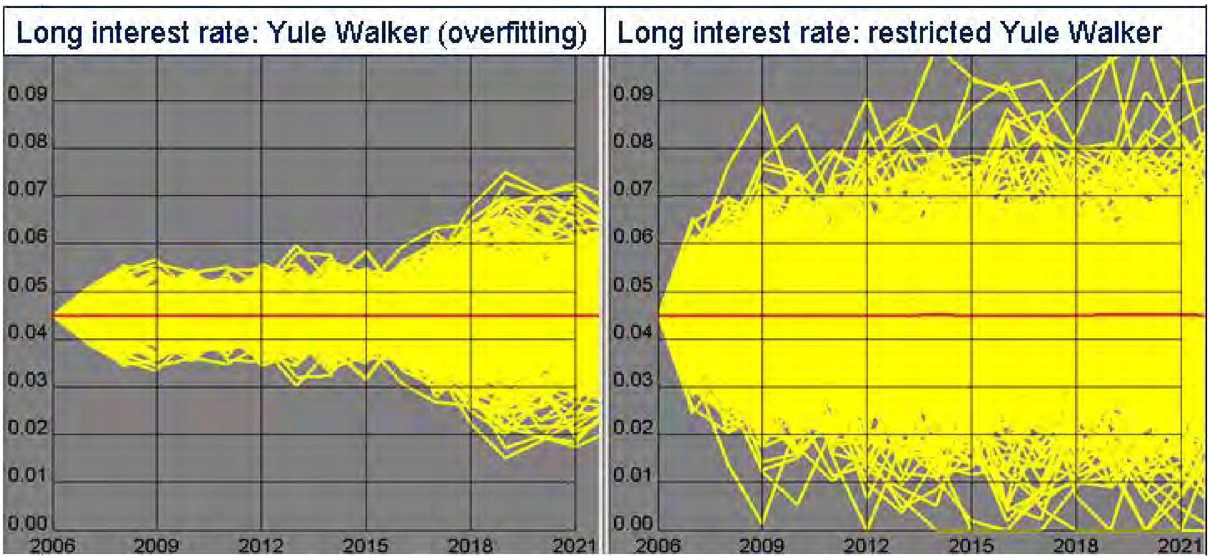

Figure 7.3: The impact of the restricted Yule-Walker estimation method on long interest rate scenarios

7.6 Conclusions about economic scenario generators

Both the VAR model and PRISMA are flexible and provide opportunities to include the user's view on the future. The VAR model is capable of modeling more characteristics of the real economy than the PRISMA generator. The VAR model captures auto-correlations and cross-correlations. The PRISMA generator does not. Problems arising when using the VAR model, like over fitting and high probabilities of negative values, can be solved or dodged using smart techniques.

The advantage of PRISMA is the fact that it is very suitable for short-term analysis. The model can estimate scenarios based on weekly or monthly data, whereas the VAR model of ALS is based on annual data.

The main conclusion is that the scenario generators discussed in this chapter are very sophisticated and form a great contribution to well-founded pension fund risk and return management.

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List of Figures

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Appendix A

Development participants file

Mortality: table of the Dutch association of Actuaries (AG). Entire population Male/Female 1995-2000 with an age correction of 1 year for men and 2 years for women;

Marriage frequencies: Every individual is assumed to be married until the pensionable age of 65;

Probability of disability:

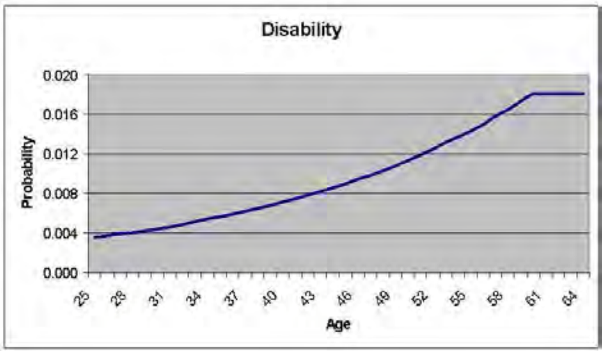

Figure A.1: Probability of disability

Probability of resignation:

Figure A.2: Probability of resignation

Company growth: The number of full time equivalents is assumed to be constant in time;

Age and gender new employees:; New participants enter the plan at an age of 25 or older. The average age of new participants is 33 for men and 27 for women. 60% of the new participants is male. 40% is female;

Transfer of pension rights: Departing participants do not transfer their accrued benefits to a new pension fund. No value transfer;

career: All participants make career according to one single career line:

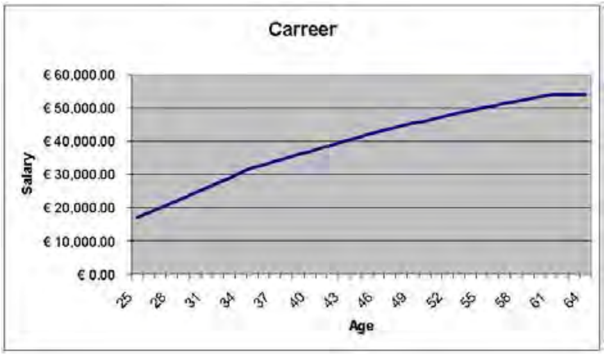

Figure A.3: Career line of all participants

Appendix B

ECF for Hollandia young and mature

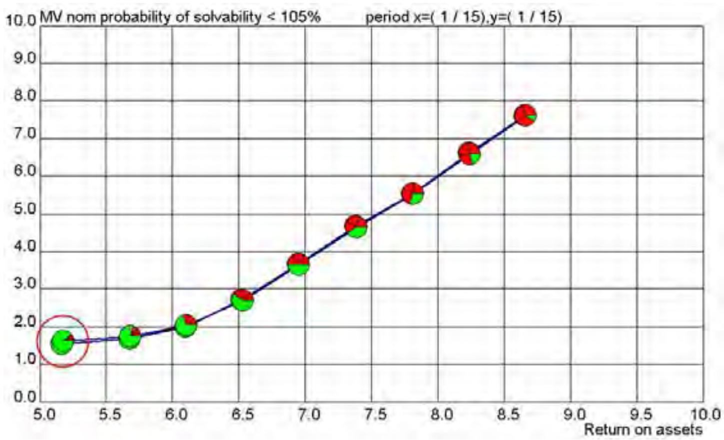

Figure B.1: The mature Hollandia fund estimated by ECF

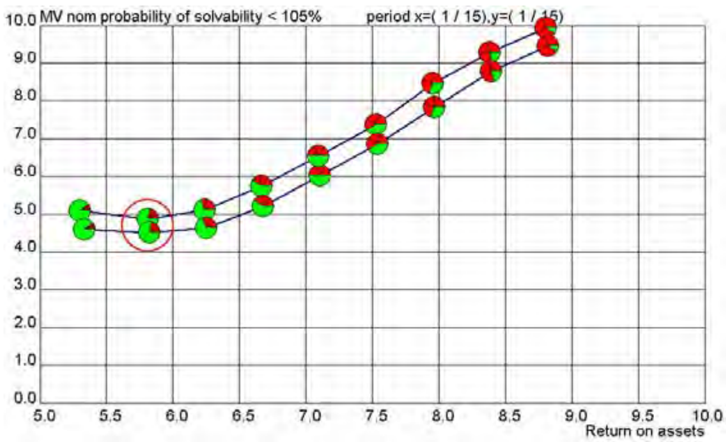

Figure B.2: The young Hollandia fund estimated by ECF

Appendix C

Assumptions asset categories

Asset category	$\mathbb{E}(r)$	σ
Bond EUR	4.61%	4.82%
EMM Bond	6.82%	16.01%
Equity EUR	8.25%	21.64%
Equity US	7.80%	16.37%
Equity Japan	8.50%	23.04%
Equity EMM	11.04%	31.68%
Indirect real estate EUR	7.51%	19.19%
Direct real estate	7.00%	8.73%
Hedge funds FoF	6.55%	8.75%
Commodities	6.57%	23.77%
Private Equity Venture Capital EUR	9.74%	36.70%
Private Equity Buy Outs Europa	8.25%	19.02%
Cash	3.73%	2.03%
High Yield	6.89%	12.46%
Infrastructure	8.10%	18.52%
Index Linked Bond	4.36%	4.54%
Bond USD	4.32%	7.36%

Table C.1: Assumptions asset categories Markowitz optimization model