The comparison of different implementations of the holistic balance sheet for pension funds

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Contents

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Management summary

In 2003 the IORP Directive was introduced, in which the occupational pensions in Europe are regulated. In order to obtain a more harmonized framework of quantitative requirements for European pension funds, the European Commission asked EIOPA to revise the IORP Directive.
Pension systems across Europe differ significantly, since a variety of policy instruments is available. In order to take into account the differences in pension systems, a holistic balance sheet is proposed by EIOPA. A holistic balance sheet is an extension of the traditional balance sheet, since next to the usual assets and liabilities, conditional assets and liabilities are stated on it. These conditional assets and liabilities are the economic value of the various policy instruments, which can be valued as embedded options with the help of derivative pricing techniques. The holistic balance sheet framework enables regulators to compare various pension systems across Europe in one framework.

We use an own ALM model to value the embedded options on the holistic balance sheet. Within this ALM model a risk model (economic scenario generator) is used which includes both stochastic jumps and a time-varying covariance matrix for normally distributed shocks. This risk model provides both real world and risk neutral scenarios. In order to compose the holistic balance sheet, risk neutral valuation is used to value the embedded options on the holistic balance sheet.

A pension fund can have various policies, where the fund can make use of various policy instruments. Therefore, each policy, or pension contract, will result in an alternative holistic balance sheet, as each policy instrument can be valued as an embedded option. It turns out that adding an additional policy instrument to the existing policy has a significant effect on all the embedded option values stated on the holistic balance sheet, since introducing an additional instrument changes how risks and rewards are allocated within the pension fund and therefore changes the value of the policy instruments valued as embedded options.

This thesis aims to provide the pension industry insights into the valuation of the holistic balance sheet and the effects of implementing it. This thesis comes up with three concrete proposals to improve the proposed holistic balance sheet framework: an open fund framework instead of a closed one, a dynamic solvency measure instead of a static one, and a prescription regarding the risk model to be used in the valuation of the holistic balance sheet.

EIOPA only proposes to value the holistic balance sheet in ABO terms, where it is assumed that the pension fund is fictitiously closed at the time the holistic balance sheet is set up. A reason for this approach could be that in this way fewer possibilities for differences in subjective interpretations are possible. However, it is more fruitful to consider a PBO framework, where the pension fund remains open for new participants during the horizon considered, new benefits are accrued, and contributions are paid, since such an approach is more in line with reality.

EIOPA proposes to value the options on the holistic balance sheet as if the fund is fictitiously closed at time zero. Additionally, EIOPA proposes a solvency measure which takes into account the embedded options stated on the holistic balance sheet. However, EIOPA does not properly clarify the required level the pension fund should have in order to be solvent, where this required level turns out to be too high for two reasons. First of all, EIOPA does not yet take into account the fact that the options on the holistic balance sheet already

are a hedge for certain risks. Secondly, EIOPA does not yet take into account the closed fund aspect.
In this thesis, a new solvency measure is introduced called the dynamic measure, which does take into account the closed fund aspect, since the required level decreases over time, as a consequence of the decreasing duration of the liabilities. Hence, the dynamic measure does take into account the horizon considered.
In general, it turns out that the policies which are less redistributive are considered insolvent by the EIOPA measure, while the same policies are solvent according to the dynamic measure.

With the holistic balance sheet, also generational effects can be shown, as different embedded options can be assigned to specific cohorts. However, these generational effects are not representative in case of the closed fund framework, as the residue is not divided among all cohorts within the fund. Hence, in case an open fund framework would be considered, i.e. a fund where new participants enter the fund after time zero, where contributions are paid, and where new benefits are accrued, the generational effects are more in line with reality. Therefore, also the holistic balance sheet in the open fund framework is set up.

The holistic balance sheet in the open fund framework differs from the holistic balance sheet in the closed fund framework in several ways. First of all, two additional aspects are stated on the open holistic balance sheet, namely the contributions paid and the new benefits accrued. In general, all the embedded options become worth more, as more participants are present in the fund. Both solvency measures can be used in the open fund framework, where the EIOPA solvency measure is slightly adjusted in this thesis. However, still the EIOPA measure does not yet overcome the fact that it does not take into account that the option values itself are already a certain hedge.
It turns out that in the open fund framework, both solvency measures give the same outcome for the alternative cases considered in this thesis, except for the cases where the initial funding position is extremely low, where the horizon is extended, and where a more friendly policy ladder is chosen. In those exceptions the EIOPA solvency measure does consider the pension funds insolvent, while the dynamic measure indicates that the funds are solvent.

Summing up, the proposal of EIOPA to introduce the holistic balance sheet is very useful, however, it needs improvements. First of all, the holistic balance sheet should be valued in an open fund framework instead of a closed fund framework, in order to provide the financial position of the pension fund which is more in line with reality. In this case, the holistic balance sheet can also be used as a continuity analysis, as a tool for policy development, and as a tool to give insights into generational effects.
Furthermore, the solvency measure as proposed by EIOPA is a threat for Dutch pension funds, since the required level is too high. Therefore, an alternative solvency measure that should be used is the dynamic solvency measure, which takes into account the solvency capital requirement set by the regulator. The dynamic solvency measure does consider the policies that are less redistributive to be solvent, while the EIOPA solvency measure does consider those policies to be insolvent.
Additionally, we propose to impose a risk model, since the holistic balance sheet is significantly dependent on the risk model used.
Finally, in order for trustees to treat the interest of all stakeholders equally, also utility valuation should be used next to market valuation. Here one should wonder how far the regulator should intervene to decide which policy is in favor of the participants within the fund, since it might turn out that participants are not pleased with the imposed solvency capital requirement.

1 Introduction

The European Commission (EC) is going to revise the IORP Directive in order to introduce a harmonized framework of quantitative requirements for European pension funds. In order to take all the differences of pension systems into account, a so-called 'holistic balance sheet approach' is proposed. This approach is a new way of pension supervision. European pension organizations are concerned that this new way of supervision is very complex and could lead to additional funding requirements which might hamper the pension benefits of European retirees[1]. In this study, the impact of the holistic balance sheet approach on Dutch pension funds is analyzed and alternative holistic balance sheet methods are proposed.

In Europe the occupational pensions are regulated in the Institution for Occupational Retirement Provision (IORP) Directive which was introduced in 2003. The objective of the IORP Directive is to provide a framework for occupational pension funds across Europe. The current IORP Directive provides national Member States a lot of freedom of determining the national quantitative requirements for pension funds. In the Netherlands, the requirements of the IORP Directive are embedded in the FTK regulation.

In April 2011 the European Commission asked the European Insurance and Occupational Pensions Authority (EIOPA) for advice on a revision of the IORP Directive. The European Commission gave several reasons to revise the current directive:

- Expanding the scope of the IORP Directive, since after the introduction of the first directive in 2003 several new European countries have joined IORP, which use pension systems that are not covered within this framework;
- Focusing on the cross border aspects for pension funds, in order to enable pension funds to manage their pension schemes of employees in different IORP member states;
- Attention for defined contribution schemes, as more countries move from defined benefit schemes to defined contribution schemes;
- Improving governance and risk management, as many pension funds became underfunded due to the financial crisis;
- Introducing risk-oriented supervision, where qualitative, quantitative, and transparency requirements should be included and possibly also a uniform security margin.

In February 2012, EIOPA gave the European Commission an extensive advice on the revision of the IORP Directive, both on qualitative and quantitative requirements. The quantitative requirements proposed by EIOPA are often based on the already existing Solvency II framework (European insurance legislation). However, it should be noted that pension funds are not precisely comparable to insurance companies. From a governance perspective pension funds are other kind of institutions. Furthermore, pension funds have the ability to use risk-mitigating instruments such as steering mechanisms (e.g. higher contributions, additional sponsor support) and adjustment mechanisms (e.g. conditional indexation, cutting benefits) in order to adjust the financial position of the fund. According to EIOPA all these unique characteristics of pension funds should be incorporated in the revised IORP Directive.

As pension systems and their steering and adjustment instruments differ significantly across Europe, it is hard to compare different pension funds of different member states of IORP. In

[1] EFRP response - EC Call for Advice to EIOPA on the Review of the IORP Directive - Consultation 2

order to obtain more harmonization across Europe, EIOPA proposes a harmonization of all the valuation rules across Europe and a so called holistic balance sheet, in order to be able to take into account all the different policy instruments of pension funds across Europe. In addition, this holistic balance sheet provides the opportunity to have a prudential framework which is based on Solvency II, but is tailor-made for IORP pension funds.
Such a balance sheet is an extension of a traditional balance sheet, as next to the usual assets and liabilities also immaterial and conditional assets and liabilities are stated. The values of these conditional assets and liabilities are conditional on the regulation of the pension system and will therefore result in different values across countries in Europe.
Hence, the holistic balance sheet gives a more complete picture of the financial position of a pension fund than the traditional balance sheet. For instance, consider two different pension funds with the same traditional balance sheet at one moment in time, and thus the same funding ratio. Suppose pension fund 1 has a policy in which the participants get conditional indexation, while pension fund 2 has the additional right to cut the benefits of the participants if the funding ratio becomes extremely low. As can be concluded from this example, the actual financial position of pension fund 2 is much better than that of pension fund 1. The funding ratio of the holistic balance sheet takes these policy instruments into account and gives thus a better representation of the financial position of the pension fund.

In its advice to the European Commission, EIOPA said that its advice is conditional on the outcomes of Quantitative Impact Studies. These studies will be performed in Q4 2012. The European Commission is willing to come up with an official proposal for an new IORP Directive before the summer of 2013. Hence, a lot of future rules are still not clear of which the impact will be investigated, where this thesis contributes to this impact study.

Several European pension systems are explained in Section 1.1 to show that different countries use different policy instruments. In Section 1.2 the differences between the FTK Regulation as it is known in the Netherlands and the revised IORP Directive are explained. Finally, in Section 1.3 a description of the research in this thesis is given, where the structure of this thesis is set out.

1.1 Pension systems in Europe

Pension systems differ significantly across Europe, as stated by OECD (2011) which presents different pension systems in 2008 across OECD countries. Most pension systems are divided into three pillars of which the first two pillars are mandatory. The first pillar is public and provides people mostly a social minimum standard way of living. It can also be the case in some countries that the first pillar provides people with an income which is a certain minimum plus an earnings related aspect. The second pillar can be either public or private and is related to occupational aspects. Finally, the third pillar is voluntary and consists of individual savings for retirement. As already mentioned, the occupational pension systems, which are in the second pillar, are regulated in the IORP Directive. Therefore, the focus lies on the second pillar of several European countries in the remainder of this section.

The second pillar of the Dutch pension system is quasi-mandatory, as several industries have asked permission for a mandatory industry pension fund. A consequence of this question is that approximately 90 percent of all employees in the Netherlands are covered within a mandatory scheme, i.e. there exists a near-universal coverage scheme. Roughly 90 percent of all pension funds in the Netherlands are covered by a private defined benefit scheme, while the remaining pension funds are covered by a private defined contribution scheme.

The accrual rate, i.e. the rate at which a worker earns benefit entitlements for each year of coverage, varies between occupational schemes in the Netherlands. Before 2005, pension fund benefits were based on the final wage scheme. From that point on, the transition was made into the direction of the average wage scheme, which is at the moment the dominant type. Furthermore, indexation given on benefits depends both on the average earnings and on the funding ratio of the pension fund in most funds. Besides that, no ceiling is set on the earnings of Dutch employees used to determine the contributions and pension benefits.

The second pillar of the pension system in the United Kingdom is a mandatory public defined benefit scheme. The accrual rate workers receive depends on their earnings, as workers with low wages get the highest accrual rates. In case of reaching a certain low earnings threshold, the accrual rate decreases, while in case of the earnings being in between a higher threshold and a ceiling, the accrual rate increases again. So, in the United Kingdom exists a ceiling, which is set equal to 119 percent of the average earnings. Again, the pension benefits are determined as a lifetime average. Furthermore, indexation is given according to inflation on prices. Besides that, a so called British Pension Protection Fund exists. In case the sponsor of the pension fund goes bankrupt and on top of that the assets in the fund are insufficient to cover the pension benefits, the British Pension Protection Fund provides compensation such that members do not get harmed by such an event.

Focusing on the German pension system (Watson Wyatt insider, 2009), occupational pensions differ over Germany, as defined benefit plans, defined contribution plans, and hybrid types are available. The defined benefit plans are the most common, where both final-average and flat-rate types are present. The plan design is strongly influenced by the funding vehicle chosen by the employer. Book reserves are the most common funding vehicle in Germany, where internal company assets are delineated for the pension plan and placed on the balance sheet. The second most common funding vehicle is the pensionskasse, where external funding is conservatively invested. The pensionskasse is comparable to life insurance, however, only employees, former employees and their dependents can become a member of this pension plan. Finally, Germany also knows a kind of Pension Protection Fund as is known in the United Kingdom.

In Switzerland, the second pillar consists of both a public defined benefit scheme and a private defined benefit scheme. The accrual rate varies with earnings and age; where the pattern is progressive with respect to earnings and increasing with respect to age. As before, a lifetime average is used to determine pension benefits. Besides that, the indexation given on benefits depends on a combination of price inflation and wage growth, which are both taken into account for 50 percent. Both the public and the private defined benefit scheme have a ceiling on the pensionable earnings equal to 106 percent of the average earnings.

A combination of a public defined benefit scheme and a pension points system exists in the second pillar of France, which are both PAYG funded. In a pension points system, workers earn pension points based on their individual earnings for each year they pay contributions. At retirement the total sum of pension points is multiplied by a pension-point value, such that the points are converted into pension payments. In this system, the accrual rate also depends on earnings; the difference is that higher rates are earned on the contributions paid above the ceiling. This is introduced to neutralize the redistribution in the public system. The ceiling of the public defined benefit scheme is set equal to 99 percent and the ceiling of the private points system is set equal to 298 percent of the average earnings (OECD, 2009). The pension benefits are determined as an average of the 25 best years. Additionally, indexation given on benefits depends on inflation on prices in France.

Furthermore, in Sweden a combination of a public notional accounts scheme and a private defined contribution scheme exists in the second pillar. In a notional accounts scheme, the contributions of each worker are recorded on an individual account on which a rate of return is applied. At retirement, the amount of capital on the accounts is converted into an annuity which is based on the life expectancy. Just as in France, the accrual rate is higher for contributions above the ceiling. The ceiling is set equal to 110 percent of the average earnings in this system. As before, a lifetime average is used to determine pension benefits. Besides that, indexation is also related to prices. The contribution rate of the defined contribution scheme is set equal to 2.5 percent. Moreover, for a large quasi-mandatory scheme, the contribution rate differs; the rate is equal to 4.5 percent up to an earnings threshold, while above this threshold the contribution rate equals 30 percent.

Additionally, in Ireland the public pension is a basic scheme paying a flat rate to all who meet the contribution conditions, where the maximum values are 28.9 percent of average earnings. A means-tested pension exists in order to provide a safety net for the low-income elderly, where the benefit of a single person is worth 27 percent of average earnings. Finally, voluntary occupational pension schemes exist in Ireland, which are assumed to be defined contribution schemes with a contribution rate of 10 percent. These voluntary occupational pension schemes have broad coverage, namely over half of the employees.

As can be seen, pension systems differ a lot across European countries. All these differences within systems have an effect on the funding ratio of pension funds. Furthermore, conditional assets and liabilities will have different values across the systems mentioned, as contributions paid and real benefits received are determined in various ways. Additionally, retirement ages are not the same for all European countries and on top of that different survival probabilities are used by different pension funds. All these results have an effect that are affecting the funding ratio. Due to these differences, the financial position of different pension funds (with different systems) will become clear with the help of the holistic balance sheet.

1.2 FTK Regulation vs. revised IORP Directive

The proposed new rules in the revised IORP Directive differ with already existing rules in the pension industry. As in this thesis the focus lies on pension funds within the Netherlands, only the differences of the revised IORP Directive with respect to the regulation in the Dutch pension industry are emphasized.
Between the FTK Regulation as known now in the Netherlands and the revised IORP Directive are three main differences. First of all, a holistic balance sheet is used, which is a more complete balance sheet than pension funds are used to. Second of all, the solvency capital requirement might be determined with a different certainty level. And finally, the liabilities are valued differently.

1.2.1 Holistic Balance Sheet

In addition to the usual, unconditional assets and liabilities, as they are stated on the traditional balance sheet, other conditional assets and liabilities are added on the holistic balance sheet, called embedded options. These are options on different kind of policy instruments a pension fund can use. A distinction can be made between two kinds of policy instruments, namely steering instruments and adjustment instruments, which leads to two kinds of options

(i.e. steering options and adjustment options).
Within the steering options, one can consider two different kind of options a pension fund can have, namely the sponsor support and the pension protection fund option. Within the adjustment options, one can make a distinction between positive adjustments and negative adjustments.

Steering options:

- The sponsor support is equal to zero in case no sponsor pays the pension fund, and will have a positive value in case a sponsor guarantees to pay a certain amount to a pension fund depending on the financial position of the fund. The sponsor support is stated on the asset side of the holistic balance sheet. Such a sponsor can either be someone outside the pension fund itself, think of an employer, or it can be the total group of working participants within the pension fund. Therefore, there are two main examples of the sponsor support, namely the employer guarantee option and the employee contribution option;
- The pension protection fund option does not play a role in most countries. However, as explained in Section 1.1, a pension protection fund exists in the United Kingdom and in Germany. This option is stated on the asset side of the holistic balance sheet.

Adjustment options:

- Positive adjustment mechanism is equal to zero in case no indexation would be given at all and increases in value as more positive indexation is given in addition to the benefits. The value of this option is stated on the liability side of the holistic balance sheet, as the pension fund pays the indexation to its members. An example of a positive adjustment mechanism is the indexation option;
- Negative adjustment mechanism is equal to zero in case the pension members just receive their accrued benefits. However, in case the funding ratio will become extremely low, the benefits will be cut in certain policies. In such policies, the negative adjustment mechanism will have a negative value, which is stated on the liability side of the holistic balance sheet. An example of a negative adjustment mechanism is the sustainability cut option.

1.2.2 Solvency Capital Requirement

Within the FTK regulation, pension funds should have a buffer such that the probability of underfunding in the next period will be smaller than 2.5%, i.e.:

$$\mathbb{P}[FR_{t+1} < 100\%] < 2.5\%,$$

where $\mathbb{P}$ stands for the real probability measure and where $FR_{t+1} = \frac{A_{t+1}}{L_{t+1}}$ is the funding ratio at time $t + 1$. Here A_{t+1} and L_{t+1} are the assets and liabilities of the pension fund at time $t + 1$ respectively.
The standard approach to determine this required buffer is done with the so called 'square root formula', which is further explained in Appendix A. The result is that a pension fund should hold a required funding ratio equal to $FR^{req} = 1 + S$, where S is given in (20).

However, in the proposed new IORP Directive, the solvency capital requirement of the pension fund might be determined at a different certainty level:

$$\mathbb{P}[FR_{t+1} < 100\%] < c\%. \tag{1}$$

The certainty with which (1) should be determined is still open and should be either determined with a certainty level of 95%, 97.5%, or 99.5%, i.e. c should be equal to 5, 2.5, or 0.5 respectively. Since this certainty level is still not set, in the remainder of this thesis the focus lies at the 97.5% certainty level.

1.2.3 Valuation method

The third main difference between the FTK regulation and the revised IORP Directive is the way in which liabilities are valued. In both regulations the valuation is based on the risk free term structure. In the FTK regulation, the swap curve is used as if it were the risk free term structure. Due to the fact that in the swap curve some credit risk is included, this results in a slightly higher term structure than the actual risk free term structure. However, in the proposed new IORP Directive, it is really stressed that the risk free term structure should be used. Therefore, EIOPA advices to lower the swap curve with 10 basis points, in order to adjust for the credit risk.
Furthermore, the term structure is stabilized in the long run according to the ultimate forward rate method, which is further explained in Appendix B. This results in either a higher term structure in the long run in case the current interest rate is low or a lower term structure in the long run in case the current interest rate is high.
Finally, an illiquidity premium might be added in times where the interest rate market is less liquid, which causes the term structure to increase. Note that this premium is most of the time equal to zero, and only gets a positive value in case of stressful financial markets.
Besides that, the value of the liabilities is increased by an extra risk margin of a fixed percentage point.

However, there are two reasons that this new valuation method will not be used in the remainder of this thesis. First of all, as the valuation method is still uncertain and under investigation, it is not clear yet which exact parameters will be used in the revised IORP Directive. Secondly, due to a different valuation method, the liabilities and the adjustment mechanism on the holistic balance sheet will not be valued market consistently, as is pointed out later on.

1.3 Research description

The proposed holistic balance sheet approach is a new method of financial supervision. In this study the impact on the balance sheet of a pension fund is analyzed for different kind of pension policies of a pension fund. Furthermore, the generational effects of those different pension policy options are presented. This is an important issue, since it is the main task for the trustees of a pension fund to treat the interests of all different stakeholders (retirees, older participants and younger participants) in an equal way.
In addition to the proposed method of implementing the holistic balance sheet, different methods are analyzed. First the effects of a 'dynamic holistic balance sheet' will be presented, which is a new approach in setting up a holistic balance sheet. In addition, also the effect of taking future pension accrual ('Projected Benefit Obligation method') is shown.

In setting up the holistic balance sheet framework, several aspects are investigated.
First of all, it is shown how a holistic balance sheet is set up. As explained before, conditional assets and liabilities are stated on the holistic balance sheet next to the usual assets and liabilities that are stated on the traditional balance sheet.
It is explained how the sponsor support and adjustment mechanism are valued as embedded options on the holistic balance sheet, where risk neutral valuation is used. Furthermore, it

is investigated what the effects of different policies are on those option values.

EIOPA gave the advice to the European Commission to value the different options on the holistic balance sheet in accumulated benefit obligation (ABO) terms. Hence, the advice is to fictitiously close the fund at the moment the options are valued, while in reality the pension fund will remain open for new participants.
The effect of this assumption is that the options are valued as if no new benefits will be accrued and as if no contributions will be paid by the participants that are already in the fund at the moment the holistic balance sheet is composed. As is pointed out later on, this assumption has a great influence on the magnitude of the different option values.
A reason that EIOPA advices to fictitiously close the fund at time zero could be that with this approach the trustees of a pension fund have fewer possibilities for differences in subjective interpretations in order to value the options on the holistic balance sheet and its resulting holistic funding ratio. In case of considering an open fund, the fund can make its own projections on the evolution of the fund, where those projections can easily be adjusted in order to manipulate the regulator to be able to prove to the regulator that the fund is solvent.
However, considering an open fund instead of a fictitiously closed fund will result in the fact that the holistic balance sheet gives a more reasonable picture of the actual financial position of the fund, as it is stated in projected benefit obligation (PBO) terms instead and can therefore be used to see whether the fund is sustainable.

The holistic balance sheet can also be implemented as a solvency measure. For the fictitiously closed fund framework EIOPA proposes a solvency measure with the help of the options on the holistic balance sheet to test whether the fund is solvent. Here the solvency capital requirement S plays an important role.
Besides the solvency measure of EIOPA, a new solvency measure is proposed in this thesis which can easily be used for both the fictitiously closed fund and for the open fund framework. This solvency measure is called the dynamic solvency measure.
Both solvency measures are compared with each other, where it is emphasized that the outcomes of the solvency tests have to be in line with the expectations the participants have of the fund. Therefore, also a generational study is done.

As is pointed out later on, this generational study does not make much sense in the closed fund framework. The reason for this consequence is that the fund will be fictitiously closed, hence the policy the fund has is not adjusted to the fact that the fund is closed. Therefore it is nowhere stated to whom the residue of the pension fund belongs, which gives the wrong picture in the generational effects.
Hence, the generational effects that are shown make only sense in the open fund framework, where the residue does not belong to a specific group of cohorts as the residue is needed as a buffer for shocks that might occur in the financial market.

In Section 2 it is explained how the options on the holistic balance sheet are valued, where also the structure of the pension fund itself is set out. In Section 3 it is investigated what the effect of different policies is on the different option values for a closed fund. The two solvency measures are introduced in Section 4, where it still is assumed that the fund is fictitiously closed. In Section 5 the fund is considered open, where it is investigated what the effects of an open fund are with respect to a closed fund. For both the closed and open fund framework a generational study is done. Finally, in Section 6 a conclusion is given.

2 Holistic balance sheet

In this section the holistic balance sheet is set up. First, related literature is described in Section 2.1. In Section 2.2 the model is introduced, which is used to value the embedded options on the holistic balance sheet. In Section 2.3 the differences of the traditional balance sheet and the holistic balance sheet are presented, whereafter the valuation of the embedded options is explained.

2.1 Related literature

The holistic balance sheet is a completely new definition that is introduced by EIOPA in the revision of the IORP Directive. It is a balance sheet that gives a better view of the actual financial position of a pension fund, which takes into account the different steering and adjustment instruments a pension fund has as it values these instruments as embedded options on the holistic balance sheet.
Kocken (2006) applies techniques from risk management and option theory to value embedded options and their hedging strategies in pension funds. The main conclusion is that properly constructed hedging strategies can add substantial value to pension funds, where both interest rate hedging strategies and option based equity hedging strategies can be applied. In case of options strategies, the pension fund characteristics are extremely important, as different characteristics require different strategies, where the policy of the fund, the maturity of its participants, and the indexation policy play an important role.
Kortleve and Ponds (2006) introduced a similar idea as the holistic balance sheet where they call it the balance sheet in economic value terms. This balance sheet is set out in a PBO framework, where the contribution option and indexation option are valued as embedded options on the balance sheet in economic value terms. In order to do so, value-based ALM is used, where the future outcomes of the ALM model are discounted back to time zero with appropriate discount factors, called deflators. They emphasized that it can be seen that a pension fund is a zero sum game in value terms, as the balance sheet in economic value terms is balanced. The main differences between the approach Kortleve and Ponds (2006) use with respect to the approach in this thesis are that in this thesis the future outcomes of the ALM model are valued to time zero with risk neutral valuation instead of with the deflator approach. Furthermore, the holistic balance sheet will be set out in both a ABO framework and a PBO framework. Additionally, the different options will be set out in separated segments in order to give more insights.

Besides the valuing of embedded options on the holistic balance sheet, these options can be divided among different generations to give insight into the different generational effects. Hoevenaars and Ponds (2008) compare different pension plans in terms of generational accounts, where the generational account option can be divided into two embedded options, namely the net benefit option and the residue option. To value the future outcomes to time zero, appropriate discount factors are used. They show that value-based generational accounting is useful to control for the intergenerational value transfers, that might occur whenever a pension fund decides to change its policy.
A more extensive study on generational accounting is done by Lekniute (2011), where a similar approach is used as in the study of Hoevenaars and Ponds (2008). Lekniute (2011) uses risk neutral valuation instead of appropriate discount factors to value the future outcomes to time zero. In this study it is concluded that no best or optimal choice for pension redesign is available, as it depends on the goals that are being pursued by the pension fund. However, it does give insights into the direction and magnitude of the effects of different policy measures and the intergenerational value transfers. Lekniute (2011) uses an ALM model to

value the different generational effects. In this thesis, the same ALM model is used to value the embedded options on the holistic balance sheet.

2.2 Model description

2.2.1 Classical ALM vs. value-based ALM

An Asset-Liability Management (ALM) analysis is a method to evaluate the pension contract. An ALM model uses a risk model that produces stochastic simulations of returns on assets, inflation, and other relevant economic data. The scenarios produced by the economic model are used in the ALM model to calculate the liabilities of a pension fund at different points in time. At the same time the model calculates the evolution of the assets, with the help of the investment strategy of the pension fund and the contribution rate set the participants have to pay. With the value of the assets and the liabilities the funding ratio can be determined over a range of future point in time.

Classical ALM analysis is a tool that shows a pension funds evolution of the funding ratio. It is able to provide the probability of underfunding at a specified moment in time. Furthermore, the classical ALM model is able to show the magnitude of the contribution level in different scenarios, in which scenarios negative or positive indexation will be given, and the resulting pension result for the participants within the pension fund. Therefore it is a useful tool for policy makers to be able to make well formed decisions. However, as Chapman, Gordon, and Speed (2001) emphasize, when projections are made further into the future, the uncertainty about key outputs increases. The classical ALM model produces funnels of doubt, where the funnels of doubts are wider whenever an asset mix is chosen with a higher expected return and thus whenever more risk is taken by the pension fund.

As Chapman et al. (2001) point out, a classical ALM analysis is a qualitative method for explaining different risks, where it is useful and gives insights into pension developments. However, classical ALM is not able to give underfunding of a pension fund a value, to give different stakeholders a value and to provide value transfers among different stakeholders in case of changing the characteristics of a pension fund and its policy.
In order to be able to value the different options on the holistic balance sheet and to show their generational effects, value-based ALM analysis is used in this thesis. Value-based ALM is able to give the pension contract a value, where the downside risk gets a higher value than the upside potential, as stakeholders experience extremely low investment returns more negative than they experience extremely high investment returns positive.
In order to do so, a pricing kernel method or risk neutral valuation can be used to value the assets and liabilities, which will both be further explained in Section 2.2.2. In case of the pricing kernel method, the cash flows are valued by using appropriate discount factors to value them back to time zero as is done by Hoevenaars and Ponds (2008). In risk neutral valuation, risk neutral scenarios are used to value the cash flows back to time zero with the risk free rate. The latter approach will be used in this thesis to value the embedded options on the holistic balance sheet and their generational effects.

2.2.2 Valuation method

In this thesis, the liabilities of a pension fund and the embedded options on the holistic balance sheet are valued. These liabilities and options should be valued market consistently, since if the price will be higher or lower than the market consistent price, arbitrage exists. The Fundamental Theorem of Asset Pricing (FTAP) is needed to make sure there is absence of arbitrage.

Before we introduce the FTAP, the important notion in finance of taking expectations under different probability measures is explained. Furthermore, it should be known that different probability measures are equivalent if they agree on which events are possible and which events are not. A change of measure can be realized by the 'Radon-Nikodym derivative' (Schumacher, 2011).
Suppose, there are two different probability measures $\mathbb{P}$ and $\mathbb{Q}$. If there exists a random variable θ such that the following holds:

$$E^{\mathbb{Q}}X = E^{\mathbb{P}}\theta X,$$

for all random variables X, then θ is said to be the Radon-Nikodym derivative of $\mathbb{Q}$ with respect to $\mathbb{P}$, where it should hold that $E^{\mathbb{P}}\theta = 1$ and $\theta_i > 0$ for all i in order to make sure that $\mathbb{Q}$ is indeed another probability measure. Here $E^{\mathbb{P}}$ is the expectation under the probability measure $\mathbb{P}$ and $E^{\mathbb{Q}}$ is the expectation under the probability measure $\mathbb{Q}$.
The same change of measure can be applied for random processes, such as Brownian motions, instead of random variables. In this case, θ_t is called the 'Radon-Nikodym process' such that, for all $0 \leq s \leq t$ it holds that

$$E_s^{\mathbb{Q}} X_t = E_s^{\mathbb{P}} \frac{\theta_t}{\theta_s} X_t,$$

where X_t is a stochastic variable, and where E_s indicates an expectation conditional on information available at time s. Again similar restrictions should hold, namely $E_s^{\mathbb{P}} \frac{\theta_t}{\theta_s} = 1$ and θ_0=1, i.e. the Radon-Nikodym process is a positive $\mathbb{P}$-martingale.

A theorem exists about the change of probability measure, namely the Girsanov theorem, which makes it easier to apply a change of measure in case of working with stochastic differential equations. The Girsanov theorem states that if we have a Brownian motion under the probability measure $\mathbb{P}$ and a process λ_t with mild boundedness conditions, then the scalar process θ_t defined by

$$d\theta_t = -\theta_t \lambda_t dW_t, \qquad \theta_0 = 1$$

is a positive $\mathbb{P}$-martingale which we can take as a Radon-Nikodym process that defines a change of measure from the original probability measure $\mathbb{P}$ to a new probability measure $\mathbb{Q}$. Under this new measure $\mathbb{Q}$, the process $W_t^{\mathbb{Q}}$ defined by

$$W_t^{\mathbb{Q}} = \lambda_t dt + dW_t$$

is a Brownian motion.
Hence, the Girsanov theorem states that changing the probability measure is actually a change in the drift term of the process, as the drift λ_t is added to the stochastic process.

As the concept of changing the probability measure is explained, the FTAP can be presented, which can be written in two different forms (Schumacher, 2011):

There is absence of arbitrage ⇔ There exists a strictly positive stochastic discount factor

There is absence of arbitrage ⇔ For any given numéraire, there is an equivalent measure such that the current relative price (relevant to the numéraire) is equal to the expectation of its future relative price under the new measure

Therefore, to value the liabilities and options, two different methods can be used. The first method is equivalent with the first form of the FTAP and is called the pricing kernel method, in which price process are multiplied by a strictly positive stochastic discount factor, such that they all become martingales under $\mathbb{P}$, i.e.:

$$E_t^{\mathbb{P}} K_T Y_T = K_t Y_t,$$

where Y_t is a price process and K_t is a stochastic process for the pricing kernel, where it holds that $K_0 = 1$. Therefore, an asset Y valued to time zero can be derived as

$$Y_0 = E_0^{\mathbb{P}} K_T Y_T. \tag{2}$$

The second method to value the liabilities and options is the equivalent martingale measure method, which is equivalent with the second form of the FTAP. The FTAP says any numéraire N_t can be chosen, where a numéraire should be always positive, a traded asset, a self-financing portfolio, and adapted to the problem at hand. If there is a probability measure $\mathbb{Q}_N$ which is equivalent to the real probability measure $\mathbb{P}$ such that it holds that

$$E_t^{\mathbb{Q}_N} \left(\frac{Y_T}{N_T} \right) = \frac{Y_t}{N_t},$$

then there is no arbitrage, where Y_t is a price process. The probability measure $\mathbb{Q}_N$ can be found with the help of the Girsanov theorem.
In case the money market account is chosen as numéraire, which is the riskless asset, then the associated equivalent martingale measure is called the risk neutral measure. It turns out that under the risk neutral measure, the expected return on all assets is the riskless return; using the risk neutral measure results in being in a risk neutral world. The risk neutral valuation method is thus a special form of the equivalent martingale measure method. The value of the same asset Y at time zero can be valued with risk neutral valuation as

$$Y_0 = E_0^{\mathbb{Q}} e^{-rT} Y_T, \tag{3}$$

where r is the risk free rate, e^{rT} is the value of the numéraire at time T, and $\mathbb{Q}$ is the risk neutral measure. Note that the risk free rate is the same for all maturities in this example, while it will not be in the remainder of this thesis.
Therefore, assets can be valued in both forms given in (2) and (3), as they provide the same market consistent value.

In the remainder of this thesis, risk neutral valuation is used. The risk model that is introduced in Section 2.2.3 returns 5000 risk neutral scenarios according to the risk neutral measure $\mathbb{Q}$ which will be inserted into the ALM model that is introduced in Section 2.2.5.

2.2.3 Risk model

As explained, an ALM model uses a risk model, i.e. an economic scenario generator, that produces stochastic simulations of returns on assets, inflation, and other relevant economic data.
Risk models widely used by the financial industry regarded events such as the 2008 credit crisis as highly unlikely. These models assumed volatilities and correlations to be constant, while both volatilities and correlations became much more extreme during the financial crisis (Van den Goorbergh, Molenaar, Steenbeek, and Vlaar, 2011).

Therefore, the risk model used in this thesis has two additional features, to overcome these drawbacks. First of all, stochastic jumps are introduced, which represent a sudden loss in confidence of the market with the consequence that the stock market drops significantly, risk

free interest rates decrease, and credit spreads increase significantly.
Secondly, a time-varying covariance matrix for normally distributed shocks is implemented in the risk model, such that volatilities and correlations can be varied. Here two dominant sources of time-varying risks are assumed, namely monetary uncertainty and real uncertainty. Furthermore, the time-varying second moments generate asymmetry in interest rates, inflation, and credit spreads, with the consequence that negative interest rates exist less likely.
The nominal and real term structure are modeled with an affine term structure model within this risk model. The model can be used under both real world and risk neutral scenarios, in which both arbitrage opportunities are absent.

This risk model with the nominal term structure is introduced by Van den Goorbergh et al. (2011) and is derived from six stochastic and four deterministic state variables. The stochastic variables are modeled with a quarterly vector autoregressive model as follows:

$$x_{t+1} = \begin{bmatrix} \pi_{t+1} \\ y_{t+1}^{(1)} \\ xs_{t+1} \\ dy_{t+1} \\ cs_{t+1} \\ mp_{t+1} \end{bmatrix} = c_t + \Gamma x_t + J_{t+1}\nu + \Sigma S_t^{1/2} \zeta_{t+1},$$

where

$$c_t = (I_6 - \Gamma)(\mu_0 + \mu_{\bar{\pi}} \bar{\pi}_t) - p\nu,$$

$$\zeta_{t+1} \sim N(0, I_6),$$

where π_t is the log of the annual inflation in the Eurozone, $y_t^{(1)}$ is the continuously compounded three-month Euribor, xs_t is the quarterly log excess return on the stock market, dy_t is the dividend yield in logit form, cs_t is the credit spread between US Baa bonds and treasuries measured in log percentages, and mp_t is an unobservable variable called the maturity preference, which measures time-varying influences on bond prices that are unrelated to the other state variables.
Furthermore, J_{t+1} is the jump indicator which is equal to one with probability p and zero otherwise and the diagonal matrix S_t captures the time-varying volatilities.
The four deterministic state variables are the medium-term price assumption $\bar{\pi}_t$ and three different lagged quarterly inflation π_t^q (i.e. lagged one, two, and three quarters).

The term structure is modeled as an affine model as

$$r_t^{(n)} = exp(A_n + B_n' x_t) - 1, \tag{4}$$

where $r_t^{(n)}$ expresses the rate with maturity n of the term structure at time t. Both a nominal and a real term structure can be derived from this model. Note that also the four deterministic variables are included in x_t, where the last three deterministic variables are equal to zero for the nominal term structure. For the exact specifications see Van den Goorbergh et al. (2011).
The rate $r_t^{(n)}$ is used in the remainder of this thesis to value the liabilities and the adjustment mechanism, in order to make sure that everything is valued in a market consistent way. Therefore, the valuation method introduced in Section 1.2.3 is not used in this thesis.

As emphasized before, we use real world scenarios and risk neutral scenarios in this thesis. Both are derived by the model introduced above. For an extensive explanation of the risk neutral measure used in the risk model, see Lin and Vlaar (2011).

An additional variable that is needed in an ALM model for a pension fund is the average wage growth. As wage growth is not traded in the market, a linear regression is used to generate scenarios for it:

$$w_{t+1} = \alpha + \beta_1 w_t + \beta_2 \pi_{t+1} + \beta_3 y_t^{(1)} + \epsilon_{t+1}, \tag{5}$$

where w is the wage growth, π is the inflation, and $y^{(1)}$ is the short term interest rate. In (5) the wage growth is estimated under the real probability measure $\mathbb{P}$.
In order to generate the wage growth under the risk neutral measure $\mathbb{Q}$, a similar regression is used, where the market related variables π and $y^{(1)}$ are inserted from the risk model introduced above under the risk neutral measure:

$$w_{t+1}^{\mathbb{Q}} = \alpha^{\mathbb{Q}} + \beta_1 w_t^{\mathbb{Q}} + \beta_2 \pi_{t+1}^{\mathbb{Q}} + \beta_3 y_t^{(1)\mathbb{Q}} + \epsilon_{t+1}.$$

Here the β coefficients are the same as in (5), while $\alpha^{\mathbb{Q}}$ is adjusted, such that it is made sure that the wage growth under the risk neutral measure is a martingale.

The total risk model that is used in the ALM model generates 5000 scenarios, both under the real probability measure $\mathbb{P}$ and the risk neutral measure $\mathbb{Q}$.

2.2.4 Pension fund characteristics

A pension fund can have different policies which it maintains. In Section 3, several different policies are compared, where the following aspects are assumed equal for each of those policies:

- The pension system is an average wage scheme, since this is the dominant type in the Netherlands, as described in Section 1.1;
- The contribution paid by the pension members is uniform across generations and scenarios;
- The benefits received by the pension members are indexed for wage growth, which is uniform across generations;
- The accrual rate ϵ is set equal to two percent of the wage level;
- An individual in the pension fund is assumed to enter the fund at the age of 25, to pay contributions during his/her working life, to start receiving pension benefits at the age of 65, and to decease at the age of 99 at maximum;
- The investment strategy considered consists of a portfolio invested for 50 percent in stocks and for 50 percent in bonds, where the investment portfolio will be rebalanced each time period.

For the number of participants within the fund, a dataset supplied by CBS (Statistics Netherlands) is used. This dataset includes the size of the Dutch population for each cohort and their survival probabilities. Furthermore, it contains projections of both the population size and the survival probabilities for future years. Additionally, the dataset is gender specific, as it is known that males and females have different survival probabilities.
In the model, the initial Dutch population is used as a starting point, which is adjusted each time step by multiplying the population by their one year conditional survival probabilities:

$$Pop_{x+1,t+1}^{male} = Pop_{x,t}^{male} \cdot p_{x,t}^{male},$$

where $Pop_{x,t}^{male}$ contains the number of males of age x at time t and $p_{x,t}^{male} = 1 - q_{x,t}^{male}$ is the one year survival probability, where $q_{x,t}^{male}$ is the one year death probability, i.e. the probability that a male person of age x will not survive another year at time t.
For participants entering the fund after time zero, i.e. generations which are not 25 years old yet at time zero, the data of the population size is used once again, as it contains the projections of the population.

A sensitivity analysis is done in Section 4 and Section 5. Here two pension fund characteristics mentioned above are varied. First of all, the investment strategy is changed in two more extreme strategies, namely a portfolio consisting of stocks completely and a portfolio consisting of bonds completely. Secondly, the pension fund itself is varied, where the Dutch fund is replaced by both a green fund and a gray fund. The specifications of these three funds are displayed in Appendix C.

2.2.5 ALM model

The risk model introduced in Section 2.2.3 is inserted in the ALM model that is explained in this section.
As known, a pension fund has assets A and liabilities L. The funding ratio of a pension fund is the number which represents whether the liabilities can be covered by the assets, and is determined as follows:

$$FR_N = \frac{A}{L_N},$$

where L_N is the value of the nominal liabilities, and FR_N is the nominal funding ratio.
In the ALM model, the initial assets of the pension fund are determined by multiplying the initial nominal funding ratio by the initial nominal liabilities, which in turn is calculated as the present value of the total accrued benefit claims at time zero.

As assumed, participants accrue benefits at a rate of two percent per year. Therefore, since a participant works for maximal 40 years, he/she can collect 80 percent of his/her average wage (plus indexation) at maximum, as after the retirement age the pension payments start. This results in an accrued benefits matrix, in which each row represents a different scenario and each column a different generation. Therefore the accrued benefits matrix at the start of time zero can be shown as follows:

$$B_0 = \begin{bmatrix} 0 & 0.02 & \dots & 0.8 & \dots & 0.8 \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & 0.02 & \dots & 0.8 & \dots & 0.8 \end{bmatrix},$$

which is updated with the average wage level matrix each time period. The accrued benefits matrix is multiplied by the population, such that is known how much the fund has to pay out in the future. To determine the present value of these accrued benefits, each element in the matrix should be multiplied by an appropriate discount factor, in which also the survival probabilities are contained. The nominal discount factor for a male individual of age x at time t for scenario s is calculated as:

$$D_{x,t}^{s,male} = \sum_{i=max(65-x,0)}^{99-x} {}_{(i-t)}p_{x-(i-t),t}^{male} \left(1 + r_{t,s}^{(i)}\right)^{-i}, \quad (6)$$

where $r_{t,s}^{(i)}$ expresses the rate with maturity i from the nominal term structure at time t in scenario s, which is introduced in (4) in Section 2.2.3 and where ${}_{(i-t)}p_{x-(i-t),t}$ is the $(i-t)$

survival probability of an individual aged $x-(i-t)$ at time t. Note that the market consistent term structure is used within the discount factor, such that the liabilities and the adjustment mechanism will be valued as such.
The discount factor is a summation that starts at $max(65-x,0)$ as the accrued benefits of the participants are only paid out when the participant is 65 years or older, where the pension payments start in $65-x$ years if the participant is not yet retired. The summation ends at $99-x$, as the pension payments stop at the moment the participant deceases, where the age of 99 is the maximum age of the participant. This results in a discount matrix for each gender in which again each row represents a scenario and each column represents a cohort. The discount matrix at time zero for the gender male can be shown as follows:

$$D_0^{male} = \begin{bmatrix} D_{25,0}^{1,male} & \dots & D_{99,0}^{1,male} \\ \vdots & \ddots & \vdots \\ D_{25,0}^{5000,male} & \dots & D_{99,0}^{5000,male} \end{bmatrix}.$$

Now, the liability matrix per gender L_t^{gender} is calculated as an elementwise matrix multiplication of the accrued benefits matrix and the discount matrix (multiplied by the number of participants, which is the same for each scenario). Therefore, the structure of the liability matrix is the same as the structure of the accrued benefits matrix and the discount matrix; each row represents a scenario, while each column represents a cohort. The value of the nominal liabilities are calculated per scenario, where it is a summation over all cohorts. For instance, the value of the initial nominal liabilities (at time zero) for scenario s are calculated as follows:

$$L_{N,0}^s = \sum_{x=25}^{99} L_0^{s,male} + \sum_{x=25}^{99} L_0^{s,female}.$$

Recall that the initial asset value for each scenario is calculated by multiplying the initial funding ratio by the value of the nominal liabilities for that same scenario.

As the initial values are set, the actual ALM model can start its time loop. Here, a horizon of 15 years into the future is considered, as this is approximately equal to the average duration of the liabilities. There are two main frameworks considered in this thesis, namely an open fund is considered in which new participants enter the fund after time zero and in which new benefits are accrued and contributions are paid by the working participants. Besides that, a fund is considered which is fictitiously closed at time zero, in which no new participants can enter after time zero, no new benefits are accrued, and no contributions are paid by the participants already in the fund at time zero.

In the open fund framework, new benefits are accrued by the working participants at the beginning of each time period. Furthermore, the working participants pay their contributions and the pensioned participants receive their benefits at the start of each period. The contributions are added to the assets, while the benefit payments are subtracted from the assets. The resulting asset value is invested in a certain investment portfolio each time period, which will be rebalanced each period:

$$A_{t+1}^s = \Bigg(A_t^s + \sum_{i=25}^{64} c_t^s \cdot \left(Pop_{i,t}^{male} + Pop_{i,t}^{female} \right) \\ - \sum_{i=65}^{99} b_t^s \cdot \left(Pop_{i,t}^{male} + Pop_{i,t}^{female} \right) \Bigg) \cdot (1 + r_t^{inv,s}),$$

where $r_t^{inv,s}$ is the return at time t in scenario s of the portfolio invested in and is obtained from the risk model introduced in Section 2.2.3. The level of the contributions c_t^s and the benefits b_t^s for a person aged i at time t in scenario s depend on the average wage level and the policy considered by the pension fund. In what way the contribution level and indexed benefit level will be determined is further explained in Section 2.4 and Section 2.5.

In the closed fund framework, no new participants can enter the fund, no contributions are paid, and no new benefits are accrued by the participants in the fund. Therefore, the evolution of the assets is different than in the open fund framework and will evolve as follows:

$$A_{t+1}^s = \Bigg(A_t^s + \sum_{i=25}^{64} c_t^{rec,s} \cdot \Big(Pop_{i,t}^{male} + Pop_{i,t}^{female}\Big)$$

$$- \sum_{i=65}^{99} b_t^s \cdot \Big(Pop_{i,t}^{male} + Pop_{i,t}^{female}\Big)\Bigg) \cdot (1 + r_t^{inv,s}),$$

in which $c_t^{rec,s}$ represents the percentage points of recovery premium at time t in scenario s the participants have to pay in certain policies where the pension fund uses the steering instrument recovery premium. In what way this percentage point of recovery premium is determined is further explained in Section 2.4.1.

After the investment returns are received by the pension fund at time t, the entitlements of the oldest cohort, the participants aged 99 at the start of time t, are removed, as all those participants are deceased during time period t. Thereafter, the indexation level the participants will receive over their accrued benefits at time $t+1$ is determined. This indexation level depends on the policy of the fund, where different types of indexation are further explained in Section 2.5.
Due to indexed accrued benefits, the value of the liabilities changes, where the value increases in case positive indexation is given and where the liabilities decrease in value if negative indexation is given. Therefore, these indexed accrued benefits affect the funding ratio of the fund. With this resulting funding ratio, the level of contribution in the open fund framework and the level of recovery premium in the closed fund framework are determined, which the participants pay at the beginning of time $t + 1$.
At the end of the time period, the wage level matrix is adjusted for the new average wage level, with which the accrued benefits are determined, and the new cohorts aged 25 are added in the open fund framework.

With the ALM model the pension result PR can be determined, which shows the purchasing power of wages of the pension the participants receive, i.e. it is a ratio of the cumulative indexation given to the participants to the cumulative wage growth:

$$PR^s = \frac{\prod_t (1 + i_t^s)}{\prod_t (1 + w_t^s)},$$

where i_t^s is the level of indexation given at time t in scenario s and w_t^s is the wage level at time t in scenario s. The level of indexation i is given in (11) and further explained in Section 2.5.

2.3 From traditional balance sheet to holistic balance sheet

A pension fund has a balance sheet on which the assets and liabilities of the fund are stated, which we call the traditional balance sheet in this thesis. A traditional balance sheet gives

the financial position of a firm at one moment in time and is given in Table 1.
However, as a pension fund has steering and adjustment instruments, the actual financial

Traditional Balance Sheet			
Assets	A_0	Liabilities	L_0
		Residue	R_0
	A_0		A_0

Table 1: The traditional balance sheet

position of a pension fund is not displayed in the traditional balance sheet. Recall the example of the two different pension funds with the same traditional balance sheet, where fund 1 gives conditional indexation and fund 2 has the additional right to cut benefits. The actual financial position of fund 2 is much better comparing it with the financial position of fund 1. Therefore, the traditional balance sheet does not provide the actual financial position of a pension fund.

The holistic balance sheet approach does include the steering and adjustment instruments of a pension fund and values them as embedded options on the holistic balance sheet. The steering option that is valued on the holistic balance sheet is named the 'sponsor support' and the adjustment option that is valued on the holistic balance sheet is named the 'adjustment mechanism', following the names introduced by EIOPA.
In Table 2 the holistic balance sheet in a closed fund framework is given, i.e. no new partic-

Holistic Balance Sheet			
Assets	A_0	Liabilities	L_0
Sponsor support	V_0^{SPS}	Adjustment mechanism	V_0^{AM}
		Residue option	V_0^{RO}
	$A_0 + V_0^{SPS}$		$A_0 + V_0^{SPS}$

Table 2: The holistic balance sheet in the closed fund framework

ipants are entering the fund after time zero, no contributions are paid, and no new benefits are accrued. In order to obtain a balanced holistic balance sheet, the residue option is added on the liability side, which can be either positive or negative.

In an open fund framework, the holistic balance sheet looks slightly different, as two additional aspects are added on the balance sheet, namely the contributions paid and the new benefits accrued during the horizon considered.

Holistic Balance Sheet			
Assets	A_0	Liabilities	L_0
Contributions	CON	New accrued benefits	NAB
Sponsor support	V_0^{SPS}	Adjustment mechanism	V_0^{AM}
		Residue option	V_0^{RO}
	$A_0 + CON + V_0^{SPS}$		$A_0 + CON + V_0^{SPS}$

Table 3: The holistic balance sheet in the open fund framework

In Table 3 the holistic balance sheet in the open fund framework is displayed, where again the residue option is added on the liability side such that the holistic balance sheet is balanced.

The valuation of all the additions on the holistic balance sheet with respect to the traditional balance sheet are explained in the remaining sections. In Section 2.4 the valuation of the sponsor support is explained, in Section 2.5 the valuation of the adjustment mechanism is explained, in Section 2.6 the valuation of the residue option is explained, and finally in Section 2.7 the two additional aspects in the open fund framework are valued.
The closed fund framework is considered in Section 3 and Section 4, while the open fund framework is considered in Section 5.

2.4 Sponsor Support

A pension fund can have some sponsor support, which it can use as steering instrument. The sponsor support can be split up into two parts. First the employee contribution option is explained in Section 2.4.1, whereafter the employer guarantee option is considered in Section 2.4.2.
Here the pension protection fund will not be considered, as this type of steering is not used within the Netherlands.

2.4.1 Employee contribution option

In order to be able to determine the value of the employee contribution option V_0^{EC}, first the cost covering contribution rate c_{base} is needed, which the working participants within a fund have to pay. This contribution rate c_{base} is set such that the costs of the pension fund are covered, i.e. the contribution rate is set each year equal to the total new accrued benefits in that year divided by the total working population in that year, which is raised with the percentage of required equity:

$$c_{base,t} = \frac{NAB_t}{\sum_{x=25}^{64}\left(Pop_{x,t}^{male} + Pop_{x,t}^{female}\right)} \cdot (1+S)\,, \tag{7}$$

where S is as given in (20) in Appendix A and NAB_t is the value of the new accrued benefits at time t which is further explained in (16) in Section 2.7.2.

A pension fund always receives the cost covering contribution from their participants, therefore this value itself is not an option for the pension fund. However, the recovery premium is, as the pension fund has the option to increase the cost covering contribution c_{base} by a certain percentage point, which depends on the nominal funding ratio as follows:

$$c_t = \begin{cases} c_{base,t} + c^{rec_1} & \text{if } FR_{N,t} \leq floor; \\ c_{base,t} + c^{rec_2} & \text{if } floor < FR_{N,t} < cap; \\ c_{base,t} & \text{if } FR_{N,t} \geq cap, \end{cases}$$

where $c^{rec_1} > c^{rec_2}$.

In order to determine the employee contribution option, one needs to take into account the difference between the actual contribution paid by the participants and the cost covering contribution, i.e. $c - c_{base}$. The contribution rate is a percentage of the wage level, therefore to obtain an absolute value, this difference should be multiplied with the wage level. Furthermore, the total number of working participants should be taken into account, which results in:

$$c_{pool,t}^{s} = \sum_{x=25}^{64} (c_t - c_{base,t}) \cdot w_{x,t}^{s} \cdot \left(Pop_{x,t}^{male} + Pop_{x,t}^{female} \right). \quad (8)$$

Now, (8) provides the amount of euros all the working participants pay to the pension fund on top of the cost covering contribution rate, for one particular scenario s and one moment in time t. To value the employee contribution option, all the scenarios and time moments over the horizon considered should be taken into account. As emphasized in Section 2.2.2, to value the options, risk neutral valuation is applied. Therefore, (8) should be discounted back to time zero with the risk free rate. In addition, the expectation with respect to the risk neutral probability measure should be taken, which results in the value of the employee contribution option at time zero:

$$V_0^{EC} = E_0^{\mathbb{Q}} \left(\sum_{t=0}^{T-1} c_{pool,t} \prod_{k=0}^{t} \left(\frac{1}{1 + r_{f,k}} \right) \right), \quad (9)$$

where $r_{f,t}$ is the risk free rate at time t and $E^{\mathbb{Q}}$ is the expectation under the probability measure $\mathbb{Q}$.
Note that the contribution option will be equal to zero in case the contribution rate is set equal to the cost covering contribution rate.

2.4.2 Employer guarantee option

Besides some sponsor support from the working participants of a pension fund, also the employer might provide the fund with some guarantees. In this thesis, one type of employer guarantee is considered, namely the type where the employers pay the pension fund an amount of money in case the funding ratio falls below some level $floor_{EG}$. The amount the employers have to pay is equal to the amount such that the funding ratio will be brought back to the level $floor_{EG}$ again as follows:

$$EG_t = \begin{cases} (floor_{EG} - FR_{N,t}) \cdot L_{N,t} & \text{if } FR_{N,t} < floor_{EG}; \\ 0 & \text{if } FR_{N,t} \geq floor_{EG}, \end{cases}$$

The employer guarantee EG_t is added to the assets of the fund A_t, such that the funding ratio $FR_{N,t}$ will be equal to $floor_{EG}$ again.

In order to value the employee guarantee option, again risk neutral valuation is used, where the option value at time zero will be derived as follows:

$$V_0^{EG} = E_0^{\mathbb{Q}} \left(\sum_{t=0}^{T-1} EG_t \prod_{k=0}^{t} \left(\frac{1}{1 + r_{f,k}} \right) \right). \quad (10)$$

2.4.3 Valuing the sponsor support

In Section 2.4.1 and Section 2.4.2 the employee contribution option and the employer guarantee option are explained respectively. The value of the sponsor support at time zero is simply the sum of both option values:

$$V_0^{SPS} = V_0^{EC} + V_0^{EG},$$

where V_0^{EC} is given in (9) and V_0^{EG} is given in (10).

2.5 Adjustment mechanism

Besides steering options, also adjustment options are stated on the holistic balance sheet. Adjustment options thank their name, as they adjust the accrued benefits of the participants. Such an adjustment can either be positive or negative, i.e. the indexation given can either be positive or negative.
There are three types of positive adjustments that can be given to participants that are considered in this thesis, namely indexation, catch up indexation, and surplus sharing.
Furthermore, two negative adjustments are considered, namely the sustainability cut and the five year recovery plan, which are both reductions of the accrued benefits.
In Section 2.5.1-2.5.5 all these adjustment rules are explained separately, whereas the valuation of the adjustment mechanism is explained in Section 2.5.6.

2.5.1 Indexation

A pension fund can choose a pension system in which a choice can be made between three types of indexation that can be given, namely:

- No indexation:
  In this case, in each year no indexation is given ($ind_1 = 0$).
- Full indexation:
  In this case, no matter what happens, full indexation is given each year ($ind_1 = w$).
- Conditional indexation:
  Indexation depends on the nominal funding ratio as follows:

  $$ind_{1,t} = \begin{cases} 0 & \text{if } FR_{N,t} \leq floor; \\ \frac{FR_{N,t} - floor}{cap - floor} w_t & \text{if } floor < FR_{N,t} < cap; \\ w_t & \text{if } FR_{N,t} \geq cap. \end{cases}$$

  If $w_t < 0$, then no indexation is given instead of w_t.

A pension without indexation is half a pension[2], therefore this type will not be considered in the ALM analysis in the remainder of this thesis.
Conditional indexation is mostly used within the Netherlands and is considered a strong adjustment instrument, as is shown in Section 3.

2.5.2 Catch up indexation

In the Netherlands, a well known type of positive adjustment is the catch up indexation in which participants receive their missed indexation back, as due to conditional indexation, the sustainability cut, and the five year recovery plan members do not receive full indexation in each scenario in this thesis.
Catch up indexation gives missed indexation back to the members in case the funding ratio is above a certain level FR_N^{cap}.

$$ind_{2,t} = \begin{cases} indmissedcum_t & \text{if } FR_{N,t} > FR_N^{cap}, \frac{FR_{N,t}}{FR_N^{cap}} > 1 + indmissedcum_t; \\ \frac{FR_{N,t}}{FR_N^{cap}} - 1 & \text{if } FR_{N,t} > FR_N^{cap}, \frac{FR_{N,t}}{FR_N^{cap}} \leq 1 + indmissedcum_t; \\ 0 & \text{otherwise,} \end{cases}$$

[2] Consider an inflation rate of two percent per year, and a working life of 40 years, then one euro will be worth $\frac{1}{1.02^{40}} \approx 0.45$ after 40 years in purchasing power.

where *indmissedcum* is the cumulative missed indexation, which is determined as

$$indmissedcum_t = \frac{1 + w_t}{1 + i_t} - 1,$$

where i is the actual indexation given, i.e. positive and negative indexation are taken into account, which is defined by

$$i_t = \sum_{k=1}^{5} (1 + ind_{k,t}) - 1, \tag{11}$$

where $ind_{3,t}, ind_{4,t}$, and $ind_{5,t}$ are defined in Section 2.5.3, Section 2.5.4, and Section 2.5.5 respectively.
Note that catch up indexation will be given until the funding ratio reaches the level FR_N^{cap} again. Besides this, additional conditions are needed. The first additional condition is that catch up indexation is given subject to a maximum, such that not all catch up indexation will be received in one period, but is smoothed over time:

$$ind_{4,t} \leq catchup^{max}.$$

The second additional condition is that the cumulative indexation that the participants missed *indmissedcum* should be larger then zero, otherwise the participants get a negative adjustment instead:

$$indmissedcum_t > 0.$$

2.5.3 Surplus sharing

The last positive adjustment considered is surplus sharing, in which participants share in the surplus of the fund. This positive adjustment instrument is only used in case the funding ratio reaches high levels. These high levels will mostly be reached due to high investment returns. Whereas a pension fund is a zero sum game and is not introduced to make profits, a pension fund can choose to let their participants share in the surplus, which is a policy instrument that also is used within the Netherlands.
The amount of surplus sharing is determined conditional on the level of the funding ratio, whereas the members share in the surplus if the funding ratio is above a certain level FR_N^{prof}. In this case, the positive indexation level is equal to:

$$ind_{3,t} = \begin{cases} 0 & \text{if } FR_{N,t} \leq FR_N^{prof}; \\ \frac{1}{\gamma}\left(\frac{FR_{N,t}}{FR_N^{prof}} - 1\right) & \text{if } FR_{N,t} > FR_N^{prof}, \end{cases}$$

where γ is the number of years over which the profit sharing is smoothed. Again note that the participants only share in the surplus as long as the funding ratio is still above FR_N^{prof}.

2.5.4 Sustainability cut

The first type of a negative adjustment is the sustainability cut, which actually can be seen as a type of negative indexation or a reduction. The sustainability cut is introduced in case the funding ratio is low.
The accrued benefits will be cut in case the funding ratio falls below a certain level FR_N^{min}. Here they are cut such that the funding ratio will be brought back to FR_N^{min} immediately. The negative adjustment is determined as follows:

$$ind_{4,t} = \begin{cases} \frac{FR_{N,t}}{FR_N^{min}} - 1 & \text{if } FR_{N,t} < FR_N^{min}; \\ 0 & \text{if } FR_{N,t} \geq FR_N^{min}. \end{cases}$$

2.5.5 Recovery plan

The last negative adjustment instrument is the recovery plan. In the Netherlands it is stated in the FTK regulation that a pension fund should have a funding ratio that is equal to at least some fixed value. However, if the funding ratio will get below this value, due to for instance low investment returns, a fund has to start a short recovery plan. In this thesis, a five year recovery plan will be considered.

A five year recovery plan starts if the funding ratio falls below a certain level $floor$. In this case the funding ratio should be at a required level each next year, if this required level is not met next year, the benefits of the participants are cut.

The funding ratio which falls below $floor$ for the first time is denoted by FR_N^*. Such that the funding ratio FR_N^* will be at least equal to $floor$ again in five years, the level with which the funding ratio should be increased each year is equal to

$$\frac{floor - FR_N^*}{5}.$$

Therefore the funding ratio that should at least be reached next year is equal to

$$FR_N^{rec} = FR_N^* + \frac{floor - FR_N^*}{5}.$$

Next year the benefits are cut by a factor such that the funding ratio will be equal to at least FR_N^{rec} immediately:

$$ind_{5,t} = \begin{cases} \frac{FR_{N,t}}{FR_N^{rec}} - 1 & \text{if } FR_{N,t} < FR_N^{rec}; \\ 0 & \text{if } FR_{N,t} \geq FR_N^{rec}, \end{cases}$$

After this, the required funding ratio for the next year is increased by the same factor $\frac{floor - FR_N^*}{5}$:

$$FR_{N,t}^{rec} = FR_{N,t-1}^{rec} + \frac{floor - FR_N^*}{5}.$$

After five years the level $floor$ is reached for sure, in which case the recovery plan is finished. In the worst case, the benefits are cut each year, which is the case if the funding ratio does not meet the required level FR_N^{rec}. However, it can also be the case that the benefits will not be cut at all, which is the case if the funding ratio meets the required level FR_N^{rec} by itself, due to for instance investment returns.

2.5.6 Valuing the adjustment mechanism

Now all the adjustment instruments are explained, the value of the adjustment mechanism can be determined. Here the adjustment mechanism is separated into five parts, namely:

- The indexation option;
- The catch up indexation option;
- The surplus sharing option;
- The sustainability cut option;
- The recovery plan option.

Each of these five options can be determined separately. In each time step ind_i $(i = 1, \dots, 5)$ is determined according to the policy ladders explained in Section 2.5.1-2.5.5. The fraction ind_i is multiplied with the accrued benefits matrix, note that the indexation given at time zero is equal to zero:

$$B_{t+1}^{ind_i,s} = ind_{i,t+1}^{s} \cdot B_t^s,$$

which in turn is multiplied pointwise by the amount of participants and the discount matrix (and summed over all cohorts):

$$B_{pool,t+1}^{ind_i,s} = \sum_{x=25}^{99} B_{x,t+1}^{ind_i,s} \cdot \left(D_{x,t}^{s,male} \cdot Pop_{x,t}^{male} + D_{x,t}^{s,female} \cdot Pop_{x,t}^{female} \right), \tag{12}$$

where the oldest cohort is not included in Pop^{male} and Pop^{female}, and where the discount factor $D_{x,t}$ includes the term structure at the end of time t.
Here (12) gives the amount of indexation given per type of indexation, which can either be positive or negative, to all the participants in the fund for one particular scenario s and one moment in time t.

To value one particular option, risk neutral valuation is used, where all the values should be discounted to time zero with the risk free rate:

$$V_0^{ind_i} = E_0^{\mathbb{Q}} \left(\sum_{t=1}^{T} B_{pool,t}^{ind_i} \prod_{k=0}^{t} \left(\frac{1}{1 + r_{f,k}} \right) \right). \tag{13}$$

The approach explained in (13) can be executed for each type of indexation, which results in five different option values, namely the indexation option value $V_0^{ind_1}$, the catch up indexation option value $V_0^{ind_2}$, the surplus sharing option value $V_0^{ind_3}$, the sustainability cut option value $V_0^{ind_4}$, and the recovery plan option value $V_0^{ind_5}$.
To determine the value at time zero of the total adjustment mechanism, one can simply add the five separate option values, or repeat the approach with i instead of ind, where i is given in (11). Therefore the value of the adjustment mechanism can be determined as follows:

$$V_0^{AM} = \sum_{k=1}^{5} V_0^{ind_k} = E_0^{\mathbb{Q}} \left(\sum_{t=1}^{T} B_{pool,t}^{i} \prod_{k=0}^{t} \left(\frac{1}{1 + r_{f,k}} \right) \right), \tag{14}$$

where

$$B_{pool,t+1}^{i,s} = \sum_{x=25}^{99} i_{t+1}^{s} \cdot B_{t+1}^{s} \cdot \left(D_{x,t}^{s,male} \cdot Pop_{x,t}^{male} + D_{x,t}^{s,female} \cdot Pop_{x,t}^{female} \right).$$

Note that in case no adjustment is done, i.e. $ind_i = 0$, $V_0^{ind_i}$ will not have any value.

2.6 Residue option

In order to keep the holistic balance sheet balanced, a residue option can be determined, which is the present value of the residue after a horizon of T years. To determine the value of this option, risk neutral valuation is used, where the residue at time T should be discounted back to time zero with the risk free rate as follows:

$$V_0^{RO} = E_0^{\mathbb{Q}} \left((A_T - L_T) \prod_{k=0}^{T} \left(\frac{1}{1 + r_{f,k}} \right) \right).$$

2.7 Additional aspects in open fund framework

Next to the unconditional assets, the unconditional liabilities, the sponsor support, the adjustment mechanism, and the residue option, two additional aspects are stated on the holistic balance sheet in the open fund framework with respect to the closed fund framework. The first aspect is the value of the contributions, where the valuation is discussed in Section 2.7.1. The second aspect is the value of the new accrued benefits, where the valuation is discussed in Section 2.7.2.

2.7.1 Contributions

The contributions CON are valued in a similar way as the employee contribution option. The employee contribution option consists of the contributions the employers pay on top of the cost covering contribution. Therefore, in order to obtain a balanced holistic balance sheet, the contributions CON are exactly the cost covering contribution. First of all, the contributions paid by all the working participants at time t can be valued for each scenario s as the cost covering contribution multiplied by the working participants multiplied by the wage level, i.e.:

$$con^s_{pool,t} = \sum_{x=25}^{64} c_{base} \cdot w^s_{x,t} \cdot \left(Pop^{male}_{x,t} + Pop^{female}_{x,t} \right). \tag{15}$$

Secondly, the contributions should be valued at the total horizon considered and valued back to time zero with the help of risk neutral valuation. Hence, the value of the contributions at time zero is equal to

$$CON = E^{\mathbb{Q}}_0 \left(\sum_{t=0}^{T-1} con_{pool,t} \prod_{k=0}^{t} \left(\frac{1}{1 + r_{f,k}} \right) \right),$$

where $con_{pool,t}$ is given in (15).

2.7.2 New accrued benefits

The new accrued benefits NAB are valued in a similar way as the adjustment mechanism. Where the adjustment mechanism consists of the indexation given over the accrued benefits, the value of the new accrued benefits reflects the nominal value of the new accrued benefits. First of all, the new accrued benefits at time t are valued as the sum of the accrual rate ϵ multiplied by the wage level for the working participants:

$$NAB^s_t = \sum_{x=25}^{64} \epsilon \cdot w^s_{x,t} \cdot \left(D^{s,male}_{x,t} \cdot Pop^{male}_{x,t} + D^{s,female}_{x,t} \cdot Pop^{female}_{x,t} \right). \tag{16}$$

Secondly, the new accrued benefits should be valued at the total horizon considered and valued back to time zero as follows:

$$NAB = E^{\mathbb{Q}}_0 \left(\sum_{t=0}^{T-1} NAB_t \prod_{k=0}^{t} \left(\frac{1}{1 + r_{f,k}} \right) \right),$$

where NAB_t is given in (16).

3 Effect of different policies on option values in closed fund framework

Policy	Employee contribution	Employer guarantee	Indexation	Catch up	Surplus sharing	Sustainability cut	Recovery plan
1			full				
2			conditional				
3	recovery		conditional				
4	recovery		conditional	✓			
5	recovery		conditional	✓		✓	
6	recovery		conditional	✓		✓	✓
7	recovery		conditional	✓	✓	✓	✓
8	recovery	✓	conditional	✓	✓	✓	✓

Table 4: Different policies that will be considered in the remainder of this section

In this section eight different policies are considered, where an overview is given in Table 4. It can be seen that in each policy an additional policy instrument is added compared to the previous policy. First of all, in Policy 1 no policy instruments will be used by the pension fund, where in each case full indexation is given to each participant.
In Policy 2, the adjustment instrument conditional indexation is introduced, where full indexation will not be given in all different scenarios. Full indexation is only given in case the funding ratio is larger than or equal to 130%, no indexation is given in case the funding ratio is smaller than or equal to 100% and conditional indexation is given in between.
In Policy 3, a recovery premium is added to Policy 2, which is also dependent on the funding ratio of the pension fund. In case the funding ratio is smaller than or equal to 95% , the recovery premium is equal to 4 percentage points and in case the funding ratio is in between 95% and 100%, the recovery premium is equal to 2 percentage points.
Catch up indexation is introduced and added to Policy 3 in Policy 4. Catch up indexation will be given to the participants of the fund if the funding ratio is larger than 130%.
A sustainability cut is added in Policy 5, which occurs if the funding ratio falls below 85%.
In Policy 6, the five year recovery plan is introduced, in which the funding ratio should be brought back to 100% after five years.
The participants share in the surplus of the pension fund in case the funding ratio is above 140% in Policy 7, where the surplus is smoothed over 10 years.
Finally, in Policy 8 the employer guarantee is added to Policy 7, where the employer pays in case the funding ratio is below 90%, i.e. due to a sustainability cut which is used if the funding ratio is below 85%, the employer will pay at most for the difference in the funding ratio between 85% and 90%.
On certain levels of the funding ratio, several policy instruments are used by the pension fund. As is shown in Section 4.4.6, the order of the policy instruments will have an influence on the different option values on the holistic balance sheet. Therefore in Figure 1 an overview is given of the different policy instruments, in which order they will be used by the pension fund, dependent on its funding ratio.

For each policy considered, it is investigated what the effects will be on the different option values on the holistic balance sheet. To give more insight into the policies and the changes they cause, first a classical ALM analysis is done. Here it can be seen how the funding ratio and the pension result will evolve over time dependent on the policy chosen.

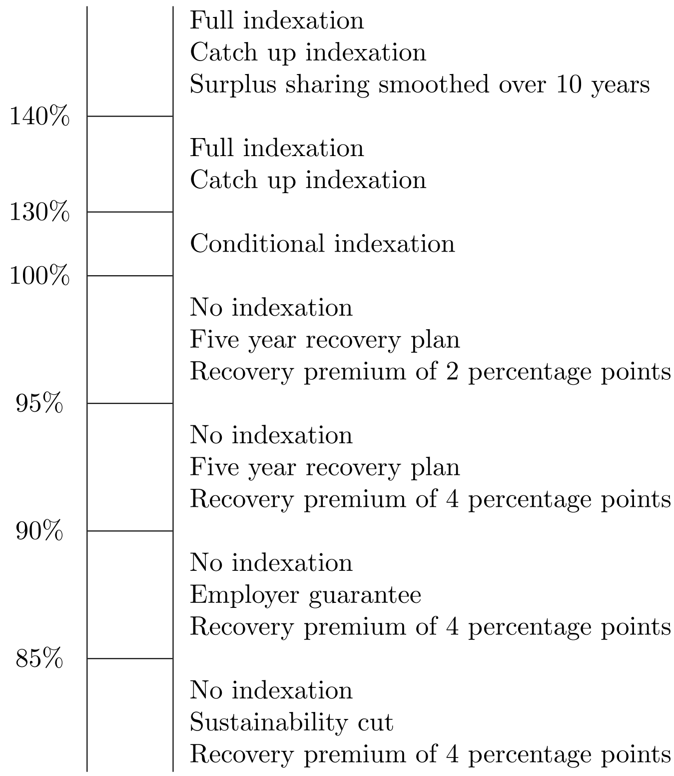

Figure 1: Order of policy instruments the pension fund can use dependent on its funding ratio

Furthermore, for each policy instrument the percentage of usage will be shown, which is a percentage across scenarios and time, along with its standard deviation.
After the classical ALM analysis, a value-based ALM analysis will be done. Here risk neutral valuation is used to value the different options that are stated on the holistic balance sheet.

Furthermore, the following assumptions are made:

- The pension fund will be closed at time zero;
- The initial funding ratio of the pension fund is equal to the required funding ratio according to the FTK regulation, i.e. $FR_0 = FR^{req} = 1 + S$, where the determination of S is explained in Appendix A;
- The pension fund invests for 50 percent in stocks and for 50 percent in bonds, where the portfolio composition is rebalanced each time period;
- The participants within the fund are a projection of the Dutch population;
- The horizon considered is equal to 15 years.

Finally, this section is concluded by showing the different generational effects each policy has by creating three disjoint cohort groups.

3.1 Policy 1: No steering

3.1.1 Classical ALM analysis

In Table 5 the classical ALM output is shown of Policy 1. It can be seen how the funding ratio evolves over time, where the expectation, standard deviation, probability of underfunding, and quantiles are given for the funding ratio after 15 years. The same information is shown for the pension result, where additionally the probability of negative indexation after 15 years is given. Furthermore, for the contribution, the indexation, and the employer guarantee, per scenario the probability of usage of these separate instruments is calculated. After that, the mean and standard deviation are derived over all scenarios, where the mean is given in the first column and the standard deviation is given between brackets. The same structure holds for the classical ALM output tables of the other seven policies.

As can be seen in Table 4 no form of steering is present in Policy 1; the pension fund does not use any of the steering and adjustment instruments. Therefore, this policy is comparable with a life insurance contract; the pension fund promises to give their participants an annuity in the future, which starts at the retirement date and is conditional on being still alive, just like a traditional life annuity which can be bought from an insurance company.
From the classical ALM output displayed in Table 5, it can also easily be seen that no policy instruments are used and full indexation will be given in every scenario, which results in a pension result equal to one. The consequence is that the funding ratio will become very volatile, where the 2.5% quantile is extremely low and equal to 0.506 and the 97.5% quantile is extremely high and equal to 2.490. It can be seen that without using policy instruments, the probability of underfunding after the horizon of 15 years is equal to 0.279, which indicates that a pension fund with this policy will not be able to pay the participants their full indexed at time zero accrued benefits in case of scenarios where the return on investments is low, i.e. bad states of the world.

Funding ratio		**Positive indexation**		**Pension result**	
$E[FR_{N,15}]$	1.314	no indexation	0.000 (0.000)	$E[PR_{15}]$	1.000
$\sigma[FR_{N,15}]$	0.496	cond. indexation	0.000 (0.000)	$\sigma[PR_{15}]$	0.000
$\mathbb{P}[FR_{N,15} < 1]$	0.279	full indexation	1.000 (0.000)	$PR_{15}^{0.025}$	1.000
$FR_{N,15}^{0.025}$	0.506	catch up ind.	0.000 (0.000)	$PR_{15}^{0.500}$	1.000
$FR_{N,15}^{0.500}$	1.256	surplus sharing	0.000 (0.000)	$PR_{15}^{0.975}$	1.000
$FR_{N,15}^{0.975}$	2.490			$\mathbb{P}[i_{15} < 0]$	0.000
		Negative indexation			
Contribution		sustainability cut	0.000 (0.000)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.000 (0.000)	recovery plan	0.000 (0.000)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 5: Classical ALM output Policy 1

3.1.2 Value-based ALM analysis

These results can be translated into the holistic balance sheet, which is presented in Table 6.[3]
First of all, it can be seen that the initial funding ratio of the pension fund is equal to 1.175, as this is equal to the unconditional assets divided by the unconditional liabilities.
Furthermore, it can be seen that the value of the residue option is negative, which can be divided into a surplus option and a deficit option. The high probability of underfunding is

[3]The holistic balance sheet is not precisely balanced due to rebalancing the investment portfolio each year and the existence of rounding-off errors.

Holistic Balance Sheet					
Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		0	Adjustment mechanism (V_0^{AM})		35.6
Employee contribution option	0		Indexation option	35.6	
Employer guarantee option	0		Catch up indexation option	0	
			Surplus sharing option	0	
			Sustainability cut option	0	
			Recovery plan option	0	
			Residue option (V_0^{RO})		-17.7
			Surplus option	14.7	
			Deficit option	-32.4	
		117.5			117.9

Table 6: Holistic balance sheet Policy 1

translated into the deficit option, which gets an extremely high negative value, as bad states get a higher value in a risk neutral world. Furthermore, the surplus option gets a lower positive value than the deficit option since the good states (i.e. the states where there is no underfunding) get a lower value than the bad states.
Finally, due to giving indexation in each scenario in spite of what happens to the financial position of the pension fund, the indexation option gets a value of 35.6, which is a very expensive option with respect to the value of the nominal liabilities.

3.2 Policy 2: Conditional indexation

3.2.1 Classical ALM analysis

Funding ratio		**Positive indexation**		**Pension result**	
$E[FR_{N,15}]$	1.478	no indexation	0.129 (0.192)	$E[PR_{15}]$	0.907
$\sigma[FR_{N,15}]$	0.442	cond. indexation	0.356 (0.214)	$\sigma[PR_{15}]$	0.082
$\mathbb{P}[FR_{N,15} < 1]$	0.107	full indexation	0.515 (0.297)	$PR_{15}^{0.025}$	0.705
$FR_{N,15}^{0.025}$	0.773	catch up ind.	0.000 (0.000)	$PR_{15}^{0.500}$	0.856
$FR_{N,15}^{0.500}$	1.409	surplus sharing	0.000 (0.000)	$PR_{15}^{0.975}$	1.000
$FR_{N,15}^{0.975}$	2.555			$\mathbb{P}[i_{15} < 0]$	0.000
		Negative indexation			
Contribution		sustainability cut	0.000 (0.000)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.000 (0.000)	recovery plan	0.000 (0.000)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 7: Classical ALM output Policy 2

In Policy 2 the instrument conditional indexation is used, which means that the participants of the fund will not get full indexation in every scenario, instead, it will be dependent on the financial position of the fund. It can be seen from the Classical ALM output in Table 7 that in this case in only approximately half of the time full indexation will be given. Furthermore, in even 12.9 percent[4] of the time no indexation at all is given to the participants of the

[4] The 12.9 percent given is the mean calculated over all scenarios and all years considered, where still a certain amount of risk is present, as the standard deviation is positive and equal to 0.192, i.e. in certain scenarios the percentage of giving no indexation lies even higher than the 12.9 percent given.

Holistic Balance Sheet					
Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		0	Adjustment mechanism (V_0^{AM})		13.0
Employee contribution option	0		Indexation option	13.0	
Employer guarantee option	0		Catch up indexation option	0	
			Surplus sharing option	0	
			Sustainability cut option	0	
			Recovery plan option	0	
			Residue option (V_0^{RO})		4.9
			Surplus option	17.5	
			Deficit option	-12.6	
		117.5			117.9

Table 8: Holistic balance sheet Policy 2

fund. This obviously affects the pension result, which is not equal to one in each scenario anymore.
Besides that, the policy instrument conditional indexation has an effect on the funding ratio, which becomes less volatile as in Policy 1. Furthermore, the funding ratio levels become higher, as the liabilities of the fund decrease in Policy 2 with respect to Policy 1. This leads to a probability of underfunding equal to 0.108, which is almost three times as low as in case no conditional indexation will be given. This indicates that introducing conditional indexation is a powerful tool for a pension fund.

3.2.2 Value-based ALM analysis

All the effects shown in the classical ALM analysis are translated into the holistic balance sheet shown in Table 8. Note that the unconditional assets and liabilities remain the same, as the initial funding ratio is exactly equal to the initial funding ratio of Policy 1.
Furthermore, the residue option increases in value from -17.7 to 4.9, which is mostly explained by the change in the deficit option, which decreases significantly in absolute value due to the decrease in the probability of underfunding. The surplus option also increases, since the funding ratio levels increase with respect to Policy 1.
Finally, the value of the indexation option is equal to 13, which is almost three times as low as the value of the same option in Policy 1. The reason that this value decreases this much is that in the bad states no indexation will be given at all. In a risk neutral world, all scenarios get a different drift term, due to the Girsanov theorem. As can be seen in Table 7, more good scenarios are present (i.e. scenarios in which overfunding occurs) than bad scenarios (i.e. scenarios in which underfunding occurs). Hence, to obtain a risk neutral world, i.e. a world where the probability of the presence of good scenarios and bad scenarios are equal, the bad scenarios get a higher value attached to it.

3.3 Policy 3: Additional instrument: recovery premium

3.3.1 Classical ALM analysis

In Policy 3 an additional recovery premium is added to Policy 2 as can be seen in Table 4. Table 9 indicates that the effect of introducing recovery premium is not as high as the effect of introducing conditional indexation. First thing to note is that when introducing the policy instrument recovery premium, this instrument will be used in 11.8 percent of the time.

Funding ratio		Positive indexation		Pension result	
$E[FR_{N,15}]$	1.489	no indexation	0.123 (0.181)	$E[PR_{15}]$	0.909
$\sigma[FR_{N,15}]$	0.437	cond. indexation	0.358 (0.215)	$\sigma[PR_{15}]$	0.080
$\mathbb{P}[FR_{N,15} < 1]$	0.098	full indexation	0.519 (0.293)	$PR_{15}^{0.025}$	0.713
$FR_{N,15}^{0.025}$	0.804	catch up ind.	0.000 (0.000)	$PR_{15}^{0.500}$	0.928
$FR_{N,15}^{0.500}$	1.421	surplus sharing	0.000 (0.000)	$PR_{15}^{0.975}$	1.000
$FR_{N,15}^{0.975}$	2.555			$\mathbb{P}[i_{15} < 0]$	0.000
		Negative indexation			
Contribution		sustainability cut	0.000 (0.000)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.117 (0.172)	recovery plan	0.000 (0.000)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 9: Classical ALM output Policy 3

As the policy instrument recovery premium is only used at funding ratio levels lower than one, the 97.5% quantile of the funding ratio will not display a significant change after 15 years with respect to Policy 2. However, the 2.5% quantile increases significantly from 0.773 to 0.804. This affects the probability of underfunding, which decreases by one percentage point.
This increase in funding ratio levels leads to the fact that no indexation will be given in 0.6 percentage point less of the time with respect to Policy 2 and that full indexation is given in 0.4 percentage point more of the time. This affects the pension result, as the 2.5% quantile increases from 0.705 to 0.713, while the volatility decreases.

3.3.2 Value-based ALM analysis

Holistic Balance Sheet

Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		2.0	Adjustment mechanism (V_0^{AM})		13.1
Employee contribution option	2.0		Indexation option	13.1	
Employer guarantee option	0		Catch up indexation option	0	
			Surplus sharing option	0	
			Sustainability cut option	0	
			Recovery plan option	0	
			Residue option (V_0^{RO})		6.8
			Surplus option	17.9	
			Deficit option	-11.1	
		119.5			119.9

Table 10: Holistic balance sheet Policy 3

All these effects are displayed in the holistic balance sheet in Table 10. The employee contribution option gets a positive value, which causes the residue option to increase, as the pension fund is a zero sum game. The deficit option decreases more in absolute value with respect to Policy 2 than the surplus option increases, as introducing recovery premium has more effect on the lower quantiles of the funding ratio.
Furthermore, as there will be given more indexation due to introducing recovery premium, although not much more, the indexation option increases in value from 13.0 to 13.1.

3.4 Policy 4: Additional instrument: catch up indexation

3.4.1 Classical ALM analysis

Funding ratio		**Positive indexation**		**Pension result**	
$E[FR_{N,15}]$	1.420	no indexation	0.129 (0.183)	$E[PR_{15}]$	0.944
$\sigma[FR_{N,15}]$	0.419	cond. indexation	0.377 (0.221)	$\sigma[PR_{15}]$	0.083
$\mathbb{P}[FR_{N,15} < 1]$	0.112	full indexation	0.494 (0.298)	$PR_{15}^{0.025}$	0.717
$FR_{N,15}^{0.025}$	0.788	catch up ind.	0.125 (0.090)	$PR_{15}^{0.500}$	0.997
$FR_{N,15}^{0.500}$	1.323	surplus sharing	0.000 (0.000)	$PR_{15}^{0.975}$	1.000
$FR_{N,15}^{0.975}$	2.497			$\mathbb{P}[i_{15} < 0]$	0.000
		Negative indexation			
Contribution		sustainability cut	0.000 (0.000)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.123 (0.174)	recovery plan	0.000 (0.000)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 11: Classical ALM output Policy 4

In Policy 4 the participants get their missed indexation back in case the funding ratio is high. From the classical ALM output in Table 11 it can be seen that in 12.5% of the time catch up indexation will be given, which affects all the other classical output results.
First of all, due to introducing catch up indexation, the funding ratio levels will decrease, where the decrease is the most significant in the higher quantiles, as catch up indexation is only given in case the funding ratio is higher than 130%. Still, the probability of underfunding increases from 9.8% to 11.2% with respect to Policy 3.
Due to the decrease in the funding ratio levels, the normal indexation given is less. Where in Policy 3 in 12.3% of the time no indexation will be given, in Policy 4 this percentage increases to 12.9. Furthermore, the time full indexation is given decreases with respect to Policy 3.
In total, the pension result increases, as catch up indexation will be given, which is mostly reflected in the 50% quantile, which increases from 0.928 to 0.997 with respect to Policy 3. The lowest quantile (2.5%) will not increase that much, as in these scenarios the funding level is not high enough such that catch up indexation can be given.
Finally, it can be seen from Table 11 that the percentage that the steering instrument recovery premium will be used increases from 11.7% to 12.3%.

3.4.2 Value-based ALM analysis

All these consequences of introducing catch up indexation are translated into the holistic balance sheet in Table 12. First of all, the residue option decreases in value, as the deficit option increases in absolute value due to an increase in the probability of underfunding and the surplus option decreases due to lower funding ratio levels.
Furthermore, it can be seen that the adjustment mechanism increases from 13.1 to 14.3, as the catch up indexation option gets a positive value. The indexation option itself decreases in value from 13.1 to 13.0, since less indexation will be given.
Finally, the employee contribution option increases in value by a small amount (from 1.996 to 2.010), which is not a significant increase. The reason for this effect is that the probability of paying recovery premium is approximately the same for both policies in the first ten years, whereas the probability increases in Policy 4 after the tenth year with respect to Policy 3. However, as the fund is closed at time zero, the effect of paying recovery premium at later years will not have extremely significant effects.

Holistic Balance Sheet					
Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		2.0	Adjustment mechanism (V_0^{AM})		14.3
Employee contribution option	2.0		Indexation option	13.0	
Employer guarantee option	0		Catch up indexation option	1.3	
			Surplus sharing option	0	
			Sustainability cut option	0	
			Recovery plan option	0	
			Residue option (V_0^{RO})		5.6
			Surplus option	16.8	
			Deficit option	-11.2	
		119.5			119.9

Table 12: Holistic balance sheet Policy 4

3.5 Policy 5: Additional instrument: sustainability cut

3.5.1 Classical ALM analysis

Funding ratio		**Positive indexation**		**Pension result**	
$E[FR_{N,15}]$	1.442	no indexation	0.109 (0.144)	$E[PR_{15}]$	0.934
$\sigma[FR_{N,15}]$	0.401	cond. indexation	0.383 (0.220)	$\sigma[PR_{15}]$	0.104
$\mathbb{P}[FR_{N,15} < 1]$	0.083	full indexation	0.508 (0.287)	$PR_{15}^{0.025}$	0.637
$FR_{N,15}^{0.025}$	0.872	catch up ind.	0.139 (0.101)	$PR_{15}^{0.500}$	0.997
$FR_{N,15}^{0.500}$	1.340	surplus sharing	0.000 (0.000)	$PR_{15}^{0.975}$	1.000
$FR_{N,15}^{0.975}$	2.497			$\mathbb{P}[i_{15} < 0]$	0.020
		Negative indexation			
Contribution		sustainability cut	0.025 (0.054)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.104 (0.137)	recovery plan	0.000 (0.000)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 13: Classical ALM output Policy 5

In Policy 5 a sustainability cut is introduced, which means that the benefits will be cut immediately if the funding ratio falls below 85%. As can be seen from Table 13 this occurs 2.5% of the time.
The first effect of introducing such a cut is that the lower funding ratio levels will increase, where the 2.5% quantile will always be higher than 0.85, which also can be seen in Table 13. Furthermore, introducing cuts will not significantly affect the 97.5% quantile after 15 years, which remains approximately the same with respect to Policy 4. Therefore, the funding ratio becomes less volatile. Additionally, these results cause the probability of underfunding to decrease by approximately two percentage points.
The indexation given will increase in Policy 5 with respect to Policy 4, since the funding ratio increases. As can be seen from Table 13 the time no indexation will be given at all decreases by two percentage points (where also the standard deviation decreases significantly), while the time full indexation is given increases by 1.4 percentage points. Furthermore, catch up indexation also increases by 1.4 percentage points.
Both the increase in indexation and the cuts have an effect on the pension result, which will decrease. The effect is largest for the 2.5% quantile, as in the downside the adjustment instrument the sustainability cut will be used and no indexation is given at all. It can be seen that this quantile decreases from 0.717 to 0.637. Due to this consequence, the pension

result gets more volatile.
Finally, it can be seen that the time where recovery premium is used, decreases from 12.3% to 10.4%, as the lower quantiles of the funding ratio increase in this case. Additionally, the standard deviation of using the instrument recovery premium decreases.

3.5.2 Value-based ALM analysis

Holistic Balance Sheet

Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		1.6	Adjustment mechanism (V_0^{AM})		3.1
Employee contribution option	1.6		Indexation option	13.4	
Employer guarantee option	0		Catch up indexation option	1.8	
			Surplus sharing option	0	
			Sustainability cut option	-12.1	
			Recovery plan option	0	
			Residue option (V_0^{RO})		16.5
			Surplus option	18.2	
			Deficit option	-1.7	
		119.1			119.6

Table 14: Holistic balance sheet Policy 5

All these effects are translated into the holistic balance sheet in Table 14. First of all, it can be seen that the residue option increases significantly in value from 5.6 to 16.5. This effect can mostly be related to the decrease in absolute value of the deficit option from -11.2 to -1.7, as the probability of underfunding decreases and the lower quantiles of the funding ratio increase with respect to Policy 4 due to the sustainability cut. Besides that, the surplus option also increases, although not as much as the deficit option.
Second of all, the indexation option increases in value from 13.0 to 13.4 and the catch up indexation option increases in value from 1.3 to 1.8, which both increase due to the fact that more indexation will be given in Policy 5.
Third of all, it can be seen in Table 14 that the sustainability cut option gets a negative value, which is significant. The reason for this significant negative value is that the benefits will only be reduced in bad scenarios (scenarios where there is underfunding), which get a high negative value in a risk neutral world. In total, this leads to an adjustment mechanism that decreases significantly.
Finally, it can be seen that the employee contribution option decreases in value from 2.0 to 1.6, since the recovery premium is used in fewer scenarios due to introducing the sustainability cut.

3.6 Policy 6: Additional instrument: recovery plan

3.6.1 Classical ALM analysis

In Policy 6 an additional five year recovery plan is introduced, where each year of the recovery plan a certain funding ratio level should be reached. In case the levels are not reached, the benefits are cut. First of all, it can be seen from Table 15 that the benefits are reduced in 3.0% of the times due to this recovery plan.
The first effect of such a recovery plan is that the different funding ratio levels increase, where the most significant increase is shown in the 2.5% quantile of the funding ratio, as

Funding ratio		Positive indexation		Pension result	
$E[FR_{N,15}]$	1.457	no indexation	0.097 (0.121)	$E[PR_{15}]$	0.927
$\sigma[FR_{N,15}]$	0.393	cond. indexation	0.382 (0.221)	$\sigma[PR_{15}]$	0.114
$\mathbb{P}[FR_{N,15} < 1]$	0.067	full indexation	0.521 (0.277)	$PR_{15}^{0.025}$	0.611
$FR_{N,15}^{0.025}$	0.945	catch up ind.	0.153 (0.114)	$PR_{15}^{0.500}$	0.996
$FR_{N,15}^{0.500}$	1.355	surplus sharing	0.000 (0.000)	$PR_{15}^{0.975}$	1.000
$FR_{N,15}^{0.975}$	2.497			$\mathbb{P}[i_{15} < 0]$	0.030
		Negative indexation			
Contribution		sustainability cut	0.020 (0.043)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.092 (0.114)	recovery plan	0.030 (0.059)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 15: Classical ALM output Policy 6

the recovery plan is only used in case the funding ratio is lower than 1.0, which causes the volatility of the funding ratio to decrease. Furthermore, the probability of underfunding is decreased by 1.6 percentage point due to introducing a recovery plan.
Due to higher funding ratio levels, the indexation given increases. It can be seen from Table 15 that the times where no indexation at all will be given, decreases from 10.9% to 9.7% with respect to Policy 5. Furthermore, full indexation can be given to the participants in more scenarios, namely in 1.3 percentage points of the time. Finally, the probability of the occurrence of catch up indexation also increases due to the five year recovery plan.
By introducing a recovery plan, the sustainability cut is not used as much as without the recovery plan. The time the sustainability cut is used decreases by 0.5 percentage point.
Both the amount of indexation and reduction given have an effect on the pension result, which will decrease in the lower quantiles. Due to the fact that the higher quantiles will not decrease, the volatility of the pension result increases.
Finally, as the funding ratio levels are higher by introducing a recovery plan, the recovery premium is not used as much as in Policy 5; it decreases from 10.4% to 9.2%.

3.6.2 Value-based ALM analysis

Holistic Balance Sheet

Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		1.1	Adjustment mechanism (V_0^{AM})		0.4
Employee contribution option	1.1		Indexation option	14.0	
Employer guarantee option	0		Catch up indexation option	2.4	
			Surplus sharing option	0	
			Sustainability cut option	-6.4	
			Recovery plan option	-9.6	
			Residue option (V_0^{RO})		18.6
			Surplus option	19.2	
			Deficit option	-0.6	
		118.6			119.0

Table 16: Holistic balance sheet Policy 6

Again, the values of the different options on the holistic balance sheet in Table 16 can be explained with all these effects. First of all, due to increasing funding ratio levels, the value of the residue option increases. Where this increase is due to both an increase in the surplus

and a decrease in absolute value in the deficit option, as both funding ratio levels above and below 100% increase by introducing a recovery plan.
The positive adjustment options increase in value with respect to Policy 5, with the same reasoning as before; more indexation and catch up indexation will be given.
Furthermore, the values of the negative adjustment options decrease with respect to Policy 5 due to the fact that the recovery plan option gets a high negative value. The reason that this value is this high, is the same as before, namely that reducing the benefits in bad scenarios (scenarios where there is underfunding) gets a high negative value in a risk neutral world. It can also be seen that the sustainability cut option increases in value, as due to introducing a recovery plan, the sustainability cut is used less than in Policy 5. In total, this causes the adjustment mechanism to decrease from 3.1 to 0.4.
Finally, it can be seen that the contribution option decreases from 1.6 to 1.1, as the recovery premium is used less in Policy 6 with respect to Policy 5.

3.7 Policy 7: Additional instrument: surplus sharing

3.7.1 Classical ALM analysis

Funding ratio		**Positive indexation**		**Pension result**	
$E[FR_{N,15}]$	1.348	no indexation	0.100 (0.121)	$E[PR_{15}]$	0.984
$\sigma[FR_{N,15}]$	0.254	cond. indexation	0.399 (0.211)	$\sigma[PR_{15}]$	0.170
$\mathbb{P}[FR_{N,15} < 1]$	0.075	full indexation	0.501 (0.263)	$PR_{15}^{0.025}$	0.611
$FR_{N,15}^{0.025}$	0.935	catch up ind.	0.136 (0.112)	$PR_{15}^{0.500}$	1.002
$FR_{N,15}^{0.500}$	1.306	surplus sharing	0.289 (0.260)	$PR_{15}^{0.975}$	1.316
$FR_{N,15}^{0.975}$	1.900			$\mathbb{P}[i_{15} < 0]$	0.033
		Negative indexation			
Contribution		sustainability cut	0.020 (0.043)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.095 (0.114)	recovery plan	0.031 (0.060)	$\mathbb{P}[EG > 0]$	0.000 (0.000)

Table 17: Classical ALM output Policy 7

In Policy 7 the participants share in the surplus in case the funding ratio is above 140%. It can be seen in Table 17 that in 28.9% of the time the participants share in the surplus. Note that this surplus sharing is smoothed over 10 years, which explains the result that the percentage of using the policy instrument surplus sharing is higher than for catch up indexation, even though catch up indexation will be given already if the funding ratio is above 130%.
The effect of introducing surplus sharing is visible in the funding ratio levels. The most significant result is that the 97.5% quantile of the funding ratio decreases from 2.497 to 1.900 with respect to Policy 6. Therefore, due to surplus sharing, the funding ratio will not get an extremely high value anymore. Since the upper quantile decreases significantly, the volatility of the funding ratio decreases from 0.393 to 0.254. Besides that, the probability of underfunding increases by 0.8 percentage point with respect to Policy 6 due to surplus sharing.
These lower funding ratio levels affect the amount of indexation given. No indexation will be given in 0.3 percentage point more of the time, while full indexation is given in 2 percentage points less of the time with respect to Policy 6. This effect also works through on the catch up indexation, which decreases by 1.7 percentage points.
As the funding ratio levels decrease, the reduction instruments will be used more extensively; the sustainability cut increases from 1.97% to 2.04%, while the recovery plan increases by

0.1 percentage point.
Both these indexation and reduction instruments have an effect on the pension result, which will increase due to the introduction of surplus sharing. This increase is only significant in the upper quantiles, as only in those quantiles the participants will share in the surplus. It can be seen that the 97.5% quantile increases from 1.000 to 1.316 with respect to Policy 6.
Finally, due to lower funding ratio levels, the steering instrument recovery premium will be used more, where the use increases from 9.2% of the time to 9.5% of the time.

3.7.2 Value-based ALM analysis

Holistic Balance Sheet

Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		1.1	Adjustment mechanism (V_0^{AM})		5.6
Employee contribution option	1.1		Indexation option	14.3	
Employer guarantee option	0		Catch up indexation option	2.3	
			Surplus sharing option	5.3	
			Sustainability cut option	-6.5	
			Recovery plan option	-9.8	
			Residue option (V_0^{RO})		13.4
			Surplus option	14.0	
			Deficit option	-0.6	
		118.6			119.0

Table 18: Holistic balance sheet Policy 7

All the effects discussed can be seen in the value of the options on the holistic balance sheet in Table 18. The residue option decreases, which is caused by a decrease in the surplus option from 19.2 to 14.0. The reason for this significant decrease is the fact that the upper quantiles of the funding ratio are significantly lower in case of surplus sharing.
Furthermore, the positive adjustment options increase in value. The reason for this effect is that the surplus sharing option gets a positive value. Additionally, the catch up indexation option decreases in value from 2.4 to 2.3 as less catch up indexation is given in Policy 7 with respect to Policy 6. Note that the indexation option itself increases in value from 14.0 to 14.3 even though there will be given less percent of the time full indexation. The reason for this increase in value is that the level of conditional indexation is higher in Policy 7.
As the negative adjustment instruments are used more extensively in Policy 7, the value of the negative adjustment options decrease with respect to Policy 6. Here the recovery plan option decreases more in value than the sustainability cut option as the use of the recovery plan is increased more than the sustainability cut with respect to Policy 6.
In total, the adjustment mechanism increases with respect to Policy 6, as the surplus sharing option gets a significant value.
Finally, the employee contribution option increases by a small amount from 1.099 to 1.118, as this steering instrument will be used in more scenarios in Policy 7 than in Policy 6.

3.8 Policy 8: Additional instrument: employer guarantee

3.8.1 Classical ALM analysis

In Policy 8 the employer gives a guarantee in case the funding ratio is between 85% and 90%, such that it brings the funding ratio back to 90%. Table 19 shows that the employer has to

Funding ratio		**Positive indexation**		**Pension result**	
$E[FR_{N,15}]$	1.356	no indexation	0.095 (0.115)	$E[PR_{15}]$	0.998
$\sigma[FR_{N,15}]$	0.254	cond. indexation	0.398 (0.211)	$\sigma[PR_{15}]$	0.156
$\mathbb{P}[FR_{N,15} < 1]$	0.069	full indexation	0.507 (0.261)	$PR_{15}^{0.025}$	0.668
$FR_{N,15}^{0.025}$	0.940	catch up ind.	0.136 (0.109)	$PR_{15}^{0.500}$	1.006
$FR_{N,15}^{0.500}$	1.313	surplus sharing	0.293 (0.259)	$PR_{15}^{0.975}$	1.316
$FR_{N,15}^{0.975}$	1.915			$\mathbb{P}[i_{15} < 0]$	0.031
		Negative indexation			
Contribution		sustainability cut	0.018 (0.039)	**Employer guarantee**	
$\mathbb{P}[c^{rec} > 0]$	0.090 (0.109)	recovery plan	0.029 (0.057)	$\mathbb{P}[EG > 0]$	0.035 (0.058)

Table 19: Classical ALM output Policy 8

pay in 3.5% of the time to make sure the funding ratio is brought back to 90%.

The effect of introducing the employer guarantee is visible on the funding ratio, where the funding ratio levels are all increased. The effects are not that significant, as the funding ratio would be brought back to 100% in a five year recovery plan considering a policy without the employer guarantee like Policy 7. In Policy 8, the funding ratio is brought to 90% immediately, whereas the funding ratio would be brought back to 90% in several steps in Policy 7. The probability of underfunding does not change much, it decreases by 0.6 percentage point, as the effect on the different funding ratio levels is not that significant.

The indexation given to the participants is affected by introducing the employer guarantee. First of all, due to higher funding ratio levels, in 0.5 percentage point of the time less no indexation at all is given, while in 0.6 percentage point of the time more full indexation is given with respect to Policy 7. The effect on the catch up indexation is less visible, as the catch up indexation given increases from 13.60% to 13.61%. Also the time where surplus sharing will be given increases by 0.4 percentage point.

As the funding ratio levels increase, the percentage of time where the benefits are reduced decreases. Both the use of the sustainability cut and the recovery plan decrease by 0.2 percentage point.

The indexation and reduction instruments have an effect on the pension result. As the benefits will be cut less, the pension result increases. The most significant increase can be seen in the 2.5% quantile, which increases from 0.611 to 0.668, as the cuts occur in the bad states where the funding ratio is low. The increase is not visible in the 97.5% quantile, as the employer guarantee is only implemented in the states where the funding ratio is lower than 90%.

Due to higher funding ratio levels, the recovery premium instrument will be used less with respect to Policy 7, which decreases by 0.5 percentage point.

3.8.2 Value-based ALM analysis

The effects just explained can be translated into value terms and added as conditional assets and liabilities on the holistic balance sheet in Table 20. The first effect that can be seen is that the residue option increases, as the funding ratio levels increase with respect to Policy 7. Here the deficit option remains approximately the same; it still decreases in absolute value (from -0.644 to -0.588) since the probability of underfunding decreases. The surplus option indicates the largest effect as the largest increases in the funding ratio occur in the higher quantiles.

The adjustment mechanism also increases. This is due to several aspects. Firstly, the indexation option, the catch up indexation option, and the surplus sharing option all increase in

Holistic Balance Sheet

Assets (A_0)		117.5	Liabilities (L_0)		100.0
Sponsor support (V_0^{SPS})		6.0	Adjustment mechanism (V_0^{AM})		9.8
Employee contribution option	1.0		Indexation option	14.5	
Employer guarantee option	5.0		Catch up indexation option	2.4	
			Surplus sharing option	5.4	
			Sustainability cut option	-5.7	
			Recovery plan option	-6.8	
			Residue option (V_0^{RO})		14.1
			Surplus option	14.7	
			Deficit option	-0.6	
		123.5			123.9

Table 20: Holistic balance sheet Policy 8

value as in more percent of the time indexation is given in Policy 8 with respect to Policy 7. Secondly, the most interesting result of introducing the employer guarantee is the effect on the negative adjustment options. First of all, the sustainability cut option decreases in absolute value from -6.5 to -5.7, as due to the employer guarantee the funding ratio is immediately brought back to 90%, such that in case the funding ratio decreases again to levels below 85% (i.e. levels where the sustainability cut is used), it will not be as far below 85% as in Policy 7. Second of all, the recovery plan option decreases in absolute value from -9.8 to -6.8; the benefits will not be cut as much, since in the first few steps of the recovery plan the recovery funding ratios are already met, due to the employer guarantee.
Finally, the sponsor support increases significantly in value, which is caused by the high positive value of the employer guarantee option. Even though the instrument is only used in 3.5% of the time, the value is high as this policy instrument is only used in the bad scenarios. Furthermore, the employee contribution option does not decrease that much in value, as the use of this steering instrument will not decrease significantly.

3.9 Generational effects in closed fund framework

As a pension fund is introduced to create risk sharing among participants, it is of great importance that a pension fund will be solvent such that it can meet the promises made to its participants. Otherwise the younger generations will suffer eventually, as the fund has no assets left to pay the accrued benefits. On the other hand, a pension fund should not withhold too much money from their participants as a safety buffer, since in this case the older participants suffer and too much wealth is pushed into the future to the younger generations. As can be seen, a pension fund should find an appropriate balance between these two contrasts.
Therefore, in the analysis in the remainder of this thesis, different cohort groups will be taken into account to see what effect different policies have on those different cohorts.
A distinction is made between three disjoint cohort groups:

- Young cohorts: participants aged 25 - 44 at time zero;
- Middle cohorts: participants aged 45 - 64 at time zero;
- Old cohorts: participants aged 65 - 99 at time zero.

Note that the disjoint groups are followed through time, where no participant can switch from one group to another.

Several options determined for the eight different policies in Section 3.1 up to Section 3.8 can be separated among these three cohort groups, where the employer guarantee option (guarantee paid by employer) and the residue option cannot yet be allocated among different cohorts.
The first option that can be divided among cohort groups, is the employee contribution option V_0^{EC}, which is part of the sponsor support. The employee contribution option has an effect on the young and middle cohort group only as the old cohort group immediately receives benefits from time zero on. The higher the value of the employee contribution option, the more contributions the participants will pay to the pension fund, the worse the effect is for those participants. Note that the remaining part of the sponsor support, the employer guarantee option V_0^{EG}, cannot be assigned to a specific cohort group within the fund.

Besides the employee contribution option, also the value of the adjustment mechanism V_0^{AM} can be separated among the cohort groups, as the adjustment mechanism has an effect on the accrued benefits. Here a distinction is made between the positive adjustment mechanism, which is the sum of the positive adjustment options, namely the indexation option, the catch up indexation option, and the surplus sharing option ind_1, ind_2, and ind_3 respectively, i.e.:

$$V_0^{AM+} = V_0^{ind_1} + V_0^{ind_2} + V_0^{ind_2},$$

and the negative adjustment mechanism, which is the sum of the negative adjustment options, namely the sustainability cut option and the recovery plan option ind_4 and ind_5 respectively, i.e.:

$$V_0^{AM-} = V_0^{ind_4} + V_0^{ind_5}.$$

The higher the value of the positive adjustment mechanism V_0^{AM+}, the more indexation the participants receive, the better the effect is for those participants. On the other hand, the higher the absolute value of the negative adjustment mechanism, the more the benefits of the participants are reduced, the worse the effect is for those participants. Note that the negative adjustment mechanism only has a value for the last four policies.

Finally, on the holistic balance sheet, the residue option is stated. The value of the residue option V_0^{RO} cannot simply be allocated among different cohorts, as the residue does not belong to a specific cohort. However, the value of the residue option still has an effect on different cohorts, as the higher the residue option, the more wealth will be shifted to the generations still in the fund after time T. Therefore, an interesting effect that is considered is the difference between the value of the residue option V_0^{RO} and the residue at time zero R_0

$$\Delta R = V_0^{RO} - R_0,$$

as this indicates the value transfer to the younger generations.
However, as the pension fund is fictitiously closed at time zero, and besides that the policy that is chosen is not adjusted to the fact that the fund is closed, the change in the residue does not give the correct picture. The reason for this fact is that nowhere in the policy is stated how the residue should be divided among different cohorts. Therefore, this study is repeated in Section 5 where the fund will not be fictitiously closed but remains open for new participants.

In total, the effect that actually can be assigned to different cohort groups is equal to the negative value of the employee contribution option plus the value of the positive adjustment mechanism plus the value of the negative adjustment mechanism:

$$\text{Total effect} = -V_0^{EC} + V_0^{AM+} + V_0^{AM-}.$$

Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
1	Young		5.2		5.2
	Middle		21.5		21.5
	Old		8.9		8.9
		Change in residue (ΔR)			-35.2
2	Young		1.6		1.6
	Middle		7.8		7.8
	Old		3.6		3.6
		Change in residue (ΔR)			-12.6
3	Young	-1.2	1.6		0.4
	Middle	-0.8	7.9		7.1
	Old		3.6		3.6
		Change in residue (ΔR)			-10.7
4	Young	-1.2	1.8		0.6
	Middle	-0.8	8.6		7.8
	Old		3.9		3.9
		Change in residue (ΔR)			-11.9
5	Young	-1.0	1.9	-2.1	-1.2
	Middle	-0.7	9.1	-7.2	1.2
	Old		4.1	-2.7	1.4
		Change in residue (ΔR)			-1.0
6	Young	-0.6	2.1	-2.7	-1.2
	Middle	-0.5	9.9	-9.5	-0.1
	Old		4.3	-3.7	0.6
		Change in residue (ΔR)			1.1
7	Young	-0.7	2.7	-2.8	-0.8
	Middle	-0.5	13.2	-9.7	3.0
	Old		5.9	-3.8	2.1
		Change in residue (ΔR)			-4.1
8	Young	-0.6	2.8	-2.2	0
	Middle	-0.4	13.5	-7.4	5.7
	Old		6.0	-2.9	3.1
		Change in residue (ΔR)			-3.4
		Employee guarantee ($-V_0^{EG}$)			-5.0

Table 21: Effects for three different cohort groups for the eight policies introduced in Section 3, namely the young cohort group, the middle cohort group, and the old cohort group.

In Table 21 the effects for the disjoint cohort groups for each policy are presented. However as emphasized before, note these generational effects are not representative as the policy of the fund is not adjusted to the fact that the fund will be fictitiously closed at time zero. It can be seen that for each policy the employee contribution option has a higher effect in absolute value for the young cohort group than for the middle cohort group. The reason for this effect is that the cohorts of the middle group start in the accumulation phase where

those participants pay recovery premium if the pension fund has a low funding position. However, the oldest cohorts in the middle cohort group will end in the pension phase where those participants start receiving their accrued benefits.
The market value of the positive adjustment mechanism is the lowest for the young cohort group, as those cohorts have not accrued as much benefits as the other two groups. Furthermore, the accrued benefits of the young cohort group do not have to be paid out for at least 20 years at time zero. The reason that the market value of the old cohort group is much lower than the market value of the middle cohort group is that due to lower survival probabilities of the old cohort group the discount factor will be lowered much more than the discount factor of the middle cohort group.
The magnitude of the negative adjustment mechanism is exactly the other way around with respect to the positive adjustment mechanism, with the same reasoning. This makes sense, as the negative adjustment mechanism is exactly the opposite of the positive adjustment mechanism. Therefore, the negative adjustment mechanism is the lowest is absolute value for the young cohort group, and the highest in absolute value for the middle cohort group.
Note that Policy 1 up to Policy 7 are zero sum games for the different generations, as the total effects, taking into account the change in the residue, sum up to approximately zero. Only Policy 8 is not a zero sum game for the different generations, as here the employer gives a certain guarantee, however, taking into account the negative effect of the employee guarantee results in the fact that all the effects sum up to approximately zero.[5]

All the separate effects for different cohort groups and different options going from one policy to another, occur with the same reasoning as explained throughout Section 3.1-3.8. Focusing on the total effects for each cohort group per policy give some new insights.
First of all, one might say that Policy 1 is preferable, since the total effects are the highest for each cohort group. However, by giving full indexation in every scenario, the probability that the fund cannot pay all their participants is extremely high. Therefore, a pension fund having a pension system like Policy 1 will not be able to give the participants in the long run all that it has promised. The consequence is that the younger participants will eventually suffer from this pension system, which also is shown in Section 5.3, where this study is repeated for the open fund framework.
From Policy 5 onwards, the deficit option decreases immensely in absolute value due to introducing benefit reductions, which indicates that the fund will not pass on the deficit to the younger participants in the long run, but solves it with the participants in the fund.
It can be seen from Table 21 that Policy 6 gives the worst effects for all cohort groups. The reason is that in Policy 6 the benefits will be cut if the funding ratio is low, but in case the funding ratio is extremely high the participants do not share in the surplus.
In Policy 7, the participants will be compromised for the benefit cuts if the funding ratio is low, as here the participants do share in the surplus. The middle cohort group benefits the most from changing from Policy 6 to Policy 7. However, the effect for the young cohort group is still negative, due to the recovery premium and the low accrued benefits.
Finally, in Policy 8 the effect for the young cohort group will not be negative anymore. Besides that, the effects for the middle and old cohort group increase further. The reason is that the employer bears a lot of the risks, which causes the market value of the employer to decrease with respect to Policy 7.
As is emphasized before, the generational effects shown in Table 21 are not representative with reality, as the fund will not be closed in reality, therefore this study is redone for the open fund framework, which is shown in Section 5.3.

[5] The effects do not sum up to zero exactly due to rebalancing rounding-off errors.

4 Holistic balance sheet used as solvency measure in closed fund framework

4.1 Introduction

In the framework without the holistic balance sheet, a way to determine when a pension fund is solvent is by checking whether the funding ratio is larger than a required level, as is the case in the FTK regulation.
The traditional funding ratio gives some insights into the solvency and the quality of the fund, as the higher the funding ratio will be, the more able the fund is to pay the accrued benefits to its participants. Therefore, the higher the funding ratio will be, the better the effects are for the participants in the fund, while a lower funding ratio means mostly bad news for its participants. Note that these effects depend on the policy of the fund, where the effects for the participants decrease for lower funding ratios if for instance the fund cuts the benefits of the participants if the funding ratio is low.
The holistic funding ratio only gives insights into the solvency of the fund and not into the quality of the fund. If the holistic funding ratio is above 100 percent, it means that the policy of the fund will be sustainable during the horizon considered, while if the holistic funding ratio is lower than 100 percent the fund has set their policy instruments poorly. This holistic funding ratio does not provide information on the effects for the different generations. For instance, the holistic funding ratio can be above 100 percent, but if the sustainability cut option is very high in absolute value, the policy used by the fund does not mean good news for its participants, as their benefits are cut extensively.[6]

In the FTK regulation, the required funding ratio is determined such that the probability of underfunding in the next year will be smaller than 2.5 percent, i.e. $FR^{req} = 1 + S$, where S is explained in Appendix A. One might wonder how far the regulator should intervene to decide what is in favor of the participants within the fund. The participants might not be pleased with the buffer S, as all working participants have to pay a cost covering contribution which is increased by S, as given in (7). The role of the regulator should be to check whether the pension fund does not promise things which are not achievable.
The embedded options on the holistic balance sheet already include a buffer for certain risks. For instance, a call option can be bought for a market consistent price in order to make sure that the buyer is protected for price rises in a perfect Black-Scholes world (Hull, 2009). Therefore, buyers of a call option have no downside risk, where they only can lose the price paid for the option they bought. The same reasoning applies for the embedded options on the holistic balance sheet. If the fund pays the market consistent value of the adjustment mechanism, the fund has no downside risks left. Therefore, one might argue that no buffer is needed, as all downside risks are hedged due to the embedded options. However, as we do not live in a perfect Black-Scholes world, still a certain buffer is needed in order to be sure that all risks are hedged.

In this section, two different solvency measures are introduced and explained. First of all, EIOPA proposes a solvency measure in which the values of the sponsor support and the

[6] If trustees of a pension fund would like to use the holistic funding ratio in order to create a policy, it should be taken into account that such a policy will lead to serious problems, as the embedded options have to be valued at certain points into the future, in order to be able to explore if the policy will be sustainable. Hence, the scenarios that have to be used explode over time, due to the fact that at time zero M scenarios are generated, which in turn also need M scenarios to value the embedded options at time one, where M is a large number like 5000. However, methods are available to overcome these nesting issues, such as the Longstaff-Schwartz method.

adjustment mechanism on the holistic balance sheet are taken into account. This solvency measure is further clarified in Section 4.2. We criticize this measure, since EIOPA does not yet take into account the fact that the embedded options on the holistic balance sheet already perform as a buffer, while on top of that EIOPA does not yet take into account the fact that the fund fictitiously closes at time zero.
Therefore we introduce a new solvency measure in which the value of the residue option plays a major role. This solvency measure is called the dynamic approach as the required criteria depends on the horizon considered, where it does take into account the aspect of fictitiously closing the fund at time zero. The dynamic measure is developed as if the regulator is right in setting the solvency capital requirement S. This second measure is further explained and illustrated in Section 4.3.

The eight policies elaborated on in Section 3 are tested by both solvency measures in Section 4.2 and Section 4.3. Therefore a summary of the eight policies introduced in Section 3 is given in Table 22. Here A_0 are the assets of the pension fund, V_0^{SPS} is the value of the

Policy	1	2	3	4	5	6	7	8
A^{HBS}	117.5	117.5	119.5	119.5	119.1	118.6	118.6	123.5
A_0	117.5	117.5	117.5	117.5	117.5	117.5	117.5	117.5
V_0^{SPS}	0	0	2.0	2.0	1.6	1.1	1.1	6.0
L^{HBS}	135.6	113.0	113.1	114.3	103.1	100.4	105.6	109.8
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	35.6	13.0	13.1	14.3	15.2	16.4	21.9	22.3
V_0^{AM-}	0	0	0	0	-12.1	-16.0	-16.3	-12.5
V_0^{RO}	-17.7	4.9	6.8	5.6	16.5	18.6	13.4	14.1
FR^{HBS}	0.867	1.040	1.057	1.046	1.156	1.181	1.123	1.125

Table 22: Summary of the option values of the eight policies introduced in Section 3

sponsor support, V_0^{AM+} is the value of the positive adjustment mechanism, V_0^{AM-} is the value of the negative adjustment mechanism, and V_0^{RO} is the value of the residue option. Furthermore, the assets on the holistic balance sheet are given by A^{HBS}, where it holds that

$$A^{HBS} = A_0 + V_0^{SPS}.$$

The liabilities on the holistic balance sheet are given by L^{HBS}, where it holds that

$$L^{HBS} = L_0 + V_0^{AM+} + V_0^{AM-}.$$

Finally, the holistic funding ratio FR^{HBS} is given by

$$FR^{HBS} = \frac{A^{HBS}}{L^{HBS}}.$$

Note that in the case the holistic funding ratio will be larger than 100%, the residue option is positive.

Finally, in Section 4.4 a sensitivity analysis is done to see the effects on both the different option values and the two solvency measures.

4.2 Solvency measure: EIOPA

EIOPA proposes a solvency measure to measure if a pension fund is solvent, in which the options on the holistic balance sheet are taken into account.
First of all, just as in the FTK regulation in the Netherlands, EIOPA proposes a solvency capital requirement which a pension fund should hold as a surplus, where the Solvency Capital Requirement formula is taken from Solvency II. As the precise parameters in this formula are not yet declared and this formula gives approximately the same result as the square root formula in the FTK regulation explained in Appendix A, in the remainder of this thesis, it is assumed that the solvency capital requirement is the same as explained in Appendix A. Therefore, the required funding ratio a pension fund should have is equal to $FR^{req} = 1 + S$.

Now, EIOPA proposes that the option values on the holistic balance sheet should be taken into consideration in meeting this solvency capital requirement.
At first, the solvency capital requirement should be determined in the usual way, i.e. with the traditional balance sheet as given in Table 1 where it holds that

$$A_0 = L_0 + R_0.$$

This means that the solvency capital requirement is equal to the percentage of the liabilities a pension fund should hold in addition to its liabilities. In the traditional case this can be translated to the fact that the residue should be larger than or equal to the solvency capital requirement, i.e. $R_0 \geq S \cdot L_0$.
However, in the EIOPA measure it is not necessarily the case that if the residue is smaller than the solvency capital requirement, the pension fund is not solvent. Namely, the values of the sponsor support and the adjustment mechanism should be taken into account, where the value of the sponsor support is added to the residue as it is stated on the asset side of the holistic balance sheet, while the value of the adjustment mechanism is subtracted as this is stated on the liability side of the holistic balance sheet. Recall that on the holistic balance sheet assets (A_0) plus the sponsor support (V_0^{SPS}) are stated on one side and liabilities (L_0) plus the positive adjustment mechanism (V_0^{AM+}) plus the negative adjustment mechanism (V_0^{AM-}) plus the residue option (V_0^{RO}) on the other side, such that it holds that

$$A_0 + V_0^{SPS} = L_0 + V_0^{AM+} + V_0^{AM-} + V_0^{RO},$$

as given in Table 2. Therefore, according to the EIOPA solvency measure, it should hold that

$$R_0 + V_0^{SPS} - V_0^{AM+} - V_0^{AM-} \geq S \cdot L_0. \tag{17}$$

The reasoning for this solvency measure is that if a pension fund is not solvent taking into account the unconditional assets and liabilities only, and the pension fund is solvent taking into account the option values, the pension fund has the right steering and adjustment instruments to recover to its required funding ratio, such that the pension fund has a hedge for shocks in returns and interest rates that might occur.

To give an example of the EIOPA solvency measure, imagine that a pension fund should hold 20% of its liabilities as surplus, i.e. $S = 20\%$. However, the actual residue of the pension fund is 10% of its liabilities, i.e. $FR = 110\%$ instead of 120%. According to the traditional rules without taking into account the holistic balance sheet, the pension fund does not meet its solvency requirement. Nevertheless, the fund can still be solvent according to the EIOPA solvency measure if for instance the sponsor support is equal to 10% of its liabilities, while the other options are equal to zero, since in this case the EIOPA solvency requirement given in (17) is satisfied, i.e. $R_0 + V_0^{SPS} - V_0^{AM+} - V_0^{AM-} = 0.10 + 0.10 - 0 - 0 = 0.20 \geq S$.

The eight policies considered in Section 3 are tested on being solvent with the help of the EIOPA solvency measure. In Table 23 the results of the test can be seen. It shows that only

Policy	1	2	3	4	5	6	7	8
EIOPA measure	-0.181	0.045	0.064	0.052	0.161	0.182	0.130	0.137
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✔	✘	✘

Table 23: EIOPA solvency test for the eight policies introduced in Section 3

Policy 6 of the eight policies considered is solvent according to the EIOPA solvency measure in spite of the fact that all pension funds start at time zero with a funding ratio equal to the required level. However, is this really the result the trustees of a pension fund would like to achieve for its participants?
As is explained in Section 5.3, Policy 1 is a really poor policy, as the residue option has a negative value. Introducing the adjustment instrument conditional indexation in Policy 2 already makes sure that the residue option becomes positive. However, Policy 2 up to Policy 4 are still poor policies, as the value of the deficit options are too high in absolute value, which indicates that the pension fund passes on the deficit to the participants still in the fund in the long run.
From the policies remaining, Policy 6 is the worst from a generational perspective, as it implements the most value transfers to its younger participants, while the separated effects are the lowest due to benefit cuts in the lower quantiles of the funding ratio and due to the absence of sharing in the high investment returns in the higher quantiles of the funding ratio. However, according to the solvency measure proposed by EIOPA, the pension fund is only solvent in case it has a pension system that points into the direction of Policy 6, which is not a pension system that would be appreciated by its older participants.

It can be seen that EIOPA aims to match the options on the holistic balance sheet with the solvency capital requirement S. As explained before, EIOPA does not yet take into account the fact that the embedded options on the holistic balance sheet already perform as a buffer, with as consequence that the buffer should not be this high. On top of that, as the fund fictitiously closes at time zero, at the end of the horizon considered fewer participants are still in the fund, while the solvency capital requirement S is based on the liabilities at time zero. Hence, for both these reasons the buffer S chosen by EIOPA is too high and not clearly addressed.

4.3 Solvency measure: dynamic approach

In this section, we introduce a new solvency measure, the dynamic solvency measure, which does take into account the fact that the fund fictitiously closes at time zero. Furthermore, the required level of this measure is set as if the regulator is right in setting the solvency capital requirement S, where the value of the residue option plays a major role. Note that the values of the other options on the holistic balance sheet are still implicitly taken into account, as a pension fund is a zero sum game.
First of all, recall that the solvency capital requirement S is the surplus a pension fund should have in addition to its liabilities, i.e. S is given as a percentage of the liabilities, where the required funding ratio results in $FR^{req} = 1 + S$, as given in Appendix A. Now the dynamic

solvency measure is determined in three steps, which are illustrated in Figure 2.

Step 1 At the start of time zero a pension fund should hold a funding ratio equal to at least $FR^{req} = 1 + S$. Therefore, one could reason that the residue option should be equal to at least S, since otherwise a negative value transfer to the younger generations is present. In general terms this can be translated to

$$V_0^{RO} \geq S \cdot L_0,$$

which is represented by the solid line in Figure 2, i.e. the value of the residue option should be at least above the solid line.

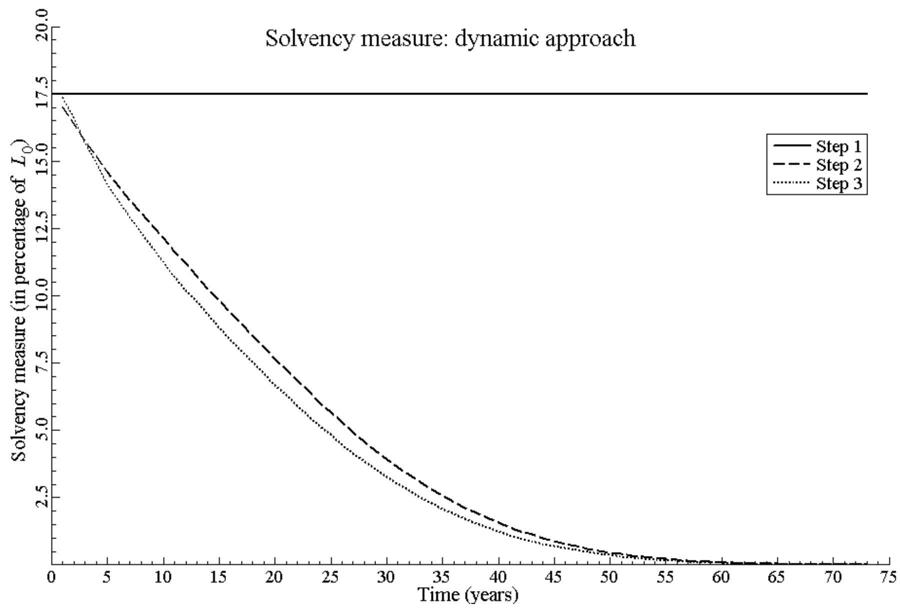

Figure 2: The dynamic solvency measure is presented in three steps, where the third and final step shows the actual dynamic solvency measure; the residue option should be larger than or equal to the dotted line, which is horizon dependent.

Step 2 However, it should be taken into account that as time passes, the liabilities shrink, due to the fact that the fund will be fictitiously closed at time zero. The solvency capital requirement S is set such that the fund will be able to meet its liabilities in case return or interest rate shocks occur. Therefore, as S is a percentage of the liabilities, the pension fund should hold for instance at time 15 the amount $S \cdot L_{15}$, since the fund has no need to withhold the amount $S \cdot L_0$. Therefore, to express the constraint in present value terms, it should hold that the residue option should be larger than or equal to the solvency capital requirement times the present value of the liabilities at the end of the horizon considered, i.e.

$$V_0^{RO} \geq S \cdot PV(L_T),$$

which is illustrated in Figure 2 by the dashed line, i.e. the value of the residue option should be at least above the dashed line. At the end of the horizon the constraint $S \cdot PV(L_T)$ goes to zero, as no liabilities are left. Figure 2 is constructed on the basis of Policy 8, note that due to different policies the present value of the liabilities after time T will be different.

Step 3 One should also take into account that due to fictitiously closing the fund at time zero, the duration of the liabilities decreases, which affects the solvency capital requirement S a pension fund should hold, to be able to be resistant for return and interest rate shocks that might occur. Therefore, the solvency capital requirement is not fixed over time, but will be decreasing over time. In the end the duration of the liabilities will go to zero, such that in case there is invested for 50% in stocks and for 50% in bonds, the solvency capital requirement will go to 12.5% (i.e. only the shocks that might occur in stock returns are taken into account in the end).[7] Therefore, the following restriction should hold instead:

$$V_0^{RO} \geq S(D_L) \cdot PV(L_T), \tag{18}$$

where S does depend on the duration of the liabilities D_L, which is illustrated by the dotted line in Figure 2, i.e. the value of the residue option should be at least above the dotted line.

After three steps, the dynamic solvency measure is presented by (18), which is given in Figure 2 as the dotted line. To be solvent, a pension fund should have a residue option that is larger than or equal to this dotted line, where the measure is dependent on the horizon considered.

In Table 24 the eight different policies presented in Section 3 are tested according to the dynamic solvency measure. To make it more comparable to the EIOPA solvency measure, the required level will not be given in terms of the magnitude of the residue option as in Figure 2, however, it will be given in terms of S. Therefore, the following is checked instead:

$$V_0^{RO} \geq S(D_L) \cdot PV(L_T) \Leftrightarrow \frac{V_0^{RO}}{PV(L_T)} \geq S(D_L).$$

It can be seen from Table 24 that Policy 5 up to Policy 8 are satisfied by the dynamic

Policy	1	2	3	4	5	6	7	8
Dynamic measure	-0.236	0.083	0.115	0.094	0.321	0.375	0.252	0.251
Required level	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
	✘	✘	✘	✘	✔	✔	✔	✔

Table 24: Dynamic solvency test for the eight policies introduced in Section 3

solvency constraint. As is explained in Section 5.3, Policy 1 up to Policy 4 are policies which have large negative value transfers to the younger generations, where the interests of all different stakeholders are not treated equally.
Second of all, Policy 5 and Policy 6 are too strict for the older generations, as the benefits will be cut in the downside of those policies but the participants will not share in the upside. It can be seen from Table 24 that the dynamic measure in Policy 5 and Policy 6 gives much higher results than the required level imposed by the solvency measure. This result also illustrates that the policies might be less strict than they are now, which will result in the fact that the residue option decreases in value.
Finally, Policy 7 and Policy 8 are better policies from a generational perspective compared to Policy 5 and Policy 6, as the value transfers between disjoint cohorts are smaller.
Since the dynamic measure does consider Policy 7 and Policy 8 to be solvent, while the EIOPA

[7] As the pension fund is fictitiously closed at time zero, the pension fund is aging, where the fund should invest more conservatively as time passes resulting in a solvency capital requirement approaching zero at the end of the horizon.

measure does not, the EIOPA solvency measure can be seen as a more strict measure. The reason for this result is that the required level of the EIOPA measure is too high as explained before, while the dynamic measure does take into account the fact that the fund is fictitiously closed at time zero.

4.4 Sensitivity analysis

In this section, a sensitivity analysis is done in which several aspects are adjusted, namely:

- Additional funding;
- Investment portfolio;
- Degree of maturity;
- Initial funding position;
- Horizon;
- Order of policy instruments;
- Policy ladders.

In the following sections the above aspects are adjusted separately and are compared with the benchmark case, in which the initial funding ratio is equal to the required funding ratio ($FR_0 = FR^{req}$), the investment portfolio consists for 50 percent of stocks and for 50 percent of bonds, the fund is equal to a projection of the Dutch population, the horizon considered is equal to 15 years ($T = 15$), and the order of the policy instruments with their policy ladders is as given in Figure 1.

4.4.1 Additional funding

In this section, one percent of the liabilities is added to the assets as additional funding. Therefore, the initial funding ratio is equal to 118.5% instead of 117.5%. In Table 25 Policy 1 up to Policy 4 are presented, for the benchmark case where the initial funding ratio is equal to the required funding ratio and for the case where the initial funding ratio is equal to the required funding ratio plus one percent. In the same structure, Policy 5 up to Policy 8 are presented in Table 26.
It can easily be seen from both tables that due to additional funding of one percent, for none of the policies the solvency measures give a different result. Therefore, in case of the EIOPA measure, still only Policy 6 is solvent, while in case of the dynamic measure Policy 5 up to Policy 8 are solvent. However, if more additional funding will be added, both the solvency tests might give another result, as is shown in Section 4.4.4.
Furthermore, it can be seen from both tables that the more policy instruments the pension contract has, the less effect adding additional funding has. For instance, in case of Policy 1, the one percent of additional funding goes straight to the residue option, which increases by the same amount. This effect can also be seen in the EIOPA measure, which increases from -0.181 to -0.171.
Considering a more complete contract like Policy 5, it can be seen in Table 26 that the one percent of additional funding will be divided among several options; the positive adjustment mechanism increases by 0.2, the negative adjustment mechanism decreases in absolute value by 0.3, and the residue option increases by 0.5. Also the effect on the two solvency measures becomes less.

Policy	$FR_0 = FR^{req}$ 1	2	3	4	$FR_0 = FR^{req} + 1\%$ 1	2	3	4
A^{HBS}	117.5	117.5	119.5	119.5	118.5	118.5	120.4	120.5
A_0	117.5	117.5	117.5	117.5	118.5	118.5	118.5	118.5
V_0^{SPS}	0	0	2.0	2.0	0	0	1.9	2.0
L^{HBS}	135.6	113.0	113.1	114.3	135.6	113.2	113.4	114.5
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	35.6	13.0	13.1	14.3	35.6	13.2	13.4	14.5
V_0^{AM-}	0	0	0	0	0	0	0	0
V_0^{RO}	-17.7	4.9	6.8	5.6	-16.7	5.6	7.5	6.3
FR^{HBS}	0.867	1.040	1.057	1.046	0.874	1.046	1.062	1.052
EIOPA measure	-0.181	0.045	0.064	0.052	-0.171	0.052	0.071	0.059
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✘	✘	✘
Dynamic measure	-0.236	0.083	0.115	0.094	-0.221	0.095	0.126	0.105
Required level	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
	✘	✘	✘	✘	✘	✘	✘	✘

Table 25: Effect of additional funding on the options on the holistic balance sheet and on the two solvency tests, for Policy 1 up to Policy 4

Policy	$FR_0 = FR^{req}$ 5	6	7	8	$FR_0 = FR^{req} + 1\%$ 5	6	7	8
A^{HBS}	119.1	118.6	118.6	123.5	120.1	119.6	119.6	124.4
A_0	117.5	117.5	117.5	117.5	118.5	118.5	118.5	118.5
V_0^{SPS}	1.6	1.1	1.1	6.0	1.6	1.1	1.1	5.9
L^{HBS}	103.1	100.4	105.6	109.8	103.6	100.9	106.4	110.5
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	15.2	16.4	21.9	22.3	15.4	16.6	22.3	22.8
V_0^{AM-}	-12.1	-16.0	-16.3	-12.5	-11.8	-15.7	-16.0	-12.3
V_0^{RO}	16.5	18.6	13.4	14.1	17.0	19.1	13.6	14.3
FR^{HBS}	1.156	1.181	1.123	1.125	1.160	1.185	1.124	1.126
EIOPA measure	0.161	0.182	0.130	0.137	0.165	0.187	0.132	0.139
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✔	✘	✘	✘	✔	✘	✘
Dynamic measure	0.321	0.375	0.252	0.251	0.328	0.381	0.254	0.253
Required level	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
	✔	✔	✔	✔	✔	✔	✔	✔

Table 26: Effect of additional funding on the options on the holistic balance sheet and on the two solvency tests, for Policy 5 up to Policy 8

In case of Policy 8, the additional funding will be divided among even more options. Additionally, the effect on the holistic funding ratio becomes rather small, as it increases from 1.125 to 1.126.
Hence, the more policy instruments the contract has, the less effect additional funding has on the holistic funding ratio and the solvency tests. The reason for this consequence is that the additional funding is divided among all the options that are stated on the holistic balance sheet, where both the asset side and the liabilities side increase by approximately the same value, since increasing the funding level has the effect that more indexation is given while less recovery premium is paid. Hence, the holistic funding ratio is approximately balanced. Therefore, pension funds with contracts that have more policy instruments have to make more effort to meet the solvency requirements based on the holistic balance sheet if they fail to do so.
From here on, only Policy 7 and Policy 8 are considered, as these are better policies from a generational perspective in comparison with the other six policies, as the value transfers are smaller, as is explained in Section 3.9 and is further explained in Section 5.3.

4.4.2 Investment portfolio

	50% Stocks/ 50% Bonds		100% Stocks		100% Bonds	
Policy	7	8	7	8	7	8
A^{HBS}	118.6	123.5	119.1	126.8	118.0	118.8
A_0	117.5	117.5	117.5	117.5	117.5	117.5
V_0^{SPS}	1.1	6.0	1.6	9.3	0.5	1.3
L^{HBS}	105.6	109.8	98.5	104.5	111.6	112.3
L_0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	21.9	22.3	30.8	32.2	16.7	16.7
V_0^{AM-}	-16.3	-12.5	-32.3	-27.7	-5.1	-4.4
V_0^{RO}	13.4	14.1	21.8	23.5	6.4	6.5
FR^{HBS}	1.123	1.125	1.208	1.213	1.057	1.057
EIOPA measure	0.130	0.137	0.205	0.222	0.064	0.064
Required level	0.175	0.175	0.312	0.312	0.051	0.051
	✘	✘	✘	✘	✔	✔
Dynamic measure	0.252	0.251	0.447	0.443	0.112	0.112
Required level	0.157	0.157	0.290	0.290	0.034	0.034
	✔	✔	✔	✔	✔	✔

Table 27: Effect of changing the investment portfolio on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 and Policy 8

In this section the investment portfolio is changed. Here two additional cases are considered, namely investing completely in stocks and investing completely in bonds. Both these investment strategies are presented in Table 27 together with the benchmark case in which is invested for 50% in stocks and for 50% in bonds. Despite the fact that the required funding ratio of the three separate investment portfolios is different, the initial funding ratio is kept the same and equal to 117.5%, in order to be able to concentrate on the effects of changing

the investment portfolio completely.
First, the effects of different investment portfolios that occur on the option values are explained. It can be seen in Table 27 that the option values increase in absolute value in case more is invested in stocks, while the option values decrease in absolute value as more is invested in bonds. This result makes sense, as stock returns are more volatile than bond returns. Due to the fact that in bad scenarios the stock returns decrease significantly more than the bond returns, the sponsor support becomes more valuable, while the value of the negative adjustment mechanism decreases significantly. It should be noted that in Policy 8 in the 100% stocks case, the sponsor support gets a strongly positive value due to the employer guarantee option.
Furthermore, in good scenarios, the stock returns increase significantly more than the bond returns, which increases the positive adjustment mechanism significantly in the 100% stocks case.
It can also be seen that in the 100% stocks case the negative adjustment mechanism increases more in absolute value than the positive adjustment mechanism increases with respect to the benchmark. The reason for this result is that bad scenarios receive more weight in a risk neutral world. The opposite effect occurs in the case where completely is invested in bonds, i.e. the negative adjustment mechanism decreases more in absolute than that the positive adjustment mechanism decreases with respect to the benchmark.
Additionally, the residue option changes significantly, where it increases in value in the 100% stocks case, and decreases in value in the 100% bonds case. This result is due to the fact that the surplus option changes significantly, where it increases in the 100% stocks case and decreases in the 100% bonds case. Furthermore, the deficit option displays the opposite effect, only in less magnitude. These results can again be explained by the fact that stock returns are more volatile.

In Table 28 the generational effects for the different investment portfolios are shown. However as emphasized in Section 3.9, note these generational effects are not representative as the policy of the fund will not be adjusted to the fact that the fund is fictitiously closed at time zero.
It can be seen that the value of the employee contribution option increases in absolute value in case of investing a larger fraction in stocks. However, this effect is not that large, as the steering instrument recovery premium does not have a great influence due to the fact that the fund is closed at time zero.
Furthermore, it can be seen that investing a larger fraction in stocks has a significant impact on the value of the adjustment mechanism for each cohort group. These effects are larger for the middle cohort group, as the cohorts in this group have accrued more benefits than the young cohort group and have higher survival probabilities than the old cohort group. It can be seen in Table 28 that the effects are larger for the negative adjustment mechanism than for the positive adjustment mechanism for both the 100% stocks case and the 100% bonds case with respect to the benchmark. For the 100% stocks case this even results in the fact that for the lower cohort groups the value of the total adjustment mechanism is negative with the consequence that the total effect is negative for those groups.
Another well known fact is that older generations should invest more conservatively, while younger generations should invest more aggressively. These facts are not necessarily visible in Table 28, as the total effects increase for all cohort groups in case a larger fraction is invested in bonds. The only exception occurs in Policy 8 for the old cohort group, where the diversified portfolio gives them the highest value. However, note that the change in residue is positive for the 100% stocks case, while it is negative for the 100% bonds case, where a positive change in the residue is considered good news for younger participants. Still, as em-

	Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
50% Stocks/ 50% Bonds	7	Young	-0.7	2.7	-2.8	-0.8
		Middle	-0.5	13.2	-9.7	3.0
		Old		5.9	-3.8	2.1
			Change in residue (ΔR)			-4.1
	8	Young	-0.6	2.8	-2.2	0
		Middle	-0.4	13.5	-7.4	5.7
		Old		6.0	-2.9	3.1
			Change in residue (ΔR)			-3.4
			Employee guarantee ($-V_0^{EG}$)			-5.0
100% Stocks	7	Young	-0.9	3.9	-5.1	-2.1
		Middle	-0.6	18.7	-19.0	-0.9
		Old		8.2	-8.2	0
			Change in residue (ΔR)			4.3
	8	Young	-0.8	4.1	-4.4	-1.1
		Middle	-0.6	19.6	-16.3	2.7
		Old		8.5	-7.0	1.5
			Change in residue (ΔR)			6.0
			Employee guarantee ($-V_0^{EG}$)			-7.8
100% Bonds	7	Young	-0.3	2.0	-1.0	0.7
		Middle	-0.2	10.0	-3.0	6.8
		Old		4.7	-1.1	3.6
			Change in residue (ΔR)			-11.1
	8	Young	-0.3	2.0	-0.9	0.8
		Middle	-0.2	10.0	-2.6	7.2
		Old		4.7	-0.9	2.8
			Change in residue (ΔR)			-11.0
			Employee guarantee ($-V_0^{EG}$)			-0.8

Table 28: Generational effects of changing the investment portfolio, for Policy 7 and Policy 8

phasized in Section 3.9, the generational effects given in Table 28 do not necessarily provide the right information as the fund will not be closed in reality. Therefore, this generational study is repeated for the open fund framework in Section 5.5.2.

Concentrating on the solvency measures, it can be seen in Table 27 that the required levels change for the different cases, whereas the required level of the 100% stocks case increases to 0.312 for the EIOPA solvency measure and to 0.290 for the dynamic solvency measure, and the required level decreases for the 100% bonds case to 0.051 and to 0.034 for the EIOPA and dynamic solvency measure respectively. The reason for these facts is that in case a larger fraction will be invested in stocks, a larger buffer should be withheld, as stock returns show more volatility.
It can be seen that due to a conservative portfolio, both policies are considered solvent according to both the EIOPA measure and the dynamic measure. The reason that the EIOPA solvency measure also is satisfied is that the required level decreases significantly. Besides that, the pension fund that invests completely in bonds starts with an initial funding ratio which is larger than the required level.
Furthermore, it can be seen in Table 27 that due to investing completely in stocks, the negative adjustment mechanisms gets a strongly negative value, which has as a consequence that the EIOPA constraint given in (17) will be very hard to meet. On the other hand, the dynamic solvency measure is not influenced by this aspect, as the residue option is still extremely valuable comparing it with the negative adjustment mechanism.

4.4.3 Degree of maturity

In this section the degree of maturity of the pension fund is varied. Next to the Dutch fund, a green and a gray fund is considered, where the Dutch fund is the average of the green and gray fund. A more extensive explanation of the green and gray fund can be found in Appendix C. In Table 29 the results of changing the fund are displayed, ceteris paribus. Note that the values given in this table are all normalized to the value of the liabilities of the specific fund. However, the liabilities of the gray fund are much higher in reality with respect to the Dutch fund, namely 140.9 in terms of the liabilities of the Dutch fund, while the liabilities of the green fund are much lower with respect to the Dutch fund, namely 62.2 in terms of the liabilities of the Dutch fund. The reason for this phenomenon is that many more participants, both workers and retirees, are present in the gray fund than in the green fund, as also can be seen in Figure 6 in Appendix C.
It can be seen in Table 29 that the value of the sponsor support is higher in the green fund, than in the gray fund. Since there are more working participants in the green fund with respect to number of the retirees than in the gray fund, i.e. the elderly dependency ratio is lower in the green fund as can be seen in Appendix C in Figure 7, more participants are in the fund respectively that pay contribution, which results in a higher value of the sponsor support for the green fund.
As in the gray fund the elderly dependency ratio is higher, more people are in the fund that receive their benefits with respect to people that are accruing benefits. Therefore the value of the residue option is lower for the gray fund than for the green fund.
Concentrating on the adjustment mechanism, it can be seen that both the effect of the positive and negative adjustment mechanism are larger for the green fund than for the gray fund. The reason for this result is that the value of the total liabilities decreases faster in the gray fund than in the green fund, due to the fact that the low survival probabilities in the gray fund drive the discount factors down. Hence, the effect of using the adjustment instruments diminishes in the gray fund. The negative adjustment mechanism increases more in absolute value for the green fund than the positive adjustment mechanism, with respect to the gray

Policy	Dutch fund 7	Dutch fund 8	Green fund 7	Green fund 8	Gray fund 7	Gray fund 8
A^{HBS}	118.6	123.5	119.1	124.7	118.4	123.0
A_0	117.5	117.5	117.5	117.5	117.5	117.5
V_0^{SPS}	1.1	6.0	1.6	7.2	0.9	5.5
L^{HBS}	105.6	109.8	104.9	109.7	105.9	109.9
L_0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	21.9	22.3	23.6	24.1	21.2	21.6
V_0^{AM-}	-16.3	-12.5	-18.7	-14.4	-15.2	-11.7
V_0^{RO}	13.4	14.1	14.6	15.5	12.9	13.5
FR^{HBS}	1.123	1.125	1.135	1.137	1.118	1.119
EIOPA measure	0.130	0.137	0.142	0.150	0.125	0.131
Required level	0.175	0.175	0.183	0.183	0.171	0.171
	✘	✘	✘	✘	✘	✘
Dynamic measure	0.252	0.251	0.242	0.242	0.258	0.256
Required level	0.157	0.157	0.160	0.160	0.155	0.155
	✔	✔	✔	✔	✔	✔

Table 29: Effect of changing the pension fund on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 and Policy 8

fund. Therefore, the total effect of the adjustment mechanism is highest for the gray fund.

The generational effects are shown in Table 30. However as emphasized in Section 3.9, note these generational effects are not representative as the policy of the fund will not be adjusted to the fact that the fund is fictitiously closed at time zero.
In Table 30 it can be seen that the effects that can be separated among the disjoint cohort groups all decrease changing from the Dutch fund to the green fund in Policy 7. The reason for these results is that in the green fund more recovery premium will be paid, while the total adjustment mechanism for all groups decreases. Note that the opposite effect occurs for the gray fund in Policy 7. These effects work through in the change in the residue, as this value increases in the green fund, while it decreases in the gray fund.
In Policy 8 the same effects can be seen, except for the fact that the effects for the middle cohort group changes, where it increases in the green fund, while it decreases in the gray fund.
Again, this generational study is repeated for the open fund framework as it is more in line with reality, where the results are shown in Section 5.5.3.

In Table 29 it can be seen that the required level of both the EIOPA solvency measure and the dynamic solvency measure change; the required level of the green fund increases, while the required level of the gray fund decreases. This is due to the fact that the duration of the liabilities increases in case of the green fund, i.e. there are more workers with respect to retirees, and the duration of the liabilities decreases in case of the gray fund, i.e. there are fewer workers with respect to retirees.
It can be seen that the EIOPA solvency measure does consider all policies for all different pension funds as being insolvent, while the dynamic solvency measure indicates that the

	Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
Dutch fund	7	Young	-0.7	2.7	-2.8	-0.8
		Middle	-0.5	13.2	-9.7	3.0
		Old		5.9	-3.8	2.1
			Change in residue (ΔR)			-4.1
	8	Young	-0.6	2.8	-2.2	0
		Middle	-0.4	13.5	-7.4	5.7
		Old		6.0	-2.9	3.1
			Change in residue (ΔR)			-3.4
			Employee guarantee ($-V_0^{EG}$)			-5.0
Green fund	7	Young	-1.0	3.9	-4.1	-1.2
		Middle	-0.6	14.8	-11.3	2.9
		Old		4.9	-3.2	1.7
			Change in residue (ΔR)			-2.9
	8	Young	-1.0	4.0	-3.2	-0.2
		Middle	-0.5	15.1	-8.7	5.9
		Old		5.0	-2.5	2.5
			Change in residue (ΔR)			-2.0
			Employee guarantee ($-V_0^{EG}$)			-5.7
Gray fund	7	Young	-0.5	2.2	-2.2	-0.5
		Middle	-0.4	12.6	-9.0	3.2
		Old		6.4	-4.0	2.4
			Change in residue (ΔR)			-4.6
	8	Young	-0.5	2.3	-1.7	0.1
		Middle	-0.4	12.8	-6.9	3.5
		Old		6.5	-3.1	3.4
			Change in residue (ΔR)			-4.0
			Employee guarantee ($-V_0^{EG}$)			-4.6

Table 30: Generational effects of changing the pension fund, for Policy 7 and Policy 8

different pensions are solvent.

4.4.4 Initial funding position

Another interesting change is a dramatic change in the initial funding position, here a really bad financial position is considered, where the initial funding ratio is equal to 80 percent, and a really good financial position is considered, where the initial funding ratio is equal to 150 percent.

In Table 31 the results are presented for the different initial funding positions. It can be seen that due to an extremely low funding position, the value of the sponsor support increases, as these steering instruments are used in the lower funding ratio levels which makes them more valuable. The opposite effect occurs in case of an extremely high funding position; the sponsor support will not be used that much, therefore this option becomes less valuable.

Furthermore, it can be seen that both the value of the positive adjustment mechanism and the negative adjustment mechanism change significantly. In case of an extremely low funding position, indexation is not given as much as in a higher funding position, which results in the fact that the positive adjustment mechanism decreases. Additionally, due to this low

Policy	$FR_0 = FR^{req}$ 7	8	$FR_0 = 80\%$ 7	8	$FR_0 = 150\%$ 7	8
A^{HBS}	118.6	123.5	82.7	92.2	150.6	153.6
A_0	117.5	117.5	80.0	80.0	150.0	150.0
V_0^{SPS}	1.1	6.0	2.7	12.2	0.6	3.6
L^{HBS}	105.6	109.8	76.5	84.9	128.8	131.4
L_0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	21.9	22.3	10.0	11.3	38.8	39.0
V_0^{AM-}	-16.3	-12.5	-33.5	-26.4	-10.0	-7.6
V_0^{RO}	13.4	14.1	6.4	7.6	22.3	22.7
FR^{HBS}	1.123	1.125	1.080	1.086	1.169	1.169
EIOPA measure	0.130	0.137	0.061	0.073	0.218	0.222
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✔	✔
Dynamic measure	0.252	0.251	0.177	0.183	0.327	0.324
Required level	0.157	0.157	0.157	0.157	0.157	0.157
	✔	✔	✔	✔	✔	✔

Table 31: Effect of changing the initial funding position on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 and Policy 8

funding position, the benefits will be cut considerably more than in the case of a higher funding position, which results in a negative adjustment mechanism with an extremely low value. Obviously the opposite effect occurs in case of an extremely high funding position.
Due to these effects, the residue option also changes in value as a pension fund is a zero sum game. The deficit option increases in absolute value in the low funding position, while the opposite effect occurs in the high funding position. However, the most significant effect is displayed in the surplus option, which decreases significantly in the low funding position and increase significantly in the high funding position, due to the fact that the probability of overfunding is much higher in the high funding position.

In Table 32 the generational effects are presented. However as emphasized in Section 3.9, note these generational effects are not representative as the policy of the fund will not be adjusted to the fact that the fund is fictitiously closed at time zero.
The effects for all the cohorts are disastrous in the case where the initial funding ratio is equal to 80 percent. The reason for those extreme negative effects is that due to a low initial funding position the indexation given to separate cohort groups is small, while the benefits will be cut excessively and the recovery premium instrument is used much. Due to these cuts, the change in the residue becomes extremely positive, which means good news for the younger participants which in turn might indicate a too strong reaction.
On the other hand, in case the initial funding position is equal to 150 percent, the opposite effects can be seen. The positive adjustment mechanism has an extremely high value, whereas the negative adjustment mechanism and the sponsor support have a low value in absolute terms. Here the change in the residue is extremely negative, which means that the older participants benefit more from the initial extremely high funding position than the younger participants.

	Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
$FR_0 = FR^{req}$	7	Young	-0.7	2.7	-2.8	-0.8
		Middle	-0.5	13.2	-9.7	3.0
		Old		5.9	-3.8	2.1
			Change in residue (ΔR)			-4.1
	8	Young	-0.6	2.8	-2.2	0
		Middle	-0.4	13.5	-7.4	5.7
		Old		6.0	-2.9	3.1
			Change in residue (ΔR)			-3.4
			Employee guarantee ($-V_0^{EG}$)			-5.0
$FR_0 = 80\%$	7	Young	-1.4	1.3	-4.7	-4.8
		Middle	-1.2	6.2	-18.8	-13.8
		Old		2.5	-10.0	-7.5
			Change in residue (ΔR)			26.4
	8	Young	-1.4	1.5	-3.7	-3.6
		Middle	-1.2	7.0	-14.8	-9.0
		Old		2.8	-7.9	-4.9
			Change in residue (ΔR)			27.6
			Employee guarantee ($-V_0^{EG}$)			-9.7
$FR_0 = 150\%$	7	Young	-0.4	4.8	-1.9	2.5
		Middle	-0.2	23.2	-6.1	16.9
		Old		10.8	-2.0	8.8
			Change in residue (ΔR)			-27.7
	8	Young	-0.4	4.8	-1.5	2.9
		Middle	-0.2	23.3	-4.7	18.4
		Old		10.9	-1.5	9.4
			Change in residue (ΔR)			-27.3
			Employee guarantee ($-V_0^{EG}$)			-3.0

Table 32: Generational effects of changing the initial funding position, for Policy 7 and Policy 8

Again these generational effects are distorted as the fund will not be closed in reality, therefore this study is repeated for the open fund framework in Section 5.5.4.

Concentrating on the solvency measures, it can be seen in Table 31 that having an extremely high initial funding ratio results in the fact that the required level of the EIOPA measure is met. Note that the required levels are the same for different initial funding ratios, as the solvency capital requirement does not depend on this aspect. The reason that the EIOPA measure will be met is that the residue R_0 is already extremely high, i.e. $R_0 = 150.0 - 117.5 = 32.5$.
It also can be seen that the dynamic measure meets the required level by a small amount in the case of an initial funding ratio of 80%, due to the fact that the residue option decreases significantly. In case the initial funding ratio would be even lower, the constraint of the dynamic measure might not be met, as the residue option is even lower in that case.
Here it is again clearly visible that the required level of the EIOPA measure is set according to the characteristics of the fund at time zero, since the pension fund with an initial funding position of 80 percent is not considered solvent over the horizon of 15 years.

4.4.5 Horizon

In this section, the horizon considered is adjusted to see what effects might occur. Besides the horizon of 15 years, a horizon of 25 years and a horizon of 35 years are investigated. In Table 33 the results are presented.

First of all, it can be seen in Table 33 that the sponsor support, the positive adjustment

	$T = 15$		$T = 25$		$T = 35$	
Policy	7	8	7	8	7	8
A^{HBS}	118.6	123.5	119.1	125.4	119.4	126.3
A_0	117.5	117.5	117.5	117.5	117.5	117.5
V_0^{SPS}	1.1	6.0	1.6	7.9	1.9	8.8
L^{HBS}	105.6	109.8	112.0	117.6	115.8	122.2
L_0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	21.9	22.3	33.0	33.9	38.8	40.2
V_0^{AM-}	-16.3	-12.5	-21.0	-16.3	-23.0	-18.0
V_0^{RO}	13.4	14.1	7.5	8.2	3.8	4.3
FR^{HBS}	1.123	1.125	1.064	1.086	1.031	1.033
EIOPA measure	0.130	0.137	0.072	0.073	0.035	0.040
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✘
Dynamic measure	0.252	0.251	0.253	0.253	0.292	0.293
Required level	0.157	0.157	0.149	0.149	0.143	0.143
	✔	✔	✔	✔	✔	✔

Table 33: Effect of changing the horizon on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 and Policy 8

mechanism, and the negative adjustment mechanism increase in absolute value in case the horizon is extended. This makes sense, as due to a longer horizon the pension fund can use the options during a longer period, which increases the value of each of the options.

Secondly, it can be seen that considering a longer horizon will decrease the effect it has on the values of the different options. The reason for this consequence is that the longer the horizon, the fewer participants are left in the fund, as the fund fictitiously closes at time zero.

In Table 34 the generational effects of extending the horizon are shown. However as emphasized in Section 3.9, note these generational effects are not representative as the policy of the fund will not be adjusted to the fact that the fund is fictitiously closed at time zero.

Due to a longer horizon, the effects are positive for all cohort groups for both policies. For the old cohort group, the effects between a horizon of 25 years and a horizon of 35 years, are almost negligible. The reason is that after 25 years, the only participants left in the old cohort group are of age 90 or older.

On the other hand, the effects of the young cohort group between the horizon of 25 years and the horizon of 35 years display the opposite effect, i.e. the effects become more significant. The reason for this result is that due to a longer horizon, more benefits are accrued and the discount factors increase at the end of the horizon, which makes the adjustment mechanism more valuable.

	Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
$T = 15$	7	Young	-0.7	2.7	-2.8	-0.8
		Middle	-0.5	13.2	-9.7	3.0
		Old		5.9	-3.8	2.1
			Change in residue (ΔR)			-4.1
	8	Young	-0.6	2.8	-2.2	0
		Middle	-0.4	13.5	-7.4	5.7
		Old		6.0	-2.9	3.1
			Change in residue (ΔR)			-3.4
			Employee guarantee ($-V_0^{EG}$)			-5.0
$T = 25$	7	Young	-1.1	5.5	-4.2	0.2
		Middle	-0.5	20.5	-12.6	7.4
		Old		7.0	-4.2	2.8
			Change in residue (ΔR)			-10.0
	8	Young	-1.1	5.7	-3.3	0.3
		Middle	-0.5	21.1	-9.8	10.8
		Old		7.1	-3.2	3.9
			Change in residue (ΔR)			-9.3
			Employee guarantee ($-V_0^{EG}$)			-6.4
$T = 35$	7	Young	-1.4	8.1	-5.2	1.5
		Middle	-0.5	23.6	-13.6	9.5
		Old		7.1	-4.2	2.9
			Change in residue (ΔR)			-13.7
	8	Young	-1.3	8.6	-4.1	3.2
		Middle	-0.5	24.4	-10.6	13.3
		Old		7.2	-3.2	4.0
			Change in residue (ΔR)			-13.2
			Employee guarantee ($-V_0^{EG}$)			-7.0

Table 34: Generational effects of changing the horizon, for Policy 7 and Policy 8

In total, every cohort group will obtain a larger effect due to a longer horizon, since the positive adjustment mechanism increases more in absolute value than the negative adjustment mechanism. Hence, the change in the residue ΔR becomes more negative in case the horizon is extended as a pension fund is a zero sum game. As emphasized before, these effects are not representative for reality, and will therefore be repeated for the open fund framework in Section 5.5.5.

Concentrating on the solvency measures in Table 33, the required level in the dynamic approach decreases over time, as explained in Section 4.3 and shown in Figure 2. Furthermore, it can be seen that the EIOPA measure rejects both policies in every case, while the dynamic measure indicates that both policies are solvent.
First of all, the required level of the EIOPA measure remains fixed. Second of all, due to the fact that the positive adjustment mechanism increases more significantly than the negative adjustment mechanism does in absolute value, the EIOPA constraint given in (17) will be hard to meet.
On the other hand, the dynamic solvency constraint is met, as the residue option is large enough. However, as can be seen in Figure 2 the residue option should be larger than or equal to approximately 2.5 after 35 years for Policy 8. Still the residue option is equal to 4.3, which indicates that the residue option might be even lower.
Here it can be concluded that the EIOPA solvency measure cannot cope with even longer horizons, while the dynamic solvency measure is able to implement a horizon extension.

4.4.6 Order of policy instruments

In this section, the order of policy instruments is changed, as changing the order of the policy instruments will have an effect on the different option values and their generational effects. Here two additional orders are considered, as given in Table 35. Order 1 is the exact opposite of the initial order, except for the fact that the sustainability cut is still followed by the employer guarantee, since the sustainability would not have any value otherwise. The changes in order 2 are not as extreme as the changes in order 1, however it is also investigated whether small changes have an effect.

Initial order	Order 1	Order 2
1. conditional indexation	1. recovery premium	1. sustainability cut
2. sustainability cut	2. surplus sharing	2. catch up
3. employer guarantee	3. recovery plan	3. conditional indexation
4. catch up	4. catch up	4. surplus sharing
5. recovery plan	5. sustainability cut	5. employer guarantee
6. surplus sharing	6. employer guarantee	6. recovery plan
7. recovery premium	7. conditional indexation	7. recovery premium

Table 35: Three different orders of policy instruments

In Table 36 the effects on the options of a different order of the policy instruments are displayed. First thing to note is that the effects are more significant in case the pension fund changes from the initial order to order 1, than from the initial order to order 2.
Concentrating on order 1, it can be seen that order 1 starts with the recovery premium, where it can be seen in Table 36 that the employee contribution option increases. Note that this effect is not as large as the effects in other option values, since the fund is fictitiously closed at time zero.

Policy	Initial order 7	Initial order 8	Order 1 7	Order 1 8	Order 2 7	Order 2 8
Sponsor support (V_0^{SPS})	1.12	6.02	1.33	3.06	1.12	6.04
Employee contribution option	1.12	1.06	1.33	1.29	1.12	1.06
Employer guarantee option	0	4.96	0	1.77	0	4.98
Adjustment mechanism (V_0^{AM})	5.63	9.83	6.44	7.81	5.74	9.95
Indexation option	14.31	14.57	14.39	14.53	14.30	14.55
Catch up indexation option	2.28	2.38	2.43	2.49	2.47	2.58
Surplus sharing option	5.30	5.37	5.79	5.83	5.29	5.36
Sustainability cut option	-6.52	-5.71	-1.21	-1.17	-6.54	-5.72
Recovery plan option	-9.74	-6.78	-14.96	-13.87	-9.78	-6.82
Residue option (V_0^{RO})	13.39	14.08	12.81	13.14	13.28	13.98
Surplus option	14.03	14.67	13.49	13.76	13.93	14.57
Deficit option	-0.64	-0.59	-0.69	-0.62	-0.65	-0.59
A^{HBS}	118.6	123.5	118.8	120.6	118.6	123.5
L^{HBS}	105.6	109.8	106.4	107.8	105.7	110.0
FR^{HBS}	1.123	1.125	1.117	1.118	1.122	1.124
EIOPA measure	0.130	0.137	0.124	0.127	0.129	0.136
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✘
Dynamic measure	0.252	0.251	0.239	0.241	0.250	0.249
Required level	0.157	0.157	0.157	0.157	0.157	0.157
	✔	✔	✔	✔	✔	✔

Table 36: Effect of changing the order of the policy instruments on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 and Policy 8

The second instrument that will be used in case of a low funding ratio is the recovery plan in order 1. It can be seen that in both Policy 7 and Policy 8 the recovery plan option has an extremely high absolute value with respect to the initial order. Due to the fact that the sustainability cut will be used later than the recovery plan, the sustainability cut decreases in absolute value. In Policy 7, the total negative adjustment mechanism changes not that significant in order 1 with respect to the initial order, however, in Policy 8 there is a significant change. The reason for this result is that in the initial order, the employer bears a lot of the risks, while in order 1, the employer guarantee will not be used that much, as the recovery plan is implemented before the employer guarantee.
In the higher quantiles of the funding ratio, the surplus sharing instrument is used first in order 1. Therefore, it can be seen that this option value increases with respect to the initial order. As cuts are done earlier in order 1 with respect to the initial order, the catch up indexation option also increases in value.
Finally, the conditional indexation is used, whereas the value of this option will not change much as this is the only policy instrument that is used for funding ratios between 100 percent and 130 percent. Furthermore, due to an increase in the positive adjustment mechanism, the residue option decreases in value.

Concentrating on order 2, it can be seen in Table 36 that few significant changes are displayed

with respect to the initial order. The sustainability cut option increases a little, as this option will now be used as the first instrument. The most significant effect can be seen in the catch up indexation option, where the value increases in both policies by approximately 0.2.
The increase in the value of the catch up indexation option works through in the residue option, which decreases, as more indexation will be given.

In Table 34 the generational effects of changing the order of the policy instruments are

	Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
Initial order	7	Young	-0.66	2.71	-2.78	-0.73
		Middle	-0.46	13.25	-9.69	3.10
		Old		5.94	-3.80	2.14
			Change in residue (ΔR)			-4.1
	8	Young	-0.62	2.78	-2.15	0.00
		Middle	-0.44	13.52	-7.44	5.64
		Old		6.03	-2.90	3.14
			Change in residue (ΔR)			-3.4
			Employee guarantee ($-V_0^{EG}$)			-5.0
Order 1	7	Young	-0.79	2.79	-2.76	-0.76
		Middle	-0.54	13.67	-9.64	3.49
		Old		6.15	-3.77	2.37
			Change in residue (ΔR)			-4.7
	8	Young	-0.76	2.82	-2.58	-0.52
		Middle	-0.53	13.82	-8.97	4.33
		Old		6.20	-3.49	2.71
			Change in residue (ΔR)			-4.4
			Employee guarantee ($-V_0^{EG}$)			-1.8
Order 2	7	Young	-0.66	2.73	-2.78	-0.72
		Middle	-0.46	13.34	-9.72	3.16
		Old		5.99	-3.81	2.17
			Change in residue (ΔR)			-4.2
	8	Young	-0.63	2.80	-2.16	0.02
		Middle	-0.44	13.62	-7.48	5.71
		Old		6.08	-2.91	3.17
			Change in residue (ΔR)			-3.5
			Employee guarantee ($-V_0^{EG}$)			-5.0

Table 37: Generational effects of changing the order of the policy instruments, for Policy 7 and Policy 8

shown. However as emphasized in Section 3.9, note these generational effects are not representative as the policy of the fund will not be adjusted to the fact that the fund is fictitiously closed at time zero.
It can be seen in Table 37 that the effects will be larger for order 1 with respect to the initial order, than for order 2 with respect to the initial order.
It can be seen that the young cohort group is worse off in order 1, while this group is better off in order 2. The reason for this result is that in order 1, the young cohort group has to pay more recovery premium, while the young cohort group gets a small amount more indexation due to catch up indexation in order 2.

The middle and old cohort group will be better off in both order 1 and order 2 with respect to the initial order, excluding order 1 Policy 8, which is also reflected in the change in the residue as ΔR becomes more negative for both orders. The reason that the middle and old cohort group are better off in order 1 Policy 7, while the young cohort group is not, is that the middle and old cohort group share more in the surplus due to more accrued benefits.
The reason that all the cohort groups will not be better off in order 1 Policy 8, is that the recovery plan option increases significantly, while the employer bears less of the risks. As these generational effects are not in line with reality, this study will be repeated for the open fund framework and is shown in Section 5.5.6.

In Table 36 it can be seen that the EIOPA solvency measure states that both policies are insolvent for each order, while the dynamic solvency measure indicates that all policies with the different orders, shown in Table 35, are solvent.

4.4.7 Policy ladders

In this section, the policy ladders presented in Figure 1 are varied, where two new policy ladders are chosen, as given in Figure 3. Ladder 1 shows a ladder where the participants will get catch up indexation and surplus sharing at a lower funding ratio level, while their benefits will be cut at a lower funding ratio level. Furthermore, the recovery premium the participants pay is lowered.
Ladder 2 shows the opposite effect, where the participants get catch up indexation and surplus sharing at a higher funding ratio level, while their benefits will be cut at a higher funding ratio level. Furthermore, the recovery premium the participants pay is increased. Hence, ladder 2 is a less friendly policy ladder.

	Initial ladder		Ladder 1		Ladder 2	
Policy	7	8	7	8	7	8
A^{HBS}	118.6	123.5	118.0	121.3	119.0	125.3
A_0	117.5	117.5	117.5	117.5	117.5	117.5
V_0^{SPS}	1.1	6.0	0.5	3.8	1.5	7.8
L^{HBS}	105.6	109.8	107.5	110.5	102.9	108.0
L_0	100.0	100.0	100.0	100.0	100.0	100.0
V_0^{AM+}	21.9	22.3	25.2	25.5	18.5	19.1
V_0^{AM-}	-16.3	-12.5	-17.7	-15.0	-15.6	-11.1
V_0^{RO}	13.4	14.1	10.9	11.2	16.5	17.7
FR^{HBS}	1.123	1.125	1.098	1.098	1.156	1.160
EIOPA measure	0.130	0.137	0.105	0.108	0.161	0.173
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✘
Dynamic measure	0.252	0.251	0.201	0.199	0.319	0.321
Required level	0.157	0.157	0.157	0.157	0.157	0.157
	✔	✔	✔	✔	✔	✔

Table 38: Effect of changing the policy ladders on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 and Policy 8

	Initial ladder	Ladder 1	Ladder 2
Full indexation Catch up indexation Surplus sharing smoothed over 10 years			
	140%	130%	160%
Full indexation Catch up indexation			
	130%	120%	140%
Conditional indexation			
	100%	100%	100%
No indexation Five year recovery plan Recovery premium of **a** percentage points			
	95%	90%	
No indexation Five year recovery plan Recovery premium of **b** percentage points			
	90%	85%	95%
No indexation Employer guarantee Recovery premium of **c** percentage points			
	85%	80%	90%
No indexation Sustainability cut Recovery premium of **c** percentage points			

Percentage points of recovery premium	**a**	**b**	**c**
Initial ladder	2	4	4
Ladder 1	1	2	2
Ladder 2	3	3	6

Figure 3: Three different policy ladders: order of policy instruments the pension fund can use dependent on its funding ratio with the additional varied percentage points of recovery premium

In Table 38 the effects of changing the policy ladders can be seen. The first effect that occurs is that the value of the sponsor support decreases in ladder 1, while it increases in ladder 2, with respect to the initial ladder. This is the consequence of a lower recovery premium in ladder 1, while in ladder 2 the recovery premium the participants have to pay is increased.

The second effect that can be seen is the increase in the value of the positive adjustment mechanism in ladder 1, while this value decreases in ladder 2, with respect to the initial ladder. This is also an obvious result, as there will be given full indexation, catch up indexation, and surplus sharing at lower funding ratio levels in ladder 1, than is given in ladder 2.

A consequence of the change in the value of the positive adjustment mechanism, is that the negative adjustment mechanism will change, whereas it increases in absolute value in ladder 1 and decrease in absolute value in ladder 2. However, at first, one might expect that the negative adjustment mechanism should increase in absolute value in ladder 2, as the benefits will be cut at higher funding levels than in ladder 1. The reason for the opposite effect is due to the positive adjustment mechanism, as in cases where there will be given more indexation, the probability that the benefits are cut in the future increases, and the other way around. Finally, due to the high positive adjustment mechanism in ladder 1, the residue option decreases, while the opposite effect occurs in ladder 2.

In Table 39 the generational effects can be seen. However as emphasized in Section 3.9,

	Policy	Cohort group	$-V_0^{EC}$	V_0^{AM+}	V_0^{AM-}	Total effect
Initial ladder	7	Young	-0.7	2.7	-2.8	-0.8
		Middle	-0.5	13.2	-9.7	3.0
		Old		5.9	-3.8	2.1
			Change in residue (ΔR)			-4.1
	8	Young	-0.6	2.8	-2.2	0
		Middle	-0.4	13.5	-7.4	5.7
		Old		6.0	-2.9	3.1
			Change in residue (ΔR)			-3.4
			Employee guarantee ($-V_0^{EG}$)			-5.0
Ladder 1	7	Young	-0.3	3.1	-3.0	-0.2
		Middle	-0.2	15.2	-10.6	4.6
		Old		6.9	-4.1	2.8
			Change in residue (ΔR)			-6.6
	8	Young	-0.3	3.2	-2.6	0.3
		Middle	-0.2	15.3	-9.0	6.1
		Old		7.0	-3.4	3.6
			Change in residue (ΔR)			-6.3
			Employee guarantee ($-V_0^{EG}$)			-3.4
Ladder 2	7	Young	-0.9	2.3	-2.6	-1.2
		Middle	-0.6	11.3	-9.3	-1.4
		Old		5.0	-3.7	1.3
			Change in residue (ΔR)			-1.0
	8	Young	-0.7	2.4	-1.9	-0.2
		Middle	-0.5	11.7	-6.6	4.6
		Old		5.1	-2.6	2.5
			Change in residue (ΔR)			0.2
			Employee guarantee ($-V_0^{EG}$)			-6.7

Table 39: Generational effects of changing the policy ladders, for Policy 7 and Policy 8

note these generational effects are not representative as the policy of the fund will not be adjusted to the fact that the fund is fictitiously closed at time zero.
The main effect that occurs is that all cohort groups will be better off in policy ladder 1 with respect to the initial ladder, while all cohort groups are worse off in policy ladder 2, concentrating on the separated total effects. The reason for this main effect is that the participants pay more recovery premium in ladder 2 than in ladder 1. Furthermore, the participants receive more indexation in ladder 1 than in ladder 2.
Additionally, due to the increase in total effects in ladder 1, the change in residue increases in absolute value, while the opposite effect occurs for ladder 2. However, these changes in the residue do not provide more information, as the fund is not really closed at time zero. Therefore, this generational study will be repeated in Section 5.5.7.

Concentrating on the solvency measures given in Table 38, it can be seen that again the EIOPA measure rejects both policies for each policy ladder, while the dynamic measure accepts all policies for each policy ladder.
It can be seen that the EIOPA measure is almost satisfied for ladder 2. Therefore, if a pension fund has to meet the EIOPA requirement in order to be solvent, a powerful thing to change are the policy ladders. However, such a change might be at the expense of the interests of the participants. On the other hand, ladder 1 will not be satisfied by the EIOPA measure constraint, as the positive adjustment mechanism gets an extremely positive significant value. Furthermore, it can be seen that the dynamic measure considers both policy ladders as solvent policies. Still the residue options might become even lower for ladder 1, even though the residue option has decreased significantly already, which indicates that even ladder 1 might be changed to an even less strict policy ladder.

5 Holistic balance sheet used as continuity analysis and solvency measure in open fund framework

5.1 Introduction

In Section 3 and Section 4 a pension fund is considered where it was fictitiously closed at time zero. In reality, if a pension fund is closing at some time in the future, the policy will be adjusted to this aspect, such that the residue is divided among all participants in the fairest way. However, as the fund will not be closed at time zero, the holistic balance sheet of a fictitiously closed fund gives a financial view of the pension fund which is not in line with reality.

Hence, in this section an alternative use of the holistic balance sheet is introduced, where the fund remains open for new participants after time zero, where contributions will be paid and where new benefits are accrued by its participants.

A holistic balance sheet in an open fund framework can be used as an additional tool for a continuity analysis. Where in the usual continuity analysis classical ALM is used, the holistic balance sheet used as continuity analysis is formed with value-based ALM. Both continuity analyses provide similar information, only the information is presented in different value terms.

The pension fund is sustainable for the horizon considered whenever the holistic funding ratio of an open fund framework holistic balance sheet is at least equal to 100 percent, as in this case the unconditional and conditional liabilities are covered by its unconditional and conditional assets. Therefore, the holistic balance sheet in the open fund framework provides trustees with a more complete picture of the evolution of the fund than the holistic balance sheet in the closed fund framework does.

As the holistic balance sheet in the open fund framework is introduced to provide a more complete picture of the financial position of a pension fund, the holistic balance sheet introduced before will be slightly adjusted and is presented in Table 3 in Section 2.3.

It can be seen that two new additions are stated on the holistic balance sheet, namely the contributions CON, which are the contributions valued at time zero that are paid by the working participants over the horizon considered and the new accrued benefits NAB, which are the new benefits valued at time zero that are accrued by the working participants over the horizon considered. Both the valuation of CON and NAB are explained in Section 2.7.

In the remainder of this section, first the eight policies introduced in Section 3 are considered in Section 5.2 for the open fund framework. In Section 5.3 the different generational effects of these eight policies are explained, which represent generational effects that are in line with reality as emphasized in Section 3.9. The solvency measures introduced in Section 4 are slightly adjusted in Section 5.4. Finally, a sensitivity analysis is done for the open fund framework in which the same aspects are adjusted as shown in Section 4.4.

5.2 Effect of different policies on option values in open fund framework

In this section, the eight policies introduced in Section 3 are considered for an open fund, i.e. the fund will not be closed at time zero as is the case in Section 3 and Section 4. In Table 40 and Table 41 a summary of these eight policies is given, where C stands for closed fund and O for open fund.

The same symbols are used as before. A_0 are the assets of the pension fund, CON are the

Policy	1_C	1_O	2_C	2_O	3_C	3_O	4_C	4_O
A^{HBS}	117.5	165.8	117.5	165.8	119.5	168.2	119.5	168.2
A_0	117.5	117.5	117.5	117.5	117.5	117.5	117.5	117.5
CON		48.3		48.3		48.3		48.3
V_0^{SPS}	0	0	0	0	2.0	2.3	2.0	2.3
L^{HBS}	135.6	187.0	113.0	157.5	113.1	157.7	114.3	159.6
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		41.2		41.2		41.2
V_0^{AM+}	35.6	45.8	13.0	16.3	13.1	16.5	14.3	18.4
V_0^{AM-}	0	0	0	0	0	0	0	0
V_0^{RO}	-17.7	-20.0	4.9	9.6	6.8	11.7	5.6	9.8
V_0^{SO}	14.7	19.5	17.5	24.3	17.9	25.0	16.8	23.3
V_0^{DO}	-32.4	-39.5	-12.6	-14.8	-11.1	-13.3	-11.2	-13.5
FR^{HBS}	0.867	0.887	1.040	1.053	1.057	1.067	1.046	1.054

Table 40: The option values of the first four policies introduced in Section 3 for an open fund

Policy	5_C	5_O	6_C	6_O	7_C	7_O	8_C	8_O
A^{HBS}	119.1	167.7	118.6	167.1	118.6	167.2	123.5	173.6
A_0	117.5	117.5	117.5	117.5	117.5	117.5	117.5	117.5
CON		48.3		48.3		48.3		48.3
V_0^{SPS}	1.6	1.9	1.1	1.3	1.1	1.3	6.0	7.7
L^{HBS}	103.1	146.0	100.4	142.2	105.6	148.0	109.8	153.3
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		41.2		41.2		41.2
V_0^{AM+}	15.2	20.0	16.4	21.7	21.9	27.9	22.3	28.4
V_0^{AM-}	-12.1	-15.1	-16.0	-20.7	-16.3	-21.0	-12.5	-16.3
V_0^{RO}	16.5	22.9	18.6	26.2	13.4	20.4	14.1	21.5
V_0^{SO}	18.2	25.8	19.2	27.4	14.0	21.7	14.7	22.6
V_0^{DO}	-1.7	-2.9	-0.6	-1.2	-0.6	-1.3	-0.6	-1.1
FR^{HBS}	1.156	1.148	1.181	1.175	1.123	1.130	1.125	1.132

Table 41: The option values of the last four policies introduced in Section 3 for an open fund

contributions paid by the working participants, V_0^{SPS} is the value of the sponsor support, L_0 are the liabilities of the pension fund, NAB are the new accrued benefits, V_0^{AM+} is the sum of the values of the positive adjustment mechanism options, V_0^{AM-} is sum of the values of the negative adjustment mechanism options, and V_0^{RO} is the value of the residue option. Additionally, V_0^{SO} is the value of the surplus option and V_0^{DO} is the value of the deficit option.
Furthermore, the assets on the asset side of the holistic balance sheet are presented by A^{HBS}, which is defined by

$$A^{HBS} = A_0 + CON + V_0^{SPS},$$

the liabilities on the liability side of the holistic balance sheet are presented by L^{HBS}, which is defined by

$$L^{HBS} = L_0 + NAB + V_0^{AM+} + V_0^{AM-},$$

and the holistic funding ratio FR^{HBS} is defined by

$$FR^{HBS} = \frac{A^{HBS}}{L^{HBS}}.$$

First aspect that can be seen in Table 40 and Table 41 is that in the open fund new benefits are accrued, so that NAB gets a positive value. Furthermore, it can be seen that contributions will be paid by the working participants. Note that CON represents the cost covering contribution that is paid, such that it holds that $CON = (1 + S) \cdot NAB$, where S is defined as explained in Appendix A.
A second thing that can be seen in both tables is that the values of the options increase in absolute magnitude, comparing the open fund framework with the closed fund framework. For instance, concentrating on the positive adjustment mechanism V_0^{AM+}, as more benefits are accrued by the participants, the absolute value of positive indexation given over these benefits increases. The same reasoning applies for the negative adjustment mechanism V_0^{AM}, since the more new accrued benefits, the higher the absolute value of negative indexation given over these benefits will be.
The reason that the sponsor support V_0^{SPS} increases in value due to an open fund is that new participants will enter the fund, which also pay recovery premium.

Another result that can be seen is that the options react in the same way to policy changes as explained in Section 3. So for instance, if the recovery premium is introduced in Policy 3, the sponsor support V_0^{SPS} gets a positive value, whereby the value of the indexation option increases with respect to Policy 2, and thus the adjustment mechanism increases, as can be seen in Table 40. The reason for this fact is that due to recovery premium, more indexation can be given to the participants of the fund with respect to Policy 2.
Another example is introducing the employer guarantee, which is the case in Policy 8 that can be seen in Table 41. Due to the employer guarantee, the sponsor support increases significantly in value, while the negative adjustment mechanism decreases in absolute value with respect to Policy 7, as the employer bears more of the risks instead of the participants bearing all the risks.

Finally, it can be seen that the value of the residue option V_0^{RO} increases for every policy by changing from a closed fund framework to an open one. The reason for this effect is that a pension fund is a zero sum game and due to the fact that the contributions are $S \cdot 100\%$ higher than the value of the new accrued benefits, more money is coming in which can be invested. Hence, in the end, the residue option gets a higher value.
Additionally, the deficit option, which is the negative part of the residue option, increases

more in absolute value for an open fund with respect to a closed fund. The reason for this fact is that due to an open fund, the value of the total unconditional assets will get higher through time. However, the effects of extremely low returns will be more significant in the open fund framework. Therefore the deficit option gets a larger negative value.
The only exception of the effect that can be seen in the residue option is Policy 1, as in this policy the value of the residue option V_0^{RO} decreases, where the deficit option increases significantly in absolute value from -32.4 to -39.5, as more bad scenarios occur in Policy 1 with respect to the other seven policies.

5.3 Generational effects in open fund framework

As in Section 5 an open fund framework is considered, the generational effects will make more sense than in a fictitiously closed fund, as the fund is not closed in reality and new participants can enter the fund after time zero.
Due to an open fund, an additional cohort group is considered, as before the new participants were not taken into account in the generational study. Therefore there are four disjoint cohort groups, namely:

- New cohorts: participants entering the fund after time zero;
- Young cohorts: participants aged 25 - 44 at time zero;
- Middle cohorts: participants aged 45 - 64 at time zero;
- Old cohorts: participants aged 65 - 99 at time zero.

Again, note that these participants will not switch from one cohort group to another as they are followed through time.

In this generational study, six aspects play a role of which five of them can be divided among disjoint cohort groups. As explained in Section 3.9, the employee contribution option V_0^{EC} can be divided among the working participants, which only excludes the old cohort group. The effect of a higher employee contribution option is considered negative for the different cohorts. Furthermore, the adjustment mechanism V_0^{AM} can be divided among all participants, where a distinction is made between the positive adjustment options V_0^{AM+} and the negative adjustment options V_0^{AM-}, where the indexation option, the catch up indexation option, and the surplus sharing option are the positive adjustment options, and where the sustainability cut option and the recovery plan option are the negative adjustment options.
Two other aspect that can be divided among different cohorts are the contributions that will be paid CON and the benefits that will be accrued NAB during the horizon considered. These two aspects can only be divided among the working participants, as the retirees do not pay any contributions and do not accrue new benefits. Note that the higher CON will be, the higher the negative effect will be for those cohorts, while the higher NAB will be, the higher the positive effect will be for those cohorts.
The sixth and final aspect that has an influence on the different cohorts is the change in the residue, which is defined as

$$\Delta R = V_0^{RO} - R_0,$$

where V_0^{RO} is the value of the residue option, and R_0 is the residue at time zero, i.e. $R_0 = A_0 - L_0$. As before the change in the residue did not make much sense, since the fund was fictitiously closed, the change in the residue makes sense in the open fund framework.
However, the change in residue cannot be assigned to one particular cohort group, as it

influences more cohorts. The more positive the change in residue ΔR will be, the more positive value transfer takes place from the older cohorts to the younger cohorts. On the other hand, the more negative the change in residue ΔR will be, the more deficit will be sent into the future and thus to younger and future participants.
Therefore, this final aspect did not make much sense in the closed fund framework, as the policy is not adjusted to the fact that the fund will be closed at time zero and thus it is not stated in the policy to which cohorts the residue belongs and how this residue can be divided among different cohorts.
Still, the change in the residue ΔR cannot be assigned to the new and young cohort group only, as a higher value of the residue change will also slightly affect the middle and old cohort group, as the benefits of those groups will be cut less in the future years in this case and more indexation will be given to them. Hence ΔR affects all participants within the fund after time T.
Note that the employee guarantee option, which is only used in Policy 8, also affects the different cohorts. However, this option cannot be divided among disjoint cohort groups, as it does not belong to a specific cohort.
Hence, the total effect that can be assigned to the different cohort groups is equal to the negative value of the contributions plus the negative value of the employee contribution option plus the value of the new accrued benefits plus the value of the positive adjustment mechanism plus the value of the negative adjustment mechanism:

$$\text{Total effect} = -CON - V_0^{EC} + NAB + V_0^{AM+} + V_0^{AM-}.$$

In Table 42 the effects for the disjoint cohort groups for the eight policies introduced in Section 3 can be seen. The effects shown in the closed fund framework in Section 3.9 in Table 21 differ quite much with respect to the effects shown in this section.
First of all, contributions are paid and new benefits accrued, such that those components get a negative and positive value respectively for the new, young, and middle cohort group. Even though it holds that $CON = (1 + S) \cdot NAB$, this effect is not true for the different cohort groups.
It can be seen that the contributions are highest in absolute value for the young cohort group, since in this group the most workers are present during the horizon of 15 years considered, while in the middle cohort group participants are present that switch from working participant to retiree and in the new cohort group only participants are present that enter the fund after time zero.
Concentrating on the new accrued benefits, it can be seen in Table 42 that the value of these new accrued benefits are the highest for the middle cohort group, since the benefits of these cohorts will be paid out first in the future with respect to the younger cohort groups. Even though there are fewer participants accruing new benefits in the middle cohort group, as a large fraction of the participants in this group becomes a retiree during the horizon considered, the value of the new accrued benefits is still higher than this same value for the young cohort group. The value of the new accrued benefits for the new cohort group is much smaller than those values of the two other cohort groups, as these benefits will not be paid out in the near future, such that the discount factors are extremely low which drives the values down.
Paying attention to the net effect of the contributions paid and the new benefits accrued, it can be seen that this net effect will be positive for the middle cohort group, while it is negative for the other two younger cohort groups.[8]

[8] The so called 'doorsneepremie', which includes a certain pay as you go aspect and means that all the participants within a fund pay a premium that consists of the same percentage of their wage level, is at the expense of the younger participants.

Policy	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
1	New	-8.2		5.0	0.8		-2.4
	Young	-23.3		18.0	9.5		4.2
	Middle	-16.8		18.1	26.6		27.9
	Old				8.9		8.9
		Change in residue (ΔR)					-37.5
2	New	-8.2		5.0	0.2		-2.9
	Young	-23.3		18.0	2.9		-2.5
	Middle	-16.8		18.1	9.6		10.9
	Old				3.6		3.6
		Change in residue (ΔR)					-7.9
3	New	-8.2	-0.5	5.0	0.2		-3.4
	Young	-23.3	-1.1	18.0	2.9		-3.5
	Middle	-16.8	-0.7	18.1	9.7		10.3
	Old				3.6		3.6
		Change in residue (ΔR)					-5.8
4	New	-8.2	-0.5	5.0	0.2		-3.4
	Young	-23.3	-1.1	18.0	3.2		-3.2
	Middle	-16.8	-0.7	18.1	10.9		11.5
	Old				4.0		4.0
		Change in residue (ΔR)					-7.7
5	New	-8.2	-0.4	5.0	0.3	-0.4	-3.6
	Young	-23.3	-0.9	18.0	3.7	-3.9	-6.4
	Middle	-16.8	-0.6	18.1	11.8	-8.3	4.1
	Old				4.2	-2.5	1.7
		Change in residue (ΔR)					5.4
6	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	4.2	-5.1	-6.9
	Middle	-16.8	-0.4	18.1	12.8	-11.5	2.2
	Old				4.4	-3.6	0.9
		Change in residue (ΔR)					8.7
7	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
		Change in residue (ΔR)					2.9
8	New	-8.2	-0.2	5.0	0.4	-0.4	-3.4
	Young	-23.3	-0.6	18.0	5.2	-4.0	-4.7
	Middle	-16.8	-0.4	18.1	16.8	-9.1	8.6
	Old				6.0	-2.8	3.2
		Change in residue (ΔR)					4.0
		Employee guarantee ($-V_0^{EG}$)					-6.5

Table 42: Effects for four different cohort groups in an open fund for the eight policies introduced in Section 3, namely the new cohort group, young cohort group, the middle cohort group, and the old cohort group.

In Table 42 it can be seen that the total effects for the new cohort group for the different policies will always be negative. The reason for this fact is that, as explained above, the value of the contributions is higher than the value of the new accrued benefits, while furthermore the effects of the employee contribution option, the positive and negative adjustment mechanisms are not that high. The adjustment mechanism for the new cohort group is that low in absolute value, since these cohorts have not accrued much benefits and on top of that, these benefits will not be paid out for a long time, such that the discount factors are extremely low.

Another large difference with respect to the closed fund framework occurs for the young cohort group. While the effect for this group was positive for Policy 1 up to Policy 4, in reality the effect that can be properly assigned to this cohort group is only positive for Policy 1. Note that the change in residue is extremely negative in Policy 1, which also should be taken into account. The effect of the change in residue is discussed extensively later on in this section. The reason that the total effect will become negative for Policy 2 up to Policy 4 with respect to the closed fund framework is thanks to the contributions CON which have a larger magnitude than the new accrued benefits NAB for the young cohort group.
Furthermore, it can be seen that the magnitude of the employee contribution option for the young cohort group gets less in most policies. The reason for this fact is that in the open fund framework new participants also take part of the burden to pay recovery premium.
Finally, it can be seen that the positive and negative adjustment mechanism increase in magnitude for the young cohort group, which makes sense as these cohorts accrue new benefits in the open fund framework on which positive and negative indexation can be given.

Concentrating on the middle cohort group, it can be seen that the total effects are positive for all policies, while it can be seen in Table 21 that the total effect was negative for Policy 6 in the closed fund framework. The reason that the total effect will be positive in the open fund framework is due to the fact that the new accrued benefits NAB have a higher value than the contributions CON paid by the middle cohort group.
Furthermore, the same effect that occurs for the young cohort group can be seen in the value of the employee contribution option; the magnitude of the contribution option decreases due to the fact that the burden of paying recovery premium is shared among more participants.
Finally, it can be seen that the positive and negative adjustment mechanism increase in magnitude for the middle cohort group, just as is the case for the young cohort group. The difference is that the positive and negative adjustment mechanism will increase by a higher absolute value than for the young cohort group, due to the fact that the benefits of the middle cohort group will be paid out sooner.
In total, the effect for the middle cohort group will increase with respect to the closed fund framework, due to the results just described.

It can be seen in Table 42 that the effects for the old cohort group will not change much with respect to the closed fund framework presented in Table 21. The reason for this consequence is that the old cohort group will not be doing anything different in the open fund framework, as the participants in this cohort group are already retired and receiving their already accrued benefits as long as they are still alive.

The final aspect that can be seen in Table 42 is the change in residue ΔR. While the change in residue was only positive for Policy 6 in the closed fund framework shown in Table 21, it is positive in Policy 5 up to Policy 8 in the open fund framework. The reasons for these changes are already explained at the end of Section 5.2, as the changes in the value of the residue option V_0^{RO} are explained and on top of that the value of the residue at time

zero R_0 remains constant, recall $\Delta R = V_0^{RO} - R_0$.
It can be seen in Table 42 that the total effects for the four cohort groups are the highest for Policy 1. However, it also can be seen that the change in the residue ΔR is significantly negative, which means that at the end of the horizon the pension fund will be highly underfunded with a large probability. The consequence is that the deficit will be pushed into the future to the younger participants, who will eventually suffer from the large deficits. Therefore, even though the effects that can be separated among the different cohort groups are the highest in Policy 1, this policy is unsustainable and not in line with the interests of all participants, as the younger participants will eventually have to deal with the deficit.
Additionally, it can be seen that the change in residue is also negative for Policy 2 up to Policy 4, however in less magnitude as in Policy 1. Due to the increase in the change in residue, a value transfer is visible where all the total effects of the different cohort groups decrease. As the change in residue is negative, the effects of the younger cohorts are even more negative than the effects that actually can be assigned to them.
Adding the sustainability cut in Policy 5 results in a positive change in residue, where the total effect of the new cohort group does not change much as it decreases from -3.4 to -3.6, and where the other thee cohort groups experience a greater loss. However, since the change in residue is positive, this affects all the different cohort groups in a positive way (mainly the younger cohorts), as the fund becomes more maintainable such that the probability of reducing the benefits in the future will be decreased.
Adding the recovery plan in Policy 6 strengthens the effects that occur of changing from Policy 4 to Policy 5, as the total effects of the cohorts decrease, while the change in residue increases. The only exception that can be seen is visible in the total effect of the new cohort group, which becomes less negative in Policy 6 with respect to Policy 5 due to the decrease in absolute value of the employee contribution option.
In Policy 7 surplus sharing is added to Policy 6. It can be seen in Table 42 that due to this surplus sharing the change in residue decreases significantly with the consequence that the total effects for the two oldest cohort groups increase the most. Still, the effects for the two youngest groups are negative. However, as the change in residue is positive, there will be a value transfer to the younger participants from which also these two younger cohort groups benefit.
Adding an employer guarantee in Policy 8 makes sure that the change in the residue will increase even further, where the total effects of all the cohort groups increase. It can be seen that the change in the total effect for the new cohort group is the smallest. Again, notice that a value transfer to the younger participants is present due to the fact that the change in residue is positive.

In total, it can be said that Policy 7 and Policy 8 are better policies from a generational perspective with respect to the other six policies, as in these two policies the value transfers from the older participants to younger and future participants of the fund are smaller.

5.4 Solvency measures: EIOPA and dynamic approach

Due to considering an open pension fund, the solvency measures introduced in Section 4.2 and Section 4.3 have to be slightly adjusted in order to make sense.

First of all, the EIOPA solvency measure should be adjusted such that next to the different options, also the new contributions that will be paid and the new benefits that will be accrued are taken into account. Therefore the restriction formula should be adjusted as follows:

$$R_0 + V_0^{SPS} - V_0^{AM} \geq S \cdot L_0 \Leftrightarrow$$
$$R_0 + CON + V_0^{SPS} - NAB - V_0^{AM} \geq S \cdot L_0. \tag{19}$$

This adjustment is made, as the EIOPA measure takes into account the conditional assets as a positive aspect, while it takes into account the conditional liabilities as a negative aspect. Here the contributions CON are stated on the asset side and should thus be added to the restriction formula, while the new accrued benefits are considered liabilities and should thus be subtracted.

The dynamic solvency measure does not explicitly take into account the different conditional assets and liabilities as the EIOPA solvency measure does; it only uses the value of the residue option V_0^{RO} explicitly. Therefore, the dynamic solvency restriction formula remains exactly the same as before, namely:

$$\frac{V_0^{RO}}{PV(L_T)} \geq S(D_L).$$

However, note that the duration of the liabilities is higher as in Section 4 as the fund is not closed at time zero and will therefore remain approximately constant. Hence, the required percentage that a pension fund should hold as a percentage of the liabilities remains approximately constant, i.e. $S(D_L)$ remains approximately constant over time.

In Table 43 the results of the EIOPA solvency test and the dynamic solvency test are

Policy	1_C	2_C	3_C	4_C	5_C	6_C	7_C	8_C
EIOPA measure	-0.181	0.045	0.064	0.052	0.161	0.182	0.130	0.137
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✔	✘	✘
Dynamic measure	-0.236	0.083	0.115	0.094	0.321	0.375	0.252	0.251
Required level	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
	✘	✘	✘	✘	✔	✔	✔	✔

Policy	1_O	2_O	3_O	4_O	5_O	6_O	7_O	8_O
EIOPA measure	-0.211	0.084	0.105	0.086	0.217	0.249	0.192	0.203
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✔	✔	✔	✔
Dynamic measure	-0.163	0.096	0.117	0.096	0.254	0.299	0.223	0.225
Required level	0.170	0.171	0.170	0.170	0.170	0.171	0.170	0.170
	✘	✘	✘	✘	✔	✔	✔	✔

Table 43: Solvency tests for the eight policies introduced in Section 3 for the closed and open fund

displayed for both the closed policies as the open policies, where C stands for closed fund and O stands for open fund. It can be seen that the required level of the EIOPA solvency measure remains the same, as this required level is equal to the solvency capital requirement at time zero S, derived as given in Appendix A, while the required level of the dynamic measure changes in the open fund framework with respect to the closed fund framework. The reason for this change is that the duration of the liabilities after the horizon of 15 years is lower in the closed fund.

Furthermore, it can be seen that where the solvency measures did not give the same result in the closed fund, those measures give the same outcome in the open fund, since Policy 5 up to Policy 8 are considered solvent by both measures.

As emphasized in Section 5.3, Policy 7 and Policy 8 are considered better from a generational perspective. Therefore, both solvency measures in the open fund give the result that trustees of a pension fund would like to maintain for its participants, as indeed both Policy 7 and Policy 8 are considered solvent. However, in the fictitiously closed fund, the EIOPA solvency measure does not give the result that trustees of a pension fund would like to achieve for its participants.
Here it can be concluded that by adjusting the EIOPA solvency measure to an open fund framework, the problem of not taking into account the fact that the fund fictitiously closes at time zero is more or less solved, as the duration of the liabilities remains approximately constant over time in an open fund framework. While, on the other hand, the duration of the liabilities did not remain constant over time in the closed fund framework, with the result that the required level of the EIOPA solvency test was too high in the closed fund framework. However, the adjusted EIOPA solvency measure still includes the aspect of not yet taking into account the fact that options themselves already perform as a certain hedge.

5.5 Sensitivity analysis

In this section, a sensitivity analysis is done again, in which the same aspects are adjusted as presented in Section 4.4, where one additional aspect is considered, namely adjusting the scenario set. In the following sections the above aspects are adjusted separately and are compared with the benchmark case, in which an open fund is considered where the initial funding ratio is equal to the required funding ratio ($FR_0 = FR^{req}$), the investment portfolio consists for 50% of stocks and for 50% of bonds, the fund is equal to a projection of the Dutch population, the horizon considered is equal to 15 years ($T = 15$), and the order of the policy instruments with their policy ladders are as given in Figure 1. Furthermore, the results are compared to the results obtained in the closed fund framework.

5.5.1 Additional funding

In this section, the initial funding ratio is equal to 118.5% instead of 117.5%, to see whether one percentage of extra assets will have an effect on the different options and the solvency tests. In Table 44 and Table 45 the eight different policies are presented for both the benchmark case and the case with the additional funding of one percentage point.

Just as in the closed fund framework in Section 4.4.1, the solvency tests do not give a different result due to one percentage point of additional funding. Furthermore, the effects of additional funding are most visible in the contracts that have the least policy instruments. Additionally, the same effects are visible in both tables as described in Section 5.2. Therefore, in the remainder of this section, only Policy 7 will be considered, as this policy is considered one of the better policies from a generational perspective as shown in Section 5.3.

5.5.2 Investment portfolio

The investment portfolio is adjusted in this section, where next to investing for 50 percent in stocks and for 50 percent in bonds, a portfolio will be considered in which completely is invested in stocks and a portfolio in which completely is invested in bonds. The results of these three different investment portfolios are presented in Table 46 for both the closed fund and the open fund framework.

Policy	$FR_0 = FR^{req}$				$FR_0 = FR^{req} + 1\%$			
	1_O	2_O	3_O	4_O	1_O	2_O	3_O	4_O
A^{HBS}	165.8	165.8	168.2	168.2	166.8	166.8	169.1	169.1
A_0	117.5	117.5	117.5	117.5	118.5	118.5	118.5	118.5
CON	48.3	48.3	48.3	48.3	48.3	48.3	48.3	48.3
V_0^{SPS}	0	0	2.3	2.3	0	0	2.3	2.3
L^{HBS}	187.0	157.5	157.7	159.6	187.0	157.8	158.0	159.9
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAB	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2
V_0^{AM+}	45.8	16.3	16.5	18.4	45.8	16.6	16.8	18.7
V_0^{AM-}	0	0	0	0	0	0	0	0
V_0^{RO}	-20.0	9.6	11.7	9.8	-19.0	10.3	12.4	10.4
FR^{HBS}	0.887	1.053	1.067	1.054	0.892	1.057	1.071	1.058
EIOPA measure	-0.211	0.084	0.105	0.086	-0.201	0.091	0.111	0.092
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✘	✘	✘	✘	✘	✘	✘
Dynamic measure	-0.163	0.096	0.117	0.096	-0.154	0.103	0.124	0.103
Required level	0.170	0.171	0.170	0.170	0.170	0.170	0.170	0.170
	✘	✘	✘	✘	✘	✘	✘	✘

Table 44: Effect of additional funding on the options on the holistic balance sheet and on the two solvency tests, for Policy 1 up to Policy 4 in an open fund

Policy	$FR_0 = FR^{req}$ 5_O	6_O	7_O	8_O	$FR_0 = FR^{req} + 1\%$ 5_O	6_O	7_O	8_O
A^{HBS}	167.7	167.1	167.2	173.6	168.7	168.1	168.1	174.4
A_0	117.5	117.5	117.5	117.5	118.5	118.5	118.5	118.5
CON	48.3	48.3	48.3	48.3	48.3	48.3	48.3	48.3
V_0^{SPS}	1.9	1.3	1.3	7.7	1.8	1.3	1.3	7.6
L^{HBS}	146.0	142.2	148.0	153.3	146.5	142.8	148.7	153.9
L_0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAB	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2
V_0^{AM+}	20.0	21.7	27.9	28.4	20.2	21.9	28.3	28.8
V_0^{AM-}	-15.1	-20.7	-21.0	-16.3	-14.9	-20.3	-20.7	-16.1
V_0^{RO}	22.9	26.2	20.4	21.5	23.4	26.6	20.7	21.8
FR^{HBS}	1.148	1.175	1.130	1.132	1.151	1.178	1.131	1.133
EIOPA measure	0.217	0.249	0.192	0.203	0.221	0.254	0.194	0.205
Required level	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
	✔	✔	✔	✔	✔	✔	✔	✔
Dynamic measure	0.254	0.299	0.223	0.225	0.258	0.303	0.225	0.227
Required level	0.170	0.171	0.170	0.170	0.170	0.170	0.170	0.170
	✔	✔	✔	✔	✔	✔	✔	✔

Table 45: Effect of additional funding on the options on the holistic balance sheet and on the two solvency tests, for Policy 5 up to Policy 8 in an open fund

It can be seen in Table 46 that the magnitude of the contributions that are paid depend on the investment portfolio, as the contributions are higher for the 100% stocks case, while they are lower for the 100% bonds case, with respect to the benchmark. The reason for this result lies in the definition of the cost covering contribution which is defined in (7). It can be seen that the cost covering contribution depends on the solvency capital requirement S, explained in Appendix A. Since stock returns are more volatile than bond returns, a higher solvency capital requirement is needed for the 100% stocks case, which results in a higher value of the contributions CON.
Furthermore, it can be seen that due to an open fund, the values of the different options increase in absolute value. First of all, the sponsor support increases for each investment portfolio by the same absolute amount, as the recovery premium consists of the same percentage points for each portfolio. On the other hand, the increase in the adjustment mechanism in absolute value is more significant for the 100% stocks case than the 100% bonds case. The reason for this effect is that stock returns are more volatile, which results in more indexation given in the good scenarios, while more negative indexation is given in the bad scenarios.
It also can be seen that the value of the residue option increases more significantly for the 100% stocks case with respect to the closed form, than for the 100% bonds case. However, these significant differences are not so much reflected in the holistic funding ratio, as due to a larger value of the total assets and liabilities in the open fund, the magnitude of the residue option will not be reflected in the holistic funding ratio.

Concentrating on the generational effects in Table 47, it can be seen that the total effects

Policy	50% Stocks/ 50% Bonds 7_C	50% Stocks/ 50% Bonds 7_O	100% Stocks 7_C	100% Stocks 7_O	100% Bonds 7_C	100% Bonds 7_O
A^{HBS}	118.6	167.2	119.1	126.8	173.3	161.5
A_0	117.5	117.5	117.5	117.5	117.5	117.5
CON		48.3		54.0		43.2
V_0^{SPS}	1.1	1.3	1.6	1.8	0.5	0.7
L^{HBS}	105.6	148.0	98.5	141.5	111.6	161.5
L_0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		41.2		41.2
V_0^{AM+}	21.9	27.9	30.8	40.7	16.7	19.7
V_0^{AM-}	-16.3	-21.0	-32.3	-40.4	-5.1	-8.2
V_0^{RO}	13.4	20.4	21.8	34.1	6.4	9.6
FR^{HBS}	1.123	1.130	1.208	1.224	1.057	1.058
EIOPA measure	0.130	0.192	0.205	0.318	0.064	0.088
Required level	0.175	0.175	0.312	0.312	0.051	0.051
	✘	✔	✘	✔	✔	✔
Dynamic measure	0.252	0.223	0.447	0.391	0.112	0.101
Required level	0.157	0.170	0.290	0.306	0.034	0.048
	✔	✔	✔	✔	✔	✔

Table 46: Effect of changing the investment portfolio on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
50% Stocks/ 50% Bonds	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
						Change in residue (ΔR)	2.9
100% Stocks	New	-9.1	-0.3	5.0	0.7	-0.9	-4.6
	Young	-26.1	-0.9	18.0	7.7	-9.2	-10.4
	Middle	-18.8	-0.6	18.1	24.0	-22.5	0.2
	Old				8.3	-7.8	0.6
						Change in residue (ΔR)	16.6
100% Bonds	New	-7.3	-0.1	5.0	0.2	-0.3	-2.4
	Young	-20.9	-0.4	18.0	3.3	-2.3	-2.2
	Middle	-15.0	-0.2	18.1	11.6	-4.5	10.0
	Old				4.5	-1.2	3.3
						Change in residue (ΔR)	-7.9

Table 47: Generational effects of changing the investment portfolio, for Policy 7 in an open fund

that can be separated among the different cohort groups are the lowest for the 100% stocks case, while these are the highest for the 100% bonds case. Therefore, in these effects the well known fact that young generations should invest aggressively, while old generations should invest conservatively are not represented. However, it can be seen that the change in the residue for the 100% bonds case is negative, which indicates that a negative value transfer to the younger and future participants is present. On the other hand, a positive change in the residue is presented in Table 47 for the aggressive portfolio, which indicates that younger and future participants will profit from this fact, where their pension result will increase and their contribution level will decrease.
Hence, a more conservative portfolio results in a higher wealth level for older participants, as older participants cannot recover from low investment returns, while a more aggressive portfolio results in a higher wealth level for younger participants, due to the prospect of higher investment returns.

Finally, it can be seen in Table 46 that in the open fund the 100% stocks case will be solvent according to the EIOPA solvency measure, while it was not solvent in the closed fund framework. A great influence on this result is the fact that the contributions the participants pay are taken into account in the open fund, where the contributions are significantly higher than the new accrued benefits in the aggressive portfolio case.
The dynamic solvency measure displays the same outcomes in both the closed fund and the open fund framework.

5.5.3 Degree of maturity

In this section, the degree of maturity of the fund is adjusted, where next to the Dutch fund, two additional funds are considered, namely the green and the gray fund. An extensive explanation of these funds is given in Appendix C. The results of the closed fund framework and the open fund framework are shown in Table 48. Again, note that the values in the table are all normalized to the value of the liabilities of the specific fund, while in reality the liabilities of the green fund are much lower, namely equal to 62.2 in terms of the liabilities of the Dutch fund, and the liabilities of the gray fund are much higher, namely equal to 140.9 in terms of the liabilities of the Dutch fund.

In Table 48 it can be seen that the values of the contributions paid CON and of the new benefits accrued NAB are much higher for the green fund than for the gray fund. The reason for this fact is that the elderly dependency ratio is much lower in the green fund, i.e. more workers with respect to retirees are present in the green fund. On top of that, the duration of the liabilities is higher for the green fund, such that the solvency capital requirement is higher, which increases the cost covering contribution given in (7) and thus increases CON. Furthermore, it can be seen in Table 48 that the values of the options increase in absolute value changing from the closed fund framework to the open fund framework. The value of the sponsor support increases more in value for the green fund than for the gray fund. The reason for this result is that there are more working participants in the green fund with respect to retirees, such that more participants are paying the same percentage points of recovery premium.
Additionally, it can be seen that both the positive and the negative adjustment mechanism increase much more in the green fund than in the gray fund. This effect is a consequence of the fact that the liabilities increase in the green fund due to more new accrued benefits, while the liabilities decrease in the gray fund due to lower survival probabilities. Therefore, the indexation given over these liabilities has a larger effect for the green fund.

The generational effects are shown in Table 49. It can be seen that the total effects of

Policy	Dutch fund 7_C	Dutch fund 7_O	Green fund 7_C	Green fund 7_O	Gray fund 7_C	Gray fund 7_O
A^{HBS}	118.6	167.2	119.1	187.0	118.4	158.5
A_0	117.5	117.5	117.5	117.5	117.5	117.5
CON		48.3		67.5		39.9
V_0^{SPS}	1.1	1.3	1.6	2.0	0.9	1.1
L^{HBS}	105.6	148.0	104.9	163.7	105.9	141.1
L_0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		57.1		34.1
V_0^{AM+}	21.9	27.9	23.6	32.0	21.2	26.1
V_0^{AM-}	-16.3	-21.0	-18.7	-25.4	-15.2	-19.1
V_0^{RO}	13.4	20.4	14.6	24.8	12.9	18.5
FR^{HBS}	1.123	1.130	1.135	1.142	1.118	1.124
EIOPA measure	0.130	0.192	0.142	0.232	0.125	0.174
Required level	0.175	0.175	0.183	0.183	0.171	0.171
	✘	✔	✘	✔	✘	✔
Dynamic measure	0.252	0.223	0.242	0.216	0.258	0.228
Required level	0.157	0.170	0.160	0.177	0.155	0.166
	✔	✔	✔	✔	✔	✔

Table 48: Effect of changing the pension fund on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
Dutch fund	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
		Change in residue (ΔR)					2.9
Green fund	New	-14.3	-0.4	9.0	0.7	-1.0	-5.9
	Young	-34.0	-1.0	26.8	7.5	-7.8	-8.4
	Middle	-19.2	-0.5	21.3	18.8	-13.6	6.7
	Old				4.9	-3.1	1.9
		Change in residue (ΔR)					7.3
Gray fund	New	-5.5	-0.2	3.3	0.3	-0.3	-2.4
	Young	-18.6	-0.5	14.1	4.0	-4.1	-5.0
	Middle	-15.8	-0.4	16.7	15.4	-10.9	5.0
	Old				6.4	-3.9	2.5
		Change in residue (ΔR)					1.1

Table 49: Generational effects of changing the pension fund, for Policy 7 in an open fund

the new, young, and old cohort group decrease in the green fund with respect to the Dutch fund, while the total effect of the middle cohort group increases. The consequence is that the change in the residue increases significantly, i.e. there is a positive value transfer to the younger generations.
The opposite effect is displayed for the gray fund, where the total effect for the middle cohort group decreases, while the total effect for the remaining groups increases. The result is that the change in residue decreases, i.e. there is less positive value transfer to the younger generations.
Hence, the gray fund is more beneficial for the older generations, while the green fund is more beneficial for the younger generations.

In Table 48, it can be seen that all the funds are solvent according to both measures in the open fund framework, while the funds were insolvent according to the EIOPA solvency measure in the closed fund framework. The reason for this change in result is that due to the open fund framework the duration of the liabilities remains approximately constant over time, such that the required level remains approximately constant. It can be seen that the required levels of both measures differ less than in the closed fund framework.

5.5.4 Initial funding position

The initial funding position is adjusted in this section, where two extreme initial funding ratios are chosen, one extremely low funding ratio equal to 80 percent and one extremely high funding ratio equal to 150 percent. In Table 50 the results are shown for the closed fund and open fund framework for Policy 7.
It can be seen that the different options increase in absolute value due to changing to an open fund framework, where those changes are for each initial funding position approximately the same. Therefore the same effects apply to the changes in option values as explained in Section 4.4.4.
Another interesting result that can be seen in Table 50 is that even though the residue option increases in value in the extremely high funding position, the holistic funding ratio decreases comparing the open fund to the closed fund. Therefore, the value of the residue option is not reflected in the holistic funding ratio, as the total assets A^{HBS} and total liabilities L^{HBS} are much higher in the open fund framework.

In Table 51 the generational effects of changing the initial funding position are presented. It can be seen that the lowest effects for the disjoint cohort groups are displayed in the extremely low initial funding position, due to the high recovery premium that has to be paid and due to the fact that the benefits will be cut extensively. On the other hand, the total effects of the extremely high initial funding position are the highest, due to the fact that there will be given a lot of indexation to the participants.
However, it also can be seen that the change in residue is extremely positive in the initial funding ratio of 80 percent, while it is extremely negative in the initial funding ratio of 150 percent, due to the fact that the policy brings the funding ratio back to a less extreme value. The consequence of these results is that a significant value transfer occurs from the older generations to the younger generations.
First of all, in the extremely low funding position, the older participants lose a lot of wealth due to the extensive cuts, while the younger participants benefit from this fact, as in particular the older participants make sure that the funding ratio will be brought back to a higher funding position.
Secondly, in the extremely high funding position, the older participants share in the surplus a lot, due to a higher indexation level on their benefits, while the younger participants will

Policy	$FR_0 = FR^{req}$ 7_C	$FR_0 = FR^{req}$ 7_O	$FR_0 = 80\%$ 7_C	$FR_0 = 80\%$ 7_O	$FR_0 = 150\%$ 7_C	$FR_0 = 150\%$ 7_O
A^{HBS}	118.6	167.2	82.7	131.3	150.6	199.1
A_0	117.5	117.5	80.0	80.0	150.0	150.0
CON		48.3		48.4		48.3
V_0^{SPS}	1.1	1.3	2.7	2.9	0.6	0.8
L^{HBS}	105.6	148.0	76.5	119.5	128.8	170.9
L_0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		41.2		41.2
V_0^{AM+}	21.9	27.9	10.0	16.3	38.8	44.3
V_0^{AM-}	-16.3	-21.0	-33.5	-37.9	-10.0	-14.6
V_0^{RO}	13.4	20.4	6.4	12.9	22.3	29.5
FR^{HBS}	1.123	1.130	1.080	1.098	1.169	1.165
EIOPA measure	0.130	0.192	0.061	0.117	0.218	0.282
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✔	✘	✘	✔	✔
Dynamic measure	0.252	0.223	0.177	0.173	0.327	0.276
Required level	0.157	0.170	0.157	0.173	0.157	0.169
	✔	✔	✔	✔	✔	✔

Table 50: Effect of changing the initial funding position on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
$FR_0 = FR^{req}$	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
						Change in residue (ΔR)	2.9
$FR_0 = 80\%$	New	-8.2	-0.3	5.0	0.4	-0.6	-3.7
	Young	-23.3	-1.4	18.0	3.4	-7.4	-10.8
	Middle	-16.8	-1.2	18.1	9.6	-20.7	-10.9
	Old				2.9	-9.2	-6.4
						Change in residue (ΔR)	32.9
$FR_0 = 150\%$	New	-8.2	-0.2	5.0	0.5	-0.5	-3.3
	Young	-23.3	-0.4	18.0	7.6	-4.0	-2.1
	Middle	-16.8	-0.2	18.1	26.0	-8.1	19.0
	Old				10.2	-2.0	8.2
						Change in residue (ΔR)	-20.5

Table 51: Generational effects of changing the initial funding position, for Policy 7 in an open fund

not benefit from the high funding position.
Therefore, the initial low funding ratio is worse for the older generations, while an initial high funding ratio is very good news for the older generations.

In Table 50 it can be seen that the case where the initial funding position is extremely low results in the fact that Policy 7 is insolvent according to the EIOPA measure, while the dynamic solvency constraint will just meet the required level. Here you might conclude that the dynamic solvency measure does not provide a justified result, as an extremely high value transfer occurs in Policy 7. However, trustees construct policies of a pension fund in order to treat the interests of all different stakeholders equally, where these decisions are based on less extreme events.

5.5.5 Horizon

In this section, the horizon considered is adjusted, where it is first extended to 25 years and secondly to 35 years. The results are presented in Table 52 for the benchmark case and the two additional cases where the horizon considered is adjusted, for both the closed fund and open fund framework.
First thing that can be seen is that the value of the new accrued benefits NAB increases

	$T=15$		$T=25$		$T=35$	
Policy	7_C	7_O	7_C	7_O	7_C	7_O
A^{HBS}	118.6	167.2	119.1	201.2	119.4	235.3
A_0	117.5	117.5	117.5	117.5	117.5	117.5
CON		48.3		81.4		114.4
V_0^{SPS}	1.1	1.3	1.6	2.3	1.9	3.3
L^{HBS}	105.6	148.0	112.0	184.8	115.8	220.3
L_0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		69.4		97.7
V_0^{AM+}	21.9	27.9	33.0	49.5	38.8	69.7
V_0^{AM-}	-16.3	-21.0	-21.0	-34.1	-23.0	-47.2
V_0^{RO}	13.4	20.4	7.5	17.9	3.8	16.5
FR^{HBS}	1.123	1.130	1.064	1.089	1.031	1.068
EIOPA measure	0.130	0.192	0.072	0.164	0.035	0.150
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✔	✘	✘	✘	✘
Dynamic measure	0.252	0.223	0.253	0.204	0.292	0.193
Required level	0.157	0.170	0.149	0.168	0.143	0.168
	✔	✔	✔	✔	✔	✔

Table 52: Effect of changing the horizon on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

significantly in case the horizon is extended. The reason for this consequence is that the participants will accrue additional benefits in the years after the benchmark horizon of 15 years. Due to the increase in the new accrued benefits, also the value of the contributions CON increases, as $CON = (1+S) \cdot NAB$.

The effect of a longer horizon can also be seen in the value of the options; the values of the options increase in absolute value more significantly for a longer horizon comparing the closed fund with the open fund. The reason that the value of the sponsor support is significantly higher for $T = 35$ comparing the open fund framework with the closed one, than the value of the sponsor support for $T = 15$ is that in the closed fund no new participants will enter, which results in the fact that the sponsor support does not increase much in value in the closed fund for a longer horizon. On the other hand, due to new entering participants in the open fund framework, the sponsor support increases in magnitude in the open fund for longer horizons.
The same reason applies to the larger increase in absolute value by considering a longer horizon for the adjustment mechanism; as new participants are entering in the open fund framework, the longer the horizon will be, the higher the value of indexation given over the accrued benefits is.

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
$T = 15$	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
		Change in residue (ΔR)					2.9
$T = 25$	New	-24.4	-0.7	16.2	2.2	-2.5	-9.2
	Young	-38.8	-1.1	33.4	13.5	-11.0	-4.0
	Middle	-18.2	-0.5	19.8	26.9	-16.6	11.4
	Old				7.0	-4.0	2.9
		Change in residue (ΔR)					0.4
$T = 35$	New	-49.2	-1.5	35.3	6.9	-7.3	-15.8
	Young	-47.1	-1.4	42.6	24.3	-17.3	1.2
	Middle	-18.2	-0.5	19.8	31.5	-18.6	14.1
	Old				7.1	-4.1	3.0
		Change in residue (ΔR)					-1.0

Table 53: Generational effects of changing the horizon, for Policy 7 in an open fund

In Table 53 the generational effects of extending the horizon are shown. It can be seen that the total effect for the new cohort group increases in absolute value as the horizon is extended. The reason for this effect is that the new cohort group is still paying contributions after 35 years, while no participant within the new cohort group is receiving benefits yet.
Furthermore, it can be seen that the total effect of the young cohort group will increase as the horizon considered is prolonged. The reason for this effect is that their benefits are increased, due to the fact that they have accrued more benefits and due to the fact that these accrued benefits will be paid out for some participants in the young cohort group, while they will be paid out soon in the future for the other participants within the young cohort group. Therefore the total effect will already be positive for $T = 35$.
For the middle cohort group, it can be seen that the value of the contributions CON and the new accrued benefits NAB will not change going from $T = 25$ to $T = 35$, as all the participants within this group will be retired from $T = 20$ on. Furthermore, it can be seen that the total effect for the middle cohort group increases as the horizon is extended, due

to the fact that these cohorts will not pay contributions anymore after $T = 20$, where they start receiving pension payments.
The effect for the old cohort group will not change much going from $T = 25$ to $T = 35$, as after $T = 25$ the only participants left in this cohort group are aged 90 or older. Still, the effect will increase as the horizon is extended, due to the fact that the increase in value of the positive adjustment mechanism is larger than the negative adjustment mechanism.
Concentrating on the change in the residue, it can be seen that the change in the residue starts at a positive value in the benchmark case, while it becomes negative in the $T = 35$ case. This effect indicates that first a positive value transfer to the younger generations is present, as the change in residue is positive, while after 35 years a positive value transfer to the older generations occurs, as the change in residue is negative. It actually turns out that after 45 years the change in residue increases to -0.52, where it increases further to -0.48 after 55 years. These results indicate that Policy 7 is a policy where the value transfers among generations will be balanced approximately over time, such that the interests of all participants are treated approximately equally.

Concentrating on the solvency measures in Table 52, it can be seen that the EIOPA measure rejects Policy 7 in case a longer horizon will be considered, while the dynamic measure considers Policy 7 to be solvent over all the three different horizons considered. The reason that the EIOPA measure still considers Policy 7 to be insolvent in the open fund framework is that the required level is still too high due to the fact that the EIOPA measure does not yet take into account the hedging behavior of options.

5.5.6 Order of policy instruments

In Section 4.4.6 two additional orders of the different policy instruments are introduced in Table 35. Both these orders are considered in the analysis of this section and are presented in Table 54.
First of all, as explained before, all the option values increase in absolute value if an open fund is considered instead of a closed fund. It can be seen in Table 54 that the increase in the employee contribution option is approximately the same for every order. The reasoning is the same as before; the recovery premium consists for each order of the same percentage point, where the amount of working participants is the same.
The increase in value of the indexation option is also approximately the same, as shown before, it does not really matter if the conditional indexation instrument is used as first instrument or as last instrument, as this is the only instrument that is used by the pension fund between the funding ratio boundaries of 100 percent and 130 percent.
The catch up indexation option increases more in absolute value for order 2 than for order 1, since the catch up indexation instrument will be used more in order 2 than in order 1 as this instrument is used earlier in the policy instrument line as can be seen in Table 35. Due to considering an open fund, the effect that can be seen in the value of the catch up indexation option is largest for order 2.
The same result can be seen for the surplus sharing option, as this policy instrument is used second in order 1, fourth in order 2, and sixth in the initial order. Therefore, the effect that can be seen in this option value by changing from an closed to an open fund, is the largest for order 1 and the smallest for the initial order.
As the sustainability cut is used at the fifth place in order 1, instead of a higher place in the other two orders, the effect of changing from a closed fund to an open fund is smallest for order 1.
Finally, the recovery plan is used earlier in order 1 than in the other two orders, therefore the effect of changing from a closed to an open fund is largest for order 1.

Policy	Initial order 7_C	Initial order 7_O	Order 1 7_C	Order 1 7_O	Order 2 7_C	Order 2 7_O
Employer contribution option (V_0^{EC})	1.12	1.33	1.33	1.57	1.12	1.34
Adjustment mechanism (V_0^{AM})	5.63	6.82	6.43	7.86	7.74	7.02
Indexation option	14.31	18.00	14.39	18.05	14.30	17.98
Catch up indexation option	2.28	3.75	2.43	3.98	2.47	4.05
Surplus sharing option	5.30	6.11	5.79	6.76	5.29	6.10
Sustainability cut option	-6.52	-8.79	-1.21	-1.77	-6.54	-8.82
Recovery plan option	-9.74	-12.24	-14.96	-19.16	-9.78	-12.28
Residue option (V_0^{RO})	13.39	20.43	12.81	19.63	13.28	20.24
Surplus option	14.03	21.71	13.49	20.99	13.93	21.54
Deficit option	-0.64	-1.28	-0.69	-1.36	-0.65	-1.30
A^{HBS}	118.6	167.2	118.8	167.4	118.6	167.2
L^{HBS}	105.6	148.0	106.4	149.0	105.7	148.2
FR^{HBS}	1.123	1.130	1.117	1.123	1.122	1.128
EIOPA measure	0.130	0.192	0.124	0.184	0.129	0.190
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✔	✘	✔	✘	✔
Dynamic measure	0.252	0.223	0.239	0.213	0.250	0.221
Required level	0.157	0.170	0.157	0.170	0.157	0.170
	✔	✔	✔	✔	✔	✔

Table 54: Effect of changing the order of the policy instruments on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

Concentrating on the generational effects shown in Table 55 it can be seen that the young, middle, and old cohort group are better off in both order 1 and order 2 with respect to the initial order, while the new cohort group will not be better off in order 1 and is slightly better off in order 2.
In the closed fund framework shown in Section 4.4.6 in Table 37 it was shown that the young cohort group would be worse off in order 1, while in the open fund framework, the more realistic case, the young cohort group is better off. The reason for this change in effect is that the new cohort group will help in paying recovery premium, such that the risks are shared among more participants.
Furthermore, the residue change is highest for the initial order, as in this order the separated effects for the different cohort groups are lower, and in total it should represent a zero sum game. Therefore, it can be concluded that the initial order will be better for the younger cohorts, while order 1 results in more wealth for the older cohorts.

In Table 54 it can be seen that all investigated orders are solvent in the open fund framework according to both solvency measures. The reason that the EIOPA measure does provide a different result intuitively is that the duration of the liabilities remains approximately constant over time, such that the required level explained in Appendix A remains approximately constant over time. However, still this required level is too high, as the EIOPA solvency measure does not yet take into account the hedging aspect of the embedded options.

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
Initial order	New	-8.20	-0.24	5.05	0.41	-0.53	-3.51
	Young	-23.34	-0.64	18.01	5.06	-5.18	-6.09
	Middle	-16.80	-0.45	18.11	16.45	-11.69	5.61
	Old				5.94	-3.63	2.30
		Change in residue ($\Delta\bar{R}$)					2.9
Order 1	New	-8.20	-0.29	5.05	0.42	-0.53	-3.55
	Young	-23.34	-0.76	18.01	5.22	-5.16	-6.03
	Middle	-16.80	-0.52	18.11	17.00	-11.64	6.14
	Old				6.15	-3.60	2.55
		Change in residue ($\Delta\bar{R}$)					2.1
Order 2	New	-8.20	-0.24	5.05	0.41	-0.53	-3.51
	Young	-23.34	-0.65	18.01	5.12	-5.20	-6.06
	Middle	-16.80	-0.45	18.11	16.60	-11.74	5.72
	Old				5.99	-3.64	2.35
		Change in residue ($\Delta\bar{R}$)					2.7

Table 55: Generational effects of changing the order of the policy instruments, for Policy 7 in an open fund

5.5.7 Policy ladders

As introduced in Section 4.4.7 two additional changed policy ladders are considered, which are both displayed in Figure 3 of which the results are shown in Table 56. It can be seen that the sponsor support increases more significantly in ladder 2 than in the other two ladders, comparing the open fund with the closed fund. The reason for this fact is that in ladder 2 the recovery premium is increased to three and six percentage points, while it is decreased in ladder 1 to one and two percentage points.
The positive adjustment mechanism does increase more significantly for ladder 1, comparing the open fund with the closed fund, as in ladder 1 positive indexation will be given at a lower funding ratio level than the other two ladders. Therefore the positive adjustment mechanism increases the least for ladder 2, as in this ladder positive indexation will be given at higher funding ratio levels than the initial ladder.

The generational effects of changing the policy ladders are shown in Table 57. It can be seen that all effects that can be divided among the different cohort groups are higher for ladder 1, while these effects are lower for ladder 2. As explained in Section 4.4.7 this effect is due to the fact that participants pay less recovery premium and receive more indexation in ladder 1 than in ladder 2.
Furthermore, it can be seen that the change in residue for ladder 1 is almost equal to zero, which indicates that not much value transfer is present between different generations. On the other hand, the change in residue increases significantly for ladder 2, which indicates that the younger generations will benefit from ladder 2.
In total, it can be concluded that the older participants will be better off in ladder 1, while the younger participants will be better off in ladder 2. Furthermore, the least value transfer occurs in ladder 1, which indicates that this policy ladder is better from a generational perspective. These examples indicate that the holistic balance sheet can easily be used as a tool for policy development.

Policy	Initial ladder 7_C	Initial ladder 7_O	Ladder 1 7_C	Ladder 1 7_O	Ladder 2 7_C	Ladder 2 7_O
A^{HBS}	118.6	167.2	118.0	166.4	119.0	167.6
A_0	117.5	117.5	117.5	117.5	117.5	117.5
CON		48.3		48.3		48.3
V_0^{SPS}	1.1	1.3	0.5	0.6	1.5	1.8
L^{HBS}	105.6	148.0	107.5	150.8	102.9	144.2
L_0	100.0	100.0	100.0	100.0	100.0	100.0
NAB		41.2		41.2		41.2
V_0^{AM+}	21.9	27.9	25.2	32.4	18.5	23.4
V_0^{AM-}	-16.3	-21.0	-17.7	-22.8	-15.6	-20.4
V_0^{RO}	13.4	20.4	10.9	16.9	16.5	24.7
FR^{HBS}	1.123	1.130	1.098	1.104	1.156	1.162
EIOPA measure	0.130	0.192	0.105	0.156	0.161	0.234
Required level	0.175	0.175	0.175	0.175	0.175	0.175
	✘	✔	✘	✘	✘	✔
Dynamic measure	0.252	0.223	0.201	0.181	0.319	0.277
Required level	0.157	0.170	0.157	0.170	0.157	0.171
	✔	✔	✔	✔	✔	✔

Table 56: Effect of changing the policy ladders on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
Initial ladder	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
		Change in residue (ΔR)					2.9
Ladder 1	New	-8.2	-0.1	5.0	0.5	-0.6	-3.4
	Young	-23.3	-0.3	18.0	5.9	-5.6	-5.3
	Middle	-16.8	-0.2	18.1	19.1	-12.7	7.5
	Old				7.0	-3.9	3.1
		Change in residue (ΔR)					-0.6
Ladder 2	New	-8.2	-0.3	5.0	0.4	-0.5	-3.6
	Young	-23.3	-0.9	18.0	4.3	-5.0	-6.9
	Middle	-16.8	-0.6	18.1	13.9	-11.3	3.3
	Old				4.9	-3.6	1.3
		Change in residue (ΔR)					7.2

Table 57: Generational effects of changing the policy ladders, for Policy 7 in an open fund

In Table 56 it can be seen that ladder 1 will not be considered solvent according to the EIOPA solvency measure in the open fund, while the other ladders will be solvent for both the EIOPA measure and the dynamic measure in the open fund. Here it can be seen that the EIOPA solvency measure does not give a result consistent with a generational perspective, as in ladder 1 the least value transfer occurs between different generations.

5.5.8 Scenario set

In this section, a whole other aspect is varied, namely the scenario set. The scenario set that is considered throughout this whole thesis is a set constructed by the risk model introduced in Section 2.2.3. In this risk model, the initial values are chosen in line with a certain time point in the financial market. The scenario set used in this thesis starts at values representative for Q4 2011, which is a point in time after the crisis. Now, another scenario set is considered, where the initial values are representative for Q4 2007, which is a point in time before the crisis and represents thus a less extreme market structure. The results are displayed in Table 58. The term structure in the scenario set Q4 2011 is much lower than the

	Q4 2011		Q4 2007	
Policy	7_C	7_O	7_C	7_O
A^{HBS}	118.6	167.2	118.9	156.7
A_0	117.5	117.5	117.5	117.5
CON		48.3		37.6
V_0^{SPS}	1.1	1.3	1.4	1.6
L^{HBS}	105.6	148.0	110.0	144.3
L_0	100.0	100.0	100.0	100.0
NAB		41.2		31.2
V_0^{AM+}	21.9	27.9	25.3	32.0
V_0^{AM-}	-16.3	-21.0	-15.3	-18.8
V_0^{RO}	13.4	20.4	8.9	13.5
FR^{HBS}	1.123	1.130	1.081	1.085
EIOPA measure	0.130	0.192	0.089	0.123
Required level	0.175	0.175	0.205	0.205
	✘	✔	✘	✘
Dynamic measure	0.252	0.223	0.194	0.181
Required level	0.157	0.170	0.182	0.200
	✔	✔	✔	✘

Table 58: Effect of changing the scenario set on the options on the holistic balance sheet and on the two solvency tests, for Policy 7 in a closed and open fund

term structure for Q4 2007. Hence, the value of the liabilities is much lower for the second scenario set Q4 2007. Note that all values presented in Table 58 are given in terms of the liabilities for each specific scenario set. The value of the liabilities for scenario set Q4 2007 is actually equal to 72.1 in terms of the liabilities of scenario set Q4 2011.
Due to lower liabilities and higher investment returns throughout the horizon considered for scenario set Q4 2007, more positive indexation can be given, which results in a higher value

of the positive adjustment mechanism. As the investment returns are higher for scenario set Q4 2007, the benefits do not have to be cut as much as for scenario set Q4 2011, which results in a lower absolute value of the negative adjustment mechanism. The steering instrument recovery premium will be used more in case of scenario set Q4 2007, which results in a higher value of the sponsor support.
The value of the residue option is much lower for the scenario set Q4 2007, since the risk free rate in this set is much higher, where the risk free rate did drop due to the financial crisis.

Policy 7_O	Cohort group	$-CON$	$-V_0^{EC}$	NAB	V_0^{AM+}	V_0^{AM-}	Total effect
Q4 2011	New	-8.2	-0.2	5.0	0.4	-0.5	-3.5
	Young	-23.3	-0.6	18.0	5.1	-5.2	-6.1
	Middle	-16.8	-0.4	18.1	16.4	-11.7	5.6
	Old				5.9	-3.6	2.3
		Change in residue (ΔR)					2.9
Q4 2007	New	-6.2	-0.3	2.4	0.3	-0.3	-4.0
	Young	-18.1	-0.8	12.0	4.6	-3.5	-5.9
	Middle	-13.2	-0.5	16.8	19.2	-11.0	11.1
	Old				8.0	-4.0	4.0
		Change in residue (ΔR)					-3.9

Table 59: Generational effects of changing the scenario set, for Policy 7 in an open fund

The generational effects for the open fund framework are displayed in Table 59. It can be seen that due to a different scenario set, a significant change is present. First of all, the middle cohort group benefits enormously from changing to the 2007 scenario set, which is due to the fact that the contributions these cohorts have to pay decrease in value, while the positive adjustment mechanism increases in value. Furthermore, the total effect of the old cohort group increases, due to a higher value of the adjustment mechanism.
These effects are at the expense of the younger cohorts, where both the total effects of the new and the young cohort group decrease, while on top of that the change in residue becomes negative.
The generational effects by changing the scenario set are significant, since the inflation rate increases in the scenario set of 2007, while the policy ladders do not depend on the inflation rate and are not adjusted in the example given in Table 59. For instance, a policy ladder can depend on the nominal funding ratio as is the case in this thesis, however, it can also depend on the ratio of the real funding ratio and the nominal funding ratio, such that the expected inflation rate is implemented in the policy ladder.
In Table 58 it can be seen that the required level of both solvency measures increases. The reason for this result is that due to a higher term structure, the interest rate shocks that might occur are higher, as the reduction factors introduced in Appendix A remain the same. It also can be seen that changing the initial values of the scenario set has a significant impact on the solvency tests, in particular only the dynamic measure for the closed fund framework considers Policy 7 to be solvent for the 2007 scenario set.
However, high interest rates and investment returns are mostly considered as good news for pension funds, since the value of the liabilities decreases while the assets increase in value. As can be seen in Table 58 the opposite effect occurs; the required levels increase, while the solvency measures decrease in value with respect to the scenario set of Q4 2011, with the

consequence that fewer solvency constraints are met.
The reason for this consequence is that due to higher asset values and lower liabilities, the pension fund can provide the participants with more indexation, with the result that the conditional liabilities significantly increase in value.
Since different initial parameters of the risk model results in different solvency test outcomes, the scenario set that is used has a great influence on the solvency tests. Hence, trustees of pension funds can easily manipulate the regulator by choosing an appropriate risk model with a resulting scenario set in order to be able to meet the solvency requirement. Therefore, we recommend EIOPA to advice the European Commission to impose a risk model for all IORP pension funds, such that each fund can generate scenarios that can be implemented in their ALM model.

6 Conclusions and recommendations

EIOPA proposes the holistic balance sheet to make the different IORP pension systems across Europe more comparable. We have evaluated this method, where all policy instruments are valued as embedded options on the balance sheet. We criticize the approach proposed by EIOPA for several reasons.
First of all, EIOPA proposes to fictitiously close the pension fund at time zero. By fictitiously closing the fund, the holistic balance sheet does not provide the trustees of a pension fund the actual financial position of the fund in line with reality, which was the reason of introducing the holistic balance sheet in the first place.
Hence, instead of closing the fund fictitiously at time zero, the fund should remain open for new participants, in order to provide a financial position of the pension fund more in line with reality. In this case, the holistic balance sheet can be used as a continuity analysis, where the holistic funding ratio should be larger than 100 percent in order to be sustainable over the horizon considered. Hence, the holistic balance sheet can also be used as a tool for policy development.
However, this level of 100 percent does not give insights into the quality of the fund, only into the solvency of a fund, while the traditional funding ratio provides both insights into the quality and the solvency of a fund. Therefore, next to the holistic balance sheet, a generational study should be done, which gives insights into the generational effects that occur for alternative policies. Note that a generational study in the closed fund framework is not representative for reality, as the residue is not divided among all cohorts within the fund.

Secondly, EIOPA proposes a solvency measure, which might be interpreted as a threat for Dutch pension funds, since the required level is too high for two reasons. The first reason is that EIOPA does not take into account the fact that the embedded options on the holistic balance sheet already perform as a buffer. The second reason is that EIOPA does not include the aspect of fictitiously closing the fund in determining the required level.
In this thesis, an alternative solvency measure is introduced named the dynamic solvency measure. This measure does take into account the aspect of fictitiously closing the fund at time zero and can also easily be used within the open fund framework. It turns out that the dynamic measure does consider policies to be solvent which have the least value transfers between disjoint cohorts, while the EIOPA measure does consider those policies to be insolvent.

The third reason we criticize the approach proposed by EIOPA is that the holistic balance sheet is significantly dependent on the risk model chosen, such that trustees of a pension fund can use an appropriate risk model in order to meet the requirements set by the regulator.
Therefore, we propose to impose a risk model for all IORP pension funds, such that trustees are not able to form a risk model optimally adjusted to their own funds.

Finally, the embedded options on the holistic balance sheet are valued in market valuation terms only. In order for trustees to treat the interest of all different stakeholders in an equal way, next to market valuation terms, the cash flows should also be translated into utility terms. Here one should wonder how far the regulator should intervene to decide which policy is in favor of the participants within the fund, since participants might not be pleased with the imposed solvency capital requirement.

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Appendices

A Square root formula

To determine the required equity pension funds should hold in the FTK regulation, the so called 'square root formula' is used which takes into account several risk components:

$$S = \sqrt{S_1^2 + S_2^2 + 2\rho S_1 S_2 + S_3^2 + S_4^2 + S_5^2 + S_6^2}, \tag{20}$$

where S is the total required equity, S_1 is the component for interest rate risk, S_2 is the component for market risk, S_3 is the component for currency risk, S_4 is the component for commodity risk, S_5 is the component for credit risk, S_6 is the component for insurance technical risk, and ρ is the correlation coefficient between S_1 and S_2 which is set equal to 0.5.

Interest rate risk affects both the assets and the liabilities of a pension fund. To determine component S_1 factors for each maturity are determined and regulated with which interest rates decrease in case an interest rate shock occurs. These factors are set such that the probability of underfunding in case an interest rate shock occurs will be smaller than 2.5%. In case one wants to calculate the required funding ratio with a different certainty level, these factors should be adapted as follows, where it is assumed that changes in interest rates are normally distributed with mean zero:

$$f_{N,\alpha} = \left(\frac{f_{N,0.025} - 1}{z_{0.025}}\right) z_\alpha + 1,$$

where $f_{N,\alpha}$ is the reduction factor such that the probability of underfunding is smaller than α%, and z_α is the inverse cumulative distribution function of the normal distribution.
Both the effect of interest rates on the assets and liabilities are dependent on their duration. Usually, the duration is determined by a rule of thumb. Here it is assumed that there is a single cash flow A at maturity N. Note that the duration of such a cash flow is approximately equal to its maturity (i.e. $D \approx N$) and can be derived as

$$D = \frac{N}{1 + r^{(N)}}.$$

However, with the ALM model, the actual duration of the liabilities at time t for one scenario s can be derived as follows:

$$D_{L,t}^s = \frac{\sum_{x=25}^{99} B_t^s \cdot \left(Pop_{x,t}^{male} \cdot D_{D,x,t}^{s,male} + Pop_{x,t}^{female} \cdot D_{D,x,t}^{s,female}\right)}{\sum_{x=25}^{99} B_t^s \cdot \left(Pop_{x,t}^{male} \cdot D_{x,t}^{s,male} + Pop_{x,t}^{female} \cdot D_{x,t}^{s,female}\right)},$$

where B_t^s are the benefits for all cohorts at time t in scenario s as explained in Section 2.2.5, where $D_{x,t}^{s,male}$ is given in (6), and where

$$D_{D,x,t}^{s,gender} = \sum_{i=max(65-x,0)}^{99-x} i \cdot {}_{i-t}p_{x-(i-t),t}^{gender} \left(1 + r_{t,s}^{(i)}\right)^{-(i+1)}.$$

As most pension funds try to match the duration of the assets with the duration of the liabilities such that $2 \cdot D_A = D_L$, it is assumed that the duration of the assets are half of the duration of the liabilities.

The effect of an interest rate shock on the assets and liabilities can be determined separately as follows:

$$\frac{\Delta_\alpha W}{W} = \frac{\frac{A}{(1+f_{N,\alpha}\cdot r^{(N)})^N} - \frac{A}{(1+r^{(N)})^N}}{\frac{A}{(1+r^{(N)})^N}} = \left(\frac{1+r^{(N)}}{1+f_{N,\alpha}\cdot r^{(N)}}\right)^N - 1 = \left(\frac{1+r^{(D)}}{1+f_{D,\alpha}\cdot r^{(D)}}\right)^D - 1,$$

where it is assumed that $N = D$. The reduction factors f are given for rounded maturities, in case the duration is not a rounded number, interpolation is used.
This leads to a total effect caused by an interest rate shock of

$$S_1 = \frac{\Delta_\alpha W_{interestrates,L}}{W_{interestrates,L}} - \alpha \cdot \frac{\Delta_\alpha W_{interestrates,A}}{W_{interestrates,A}},$$

which can be derived for several quantiles (α's).

FTK regulation also states that the shock for investing completely in stocks is equal to

$$\frac{\Delta_{0.025} W_{stocks}}{W_{stocks}} = 25\%.$$

Note that this shock is determined such that the probability of underfunding in the next period is smaller than 2.5%, where a normal distribution is assumed. In case one wants to determine a different certainty level, than one needs to assume that stock returns are normally distributed with a mean of 8% (as stock returns are around 8% in reality). This leads to:

$$S_2 = \frac{\Delta_\alpha W_{stocks}}{W_{stocks}} = -\left(0.08 + z_\alpha \cdot \frac{-0.25 - 0.08}{z_{0.025}}\right),$$

which is the total effect caused by a shock in stock returns and can also be derived for several quantiles (α's).

The total required equity can be determined with (20), where the percentage invested in stocks and bonds can be adjusted, which causes the values of S_1 and S_2 to change. The required funding ratio is then equal to

$$FR^{req} = 1 + S.$$

B IORP valuation method

First the swap curve is lowered by 10 basis points (to adjust for credit risk).
Second, the ultimate forward rate method is used to stabilize the term structure in the long run.
The one year forward rate is determined with the swap curve:

$$f_t(t_1, t_2) = \frac{\left(1 + r_{t_2}^{(d_2)}\right)^{d_2}}{\left(1 + r_{t_1}^{(d_1)}\right)^{d_1}} - 1,$$

where $f_t(t_1, t_2)$ is the one year forward rate between term t_1 and t_2, d_1 is the length of the time period between time 0 and time t_1 and d_2 is the length of the time period between time 0 and time t_2. Note that $t_2 - t_1 = 1$ and $d_2 - d_1 = 1$, as these are one year forward rates.
The forward rate curve is adjusted such that it tends to the ultimate forward rate of 4.2%

in the long run. From the year 20 on there is a linear extrapolation to this ultimate forward rate such that it is equal to the ultimate forward rate from year 60 onwards:

$$adjf_t(t_1,t_2) = \begin{cases} f_t(t_1,t_2) & \text{if } t_2 = 2,\dots,20; \\ \frac{t_2-20}{40}\cdot 0.042 + \frac{60-t_2}{40}\cdot f_t(t_1,t_2) & \text{if } t_2 = 21,\dots,59; \\ 0.042 & \text{if } t_2 = 60,\dots \end{cases}$$

Now the ultimate forward rate curve is determined as follows:

$$\begin{cases} ufr_t^{(d_2)} = r_t^{(d_2)} & \text{if } d_2 = 1; \\ ufr_t^{(d_2)} = \left((1 + adjf_t(t_1,t_2)) \cdot \left(1 + ufr_t^{(d_1)}\right)^{d_1} \right)^{\frac{1}{d_2}} - 1 & \text{if } d_2 = 2,\dots \end{cases}$$

If the current market term structure is low, the ultimate forward rate method makes sure that the curve becomes higher in the long run, while if the current market term structure is high, the curve will become lower in the long run.

C Pension funds

In this thesis, a distinction can be made between several funds. The first fund considered is equal to a fraction of the projections from Statistics Netherlands (CBS) with their survival probabilities. This Dutch fund is used in the main analysis of this thesis.
To investigate the effects of different funds on the holistic balance sheet and its options, two additional funds are considered, namely a green fund and a gray fund. Both these funds are created from the Dutch population, where the initial situation is adjusted. For each generation an alternative weight is chosen with respect to the Dutch fund. This results in the fact that the average of the green and the gray fund is equal to the Dutch fund, as the same survival probabilities are considered.

In Figure 4 the amount of workers and retirees in the green and gray fund is displayed as if the fund evolves further over time. It can be seen that the number of retirees in the gray fund is much higher than in the green fund for the first 50 years.
More importantly, it can easily be seen from Figure 5 that the elderly dependency ratio (i.e. the number of retirees divided by the number of workers) is much higher for the gray fund than for the green fund, which is obvious, as there are more older people in a gray fund. It can also be seen from both figures that the initial situation, green or gray, disappears in the long run.

Furthermore, in this thesis closed funds are considered, which means that the fund closes at time zero and no new participants can enter the fund. In Figure 6 the number of workers and retirees is shown in case a closed fund is considered. Note that after 40 years no workers are left in the fund, as one enters the fund at age 25 and retires at age 65. Additionally, after 75 years no one is left, as according to the survival tables everybody dies at the age of 99 at maximum. Note that also here the initial situation disappears in the long run.
The elderly dependency ratio for the closed green and gray fund is shown in Figure 7. It can be seen that due to closing the fund, this ratio increases significantly, where the ratio of the gray fund is the highest.

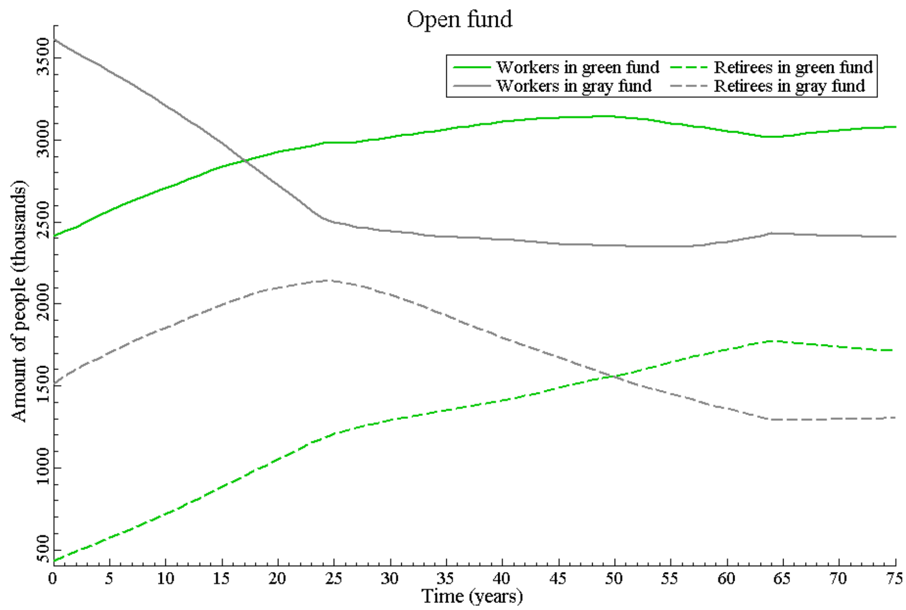

Figure 4: Proportions of workers and retirees in open green and gray fund

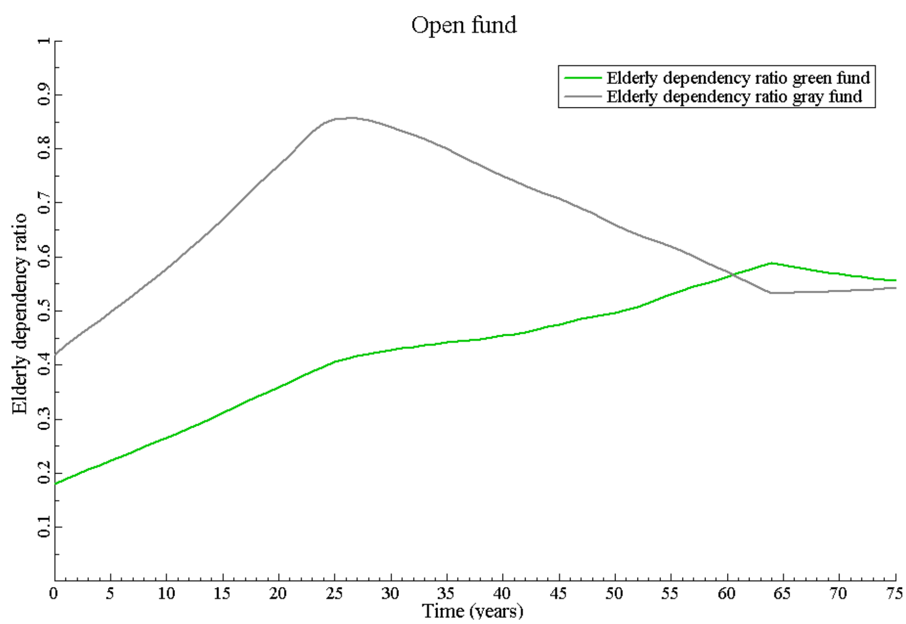

Figure 5: Elderly dependency ratio of open green and gray fund

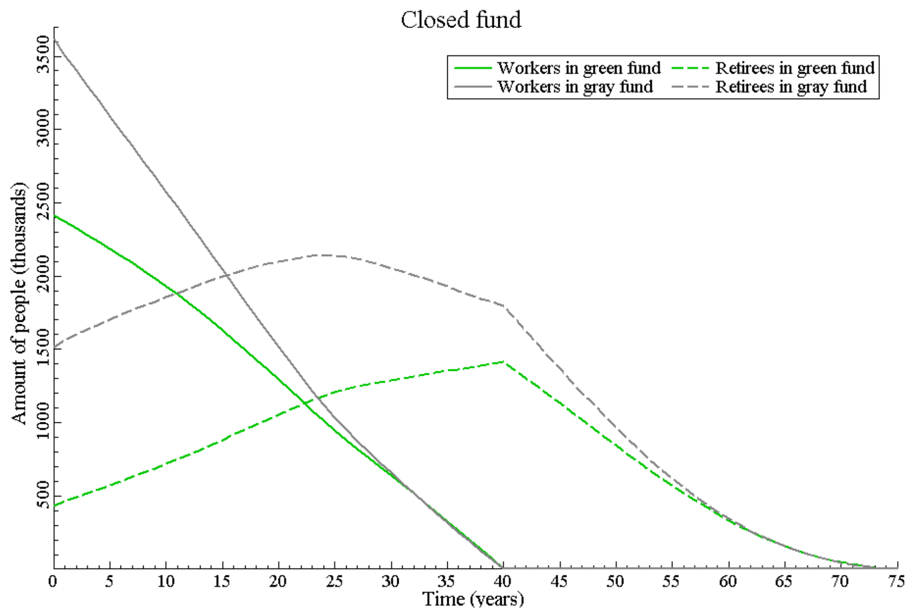

Figure 6: Proportions of workers and retirees in closed green and gray fund

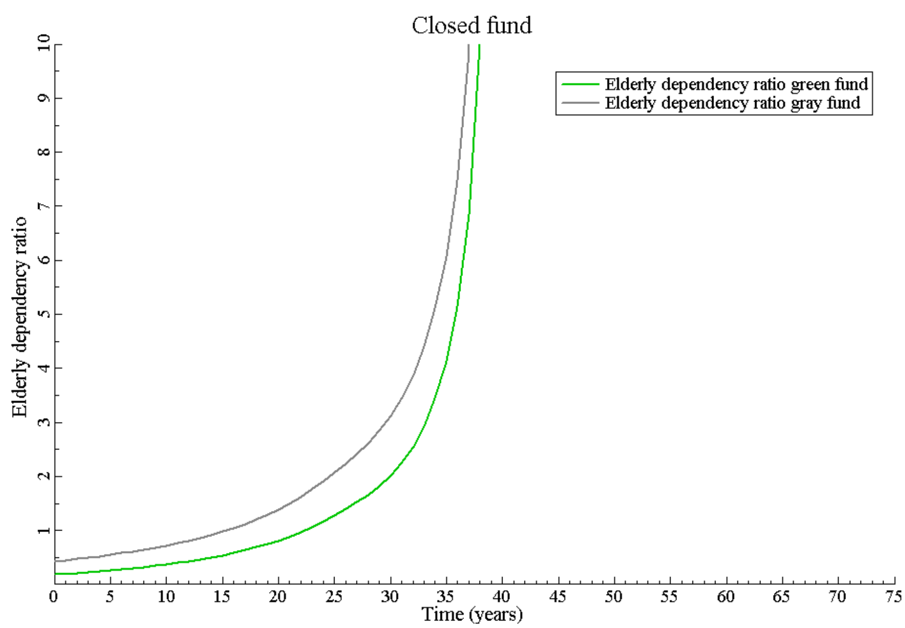

Figure 7: Elderly dependency ratio of closed green and gray fund