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A Value-Based Approach to Pension Plan Redesign in the Netherlands

Who Will Gain and Who Will Lose?

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A value-based approach to pension plan redesign in the Netherlands.
Who will gain and who will lose?

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Abstract

The focus of this thesis is the intergenerational effects of the second pillar pension plan redesign in the Netherlands. We propose a tool that combines generational accounting and value-based ALM that adopts risk neutral valuation to assess the redistribution effects of different changes in the pension plan. Two groups of changes are considered: firstly, the Dutch pension system development from traditional DB to collective DC with explicit contract is evaluated; secondly, shifting from nominal to the real framework using the adjusted real term structure, expected real returns and the combination method is analyzed. The results show that changes in discounting method can involve substantial redistribution among generations, often surpassing in magnitude the transfers implied by pension plan development. The results also indicate that by setting parameters of the pension plan redesign simultaneously an acceptable level of redistribution can be achieved. The tool that we present allows for quantitative evaluation of the value transfers and hence makes better informed decisions on pension redesign possible. The application of this approach is not limited to the second pension pillar only; it can as well be applied to other systems with collective features.

Contents

Acknowledgement **4**

1 Introduction **5**

1.1 The problem . . . 5
1.2 Research description . . . 5
1.3 Redistribution and fairness . . . 6
1.4 Research methods . . . 7

2 Model description **8**

2.1 Approach . . . 8
2.2 Model . . . 9
2.2.1 Pension fund characteristics . . . 9
2.2.2 Core model . . . 10
2.2.3 Generational accounts extension . . . 11
2.3 Valuation . . . 12
2.3.1 Scenario set . . . 13
2.3.2 Value of the pension deal . . . 14
2.4 Results evaluation methods . . . 15

3 Change in the nature of contract **16**

3.1 Approach . . . 16
3.2 Classical DB: unconditional indexation, variable contribution . . . 18
3.2.1 Contract specification . . . 18
3.2.2 Classical ALM analysis . . . 19
3.3 Hybrid: conditional indexation, variable contribution . . . 20
3.3.1 Contract specification . . . 20
3.3.2 Classical ALM analysis . . . 20
3.3.3 Value-based ALM analysis . . . 21
3.4 Collective DC: conditional indexation, fixed contribution . . . 23
3.4.1 Contract specification . . . 23
3.4.2 Classical ALM analysis . . . 24
3.4.3 Value-based ALM analysis . . . 24
3.5 Collective DC: fixed contribution, conditional indexation with cuts . . . 25
3.5.1 Contract specification . . . 26
3.5.2 Classical ALM analysis . . . 26
3.5.3 Value-based ALM analysis . . . 27
3.6 Collective DC: fixed contribution, conditional indexation with cuts and surplus sharing . . . 28
3.6.1 Contract specification . . . 28
3.6.2 Classical ALM analysis . . . 28
3.6.3 Value-based ALM analysis . . . 29
3.7 Final note on contract changes . . . 30

4 Change in discounting method **33**

4.1 Approach . . . 33
4.2 Changing the discount rate . . . 34
4.2.1 Adjusted real term structure . . . 34
4.2.2 Expected real returns . . . 34
4.2.3 Soft real: combination . . . 34
4.2.4 Results . . . 36

4.3 Adjusting the indexation levels . . . 37
4.3.1 Maintaining comparable level of generosity . . . 37
4.3.2 Restoring the generosity balance . . . 39
4.4 Changing the closure rule . . . 39
4.5 Open fund comparison . . . 41
4.6 Classical ALM analysis . . . 42
4.7 Final note on discounting . . . 43

5 Sensitivity analysis 44
5.1 Fund population . . . 44
5.2 Initial funding position . . . 46
5.3 Longevity risk . . . 48
5.4 Other aspects . . . 48

6 Conclusions 49

References 51

Appendices 52

A Pension plan specifications 52
A.1 Catch-up indexation . . . 52
A.2 Solvency cut . . . 53

B Graphs 54
B.1 Value transfers at individual level: decomposition to net benefit and residue . . . 54

C Tables 55
C.1 Classical ALM. Contract changes . . . 55
C.2 Classical ALM. Discounting changes . . . 57
C.3 Value-based ALM. Discounting changes . . . 59
C.4 Value-based ALM. Sensitivity to fund population . . . 61
C.5 Value-based ALM. Sensitivity to initial funding position . . . 62

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1 Introduction

1.1 The problem

The pension system of the Netherlands is ranked number one in the world according to the well known Melbourne Mercer Global Pension Index (Melbourne Mercer Global Pension Index Report, 2010). Still its second pillar occupational pension funds' policy proved to be unsustainable during the turbulent times in the markets. The buffers accumulated over time have been depleted during the recent financial crisis, leaving the pension funds with unacceptably low funding ratios. Poor stock returns have driven the assets of pension funds down, and the historically low nominal interest rates led to surging liabilities, both effects forcing the funding ratios fall to unacceptable levels. Even worse for the pension funds, there has been a significant increase in life expectancy, leading to the cuts of several more points in the funding ratios to adjust for the longer horizon of benefit payments. Given all these challenges it was realized that the Dutch pension system requires reconsideration of its features. Bovenberg and Nijman (2011) examine the collective pension system of the Netherlands in the wake of crisis and suggest possible reforms to improve the sustainability of the system.

The *Pensioenakkoord* discussion of the Netherlands proceeds with a goal of changing the pension system for better. The social partners (employer organizations and labor unions) are looking for a pension contract that would be shock resilient, would not put upwards pressure on the contribution rate, provide a balance between nominal guarantees and real ambition, be clearly defined and complete, and finally keep the risk sharing feature of the current contract without disrupting the generational balance (Ambachtsheer, 2011). Needless to say, the task is not trivial, for any change in the contract involves multiple effects on solvency and sustainability of the pension plan and last but not least, the generational balance.

1.2 Research description

We direct the discussion to addressing the issues that drive redistribution. Every change in the pension deal has a smaller or bigger effect on certain generations and redistribution is inevitable. It is hence important that policymakers are well aware of the effects following each change in the system so that a system with desirable features can be achieved and the effects for different generations mitigated to an acceptable level. As value transfers among generations cannot be avoided, it must be dealt with by understanding what causes redistribution to make sound decisions in pension plan redesign.

This research focuses on the value transfers among generations due to the changes in the pension contract. In Chapter 2 we explain the technical details of the research methods and the next two chapters are devoted to evaluating the effects of changes in pension system. In Chapter 3 we first examine the value transfers in historical context, looking at the contract development from traditional DB, a plan with guaranteed benefits and variable contribution, to a collective DC, where contribution is fixed and benefits are dependent on the funding ratio of the pension fund, moving a step further to a complete explicit contract. This evolvement is mostly disadvantageous to the elderly but can be explained by the favorable conditions for them in the past.

Then in Chapter 4 we focus on the possible shift from nominal framework to the real one. We choose the adjusted real term structure, the expected real returns and the combination of the two as the possible variants of real discounting. As real discounting involves significant redistribution from elderly to the young, we analyze the change in discount rate together with adjusted indexation policy to counterbalance the effect. We show that the importance of the changes in discounting within the pension system should not be underestimated. This change is not as straightforward as it might seem at first glance, as there are many effects involved, each with different implications on generational balance. When explaining the results we keep in mind our goal of framing the discussion rather than deciding on what is best. The general findings show that different discounting methods have different implications on intergenerational redistribution and the magnitude of it can even overpass the effects of pension contract development from traditional DB to collective DC. Hence it can lead to considerable value transfers among generations.

Finally, the robustness of the results is discussed in Chapter 5. We look at the results for a younger as well as a more mature pension fund, as compared to the benchmark average pension fund. The robustness to the initial state of the financial position of the pension fund is checked by assuming both lower and higher initial funding ratio of the fund, in contrast to the benchmark position.

The goal of the thesis is by no means finding the best (or most acceptable) pension reform but rather draw the attention to the implications of each change in the system on the intergenerational redistribution, decomposing the result in several steps and untangling the effects involved. It is meant to serve as a tool to assist identifying the reform's impact on generational balance and to give insight and policy advice helping the policy makers to make well-informed decisions.

1.3 Redistribution and fairness

Collective pension contracts with intergenerational risk sharing are said to be beneficial to all generations as compared to individual plans. Cui, de Jong and Ponds (2009) advocate for welfare enhancing features of intergenerational risk sharing in the pension schemes, stating that it is possible to share risks in funded plans, not only government run PAYG schemes. However, the pension contracts with collective features are subject to value transfers among generations and thus questions arise whether a plan with such feature is fair. The concept of fairness is probably the most arbitrary part in pension plan design, for each and every person has a different understanding of what is fair and equitable. A proper definition is difficult to achieve; here we present a broad view of the concept.

From an actuarial point of view, a plan could be perceived as fair if the present value of contributions paid throughout one's life is equal to the present value of benefits one receives during the years in retirement. Alternatively, actuarial fairness can be defined as the marginal return on contributions equal to the market interest rate (Lindbeck and Persson, 2003), or as zero net benefits independent of the age a person enters the retirement stage (Börsch-Supan, 1992). Even if the system is fair to everyone *ex ante*, it is not necessarily so *ex post*. The system might be designed in such a way that it is neutral to all generations beforehand but some generations are destined to be better off than others due to the differences in actual market contingencies during their lifetime.

Designing an actuarially fair transition from one plan to another is not an easy task in reality. If uniform life tables are used, the implicit return on savings is on average always higher for women than men due to the higher life expectancy of females. When the scheme is characterized by a uniform contribution and accrual (which currently is the case in the Netherlands), differences occur automatically between those who participate in the fund only in their early years of working life versus those who participate only in the later years; those who have very steep wage profiles (the trend that is usually attributed to highly educated people) and the ones having stable wages across life (Bovenberg, 2008). These intragenerational transfers seem unavoidable and sometimes are even designed to be there. Besides the obvious intragenerational redistribution, there are also intergeneration value transfers involved, that due to a specific change in the contract can reach unacceptable levels, which is the main topic of this research.

Apparently the issue of fairness is very arbitrary and there is no best answer to what the pension plan redesign should be (the ongoing *Pensioenakkoord* discussion is a living proof of it). As fairness is difficult to define, the least that can be done is evaluating the effects of pension reform on the generational balance with a goal of making better informed decisions. Given the criteria of what level of redistribution is acceptable, it is possible to choose the parameters of a new plan so that it suits the view of policymakers with respect to value transfers among generations.

The effect of the pension reform on the generational balance has been a widely discussed issue lately in Dutch media with a number of publications regarding the topic. The Netherlands Bureau for Economic Policy Analysis (CPB) has recently released a CPB Notitie (2011) regarding the *Pensioenakkoord* with a lot of attention to intergenerational effects. Although there have been some intuitive explanations of the effects of the pension reform on the intergenerational redistribution, a quantitative study has not been done yet. Hence this research contributes to the current pension discussion by employing a quantitative approach and thus not only stating the direction of redistribution but also allowing to compare the size of intergenerational transfers for different changes in the contract for a better understanding.

1.4 Research methods

We use the generational accounting technique and value-based ALM in order to perform the calculations. Generational accounting is a method of creating separate generational accounts where the cashflows throughout each generation's lifetime are reported, in this way obtaining the lifetime gain or loss that each generation faces in a particular system. The idea of generational accounting was first introduced by Auerbach, Gokhale and Kotlikoff (1991). It was used to evaluate adequacy of US government fiscal policy and its implications for the future generations, arguing that the measure of deficit is arbitrary, easily manipulated and may not provide the whole picture, while generational accounting avoids these problems.

The approach was followed by a number of attempts to evaluate the public finance effects for different generations in other countries. Van Ewijk *et al.* (2006) study the government reforms needed to make government finances sustainable in a light of intergenerational balance and equity, as each policy might have a (un)wanted effect on particular generations living now or in the future. Van der Horst *et al.* (2011) research the effects of fiscal policy reforms on the lifetime generational accounts of different cohorts. They scale the net benefits of future cohorts for the productivity growth, due to which future cohorts are expected to have a higher earnings potential. To show the effect, they express the change in lifetime net benefit in terms of annuity which indicates how much a particular generation is to gain or lose in Euros per year for the rest of its life. Ter Rele and Labanca (2010) applied the generational accounts for the Netherlands, evaluating the effects of government spending and taxation. It extends a conventional generational accounting by including not only the future cash flows but also those of the past in order to obtain complete lifetime generational accounts. The transfers of the second pillar pension system are not taken into account and thus it is a possible use of this master thesis.

Hoevenaars and Ponds (2008) applied the generational accounting concept to evaluate the transfers among generations in funded collective pension plans. They study in a stochastic framework the balance sheet of a pension fund in terms of generational options that are embedded in a plan. They apply a closed fund approach with a horizon of 20 years. The model considered in this thesis extends their approach in a way that it allows for the open fund approach, as well as for any closure moment.

To come up with the value of a pension deal to a participant we combine generational accounting with value-based ALM technique. Value-based ALM is a term describing the risk neutral valuation technique embedded in the ALM model. It is derived from derivatives pricing theory, as the pension contract is in fact a combination of embedded options whose payoff depends on market contingencies. De Jong (2004) discusses the deflator (stochastic discount factor) approach in valuing contracts with embedded options, such as pension plans, by using the contingent claims analysis in a risk neutral setting. In this thesis an alternative equivalent approach of risk neutral scenarios is used.

2 Model description

2.1 Approach

The pension fund, as many other financial institutions faces the risks arising because of a mismatch between assets and liabilities. To manage these risks an Asset-Liability Management (ALM) model has been used traditionally. It models many scenarios of possible future developments of variables involved, in this way giving insight into the effects of different decisions taken on the results of pension fund, e.g. the probability of underfunding, benefit cut or full indexation.

Classical ALM is a powerful tool enabling policy makers to understand possible future outcomes better and make sound and well-founded decisions. Despite that, an often seen critique is that classical ALM only teaches a well known truth that the more risk you take, the higher expected return is and the more volatile funding ratio becomes. The one thing missing is that it does not take into account the value transfers and effects for different cohorts.

To overcome this criticism we employ two additional techniques apart from classical ALM. Firstly, we use the generational accounting approach. The generational accounting technique records the cash flows of different generations into separate accounts. Hence the benefits and contributions in the pension fund are followed not only on aggregate level but also cohort level, making it possible to determine the effects of different policy measure for people of different age. Therefore we can see a complete picture of the benefits and contributions a person in a specific cohort pays and receives throughout his or her lifetime. Secondly, we use risk neutral valuation to determine the value of the pension deal to participants and call this technique a value-based ALM. While classical ALM gives insight into a distribution of possible outcomes such as funding ratio or replacement ratio, value-based ALM returns the value of the pension contract. The benefits and contributions that one pays or receives are dependent on the funding ratio which itself depends on the asset returns and inflation. We therefore can view the benefits and contributions as contingent claims, i.e. the derivatives whose payoff depends on market development. These claims can be priced by either using the deflators approach (De Jong, 2004) or risk neutral scenarios; in our research the latter approach is used. A separate section is devoted to explaining the scenario generating process and valuation in more detail after the description of the model.

In the following sections the building blocks of the model, the way of obtaining the cash flows of different generations and the valuation technique are explained in detail.

2.2 Model

To evaluate the effects of a change in a pension plan for different cohorts we use a stylized pension fund model, that is quite extensive and is based on real life features. A core model is used for real world analysis, while for the risk neutral valuation an extension of generational accounts is added to the model. A pension fund is modeled for a number of years to the future using the predetermined pension deal specifications, statistical data and generated scenarios.

2.2.1 Pension fund characteristics

The model allows for determining the specific aspects of a pension deal beforehand which allows us to evaluate all the different pension plan variants. Besides these parameters that can be changed for a specific plan there are some underlying assumptions that hold for each pension contract that we consider.

1. Pension contract is an average wage plan.[1]
2. The benefits are assumed to be indexed for wage growth, which is uniform across generations.
3. Contribution is uniform across generations and scenarios (but might be variable across time).
4. The accrual rate ε is set at 2% of the wage level.
5. The initial funding position is set to 125% in nominal terms.
6. The investment policy is set to 50% asset allocation in stocks and 50% in bonds.
7. The individual enters the pension fund at the age of 25, starts collecting benefits at the age of 65 and deceases at the age of 100 at maximum.

Therefore, any person is a participant in a fund for a maximum period of 75 years and at any given period in time there are 75 generations participating in a fund. The size of each generation is determined by the survival probabilities. When an individual contributes to the system for 40 years, he/she accrues 2% of the wage level in the years they participated, as a result collecting 80% of their average wage (plus the indexation) at retirement.

The stylized pension fund covers the whole population of the Netherlands. For that purpose, we use the data supplied by CBS (*Centraal Bureau voor de Statistiek*). It includes the population size (specified at a cohort level) and the survival rates for each generation as well as projections of both for the upcoming years. The data set is also gender specific, so the differences in male and female population and male and female survival rates are taken into account.

The model uses the initial population data set and adjusts it with survival probabilities using the Bayes rule to determine the size of each cohort in the future periods. For example, the size of male population of generation x at a time t can be expressed as:

$$MalePop_t^x = MalePop_{t-1}^{x-1} \cdot p_x^{male}(t|t-1) \tag{1}$$

where $p_x^{male}(t|t-1)$ is a probability of a male person surviving to age x in period t, conditional on this person having survived to age $x-1$ in $t-1$.

[1] Up to 2005 most pension plans in the Netherlands were final wage plans. Since then a gradual transition to the average wage plan has taken place and now this is a dominant plan type.

2.2.2 Core model

The starting point in the model is defining the initial assets that the fund holds. This is done by multiplying the initial funding ratio (predetermined before running the model) and initial liabilities, calculated as the present value of the total accrued benefit claims. It is assumed that the initial wage level is equal to 1 and that benefits are fully indexed up to now, so that the accrued benefits for each cohort are equal to the accrual rate ε times the number of years of service, as a percentage of a current wage. The accrued benefits matrix in each period represents the percentage of the current wage level that each generation has already accrued. Each line in the matrix represents one scenario and each column shows the benefits for generations beginning with the one that is 25 years old now and has not accrued any benefits yet, and ending with the oldest generation.

Initially the accrued benefits are the same for each of the 5000 scenarios as we assume that full indexation has been granted up to the time period that we start our model in; however, for the rest of the time periods they differ due to the difference between actual and full indexation in each scenario.

To calculate the liabilities, the elements in the accrued benefit matrix are multiplied by the elements in the discount matrix. The discount elements are gender-, cohort- and scenario-specific and are constructed as a sum of discount factors retrieved from the term structure in the current period in a particular scenario and the survival probabilities, used to calculate the present value of accrued benefits. For example, in case of a 65 year old participant, the discount element $D_{t,s}^{65}$ represents the sum of discount factors for accrued benefits to be paid now and up to 35 years into the future. In general, $D_{t,s}^{x}$ is calculated as:

$$D_{t,s}^{x} = \sum_{i=max(65-x,0)}^{99-x} p_x(i|t)\left(R_{t,s}^{(i)}\right)^{-i} \tag{2}$$

where $R_{0,s}^{(i)}$ stands for the rate with maturity i from the current nominal term structure in scenario s. We can actually sum the discount factors since the accrued benefit is the same for all future years. The discount element and hence the present value of accrued benefit claims is highest for the middle-aged cohorts, as they already collect benefits or will start to collect them soon and so have many years of benefits ahead. Therefore the fund needs to have many assets to be able to cover the liabilities for these cohorts, while for the very youngest and oldest cohorts the present value gets lower as the benefits for the former group do not yet have to be paid for many years and assets can be invested to generate return, and for the latter group there are only a few benefit payments left and the low survival probabilities at that age drive the discount factors even lower. The survival probabilities that are incorporated in the discount matrix for defining the liabilities are conditional survival probabilities of surviving up to a particular year in the future given that a person has survived up to this year.

When the initial assets are determined, the time loop starts running. In the beginning of each period the benefits (B) are paid to current pensioners and contributions (C) received from currently working generations (the size of benefits and contributions depends on a pension plan variant and will be explained in detail further). After adjusting the assets for these cash flows they are invested to stocks and bonds in a predetermined proportion. The assets of scenario s in period t can hence be calculated as:

$$A_{t,s} = \left(A_{t-1,s} + \sum_{i=25}^{64} C_{t,s}^{i} \cdot (MalePop_t^i + FemalePop_t^i) - \sum_{i=65}^{99} B_{t,s}^{i} \cdot (MalePop_t^i + FemalePop_t^i)\right) \cdot R_t^{inv} \tag{3}$$

Here $C^i_{t,s}$ represents the contribution paid by individual of age i at time t in scenario s and $B^i_{t,s}$ stands for the benefit received by individual of age i at time t in scenario s. The accrued benefit matrix is updated to account for the contributions that the working generations have paid as they accrue additional benefits. At the end of each period a new term structure is determined to calculate the liabilities of the fund by multiplying the accrued benefit matrix and the discount matrix. This gives the funding position of the fund after the inflows and outflows as well as investment returns.

Given the funding ratio, the accrued benefits matrix is adjusted by awarding indexation or applying cuts. The exact specifications of the benefit adjustment depend on the specific pension plan variant and will be discussed in more detail later.

The final benefits thus are equal to the benefits that each generation has accrued up to and in this period, plus any indexation given minus the cuts or surplus sharing if any. After the new benefits have been defined, the process of updating the matrices starts. The population numbers are adjusted given the projection of survival probabilities for that year. The matrix of wage level is adjusted for the growth levels for that year in each scenario. When the real world scenarios are used, the model ends after the time loop stops and gives the output for specified ratios. These include the development of a funding ratio, replacement ratio or indexation rate over time and the distribution of them through all scenarios.

2.2.3 Generational accounts extension

The risk neutral part of the model has the additional part with a matrix of generational accounts. While the time loop runs, benefits received and contributions paid by different cohorts are all recorded in this matrix. So after the time loop has ended we have a complete picture of the cash flows throughout the lifetime of the generations being evaluated during a chosen horizon.

Two approaches are considered here with respect to valuing the pension deal: an open fund approach and a closed fund approach.

Open fund In the open fund approach the benefits and contributions for each generation are recorded while time loop runs for 75 years, so that the generational account of the youngest already participating cohort can be completed. Generational accounts matrix for a particular scenario in the open fund setting can be depicted as follows:

$$\begin{bmatrix} C^{25}_{0,s} & C^{26}_{1,s} & C^{27}_{2,s} & \dots & C^{64}_{40,s} & B^{65}_{41,s} & \dots & B^{98}_{73,s} & B^{99}_{74,s} \\ C^{26}_{0,s} & C^{27}_{1,s} & C^{28}_{2,s} & \dots & B^{65}_{40,s} & B^{66}_{41,s} & \dots & B^{99}_{73,s} & 0 \\ \vdots & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\ C^{64}_{0,s} & B^{65}_{1,s} & B^{66}_{2,s} & \dots & 0 & 0 & \dots & 0 & 0 \\ B^{65}_{0,s} & B^{66}_{1,s} & B^{67}_{2,s} & \dots & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\ B^{98}_{0,s} & B^{99}_{1,s} & 0 & \dots & 0 & 0 & \dots & 0 & 0 \\ B^{99}_{0,s} & 0 & 0 & \dots & 0 & 0 & \dots & 0 & 0 \end{bmatrix}$$

Here each row represents a generational account of a particular cohort, the first row representing the cohort that is 25 years now and has just entered the fund, while the last line represents the oldest cohort that has only one benefit to be received. Each column of the matrix represents a different year and if a generation is no longer alive in this year, 0 is entered.

Closed fund In the closed fund approach[2] the fund is assumed to be liquidated after 25 years and the residue option is added at the end of the last period, that is, a deficit or surplus of the pension fund at the time of closure is distributed to its participants at that moment in time according to their accrued benefits. The residue is distributed for generations that are currently 1 to 74 years old, for the generation that has just been born will not have any benefits accrued yet at the time of closure and the rest of the generations will be deceased already by that time.

$$\begin{bmatrix} 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & C^{25}_{24,s} \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ C^{24}_{0,s} & C^{25}_{1,s} & C^{26}_{2,s} & \dots & C^{47}_{23,s} & B^{48}_{24,s} \\ C^{25}_{0,s} & C^{26}_{1,s} & C^{27}_{2,s} & \dots & C^{48}_{23,s} & B^{49}_{24,s} \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ C^{64}_{0,s} & B^{65}_{1,s} & B^{66}_{2,s} & \dots & B^{87}_{23,s} & B^{88}_{24,s} \\ B^{65}_{0,s} & B^{66}_{1,s} & B^{67}_{2,s} & \dots & B^{88}_{23,s} & B^{89}_{24,s} \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ B^{98}_{0,s} & B^{99}_{1,s} & 0 & \dots & 0 & 0 \\ B^{99}_{0,s} & 0 & 0 & \dots & 0 & 0 \end{bmatrix} + \begin{bmatrix} 0 \\ R^1_s \\ R^2_s \\ \vdots \\ R^{73}_s \\ R^{74}_s \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

We suggest one could look at these two approaches the following way. The pension system arrangement usually does not last more than a couple of decades due to political or economic reasons. Hence a 25 year horizon is already quite long for a pension contract to remain intact. If the pension plan is to be changed after that period of time, the change is likely to be more beneficial in case of surplus than in case of deficit. The participant thus has interest in the funding position of the fund: even if it does not benefit him or her directly through benefits or contributions during the 25 years, they are very likely to be better off in a fund with higher funding ratio, keeping all else *ceteris paribus*. When one wants to see a pure effect of a reform on the benefits that a participant receives and premium he/she pays throughout their remaining lifetime, the open fund setting is more suitable as it avoids indirect effects in evaluating the reform.

2.3 Valuation

Pension deal is a financial contract whose payoff depends on market contingency. For example, it can be determined in the contract that benefits are higher and/or contributions are lower in case good market outcomes materialize, and vice versa. Then the implicit return of the pension deal depends on the specifications of the plan as well as market conditions that materialize. Hence the benefits and contributions are essentially the functions of the funding ratio of the pension fund and contingent claims analysis can be used to value the pension scheme. If we perceive the pension contract as a combination of contingent claims, we can value the pension deal using derivative pricing technique of risk neutral valuation, introduced by Black and Scholes (1973).

To explain it let us first look at a classical example from option pricing theory. Consider a S euro stock that at time T can be worth either $S \cdot u$ or $S \cdot d$ euros. A riskless portfolio can be constructed by buying Δ shares and going short one derivative (like call or put option). If we denote the payoff of option as f_u and f_d for good and bad scenario respectively, then $\Delta = \frac{f_u - f_d}{S \cdot u - S \cdot d}$ in order for the portfolio to be riskless. As this portfolio is riskless, under the no-arbitrage condition it

[2]The term closed fund approach that we use in this thesis should not be confused with another use of term closed fund, where the risks in the pension plan are shared only within currently participating generations.

must earn a risk-free rate of return r and thus the following is true: $\Delta S - f = (\Delta Su - f_u)e^{-rT}$. By substituting for Δ we arrive at $f = (qf_u + (1-q)f_d)e^{-rT}$, where $q = \frac{e^rT-d}{u-d}$. If we assume q is a probability of stock price moving up and $1-q$ is a probability of it moving down, we can see that the expected return on stock is a risk free rate. Therefore the derivative price can be obtained by assuming a risk free rate of return on the underlying and discounting at the risk-free rate. To stress that these probabilities are not real-world probabilities but rather a tool to price the derivative, they are called risk neutral probabilities (Hull, 2009).

This is just a binomial one period example of plain vanilla option pricing. The pension deal however is a much more complicated contract consisting of embedded options, not even mentioning that there are many more than two possible outcomes for the underlying variables. Therefore to value the contract we use the generated scenarios for the underlying variables. One can calculate the market value of a contingent claim by either using deflators and real world scenarios, or risk neutral scenarios. The following expression shows that these are alternative methods that result in the same outcome:

$$V = \mathrm{E}_t(D_T X_T) = \mathrm{E}_t^{\mathbb{Q}}(e^{-rT} X_T) \tag{4}$$

Here V represents the value of the contingent claim with outcomes X_T and D_T is a stochastic discounting factor (deflator) for scenarios in X_T. $\mathrm{E}_t^{\mathbb{Q}}$ is the risk neutral expectation in the $\mathbb{Q}$ world of the cashflows discounted at the risk free rate. Therefore to come up with a market value using real world scenarios we have to calculate the expectation of outcomes in each scenario weighted with a deflator, or, alternatively, one can calculate the expectation under $\mathbb{Q}$ measure, i.e. the expectation of the outcomes under risk neutral scenarios, discounting them using risk free rate (Cochrane, 2001). We use the latter method for our analysis.

The following two sections will focus on scenarios and valuing the pension contract respectively.

2.3.1 Scenario set

The ALM model is based on Monte Carlo simulation of 5000 possible future economic scenarios. As the aim of the thesis is to evaluate the effect of a change in a pension plan in both classical ALM and value based ALM, we use two sets of scenarios: real world and risk neutral, each explained in following sections more in detail.

Real world scenarios The results of a pension fund are dependent on the future outcomes of a number of risky variables. These are the return on stocks, return on bonds, for they determine the investment return, and the wage growth, as it is important for nominal contribution size and indexation of benefits. The term structure also plays a key role as it is used to discount the accrued benefits in order to evaluate the liabilities of the fund. Scenario generating process deserves a thesis on its own, so only the basic information will be given here not going into the details.

The vector auto-regressive model with jumps and time-varying volatilities is used for the dynamics of state variables:

$$\mathbf{x}_{t+1} = \begin{bmatrix} \pi_{t+1} \\ y_{t+1} \\ xs_{t+1} \\ dy_{t+1} \\ cs_{t+1} \\ mp_{t+1} \end{bmatrix} = \mathbf{c}_t + \mathbf{\Gamma}\mathbf{x_t} + J_{t+1} + \mathbf{\Sigma}\mathbf{S}_t^{1/2}\zeta_{t+1} \tag{5}$$

$$\mathbf{c}_t = (\mathbf{I}_6 - \mathbf{\Gamma})(\mu_0 + \mu_{\bar{\pi}}\bar{\pi}_t) - \mathbf{p}\nu \tag{6}$$

$$\zeta_{t+1} \sim \mathbb{N}(\mathbf{0}, \mathbf{I}_6) \tag{7}$$

Here π_{t+1} stands for Eurozone inflation, y_{t+1} is Euribor three months rate, xs_{t+1} excess return on stocks, dy_{t+1} dividend yield, cs_{t+1} credit spread and mp_{t+1} maturity preference. $\bar{\pi}_t$ stands for deterministic inflation target. Jumps are modeled by jump indicator J_{t+1} with probability $\boldsymbol{p}$ and size ν, while time varying volatility is obtained by diagonal matrix $\boldsymbol{S}_t$ (Van den Goorbergh, Molenaar, Steenbeek and Vlaar, 2011).

The term structure is constructed using affine term structure model. The parameters for it and other variables are calibrated on the historical data to generate the real world scenarios. As the model incorporates low probability jump process and allows for time varying volatilities and correlations, this is a big improvement with respect to previously used models that considered crises as highly unlikely and volatilities constant, both of the assumptions being obviously wrong, as recent two crises with high volatility in markets over the past decade suggest.

Jumps here stand for sudden drop in confidence, decrease in stock market, lowering interest rates and high credit spreads. Probability of jump is assumed constant, as crisis can occur whenever and is unpredictable.

Also a time varying covariance matrix for the normally distributed shocks is introduced with two sources of uncertainty: monetary (inflationary) and real (affecting risk aversion). The importance of these sources depends on a number of driving variables. Monetary volatility factor increases with current inflation and short term interest rate, while risk aversion volatility factor increases with credit spread and dividend yield and decreases with the stock market return. Equity option and swaption prices are incorporated for second moments. For a more extensive description of scenario generating process one should refer to Van den Goorbergh, Molenaar, Steenbeek and Vlaar (2011).

Risk neutral scenarios We use risk neutral valuation and hence risk neutral scenarios in value-based ALM part of the model to calculate the value of the contract. For that reason, the real world scenarios are transformed to the risk neutral measure (for an extensive explanation refer to Lin and Vlaar, 2011). Wage growth is not tradable, so a slightly different procedure is used to generate scenarios for it. A regression equation for wage growth with lagged wage growth w, inflation π and lagged short term interest rate $y^{(1)}$ is estimated under $\mathbb{P}$ measure.

$$w_{t+1} = \alpha + \beta_w w_t + \beta_\pi \pi_{t+1} + \beta_y y_t + \epsilon_{t+1} \tag{8}$$

Given the nominal and real term structure the dynamics of π and y under $\mathbb{Q}$ measure are obtained. Then to generate w under $\mathbb{Q}$ measure the above mentioned regression equation is used with the estimated parameters, and market related variables π and y are given the dynamics under $\mathbb{Q}$.

$$w^{\mathbb{Q}}_{t+1} = \alpha + \beta_w w^{\mathbb{Q}}_t + \beta_\pi \pi^{\mathbb{Q}}_{t+1} + \beta_y y^{\mathbb{Q}}_t + \epsilon_{t+1} \tag{9}$$

For there is no predictability in $\mathbb{Q}$ world, the scenarios for variables that are priced in the markets in the simulations are assumed to follow martingale sequence.

2.3.2 Value of the pension deal

The value of a generational account of the youngest generation at the moment ($t = 0$) is calculated as the expectations under $\mathbb{Q}$-measure of all future cash flows. In the open setting it is done as follows:

$$V_0^{25} = \mathrm{E}_0^{\mathbb{Q}}(GA_0^{25}) = \mathrm{E}_0^{\mathbb{Q}}\left(\sum_{i=0}^{39} -\left(p_{25}(0{+}i|0)C_{0+i}^{x+i}\prod_{j=0}^{i}(R_j^f)^{-1}\right)+\sum_{i=40}^{74}\left(p_{25}(0{+}i|0)B_{0+i}^{x+i}\prod_{j=0}^{i}(R_j^f)^{-1}\right)\right) \quad (10)$$

Here R_j^f represents return on investment in short term risk free bonds: $R_j^f = 1 + r_j^f$, where r_j^f is a risk-free rate of return, and $R_0^f = 1$. The expectations are calculated by taking the mean over all scenarios.

In general case, we calculate the generational account value of a person aged x at time t as follows. For a person aged 65 or more it is:

$$V_t^x = \mathrm{E}_t^{\mathbb{Q}}(GA_t^x) = \mathrm{E}_t^{\mathbb{Q}}\left(\sum_{i=x}^{99}\left(p_x(t+(i-x)|t)B_{t+(i-x)}^{i}\prod_{j=t}^{t+(i-x)}(R_j^f)^{-1}\right)\right), x \geq 65 \quad (11)$$

while for a person younger than 65 it is:

$$V_t^x = \mathrm{E}_t^{\mathbb{Q}}(GA_t^x) = \mathrm{E}_t^{\mathbb{Q}}\left(\sum_{i=x}^{64} -\left(p_x(t+(i-x)|t)C_{t+(i-x)}^{i}\prod_{j=t}^{t+(i-x)}(R_j^f)^{-1}\right)\right.$$
$$\left. + \sum_{i=65}^{99}\left(p_x((t+65-x)+(i-65)|t)B_{(t+65-x)+(i-65)}^{i}\prod_{j=t}^{(t+65-x)+(i-65)}(R_j^f)^{-1}\right)\right), x < 65 \quad (12)$$

Thus the outcome is a value of the pension deal for the representative member of each cohort x (since the survival probabilities are gender specific, values are different for males and females).

Note that we calculate the value of the pension deal in the initial period but the results are in fact time dependent and hence the value calculated next period would be already different from the current one. The values for the closed fund setting are derived accordingly with a horizon of 25 years and the last benefit or contribution supplemented with the share of final assets for the cohorts alive at the moment of closure.

Since we analyze the effects of pension redesign, or simply the change in contract, we are interested in the changes in value of the plan to each generation. Hence we measure

$$\Delta V^x = V_t^x - {V'}_t^x \quad (13)$$

where V_t^x is a value of a new pension plan to a participant of age x and ${V'}_t^x$ is a value of a plan that we compare the new one to; we call it the benchmark plan. When we will evaluate contract changes in Chapter 3 the benchmark will differ from plan to plan, while in discounting changes analysis in Chapter 4 the benchmark will remain the same.

2.4 Results evaluation methods

We will present the results in both classical ALM and value-base ALM framework.

The output of classical ALM is oriented to solvency of a pension fund and forms the basis for policy making and decision on indexation. It focuses on the development of certain indicators over time. The most important indicator is the funding ratio (FR), which is calculated in nominal and real terms:

$$FR_N = \frac{A}{L_N} \quad (14)$$

$$FR_R = \frac{A}{L_R} \tag{15}$$

Here A stands for assets of the fund, L_N represents nominal liabilities and L_R stands for real liabilities.

As it is an ALM study, the set of possible future paths of FR development is given at the end of simulation period. This is depicted as a 2,5%, 50% and 97,5% quantiles of the distribution of possible FRs at certain times during the horizon that is being evaluated. The outcome data allows for evaluation of what is the possibility of a pension fund becoming insolvent after some years (that is, the possibility of the FR going below some threshold) so it is a nice tool to evaluate what is the impact of a change in pension plan on solvency of the pension fund.

Similarly the future development of the indexation level is given. Replacement rate (RPR) is defined as the ratio of the actual accrued benefits to the wage level:

$$RPR^x_{t,s} = \frac{B^x_{t,s}}{W_{t,s}} \tag{16}$$

In case full indexation has been given throughout the considered period, RPR is 80% for pensioners; for workers it is a number of years participated times the accrual rate in each scenario. Replacement level differs for different generations, so the quantiles are represented for several chosen generations.

It also holds for the pension result (PR), which is calculated as the ratio of cumulative indexation to the cumulative wage growth:

$$PR^x_{t,s} = \frac{\prod_t ind^x_{t,s}}{\prod_t w^x_{t,s}} \tag{17}$$

here w is the wage growth in a particular period in time and ind is the indexation rate.

It is often discussed which one of the two indexation measures should be used; we report both. The replacement ratio is an important figure from the participant's point of view; after all, the pensioners are eventually most interested in how their benefit stands relative to the wage level. The replacement rate for the older generations, however, incorporates the initial assumption that all the benefits accrued before the model starts are fully indexed. Hence RPR includes the pre-model years with assumed full indexation, while PR overcomes this issue as the cumulative indexation is compared to the cumulative wage growth only for the years in the model. The pension result, however, does not incorporate the new accrual effects; it only measures the cumulative indexation rate, while in fact the indexation has different effect on accruals of young generations than the older ones. As a consequence, both measures give a related information but from different perspectives.

The value based ALM concentrates on the value of the pension deal and redistribution issues, therefore the total magnitude of value transfers will be presented as well as changes in value for individual participants of the pension plan foregoing the reform.

3 Change in the nature of contract

3.1 Approach

The Netherlands pension system as a whole has been in place for many years already without big changes in its design. The Dutch system consists of a residence based universal first pillar, the quasi-mandatory funded second pillar and voluntary third pillar, and is often cited as the best in the world but still has not managed to avoid sustainability problems. In attempt to improve sustainability the second pillar pension plans have evolved in the recent years. In this chapter we will look at the general pattern of these changes and evaluate the generational redistribution in historical context.

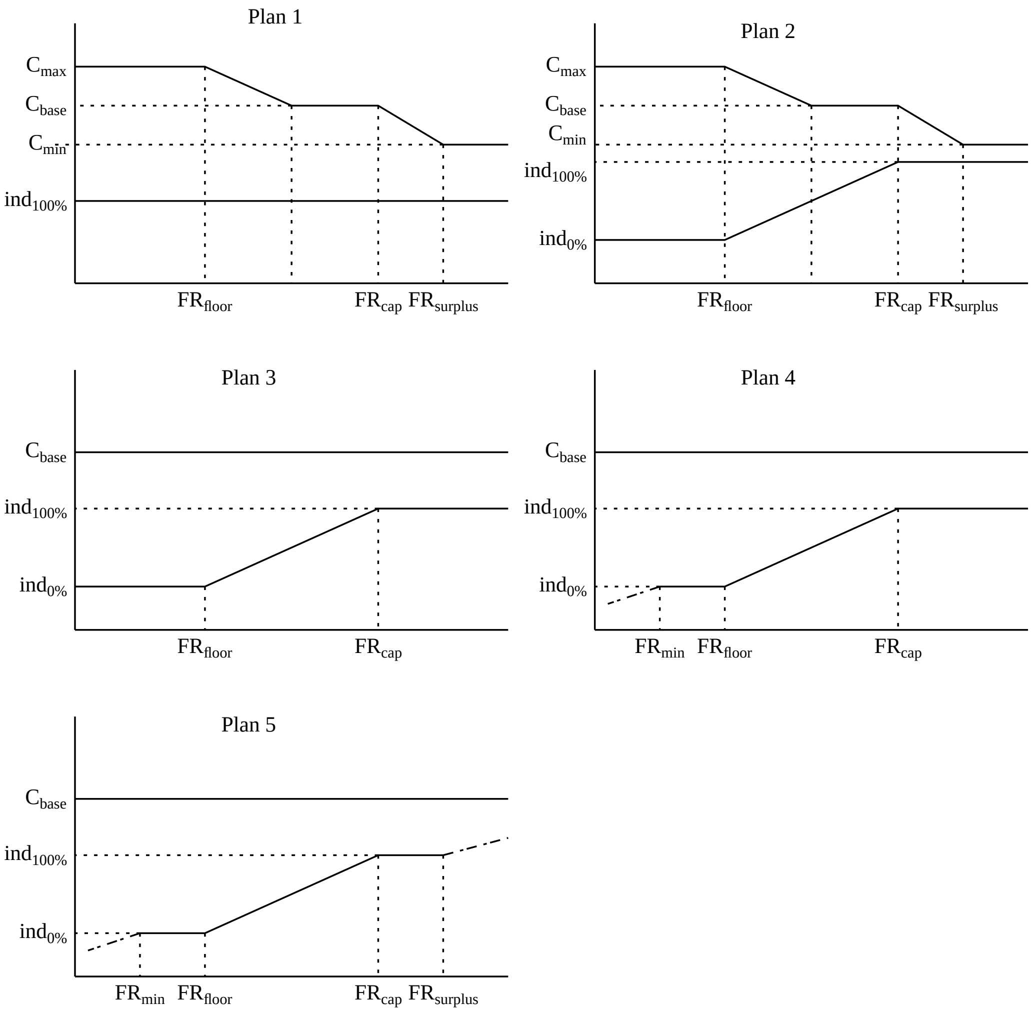

Figure 1: Graphical representation of contribution and indexation rules in pension plan variants

The changes we consider are represented in Figure 1. Each of the five diagrams is a graphical representation of rules defining benefits and contributions dependent on the funding ratio of the fund in each of the five pension contracts. The upper line in the diagram stands for the contribution level, while the lower line defines the indexation rule. Thus a straight line represents fixed benefit or contribution, while a sloped line shows the contribution or indexation levels conditional on the funding position. In that case the y-axis shows the level of contribution or indexation for corresponding funding ratio levels represented on x-axis.

We decompose the evolution of the pension plan into four steps. We start with a traditional DB plan with guaranteed indexation of benefits and variable contribution rate (Plan 1), the plan that used to be dominant several years ago. As it appears, guaranteeing full indexation and relying on contribution rate as the only steering variable proved unsustainable. Around 2005 the so called policy ladder[3] was introduced (Plan 2), meaning that full indexation is granted only when the funding ratio rises above certain level. This feature of the contract is in place up to this day and its introduction is the first step that we consider. The second step is fixing the contribution rate (Plan 3), representing a decreasing importance of using the contribution rate to absorb the shocks. The remaining steps are meant to make the pension contract complete, foregoing a common critique that an incomplete pension deal leaves an open question of who is to assume a deficit or surplus. With the third step we introduce a benefit reduction when the funding ratio falls below some level and a recovery plan allowing the fund to recover within five years (Plan 4). This measure deals with the downside risk of the incomplete contract. Finally, the fourth step addresses the upside risk by implementing a rule of surplus sharing (Plan 5).

In the Figure 1 as well as further in the text min refers to a critical funding ratio level at which benefits are cut, $floor$ is the minimum level for indexation, cap is a level for full indexation and $surplus$ is a minimum level for surplus sharing option to come in the money. We set $min = 0,85$, $floor = 1,00$, $cap = 1,30$ and $surplus = 1,60$ of the nominal funding ratio level.

In the following sections we will define the pension contracts more specifically, describe their performance with reference to classical ALM output in the closed and open setting and examine the implications of reform on the value of pension plan for different generations.

3.2 Classical DB: unconditional indexation, variable contribution

3.2.1 Contract specification

The first pension contract that we consider is a traditional average wage Defined Benefit (DB) plan with full indexation guarantee. The only steering variable in this pension plan variant is the contribution rate.

Variable contribution The contribution rate varies from time to time depending on the funding position of the pension fund and is set as follows:

$$c = \begin{cases} c_{max} & \text{if } FR_N < floor, \\ c_{max} - \left(\frac{FR_N - floor}{\frac{floor+cap}{2} - floor} \right) (c_{max} - c_{base}) & \text{if } floor \leq FR_N \leq \frac{floor+cap}{2}, \\ c_{base} & \text{if } \frac{floor+cap}{2} < FR_N < cap, \\ c_{base} - \left(\frac{FR_N - cap}{surplus - cap} \right) (c_{base} - c_{min}) & \text{if } cap \leq FR_N \leq surplus, \\ c_{min} & \text{if } FR_N > surplus. \end{cases} \tag{18}$$

where $c_{base} = \frac{c_{max}+c_{min}}{2}$. We set $c_{min} = 15\%$ and $c_{max} = 25\%$ with the additional condition that

$$|c_t - c_{t-1}| \leq 0.02 \tag{19}$$

hence preventing the contribution from being increased more that 2 percentage points annually. This is to prevent drastic changes in contribution level, as it is difficult to implement in reality due to the pressure from labor unions and other parties involved. Here $floor$ is the minimum level of FR_N below which the maximum premium rate is applied and cap is the level of FR_N

[3]The term policy ladder refers to the indexation policy, e.g. specific rules defining at what funding ratio levels the indexation is granted

above which the minimum premium rate is applied. The benefits in this plan are always given full wage indexation independent of the funding ratio.

3.2.2 Classical ALM analysis

We will firstly discuss classical ALM output to assess the pension scheme's performance before looking at the generational effects. For convenience we enclose a table with funding ratios after 25 and 75 years as well as the replacement rates and pension results for 25 year cohort after 25 and 70 years. The indexation of a 25 year cohort does not include any assumptions about the pre-model benefit indexation. For that reason we choose to show the indexation results in the table for this particular generation. The more comprehensive table with results for other key cohorts can be found in Appendix A.2. Note that the replacement rate for 25 year old cohort is 0,5 in 25 years and 0,8 in 70 years in case full indexation has been granted.

This pension contract, by definition, shows excellent indexation results, but also enlightens a problem of sustainability when too generous indexation is given. An incredibly poor funding position in worst case scenarios is caused by unconditional full indexation. Given the fact that in this pension scheme only contribution rate is used to absorb shocks (and contribution is quite a limited tool due to the constraints mentioned above) it is unsurprising that the funding ratio in the $2,5\%$ quantile plummets to the level of around 60% in 25 years and the probability of funding ratio going below 100% is as high as 21%. The longer horizon of 75 years results in extreme outcomes, proving once again that such a plan is unsustainable in the long term. The nominal funding ratio at $2,5\%$ quantile plunges to 11% and the probability of nominal underfunding almost reaches 27% in year 75. The indexation is no longer full in lowest quantiles as in these extreme outcomes the benefit cut mechanism is triggered in order to avoid a complete depletion of assets. Of course, a situation like this is very unlikely to happen in reality as some measures would be taken well before the fund is almost insolvent, but this calculation lets us better understand the severity of the situation.

Horizon	$FR_N^{0,025}$	$FR_N^{0,5}$	$FR_N^{0,975}$	$FR_R^{0,025}$	$FR_R^{0,5}$	$FR_R^{0,975}$	$p(FR_N < 1)$
25	0,6093	1,3349	2,6109	0,4376	0,9707	1,9044	0,2146
75	0,1123	1,8166	10,6782	0,0796	1,3087	7,6893	0,2676

Horizon	$RPR_{25}^{0,025}$	$RPR_{25}^{0,5}$	$RPR_{25}^{0,975}$	$PR_{25}^{0,025}$	$PR_{25}^{0,5}$	$PR_{25}^{0,975}$	$p(i < 0)$
25	0,5000	0,5000	0,5000	1,0000	1,0000	1,0000	0,0000
70	0,3903	0,8000	0,8000	0,4869	1,0000	1,0000	0,0032

Table 1: Key figures for Plan 1. The upper panel represents the 2,5%, 50% and 97,5% quantiles for the nominal and real funding ratio, as well as probability of nominal underfunding after 25 and 75 years. The lower panel shows the same quantiles of the replacement ratio and pension result for cohorts of 25, 45 and 65 years old in 25 and 70 years, as well as probability of benefit cut during these years

The upside on the other hand is unlimited, as there is effectively a cap on maximum benefits: the full indexation is the most that a participant of this scheme can expect. In our simulation the median funding ratio stays around 133% and reaches 261% in the $97,5\%$ quantile after 25 years, whereas for 75 years horizon the numbers are 181% and the extreme 1068% respectively.

3.3 Hybrid: conditional indexation, variable contribution

A natural move given the funding problems in the traditional DB plan described above is to make the indexation conditional on the funding position.

3.3.1 Contract specification

The contract is in principle the same as Plan 1 with one crucial adjustment: the full indexation is no longer guaranteed. The participants of this pension plan cannot expect the benefits fully indexed to the wage growth anymore; it is only the best case scenario that would lead to this outcome.

Conditional indexation The conditional wage indexation of benefits is determined as follows:

$$ind = \begin{cases} 1 & \text{if } FR_N < floor, \\ 1 + \left(\frac{FR_N - floor}{cap - floor}\right) w & \text{if } floor \leq FR_N \leq cap, \\ 1 + w & \text{if } FR_N > cap. \end{cases} \tag{20}$$

In case indexation was missed in the past and the funding position is adequate, the catch-up indexation can be awarded, which is explained in detail in Appendix A.1. To sum it up, the benefits downside in this pension contract is limited to the nominal level but benefits are capped at the full indexation. Indexation in a particular period can be higher than the wage inflation in case of missing indexation in the past but cannot be negative.

3.3.2 Classical ALM analysis

A move to conditional indexation improves the results with respect to the funding position. While the upper quantiles of the funding ratio (both nominal and real) remain in line with previous plan, the results of the $2,5\%$ worst cases improve significantly. The nominal funding ratio jumps from roughly 61% to 89% in 25 years and from 11% to 94% in 75 years; the real funding ratio improves accordingly.

Horizon	$FR_N^{0,025}$	$FR_N^{0,5}$	$FR_N^{0,975}$	$FR_R^{0,025}$	$FR_R^{0,5}$	$FR_R^{0,975}$	$p(FR_N < 1)$
25	0,8937	1,3622	2,6223	0,6369	0,9885	1,9107	0,0662
75	0,9392	2,0561	10,8171	0,6650	1,4820	7,8051	0,0424

Horizon	$RPR_{25}^{0,025}$	$RPR_{25}^{0,5}$	$RPR_{25}^{0,975}$	$PR_{25}^{0,025}$	$PR_{25}^{0,5}$	$PR_{25}^{0,975}$	$p(i < 0)$
25	0,3866	0,5000	0,5000	0,6444	0,9482	1,0000	0,0000
70	0,4613	0,8000	0,8000	0,4880	0,9372	1,0000	0,0000

Table 2: Key figures for Plan 2. The upper panel represents the 2,5%, 50% and 97,5% quantiles for the nominal and real funding ratio, as well as probability of nominal underfunding after 25 and 75 years. The lower panel shows the same quantiles of the replacement ratio and pension result for cohorts of 25, 45 and 65 years old in 25 and 70 years, as well as probability of benefit cut during these years

This enhancement of solvency position comes at the cost of indexation. Again, indexation in good scenarios remains intact but the indexation position deteriorates for worse case scenarios. All in all, the chance of underfunding decreases from previous more than 20% to a much lower 6, 6% in 25 years and even lower 4, 2% in 75 years but it comes with lower indexation potential in bad states of the world.

3.3.3 Value-based ALM analysis

Throughout this chapter we will follow a consistent approach of examining four graphs in order to explain the redistribution effects involved in each reform. In each graph the x-axis shows the age of the cohort or individual and y-axis represents the gain or loss for that particular cohort or individual due to the change in contract.

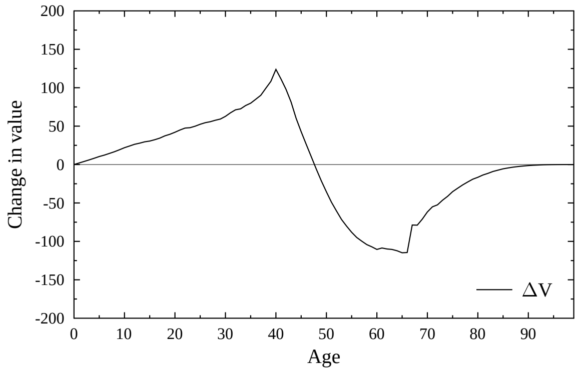

Figure 2a: Change in value at a cohort level when moving from Plan 1 to Plan 2 in the closed setting

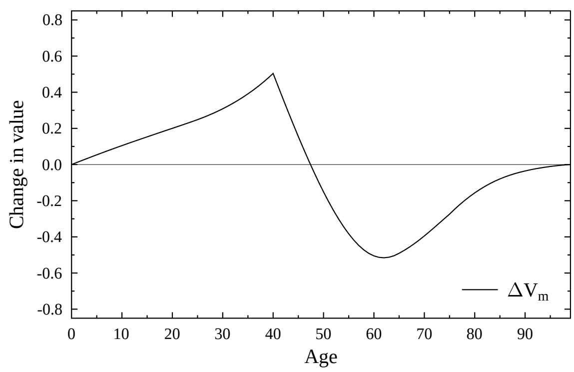

Figure 2b: Individual gender specific change in value when moving from Plan 1 to Plan 2 in the closed setting

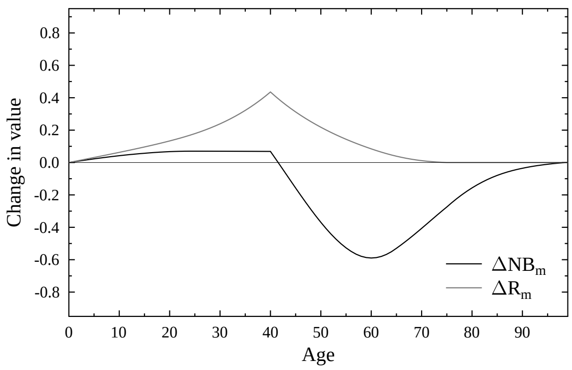

Figure 2c: Change in the net benefit and residue when moving from Plan 1 to Plan 2 in the closed setting

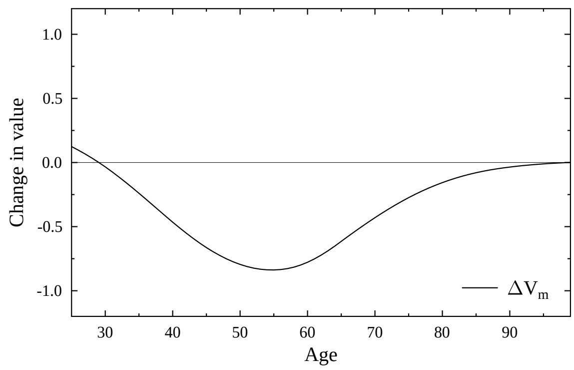

Figure 2d: Individual gender specific change in value when moving from Plan 1 to Plan 2 in the open setting

The first graph is a cohort-level graph where the total gain or loss of all people in the cohort is expressed in thousands of annual wage levels. This figure shows a zero-sum game, since the aggregate gain of all generations that benefit from the change is equal to the aggregate loss of all losing generations when we close the fund. The numbers on y-axis are therefore difficult to interpret because the sizes of generations differ. Hence in the second graph we show the effect for individual in each cohort that is expressed in annual wage levels.

The third figure decomposes the latter to the change in net benefit and the change in share of final assets (or alternatively, the change in share of fund's residue). The net benefit part of the change shows the direct impact of the pension reform on the level of benefits that one receives and premium that one pays. The residue part explains the other side of the picture, namely the implications on the funding position of the fund. A positive shift in the funding ratio implies a positive change in residue while the deteriorated funding position would be reflected by a negative change in residue. The closed fund approach thus implies that we divide the benefit or loss of the enhanced or worsened funding position to the cohorts living at the moment of closure.

The open fund approach is different in that perspective. In the open setting we leave the funding position of the fund intact, assuming it for the future cohorts. Consequently, the change in value has only the direct component in this case (but dependent on the funding position still), as the residue component is shifted to the future. This effect is shown in the fourth figure.

As the effects follow a similar patter for both males and females (for females being somewhat more extreme most of the time) and the topic of the thesis concentrates on the inter- rather than intra-generational transfers, we will not discuss the differences in the effects for genders in detail. In the graphs we will only show the results for male participants; the results for female participants however will be presented in the table in the end of the chapter. For easier comparison the scale of y-axis remains the same throughout analysis of different reforms.

Figures 2 a-d show the intergenerational effects of introducing conditional indexation, i.e. moving from Plan 1 to Plan 2. A clear pattern can be seen that switching from full indexation plan to a plan with conditional indexation is favorable to the cohorts younger than 50 years but disadvantageous for the older cohorts. From the change in net benefit it can be observed that the reform is favorable to the very youngest cohorts that are less than 40 years old now and in 25 years will not have retired yet. They benefit from the direct impact of a better funding position by having to contribute less to the scheme. This is of course at the expense of the elderly who receive less indexation. The line of change in residue confirms the improved funding position, as it is positive for all cohorts and peaks at the cohort of age 40 that will turn 65 and retire in 25 years time and hence will have accrued the most liabilities at that time. Therefore the change in residue enhances the positive effect for the cohorts of up to 40 years and mitigates the effect somewhat for the cohorts aged 40-75, while the oldest cohorts will not be alive at the moment of closure and thus the effect for these generations is the same, would it be an open or a closed fund. The total effect of making the indexation conditional is the value redistribution from elderly to the young.

Let us now switch to the open fund and look at the direct effect on benefits and contributions of the cohorts currently in the fund during the 75 years horizon so that the generational accounts of all generations are complete. A different situation can now be seen. The effect stays unchanged for cohorts above 75, as explained before. Most of the other cohorts (except for the very youngest ones) are worse off when we look at the pure effect as compared to the closed setting. This is because the indirect effect of a changed funding position dominates the direct effect on benefits and contributions. In a 75 years horizon we see that the negative effect gets stronger when going from the oldest cohorts to the 55 year old ones. Up to this point, a negative effect of lower indexation is apparent. At a cohort of around 55 is a breaking point where the generations actually start benefiting from the improved funding position and hence lower contributions, up until the cohort of around 30 where the negative effect of conditional indexation is finally offset by the positive effect of lower contribution rates. As the total change in value for all currently participating cohorts is negative, a natural conclusion is that the future participants should gain due to this change in contract. It is also supported by the fact that the funding position improves significantly (especially on the left side of the distribution).

One thing to consider is that in this particular plan setting a message that the current cohorts lose due to introduction of conditional indexation might be misleading. One must be aware of the fact that in the benchmark plan with full indexation in a long horizon of 75 years the fund can reach extremely low funding ratios so it might happen that it defaults on its liabilities in which case any current participant would be actually better off in a plan with conditional indexation.

While the increased or decreased funding position is allocated to the living cohorts in the closed fund, in the open fund this position is shifted to the future. So the conclusion is in fact the same in open and closed settings, as they just have different breaking points to separate young and old, current and future cohorts. It is important to stress that, although not visible in the picture, open fund is still a zero-sum game: a loss for the current cohorts implies a gain for the future cohorts.

3.4 Collective DC: conditional indexation, fixed contribution

The second step we consider is moving from variable to a stable contribution rate, as the contribution rate has gradually lost its importance in absorbing shocks and is less and less used as a steering variable.

3.4.1 Contract specification

Fixed contribution When moving from Plan 2 to Plan 3 we set the contribution rate to a fixed level that is chosen in such a way that the present value of contributions is approximately equal to the present value of the accrued benefits in the same year. Hence the following condition should hold

$$c \sum_{x=25}^{64} W^x Pop^x = \varepsilon \sum_{x=25}^{64} D_c^x \tag{21}$$

and thus

$$c = \frac{\varepsilon \sum_{x=25}^{64} D_c^x}{\sum_{x=25}^{64} W^x Pop^x} \tag{22}$$

where

$$D_c^x = MalePop^x W^x \sum_{i=65-x}^{99-x} p_x(i|t) \left(R^{(i)}\right)^{-i} + FemalePop^x W^x \sum_{i=65-x}^{99-x} p_x(i|t) \left(R^{(i)}\right)^{-i} \tag{23}$$

We use $2,5\%$ interest rate for discounting (assuming the real returns of this size) we arrive at approximately 20% level of contribution at the initial period. Of course this level changes each year due to the changes in composition of population and the discount rate but as we want to evaluate the effect of keeping the contribution constant, we set it at the initial 20% level independent of further developments.

3.4.2 Classical ALM analysis

Fixing the contribution level appears to have mixed results.

Horizon	$FR_N^{0,025}$	$FR_N^{0,5}$	$FR_N^{0,975}$	$FR_R^{0,025}$	$FR_R^{0,5}$	$FR_R^{0,975}$	$p(FR_N < 1)$
25	0,8633	1,3814	2,7665	0,6143	1,0037	2,0201	0,0738
75	0,9037	2,3963	12,6178	0,6319	1,7261	9,1435	0,0508

Horizon	$RPR_{25}^{0,025}$	$RPR_{25}^{0,5}$	$RPR_{25}^{0,975}$	$PR_{25}^{0,025}$	$PR_{25}^{0,5}$	$PR_{25}^{0,975}$	$p(i < 0)$
25	0,3796	0,5000	0,5000	0,6236	0,9498	1,0000	0,0000
70	0,3959	0,8000	0,8000	0,4093	0,9407	1,0000	0,0000

Table 3: Key figures for Plan 3. The upper panel represents the 2,5%, 50% and 97,5% quantiles for the nominal and real funding ratio, as well as probability of nominal underfunding after 25 and 75 years. The lower panel shows the same quantiles of the replacement ratio and pension result for cohorts of 25, 45 and 65 years old in 25 and 70 years, as well as probability of benefit cut during these years

One out of two steering instruments is abandoned in this plan and thus the fund has to rely on conditional indexation as the only control variable. In bad world scenarios the variable contribution would absorb part of the shock but with fixed contribution the funding ratio is affected instead. In good world scenarios variable contribution would be actually lower than the fixed one and hence the funding ratio is higher in the highest quantiles in fixed contribution plan. Therefore keeping the premium constant results in a more volatile funding ratio, both in real and nominal terms. Consequently, the probability of the funding ratio falling below 100% increases to $7,4\%$ after 25 years and 5% after 75 years as compared to $6,6\%$ and $4,2\%$ in the contract with variable premium respectively. As a result, the replacement ratio and pension result of the worst case scenarios become lower but gradually overtake the results in the upper quantiles, stopping at a maximum full indexation. One may say that increase in funding ratio volatility is not a desired situation but a fixed contribution is beneficial from a perspective of actual implementability, as changing the premium rate is a politically difficult decision to make.

3.4.3 Value-based ALM analysis

The effect in a closed fund setting looks quite neutral, as the total magnitude of the change is very low. It is worth noticing that the fixed contribution level is the average between the lower and the upper bound of variable contribution, hence on average the contribution could be expected to be at a similar level in both cases, which supports the small scale of value transfers. Decomposition clarifies the shape of the redistribution line. The change in net benefit is negative for the cohorts 50 years and older, as the benefits become the only steering instrument and thus absorb more downside risk than before (upside is limited to full indexation). The youngest cohorts are the ones to gain, the change in net benefit being largest for the very youngest cohorts and much smaller albeit still positive for the cohorts of 20 to 40 years old. This implies that initially the contribution level is on average higher than variable rate but gradually becomes relatively lower afterwards, offsetting the loss incurred in the first years for cohorts 20-40 and showing up as a positive gain for the very youngest. The change in residue follows the opposite pattern and is slightly positive for elderly and slightly negative for the young, following a mixed result of higher funding ratio in good scenarios and lower funding ratio in bad ones. All in all, the effect is just marginally different from zero to most cohorts.

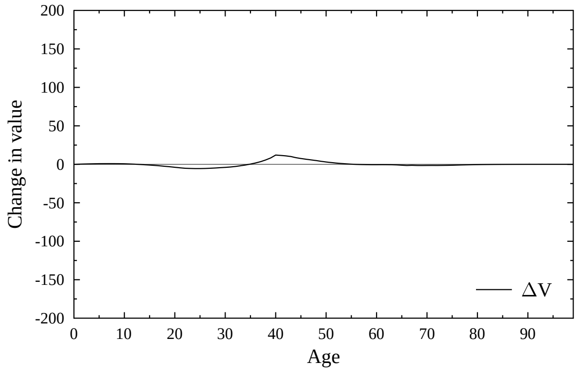

Figure 3a: Change in value at a cohort level when moving from Plan 2 to Plan 3 in the closed setting

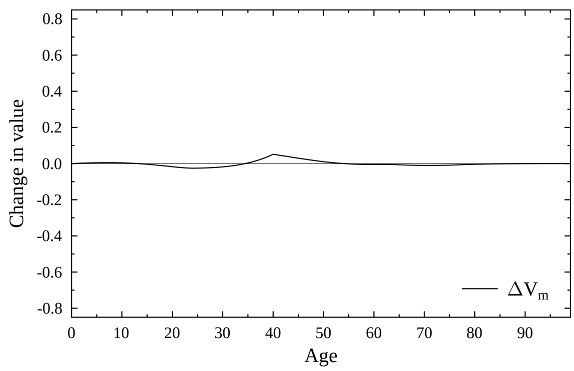

Figure 3b: Individual gender specific change in value when moving from Plan 2 to Plan 3 in the closed setting

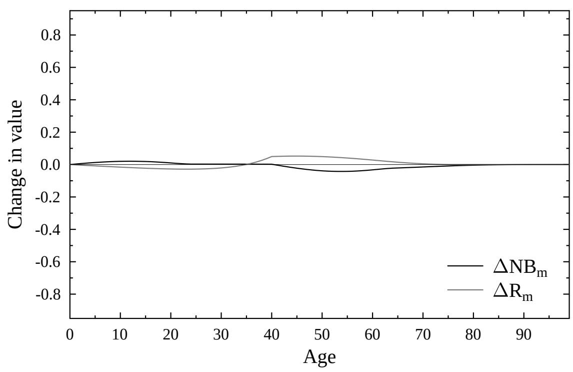

Figure 3c: Change in the net benefit and residue when moving from Plan 2 to Plan 3 in the closed setting

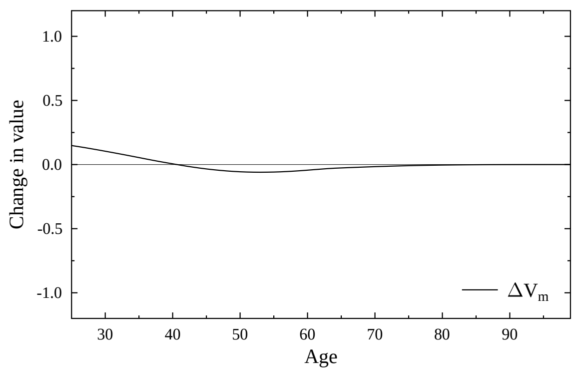

Figure 3d: Individual gender specific change in value when moving from Plan 2 to Plan 3 in the open setting

In the open fund setting the outcome is a negative change for cohorts above 40 years, for these are the cohorts that suffer in bad scenarios because they have to assume more risk now due to the loss of contribution as a steering instrument. The younger cohorts gain because they do not have to participate in absorbing the risk through contribution anymore. At the same time the cohorts in the future might lose somewhat due to a more volatile funding ratio. Hence the conclusion remains that the effects are not strong and thus the direction of redistribution in the end is difficult to define.

3.5 Collective DC: fixed contribution, conditional indexation with cuts

When it comes to the shocks on the downside, the policy of how to deal with adverse outcomes is not explicitly defined or might not be followed directly. Effectively the supervising bodies require to create an action plan so that recovery in 5 years time[4] is possible. Therefore the

[4]The recovery period before the financial crisis used to be 3 years but was extended to 5 years due to the difficult position of pension funds

third step we consider is introducing explicit rules of action in case of underfunding. We apply a benefit reduction if the funding ratio reaches an unacceptably low level (sustainability cut) and, in compliance with supervisory requirements, a recovery plan that is triggered if the funding ratio reaches some threshold (solvency cut).

3.5.1 Contract specification

Sustainability cut The benefits can not only be increased, but also cut if adverse market conditions materialize. We call a level of the funding ratio at which the benefits are cut the minimum level (min). If the condition of funding ratio decreasing below this level is met, the benefits for all cohorts are corrected with a factor cor_{min}:

$$cor_{min} = \begin{cases} 1 & \text{if } FR_N \geq min, \\ FR_N/min & \text{if } FR_N < min. \end{cases} \tag{24}$$

Therefore if the funding ratio is greater than or equal to min the benefits stay at the initial level, while if the funding ratio goes below the min level, benefits are cut with an equal percentage for every generation, the percentage being such that the funding ratio immediately comes back to the min level.

Solvency cut The solvency cut is an additional tool to make sure that the fund complies with supervisory requirements. The current Dutch Financial Assessment Framework (*Financieel Toetsingskader* - FTK) sets a 5 year recovery period for which a fund with funding ratio that has fallen below the $floor$ level has to prepare a recovery plan of how to bring the funding ratio back to this level. To account for this policy requirement we implement a solvency cut in our stylized fund model. A more detailed description of the solvency cut algorithm can be found in Appendix A.2.

3.5.2 Classical ALM analysis

A plan with explicit policy of actions in case of underfunding performs much better in worse scenarios from the solvency perspective. The probability of funding ratio falling below 100% declines from more than 7% to less than 5% during 25 years and from 5% to 3% during 75 years horizon.

Horizon	$FR_N^{0,025}$	$FR_N^{0,5}$	$FR_N^{0,975}$	$FR_R^{0,025}$	$FR_R^{0,5}$	$FR_R^{0,975}$	$p(FR_N < 1)$
25	0,9591	1,3871	2,7665	0,6847	1,0076	2,0206	0,0486
75	0,9852	2,4272	12,6357	0,6960	1,7467	9,1470	0,0306

Horizon	$RPR_{25}^{0,025}$	$RPR_{25}^{0,5}$	$RPR_{25}^{0,975}$	$PR_{25}^{0,025}$	$PR_{25}^{0,5}$	$PR_{25}^{0,975}$	$p(i < 0)$
25	0,3533	0,5000	0,5000	0,5460	0,9479	1,0000	0,0201
70	0,4205	0,8000	0,8000	0,4105	0,9357	1,0000	0,0173

Table 4: Key figures for Plan 4. The upper panel represents the 2,5%, 50% and 97,5% quantiles for the nominal and real funding ratio, as well as probability of nominal underfunding after 25 and 75 years. The lower panel shows the same quantiles of the replacement ratio and pension result for cohorts of 25, 45 and 65 years old in 25 and 70 years, as well as probability of benefit cut during these years

The median funding ratio as well as funding ratio at 97,5% quantile improve marginally. The situation on the downside, however, is significantly improved: funding ratio levels at 2,5% jump from roughly 86% to 96% in nominal terms in 25 years and from 90% to 98,5% in 75 years. The indexation decreases in the shorter horizon, leading to the pension result that is up to 8 percentage points lower than in a plan with no policy of reducing the benefits in bad scenarios. In the longer horizon the effect on indexation becomes only marginal. There is now an average 2% probability of cut during the 25 years which decreases to 1,7% probability during 75 years, as opposed to zero probability in all previously analyzed plans.

3.5.3 Value-based ALM analysis

The redistribution picture is similar as in case of introducing conditional indexation. In fact, an explicit policy of benefit cut is just additional condition on the indexation policy. Whereas before the conditionality was limited to full indexation at maximum and no indexation at minimum, now the indexation can also become negative.

Figure 4a: Change in value at a cohort level when moving from Plan 3 to Plan 4 in the closed setting

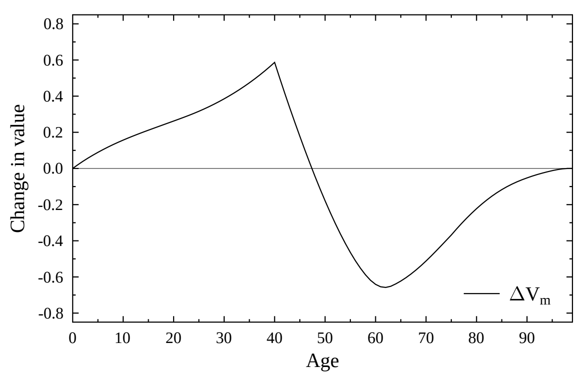

Figure 4b: Individual gender specific change in value when moving from Plan 3 to Plan 4 in the closed setting

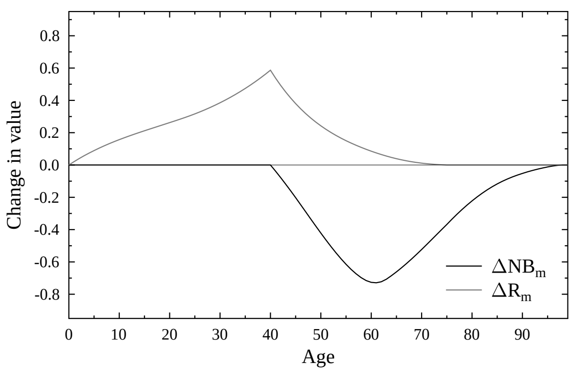

Figure 4c: Change in the net benefit and residue when moving from Plan 3 to Plan 4 in the closed setting

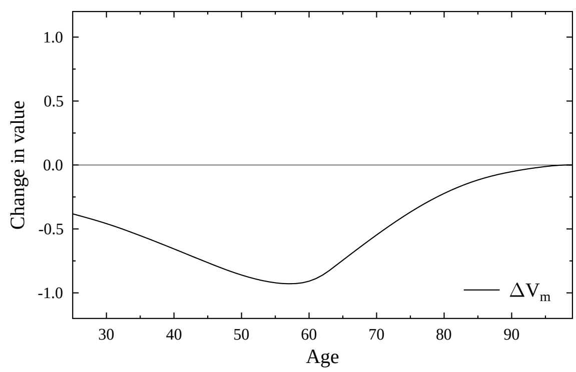

Figure 4d: Individual gender specific change in value when moving from Plan 3 to Plan 4 in the open setting

Hence this policy change is in general negative for the oldest. Decomposing Figure 4b into the change in net benefit and residue (Figure 4c), we see that the net benefit is negative for all cohorts older than 40. This is due to the cuts in bad scenarios that accumulate over time and hence hurt the participants that are around 60 the most, as they have the most years remaining of collecting benefits in our evaluation period. For the cohorts of up to 40 years old the net benefit change is zero as in 25 years they only pay contribution which is fixed. The residue part changes the picture by adding a positive amount for all cohorts of up to 75 years old. This illustrates the positive implications of benefit cuts on the funding position. Hence in the closed fund the positive change in value peaks around 40 years due to a better funding position, moves from positive to negative for cohorts 40-60 due to the opposite effects on net benefit and residue, and remains negative for the very oldest cohorts.

In the open fund the effect is negative for all currently participating cohorts. When we look at a pure effect of introducing cuts on the net benefits, it is clear that everybody who will receive benefits in the evaluation period should lose. The funding position improves quite significantly but it is shifted to cohorts outside of our evaluation. It is not hard to notice that the change in net benefit would be negative no matter what evaluation period we choose, as long as the fund with a benchmark plan without cuts remains solvent (which will not necessarily be the case). In the long term it should converge to zero as the funding position should improve dramatically in the long term, for the indexation is limited to full wage growth level. This is, however, only the case if the fund maintains the surplus for infinite time, never distributing it to participants (highly unlikely). Then it is no longer a zero sum game for the participants, as the fund itself enters the game. In any case, the net effect is negative for all current participants but becomes positive for younger ones if an improved funding position is taken into account.

3.6 Collective DC: fixed contribution, conditional indexation with cuts and surplus sharing

The final change in the contract that we believe is worth addressing is dealing with the upside. We modify the previous contract by specifying how the surplus is treated. In the *Pensioenakkoord* it is stated that a smoothing period of 10 years is a prudent solution. We follow their advice and specify a contract with a surplus sharing option where the shock is distributed within 10 years.

3.6.1 Contract specification

Surplus sharing In this pension contract the surplus sharing option is exercised in good scenarios by increasing benefits of all cohorts by the factor $cor_{surplus}$ that is calculated as follows:

$$cor_{surplus} = \begin{cases} 1 & \text{if } FR_N \leq surplus, \\ 1 + ((FR_N/surplus - 1)\gamma) & \text{if } FR_N > surplus. \end{cases} \tag{25}$$

where the smoothing factor $\gamma = 1/10$, in compliance with supervisory recommendation.

3.6.2 Classical ALM analysis

There is now a negative pressure on the funding position, that affects the funding ratio in the lowest quantiles only slightly but the impact rises with the quantile. So in the very best scenarios the funding ratio is significantly lower, as the surplus is distributed to participants when the surplus sharing option comes in the money. Hence after 25 years the funding ratio in $97,5\%$

quantile drops from 277% to 212%. The 75 year horizon shows the reduction from the extreme 1264% to a more prudent 238%. Once again proving the opposite relationship with funding ratio, replacement rates in highest quantiles improve significantly, to a level well above the full indexation.

Horizon	$FR_N^{0,025}$	$FR_N^{0,5}$	$FR_N^{0,975}$	$FR_R^{0,025}$	$FR_R^{0,5}$	$FR_R^{0,975}$	$p(FR_N < 1)$
25	0,9532	1,3569	2,1222	0,6831	0,9874	1,5627	0,0506
75	0,9670	1,5830	2,3807	0,6850	1,1569	1,7992	0,0400

Horizon	$RPR_{25}^{0,025}$	$RPR_{25}^{0,5}$	$RPR_{25}^{0,975}$	$PR_{25}^{0,025}$	$PR_{25}^{0,5}$	$PR_{25}^{0,975}$	$p(i < 0)$
25	0,3533	0,5000	0,6320	0,5440	0,9624	1,3521	0,0204
70	0,4195	0,9989	3,4155	0,4122	1,1792	4,5865	0,0186

Table 5: Key figures for Plan 5. The upper panel represents the 2,5%, 50% and 97,5% quantiles for the nominal and real funding ratio, as well as probability of nominal underfunding after 25 and 75 years. The lower panel shows the same quantiles of the replacement ratio and pension result for cohorts of 25, 45 and 65 years old in 25 and 70 years, as well as probability of benefit cut during these years

3.6.3 Value-based ALM analysis

Looking at the picture of zero-sum game (Figure 5a), introducing a surplus sharing is beneficial to the elderly and harmful to the young. When we look at the change in net benefit and residue separately, we see that indeed all the pensioners in our evaluation period of 25 years gain substantially, benefiting from the surplus sharing option in good times. The surplus sharing has no impact on change in net benefit for the youngest cohorts because during the 25 years horizon they only pay contribution which is fixed in both plans. The change in residue is negative for all cohorts alive at the closure time, reflecting the worsened funding position. Hence the change in residue is the component that makes the net position of the youngest cohorts negative and lowers the gain of the middle cohorts. This is due to the indirect effect of worsened funding position.

When we look at the open fund picture, only the direct effect on the increase in benefits for all cohorts in the evaluation period is visible, hence showing a positive gain in value. Needless to say, surplus sharing decreases the safety buffer of the fund, so the future cohorts should lose in value terms due to a lower capacity to absorb shocks. Therefore the worsening in funding position that already affects the young cohorts in a closed fund setting is shifted to the future cohorts in the open fund setting.

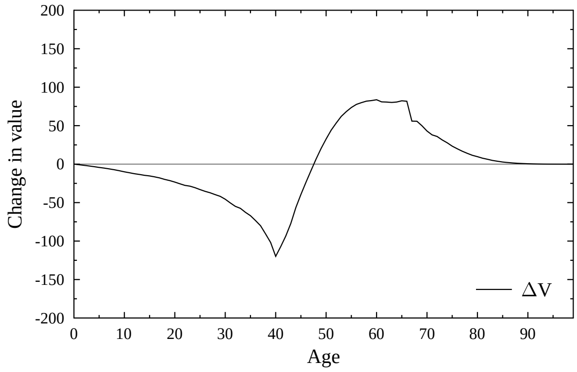

Figure 5a: Change in value at a cohort level when moving from Plan 4 to Plan 5 in the closed setting

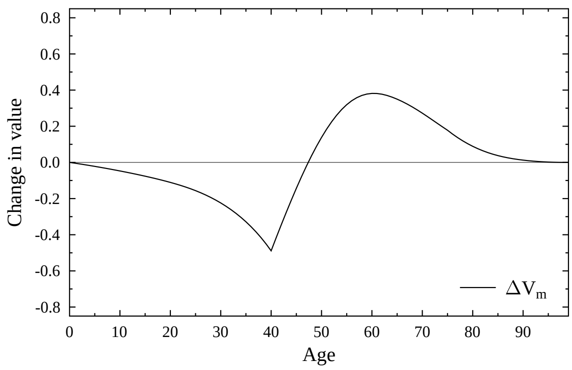

Figure 5b: Individual gender specific change in value when moving from Plan 4 to Plan 5 in the closed setting

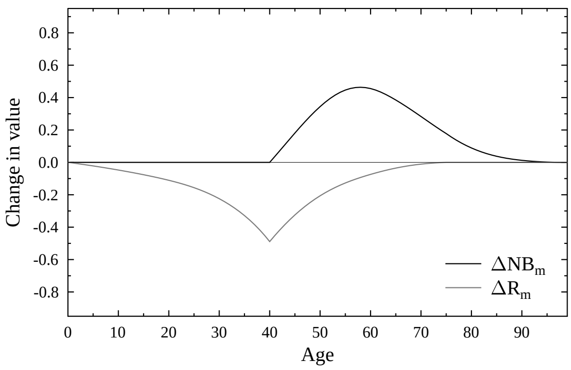

Figure 5c: Change in the net benefit and residue when moving from Plan 4 to Plan 5 in the closed setting

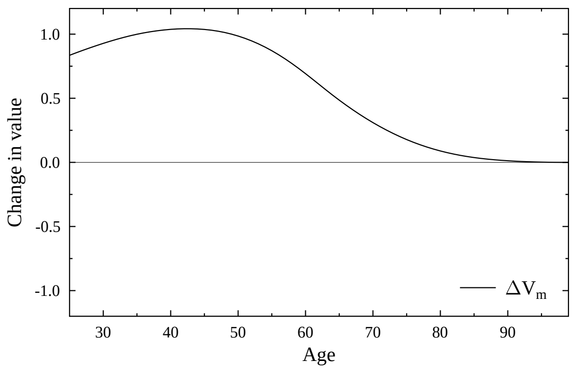

Figure 5d: Individual gender specific change in value when moving from Plan 4 to Plan 5 in the open setting

3.7 Final note on contract changes

The previous sections were designed to examine each change in a pension contract separately, paying attention to the general pattern of the effects and not their relative magnitude. Here we combine the results of previous analysis to a more general picture as well as provide a table with a quantitative information on the magnitude of the changes in value. For an easier reference we will first summarize the pension plans considered:

Name	Contribution	Indexation	Benefit cut	Surplus sharing
Plan 1	variable	unconditional		
Plan 2	variable	conditional		
Plan 3	fixed	conditional		
Plan 4	fixed	conditional	✓	
Plan 5	fixed	conditional	✓	✓

Table 6: Plan summary

The table with value-based ALM results shows the individual change in value of a pension deal for a representative member of the three key cohorts: 25, 45 and 65 years old at the starting time. The change in value is the amount that a person gains or loses throughout their remaining time in the system during evaluation horizon (including the residue allocation), discounted back to the current time period and expressed at the current annual wage levels. The first two rows of the table help in assessing the magnitude of the effect of each change in the system. The first row represents the total absolute change in value and is calculated as the sum of absolute changes in value for each cohort:

$$\sum |\Delta V| = \sum_{i=25}^{99} \left(|\Delta V^i_{male}| \cdot MalePop^i + |\Delta V^i_{female}| \cdot FemalePop^i \right) \tag{26}$$

One could also divide the numbers in the first row of the table by 2, keeping in mind that both gains and losses are implicit in $\sum |\Delta V|$ figures so in fact the value transfers are calculated twice. The second row corresponds to a relative change, where the absolute change in value is expressed as a percentage of the total value of a pension deal to all cohorts. A point for attention is that while the sum of changes in value is zero in a closed fund setting, it is not the case for the redistribution figures that we report in the first two rows because here the absolute change in value is measured.

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$
$\sum \|\Delta V\|$	4574,47	214,78	5796,05	3442,99	6960,34
$\frac{\sum \|\Delta V\|}{\sum V}$	0,0628	0,0029	0,0796	0,0473	0,0956
ΔV_{25}^{male}	0,2483	-0,0251	0,3164	-0,1561	0,3834
ΔV_{25}^{female}	0,2617	-0,0287	0,3425	-0,1656	0,4099
ΔV_{45}^{male}	0,1548	0,0298	0,1778	-0,1435	0,2190
ΔV_{45}^{female}	0,1844	0,0300	0,2172	-0,1696	0,2621
ΔV_{65}^{male}	-0,4906	-0,0066	-0,6227	0,3499	-0,7700
ΔV_{65}^{female}	-0,5303	-0,0036	-0,6686	0,3822	-0,8203

Table 7: Value-based ALM output for contract changes in the closed setting. The upper panel shows the magnitude of value transfers: the nominal absolute changes in value are shown in the first row and the second row shows it relative to the total value of the plan. The lower panel shows the changes in value for representative male and female members of cohorts that are 25, 45 and 65 now, expressed in annual wage levels

One can observe that the highest redistribution, which amounts to almost 8% of the total value, occurs as a result of introduced benefit cut ($3 \to 4$). A contract with explicitly defined downside risk induces the value transfer from oldest to the the middle and young cohorts. The 65 year cohort loses more than 60% of the current wage level, while the youngest ones gain more than 30%. The effect of moving from classical DB to a system with conditional indexation and hence more flexible benefits ($1 \to 2$) is also leading at the magnitude of redistribution, shifting as much as 6% of the value amongst cohorts. In this case the elderly again are the disadvantaged, losing around 50% of the current wage level in value, with the 25 and 45 years cohorts gaining around 25% and 15% respectively. The change from variable contribution level to a fixed one ($2 \to 3$) has quite a moderate effect in this case due to the offsetting effects, whereas the last change considered ($4 \to 5$) is positive for the elderly and has a sizeable magnitude. The 65 year cohort benefits from a more than 35% gain in value due to the surplus sharing option that they can exercise, while the 25 and 45 year cohorts lose around 15%.

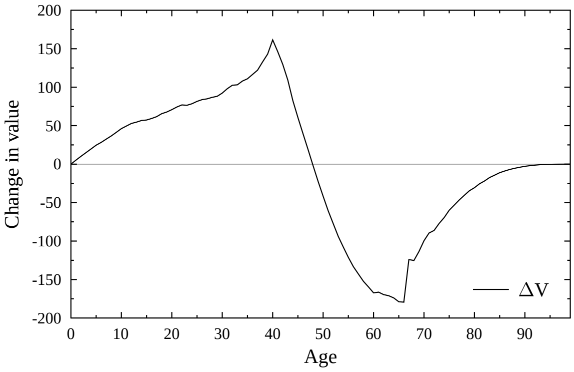

Figure 6a: Change in value at a cohort level when moving from Plan 1 to Plan 5 in the closed setting

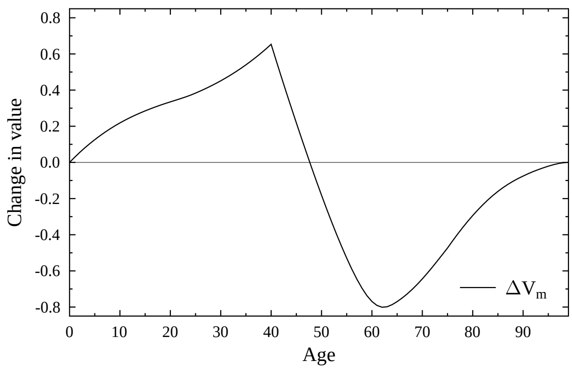

Figure 6b: Individual gender specific change in value when moving from Plan 1 to Plan 5 in the closed setting

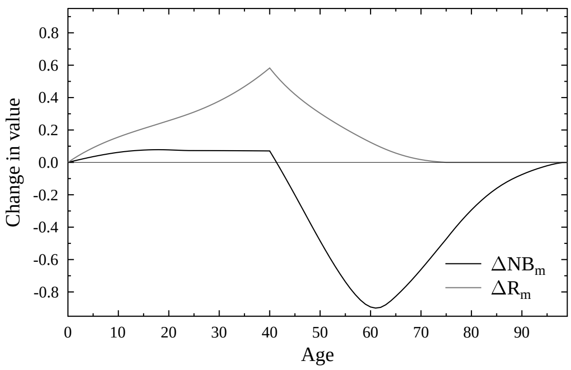

Figure 6c: Change in the net benefit and residue when moving from Plan 1 to Plan 5 in the closed setting

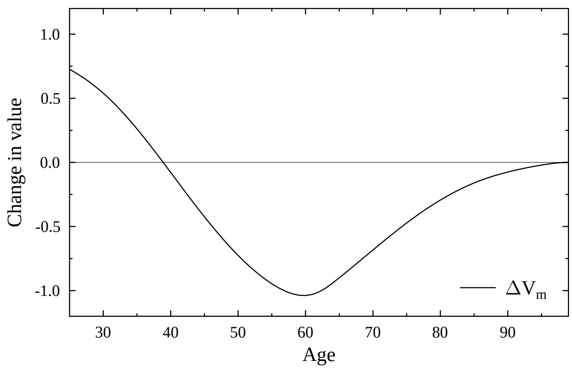

Figure 6d: Individual gender specific change in value when moving from Plan 1 to Plan 5 in the open setting

It is important to realize that all the changes overviewed here occurred in different points in time (or are still to be implemented). A person that might have belonged to the youngest cohort at the time of the first change may already have been in the middle cohort at the time of another change, depending on the timing of each change. Hence the timing of changes plays a key role in evaluating the total effect. Nevertheless, we assume that these changes are implemented not too far away from each other in time, as is the case in the Netherlands where the changes in general occurred in the last decade, so that we can evaluate the total effect of moving from classical DB to a collective DC with explicit contract. This assumption is a good approximation of a general situation, as there have been quite some changes in the pension plan just in recent years. For a specific fund with a certain timeline of changes a separate and more precise analysis can be done. However, for our purposes of understanding the general implications this approach suffices.

As shown in Figures 6 a-d, the tendency is the disadvantageous position of the elderly due to the discussed changes. However, the judgement should not be made without fully taking into account the past. It is well known that elderly previously paid contributions that were too low given the rate of accrual or the contribution holidays. Hence it should not be surprising that the measures taken to correct for unsustainable features of the plan are unfavorable to the elderly.

4 Change in discounting method

4.1 Approach

Traditionally liabilities of the pension funds have been discounted using a fixed discount rate (usually 4%). Just several years ago, following the FTK framework, Dutch pension funds switched to market-based discounting, using the swap curve and essentially using risk free discount rates to determine the present value of liabilities. There has been quite some discussion since lead by the criticism that pension funds are financial units with long term horizon and so they should not allow for their funding ratios to fluctuate with every twist and turn in financial markets. Pension funds, it is argued, have quite long duration and thus should not be concerned with the short term volatility. Another critique often heard is that a risk free rate is too prudent to discount the liabilities of the pension funds that in reality invest up to 70% and more to risky assets.

Liabilities discounting apparently is an inexhaustible topic, as it is one of the most widely discussed features of the new pension deal. Many worry that different discounting methods have diverse effects on incentives to what level of risk to assume. Here we want to draw the attention to the fact that the discounting is also very important with respect to generational redistribution: the total redistribution due to a change in discounting method can be almost as large as moving from DB to collective DC (or, depending on the closure rule, even much higher than that). Therefore the importance and magnitude of it should not in any case be underestimated.

There are many proposals concerning the discounting method, ranging from nominal (so staying with the current discounting using the swap curve) to real term structure to expected returns, or even the combination of them. We will discuss the effects of moving to discounting using real term structure, expected returns and the combination of the two. As a benchmark pension plan for evaluating the effects of discounting we choose the pension Plan 5 which is designed to reflect the complete pension contract.

Moving from nominal to real framework in our analysis involves three main steps. Firstly the discount rate is changed from the nominal term structure to one of the three variants of discounting discussed above without making any adjustments to the indexation policy. As we will see later, this implies a substantial redistribution, so it is likely that the indexation rule is adjusted to account for that. Hence the second step is adjusting the critical funding ratio levels at which indexation is given. Finally, one can argue that in the real framework the nominal closure rule is not appropriate anymore. Changing the closure rule is thus the third step in our analysis. Since the way of allocating the residue at the end of evaluation horizon is arbitrary we will devote a section in the end of the chapter to discuss how the results are comparable in the open fund setting.

Since we are more interested in effects at individual level, we will not report the cohort level graphs in this chapter. To avoid excess graphs we will not report the decomposed net benefit and residue graphs where unnecessary (they can be found in Appendix B.1).

4.2 Changing the discount rate

4.2.1 Adjusted real term structure

The first discounting method we look at is using the real term structure lowered by 1 percentage point (we call it Plan 6). The real term structure is essentially the nominal one adjusted for the price inflation. As our stylized fund gives indexation for wage growth (which is the case for most pension funds in the Netherlands), it is sensible to adjust the real term structure for that. We choose 1 percentage point deduction, for it is assumed that wage growth is on average approximately 1 percentage point higher than price inflation. Like discussed before, we first examine the effect of changing the critical levels of the funding ratio so that a comparable generosity level is maintained and then switch to a stricter plan with respect to indexation.

4.2.2 Expected real returns

The second approach for discounting the pension fund's liabilities that we want to evaluate is the expected real returns (Plan 7). This is probably the most controversial method of discounting. On the one hand, the risk free rate does not reflect the investment risk appropriately so it is argued that participants are not compensated for the risk they take. On the other hand, discounting based on expected returns might induce pension fund boards to give indexation for the results that have not yet been achieved. Another shortcoming of this method is that it makes the so called creative accounting and hence manipulation of the system possible. One thing is clear: discounting based on expected returns would require a careful supervisory regulation. In any case, by accepting the proposal of discounting liabilities with expected returns the youngest generations effectively agree on underwriting the risk that the actual achieved investment returns will be lower, as there is a two-sided risk involved: having ambition that is unrealistically high and realizing returns that are too low. As a response to the former problem a cap on maximum assumed expected returns could be put in place, in order to avoid too optimistic assumptions. There is no cure for the latter problem though, so it is important to be sure that participants actually understand what risks they are taking. Hence communication would play a crucial role in this variant.

Putting the aforementioned shortcomings aside, we want to investigate the effect of implementing such a system on the intergenerational redistribution. We assume the expected return on stocks to be equal to 7% and the return on stocks of 4%, which given the asset allocation of 50% stocks and 50% bonds results in $5,5\%$ returns on investment. As we are in a real framework now, we subtract 3% for expected wage growth (which is a basis for indexation). This gives us a fixed $2,5\%$ expected real return.

4.2.3 Soft real: combination

It is often said that fixed or risk-free discount rates do not appropriately account for the risk that the participants of the pension scheme effectively take. Risk free rates are thought to be too prudent for discounting long term cash flows, while expected returns might be too generous for discounting of short term cash flows. A recent proposal of Nijman and Werker (2011) is specifically designed to deal with this criticism. Here we apply and evaluate a simplified version of their idea of combining the expected returns and risk free rate to come up with an appropriate discount curve that reflects the interests and risks taken by all participants.

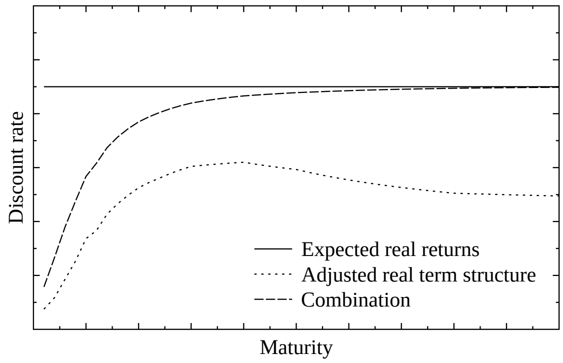

Figure 7: The graphical representation of the idea of soft real discounting

The idea is to discount the short term cash flows using the rate that is close to risk free and gradually increases with maturity so that the long term cash flows are discounted using the rate close to expected real returns, setting the parameter determining how fast the discount rate reaches expected returns dependent on the level of shock smoothing involved in the contract:

$$R^{(i)} = \left(R_N^{(i)} - \pi^e\right) + c_i \left(\mu - R_N^{(i)}\right) \tag{27}$$

where $R_N^{(i)}$ represents a nominal interest rate for maturity i, π^e is the expected wage growth and μ is the expected investment return. c_i is a decreasing function of i that we specify as

$$c_i = 1 - \left(1 - \frac{1}{k}\right)^i \tag{28}$$

where k is a smoothing parameter reflecting the number of years during which the shock can be smoothed ($k \geq 1$). So for discounting long dated cash flows c goes to 1 and for short term cash flows c_i is close to 0. Hence:

$$\lim_{i\to\infty} c_i = 1 \Rightarrow \lim_{i\to\infty} R^{(i)} = \mu - \pi^e \tag{29}$$

$$\lim_{i\to 0} c_i = 0 \Rightarrow \lim_{i\to 0} R^{(i)} = R_N^{(i)} - \pi^e \tag{30}$$

k is essentially a parameter determining how fast the discount rate moves from risk free rate towards the expected real returns when maturity increases.

$$\lim_{k\to\infty} c_i = 0 \tag{31}$$

$$\lim_{k\to 1} c_i = 1 \tag{32}$$

With longer smoothing horizon c_i gets closer to zero and t he discount rate slower departures from the risk free rate; the shorter smoothing period implies that c_i is closer to one, and the discount rate converges towards expected real returns faster. The reasoning is that when there is a lot of risk smoothing involved, participants essentially take only minimum risk and hence their liabilities should be discounted with risk free rate, whereas if the smoothing horizon is very short, participants are heavily exposed to risk and should be compensated for it with the expected returns discount rate. The method is thus claimed to be more consistent with the risk exposure of participants as the parallel can be drawn to security market line, implying that more risk is compensated with higher expected returns.

We evaluate two types of soft real discounting: first using 10 years smoothing horizon (Plan 8) and then increasing the smoothing period to 20 years (Plan 9), to see the effect of longer smoothing horizon.

For an easier reference we summarize the indexation methods considered:

Name	Discounting rule
Plan 6	real adjusted term structure
Plan 7	expected real returns
Plan 8	combination with 10 years smoothing period
Plan 9	combination with 20 years smoothing period

Table 8: Discounting methods summary

4.2.4 Results

Switching from nominal to real discounting involves value transfers among cohorts which are shown in Figure 8a. Each line represents the change in value for a participant in a particular cohort when discount rate is changed from nominal term structure to the different rates discussed above. In Figure 8b these changes are decomposed to change in net benefit and residue.

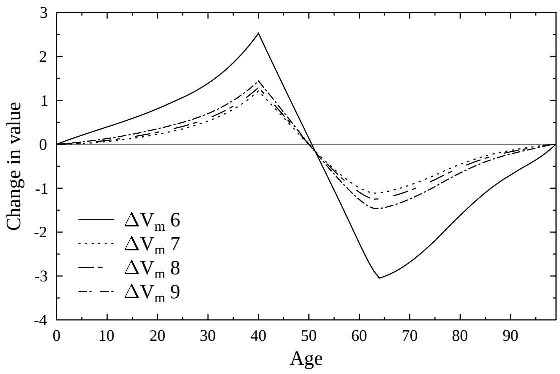

Figure 8a: Change in value for male individual when changing the discount rate from nominal to real in the closed setting

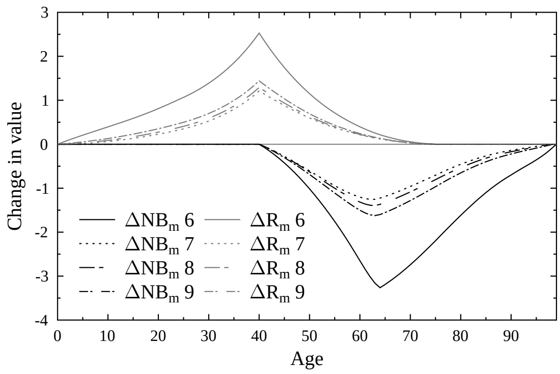

Figure 8b: Change in the net benefit and residue when changing the discount rate from nominal to real in the closed setting

As might be expected, lowering the interest rate used for discounting results in lower funding ratios and subsequently lower indexation for current pensioners. This is confirmed by the negative change in the net benefit for all the cohorts that receive benefits in our evaluation period of 25 years. For the cohorts that have just entered the retirement the loss is substantial, exceeding 2,5 annual wage levels in case the real term structure is used for discounting. The negative net benefit effect is counterbalanced by positive change in residue, as lowering the discount rate results in significantly improved funding position of the pension fund. Hence the individual in cohort of age 40 would gain more than 2,5 annual wage levels as a result of the reform of switching to real discount rate. The total effect is therefore positive to cohorts younger than 50 years and negative for the older generations (Figure 8a). Switching to expected real returns implies the lowest redistribution out of all discounting methods considered. This is due to the fact that expected returns adjusted for wage growth are still higher than real (wage) term structure and for that reason is closer to the nominal discount rate, so the magnitude of redistribution is much less when real returns are used. Since the soft real method is effectively a weighted average of real rate and expected real returns, it is no surprise that the effects of soft real discounting stand between the two. The value transfers are lower than when using real rate but increase with longer horizon of smoothing.

4.3 Adjusting the indexation levels

The previous section made it clear that switching from nominal to real discounting regime (and effectively lowering the discount rate) without adjusting the policy ladder leaves the elderly in a very disadvantageous position. To correct for that, the indexation policy should be adjusted simultaneously with discount rate change. This can be done in many ways; we choose to evaluate two of them.

Firstly we will adjust the policy ladder for indexation in a way that the indexation in the real framework is given at comparable levels as in the nominal framework, so that the relative level of generosity of indexation is retained. In our benchmark contract full indexation is granted when the nominal funding ratio reaches 130% level. This level is however considered too generous, as with wage indexation an appropriate level should be at around 145% nominal funding ratio (given the assumptions of approximately 3% wage growth and the fund's duration of 15). Therefore for comparable indexation rule in the real setting we alter the policy ladder so that full indexation is given at 90% real funding ratio level (hence keeping the current generosity level). The term real funding ratio in this chapter refers to the funding ratio calculated using one of the examined methods, except for the classical ALM data in the tables where for comparison reasons we convert the funding ratio to the one calculated using the real term structure.

Many agree that giving full indexation at 90% real funding ratio level is not sustainable and in the end we want to see the effect of moving from nominal to real framework adjusting the policy ladder in a way that full indexation is only given at 100% real funding ratio level. Hence our second step is to switch to the not so generous indexation rule with full indexation at 100% real funding ratio level, which is considered more appropriate and is also suggested by supervisor, but leaves the elderly worse off due to stricter policy ladder for indexation.

4.3.1 Maintaining comparable level of generosity

Before considering the total effect of moving from benchmark plan with nominal discounting and nominal indexation ladder to the real one with adjusted ladder levels we will first examine the pure effect of changing the policy ladder.

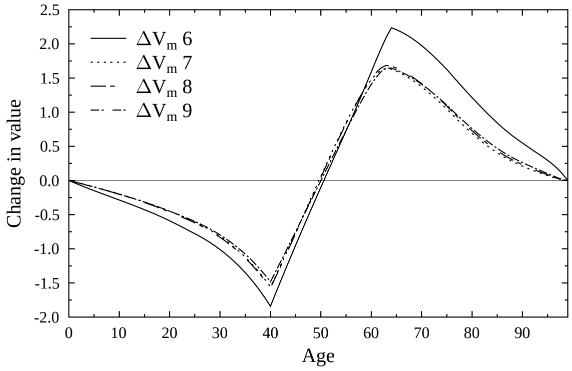

Figure 9a: Change in value for male individual when adjusting the policy ladder for comparable generosity in the closed setting

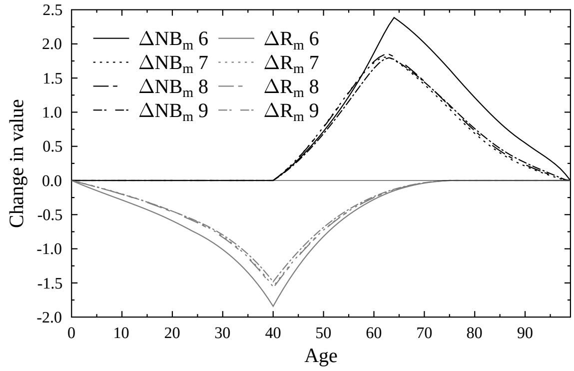

Figure 9b: Change in the net benefit and residue when adjusting the policy ladder for comparable generosity in the closed setting

As can be seen from Figures 9 a-b, the effect of shifting the policy ladder so that the full indexation is given at lower levels of real funding ratio (from 130% to 90%) is just the opposite from the effect of changing the discounting without adjusting policy levels. Since the policy is now changed in a way that full indexation is granted at lower levels, keeping all else *ceteris paribus*, the elderly receive higher benefits and hence the cohorts just entering the retirement experience the gain in value of more than 2 annual wage levels. This of course results in a worsened funding position and negative change in residue for younger generations.

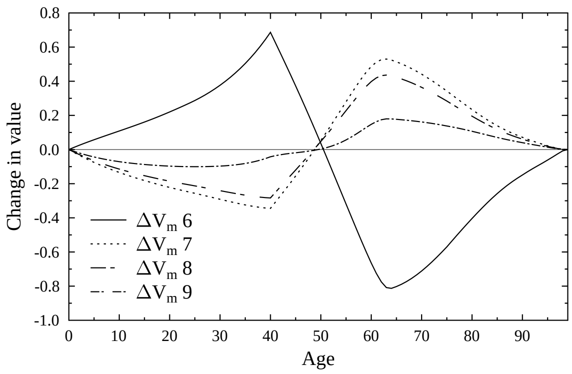

Figure 10a: Change in value for male individual when changing the discount rate and adjusting the policy ladder to comparable level in the closed setting

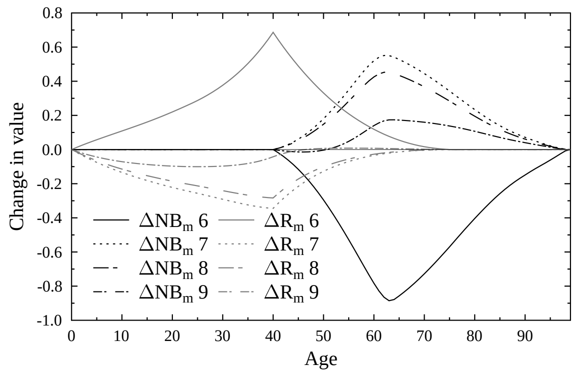

Figure 10b: Change in the net benefit and residue when changing the discount rate and adjusting the policy ladder to comparable level in the closed setting

Figures 10 a-b exhibit the total effect effect of changing discounting and adjusting indexation policy. As the two effects are of opposite directions, they partly cancel out, resulting in lower transfers. Now we can conclude that maintaining a comparable generosity of indexation policy and discounting with the adjusted real term structure improves the relative position of the younger generations, while discounting with expected real returns leaves the elderly better off. Note that the effects of soft real discounting methods are again between the two and hence allow for achieving a more neutral outcome with respect to redistribution. The contract with soft real discounting and smoothing period of 20 years involves only negligible levels of redistribution.

4.3.2 Restoring the generosity balance

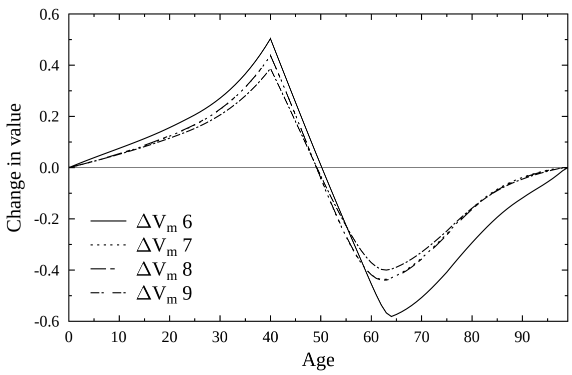

Figure 11: Change in value for male individual when adjusting the policy ladder to a more prudent level in the closed setting

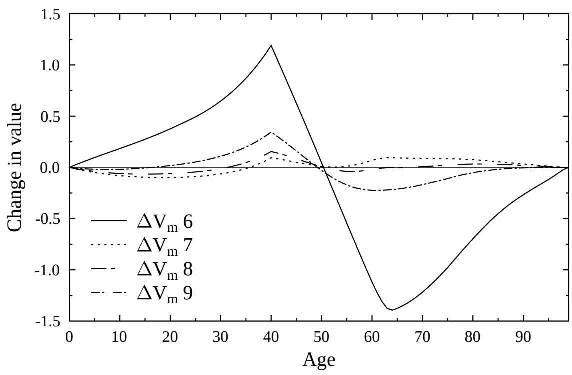

Figure 12: Change in value when changing the discount rate and adjusting the policy ladder to a more prudent level in the closed setting

As explained before, we also examine the effects of shifting to a more prudent indexation policy, i.e. giving full indexation only at 100% real funding ratio level. The effect of making the indexation more prudent keeping all else *ceteris paribus* is favorable to the young cohorts. Giving full indexation at 100% real funding ratio level as compared to 90% can result in up to half the annual wage level gain for the young and a loss of comparable size for the elderly (Figure 11). Hence the total effect of moving from nominal framework to a plan with real discounting and a more prudent policy ladder (Figure 12) is more beneficial to the young as compared to Figure 10a. Now we see that real term structure discounting in combination with stricter policy ladder results in higher redistribution of value from elderly to the young, while the other three discounting variants due to the opposite effects offsetting each other involve only slight levels of value transfers.

4.4 Changing the closure rule

The closure rule in the closed fund setting helps us to take into account the improvement or worsening of the funding position occurring due to the change in pension contract. How to allocate the final assets of the pension fund is an arbitrary decision. Up to now the nominal closure rule was used, meaning that the assets were divided proportionally to the nominal liabilities for each cohort:

$$A^x = \frac{L_N^x}{L_N} \tag{33}$$

Since we consider the real framework in this chapter, it is reasonable to assume that assets are also divided proportionally to the real liabilities for each cohort.

$$A^x = \frac{L_R^x}{L_R} \tag{34}$$

Therefore the real closure rule here refers to allocating the assets proportionally to the liabilities for each cohort calculated using one of the discussed discounting rules.

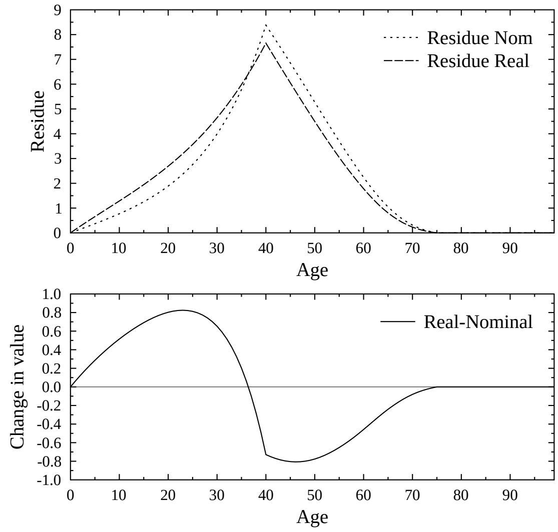

Figure 13: Change in residue when adjusted real (Plan 6) as opposed to nominal closure rule is applied

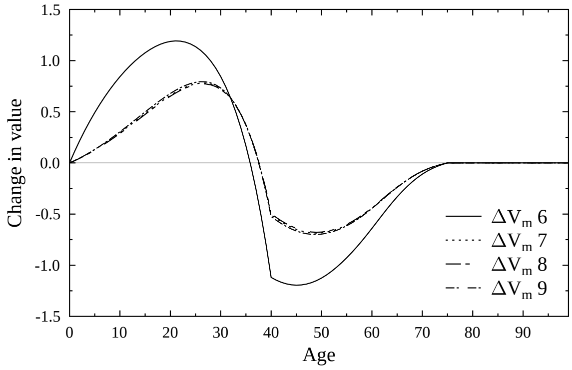

Figure 14: Change in value for male individual when changing the closure rule from nominal to real in the closed setting

Figure 13 shows how the same residue is split in case nominal and adjusted real rates are used for discounting. It is clear that the latter one is beneficial for the young. Under nominal discounting, the liabilities that the youngest have accrued are heavily discounted, as they are due only in several decades. These long duration liabilities are much more sensitive to a change in discount rate than the liabilities of the elderly with a lower duration. A lower real rate is thus very advantageous to young cohorts: given this calculation they possess rights to a higher share of final assets, as opposed to the older cohorts for whom the benefits will be due already and change in discounting will have a relatively small impact. Figure 14 displays the effect for all the discounting methods but the pattern remains the same for all of them.

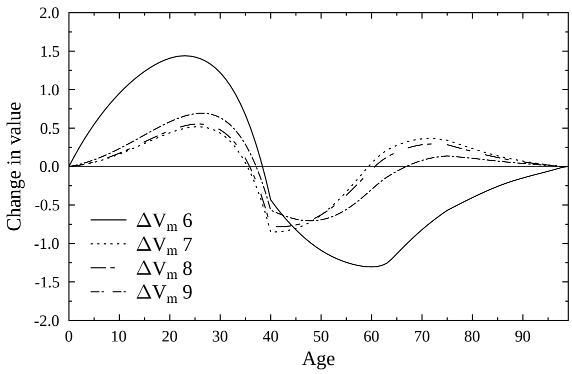

Figure 15: Change in value for male individual when changing the discount rate and adjusting the policy ladder to a comparable level and using the real closure rule in the closed setting

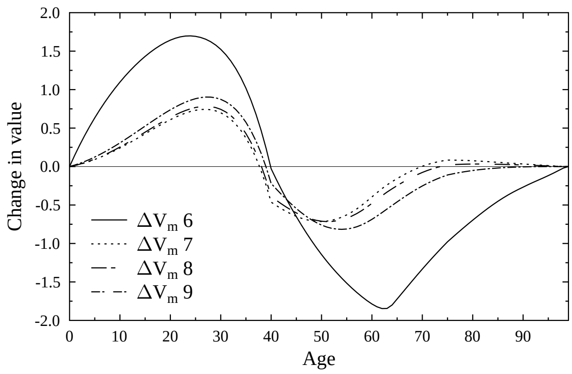

Figure 16: Change in value for male individual when changing the discount rate and adjusting the policy ladder to a more prudent level and using the real closure rule in the closed setting

Figures 15 and 16 display how the total effect of moving from nominal plan looks like when the real closure rule is used. We see that the effect of changing the closure rule is quite substantial and determines the final outcome being positive for the young cohorts, no matter which generosity level for policy ladder is used (even though the gain is bigger for a stricter policy ladder, reaching almost 2 annual wage levels for the cohorts just entering the fund). The elderly cohorts are still better off in a plan with more generous indexation policy. Hence when moving from nominal framework to the real one the conclusions drawn before still hold with exception for the expected return and soft real discounting where the effects change direction from slightly negative to slightly positive for the young and vice versa for the old, since the effect of closure rule is dominating in these cases.

4.5 Open fund comparison

To avoid the arbitrary closure rule we evaluate the results discussed above in the open setting too. Figures 17-20 demonstrate the open fund equivalents for the effects examined in the closed setting.

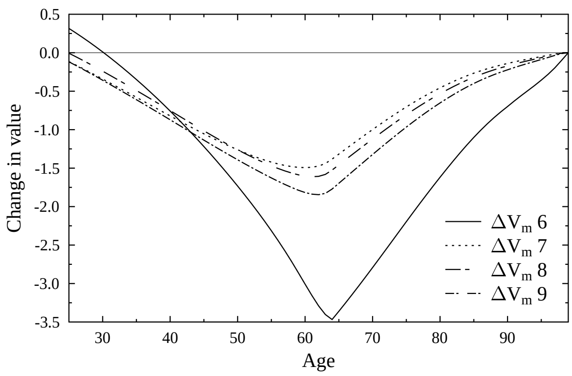

Figure 17: Change in value for male individual when changing the discount rate from nominal to real in the open setting

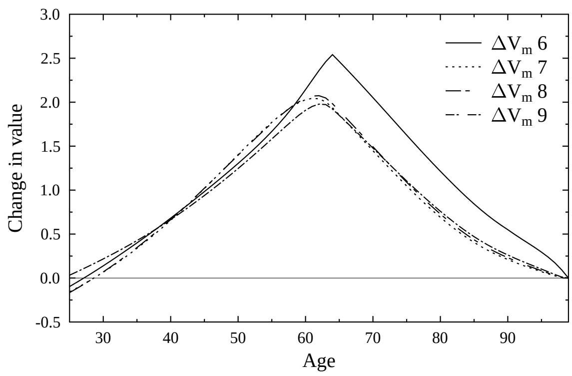

Figure 18: Change in value for male individual when adjusting the policy ladder for comparable generosity in the open setting

As can be seen the effects are very much comparable; they are just extended through a longer horizon because the surplus or the deficit is put forward to the future. The effect of switching from nominal to real discounting is now negative for most of the currently participating cohorts (the cohorts just entering retirement lose up to 3 annual wage levels) as the improved funding position is left for the future (Figure 17). Discounting using the real term structure still implies the highest value redistribution. Changing the policy ladder is now positive for most of the current participants, reaching almost 3 annual wage levels in gain for those entering retirement (Figure 18).

The conclusions for aggregate effect of combining changes in discounting and indexation policy still hold. While with the indexation policy of comparable generosity discounting with real term structure implies losses to the elderly, expected returns imply gains for them and soft real method with 20 years smoothing is the most neutral (Figure 19), with stricter policy ladder all effects become more negative (Figure 20). Therefore discounting using real term structure now worsens the oldest cohorts' situation significantly and the rest of the discounting methods become rather neutral with respect to intergenerational redistribution.

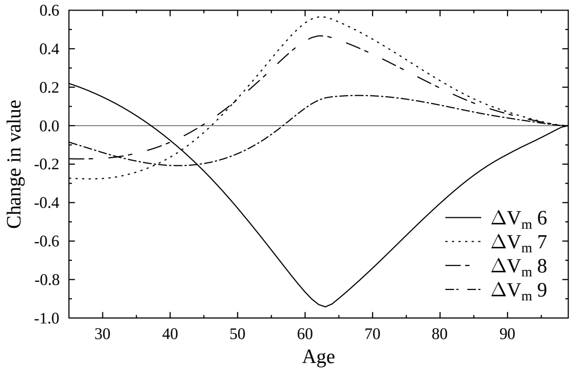

Figure 19: Change in value for male individual when changing the discount rate and adjusting the policy ladder to comparable level in the open setting

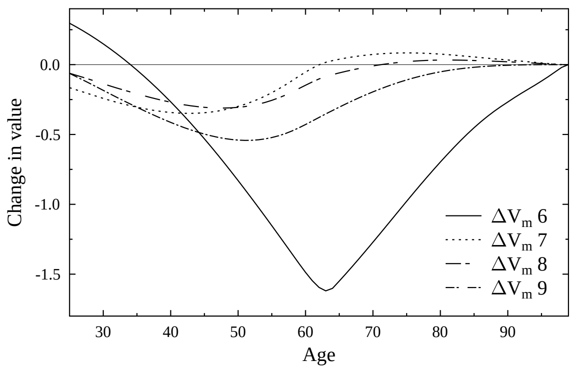

Figure 20: Change in value for male individual when changing the discount rate and adjusting the policy ladder to a more prudent level in the closed setting

4.6 Classical ALM analysis

This section will briefly outline how the changes in discounting affect pension fund's solvency and the indexation results for the pensioners. We will present the main results for a comparable level of indexation policy (an extensive version of it can be found in the Appendix C.2).

Ratio	Horizon	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9
$FR_N^{0,025}$	75	0,9670	1,1551	0,6805	0,7330	0,8105
$FR_N^{0,5}$	75	1,5830	1,8504	1,0818	1,1747	1,4315
$FR_N^{0,975}$	75	2,3807	2,6507	1,7807	1,9039	2,6030
$FR_R^{0,025}$	75	0,6850	0,8191	0,4800	0,5171	0,5738
$FR_R^{0,5}$	75	1,1569	1,3614	0,7806	0,8516	1,0455
$FR_R^{0,975}$	75	1,7992	1,9852	1,3345	1,4323	1,9640
$p(FR_N < 1)$	75	0,0400	0,0006	0,3698	0,2616	0,1430
$RPR_{25}^{0,025}$	70	0,4195	0,4341	0,3558	0,3693	0,3843
$RPR_{25}^{0,5}$	70	0,9989	1,0401	0,9108	0,9416	0,9622
$RPR_{25}^{0,975}$	70	3,4155	3,7478	3,0531	3,1812	3,1622
$PR_{25}^{0,025}$	70	0,4122	0,3816	0,4157	0,4211	0,4170
$PR_{25}^{0,5}$	70	1,1792	1,0989	1,2196	1,2312	1,2010
$PR_{25}^{0,975}$	70	4,5865	4,5520	4,5683	4,6695	4,4607
$p(i_{25} < 0)$	70	0,0186	0,0298	0,0112	0,0106	0,0100

Table 9: Classical ALM output for discounting changes with a comparable level of generosity in the open setting. The upper panel represents the 2,5%, 50% and 97,5% quantiles for the nominal and real funding ratio, as well as probability of nominal underfunding after 75 years. The lower panel shows the same quantiles of the replacement ratio and pension result for cohort of 25 years old in 70 years, as well as probability of benefit cut during these years

It is important to note that the funding ratio levels that are presented in the tables are calculated in the same manner for changes in discounting as they were for changes in the contract, i.e. using nominal term structure for nominal funding ratio and real for real funding ratio. There is one difference now though. The nominal funding ratio calculated for the plans evaluated in Chapter 3 was actually used for making decisions on indexation to be given, while here the funding ratio used for steering is calculated according to a specific rule being evaluated but the funding ratio levels given in the tables are calculated as before. Hence the comparison of nominal ar real funding ratios in both sets of changes is actually possible.

Switching to discounting with adjusted real interest rate affects the solvency of the fund positively. We see that the probability of nominal funding ratio decreasing below 100% is almost negligible after 75 years and the funding ratio levels increase significantly in all quantiles, as compared to the benchmark nominal Plan 5. A switch to discounting based on expected real returns leads to deterioration of a funding position in all quantiles and the nominal funding ratio is exposed to a soaring 37% probability of being below 100% threshold in 75 years. This is caused by the very generous indexation for the elderly, while the indexation figures for the 25 year cohort are not so high anymore as they already feel the effects of the worsened funding ratio. Probability of a cut for this cohort is still lower than in Plan 7 though, because the effect of higher discount rate outweighs the effect of lower funding ratio due to higher indexation granted before. Moving from nominal framework to a soft real discounting has the effect that stands between the effects of switching to method based on real term structure and the method based on expected real returns. It is, after all, a discounting technique that is effectively the weighted average of the two. For a lower smoothing horizon the funding ratios are just slightly above the ones in Plan 7 but with a longer smoothing period the results approach those of Plan 6. When we look at the replacement rate and pension result, the situation is similar. The indexation results are closer to the expected real returns variant for shorter smoothing period and move towards adjusted real term structure variant when a longer smoothing horizon is applied.

The results retain the same tendency independent of which policy ladder is applied. Of course, with a more generous policy ladder funding ratios are lower and indexation results better than with a stricter policy of indexation. The results for a stricter policy can be seen in the Appendix C.2.

4.7 Final note on discounting

An important conclusion that we can draw given the calculations is that changing the discount rate is as significant regarding the generational transfers as changes in the pension system itself. While the total effect of the change from traditional DB to collective DC amounts to more than 9% of the total value, the switch to discounting using adjusted real term structure can also imply up to 9% value transfers under the assumption of nominal closure rule (the tables with the exact numbers can be found in Appendix C.3). The real closure rule strengthens the effect even more, driving the value redistribution up to 22% with a maintained generosity level. The shift to adjusted real term structure discounting causes the highest level of redistribution, while the rest of the methods imply lower value transfers. The conclusions in the closed fund setting hold in the open setting as well. The real term structure discounting results in highest value transfers, reaching and even overtaking in magnitude the effect of system development from traditional DB to collective DC. The rest of valuation techniques involve much lower redistribution.

Not surprisingly, giving full indexation at 90% level implies less redistribution than following the supervisory advice and granting full indexation only at 100% real funding position. Indeed, shifting to more prudent indexation policy leads to a significant loss for the oldest cohorts. The tables for stricter policy ladder can also be found in Appendix C.3.

An interesting observation can be made regarding the neutral transition. If policy makers aim at a policy reform with minimum redistribution, the soft real discounting can help to reach this goal. We see that soft real contract with 20 years smoothing horizon implies relatively low value transfers. When a stricter indexation policy is introduced, soft real plan with 10 years smoothing results in the least redistributive transition. Combining the decisions on policy ladder generosity and the coefficient of smoothing the outcome with rather neutral redistribution can be achieved. Therefore the lesson is that to achieve desirable outcomes decisions on parameters of the system have to be made simultaneously.

5 Sensitivity analysis

5.1 Fund population

Up to now we have considered the pension fund with an average population, which represents the total population of the Netherlands. As the country has an exceptionally high participation rate due to its quasi-mandatory system[5], the national fund specification gives a reasonable indication of what the effect of a policy change would be on the whole population of the Netherlands.

The results might be specific to the population composition of the fund, so we consider a relatively young (green) and a relatively old (grey) fund too. To obtain the population numbers for these fund types, we change the initial number of people in each cohort so that the green fund has a larger proportion of young people as compared to the national fund, while the grey fund has a larger proportion of the elderly. The fertility and mortality is assumed to be the same for all fund specifications. To examine the effects of population composition we enclose the tables with value-based ALM results: 10a, 10b and 10c for green, national and grey pension funds respectively (here we present results for the open setting; the closed fund results can be found in Appendix C.4). Note that the first rows of the tables are not comparable as they state the nominal figures that depend on the number of people in the fund.

The first change of abandoning unconditional indexation ($1 \rightarrow 2$) deserves a special discussion. We see that the 65 year cohort loses more than 56% of the annual wage level in the green fund (Table 10a) and 62% in the grey fund (Table 10c), for they lose the guarantee of a fully indexed benefit. The 25 year cohort also experiences a loss of 27% in the green fund, but with maturity of the fund their position improves substantially. A matured population of this fund adds pressure on solvency of it and 75 years horizon becomes simply too long to keep this plan running, leading to emergency cuts in benefits to avoid a complete depletion of assets, and hence an extreme positive gain for 25 year cohort. Of course, keeping this plan in place for so long is unrealistic but it shows that a pension fund with grey population becomes insolvent under fixed benefit plan and a plan with conditional indexation suddenly becomes a desired option for the young. Even though they might get less than full benefit, it is still more than nothing in an almost certain case of default! Therefore giving full indexation independently of the fund's financial position is unsustainable policy, and the more so the older fund's population is.

When fixing the contribution rate ($2 \rightarrow 3$) is considered, the younger cohorts are relatively better off in the grey fund than in the green one: 25 year cohort is almost indifferent in the green fund but gains up to 35% of annual wage in the grey fund. This can be explained by the fact that in the matured fund part of the burden of older population should have been born by higher contributions (apart from the indexation level as a steering variable), had it not been set constant.

[5] When a majority of sector workers agree on participating, it becomes mandatory for the rest

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	1772,5	210,1	2140,9	2531,4	1592,5	1822,0	573,7	387,4	472,9
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0970	0,0127	0,1314	0,1789	0,0872	0,1092	0,0344	0,0232	0,0284
ΔV_{25}^{male}	-0,2688	-0,0148	-0,4904	0,7629	-0,0111	0,1518	-0,1383	-0,0524	-0,0473
ΔV_{25}^{female}	-0,2859	-0,0088	-0,5268	0,8391	0,0176	0,1843	-0,1505	-0,0563	-0,0452
ΔV_{45}^{male}	-0,7579	-0,1121	-0,8221	1,0591	-0,6328	-0,5540	-0,0290	-0,0186	-0,2648
ΔV_{45}^{female}	-0,8402	-0,1209	-0,8971	1,1879	-0,6704	-0,5792	-0,0498	-0,0323	-0,2974
ΔV_{65}^{male}	-0,5577	-0,0325	-0,7666	0,5360	-0,8207	-1,3639	0,4477	0,3485	0,0534
ΔV_{65}^{female}	-0,6446	-0,0396	-0,8690	0,6364	-0,9168	-1,4865	0,4776	0,3695	0,0352

Table 10a: Value-based ALM output (with a comparable level of generosity in real plans) for the pension fund with **green population** in the open setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	6109,5	558,0	8096,0	9519,7	7260,1	5276,2	3490,4	2684,4	1720,5
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0743	0,0073	0,1063	0,1398	0,0883	0,0680	0,0450	0,0346	0,0222
ΔV_{25}^{male}	0,1245	0,1484	-0,3821	0,8351	0,7259	0,2194	-0,2728	-0,1722	-0,0856
ΔV_{25}^{female}	0,1377	0,1625	-0,4065	0,9235	0,8172	0,2540	-0,3005	-0,1913	-0,0881
ΔV_{45}^{male}	-0,6634	-0,0341	-0,7632	1,0368	-0,4240	-0,2361	-0,0352	0,0072	-0,1971
ΔV_{45}^{female}	-0,7117	-0,0316	-0,8279	1,1685	-0,4027	-0,2357	-0,0631	-0,0102	-0,2260
ΔV_{65}^{male}	-0,6148	-0,0263	-0,7444	0,4853	-0,9002	-0,8981	0,5392	0,4452	0,1533
ΔV_{65}^{female}	-0,7100	-0,0316	-0,8443	0,5789	-1,0069	-0,9725	0,5795	0,4786	0,1486

Table 10b: Value-based ALM output (with a comparable level of generosity in real plans) for the pension fund with **the Netherlands population** in the open setting

Value-based ALM - grey fund - open - d145 - ifr125

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	21609,1	474,1	3325,0	3924,1	23009,7	1731,1	1801,9	1459,2	789,4
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	1,2901	0,0138	0,0958	0,1250	1,3738	0,0490	0,0510	0,0413	0,0224
ΔV_{25}^{male}	57,6317	0,3493	-0,2930	0,9394	58,6275	0,2445	-0,4230	-0,3151	-0,1411
ΔV_{25}^{female}	89,0714	0,3745	-0,3065	1,0450	90,1844	0,2765	-0,4695	-0,3532	-0,1500
ΔV_{45}^{male}	-0,3729	0,0952	-0,7351	1,0468	0,0339	-0,0320	-0,0648	-0,0002	-0,1706
ΔV_{45}^{female}	-0,3717	0,1179	-0,7933	1,1851	0,1381	-0,0150	-0,1018	-0,0245	-0,1996
ΔV_{65}^{male}	-0,6189	-0,0147	-0,7378	0,4660	-0,9054	-0,6628	0,5819	0,4921	0,2012
ΔV_{65}^{female}	-0,7068	-0,0157	-0,8372	0,5573	-1,0025	-0,7096	0,6267	0,5315	0,2034

Table 10c: Value-based ALM output (with a comparable level of generosity in real plans) for the pension fund with **grey population** in the open setting

For the changes of making the contract explicit, i.e. introducing the cut of benefits ($3 \to 4$) and surplus sharing option ($4 \to 5$), the value transfers decrease with maturity of the fund. The effect of the cut in benefits is negative for all the current cohorts but the young are better off in the grey fund (30% loss as compared to 50% loss in the green fund). This is because cutting benefits in the grey fund has the biggest impact on the future funding ratio, which enhances the position of the young. The surplus sharing option benefits the current cohorts independent of how mature the fund is but the gain for the elderly is somewhat higher in the young fund (54% gain for a male participant as compared with 47% in the grey fund) while the gain for the young is higher in a grey fund (93% versus 76% gain).

As for the discounting methods, the real term structure method ($5 \rightarrow 6$) is more disadvantageous for pensioners in a green fund than in the grey fund (136% loss and 66% loss respectively). In the green fund there are relatively more young participants with long duration and hence decrease in discount rate drives the liabilities of the fund up more, having a negative effect on the funding ratio and indexation. When the expected real returns are used ($5 \rightarrow 7$), by a similar reasoning the youngest cohorts lose more in the grey fund than in the green one (-42% and -14% respectively). Finally, the soft real contract still retains its qualities as being the intermediate method between the two previous ones.

5.2 Initial funding position

As a starting point in the model the initial pension fund's financial position must be assumed. So far we evaluated the default pension fund with initial nominal funding ratio of 125%. Understanding that this is a crucial assumption, in this section we want to examine the sensitivity of results for two more cases: a fund with a lower starting funding position of 100% nominal funding ratio and a fund with a higher initial nominal funding ratio of 150%. To avoid repetition we only present the tables for the open fund (the effects are of a similar nature in the closed setting and can be found in Appendix C.5).

Introducing conditional indexation is obviously disadvantageous to the elderly cohorts. The effect gets stronger for the assumption of lower initial funding ratio: with the initial funding ratio position of 150% the 65 year cohort loses 36%, for default assumption of 125% the loss is already 61% and for 100% it jumps to more than a full annual wage level. The effects is similar albeit smaller for middle cohorts, while the position of the youngest ones follows a reverse trend. This is because in case of bad initial funding position full indexation for pensioners no longer applies and thus the funding ratio improves in the longer term. The relative value redistribution is hence the highest for the lowest initial funding ratio: it reaches 11% of total value, as compared to only 5% in case of 150% ratio.

Setting a constant premium level is rather neutral for initial funding ratio of 125%, amounting to less than 1% in value transfers. The effect gets more pronounced for better and worse initial funding positions. At 125% there is little effect but for lower funding position the young gain up to 55% as they effectively have to pay less in fixed contribution than they would have paid had it been variable. This leads to gain for the 25 year cohort and consequently a loss for the 65 year cohort arising from lower indexation due to lower premium paid by the young. For 150% initial funding position, the younger cohorts have to pay more than they would have paid in case of variable contribution, resulting in around 50% gain for the pensioners and 40% loss for the young. Hence the total value transfers increase with more extreme initial funding ratios.

The total value transfers caused by making the downside risk explicit by introducing a possibility of benefit cut decrease with the initial funding ratio: in 150% case the redistribution is around 8% of value, while in 100% case it reaches 14%. The put option held by pensioners in a plan without cuts becomes more valuable with worse initial funding position, hence the loss is highest when cuts are introduced in 100% case. The younger ones become better off with lower initial funding position assumption, as in this case cuts are more likely to be implemented allowing for a better funding position in the future.

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	8520,4	2349,1	10013,4	4538,9	15168,4	5263,9	3870,4	3015,8	2259,5
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,1114	0,0342	0,1418	0,0749	0,1984	0,0808	0,0594	0,0463	0,0347

ΔV_{25}^{male}	0,3308	0,5563	-0,3151	0,5450	1,1169	0,2113	-0,2672	-0,1784	-0,1464
ΔV_{25}^{female}	0,3565	0,5652	-0,3309	0,6053	1,1961	0,2436	-0,2950	-0,1984	-0,1600
ΔV_{45}^{male}	-0,7801	0,2185	-0,7708	0,5019	-0,8305	-0,1224	-0,1320	-0,0812	-0,1509
ΔV_{45}^{female}	-0,8240	0,2109	-0,8277	0,5728	-0,8680	-0,1137	-0,1676	-0,1070	-0,1801
ΔV_{65}^{male}	-1,0168	-0,1069	-1,2452	0,1542	-2,2146	-1,0563	0,6488	0,5390	0,3296
ΔV_{65}^{female}	-1,1562	-0,1252	-1,3721	0,1900	-2,4633	-1,1186	0,6797	0,5646	0,3374

Table 11a: Value-based ALM output (with a comparable level of generosity in real plans) for the pension fund with **initial nominal funding ratio of 100%** in the open setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	6109,5	558,0	8096,0	9519,7	7260,1	5276,2	3490,4	2684,4	1720,5
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0743	0,0073	0,1063	0,1398	0,0883	0,0680	0,0450	0,0346	0,0222

ΔV_{25}^{male}	0,1245	0,1484	-0,3821	0,8351	0,7259	0,2194	-0,2728	-0,1722	-0,0856
ΔV_{25}^{female}	0,1377	0,1625	-0,4065	0,9235	0,8172	0,2540	-0,3005	-0,1913	-0,0881
ΔV_{45}^{male}	-0,6634	-0,0341	-0,7632	1,0368	-0,4240	-0,2361	-0,0352	0,0072	-0,1971
ΔV_{45}^{female}	-0,7117	-0,0316	-0,8279	1,1685	-0,4027	-0,2357	-0,0631	-0,0102	-0,2260
ΔV_{65}^{male}	-0,6148	-0,0263	-0,7444	0,4853	-0,9002	-0,8981	0,5392	0,4452	0,1533
ΔV_{65}^{female}	-0,7100	-0,0316	-0,8443	0,5789	-1,0069	-0,9725	0,5795	0,4786	0,1486

Table 11b: Value-based ALM output (with a comparable level of generosity in real plans) for the pension fund with **initial nominal funding ratio of 125%** in the open setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	4286,2	1920,6	6693,6	16676,9	3813,1	5854,9	3920,6	2945,8	1710,4
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0497	0,0234	0,0836	0,2273	0,0442	0,0650	0,0435	0,0327	0,0190

ΔV_{25}^{male}	0,0120	-0,2056	-0,4053	1,1435	0,5446	0,2859	-0,3272	-0,2003	0,0320
ΔV_{25}^{female}	0,0173	-0,1886	-0,4344	1,2625	0,6568	0,3275	-0,3608	-0,2232	0,0459
ΔV_{45}^{male}	-0,5081	-0,2637	-0,6935	1,7353	0,2699	-0,2854	0,0336	0,0878	-0,2243
ΔV_{45}^{female}	-0,5504	-0,2552	-0,7584	1,9432	0,3792	-0,2847	0,0097	0,0774	-0,2469
ΔV_{65}^{male}	-0,3558	0,0085	-0,4899	1,1053	0,2682	-0,9152	0,5872	0,4546	-0,1130
ΔV_{65}^{female}	-0,4177	0,0098	-0,5681	1,2902	0,3142	-1,0057	0,6407	0,4985	-0,1399

Table 11c: Value-based ALM output (with a comparable level of generosity in real plans) for the pension fund with **initial nominal funding ratio of 150%** in the open setting

The surplus sharing option is the most valuable with higher initial funding position. This leads to extreme improvements in the position of 45 and 65 year old cohorts when initial funding ratio goes from 100% to 150%. It comes naturally then that the 25 year old cohort becomes relatively worse with better starting funding position, as in this case more money is given away in benefits for the older cohorts. The value transfers are hence more than 7% for 100% assumption and jump to almost 23% for 150% assumption.

The results for different valuation techniques are much more robust to different initial funding ratio assumptions. That can be explained by the fact that the plan considered is now essentially the same in all variants but there is redistribution due to different discounting rules. The discounting method affects different generations similarly, whether the initial funding position is good or bad.

5.3 Longevity risk

Longevity risk is a topic that deserves a separate research on itself; however, it is not the focus of this research and hence we take survival probabilities and projections for the future as given, not accounting for the uncertainty about it.

In the past, statistically the life expectancy of people has always been underestimated. In the future, however, nobody knows if that continues to be the case. Statisticians have increased their forecasts quite steeply already, which gives more confidence that the forecasts will be more accurate (as there are some speculations that the trend will not get much steeper due to biological constraints of humans). Still, the factors influencing life expectancy remain vague and we believe it is not beneficial to complicate the model even further to account for the longevity risk caused by these uncertain factors.

Broer, Knaap and Westerhout (2010) analyze the macroeconomic risks that affect the returns of pension schemes, both PAYG and funded. They find that returns on funded plans are much more volatile; however, they come up with the result that longevity risk is just moderate. They consider the longevity risk as a deviation of actual life expectancy from the statistical expectations, and it is not expected to diverge much due to large additions by statisticians. Therefore in this work we do not analyze the longevity risk in depth.

5.4 Other aspects

In this thesis we concentrate on the second pillar pension scheme only. This makes it difficult to evaluate the fairness for specific cohorts due to two reasons: firstly, the model does not take into account any past gains or losses; and secondly, alternative income sources are not evaluated.

Past There is an open question for what weight should be given to the transfers in the past when searching for a better system for the future, or whether they should be accounted for at all. One could argue that bygones are bygones and it should not be taken into account. After all, if the cash flows of the past would be given a full weight, it could well lead to very extreme outcomes. For the pension system in the past was much more generous than the current one, the elderly of today gained a lot in the past and if they were to compensate for these past gains from their current benefits, that could lead to the outcomes that are not acceptable to a society as a whole.

Yet another argument for not considering past gains or losses is that *ex post* outcomes should not be compensated as they were a part of a contract *ex ante*. Therefore, corrections for that should not be included in the fairness evaluation.

Even if we would like to take the gains and losses of the past into account, often the data on it is very limited or extremely time consuming to collect, putting constraints on evaluation of the past.

Parallel sources Our analysis can help in evaluating the fairness in a second pillar pension scheme. The question is, are the results meaningful in absence of a general picture, so not taking into account all parallel income sources. These can be first pension pillar or the government transfers, that can involve intergenerational redistribution, as well as personal sources of retirement income, usually the most significant one being the owned housing wealth, if any. In this view, this research finds its place next to the recent research of Centraal Planbureau (CPB) which considers other spheres than second pension pillar, hence the combination of them could make a picture more or less complete. The research on all the parallel sources is, however, too complex for this master thesis and thus is left for the future.

6 Conclusions

The ongoing pension plan redesign discussion is a clear indication that finding a contract that improves sustainability and solvency of the fund without disrupting the generational balance is not a trivial task; each change in the system involves complex implications on the performance of the pension fund and the intergenerational balance.

There is no one answer to the question what is the best choice for pension redesign. The appropriate pension plan redesign decision depends on the goals that are being pursued. We present a valuable tool to take into account the generational transfers when making the decision, by combining the generational accounting and risk neutral valuation. The importance of intergenerational redistribution in the pension system is backed by quite some attention to it in the Dutch media recently. However, these intergenerational effects are often evaluated just qualitatively (if at all) and are not based on any explicit calculations. This research adds value to the current pension discussion by shedding some light on the direction and magnitude of the effects of different policy measures and value transfers implied by them.

We look at the general development of the Dutch second pillar occupational pension contract, stepping over from traditional DB to the hybrid plan, to collective DC and finally making the contract more explicit by introducing benefit cuts and surplus sharing option. We find that these steps have diverse effects but the combined result is value redistribution from elderly to the young cohorts. The separate steps have very different effects on redistribution, ranging from half the annual wage loss to half the annual wage gain for the elderly. The aggregate effect, however, leaves the oldest cohorts disadvantaged. As explained in the text, this effect should not be considered on its own but rather in coherence with the beneficial position of these cohorts in the past.

We also examine an often discussed step of shifting from nominal to the real setting. We show that it is a complex process involving difficult choices to be made. The crucial decisions are choosing the discount rate to be used and the way of indexation policy adjustment. The real term structure adjusted for the wage growth, the expected real returns and the combination of these two are examined as the possible choices for discounting in the real framework. For the indexation policy adjustment a transition keeping the current generosity level and a stricter indexation policy with full indexation at the real funding ratio of 100% is evaluated.

The results indicate that both are potentially value redistributing steps and depending on what discounting method is applied and how the indexation policy is adjusted, can imply significant value transfers. The adjusted real term structure seems to be most redistributive out of the discounting methods; the stricter indexation policy also increases value redistribution from the elderly to the young. The combination soft real discounting method together with policy adjustment turns out to give quite neutral results in that respect.

As redistribution cannot be completely avoided, the extreme effects of value transfers can be mitigated by sensibly choosing the policy parameters for the reform in order to achieve more neutral effects of the reform regarding intergenerational value transfers. Smoothing parameter of the soft real method can be chosen simultaneously with indexation policy adjustment to arrive at an acceptable level of redistribution. This acceptable level, however, is difficult to define as there is no universal definition of fairness. In this research we show the effects of reforms in order to equip the policy makers with information helping them to make sound decisions on pension plan redesign.

Finally, we address some issues for further research. Firstly, this research concentrates on the intergenerational effects. A possible way of making the analysis more extensive would be to assess the intragenerational effects too. Allowing the individual wage path development as opposed to the uniform one applied here would enable us to get insight into the effects for high and low income, steep and stable wage profile individuals. Secondly, a simplifying assumption of 50/50 asset mix could be relaxed, evaluating the impact of different asset allocation. Thirdly, the effects of price versus wage indexation could be possibly interesting due to their different correlation features with asset returns.

It goes without saying that this tool is not limited to evaluating the effects in second pension pillar. It can as well be applied to the first pillar pension, the public finances or any other setting involving collective features.

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Appendices

A Pension plan specifications

A.1 Catch-up indexation

If the FR_N exceeds *cap*, an additional catch-up indexation can be given to compensate for the missed indexation in the past. There is however no compensation given for the benefits lost in the past due to partial indexation, only the future benefits are increased.

The missed indexation is determined by comparing the actual wage level with the accrued benefits. If a full wage indexation had been given in the past, all the current pensioners would have the benefits equal to 80% of the current wage level and the current workers would have accrued a part of a current wage proportional to their number of years of participation in the fund times the accrual rate. The missed indexation then can be determined by subtracting the actual accrued benefits from the full accrued benefits times the current wage level. The result is then a missed indexation for the current period for each cohort in each scenario. We then multiply the result with a discount matrix to account for the impact of the missed indexation in the future too. The total missed indexation in each scenario is calculated by summing up the values for all cohorts.

After the total missed indexation *missind* has been identified, the excess assets *excessA* exceeding the *cap* level are calculated for each scenario.

$$excessA = \begin{cases} \frac{FR_N - cap}{cap} \cdot L_N & \text{if } FR_N > cap, \\ 0 & \text{if } FR_N \leq cap. \end{cases} \tag{35}$$

If the assets available are more than the missed indexation, it is fully compensated and the benefits are set to the full level for all cohorts. If excess assets are not sufficient, an equal part *comp* of missed indexation is compensated for all cohorts.

$$comp = \begin{cases} 1 & \text{if } excessA \geq missind, \\ excessA/missind & \text{if } excessA < missind. \end{cases} \tag{36}$$

Then the final compensation for generation x is $comp_x$ equal to:

$$comp_x = comp \cdot missind_x \tag{37}$$

As the missed indexation is cohort specific, each generation receives a different compensation for it. We view this approach as fair, for it gives each cohort an equal part of the missed indexation, so compensation is uniform in relative terms.

In case there are not enough excess assets to compensate for the missed indexation fully, the funding ratio goes back to a *cap* level after the partial compensation has been given. If it was initially below *cap* level and no compensation was given, the funding ratio stays the same and if a full compensation was applied, the funding ratio decreases but to the level higher than *cap*.

A.2 Solvency cut

The algorithm for a solvency cut works as follows. If the funding ratio falls below a threshold of $floor$ level, it automatically triggers a part of the model responsible for the recovery plan. Here the required annual increase in the funding ratio ($step$) is determined as

$$step = \frac{floor - FR_N^{\star}}{5} \tag{38}$$

Here $FR_N^{\star}$ is the funding ratio level that we fix when it first goes below $floor$ and keep it fixed for the next 5 years. The required funding ratio for the next year is then

$$FR_{req} = FR_N^{\star} + step \tag{39}$$

Next year all benefits are corrected with a factor cor_{req}

$$cor_{req} = \begin{cases} 1 & \text{if } FR_N \geq FR_{req}, \\ FR_N/FR_{req} & \text{if } FR_N < FR_{req}. \end{cases} \tag{40}$$

so that the funding ratio after correction is equal to at least the level FR_{req} that was set before. The required level is then enhanced with $step$ again and the process is repeated for five years (or less if the funding ratio surpasses the threshold of $floor$ earlier in which case the recovery plan is terminated). Hence in the worst case the benefits are cut each year to reach the funding ratio of $floor$ in five years while in the better scenarios the cuts are not needed and the funding ratio increases on its own. In either case, the result is that after five years the funding ratio is $floor$ at minimum.

B Graphs

B.1 Value transfers at individual level: decomposition to net benefit and residue

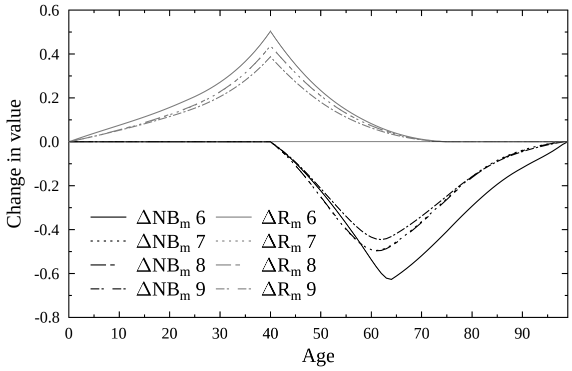

Figure 21: Change in the net benefit and residue for male individual when adjusting the policy ladder to a more prudent level in the closed setting

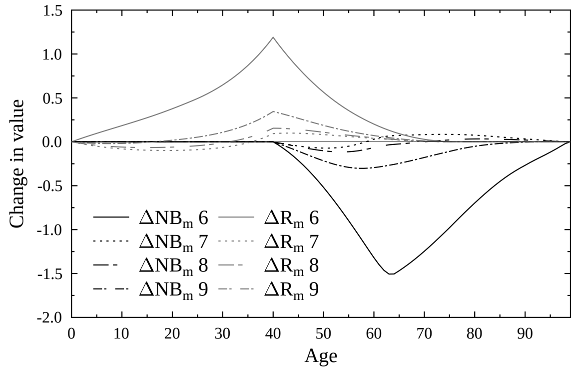

Figure 22: Change in the net benefit and residue when changing the discount rate and adjusting the policy ladder to a more prudent level in the closed setting

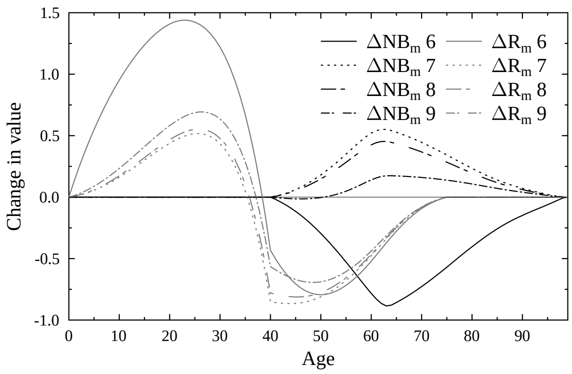

Figure 23: Change in the net benefit and residue for male individual when changing the discount rate and adjusting the policy ladder to a comparable level and using the real closure rule in the closed setting

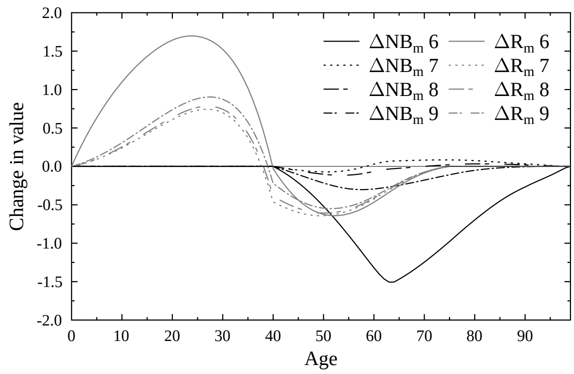

Figure 24: Change in the net benefit and residue for male individual when changing the discount rate and adjusting the policy ladder to a more prudent level and using the real closure rule in the closed setting

C Tables

C.1 Classical ALM. Contract changes

Ratio	Horizon	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
$FR_N^{0,025}$	5	0,7874	0,8701	0,8630	0,9351	0,9351
	15	0,6978	0,8663	0,8517	0,9400	0,9389
	25	0,6093	0,8937	0,8633	0,9591	0,9532
$FR_N^{0,5}$	5	1,2712	1,2925	1,2949	1,2975	1,2970
	15	1,2850	1,3000	1,3030	1,3051	1,3000
	25	1,3349	1,3622	1,3814	1,3871	1,3569
$FR_N^{0,975}$	5	1,7821	1,7822	1,7992	1,7992	1,7610
	15	2,0948	2,0963	2,1644	2,1644	1,9398
	25	2,6109	2,6223	2,7665	2,7665	2,1222
$FR_R^{0,025}$	5	0,5436	0,6028	0,5935	0,6476	0,6476
	15	0,4989	0,6150	0,6039	0,6662	0,6656
	25	0,4376	0,6369	0,6143	0,6847	0,6831
$FR_R^{0,5}$	5	0,8886	0,9015	0,9017	0,9021	0,9019
	15	0,9241	0,9394	0,9416	0,9426	0,9387
	25	0,9707	0,9885	1,0037	1,0076	0,9874
$FR_R^{0,975}$	5	1,2536	1,2538	1,2672	1,2672	1,2386
	15	1,5072	1,5107	1,5554	1,5554	1,4092
	25	1,9044	1,9107	2,0201	2,0206	1,5627
$p(FR_N < 1)$	25	0,2146	0,0662	0,0738	0,0486	0,0506
$RPR_{25}^{0,025}$	25	0,5000	0,3866	0,3796	0,3533	0,3533
$RPR_{45}^{0,025}$	25	0,8000	0,5653	0,5443	0,4966	0,4966
$RPR_{65}^{0,025}$	25	0,8000	0,5344	0,5101	0,4677	0,4672
$RPR_{25}^{0,5}$	25	0,5000	0,5000	0,5000	0,5000	0,5000
$RPR_{45}^{0,5}$	25	0,8000	0,8000	0,8000	0,8000	0,8000
$RPR_{65}^{0,5}$	25	0,8000	0,8000	0,8000	0,8000	0,8000
$RPR_{25}^{0,975}$	25	0,5000	0,5000	0,5000	0,5000	0,6320
$RPR_{45}^{0,975}$	25	0,8000	0,8000	0,8000	0,8000	1,0711
$RPR_{65}^{0,975}$	25	0,8000	0,8000	0,8000	0,8000	1,0917
$PR_{25}^{0,025}$	25	1,0000	0,6444	0,6236	0,5460	0,5440
$PR_{45}^{0,025}$	25	1,0000	0,6604	0,6328	0,5712	0,5706
$PR_{65}^{0,025}$	25	1,0000	0,6679	0,6376	0,5846	0,5840
$PR_{25}^{0,5}$	25	1,0000	0,9482	0,9498	0,9479	0,9624
$PR_{45}^{0,5}$	25	1,0000	0,9795	0,9803	0,9790	0,9888
$PR_{65}^{0,5}$	25	1,0000	1,0000	1,0000	1,0000	1,0000
$PR_{25}^{0,975}$	25	1,0000	1,0000	1,0000	1,0000	1,3521
$PR_{45}^{0,975}$	25	1,0000	1,0000	1,0000	1,0000	1,3612
$PR_{65}^{0,975}$	25	1,0000	1,0000	1,0000	1,0000	1,3646
$p(i < 0)$	25	0,0000	0,0000	0,0000	0,0201	0,0204

Table 12: Classical ALM output for contract changes in the closed setting

Ratio	Horizon	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
$FR_N^{0,025}$	25	0,6093	0,8937	0,8633	0,9591	0,9532
	50	0,2200	0,8981	0,8677	0,9727	0,9564
	75	0,1123	0,9392	0,9037	0,9852	0,9670
$FR_N^{0,5}$	25	1,3349	1,3622	1,3814	1,3871	1,3569
	50	1,5327	1,6318	1,7500	1,7655	1,4904
	75	1,8166	2,0561	2,3963	2,4272	1,5830
$FR_N^{0,975}$	25	2,6109	2,6223	2,7665	2,7665	2,1222
	50	4,9921	5,0570	5,6204	5,6259	2,2965
	75	10,6782	10,8171	12,6178	12,6357	2,3807
$FR_R^{0,025}$	25	0,4376	0,6369	0,6143	0,6847	0,6831
	50	0,1593	0,6378	0,6109	0,6916	0,6816
	75	0,0796	0,6650	0,6319	0,6960	0,6850
$FR_R^{0,5}$	25	0,9707	0,9885	1,0037	1,0076	0,9874
	50	1,1066	1,1771	1,2648	1,2769	1,0850
	75	1,3087	1,4820	1,7261	1,7467	1,1569
$FR_R^{0,975}$	25	1,9044	1,9107	2,0201	2,0206	1,5627
	50	3,6259	3,6525	4,0679	4,0827	1,7010
	75	7,6893	7,8051	9,1435	9,1470	1,7992
$p(FR_N < 1)$	75	0,2676	0,0424	0,0508	0,0306	0,0400
$RPR_{25}^{0,025}$	70	0,3903	0,4613	0,3959	0,4205	0,4195
$RPR_{45}^{0,025}$	50	0,8000	0,4709	0,4142	0,4280	0,4254
$RPR_{65}^{0,025}$	30	0,8000	0,5119	0,4796	0,4485	0,4485
$RPR_{25}^{0,5}$	70	0,8000	0,8000	0,8000	0,8000	0,9989
$RPR_{45}^{0,5}$	50	0,8000	0,8000	0,8000	0,8000	0,8696
$RPR_{65}^{0,5}$	30	0,8000	0,8000	0,8000	0,8000	0,8032
$RPR_{25}^{0,975}$	70	0,8000	0,8000	0,8000	0,8000	3,4155
$RPR_{45}^{0,975}$	50	0,8000	0,8000	0,8000	0,8000	2,0726
$RPR_{65}^{0,975}$	30	0,8000	0,8000	0,8000	0,8000	1,2327
$PR_{25}^{0,025}$	70	0,4869	0,4880	0,4093	0,4105	0,4122
$PR_{45}^{0,025}$	50	1,0000	0,5675	0,4973	0,5068	0,5065
$PR_{65}^{0,025}$	30	1,0000	0,6398	0,5995	0,5606	0,5606
$PR_{25}^{0,5}$	70	1,0000	0,9372	0,9407	0,9357	1,1792
$PR_{45}^{0,5}$	50	1,0000	0,9816	0,9831	0,9822	1,0701
$PR_{65}^{0,5}$	30	1,0000	1,0000	1,0000	1,0000	1,0040
$PR_{25}^{0,975}$	70	1,0000	1,0000	1,0000	1,0000	4,5865
$PR_{45}^{0,975}$	50	1,0000	1,0000	1,0000	1,0000	2,5952
$PR_{65}^{0,975}$	30	1,0000	1,0000	1,0000	1,0000	1,5409
$p(i_{25} < 0)$	70	0,0032	0,0000	0,0000	0,0173	0,0186
$p(i_{45} < 0)$	50	0,0009	0,0000	0,0000	0,0188	0,0196
$p(i_{65} < 0)$	30	0,0000	0,0000	0,0000	0,0200	0,0204

Table 13: Classical ALM output for contract changes in the open setting

C.2 Classical ALM. Discounting changes

Ratio	Horizon	V5	V6	V7	V8	V9
$FR_N^{0,025}$	25	0,9532	1,1000	0,7183	0,7626	0,8192
	50	0,9564	1,1255	0,6875	0,7350	0,8036
	75	0,9670	1,1551	0,6805	0,7330	0,8105
$FR_N^{0,5}$	25	1,3569	1,4915	1,1785	1,2262	1,3039
	50	1,4904	1,7154	1,1151	1,1912	1,3727
	75	1,5830	1,8504	1,0818	1,1747	1,4315
$FR_N^{0,975}$	25	2,1222	2,3258	1,7710	1,8529	2,1542
	50	2,2965	2,5823	1,7886	1,8935	2,4158
	75	2,3807	2,6507	1,7807	1,9039	2,6030
$FR_R^{0,025}$	25	0,6831	0,7886	0,5159	0,5485	0,5865
	50	0,6816	0,8008	0,4933	0,5237	0,5729
	75	0,6850	0,8191	0,4800	0,5171	0,5738
$FR_R^{0,5}$	25	0,9874	1,0760	0,8596	0,8937	0,9491
	50	1,0850	1,2489	0,8119	0,8679	1,0003
	75	1,1569	1,3614	0,7806	0,8516	1,0455
$FR_R^{0,975}$	25	1,5627	1,7053	1,3030	1,3645	1,5847
	50	1,7010	1,9108	1,3299	1,4075	1,7982
	75	1,7992	1,9852	1,3345	1,4323	1,9640
$p(FR_N < 1)$	75	0,0400	0,0006	0,3698	0,2616	0,1430
$RPR_{25}^{0,025}$	70	0,4195	0,4341	0,3558	0,3693	0,3843
$RPR_{45}^{0,025}$	50	0,4254	0,4132	0,4090	0,4119	0,4166
$RPR_{65}^{0,025}$	30	0,4485	0,4027	0,5210	0,5064	0,4882
$RPR_{25}^{0,5}$	70	0,9989	1,0401	0,9108	0,9416	0,9622
$RPR_{45}^{0,5}$	50	0,8696	0,8563	0,9345	0,9237	0,8825
$RPR_{65}^{0,5}$	30	0,8032	0,8000	0,8901	0,8611	0,8202
$RPR_{25}^{0,975}$	70	3,4155	3,7478	3,0531	3,1812	3,1622
$RPR_{45}^{0,975}$	50	2,0726	2,0235	2,2540	2,2439	1,9483
$RPR_{65}^{0,975}$	30	1,2327	1,1401	1,4853	1,4294	1,1882
$PR_{25}^{0,025}$	70	0,4122	0,3816	0,4157	0,4211	0,4170
$PR_{45}^{0,025}$	50	0,5065	0,4699	0,5123	0,5107	0,5103
$PR_{65}^{0,025}$	30	0,5606	0,5033	0,6512	0,6331	0,6103
$PR_{25}^{0,5}$	70	1,1792	1,0989	1,2196	1,2312	1,2010
$PR_{45}^{0,5}$	50	1,0701	1,0127	1,1885	1,1655	1,1006
$PR_{65}^{0,5}$	30	1,0040	1,0000	1,1126	1,0763	1,0253
$PR_{25}^{0,975}$	70	4,5865	4,5520	4,5683	4,6695	4,4607
$PR_{45}^{0,975}$	50	2,5952	2,4890	2,9219	2,8864	2,4667
$PR_{65}^{0,975}$	30	1,5409	1,4251	1,8566	1,7867	1,4853
$p(i_{25} < 0)$	70	0,0186	0,0298	0,0112	0,0106	0,0100
$p(i_{45} < 0)$	50	0,0196	0,0354	0,0089	0,0089	0,0093
$p(i_{65} < 0)$	30	0,0204	0,0449	0,0053	0,0058	0,0073

Table 14: Classical ALM output for discounting changes with a comparable level of generosity in the open setting

Ratio	Horizon	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9
$FR_N^{0,025}$	25	0,9532	1,2211	0,8039	0,8455	0,8959
	50	0,9564	1,2641	0,7824	0,8371	0,9032
	75	0,9670	1,3043	0,7798	0,8401	0,9232
$FR_N^{0,5}$	25	1,3569	1,6413	1,2793	1,3162	1,3649
	50	1,4904	1,9306	1,2851	1,3656	1,5393
	75	1,5830	2,1241	1,2912	1,3977	1,6832
$FR_N^{0,975}$	25	2,1222	2,5148	1,9573	2,0345	2,3202
	50	2,2965	2,8996	2,0334	2,1497	2,7139
	75	2,3807	3,0048	2,0600	2,1886	2,9732
$FR_R^{0,025}$	25	0,6831	0,8724	0,5754	0,6034	0,6405
	50	0,6816	0,8975	0,5569	0,5952	0,6406
	75	0,6850	0,9279	0,5548	0,5978	0,6525
$FR_R^{0,5}$	25	0,9874	1,1882	0,9325	0,9583	0,9920
	50	1,0850	1,4032	0,9349	0,9934	1,1185
	75	1,1569	1,5647	0,9398	1,0232	1,2293
$FR_R^{0,975}$	25	1,5627	1,8422	1,4383	1,4928	1,7043
	50	1,7010	2,1419	1,5092	1,5919	2,0150
	75	1,7992	2,2520	1,5532	1,6496	2,2375
$p(FR_N < 1)$	75	0,0400	0,0000	0,1700	0,1150	0,0546
$RPR_{25}^{0,025}$	70	0,4195	0,4487	0,3781	0,3851	0,4005
$RPR_{45}^{0,025}$	50	0,4254	0,4096	0,4171	0,4112	0,4116
$RPR_{65}^{0,025}$	30	0,4485	0,3643	0,4935	0,4754	0,4587
$RPR_{25}^{0,5}$	70	0,9989	1,0579	0,9708	0,9864	0,9627
$RPR_{45}^{0,5}$	50	0,8696	0,8424	0,9089	0,8911	0,8508
$RPR_{65}^{0,5}$	30	0,8032	0,8000	0,8335	0,8154	0,8021
$RPR_{25}^{0,975}$	70	3,4155	3,7475	3,3267	3,3939	3,1237
$RPR_{45}^{0,975}$	50	2,0726	1,9025	2,2129	2,1702	1,8219
$RPR_{65}^{0,975}$	30	1,2327	1,0571	1,3632	1,3062	1,0983
$PR_{25}^{0,025}$	70	0,4122	0,3540	0,4175	0,4178	0,4145
$PR_{45}^{0,025}$	50	0,5065	0,4398	0,5108	0,5055	0,4993
$PR_{65}^{0,025}$	30	0,5606	0,4554	0,6168	0,5942	0,5733
$PR_{25}^{0,5}$	70	1,1792	1,0218	1,2358	1,2247	1,1488
$PR_{45}^{0,5}$	50	1,0701	0,9712	1,1359	1,1077	1,0473
$PR_{65}^{0,5}$	30	1,0040	1,0000	1,0419	1,0192	1,0027
$PR_{25}^{0,975}$	70	4,5865	4,2324	4,7541	4,7463	4,2128
$PR_{45}^{0,975}$	50	2,5952	2,2628	2,8220	2,7403	2,2703
$PR_{65}^{0,975}$	30	1,5409	1,3213	1,7040	1,6327	1,3729
$p(i_{25} < 0)$	70	0,0186	0,0384	0,0094	0,0096	0,0107
$p(i_{45} < 0)$	50	0,0196	0,0482	0,0084	0,0093	0,0112
$p(i_{65} < 0)$	30	0,0204	0,0662	0,0065	0,0078	0,0107

Table 15: Classical ALM output for discounting changes with a stricter indexation policy in the open setting.

C.3 Value-based ALM. Discounting changes

	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	6960,34	6336,47	4387,94	3619,08	1414,46
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0956	0,0870	0,0603	0,0497	0,0194

ΔV_{25}^{male}	0,3834	0,2872	-0,2563	-0,2128	-0,1003
ΔV_{25}^{female}	0,4099	0,3082	-0,2789	-0,2316	-0,1106
ΔV_{45}^{male}	0,2190	0,3727	-0,1549	-0,1198	-0,0189
ΔV_{45}^{female}	0,2621	0,4192	-0,1828	-0,1422	-0,0247
ΔV_{65}^{male}	-0,7700	-0,8024	0,5137	0,4230	0,1770
ΔV_{65}^{female}	-0,8203	-0,8359	0,5437	0,4473	0,1834

Table 16: Value-based ALM output for discounting changes with a comparable level of generosity and the nominal closure rule in the closed setting. The upper panel shows the magnitude of value transfers: the nominal absolute changes in value are shown in the first row and the second row shows it relative to the total value of the plan. The lower panel shows the changes in value for representative male and female members of cohorts that are 25, 45 and 65 now, expressed in annual wage levels

	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	6960,34	16428,52	6253,18	6123,70	6714,53
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0956	0,2256	0,0859	0,0841	0,0922

ΔV_{25}^{male}	0,3834	1,4237	0,5164	0,5517	0,6876
ΔV_{25}^{female}	0,4099	1,6214	0,5763	0,6146	0,7627
ΔV_{45}^{male}	0,2190	-0,8222	-0,8037	-0,7597	-0,6844
ΔV_{45}^{female}	0,2621	-0,7479	-0,7814	-0,7321	-0,6411
ΔV_{65}^{male}	-0,7700	-1,1343	0,2755	0,1875	-0,0618
ΔV_{65}^{female}	-0,8203	-1,3026	0,2109	0,1184	-0,1503

Table 17: Value-based ALM output for discounting changes with a comparable level of generosity and the real closure rule in the closed setting

	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	7260,14	5276,23	3490,41	2684,39	1720,50
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0883	0,0680	0,0450	0,0346	0,0222

ΔV_{25}^{male}	0,7259	0,2194	-0,2728	-0,1722	-0,0856
ΔV_{25}^{female}	0,8172	0,2540	-0,3005	-0,1913	-0,0881
ΔV_{45}^{male}	-0,4240	-0,2361	-0,0352	0,0072	-0,1971
ΔV_{45}^{female}	-0,4027	-0,2357	-0,0631	-0,0102	-0,2260
ΔV_{65}^{male}	-0,9002	-0,8981	0,5392	0,4452	0,1533
ΔV_{65}^{female}	-1,0069	-0,9725	0,5795	0,4786	0,1486

Table 18: Value-based ALM output for discounting changes with a comparable level of generosity in the open setting

	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	6960,34	10832,62	1065,77	747,07	1983,20
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0956	0,1488	0,0146	0,0103	0,0272
ΔV_{25}^{male}	0,3834	0,4932	-0,0894	-0,0445	0,0530
ΔV_{25}^{female}	0,4099	0,5289	-0,1004	-0,0516	0,0535
ΔV_{45}^{male}	0,2190	0,6265	0,0492	0,0842	0,1602
ΔV_{45}^{female}	0,2621	0,7054	0,0503	0,0908	0,1798
ΔV_{65}^{male}	-0,7700	-1,3757	0,0924	-0,0020	-0,2116
ΔV_{65}^{female}	-0,8203	-1,4339	0,0952	-0,0046	-0,2283

Table 19: Value-based ALM output for discounting changes with a stricter indexation policy and the nominal closure rule in the closed setting

	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	6960,34	20150,23	7039,02	7353,79	8750,85
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0956	0,2768	0,0967	0,1010	0,1202
ΔV_{25}^{male}	0,3834	1,6922	0,7314	0,7676	0,8821
ΔV_{25}^{female}	0,4099	1,9155	0,8082	0,8475	0,9726
ΔV_{45}^{male}	0,2190	-0,6513	-0,6474	-0,6028	-0,5460
ΔV_{45}^{female}	0,2621	-0,5459	-0,5952	-0,5454	-0,4766
ΔV_{65}^{male}	-0,7700	-1,7216	-0,1564	-0,2480	-0,4595
ΔV_{65}^{female}	-0,8203	-1,9204	-0,2523	-0,3483	-0,5749

Table 20: Value-based ALM output for discounting changes with a stricter indexation policy and the real closure rule in the closed setting

	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	7260,14	9393,03	2504,06	2187,29	4217,90
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0883	0,1210	0,0323	0,0282	0,0543
ΔV_{25}^{male}	0,7259	0,2963	-0,1651	-0,0620	-0,0630
ΔV_{25}^{female}	0,8172	0,3510	-0,1724	-0,0595	-0,0549
ΔV_{45}^{male}	-0,4240	-0,5312	-0,3445	-0,3057	-0,4973
ΔV_{45}^{female}	-0,4027	-0,5476	-0,3883	-0,3396	-0,5471
ΔV_{65}^{male}	-0,9002	-1,5495	0,0384	-0,0593	-0,3043
ΔV_{65}^{female}	-1,0069	-1,6826	0,0171	-0,0874	-0,3623

Table 21: Value-based ALM output for discounting changes with a stricter indexation policy in the open setting

C.4 Value-based ALM. Sensitivity to fund population

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	939,9	135,2	1329,4	879,5	1342,3	5264,8	1905,1	1933,7	2235,4
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0643	0,0092	0,0909	0,0602	0,0918	0,3602	0,1303	0,1323	0,1529
ΔV_{25}^{male}	0,1721	-0,0467	0,2311	-0,1333	0,2232	1,2601	0,5588	0,5850	0,6849
ΔV_{25}^{female}	0,1806	-0,0500	0,2503	-0,1412	0,2398	1,4405	0,6234	0,6519	0,7612
ΔV_{45}^{male}	0,0181	0,0593	0,0197	-0,0584	0,0386	-1,2396	-0,8769	-0,8556	-0,8481
ΔV_{45}^{female}	0,0315	0,0634	0,0415	-0,0775	0,0590	-1,2056	-0,8551	-0,8307	-0,8151
ΔV_{65}^{male}	-0,4598	-0,0005	-0,6610	0,4086	-0,7127	-1,6154	0,1680	0,0753	-0,1828
ΔV_{65}^{female}	-0,5025	0,0061	-0,7165	0,4512	-0,7618	-1,8382	0,0863	-0,0126	-0,2936

Table 22: Value-based ALM output (with a comparable level of generosity and real closure rule in real plans) for the pension fund with the green population in the closed setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	4574,5	214,8	5796,1	3443,0	6960,3	16428,5	6253,2	6123,7	6714,5
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0628	0,0029	0,0796	0,0473	0,0956	0,2256	0,0859	0,0841	0,0922
ΔV_{25}^{male}	0,2483	-0,0251	0,3164	-0,1561	0,3834	1,4237	0,5164	0,5517	0,6876
ΔV_{25}^{female}	0,2617	-0,0287	0,3425	-0,1656	0,4099	1,6214	0,5763	0,6146	0,7627
ΔV_{45}^{male}	0,1548	0,0298	0,1778	-0,1435	0,2190	-0,8222	-0,8037	-0,7597	-0,6844
ΔV_{45}^{female}	0,1844	0,0300	0,2172	-0,1696	0,2621	-0,7479	-0,7814	-0,7321	-0,6411
ΔV_{65}^{male}	-0,4906	-0,0066	-0,6227	0,3499	-0,7700	-1,1343	0,2755	0,1875	-0,0618
ΔV_{65}^{female}	-0,5303	-0,0036	-0,6686	0,3822	-0,8203	-1,3026	0,2109	0,1184	-0,1503

Table 23: Value-based ALM output (with a comparable level of generosity and real closure rule in real plans) for the pension fund with the Netherlands population in the closed setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum \lvert\Delta V\rvert$	2096,6	63,3	2528,9	1422,6	3253,9	5555,9	2379,2	2255,4	2287,3
$\frac{\sum \lvert\Delta V\rvert}{\sum V}$	0,0613	0,0019	0,0740	0,0416	0,0952	0,1626	0,0696	0,0660	0,0669
ΔV_{25}^{male}	0,3038	-0,0103	0,3839	-0,1750	0,5023	1,5394	0,4818	0,5232	0,6867
ΔV_{25}^{female}	0,3208	-0,0139	0,4156	-0,1857	0,5368	1,7496	0,5380	0,5829	0,7608
ΔV_{45}^{male}	0,2710	0,0185	0,2975	-0,2006	0,3865	-0,5586	-0,7772	-0,7173	-0,5899
ΔV_{45}^{female}	0,3141	0,0169	0,3505	-0,2318	0,4497	-0,4577	-0,7564	-0,6898	-0,5407
ΔV_{65}^{male}	-0,5032	-0,0083	-0,6017	0,3232	-0,7901	-0,8901	0,3275	0,2432	-0,0005
ΔV_{65}^{female}	-0,5385	-0,0069	-0,6410	0,3499	-0,8365	-1,0271	0,2712	0,1836	-0,0767

Table 24: Value-based ALM output (with a comparable level of generosity and real closure rule in real plans) for the pension fund with the grey population in the closed setting

C.5 Value-based ALM. Sensitivity to initial funding position

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum\lvert\Delta V\rvert$	7498,6	1284,6	9101,9	1053,5	16479,8	14978,2	6123,7	5808,8	5677,9
$\frac{\sum\lvert\Delta V\rvert}{\sum V}$	0,1284	0,0220	0,1560	0,0181	0,2821	0,2568	0,1050	0,0996	0,0973
ΔV_{25}^{male}	0,3955	0,2249	0,4664	-0,0481	1,0387	1,2723	0,3780	0,4148	0,5041
ΔV_{25}^{female}	0,4165	0,2116	0,5040	-0,0509	1,0811	1,4487	0,4239	0,4637	0,5612
ΔV_{45}^{male}	0,3047	-0,0542	0,4033	-0,0293	0,6246	-0,6101	-0,7741	-0,7206	-0,6589
ΔV_{45}^{female}	0,3546	-0,0945	0,4689	-0,0371	0,6918	-0,5426	-0,7685	-0,7091	-0,6370
ΔV_{65}^{male}	-0,8417	-0,1426	-1,0884	0,0990	-1,9737	-1,2421	0,4387	0,3334	0,1432
ΔV_{65}^{female}	-0,9029	-0,1762	-1,1466	0,1095	-2,1162	-1,3785	0,3863	0,2775	0,0777

Table 25: Value-based ALM output (with a comparable level of generosity and real closure rule in real plans) for the pension fund with initial nominal funding ratio of 100% in the closed setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum\lvert\Delta V\rvert$	4574,5	214,8	5796,1	3443,0	6960,3	16428,5	6253,2	6123,7	6714,5
$\frac{\sum\lvert\Delta V\rvert}{\sum V}$	0,0628	0,0029	0,0796	0,0473	0,0956	0,2256	0,0859	0,0841	0,0922
ΔV_{25}^{male}	0,2483	-0,0251	0,3164	-0,1561	0,3834	1,4237	0,5164	0,5517	0,6876
ΔV_{25}^{female}	0,2617	-0,0287	0,3425	-0,1656	0,4099	1,6214	0,5763	0,6146	0,7627
ΔV_{45}^{male}	0,1548	0,0298	0,1778	-0,1435	0,2190	-0,8222	-0,8037	-0,7597	-0,6844
ΔV_{45}^{female}	0,1844	0,0300	0,2172	-0,1696	0,2621	-0,7479	-0,7814	-0,7321	-0,6411
ΔV_{65}^{male}	-0,4906	-0,0066	-0,6227	0,3499	-0,7700	-1,1343	0,2755	0,1875	-0,0618
ΔV_{65}^{female}	-0,5303	-0,0036	-0,6686	0,3822	-0,8203	-1,3026	0,2109	0,1184	-0,1503

Table 26: Value-based ALM output (with a comparable level of generosity and real closure rule in real plans) for the pension fund with initial nominal funding ratio of 125% in the closed setting

	$1 \to 2$	$2 \to 3$	$3 \to 4$	$4 \to 5$	$1 \to 5$	$5 \to 6$	$5 \to 7$	$5 \to 8$	$5 \to 9$
$\sum\lvert\Delta V\rvert$	2662,0	1290,0	3961,9	7884,6	2117,1	18543,0	6981,1	6831,8	8626,0
$\frac{\sum\lvert\Delta V\rvert}{\sum V}$	0,0305	0,0148	0,0454	0,0903	0,0243	0,2124	0,0800	0,0783	0,0988
ΔV_{25}^{male}	0,1475	-0,2201	0,2245	-0,3580	-0,2062	1,6346	0,6085	0,6566	0,9076
ΔV_{25}^{female}	0,1555	-0,2150	0,2435	-0,3802	-0,1962	1,8596	0,6786	0,7308	1,0034
ΔV_{45}^{male}	0,0707	0,1129	0,0777	-0,3860	-0,1246	-0,9632	-0,8914	-0,8306	-0,6591
ΔV_{45}^{female}	0,0877	0,1482	0,1030	-0,4460	-0,1070	-0,8724	-0,8577	-0,7897	-0,5863
ΔV_{65}^{male}	-0,2720	0,0786	-0,3934	0,8510	0,2642	-1,2029	0,2622	0,1384	-0,3515
ΔV_{65}^{female}	-0,2963	0,1098	-0,4284	0,9217	0,3066	-1,4076	0,1860	0,0562	-0,4706

Table 27: Value-based ALM output (with a comparable level of generosity and real closure rule in real plans) for the pension fund with initial nominal funding ratio of 150% in the closed setting