Network for Studies on Pensions, Aging and Retirement

Netspar THESES

Gianna Fabbro

Welfare of Pension Plans

MSc Thesis 2010-036

Welfare of pension plans

Gianna Fabbro
s1531883

June 22, 2010

Master thesis Actuarial Studies
Faculty of Economics and Business

Welfare of pension plans

Which pension plan gives the highest welfare to the participants?

G.A.Fabbro

Abstract

In this thesis the welfare properties of different pension plans have been investigated. We wanted to answer which pension plan gives the highest welfare? More specifically, does certainty in benefit or contribution give a higher welfare? The welfare has been analyzed using the Expected Utility Theory approach and the Cumulative Prospect Theory approach. Which pension plan gives the highest welfare, depends on the theory used. However, the pension plan should be a collective pension plan where certainty in the benefit is more important than certainty in the contribution.

Keywords: Pension, Utility Theory, Prospect Theory.

Supervisors : dr. L. Schoonbeek
: dr. L. Spierdijk

Groningen June 22, 2010

Preface

In January 2010 the final project of my study Econometrics at the Groningen University commenced: my Master Thesis. For six months I investigated for PGGM an interesting and present-day issue. I had six pleasant months and I learned a lot. I want to thank all my colleagues for the good time. Especially I want to thank my supervisors, Pascal Janssen and Dick Boeijen, for their help.

For the assistance at the university I want to express my gratitude to Professors Laura Spierdijk and Bert Schoonbeek; their comments and assistance were very valuable. I also like to thank all others who showed their interest in my thesis. Especially I want to thank my father, Niels Holtrop and Jeroen Lössbroek for reading my thesis, for their useful comments about spelling, style and language. Also I want to thank Remko Amelink for helping with my lay-out. Finally, I want to thank my parents for giving me the opportunity and for giving me all the help to complete my study.

I hope you will enjoy reading my thesis.

Gianna Fabbro
Groningen, June 2010

Summary

In this thesis the welfare properties of different pension plans has been investigated. We wanted to answer, which pension plan gives the highest welfare? More specifically, does certainty in benefit or contribution give a higher welfare? The welfare has been analyzed using the Expected Utility Theory approach and the Cumulative Prospect Theory approach.

We started by giving the definition of the different pension plans. Seven pension plans were investigated, three individual pension plans and four collective pension plans. The collective pension plans share the risks between different generations. This implies a less variable contribution and/or benefit. Each pension plan has a different trade off between the certainty in the benefit or contribution. The Defined Benefit pension plan has a fixed benefit, with a variable contribution. On the other hand, the Defined Contribution pension plan has a fixed contribution and a variable benefit. The hybrid pension plans have a moderately variable contribution and a moderately variable benefit. The formal models for these pension plans were introduced in chapter three. Here the simple economy assumed was explained plus the models for calculating the liabilities, contributions and benefits. In chapter four the Expected Utility Theory and the corresponding CRRA utility function were introduced. Also, the consumption paths for the different pension plans were simulated. The consumption paths for the different pension plans confirmed the properties explained in chapter 2, about the variable or fixed contribution and benefit. Next, the welfare for the different pension plans has been calculated. This yielded interesting outcomes. The best pension plan appeared to be the collective Defined Benefit pension plan with conditional indexation where the deficit is settled in three years. The deficit is the difference between the assets and liabilities. The pension plan based on the plan of the health sector of The Netherlands gave the lowest welfare compared to the other collective pension plans. Chapter 5 repeated the welfare analysis done in chapter 4, using the Cumulative Prospect Theory. The Cumulative Prospect Theory incorporates various properties violated by the Expected Utility Theory. Now the Collective Defined Benefit pension plan gave the highest welfare. Also, the deficit settled gradually gave the highest welfare. The difference in conclusion between the two utility theories are because of the property of the Cumulative Prospect Theory that a loss is punished harder than a gain. The Collective Defined Benefit pension plan can have a loss or gain in the contribution. The Collective Defined Benefit pension plan with conditional indexation again can have a loss or gain in the contribution and at the same time has also the possibility of a loss in the benefit. By taking a contribution calculated as a fixed percentage of income, the possibility of a loss in the contribution is reduced.

Which pension plan gives the highest welfare, thus depends on the theory used. The Expected Utility Theory is relatively easy and widely used in the economic literature. The Cumulative Prospect Theory is more difficult, but represents individual preferences more accurately (Tversky and Kahneman (1979) and Tversky and Kahneman (1992)). The Cumulative Prospect Theory incorporates some of the properties violated by the Expected Utility Theory. However, in any case the pension plan should be a collective plan where certainty in the benefit is more important than certainty in the contribution.

Contents

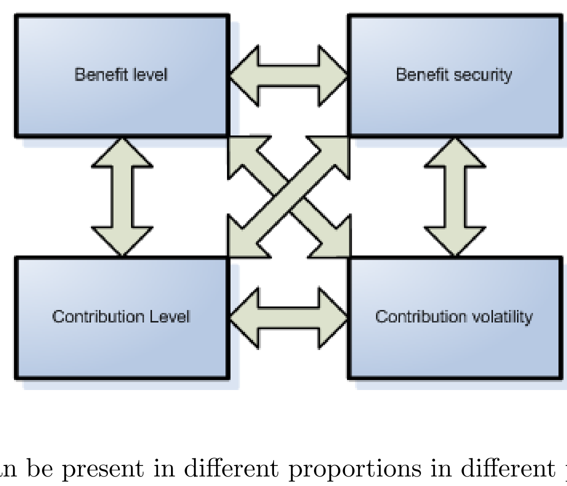
Chapter 1

Introduction

An employee wants to have an amount of money for consumption after retirement that is certain. He can achieve this on his own by saving/investing during his career life. This achievement requires discipline and knowledge about investing. However, individuals are generally not equipped to make decisions for their future retirement, nor do they want to make these decisions (Aaron (1999), Van der Lecq and Steenbeek (2006) and Van Rooij, Kool, and Prast (2004)). To solve these problems an employee can accrue a pension at a pension fund. A pension fund can hire employees with knowledge about investing and impose the discipline of saving an adequate amount each year. Also, a pension fund can make use of economies of scale by pooling many employees, which for example lowers administration costs.

A pension plan has different characteristics: the level of the benefit, the certainty of the benefit, the level of the contribution and the volatility of the contribution. Between these characteristics there exists a trade off. The more certainty given with regard to the benefit, the more volatile the contribution will be. Also, the higher the benefit, the higher the contribution needs to be. Figure 1.1 depicts the trade off between the different characteristics (taken from Kakes and Broeders (2006)).

Figure 1.1: Trade off of between pension characteristics



These characteristics can be present in different proportions in different pension plans. The question that a pension fund faces is: Which combination of characteristics do the participants prefer?

In the recent financial crisis of 2008, pension funds started to realize that the pension plans offered to their participants are not sustainable (Goudswaard, Beetsma, Nijman, and Schnabel (2010)). In other words the combination of characteristics chosen is not sustainable, there is too much certainty offered with regard to the benefit in comparison to the volatility of the contribution and the level of contribution. Consequently, in the end the certainty promised is not certain at all. Hence, pension funds face the problem of developing a new pension plan that is sustainable. The question is which sustainable combination of characteristics to use. One consideration in choosing about the combination of characteristics is to take the preferences of the participants into account.

1.1 Problem description

As mentioned above, the issue that a pension fund faces is which pension plan to offer its participants. This is a very difficult question, since the board of the pension fund does not exactly know the preferences of its participants. The fact that the participants do not have the same preferences makes the question even more difficult. One criterion in deciding which pension plan to offer is which trade off of the characteristics gives the participant the highest individual welfare. In this thesis the question that will be answered is:

Which pension plan gives the highest welfare to the participants?

Four pension plans will be compared with each other to determine the highest welfare. The four investigated plans are:

1. Defined Benefit pension plan;
2. Defined Contribution pension plan;
3. Defined Benefit pension plan with conditional indexation;
4. The pension plan based on the plan of the health sector in The Netherlands.

The first three pension plans will be analyzed in an individual setting and all four pension plans will be analyzed in a collective setting, giving a total of seven pension plans to be analyzed. The first two pension plans are two extremes, while the third is a hybrid pension plan that is in between the first two. The fourth pension plan is a pension plan based on one used in practice, which is also a hybrid pension plan.

In this thesis the welfare analysis will be done using utility theory. The theories used are the Expected Utility Theory (EUT) (Von Neumann and Morgenstern (1953)) and the cumulative prospect theory (CPT) (Tversky and Kahneman (1992)). As a starting point the model of the economy and the pension model of Cui, de Jong, and Ponds (2005) and Cui, de Jong, and Ponds (2006) will be used. The pension model will be modified to fit the setting of a pension fund in The Netherlands, i.e. the benefit, contribution and liabilities will be calculated differently. For the Expected Utility Theory (EUT) the constant relative risk aversion (CRRA) utility function is used. The EUT is commonly used in the economic literature to investigate pension plans, see Cui et al. (2005), Doskeland and Nordahl (2008) and Teulings and de Vries (2006). The EUT is used frequently in the economic literature, since it is relatively easy to calculate. Although the EUT is frequently used in the economic literature, there are arguments stating why the Expected Utility Theory is not the best utility theory (see for example Tversky and Kahneman (1979) and Tversky and Kahneman (1992)). In the EUT the expectation of the utilities is taken. However, the actual probability corresponding to every outcome might not correspond with the psychological weight given by the consumer to the outcome. The CPT is a relative new utility theory, which captures the individual preferences more accurately (Tversky and Kahneman (1992)). The question posed above (which pension plan gives the highest welfare to the participants?), will be answered again using the CPT.

1.2 Thesis outline

In chapter 2 the characteristics of the seven pension plans will be given and the difference between an individual and collective setting will be explained. In chapter 3 the model of the economy assumed and the capital structure of the different pension plans will be discussed. Moreover, the model that calculates the contribution and benefit will be presented. In chapter 4 the seven pension plans will be compared with each other using the Expected Utility Theory. The utility of an individual depends on his consumption path during the years. The consumption path is the amount of money that the employee has for consumption during his lifetime. This consumption path is not known in advance, it depends on several factors. To calculate the utility, the consumption path will be simulated. The assumptions made for this analysis will also be discussed in chapter 4. To decide which pension plan gives the highest welfare, the certainty equivalent consumption (CEC) of each pension plan will be compared to that of the other pension plans. The CEC is the lowest consumption the employee must obtain with certainty to get the same utility obtained with the uncertain consumption path. In chapter 5 the whole welfare analysis will be redone, now using the CPT. The thesis will be concluded in chapter 6.

Chapter 2

Pension plans

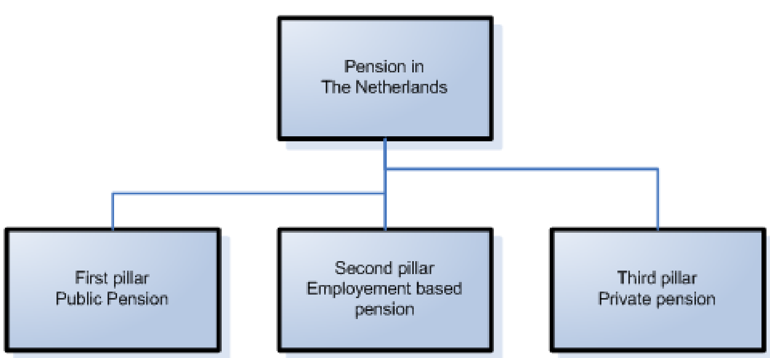
Pension plans are arrangements to provide participants with an income during retirement, when they are no longer earning a steady income from employment. Often, pension plans require both the employer and employee to contribute money to a fund during employment in order to receive a life lasting benefit upon retirement. A recipient of a pension is called a pensioner or retiree. Pension plans are the most important source of income during retirement. Consequently, this is a very important issue for our society. Pension plans are a form of long term savings, a so called "deferred compensation". The contributions paid today are invested for the future, when the employees retire to provide their income.

This chapter is organized as follows. First, pensions in The Netherlands are discussed. The three pillar system of The Netherlands and the regulations of the government on pension funds will be explained here. Next, the individual and collective pension plans investigated in this thesis are presented.

2.1 Pension in The Netherlands

The pension system in The Netherlands is based on three pillars: public pensions, employment based pensions, and private pensions. The public pension is a pension that is administered by the government. The employment based and private pensions are not administered by the government, although they are tightly regulated by the government.

Figure 2.1: The three pillar pension system in The Netherlands



2.1.1 First pillar (public pension plans)

The Old Age Pension Act (AOW[1]) of 1956 established a public pension, guaranteed for all citizens. The law provides a pension from one's 65th birthday to everyone who has lived in The Netherlands between his 15th and 65th birthday. For those who have not lived in The Netherlands the full 50 years, the amount is proportionally reduced. The contributions to the AOW are paid as taxes on salaries, with the consequence that the more you earn, the higher your contribution. However, a maximum contribution is set by law. If a pensioner has a common household with someone else (for example, in the case of marriage or cohabitation), the monthly amount one obtains is lower than if he or she lives alone.

The AOW is a "Pay as you go" pension plan. This means that the benefits for the retirees are paid from the contributions paid in the same year by the working generation. A "Pay as you go" pension plan is consequently a pension plan without accrued funds from the past. The AOW has become expensive due to the facts that people live longer and the working generation gets smaller relative to the number of retirees. At the moment there is a debate regarding increasing the pension age from one's 65th to one's 67th birthday.

2.1.2 Second pillar (employment based pension plans)

Employment based pension plans are offered by the employer. Employees are obliged by the Dutch law to participate in the pension fund offered by their employer. Most occupational pension plans are funded pension plans. A funded pension plan is a pension plan where the benefit of the retirees is paid from the contributions paid in the past. These past contributions have been invested to be able to pay for the benefit now.

The government regulates the pension funds via the Dutch Central Bank (DNB). The law that a pension fund has to obey is called "Pension Act". [2] In The Netherlands the pension benefit is in general calculated as follows: the employee will accrue each year the privilege of 1.75% of his salary, with a target of 70% of the average salary as benefit at retirement. In calculating the liabilities it is not permitted to take the difference between all future discounted contributions and all future discounted benefits, as used in the models in the literature (Cui et al. (2005)). The contribution paid by the employees has to be sufficient to cover the benefit accrued that year. The Pension Act also stipulates that a pension fund must have a sufficient buffer to ensure the promises made to the participants. To achieve this the Pension Act stipulates a boundary for the nominal funding ratio[3], below which a pension fund should not fall. This boundary is set at 105% nominal funding ratio. In the case the funding ratio falls below this boundary, the pension fund has to draw up a recovery plan, in which it states how it will recover over the course of three years.[4] In other words, the pension fund has to take measures to get back above the boundary of 105% in three years.

There are several types of pension plans that an employer can offer to his employees. The employment based pension plans that will be investigated are: the Defined Benefit pension plan, the Defined Contribution pension plan, the Defined Benefit pension plan with conditional indexation and the pension plan based on the plan of the health sector in The Netherlands. These pension plans will be investigated in an individual setting and in a collective setting. In this thesis we will only analyze the employment based pension plans, we do not take into account the first and third pillar. This is done for simplicity, but it probably affects the results.

[1] "Algemene OuderdomsWet" in Dutch.
[2] Reference: www.dnb.nl.
[3] The funding ratio is calculated by dividing the assets by the liabilities.
[4] Pension Act article 140.

2.1.3 Third pillar (private pension plans)

If an individual is not comfortable with his pension prospect of the public and employment based pension plans, he has the possibility to take a private pension plan. This is usually taken at a private life insurer, often in the form of an annuity. A private pension plan will always be in the form of an individual pension plan. According to Van Els, Van den End, and Rooij (2004), in 2004 35% of the people in The Netherlands took a private pension plan. A disadvantage of private pension plans compared to employment based pension plans, is that the payments to private pension plans may not be tax deductible like the contributions of employment based pension plans. There is a maximum amount of money paid as contribution that is tax deductible.

2.2 Individual pension plans

In this section the pension plans will be considered in an individual setting. In the next section they will be considered in a collective setting.

2.2.1 Individual Defined Benefit

The definition of a Defined Benefit (DB) pension plan is (OECD (2005)):
"A plan where benefits are linked through a formula to the members' wages or salaries, length of employment, or other factors."
In other words, in a DB pension plan the benefit at retirement is fixed from the beginning, while the contribution paid during the career life can vary. To cover the benefit, a contribution will be paid during the career life of the employee. The contribution is calculated by taking into account the life expectancy, longevity risk, the retirement age, the age of entering the pension fund, the benefit amount predetermined, the inflation expectation and the investment risk. Since the benefit is predetermined while the investment returns are not, there is a probability that the pension fund cannot pay the benefit. To minimize this risk the contribution necessary to realize the predetermined benefit is evaluated regularly and adjusted. The consequence of this is that the volatility of the contribution will be high. Hence, the contribution payer is the one that bears the risk of investments and inflation.

To make sure that the benefit keeps its purchasing power, the benefit will be indexed for inflation each year, i.e. unconditional indexation. Indexation can be done on the basis of price inflation or wage inflation. Wage inflation is normally higher than price inflation. In this thesis wage inflation is used during the career life, while price inflation is used in the period after retirement. The individual Defined Benefit (IDB) pension plan is a special form of the DB pension plan. In the case of the IDB pension plan each individual saves for his own pension benefit.

2.2.2 Individual Defined Contribution

A Defined Contribution (DC) pension plan is an (OECD (2005)):
"Employment based pension plan under which the plan sponsor pays fixed contributions and has no legal or constructive obligation to pay further contributions to an ongoing plan in the event of unfavourable plan experience."
In other words, in a DC pension plan the contribution that has to be paid is predetermined and fixed. The benefit on the other hand is not fixed, which implies that if investment returns are lower than expected, the benefit will be lower and conversely. The individual Defined Contribution (IDC) pension plan is a special form of the DC pension plan. In the case of the IDC pension plan each individual saves for his own pension benefit.

The contribution paid will be invested for a future benefit. At the end, the assets will have a value depending on the investment returns and inflation. At the moment of retirement the assets will be used to buy an increasing annuity. The risk is that if the interest rate is low and/or if the life expectancy is higher the benefit will be lower. The advantage of this pension plan is the fixed contribution, so the employee knows beforehand how much money he has left for consumption after paying the contribution. The disadvantage is that the benefit is not known beforehand i.e. the money available for consumption at retirement is uncertain.

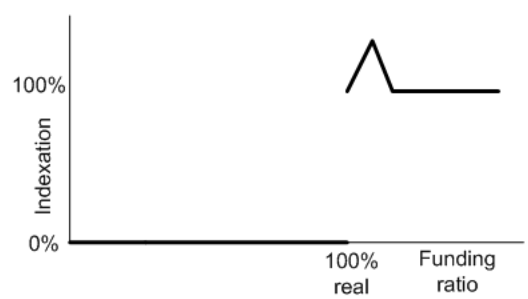
According to Van Els et al. (2004), 90% of the employment based pension plans in 2003 are of the form of a Defined Benefit. However, according to Ponds and Van Riel (2007) in 2007 there has been an evolution from the Defined Benefit pension plan to a hybrid pension plan, which is in between the Defined Benefit pension plan and the Defined Contribution pension plan. Also, in the UK and the US there has been a shift from a Defined Benefit pension plan to a Defined Contribution pension plan.

2.2.3 Individual Defined Benefit with conditional indexation

The third pension plan that will be investigated is the Individual Defined Benefit pension plan with conditional indexation (IHDB). This pension plan is a special form of the IDB pension plan, it is a hybrid pension plan. In an IHDB pension plan the indexation of the benefit is not guaranteed. The IHDB pension plan uses two steering mechanisms to control solvency risk, i.e. the contribution and the benefit. The indexation depends on agreements made at the start of the pension plan. In this thesis, just as in practice (PFZW (2009)), it depends on the funding ratio. The funding ratio of a pension fund is defined as total assets divided by total liabilities. The funding ratio can be calculated with either real discount rates or nominal discount rates. A real funding ratio is based on the former, while a nominal funding ratio on the latter.

The indexation of the benefit will be 0% when the real funding ratio is below 100%, and 100% when the real funding ratio is 100%. When the real funding ratio is above 100% extra indexation is given to compensate for the lost indexation in the past, which is denoted as a peak in figure 2.2. The extra indexation given when the real funding ratio is above 100% is only to compensate for lost indexation in the past. As a result, if the lost indexation in the past is compensated and the real funding ratio is still above 100%, no extra indexation will be given. However, a buffer will be kept for bad years in the future.

Figure 2.2: Individual indexation ladder



If the real funding ratio is below 100%, indexation cannot be used as a tool to increase the funding ratio and the contribution has to be increased to be able to guarantee the benefit at retirement. As mentioned before the IHDB pension plan is in between the IDB pension plan and IDC pension plan. In the former the benefit is fixed, while in the latter the contribution is fixed. In the IHDB pension plan the benefit is partially fixed, since the indexation depends on the funding ratio. Moreover, in the IHDB pension plan the contribution will vary more than in the IDC pension plan and less than the IDB pension plan.

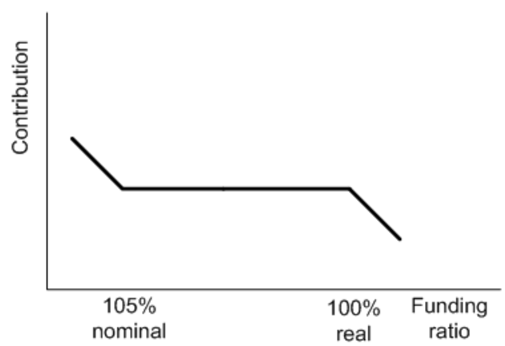
2.3 Collective pension plans

In this section the collective pension plans will be presented. The main difference between collective and individual pension plans is that in the former a group of participants will contribute to the assets and liabilities in the pension fund instead of one person. This implies that at retirement no increasing annuity has to be acquired to ensure that the benefit can be paid, as the benefit will be paid from the collective assets. Therefore the investment risk will be spread over several generations. Consequently, by having a collective pension plan that spreads the investment risk over several generations, the contributions and benefits will be less volatile. This will create the prospect that a crash of the stock market (like in 2008) will not have as big an impact on the contributions and/or benefits, since these will be spread out over an extended period.

2.3.1 Collective Defined Benefit

In a Collective Defined Benefit (CDB) pension plan the benefits will be paid from the collective assets. If the assets are not sufficient to compensate the current and future benefits, the contribution of the working generation will increase. This is the case when the nominal funding ratio is below 105%. When the real funding ratio is above 100%, the participants will get a temporary discount on their contribution. The contribution ladder is shown graphically in figure 2.3.

Figure 2.3: Contribution ladder of the CDB pension plan



The advantage of this pension plan is that upsets in investment returns will be spread over a period of time. To guarantee that the pension fund is able to pay the benefits, the contribution will have to change when the nominal funding ratio is too low, i.e. under 105%. The main disadvantage of this pension plan is that in the case of a severe investment downfall the active participants will have to increase their contribution for both their own benefit later on and the benefits paid out now. The retirees will receive an indexed lifelong benefit (as set initially).

2.3.2 Collective Defined Contribution

In the Collective Defined Contribution (CDC) pension plan the contribution is fixed, just as with the IDC pension plan. The difference is that while in an IDC pension plan the benefit only depends on the individual returns, in a CDC pension plan all contributions are pooled and invested, making use of economies of scale. There are various ways to define the CDC pension plan. The specific version of the CDC pension plan available in The Netherlands (Schuit (2006)) gives a benefit that is accrued in the same way as with a CDB pension plan. Only, instead of increasing the contribution when there is underfunding, the benefit will decrease. Consequently, in a CDB pension plan the benefit is fixed and the contribution will change, while in a CDC pension plan the contribution is fixed and the benefit will be lower.

2.3.3 Collective Defined Benefit with conditional indexation

In the Collective Defined Benefit (CHDB) pension plan with conditional indexation we have almost the same situation as for the CDB pension plan. The major difference is that in case of unfavourable investment returns, not only the contribution will increase but also the benefit will decrease. Consequently, in case of unfavourable investment returns not only active participants will bear the risk, but also retired participants. The risks are shared between all generations. The contribution in a CHDB pension plan follows the same contribution ladder as in the IDB pension plan given in figure 2.3. Besides the contribution ladder, there is also an indexation ladder, where the indexation of the benefit depends on the funding ratio. The indexation ladder used in this thesis is from Blommenstein, Janssen, Kortleve, and Yermo (2009).

Figure 2.4: Collective indexation ladder

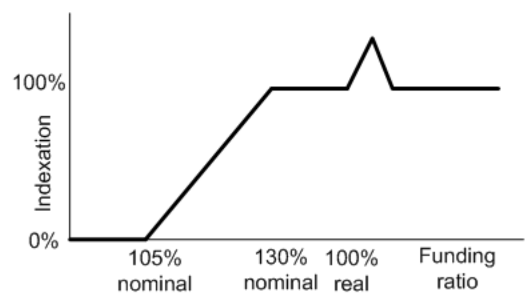


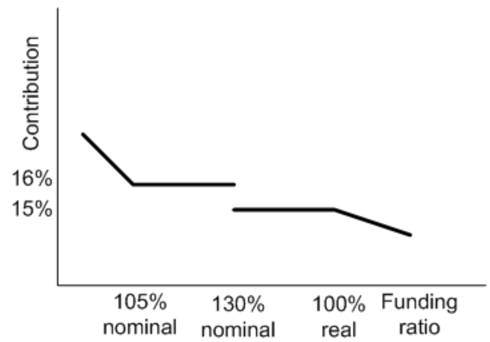
Figure 2.4 illustrates that if the nominal funding ratio is between 105% and 130% the indexation will be cut linearly with 0% indexation at a nominal funding ratio of 105% and full indexation when the nominal fund is 130%. This cut in indexation will be compensated when the real funding ratio is above 100%, which is illustrated as a peak in figure 2.4. If the nominal funding ratio is below 105%, indexation cannot be used as a tool to increase the funding ratio and the contribution has to be increased to be able to guarantee the benefit at retirement.

2.3.4 Pension plan of the health sector in The Netherlands

Additional to the six theoretical pension plans, a pension plan based on an actual pension plan in The Netherlands will be analyzed in this thesis. The pension plan selected is based on the pension plan of the health sector (HS)[5]. This pension plan is a special form of the CHDB pension plan as it has the same indexation ladder, but uses a different contribution ladder (PFZW (2009)). The contribution is increased when the nominal funding ratio is below 105%. This to raise the nominal funding ratio back to 105% in 3 years. The contribution is 16% of income when the nominal funding ratio is between 105% and 130%. Between a nominal funding ratio of 130% and a real funding ratio of 100% the contribution is 15% of the income. When the real funding ratio is above 100%, 1/15 part of the surplus will be allocated to provide the working participants a discount on the contribution. In figure 2.5 this contribution ladder is illustrated.

[5]More information about the pension fund can be found on www.pfzw.nl.

Figure 2.5: Contribution ladder of the HS pension plan



2.4 Summary

The seven pension plans analyzed in this thesis have different characteristics when it comes to the cash flows of the contributions and the benefits. These characteristics are summarized in the following table.

Table 2.1: Characteristics of pension plans

Pension plan	**Contribution**	**Benefit**
IDB / CDB	variable	fixed
IDC / CDC	fixed	variable
IHDB / CHDB	variable	variable
HS	variable	variable

IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector

Next to the basic difference between the various pension plans, there are also differences in the individual and collective setting. This will result in a different contribution and benefit path for the different pension plans. In the next chapter the models for the contribution and benefit for the different pension plans will be analyzed.

Chapter 3

Capital structure

To calculate the welfare of the different pension plans explained in the previous chapter the consumption path of each pension plan has to be modelled. The consumption path is the amount of money that the employee has for consumption during his lifetime. To model this consumption path we need to know how to calculate the contribution and benefit for each pension plan.

The chapter is organized as follows. The model for the economy and pension plans is presented. First an individual pension plan will be discussed, followed by a collective pension plan. The rest of the pension plans can be found in appendix A. The model for the economy is taken from Cui et al. (2005), while the pension model is adjusted to fit the actual setting in The Netherlands.

3.1 The model of the economy

We assume a financial market with two assets, namely bonds and equity, as defined in Cui et al. (2005). If a standard non-arbitrage economy is assumed, the dynamics of bonds and equity are

$$B_t = \rho B_t dt \tag{3.1}$$

$$dE_t = (\mu E_t dt + \sigma E_t dZ_t) \tag{3.2}$$

Here (3.1) represents the dynamics for bonds (B), while (3.2) denotes the dynamics for equity (E). ρ is the risk free returns of bonds, μ is the mean rate of return of equity, σ is the standard deviation of the equity returns, and Z_t is a Brownian motion. The properties of a Brownian motion are

$$\begin{aligned} Z_0 &= 0 \\ Z_t - Z_s &\sim N(0, t-s) \text{ for all } t \geq s \end{aligned} \tag{3.3}$$

Here $N(0, t-s)$ is a normal distribution, with mean 0 and standard deviation $t-s$. Defining the dynamics of equity as above means that we assume that the returns are normally distributed. This is not true in reality, the normal distribution is a rough approximation of the real distribution (Oficer (1972)). It is an assumption often made to make the model more simple, see Cui et al. (2005), Black and Scholes (1973) and Doskeland and Nordahl (2008). The consequence of this assumption is that extreme events will be underestimated. The investment returns depend among others on the fraction of wealth invested in equity and bonds. Equity has a higher expected return, but also a higher volatility. The bigger the fraction invested in equity, the higher the expected returns of investments and at the same time the higher the volatility. In other words, the higher the fraction invested in equity the higher the expected benefit, while at the same time the certainty of the benefit will be lower, and/or the volatility of the contribution will be higher. With the fraction invested in equity denoted by θ, the dynamics of total assets (A_t) will be

$$dAt = (\rho + \theta(\mu - \rho))A_t dt + \theta\sigma A_t dZ_t \tag{3.4}$$

This model for the economy will be used for all pension plans. Although both the model of the economy and the pension model is taken from Cui et al. (2005), the pension model is adjusted. The adjustments made are as follows:

1. Inflation and indexation are incorporated. Whether the benefit is indexed or not will depend on the pension plan.
2. Also the legal requirement that stipulates that a pension fund has to meet certain funding ratio requirements is incorporated. Hence, contribution ladders are introduced that stipulate how the contribution is calculated.
3. The way the benefit is accrued is also adjusted. The employee will accrue each year he works $a\%$ benefit. Hence, for the year he does not work he will not accrue benefit.
4. Finally, the way the liability is calculated is adjusted. The liability in Cui et al. (2005) is calculated by taking future contributions into account, which is not allowed by Dutch law. In this thesis the liability will be calculated by taking the difference between accrued assets, contributions paid that year and the discounted value of the accrued benefit.

3.2 Individual pension plans

In an individual pension plan, before retirement the assets will automatically grow with the contributions paid, while after retirement the assets will decrease with the benefits paid. Hence equation (3.4) will become

$$dAt = \begin{cases} (\rho + \theta(\mu - \rho))A_t dt + \theta\sigma A_t dZ_t + c_t dt & \text{for } 0 \leq t < R \\ (\rho + \theta(\mu - \rho))A_t dt + \theta\sigma A_t dZ_t - b_t dt & \text{for } R \leq t < D \end{cases} \tag{3.5}$$

Here R is the retirement age, D the age of death, which is deterministic, c_t the contribution paid at the beginning of year t, and b_t the benefit received by the participant when retired. Given (3.5) the assets at year t will be

$$At = \begin{cases} A_0 + \int_0^t (\rho + \theta(\mu - \rho))A_s ds + \int_0^t \theta\sigma A_s dZ_s + \int_0^t c_s ds & \text{for } 0 \leq t < R \\ A_R + \int_R^t (\rho + \theta(\mu - \rho))A_s ds + \int_R^t \theta\sigma A_s dZ_s - \int_R^t b_s ds & \text{for } R \leq t < D \end{cases} \tag{3.6}$$

Here A_0 is initial wealth, or c_0, i.e. the contribution paid in year 0. Hence, all contributions will be invested to be able to pay the benefit when the participant is retired.
The liabilities (L) are calculated by taking the discounted value of the accrued benefit in year t.

$$L_t = b_t \cdot CW_t \tag{3.7}$$

with

$$CW_t = \begin{cases} e^{(-r \cdot (R-t))} * \frac{1 - \left(\frac{1}{1+r}\right)^{(D-R)}}{r} & \text{for } 0 \leq t < R \\ \frac{1 - \left(\frac{1}{1+r}\right)^{(D-t)}}{r} & \text{for } R \leq t < D \end{cases} \tag{3.8}$$

Here r is the real discount rate and CW_t the discount factor (Pinkse and Bruijns (1992)). The discount factor consists of two parts in the years the employee works. The second part is the increasing annuity of the accrued benefit, and the first part discounts this increasing annuity to year t. When the employee is retired the discount factor consists of one part which is the increasing annuity of the benefit for the years left till he dies. In other words, the liabilities are the future pension payments as accrued until year t discounted to the present. When the real interest rate is used, CW will be the real discount factor denoted as CWr, while when the nominal interest rate is used CW will be the nominal discount factor denoted as CWn. When the real discount factor is used we have the real liability (Lr) and when the nominal discount factor is used we have the nominal liability (Ln). Next, we define the real surplus as the difference between the assets and real liabilities i.e.

$$Sr_t = A_t - Lr_t \tag{3.9}$$

The surplus is the amount of money in year t that is left after subtraction of the present value of the benefits from the accumulated assets. The funding ratio is calculated by dividing the assets by the liabilities.

$$F_t = \frac{A_t}{L_t} \tag{3.10}$$

Here again we have the real funding ratio (Fr) when the real liabilities are used and the nominal funding ratio (Fn) when the nominal liabilities are used.
To calculate the welfare of each pension plan in the next chapter the contribution and benefit path has to be known. The dynamics of the contribution and benefit of each individual pension plan will be given below.

3.2.1 Individual Defined Benefit with conditional indexation

The contribution each year has to be enough to pay the, say $a\%$, benefit accrual that year. Since at retirement the assets have to be enough to buy an increasing annuity, the contribution has to be based on the real discount rate, i.e. the real funding ratio has to be 100%. The contribution in year 0 will be much lower than the contribution in year 30, since the present value of the $a\%$ benefit accrual in year 0 will be lower than in year 30. So, the contribution will automatically increase every year to take this into account. To be able to promise the benefit in year t, the contribution has to be adjusted from time to time. The contribution will be adjusted on the basis of the surplus given in (3.9). If there is an asset deficit the surplus will be negative and the contribution will be calculated by adding the amount necessary to cover the benefits accrual to this deficit. In The Netherlands the law says that the deficit has to be corrected in three years. To take this into account the deficit will be divided by three. Two years before retirement the deficit cannot be corrected in three years, since the employee will retire after two years. In that case the deficit will be corrected in the time left to retirement. At retirement the contribution is 0. In other words, we obtain:

$$c_t = \begin{cases} CWr_t \cdot a\% \cdot I_t - \frac{Sr_t}{\min(3,R-t)} \text{ for } t < R \\ 0 \text{ for } t \geq R \end{cases} \tag{3.11}$$

Here I_t is the income in year t.
We can also calculate the contribution as a fixed percentage of income. The percentage will be the percentage of income needed at the middle of the career life to cover the accrued benefit. This system is widely used in practice.[1] The contribution will vary again depending on the assets and liabilities.

[1]For example, in the pension plan of the health sector of The Netherlands.

$$c_t = \begin{cases} \hat{c} \cdot I_t - \min(0, \frac{Sr_t}{3}) & \text{for } t < R/2 \\ \hat{c} \cdot I_t - \frac{Sr_t}{\min(3, R-t)} & \text{for } R/2 \leq t < R \\ 0 \text{ for } t \geq R \end{cases} \tag{3.12}$$

with

$$\hat{c} \quad = \quad CWr_{\frac{R}{2}} * \cdot a\% \tag{3.13}$$

The percentage is calculated in the middle of the employee career life, hence $R/2$. In the first half of the career life the employee will pay too much, which will result in a surplus of the asset. Hence, in the first half there will be no discount in the contribution. Otherwise, the contribution will decrease enormously after one year and we are back in the situation of (3.11). In the second half of the career life the employee will pay too little contributions. Then a contribution discount is given in case of a positive surplus to make sure that the assets are not too high at retirement.

In addition, the contribution is subjected to two constraints. The contribution cannot be higher than 90% of the income, i.e. the employee needs to have some money left for consumption after paying the contribution. Hence, if $c_t > 0.9 \cdot I(t)$, then $c_t = 0.9 \cdot I_t$. The second constraint is that the contribution cannot be negative, hence $c_t \geq 0$.

The biggest difference in the two methods of calculating the contribution is that with the first method the contribution is by definition more volatile. This is true, since even if there is no asset deficit or surplus, the contribution will increase every year. In the second method the contribution will only increase with inflation or a salary increase.

The employee will accrue each year the privilege of $a\%$ of his income which will be indexed for wage inflation before retirement and for price inflation after retirement, depending on the real funding ratio. Given the funding ratio and the indexation ladder in figure 2.4, the indexation will be:

$$ind_t = \begin{cases} 0\% & \text{for } Fr_t < 100\% \\ 100\% & \text{for } Fr_t = 100\% \\ \geq 100\% & \text{for } Fr_t > 100\% \end{cases} \tag{3.14}$$

If the real funding ratio is higher than 100%, lost indexation in the past will be compensated. No extra indexation is given, only lost indexation is compensated. This is done by calculating a shadow benefit (bf_t) which is always indexed for inflation independent of the funding ratio. When the real funding ratio is above 100% the surplus will be divided by the CW_t factor to see how much benefit can be bought from this surplus. This value will be added to the benefit with the constraint that it cannot be higher than bf_t. Given the real funding ratio and the indexation, the benefit can be calculated as follows

$$b_t = \begin{cases} a\% * I_0 & \text{for } t = 0 \\ b_{t-1} \cdot (1 + (infw_t \cdot ind_t)) + a\% * I_t & \text{for } 0 \leq t < R \text{ and } Fr_t < 100 \\ \min\{b_{t-1} \cdot (1 + (infw_t \cdot ind_t)) + a\% * I_t + S_t/CW_t; bf_t\} & \text{for } 0 \leq t < R \text{ and } Fr_t > 100 \\ b_{t-1} \cdot (1 + inf_t) & \text{for } R \leq t < D \end{cases} \tag{3.15}$$

with

$$bf_t = \begin{cases} a\% * I_0 & \text{for } t = 0 \\ bf_{t-1} \cdot (1 + infw_t) + a\% * I_t & \text{for } 0 \leq t < R \end{cases} \tag{3.16}$$

Here $infw_t$ is the wage inflation between time $t-1$ and time t, and inf_t the price inflation. After retirement an increasing annuity will be bought to make the comparison with the other pension plans fair.

3.3 Collective pension plans

The dynamics of the assets, liabilities, contributions and benefits will be different in a collective setting than in an individual setting. We assume 40 working years and 15 retired years, giving 55 years in total. In the collective setting, we further assume that for every age there is one employee or retiree, i.e. we have a pension fund with 55 participants.

The assets in year t will be the return on the assets of the period before, plus the assets in year $t-1$, plus all contributions paid by the working participants, minus all benefits paid to the retired participants:

$$dAt = (\rho + \theta(\mu - \rho))A_t dt + \theta\sigma A_t dZ_t + (\sum_{i=0}^{39} c_{t,i})dt - (\sum_{i=41}^{54} b_{t,i})dt \tag{3.17}$$

Here i is the age of the participant, $c_{t,i}$ the contribution paid by individual i in year t, and $b_{t,i}$ the benefit received by individual i in year t. Integrating this differential equation we will get the following expression for the assets in year t:

$$At = A_0 + \int_0^t (\rho + \theta(\mu - \rho))A_s ds + \int_0^t \theta\sigma A_s dZ_s + \int_0^t (\sum_{i=0}^{39} c_{t,i})ds - \int_0^t (\sum_{i=41}^{54} b_{t,i})ds \tag{3.18}$$

In year 0 we assume a real funding ratio of 100%, so the assets in year 0 are equal to the liabilities in that year, i.e. $A_0 = L_0$. The liability in year t is defined as the sum of all the individual liabilities.

$$L_t = \sum_{i=0}^{54} L_{t,i} \text{ for } t \geq 0 \tag{3.19}$$

Here $L_{t,i}$ is the liability of participant i in year t, defined as follows

$$L_{t,i} = b_{t,i} \cdot CW_{t,i} \tag{3.20}$$

with

$$CW_{t,i} = \begin{cases} e^{(-r\cdot(R-i))} * \frac{1-\left(\frac{1}{1+r}\right)^{(D-R)}}{r} & \text{for } 0 \leq i < R \\ \frac{1-\left(\frac{1}{1+r}\right)^{(D-i)}}{r} & \text{for } R \leq i < D \end{cases} \tag{3.21}$$

Here r is the real or nominal interest rate, and $CW_{t,i}$ the discount factor for individual i in year t. When the real interest rate is used, $CW_{t,i}$ will be the real discount factor denoted as $CWr_{t,i}$, while when the nominal interest rate is used CW will be the nominal discount factor denoted as $CWn_{t,i}$. The funding ratio is defined as in (3.10). The real surplus (S_r) is calculated using the real discount rate and is defined as in equation (3.9). The nominal surplus is calculated using the nominal discount rate and defined as

$$Sn_t = A_t - 1.05 \cdot Ln_t \tag{3.22}$$

The nominal surplus for the collective pension plan is calculated differently because a pension fund is underfunded in the collective setting when the nominal funding ratio is below 105% rather than below 100%.[2]

Now that the dynamics of the assets and liabilities in a collective setting are known, the model for the contribution and benefit path in a collective setting can be given.

[2] As stated in the Pension Act.

3.3.1 Collective Defined Benefit with conditional indexation

The contributions can be calculated with two methods, as with the individual pension plan. The differences are that the contribution will depend on the collective funding ratio and that the surplus will be settled by all the working participants instead of one person. Given the contribution ladder in figure 2.3, the contribution for method one, where the contribution is calculated to cover the benefit accrual each year, is

$$c_{t,i} = \begin{cases} CWr_{t,i} \cdot a\% \cdot I_{t,i} - \frac{Sn_t/40}{3} & \text{for } Fn_t < 105\% \\ CWr_{t,i} \cdot a\% \cdot I_{t,i} - \frac{Sr_t/40}{3} & \text{for } Fr_t > 100\% \\ CWr_{t,i} \cdot a\% \cdot I_{t,i} & \text{for } Fn_t \geq 105\% \text{ and } Fr_t \leq 100\% \end{cases} \tag{3.23}$$

Here we have that, if the pension fund has a nominal funding ratio below 105%, it has to raise the contribution with the nominal deficit divided by the total number of working participants, while when it is above the real funding ratio of 100% it can decrease the contribution with the real surplus. In between the contribution will not depend on the surplus. For the second method, where the contribution is calculated as a fixed percentage of income, we have

$$c_{t,i} = \begin{cases} \hat{c} \cdot I_{t,i} - \frac{Sn_t/40}{3} & \text{for } Fn_t < 105\% \\ \hat{c} \cdot I_{t,i} - \frac{Sr_t/40}{3} & \text{for } Fr_t > 100\% \\ \hat{c} \cdot I_{t,i} & \text{for } Fn_t \geq 105\% \text{ and } Fr_t \leq 100\% \end{cases} \tag{3.24}$$

with $\hat{c}$ defined as in (3.13), and $I_{t,i}$ the income for individual i in year t. The contribution again has as constraints that it cannot be negative or higher than 90% of the income and it is 0 at retirement.

In year 0 we assume that all benefits have been indexed. Each year the working participants of the pension fund, provided they have worked, accrue $a\%$ benefit which has been indexed for wage inflation. The retired participant have accrued benefit for R years which has been indexed for the wage inflation during the career and for price inflation after retirement. Hence, in year 0 we have that the benefits are

$$b_{0,i} = \begin{cases} a\% * I_{0,i} \cdot (i+1) & \text{for } t = 0 \text{ and } 0 < i < R \\ a\% * I_{0,R} \cdot R \cdot \left(\frac{1+inf_t}{infw_t}\right)^{i-R} & \text{for } t = 0 \text{ and } i \geq R \end{cases} \tag{3.25}$$

In the years unequal to 0 the employee accrues each year the privilege of $a\%$ of his income during his career life, which is indexed for wage inflation before retirement and for price inflation after retirement, depending on the real funding ratio. Given the funding ratio and the indexation ladder in figure 2.4 the indexation will be

$$ind_t = \begin{cases} 0\% & \text{for } Fn_t < 105\% \\ \frac{Fn_t - 105\%}{130\% - 105\%} & \text{for } 105\% \leq Fn_t \leq 130\% \\ 100\% & \text{for } Fn_t > 130\% \text{ and } Fr_t \leq 100\% \\ \geq 100\% & \text{for } Fr_t > 100\% \end{cases} \tag{3.26}$$

The benefit in year 0 is calculated again as in the CDB pension plan, given in (3.1), since the benefits are fully indexed at the beginning. Given the indexation and a real funding ratio below 100%, the benefits for the years unequal to 0 can be calculated as follows

$$b_{t,i} = \begin{cases} b_{t-1,i-1} \cdot (1 + infw_t \cdot ind_t) + a\% * I_{t,i} & \text{for } 0 < i < R \\ b_{t-1,i-1} \cdot (1 + inf_t \cdot ind_t) & \text{for } R \leq i < D \end{cases} \tag{3.27}$$

In case the real funding ratio is above 100%, the benefit decreased in the past will be compensated. This will only be done for lost benefit, so no extra benefit is given above the lost accrued benefit.

$$b_{t,i} = \begin{cases} \min((b_{t-1,i-1} \cdot (1 + infw_t) + a\% * I_{t,i}) \cdot (1 + \frac{Fr_t - 1}{3}); bf(t,i)) & \text{for } 0 < i < R \\ \min(b_{t-1,i-1} \cdot (1 + inf_t) \cdot (1 + \frac{Fr_t - 1}{3}); bf(t,i)) & \text{for } R \leq i < D \end{cases} \tag{3.28}$$

where

$$bf_{t,i} = \begin{cases} bf_{t-1,i-1} \cdot (1 + infw_t) + a\% * I_{t,i} & \text{for } 0 < i < R \\ bf_{t-1,i-1} \cdot (1 + inf_t) & \text{for } R \leq i < D \end{cases} \tag{3.29}$$

Here bf is the shadow benefit, which will be the same as the benefit when the benefit is never decreased to raise the funding ratio.

3.4 Summary

In this chapter the models for the CHDB pension plan was presented. In the individual case, the benefit and contribution was calculated on the basis of the real discount rates, while in the collective case both the nominal and real funding ratio were important. The models for the other pension plans can be found in Appendix A.

Looking back at figure 1.1, where the trade off of the characteristics is shown, we can conclude that the IDB and the CDB pension plan give a very high certainty to the benefit, while having a very volatile contribution. The IDC and the CDC pension plan on the other hand give a certain contribution, while the benefit is very uncertain. The IHDB, CHDB and the HS pension plans are in between, having a volatile contribution and an uncertain benefit. In the next chapters these models will be implemented in the programming language Matlab, and the welfare will be calculated.

Chapter 4

Welfare analysis with Expected Utility Theory

A pension plan has several characteristics, like whether or not accrued pension rights are guaranteed, how much risk is taken and whether the contribution is fixed or variable. The question that a pension fund faces is: Which combination of characteristics do the participants prefer? One way of measuring which pension plan is preferred by the participants is with utility functions. Utility functions can be seen as a method to measure welfare.

This chapter is organised as follows. First, the CRRA utility function is explained, followed by the assumptions made for the welfare analysis. Then the cash flows of the different pension plans are discussed. In the following section the results are discussed, followed by a sensitivity analysis. The chapter will be concluded with a summary.

4.1 CRRA Utility function

The constant relative risk aversion (CRRA) utility function is commonly used in the literature to investigate pension plans, see Cui et al. (2005), Doskeland and Nordahl (2008) and Teulings and de Vries (2006). The CRRA utility function is of the following form:

$$u(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma} \tag{4.1}$$

Here γ is the risk aversion coefficient and C_t the consumption at time t for a particular individual. The consumption before retirement is the income (I_t) minus the contribution (c_t), and after retirement the consumption equals the benefit (b_t).

$$C_t = \begin{cases} I_t - c_t & \text{for } t < R \\ b_t & \text{for } R \leq t < D \end{cases} \tag{4.2}$$

Here R is the time of retirement and D the time of death. The consumption for the different pension plans will differ in time and volatility depending on the contribution and benefit path. The contribution and benefit at time t depend on inflation, investment returns, and the type of pension plan. According to the Expected Utility Theory, the total utility of a pension plan is the expectation of the discounted sum of the per-period utilities, i.e.

$$U = E\left[\int_0^D \exp^{-rt} u(C_t)dt\right] \tag{4.3}$$

Here r is the discount rate and $u(C_t)$ is defined as in (4.1). The utility gives a ranking of the different pension plans. To facilitate comparison the Certainty Equivalent Consumption (CEC) will be used. The CEC reflects to what extent a pension plan is preferred. The CEC is the lowest consumption the employee must obtain with certainty to get the same utility obtained with the uncertain consumption path. Hence

$$\begin{aligned} \hat{U} &= \int_0^D \exp^{-rt} u(CEC)dt \\ &= \int_0^D \exp^{-rt} \frac{CEC^{1-\gamma}}{1-\gamma}dt \end{aligned} \tag{4.4}$$

Here $\hat{U}$ is the utility obtained with the pension plan, calculated with equation (4.3).

4.2 Assumptions

There are a lot of parameters in our models for the consumption path and utility. The numerical values chosen will affect utility and hence welfare. We will discuss the risk aversion parameter, the investment returns and the discount factor. The actuarial and economic assumptions will also be mentioned.

Risk aversion parameter

The risk aversion parameter is crucial, it will affect the pension plans that are preferred. If the participants are very risk averse they prefer a pension plan that gives a lot of certainty, while if the participants are less risk averse they prefer a more risky pension plan. There are many studies on which risk aversion parameter to use, see for instance Teulings and de Vries (2006) and Beetsma and Schotman (2001). They state that risk aversion parameters between 1 and 10 are reasonable. Van Rooij et al. (2004) found that people are more risk averse when it comes to pension decisions. In this thesis a risk aversion parameter of 7 is taken and for a sensitivity analysis also risk aversion parameters of 5 and 9 are taken.

Investment returns

The investment mix is important for the overall investment return and volatility. The more a pension fund invests in equity, the higher the expected return will be. However, higher equity investment also leads to more volatile returns. Hence, the more a pension fund invests in equity the riskier its pension plan will be. Once more, a risky pension plan will be unattractive to risk averse participants. In the beginning of the career an employee can take more risk, since the horizon is longer. Close to retirement an employee can take less risk and will invest more in the risk free asset (Teulings and de Vries (2006), Hoevenaarsa and Ponds (2008)). For simplicity a fixed investment mix is assumed instead of variable one as explained by Teulings and de Vries (2006) and Hoevenaarsa and Ponds (2008)

In Kakes and Broeders (2006) we can find that pension funds in The Netherlands in 1995 invested on average 26% of their assets in equity. This percentage was 46% in 2005. In the third quarter of 2008 it even increased to 49% (VB (2009)). After the stock market crash of 2008 the percentage invested in equity decreased. According to Gollier (2008) the target fraction invested in equity should be between 40 and 60%. In this thesis an investment mix of 60% in bonds and 40% in equity is used. This will give a θ of 0.4, i.e. the fraction invested in equity is 40%.

According to Kakes and Broeders (2006) pension funds in 2005 invested 76% of their assets internationally. Consequently, the (S&P500)[1] index is used to calculate the mean return and standard deviation. The geometric mean will be taken instead of the arithmetic mean, since the geometric

[1] Yearly data of the S&P500 for the period January 1950 till January 2010 taken from Yahoo Finance.

mean is more reliable to predict future returns, while the arithmetic mean is trustworthy for historical returns (Bodie, Kane, and Marcus (2009)). The mean return of the S&P500 is 7% and the standard deviation is 15.2%. Hence, a mean investment return of 7% and a standard deviation of 15.2% is assumed. Also, as mentioned in chapter 3, the investment returns are assumed to be normally distributed.

Discount factor

The policy of the European Central Bank (ECB) is to have a price inflation as close to 2% as possible (ECB (2004)). Looking at empirical data for the period February 1994 till December 2009,[2], the mean for the price inflation is 1.9%. This is very close to the 2%, the target of the ECB. For this reason, a price inflation of 2% is taken. The mean of the wage inflation is 2.8%.[3]

As mentioned before, the interest rate is a risk for pension funds and its participants. The higher the interest rate, the lower the discount factor of the liability is. Indirectly this will affect the contribution and in the individual setting the benefit. Hence, interest rates can have an impact on the cash flows and consequently on the utility. In the past, interest rates fluctuated a lot, being very high in the seventies.[4] At the moment the interest rate are historically low. Nowadays pension funds are obliged to use the market interest rate. However, in the past they used the fixed actuarial discount rate of 4% (van Rooij, Siegman, and Vlaar (2005)). For simplicity a fixed actuarial discount rate of 4% will be used in this thesis. Assuming a fixed interest rate means that in our model the interest rate will not be a risk. The real interest rate is the nominal interest rate minus price inflation, i.e. 2%.

Actuarial and economic assumptions

To compare the different pension plans, all basic contributions will be the same. In other words, the expected benefit in year 0 for all pension plans will be the same, not taking the investment returns into account. Also, in all individual pension plans an increasing annuity will be bought at retirement, to be able to guarantee the benefit. In calculating the cost for buying this annuity no administration costs or risk premiums are taken into account. Contribution and benefit payments will be done at the beginning of the year.

In the collective pension plans we will look at a particular individual in a collective setting. This is done by taking the consumption path for the individual that enters the pension fund in year 0. For every age there is one participant. For the collective pension plans the initial real funding ratio is set to 100%, and all initial accrued benefits are indexed.

Income is taken constant and income in year 0 is normalized to 1. Each year income grows with wage inflation. At retirement, the only consumption that the retiree has is his pension benefit. Also, income taxes and the first and third pillar are not taken into account. The individual does not save or invest his salary or benefit, he consumes each year his whole salary or benefit. The last assumption is that the initial wealth of the individual is 0. For the individual pension plans we assume the following dynamics for the income.

$$I_t = \begin{cases} 1 & \text{for } t = 0 \\ I_{t-1} \cdot e^{infw \cdot t} & \text{for } 0 < t < R \\ 0 & \text{for } R \leq t < D \end{cases} \tag{4.5}$$

Here $infw$ is the wage inflation between time $t-1$ and t.

[2]Source Statistics Netherlands (CBS) www.CBS.nl.
[3]Yearly data for the period 2000 till 2009 taken from CBS, www.CBS.nl.
[4]Source CBS, www.CBS.nl.

For the collective pension plans we have that the income for the employees will be the same for every age, since there is no career growth. Retirees will again earn no income next to the pension benefit, and in year 0 every employee will start with an income of 1.

$$I_{t,i} = \begin{cases} 1 \cdot e^{infw \cdot t} & \text{for } i < R \\ 0 & \text{for } i \geq R \end{cases} \tag{4.6}$$

It is assumed that an employee starts working at age 25 and works till retirement (R), this is in The Netherlands the age of 65. The expected age of death for a 25 year old individual is 80 (AI (2010)). Since we start counting from $t = 0$, we have that the time of retirement (R) is 40 and the time of death (D) is 55. Also, the time of death is assumed to be deterministic. Since we assume that an employee works for 40 years before retirement, the benefit accrual per year is 1,75%.

4.3 Cash flow analysis

Before the utility is calculated, the consumption path for the different pension plans is shown. The consumption is divided by the income to obtain consumption as a percentage of income. Therefore, if the consumption as percentage is 80%, the employee has 80% of his income left for consumption after paying the contribution. The consumption path of each scenario differs because of the uncertainty in investment returns.

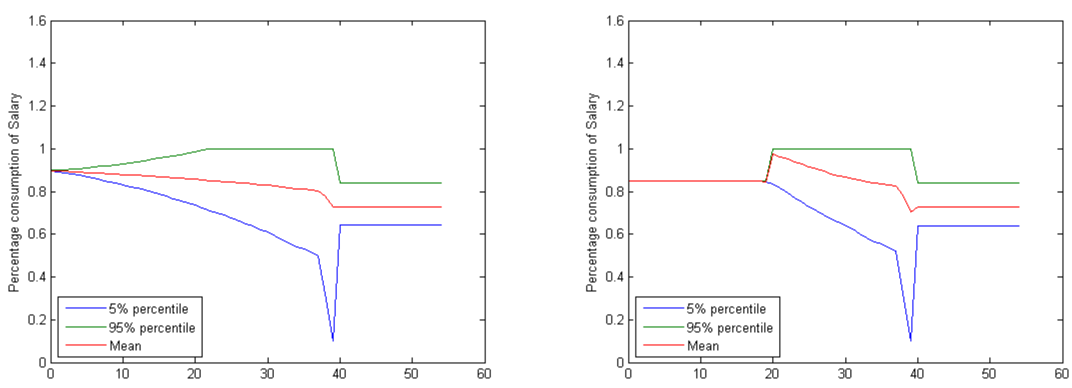
Individual Defined Benefit

In the IDB pension plan the accrued pension rights are guaranteed, while the contribution is variable.

Figure 4.1: Real consumption IDB pension plan

(a) Calculated with the first method.

(b) Calculated with the second method.



The result depicted is expressed in percentage consumption of salary over time. In panel (a) the contribution is calculated with the first method, a contribution that covers the cost of the benefit accrual that year. In panel (b) the contribution is calculated with the second method, based on a fixed percentage of income.

The first thing we notice by looking at the figures above is that the benefit is not always the same. The reason that this is not the case is that in an individual pension plan, if in the last year before retirement the investment return is different than expected, the assets have a different value than necessary to buy an increasing annuity. This difference is very small. From the graphs we can conclude that with the second method the consumption is a lower percentage of income in year 0, which is as expected, since with this method the employee will pay too much contribution in the first half of his career life. Also, we observe that the benefit is as planned, around 70% of the income. The benefit is supposed to be 70% of the career average, but since there is no career growth it is also 70% of the final income. We also notice that with the second method the consumption percentage of income for the first 20 years is for every scenario the same, because in this period no discount on the contribution is given, while the contribution is too high. In year 20 when a contribution discount is given, the consumption raises temporarily, since the assets are higher than necessary. The last thing to mention is that there is a decrease of the consumption at the end of the career life. This is because at the end there are not three years left to correct the surplus, but one or two years. Also, at the end changes in investment returns have a bigger effect on the benefit, since the assets are higher than at the beginning. This suggests that close to retirement the individual should take less investment risk, since he cannot bear this risk in such a short time. Teulings and de Vries (2006) also concluded this in their research about the optimal investment cycle.

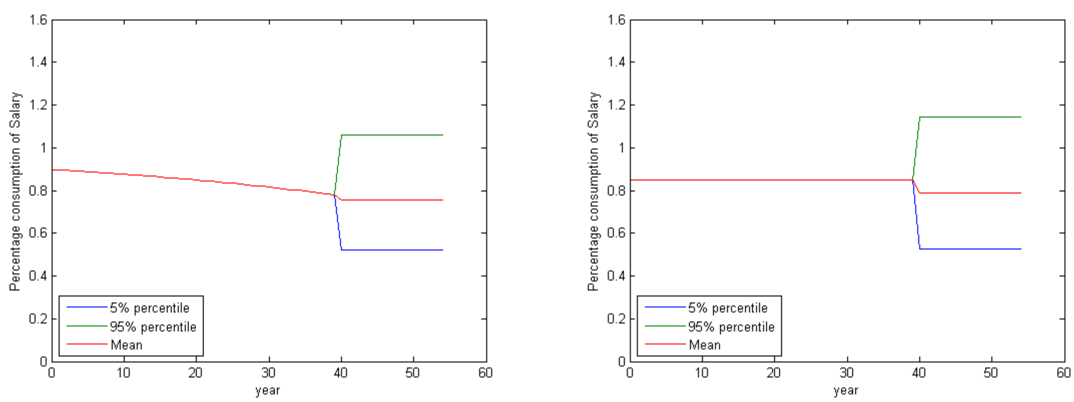
Individual Defined Contribution

In the IDC pension plan the contribution is fixed, while the accrued pension rights are not guaranteed.

Figure 4.2: Real consumption IDC pension plan

(a) Calculated with the first method.

(b) Calculated with the second method.



The result depicted is expressed in percentage consumption of salary over time. In panel (a) the contribution is calculated with the first method, a contribution that covers the cost of the benefit accrual that year. In panel (b) the contribution is calculated with the second method, based on a fixed percentage of income.

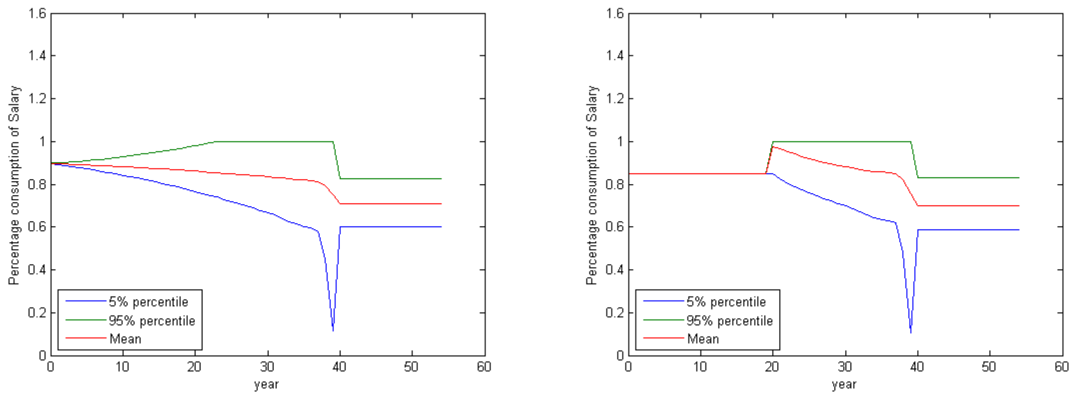
In figure 4.2 we can see that the consumption before retirement has no volatility over the scenarios, since the contribution is the same for every scenario. In the second method the percentage consumption of income is a straight line, because the contribution is a fixed percentage of income, while with the first method the line is slightly downward sloping, since the contribution increases over time. This is because the cost of 1.75% benefit accrual in the end is more expensive than in the beginning. The next thing to notice is that there is a big volatility in consumption at retirement. This is the case, since contribution is fixed and the increasing annuity that can be bought depends on the past investment returns. We also observe that with the second method the 95% percentile for the benefit is higher than with the first method and that the benefit is more volatile. This is because with this method, more contribution is paid at the beginning, so the assets will be higher in the beginning. As a result, the investment returns will have a bigger effect on the assets in the end.

Individual Defined Benefit with conditional indexation

The IHDB pension plan has variable contribution and at the same time only the accrued nominal pension rights are guaranteed, the indexation of the benefit depends on the funding ratio.

Figure 4.3: Real consumption IHDB pension plan

(a) Calculated with the first method. (b) Calculated with the second method.



The result depicted is expressed in percentage consumption of salary over time. In panel (a) the contribution is calculated with the first method, a contribution that covers the cost of the benefit accrual that year. In panel (b) the contribution is calculated with the second method, based on a fixed percentage of income.

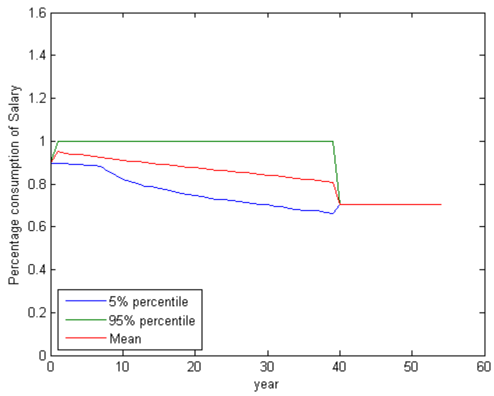
The figures for the IHDB pension plan look a lot like the figures of the IDB pension plan. This is because in the individual setting the indexation ladder is very extreme. In the IHDB pension plan the indexation is either 0% or 100% and when the indexation is 100% it is at the same time compensating lost indexation. The benefit is more volatile than for the IDB pension plan. Since in the IDB pension plan there should be no volatility in the benefit, while in the IHDB pension plan the benefit depends on the funding ratio.

Collective Defined Benefit

In the CDB pension plan the contribution is less variable than in the IDB pension plan, since it depends on the collective assets and liabilities. The accrued pension rights are still guaranteed.
The first thing to notice is that in the collective setting the consumption path is very smooth, and there are no peaks. The years where the investment returns are unfavourable are smoothed out. In a collective setting, the benefit at retirement is the same in every scenario, as promised. At the moment that the assets are not enough for this benefit, the working participants will pay more contribution to make sure that the benefit promised can be paid. We can also see that in the beginning the participants get a contribution discount, since in year 0 the initial real funding ratio is 100%. The 5% percentile line is straight in the beginning, this is again because of the initial funding ratio. Only when the nominal funding ratio is below 105%, the contribution will increase and consequently, the consumption will decrease. This will take some time and so the consumption will be straight in the beginning. The last thing to notice is that again there is a drop in consumption at retirement, since the objective is to have 70% of income at retirement, not 100%.

Figure 4.4: Real consumption CDB pension plan

(a) Calculated with the first method. (b) Calculated with the second method.

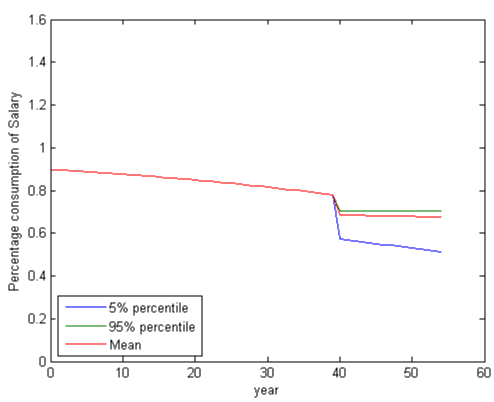


The result depicted is expressed in percentage consumption of salary over time. In panel (a) the contribution is calculated with the first method, a contribution that covers the cost of the benefit accrual that year. In panel (b) the contribution is calculated with the second method, based on a fixed percentage of income.

Collective Defined Contribution

Figure 4.5: Real consumption CDC pension plan

(a) Calculated with the first method. (b) Calculated with the second method.



The result depicted is expressed in percentage consumption of salary over time. In panel (a) the contribution is calculated with the first method, a contribution that covers the cost of the benefit accrual that year. In panel (b) the contribution is calculated with the second method, based on a fixed percentage of income.

In a CDC pension plan the contribution is fixed, hence the consumption percentage of income is for every scenario in the first 40 years the same. At retirement no increasing annuity is bought. On the other hand, the benefit decreases in case of underfunding. This is why the benefit is not a straight line but decreases for the 5% percentile. The benefit is also less volatile than in the individual setting, since the investment and interest rate risk are spread out over several generations.

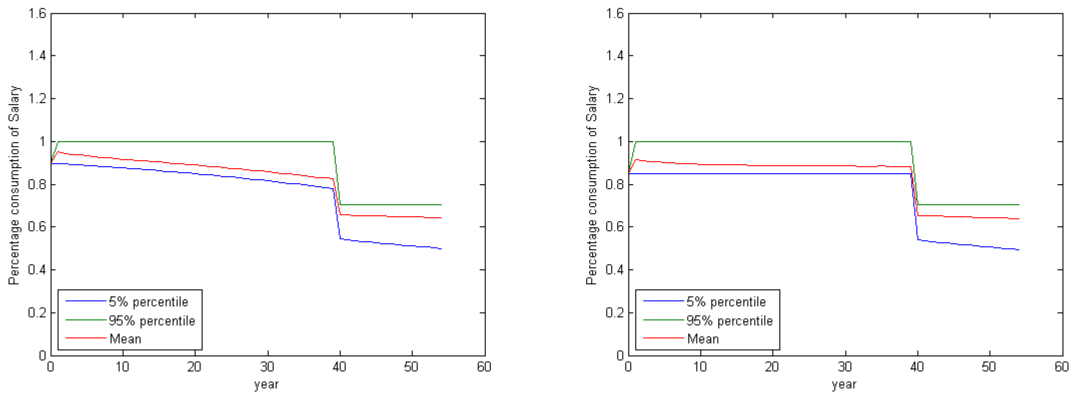
Collective Defined Benefit with conditional indexation

The CHDB pension plan is a collective pension plan where both the indexation of the benefit and the contribution depend on the funding ratio.

Figure 4.6: Real consumption CHDB pension plan

(a) Calculated with the first method.

(b) Calculated with the second method.



The result depicted is expressed in percentage consumption of salary over time. In panel (a) the contribution is calculated with the first method, a contribution that covers the cost of the benefit accrual that year. In panel (b) the contribution is calculated with the second method, based on a fixed percentage of income.

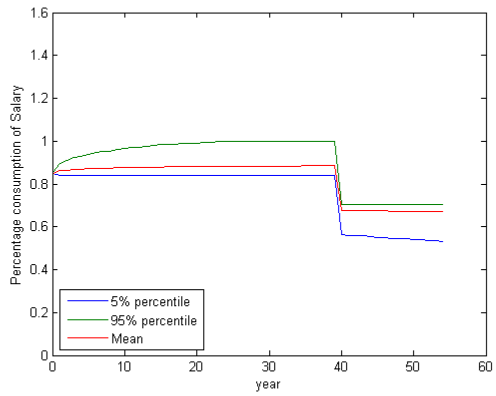
In figure 4.6 we can see that a CHDB pension plan is in between a CDB pension plan and a CDC pension plan. The consumption is more volatile during the first 40 years than in the former pension plan and less volatile than the latter pension plan. On the other hand, the benefit is more volatile than the CDB pension plan and less volatile than in the CDC pension plan, as was expected.

Pension plan of the health sector in The Netherlands

The HS pension plan is a collective hybrid pension plan where both the indexation of the benefit and the contribution depend on the funding ratio. The HS and CDB pension plan have the same indexation ladder, the contribution ladder differs.

It is not surprising that the consumption path of a HS pension plan looks a lot like that of the CHDB pension plan. They both use both the contribution and the indexation of the benefit as a tool to increase the real funding ratio.

Figure 4.7: Real consumption HS pension plan



The result depicted is expressed in percentage consumption of salary over time.

4.4 Analysis of the CEC

The results of the CEC for the different pension plans are given in table 4.1. The results are calculated based on 10,000 simulations of the consumption path. The consumption path of each scenario differs because of the uncertainty in investment returns.

Table 4.1: CEC for different pension plans

Pension plan	First method	Second method
	$\gamma = 5$	
IDB	Benchmark	-3.54
IHDB	2.64	-0.77
IDC	4.83	1.10
CDB	8.22	4.91
CHDB	**8.77**	5.35
CDC	4.81	1.04
HS	N.A.	3.20
	$\gamma = 7$	
IDB	Benchmark	-4.26
IHDB	3.39	-0.82
IDC	6.60	2.09
CDB	9.96	5.88
CHDB	**10.38**	6.31
CDC	6.61	2.08
HS	N.A.	3.98
	$\gamma = 9$	
IDB	Benchmark	-4.99
IHDB	4.26	-0.34
IDC	8.05	3.09
CDB	11.21	6.64
CHDB	**11.63**	7.08
CDC	8.06	3.10
HS	N.A.	4.76

The results are depicted as a percentage change in comparison to the CEC of the IDB pension plan.
The HS pension plan is only calculated with the second method giving a not available result for the first method. The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. γ is the risk averse parameter, where the higher it is the more risk averse an individual is. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

We notice that the CHDB pension plan calculated with the first method gives the highest CEC for all risk aversion parameters. The CHDB pension plan is a pension plan where the risk is smoothed out over different generations. It combines the CDB pension plan and CDC pension plan. The worst pension plan is the IDB pension plan calculated with the second method, since the consumption in the beginning is very volatile, which is not preferred by the employees. Not surprisingly, it is noticed that collective pension plans give a higher CEC than individual pension plans. Hence, collective risk sharing does add value as already shown by Gollier (2008) and Ponds and Van Riel (2007). It is remarkable that the pension plan offered in practice (the HS pension plan) performs worse in terms of CEC. One reason could be that the HS pension plan is calculated with the second method, which performs bad compared to the first method.

The reason that a pension plan used in practice if its results are unsatisfactory is that a pension plan of which the performance is good in terms of the CEC is not by definition sustainable in practice. If we analyze, for example, the IDC pension plan we observe that it gives a pretty high CEC, which is surprising due to the risk aversion of pension fund participants. The issue now is whether this pension plan will be sustainable in practice. A government cannot have a situation where the benefit for the retiree is too low to survive, when the investment returns were bad. It is also not possible for an employee to retire before the age of 65 when he has enough money to buy an increasing annuity that gives him a high enough benefit, because he was lucky to get high returns. These situations are not good for the economy, because in that case there will be generations with either too little money or generations with too much money. In the former case an employee wants to keep working after retirement, which will not be always possible, because of an oversize work force. In the latter case the employee wants to retire early, with as a consequence an undersized work force. The CDC pension plan as implemented in The Netherlands solves some of these problems, but still has a relatively high volatility in the benefit. This has lead to a widespread debate about whether this is socially responsible or not.

Also, the second method always has a lower CEC than the first method. This is because with the second method initially more contribution is paid than necessary, which is compensated in the end. Due to the fact that we discount the utility, more weight is given to consumption in the beginning than in the future. This is also how an individual looks at money, he prefers to have the money now rather than after 30 years. However, in practice part or the full contribution is paid by the employer. Consequently, when the contribution is calculated with the second method the contribution for the company will be higher for an older employee than for a younger one. This implies that an employer might consider not to hire the older employee because of the higher cost, putting him in a disadvantage.

4.5 Sensitivity analysis

Besides the results discussed in the previous section, this thesis will contain some sensitivity analysis. The full results of the sensitivity analysis can be found in appendix D. Sensitivity analysis is executed for different horizons in which underfunding has to be brought back to the margin. Another mean investment return is taken on the basis of a current report done for the government (Don, Driessen, van Ewijk, Knot, and van Popta (2009)). Next to changing the mean return, the standard deviation of the return will also be put to a robustness test. Since the initial funding ratio in collective pension plans can have a big influence, the analysis for the collective pension plans will be calculated using a random initial real funding ratio. The last assumption put to the test is the assumption of 40% invested in equity.

Time horizon

The time horizon chosen to settle the deficit will have an impact on how volatile the contribution is. The shorter the horizon is the more volatile the contribution will be and conversely. The horizon of three years was chosen because this is stipulated by the Old Age Pension Act However, changing the horizon could have a big impact on welfare.

If the horizon in which the deficit is settled is decreased from 3 years to one year, the CEC will decrease. This is as expected, since when the horizon is decreased, the contribution is more volatile and hence, the consumption has bigger shocks.
We also increased the horizon. In the individual setting it is increased to the number of years left to retirement. In the collective setting the deficit is divided by 40, the total number of years in the workforce. If an employee retires and thus gets out of the workforce, a new one enters in the collective setting. Therefore, we can take the whole 40 years as horizon, instead of the years in the workforce left as in the individual setting. Consequently, the CEC will decrease, which is not as expected. The longer the horizon in which the deficit is settled, the less volatile the contribution will be, and the less volatile the consumption will be. We would expect that the less volatile the consumption is the higher the CEC is. That the CEC decrease is probably the case, because in the beginning the participant gets a discount on the contribution, since an initial real funding ratio of 100% is taken. The participants will then prefer to get a large contribution discount now instead of a gradual contribution discount. In other words, when a time horizon of three years is used, the bigger discount in year 0, which preferred over a gradual settled deficit. When a time horizon of one year is used, the even bigger discount in year 0 does not add up to the more volatile contribution.

Mean return

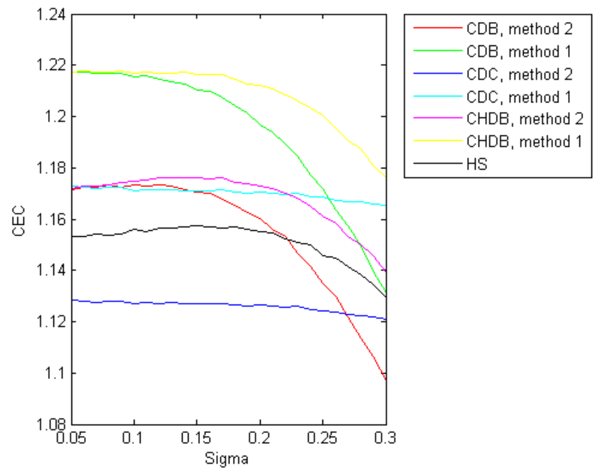
As a result of the economic crisis the Dutch government installed several committees to investigate what went wrong and to make recommendations for the future. One of those committees, the Committee Parameters (Don et al. (2009)) investigated which mean return parameters to use. Since the committee could not reach a mutual agreement, the advice is separated in an advice from the experts, consisting of the DNB and the CPB,[5] and an advice from the social partners represented by StvdA.[6] To see the effects of these advice, the analysis is done with the recommendation of the experts and the social partners. When the mean return advised by the experts, 6%, is used instead of 7% , the conclusion of which pension plan is the best does not change. The social partners recommend a mean return of 7.25%. If this mean return is used, again the conclusion does not change. As one would expect a mean return of 6% gives a lower CEC, while a mean return of 7.25% gives a higher CEC.

Standard deviation

It is also very interesting to see the changes in CEC when the standard deviation of the investment return is unequal to 15.2%. Since there has been no investigation of this by the Committee Parameters (Don et al. (2009)), extreme standard deviations of 20% and 10% where chosen. When the standard deviation is increased, the conclusions do not change. However, when the standard deviation is decreased, we have that for a risk aversion parameter of 5 and 7, the CDB pension plan calculated with the first method, where the deficit is settled in one year gives the same CEC as when the deficit is settled in three years. For a risk aversion parameter of 9, the CHDB pension plan calculated with the first method, where the deficit is settled in three years gives the highest CEC. The CEC for the collective pension plans are also plotted against the standard deviation. The CHDB pension plan calculated with the first method has the highest CEC for all standard deviations.

[5]Statistics Netherlands.
[6]Stichting van de Arbeid (The Labour Foundation).

Figure 4.8: CEC for different volatilities for different pension plans

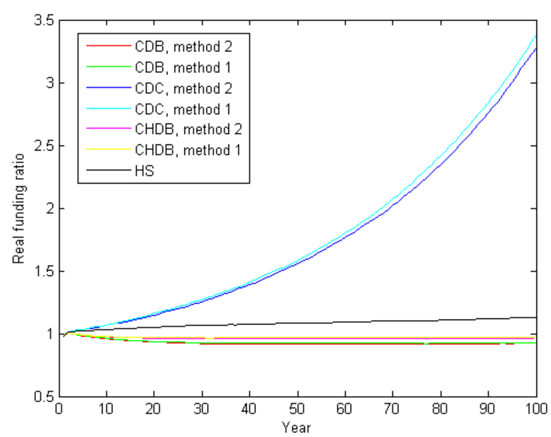


The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

Initial funding ratio

The initial real funding ratio of 100% has a big effect on the results. Depending on the pension plan, the pension plan uses its buffer very quickly, keeps it stable or makes it higher. The average real funding ratio of the collective pension plans over time are presented in figure 4.9.

Figure 4.9: Real funding ratio



The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector

Here we can see that the CDB pension plan and the CHDB pension plan use the buffer, since the real funding ratio decreases. The HS pension plan increases its buffer to above 100%, while de CDC pension plan increases its buffer enormously to above 300%. Since in the CDC pension plan the real funding ratio increases a lot and there are no contribution discounts given, we can conclude that the contribution is too high. The HS pension plan gives less contribution discount than the CHDB pension plan and hence the real funding ratio for the HS pension plan increases, while for the CHDB pension plan it decreases.

Since pension plans do not maintain a real funding ratio of 100% during the years, we take a random initial real funding ratio. The random initial real funding ratio is calculated by simulating 100 years in advance before calculating the consumption path for an individual. When a random initial real funding ratio is used we do not see that in first few years the employee get a discount on contribution like we saw in the figures previously. The CEC is also calculated with an initial real funding ratio of 100%, but where the income is corrected for 100 years wage inflation. This is done to make a comparison with the results of the previous section. In table 4.2 the results can be found.

The conclusion is the same as in the previous section. The CHDB pension plan calculated with the first method gives the highest CEC. When an initial real funding ratio of 100% is used, where income is corrected for wage inflation, we have that the CEC is higher than when a random initial real funding ratio. This is as expected, since the mean real funding ratio in 100 years is lower than 100% for the CDB pension plan and CHDB pension plan.

Table 4.2: CEC for different pension plans

Pension plan	**First method**	**Second method**
	$\gamma = 5$	
IDB	Benchmark	-3.49
IHDB	2.68	-0.83
IDC	4.83	1.10
CDB	8.19	4.29
CHDB	**15.40**	13.67
CDC	4.87	1.10
HS	N.A.	13.54
	Random initial real funding ratio	
CDB	8.15	4.32
CHDB	**10.82**	7.25
CDC	7.78	3.90
HS	N.A.	8.42
HS	N.A.	9.83
	$\gamma = 7$	
IDB	Benchmark	-4.41
IHDB	3.59	-0.58
IDC	6.60	2.09
CDB	10.15	6.09
CHDB	**16.07**	13.47
CDC	6.88	2.34
HS	N.A.	13.37
	Random initial real funding ratio	
CDB	9.88	5.31
CHDB	**12.91**	8.62
CDC	9.86	5.20

Table 4.2: Continued

Pension plan	First method	Second method
	$\gamma = 9$	
IDB	Benchmark	-5.48
IHDB	3.49	-0.93
IDC	8.05	3.09
CDB	10.75	6.20
CHDB	**15.58**	12.18
CDC	7.64	2.70
HS	N.A.	12.10
	Random initial real funding ratio	
CDB	10.42	5.45
CHDB	**13.63**	8.94
CDC	10.65	5.57
HS	N.A.	10.22

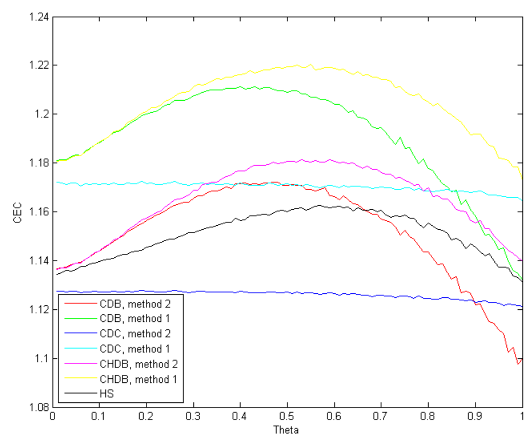
The results are depicted as a percentage change in comparison to the CEC of the IDB pension plan.
The HS pension plan is only calculated with the second method giving a not available result for the first method. The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. γ is the risk averse parameter, where the higher it is the more risk averse an individual is. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

Investment mix

The last assumption put to the test is the fraction invested in equity. The analysis is done with the assumption that 40% is invested in equity, because the fraction invested in equity decreased after the economic crisis. However, in 2008 it was nearly 50%. To see what the effects are on CEC if the fraction invested in equity did not decreased, the analysis is done over with 50% invested in equity. When this is done we can see that the conclusions drawn in the previous section do not change. The CHDB pension plan calculated with the first method and where the deficit is settled in three years gives the highest CEC. Also, generally increasing the fraction invested in equity does not increase the CEC. The CEC for the collective pension plans is also plotted against the fraction invested in equity in figure 4.10.

In figure 4.10 we can see that the CEC for the CDC pension plan is flat. This is because the contribution asked is apparently too high and there will be no contribution discount, so the percentage invested in equity will not have that big of an impact. For the other pension plans the optimum lies in between a fraction of between 40% and 70% invested in equity. This is in line with the conclusion of Gollier (2008) that the percentage invested in equity should be between 40 and 60%. For the more hybrid pension plan a higher percentage invested in equity than in the CDB pension plan gives the optimum. The last thing to notice is that as already seen the first method gives a higher or equal CEC for every percentage invested in equity for every pension plan.

Figure 4.10: CEC for different investment mixes for different pension plans



The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector

4.6 Summary

Assuming the CRRA utility function, the hybrid pension plans give the highest welfare. Overall changing the risk aversion parameter, the mean return and the standard deviation of the investment return do not affect the conclusion. An individual prefers to spread out the uncertainty over the contribution and the benefit, instead of only spreading out over the contribution or the benefit. This is exactly what a hybrid pension plan does. The EUT has various drawbacks which can influence our conclusion. Hence, in the next chapter another utility theory is taken that captures more accurately individual preferences.

Chapter 5

Welfare analysis with Cumulative Prospect Theory

In the previous chapter we used the Expected Utility Theory (EUT) for the welfare analysis. The EUT is a utility theory frequently used in the economic literature. However, there are also arguments to be found stating that the EUT does not describe the individual preferences accurately, see for example Tversky and Kahneman (1979) and Tversky and Kahneman (1992). The Cumulative Prospect Theory (CPT) incorporates some of the properties violated by the EUT.

The chapter is organized as follows. First, the arguments why EUT is not a good utility theory will be discussed, followed by the definition of the CPT. Next, the assumptions made will be discussed. In the fourth section, the CEC results of the different pension plans will be discussed, followed by the sensitivity analysis. The penultimate section compares the result of the welfare analysis with current developments, while the last section of this chapter gives a summary.

5.1 Properties of CPT

In the EUT the expectation of the utilities is taken. However, the actual probability corresponding to every outcome might not correspond with the psychological weight given by the consumer to the outcome. Tversky and Kahneman (1979) developed an alternative model, which explained the major violations of EUT, called Prospect Theory. In their paper "Advances in Prospect Theory: Cumulative Representation of Uncertainty" (Tversky and Kahneman (1992)), a new version of the Prospect Theory is presented, called Cumulative Prospect Theory (CPT). The CPT will be used in this thesis, since it has been one of the most fully developed and thoroughly investigated models according to Doskeland and Nordahl (2008). Also, according to Gonzales and Wu (1996) CPT is supported by most of the current empirical evidence. Before giving the definition of the CPT, the properties violated by the EUT incorporated by the CPT will be discussed.

Framing

According to the EUT, the presentation of the outcomes does not affect the decision. There is a lot of evidence that this is not the case. The decision made depends on how the options are presented (framing) (Kahneman and Tversky (1984), Tversky and Kahneman (1986)). For example, if a doctor says you have 20% chance of dying, or you have 80% chance of surviving in surgery, the outcome will be the same. However, you will react differently depending on how the message is presented (framed). This suggest that the preference and thus the utility depends on framing. One way of framing is by not looking at the total amount of money, but at the gain or the loss compared to a reference point. The CPT does not look at the total wealth (as is done with the EUT), but at the gain or loss compared to the reference point.

Non linear preference

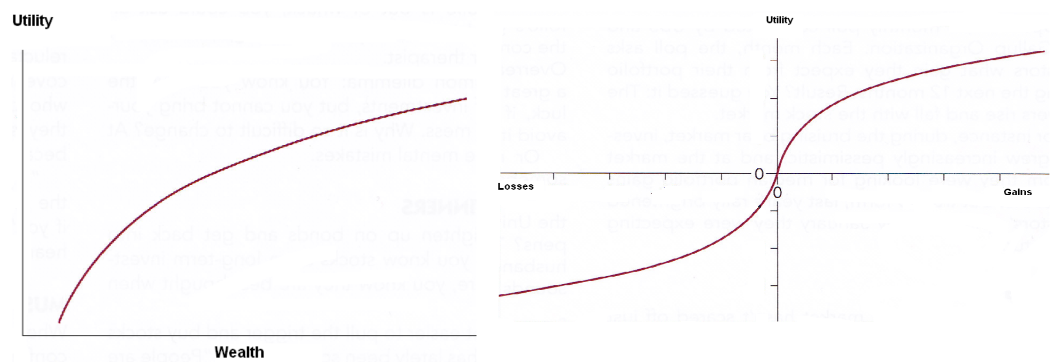
Allais (1953) showed that the assumption that the utility is linear in outcome probabilities does not hold in practice although EUT makes this assumption. He showed that a probability reduction from 1 to 0.99 might have more impact on the utility than a reduction in probability from 0.01 to 0. This can be seen in the Russian roulette example (Gonzales and Wu (1996), Tversky and Kahneman (1979)), where people are willing to pay more to reduce the number of bullets from 1 to 0 out of 6 than reducing the number of bullets from 4 to 3 out of 6. In both options the probability of surviving increases with 1/6. However, people put more weight on the lower probability of dying. More recently, Cmaerer and Ho (1994) also showed the importance of non linear preferences.

Risk seeking

Risk seeking is the phenomenon where people are willing to take risk for losses, while they are at the same time risk averse in gains. In other words, they prefer the risk of a bigger loss over the certainty of a smaller loss, while they prefer a certain smaller gain over the risk of a bigger gain. In other words, the utility is convex in losses, and concave in gains. EUT assumes risk averse behaviour everywhere, since it values total wealth. This implies that while in EUT the utility is concave, in the CPT it is inverse S-shaped. Below this can be seen graphically (Bodie et al. (2009)).

Figure 5.1: Hypothetical utility function

(a) Expected Utility Theory (b) Cumulative Prospect Theory

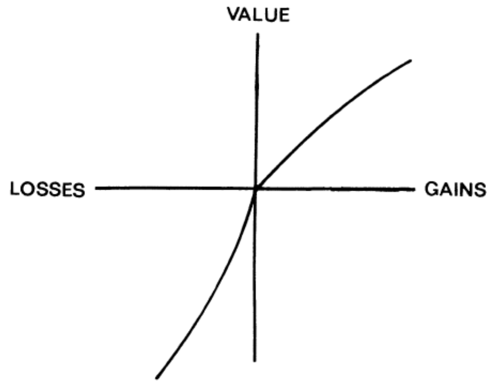


The Utility function in the CPT is convex in losses, and concave in gains, while the EUT it is concave.

Loss aversion

Loss aversion is the phenomenon that losses seem bigger than gains. The existence of loss aversion has been shown by Tversky and Kahneman (1991) and Kahneman and Tversky (1984). When losses seem bigger than gains, a utility will decrease more with an increase in loss than it increases with the same difference in the gains, i.e. the utility is steeper for losses than for gains. In figure 5.2 it is seen how this property changes figure 5.1b (Tversky and Kahneman (1979)).

Figure 5.2: Hypothetical Cumulative Prospect utility function



When losses seem bigger than gains, a utility will decrease more with an increase in loss than it increases with the same difference in the gains. Here is seen how this property changes figure 5.1b

5.2 CPT Utility function

As mentioned above, a reference point is very important in calculating the utility, since CPT takes the gains and losses relative to the reference point. In our analysis the reference point taken is the consumption path that an individual expects in year 0 (C_t^*), i.e. where the contribution is calculated as with the DC pension plan and the benefit as with the DB pension plan. The utility is not calculated with the consumption path, but with the gain or loss of the consumption path compared to the expected consumption path. i.e. the gain (g) is defined as

$$g_t = C_t - C_t^* \tag{5.1}$$

Here C_t is the actual consumption calculated as in equation (4.2), while C_t^* is the expected consumption. The consumption will deviate from the expected consumption because of volatility in the investment returns. If the consumption is lower than the expected consumption we will have a loss and g is negative. Next, we calculate the utility per scenario (G) as follows

$$G_j = \int_0^D e^{-rt} v(g_j(t))dt \tag{5.2}$$

Here g is the matrix of the gains, with j the scenario and t the time and $v(\cdot)$ is the utility function.The definition of $v(g_j)$ is (Tversky and Kahneman (1992)),

$$v(g_t) = \begin{cases} g_t^{\alpha} & \text{for } g_t \geq 0 \\ -\lambda(-g_t)^{\beta} & \text{for } g_t < 0 \end{cases} \tag{5.3}$$

Here λ measures how much more sensitive an individual is to a loss compared to a gain. α measures the sensitivity to an increasing gain, while β measures the sensitivity to an increasing loss. The second important property of the CPT utility is that it makes a difference between the losses and the gains. Hence G_j will be ordered in gains and losses. Now the total utility (V) is (Tversky and Kahneman (1992)),

$$V(g,p) = V^+(g,p) + V^-(g,p) \tag{5.4}$$

Here V^+ is the utility for the gains, while V^- is the utility of the losses, defined as follows,

$$\begin{aligned} V^+(g,p) &= w^+(p_1)G_j + \sum_{j=2}^{k}\big([w^+(p_1+\ldots+p_j) - w^+(p_1+\ldots+p_{j-1})]\cdot G_j\big) \\ V^-(g,p) &= \sum_{j=k+1}^{n-1}\big([w^-(p_j+\ldots+p_n) - w^-(p_{j+1}+\ldots+p_n)]G_j\big) + w^-(p_n)\cdot G_j \end{aligned} \tag{5.5}$$

Here G is the vector with the utility per scenario, p the vector with the corresponding probabilities, n the number of scenarios, from which k are gains and $n-k$ are losses, $w(\cdot)$ is the probability weighted function. The probability weighted function weights the actual probability of the outcome to get the psychological weight corresponding to the same outcome. In this thesis we have n scenarios, each having to the same probability of $1/n$. Given that the probability for every j is $1/n$, (5.5) reduces to

$$\begin{aligned} V^+(g,p) &= w^+(1/n)G_1 + \sum_{j=2}^{k}\big([w^+(j\cdot 1/n) - w^+(j-1\cdot 1/n)]\cdot G_j\big) \\ V^-(g,p) &= \sum_{j=k+1}^{n-1}\big([w^-((n-j+1)\cdot 1/n) - w^-((n-j)\cdot 1/n)]G_j\big) + w^-(1/n)\cdot G_n \end{aligned} \tag{5.6}$$

A simple numerical example for the application of the CPT can be found in appendix B.

5.3 Assumptions

Probability weighted function

The probability weighted function should have the properties of non linearity, loss aversion and risk seeking. To incorporate these properties, the probability weighted function has to be inverse S-shaped. Tversky and Kahneman (1992) defined a separate probability weighted function for gains (w^+) and for losses (w^-) as follows,

$$\begin{aligned} w^+(p) &= \frac{p^\psi}{(p^\psi + (1-p)^\psi)^{1/\psi}} \\ w^-(p) &= \frac{p^\delta}{(p^\delta + (1-p)^\delta)^{1/\delta}} \end{aligned} \tag{5.7}$$

Here ψ and δ determine the degree of the S-shape of the probability weighted function. The former determines the degree of the S-shape of the positive probability weighted function, while the latter for the negative probability weighted function. The higher the parameters the more S-shaped the probability weighted function is and conversely. Hence, the higher the parameters, the more non linear, risk seeking and loss averse the people are.

Prelec (1998) defined a probability weighted function that is equal for both gains and losses.

$$w(p) = e^{-(-ln(p))\varphi} \tag{5.8}$$

Here φ stands for the degree of the S-shape of the probability weighted function.
Note that for $\varphi = 1, w(p)$ will be equal to p, and when $w(p) = p$ we will be back to the EUT. According to Doskeland and Nordahl (2008) the probability weighted function of Prelec (1998) is based on behaviour properties, while the probability weighted function of Tversky and Kahneman (1992) is based on convenience of the functional form.

Risk aversion parameters

The choice of risk aversion parameters is very important. The risk aversion parameters will have a big impact on the utility. There are various studies on which risk aversion parameters to take. Below, a table can be found that summarizes different risk aversion parameters estimated by different papers.

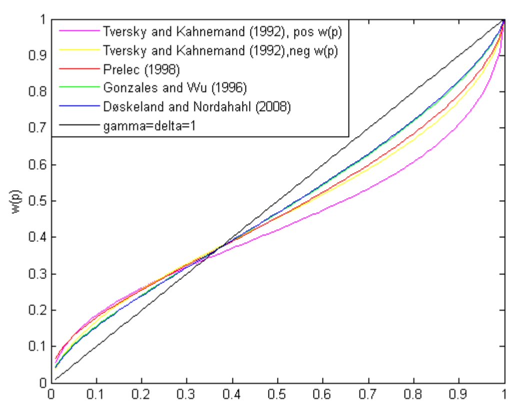
Table 5.1: Risk aversion parameters

Probability weighted function (5.7)	ψ	δ	α	β	λ
Tversky and Kahneman (1992)	0.61	0.69	0.88	0.88	2.25
Probability weighted function (5.8)	φ		α	β	λ
Doskeland and Nordahl (2008)	0.75		0.5	0.5	2.25
Gonzales and Wu (1996)	0.74		0.48		

Here ψ, δ and φ stands for the degree of the S-shape of the probability weighted function. λ measures how much more sensitive an individual is to a loss compared to a gain. α measures the sensitivity to an increasing gain, while β measures the sensitivity to an increasing loss.

Gonzales and Wu (1996) investigated the parameters for gains only, not for losses. The risk aversion parameter affects the S-shaped utility. The different values for the different probability weighted functions with the corresponding parameters are found in figure 5.3.

Figure 5.3: Probability weighted function



The S-shape curve of the probability weighted function is depicted for different combination of risk averse parameters. also the probability weighted function estimated by Tversky and Kahneman (1992) and Prelec (1998) is depicted.

In this figure we see that the higher the parameters, the more S-shaped the probability weighted function is. As a reference point the graph corresponding to a risk aversion parameter of 1 is also depicted. If the employee is above the diagonal line he is risk seeking, while if the employee is below the diagonal line, he is risk averse.

Initially the risk aversion parameters estimated by Doskeland and Nordahl (2008) will be taken, since they also use these values for their analysis of pension insurance contracts. As a sensitivity analysis, the analysis will also be done for the other risk aversion parameters depicted in table 5.1.

5.4 Analysis of the CEC

Before interpreting the results, the properties of the pension plans in terms of losses and gains, compared to the reference point, are discussed. The Defined Benefit pension plan does not have a loss or gain in the benefit, you receive what you expect, while there could be a loss or gain in the contribution. With the IDC pension plan there is a possibility of a gain or loss in the benefit, while there is no gain or loss in the contribution. In the CDC pension plan you pay the contribution you expect, no gain or loss, and you receive the benefit you expect or lower, hence there is only a possibility of a loss. The hybrid pension plans have in both the contribution and benefit the possibility of a loss, while in the contribution there is also the possibility of a gain. A summary of these properties is found in table 5.2.

Table 5.2: Characteristics of pension plans

Pension plan	**Contribution**	**Benefit**
IDB pension plan	+/-	fixed
IDC pension plan	fixed	+/-
IHDB pension plan	+/-	-
CDC pension plan	fixed	-
CHDB pension plan	+/-	-
HS pension plan	+/-	-

The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

A +/- means the possibility of a gain or loss, while a - means only a possibility of a loss.
The results for the different pension plans are given in table 5.3. The results are depicted as percentage difference in CEC compared to the CEC of the IDB. The results depicted in table 5.3 are calculated based on 10,000 simulations of the consumption path.

The CDB pension plan calculated with the second method gives the highest CEC. This is a different outcome than if the individual preferences where describe by the EUT. The difference in conclusion between the two utility theories arises because of the property of the CPT that a loss is punished harder than a gain is rewarded. The CDB pension plan can have a loss or gain in the contribution. The CHDB pension plan again can have a loss or gain in the contribution and at the same time has also the possibility of a loss in the benefit. So we can conclude that certainty in the benefit is more important than certainty in contribution. However, Tamerus (2009) argues that how the CDB pension plan is defined in practice now is not sustainable. This is because for the CDB pension plan to be sustainable the contribution has to be very volatile, which is not feasible in practice. The pension plan that gives the lowest CEC depends on which parameters are used. When the parameters estimated by Doskeland and Nordahl (2008) or Tversky and Kahneman (1992) are used, the IHDB pension plan gives the lowest CEC. When the parameters estimated by Gonzales and Wu (1996) are used the IDC pension plan gives the lowest CEC.

The advantage of the CHDB pension plan to the CDB pension plan is that the contribution is less volatile. By calculating the contribution with method two the contribution will be less volatile. Unlike with the EUT, the second method gives a higher CEC than the first method. According to the CPT a fixed contribution percentage of income is preferred. This is the case, since with the second method we have less often a loss in the contribution.

Table 5.3: CEC for different pension plans

Pension plan	First method	Second method
	Doskeland and Nordahl (2008)	
IDB	Benchmark	0.70
IHDB	-0.07	0.53
IDC	0.50	1.08
CDB	2.87	**3.15**
CHDB	1.68	2.04
CDC	1.12	1.55
HS	N.A.	1.69
	Tversky and Kahneman (1992)	
IDB	Benchmark	0.58
IHDB	-0.14	0.40
IDC	-0.25	0.27
CDB	0.69	**1.14**
CHDB	0.57	1.05
CDC	0.46	0.93
HS	N.A.	0.50
	Gonzales and Wu (1996)	
IDB	Benchmark	0.56
IHDB	-0.12	0.41
IDC	-0.25	0.28
CDB	0.48	**0.95**
CHDB	0.41	0.89
CDC	0.36	0.84
HS	N.A.	0.36

The results are depicted as a percentage change in comparison to the CEC of the IDB pension plan.
The HS pension plan is only calculated with the second method giving a not available result for the first method. The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. The papers stand for combination of risk averse parameters. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

As with the EUT, collective pension plans have a higher CEC than individual pension plans. However, the increase in CEC for the CPT is smaller than for the EUT. In other words, if the individual preferences are best describe by the CPT, collective risk sharing adds less welfare than if the preferences are best describe by the EUT. Also, for the CPT the Defined Contribution pension plans do worse. In the case of the EUT the bad years compensate with the goods years. In the case of the CPT the bad years are punished harder than the good ones are rewarded. The next surprising observation is that the differences between the CEC are smaller with the CPT than with the EUT. The last thing to notice is that the conclusion is the same regardless of the parameters chosen.

5.5 Sensitivity analysis

Besides the results discussed in the previous section, some sensitivity analysis will be done. Sensitivity analysis is executed for the time horizon, the mean and standard deviation for the investment return, a random initial real funding ratio and the fraction invested in equity. The result of the sensitivity analysis can be found in the Appendix D.

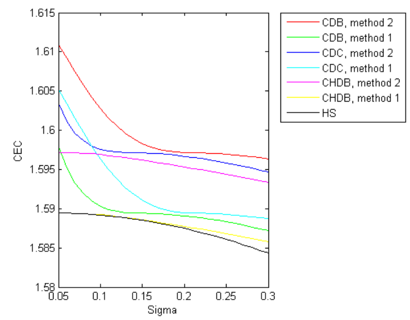
Time horizon

The longer the horizon over which the deficit is settled, the higher the CEC. This is as expected, since then the contribution will be less volatile. Also, the longer the horizon, the lower the loss per year, for the bad scenarios. However, the longer the horizon the smaller the gain per year, for the favourable scenarios. Since a loss is punished harder than a gain is rewarded, the possibility of a smaller loss is preferred over the possibility of a bigger gain. With the EUT we saw that the time horizon of three years was preferred, since the employee prefers a big discount now instead of a gradual discount. A big discount now has a bigger risk of a future loss than a gradual discount now. Hence, with the CPT gradually discount is preferred to lower the risk of a loss in the future.

Mean return and standard deviation

The mean return and standard deviation of the investment returns do not have an impact on the conclusions of the previous section. Also, when the mean return is higher or the standard deviation is lower the CEC will be higher and conversely, which is logical. The CEC for the collective pension plans is also plotted against the standard deviation.

Figure 5.4: CEC for different volatilities for different pension plans



The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector

In figure 5.4 it is seen that the CDB pension plan calculated with the second method always has the highest CEC. The HS pension plan always has the lowest CEC. Also, the lower the standard deviation the higher the CEC for al pension plans is, as expected.

Initial funding ratio

Again a random initial real funding ratio is taken. The results can be found in table 5.4. When a random initial real funding ratio is taken the conclusion changes. The second method does not give in all cases the highest CEC any more. It depends on the time horizon and parameters used. When the deficit is settled in three years either the CDB pension plan calculated with the first method or the HS pension plan give the highest CEC. When the time horizon is increased or decreased the conclusion changes. For all three parameter combinations used, the CHDB pension plan calculated with the first method where the deficit is settled gradually gives the highest CEC. Also, the employee has a higher CEC when a random initial real funding ratio is used instead of a real initial funding ratio of 100%. This is because when a random initial real funding ratio is used the contribution will be less volatile, since the real funding ratio is in a stable state.

Table 5.4: CEC for different pension plans

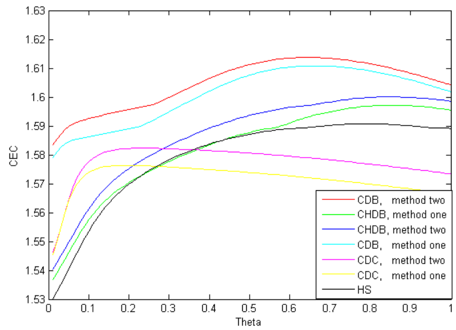
Pension plan	First method	Second method
	Doskeland and Nordahl (2008)	
IDB	Benchmark	0.70
IHDB	-0.07	0.53
IDC	0.50	1.08
CDB	2.87	**3.15**
CHDB	1.49	1.79
CDC	1.12	1.55
HS	N.A.	1.31
	Random initial real funding ratio	
CDB	7.83	7.84
CHDB	7.00	6.95
CDC	4.65	4.88
HS	N.A.	**8.85**
	Tversky and Kahneman (1992)	
IDB	Benchmark	0.58
IHDB	-0.14	0.40
IDC	-0.25	0.27
CDB	0.69	**1.14**
CHDB	0.55	1.02
CDC	0.46	0.93
HS	N.A.	0.33
	Random initial real funding ratio	
CDB	**10.28**	9.99
CHDB	8.85	8.43
CDC	5.25	5.03
HS	N.A.	10.25
	Gonzales and Wu (1996)	
IDB	Benchmark	0.56
IHDB	-0.12	0.41
IDC	-0.25	0.28
CDB	0.48	**0.95**
CHDB	0.40	0.89
CDC	0.37	0.85
HS	N.A.	0.22
	Random initial real funding ratio	
CDB	**10.42**	10.07
CHDB	8.76	8.24
CDC	5.75	5.48
HS	N.A.	10.07

The results are depicted as a percentage change in comparison to the CEC of the IDB pension plan. The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

Investment mix

When the percentage invested in equity is increased to 50% the conclusion does not change. Also, the CEC for the collective pension plans is plotted against the fraction invested in equity.
The CDB pension plan calculated with both the first and second method gives the highest CEC for every investment mix. It is surprising that the CDC pension plan has its optimum at 10% invested in equity, which is pretty low. This is because with the CDC pension plan there is no certainty in the benefit. Since this is important to the employees, less risk should be taken when investing. The CHDB pension plan and the HS pension plan both have their optimum around 80%, which is pretty high. Hence, for the CPT the optimal percentage invested in equity depends on the pension plan. That the optimum is the same for both the CHDB and HS pension plan was as expected, since the pension plans look alike. Based on figure 5.5 we can again conclude that certainty in the benefit is very important. For the pension plan where less certainty is given

Figure 5.5: CEC for different investment mixes for different pension plans



The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector

for the benefit, less risk should be taken than for pension plans where more certainty is given for the benefit. Moreover, the riskier the pension plan the saver the investment policy of the pension fund should be. For the EUT we had that for all pension plans the optimal range in between 40% and 60%.

5.6 Summary

The utility calculated with the CPT is concave for gains and convex for losses. The utility is also steeper for losses than for gains. These properties are achieved with the probability weighted function. Also, the utility is calculated on the basis of a reference point instead of total wealth. The most important conclusion is that the CDB pension plan calculated with the second method, where the deficit is gradually settled, gives the highest welfare. In general, the higher the certainty and the lower the possibility of a loss, the higher the welfare is.

Chapter 6

Conclusion

In this thesis the welfare properties of different pension plans have been investigated. We wanted to answer which pension plan gives the highest welfare? More specifically, does certainty in benefit or contribution give a higher welfare? The welfare has been analyzed using the Expected Utility Theory approach and the Cumulative Prospect Theory approach.

First we looked at the case where the individual preferences are described by the Expected Utility Theory. In this case the collective Defined Benefit pension plan with conditional indexation gives the highest welfare. Here the contribution calculated to be enough to pay the $a\%$ benefit accrual that year, gives the highest welfare. This is because the contribution will be lower in this case. The Pension Act also stipulates that a pension fund must have a sufficient buffer to ensure the promises made to the participants. To achieve this the Pension Act stipulates a boundary for the nominal funding ratio[1], below which a pension fund should not fall. This boundary is set at 105% nominal funding ratio. In the case the funding ratio falls below this boundary, the pension fund has to draw up a recovery plan, in which it states how it will recover over the course of three years.[2] In other words, the difference between the assets and liabilities (deficit) has to be settled in three years. However, a deficit settled on a different time horizon can give a higher welfare. This is not the case when the individual preferences are described by the Expected Utility Theory. A deficit settled in three years gives the highest welfare. This is probably the case because of the initial real funding ratio of 100%. When a random initial real funding ratio is chosen a gradually settled deficit gives the highest welfare. The conclusion was independent of the risk aversion parameters taken.

Next the case where the individual preferences are described by the Cumulative Prospect Theory has been discussed. Here the Collective Defined Benefit pension plan gives the highest welfare. The contribution calculated as a fixed percentage of income, gives the highest welfare. This is the case, since, when the contribution is calculated as a fixed percentage of income, there will be less often a contribution increment. According to the Cumulative Prospect Theory an individual prefers to pay a higher contribution from the beginning instead of having a contribution increment. A gradually settled deficit also gives a higher welfare when the preferences of individuals are best described by the Cumulative Prospect Theory. A gradually settled deficit gives a higher welfare, since the contribution will be less volatile. Again the conclusion was independent of the risk aversion parameters taken. The difference in conclusion between the two utility theories comes from the fact that the Cumulative Prospect Theory that a loss is punished harder than a gain is rewarded. The Collective Defined Benefit pension plan can have a loss or gain in the contribution. The Collective Defined Benefit pension plan with again can have a loss or gain in the contribution and at the same time has also the possibility of a loss in the benefit. So we can conclude that certainty in the benefit is more important than certainty in contribution.

[1] The funding ratio is calculated by dividing the assets by the liabilities.
[2] Pension Act article 140.

By taking a contribution calculated as a fixed percentage of income, the possibility of a loss in the contribution is reduced. Settling the deficit gradually makes the contribution less volatile.

For both theories the collective pension plans gave a higher welfare than the individual pension plans. Hence, we can conclude that collective risk sharing does add value. Collective risk sharing does not occur naturally (Van Els et al. (2004)). In particular, Collective risk sharing does not occur voluntarily. This implies that collective risk sharing should be mandatory. Varian and Gordon (1988) and Van Hemert (2005) investigated in which ways collective risk sharing should be imposed.

Which pension plan gives the highest welfare, thus depends on the theory used. The Expected Utility Theory is relatively easy and widely used in the economic literature. The Cumulative Prospect Theory is more difficult, but represents individual preferences more accurately (Tversky and Kahneman (1979) and Tversky and Kahneman (1992)). The Cumulative Prospect Theory incorporates some of the properties violated by the Expected Utility Theory. However, in any case the pension plan should be a collective plan where certainty in the benefit is more important than certainty in the contribution.

6.1 Current developments

As a result of the economic crisis, the Dutch government installed several committees to investigate what went wrong and to make recommendations how the pension system should be in the future. One of those committees, the Committee "Beleggingsbeleid en risicobeheer" (Frijns, Nijsen, and Scholtens (2010)) investigated how pension funds organized their risk management and governance, and any conditions that stand in the way of good risk management.[3] The other Committee, Toekomstbestendigheid aanvullende pensioenregelingen (Goudswaard et al. (2010)), investigated whether pension plans are future-proof.[4] The conclusions and recommendations of these committees which influence the conclusion will be discussed.

One of the main problems that the committees foresee is the aging of the population and the longevity risk. People live longer and the number of pensioners divided by the number of working participants is getting higher. This gives rise to a lot of problems for pension funds. Because of the aging of the population the contribution as a tool to increase the funding ratio will be less effective. In the Defined Benefit and Hybrid pension plans the contribution is intensively used as a tool to increase funding ratios. This is especially the case with the former pension plan. If this tool is less effective the promises made about the benefit have to be weakened. In our model the age of death was assumed deterministic, not taking this risk into account. The fact that people live longer makes pensions much more expensive. The longer the participant lives, the longer a benefit has to be paid. To accrue this benefit higher returns have to be achieved on investments or the contribution has to be increased. To achieve a higher return on investments more risk has to be taken, which makes the pension plan more vulnerable to investment returns. In the past we have seen that these phenomena had the result that pension funds started to invest more in equity to get higher returns. In the analysis done it appeared that employees have an optimum per pension plan of how much to invest in equity. Moreover, there is an optimum in more risk to a higher contribution. The third problem is that the Old Age Pension Act stipulates nominal thresholds, with the result that pension funds are focused on the nominal goal, an un indexed benefit. Hence, the committees advice that the Old Age Pension Act incorporates real thresholds instead of nominal ones.

[3] In English, Investment and risk management.
[4] In English, Future proofing employment based pension plans.

One of the main conclusions was that the ambition of a pension fund should be in real terms. In other words, the promises made should be in real terms, i.e. indexed benefit. This is because, only an indexed benefit has economic value for an employee. Hence, the funding ratio thresholds stipulated in the Old age Pension Act should be real funding ratios. If this changes, the pension contracts as defined in chapter 2 will change, changing the conclusion. The real ambition plus the aging of the population and longevity risk imply that pensions get more expensive and vulnerable.

Recommendations to solve this problem are to have a lower ambition, such as a lower benefit accrual per year, switching from indexing on wage inflation to price inflation or increasing the pension age.

6.2 Recommendations for further research

In this research, we used the model of the economy of Cui et al. (2005), Cui et al. (2006) and Doskeland and Nordahl (2008) and the pension model as proposed in Cui et al. (2005), Cui et al. (2006) as a starting point. The pension model has been modified to fit the realistic setting of a pension fund in The Netherlands. These models still have many shortcomings. The assumptions made influence the outcome. In this section some of these assumptions are discussed, which leads to recommendations for further research.

In this thesis normality of the investment returns is assumed. This is not true in reality, the normal distribution is a rough approximation of the real distribution (Oficer (1972)). It is an assumption often made to make the model more simple (Black and Scholes (1973)). The consequence of this assumption is that extreme events will be underestimated. This implies that the pension plans modelled in this thesis are more risky in practice.

The next assumption to look at is the discount rate. A fixed actuarial discount rate is assumed, as was done in the past (van Rooij et al. (2005)). For the model to be more realistic an interest rate curve has to be modelled, as a pension fund is obliged to use this nowadays (van Rooij et al. (2005)).

The income was assumed to be fixed and it only grows with wage inflation. Also, it was assumed that the employee always has an income and does not have wealth next to the income. This in reality is not true, an employee can be unemployed for a period during his lifetime, and he might save and/or invest himself. Also, his income is not constant, but differs across time. Janssen (2006) made a model for the case where income is stochastic, which could be incorporated in the model represented in this thesis.

The public pension (AOW) is not taken into account. Taking the AOW into account gives a certain lower bound for the benefit at retirement. This might imply that the participants are willing to take more risk.

We assumed that at every age there is one participant, i.e. every generation is identical. This is not true, the generations have different proportions in time, and are not equal. Wijbenga (2009) has investigated the effect of incorporating the baby boom generation. His model could be expanded and incorporated in the model presented in this thesis.

At the moment there are a lot of developments in the Dutch pension sector. There is a debate regarding increasing the pension age from one's 65th to one's 67th birthday. People live longer than they used to, we expect them to live longer in the future. This is called longevity risk. We did not take these developments into account. Models that could be used for future mortality are, for example, Lee and Carter (1992) and Ballotta and Haberman (2006). Also, the conclusions are based on pension plans used at the moment, the conclusion is likely to change if the recommendations of the committees installed by the government are implemented.

The last assumption relates to the input for the utility function. The risk aversion parameters for the utility function were investigated on the basis of a small sample for people. However, a pension fund is not interested in preferences of people in general. The pension fund is interested in the preferences of its participants. Since pension funds do not have the same characteristics (Frijns et al. (2010)), we advice that the pension fund investigates which parameters correspond to their participants.

Appendix A

Capital structure

A.1 Individual pension plans

A.1.1 Individual Defined Benefit

The contribution of the IDB pension plan will be calculated in the same way as in the IHDB pension plan, i.e. as in (3.11) and (3.12). The difference between the IDB pension plan and the IHDB pension plan is that in the latter the indexation of the benefit depends on the funding ratio.

The employee will accrue each year the privilege of $a\%$ of his income which will be indexed for wage inflation before retirement and for price inflation after retirement. Hence, the dynamics of the benefit are:

$$b_t = \begin{cases} a\% * I_0 & \text{for } t = 0 \\ b_{t-1} \cdot (1 + infw_t) + a\% * I_t & \text{for } 0 \leq t < R \\ b_{t-1} \cdot (1 + inf_t) & \text{for } R \leq t < D \end{cases} \tag{A.1}$$

Here $infw_t$ is the wage inflation between time $t-1$ and time t, and inf_t the price inflation. We see that before retirement the benefit will be indexed with the wage inflation and that the benefit will increase each year with $a\%$ of the income. If after retirement the investment returns turn out to be unfavourable, the pension fund cannot steer with the contribution. Hence, an increasing annuity will be bought at retirement. An increasing annuity will take indexation into account, since the benefit will increase each year with the inflation. By buying an increasing annuity the pension fund guarantees the benefit promised. Hence, before retirement the benefit can be promised by changing the contribution, and after retirement by buying an increasing annuity.

A.1.2 Individual Defined Contribution

In the IDC pension plan the contribution can again be calculated in two different ways. The first one is with an increase in contribution every year based on the age of the employee, independent of the returns of the assets. The second way is that the contribution is a fixed percentage of the income. Hence the real contribution will then be constant.

$$c_t = \begin{cases} CWr_t \cdot a\% \cdot I_t & \text{for method one} \\ \hat{c} \cdot I_t & \text{for method two} \end{cases} \tag{A.2}$$

As can be seen the contribution is almost the same as in (3.11) or (3.12), only it is independent of the surplus. Although the contribution is independent of investment returns, the benefit depends on inflation and investment returns. In an IDC pension plan the benefit does not depend on the income as with the IDB pension plan. The asset at retirement, A_R, will be used to buy an increasing annuity.

$$b_t = \begin{cases} 0 & \text{for } t < R \\ \left(\frac{A_R}{1-(\frac{1}{1+r})^{D-R}}\right)/r & \text{for } t = R \\ b_{t-1} \cdot (1 + inf_t) & \text{for } R < t < D \end{cases} \tag{A.3}$$

Here r is the real interest rate.

A.2 Collective pension plans

A.2.1 Collective Defined Benefit

The contribution will be calculated in exactly the same way as with the CHDB pension plan given in (3.23) and (3.24). However, the contribution will be more volatile than the contribution in the CHDB pension plan because the funding ratio will be more often below 105%. This is due to the fact that with the CHDB pension plan the indexation will not always be 100%, it depends on the funding ratio.

The benefit in year 0 is calculated again as in the CHDB pension plan, as in (3.25), since the benefits are fully indexed at the beginning. In the years unequal to 0 The employee accrues each year the privilege of $a\%$ of his income during his career life, which is indexed for wage inflation before retirement and for price inflation after retirement.

$$b_{t,i} = \begin{cases} a\% * I_{t,i} & \text{for } i = 0 \\ b_{t-1,i-1} \cdot (1 + infw_t) + a\% * I_{t,i} & \text{for } 0 < i < R \\ b_{t-1,i-1} \cdot (1 + inf_t) & \text{for } R \leq i < D \end{cases} \tag{A.4}$$

A.2.2 Collective Defined Contribution

In the CDC pension plan, like in the IDC pension plan, the contribution is fixed, independent of investment returns. Also, the contribution can be calculated using two methods, like in all other pension plans.

$$c_{t,i} = \begin{cases} CW_{t,i} \cdot a\% \cdot I_{t,i} & \text{for method one} \\ \hat{c} \cdot I_{t,i} & \text{for method two} \end{cases} \tag{A.5}$$

There are not many CDC pension plans in The Netherlands. The CDC pension plans in The Netherlands have the construction that they will pay out the benefit calculated in the same way as in a CDB pension plan. The difference is that when the nominal funding ratio is too low the benefit will be lowered instead of increasing the contribution. The benefit in year 0 will be calculated in the same way as with the CHDB pension plan, given in (3.25). When the nominal funding ratio is above 105% and the real funding ratio is below 100%, the benefit is calculated as in the CDB pension plan, given in (A.4). In case the nominal funding ratio is below 105%, the benefit has to be decreased so that the nominal funding ratio will increase to 105% in 3 years. Hence, in case the nominal funding ratio is below 105%, the benefit will be calculated as follows

$$b_{t,i} = \begin{cases} (a\% * I_{t,i}) \cdot d_t & \text{for } i = 0 \\ (b_{t-1,i-1} \cdot (1 + infw_t) + a\% * I_{t,i}) \cdot d_t & \text{for } 0 < i < R \\ (b_{t-1,i-1} \cdot (1 + inf_t)) \cdot d_t & \text{for } R \leq i < D \end{cases} \tag{A.6}$$

with

$$d_t = (1 - (1 - \frac{F(t)}{105\%})/3) \tag{A.7}$$

Here d_t is the factor by which the benefit has to be decreased. If we would like to correct the benefits, so that in one year the nominal funding ratio will be back to 105%, we have to multiply the benefit with the fraction of the current nominal funding ratio with the target nominal funding ratio of 105%. However, we want to do this in 3 years, so we will subtract it from one, and divide it by three. This is how much the benefit has to decrease. By calculating the benefit in this way, and not with the absolute surplus, the benefit for every participant of the pension fund will decrease with the same factor. Otherwise, the situation could occur where more money has to be subtracted from the benefit than the individual has accrued.

When the real funding ratio is above 100%, the lost indexation will be caught up in the same way as with the CHDB pension plan given in (3.28) and (3.29).

A.2.3 Pension plan of the health sector in The Netherlands

The model of the HS pension plan is the same as with the CHDB pension plan except for the contribution. Given the contribution ladder shown in figure 2.5 the dynamics of the contribution is

$$c_{t,i} = \begin{cases} 16\% \cdot I_{t,i} - \frac{Sn_t/40}{3} & \text{for } Fn_t < 105\% \\ 16\% \cdot I_{t,i} & \text{for } Fn_t > 105\% \text{ and } Fn_t < 130\% \\ 15\% \cdot I_{t,i} & \text{for } Fn > 130\% \text{ and } Fr_t < 100\% \\ 15\% \cdot I_{t,i} - \frac{Sr_t/15}{40} & \text{for } Fr_t > 100\% \end{cases} \tag{A.8}$$

The indexation and benefit will be calculated in the same way as in (3.23), (3.24),(3.25), (3.26) and (3.27).

Appendix B

A simple example of the Cumulative Prospect Theory

In this section a simple example of the Cumulative Prospect Theory (CPT) found in Tversky and Kahneman (1992) will be discussed. Consider the following situation, roll a dice. If the outcome of the dice is even you receive the outcome. If the outcome is uneven you pay the outcome. The possible positive outcome are you receive 6, 4 or 2 euros, while the possible negative outcomes are pay 1, 3 or 5 euros. Every outcome has a probability of $\frac{1}{6}$. Equation (5.6) will be as follows

$$\begin{aligned} V^+(g,p) &= w^+(p)v(g_1) + \sum_{j=2}^{k} \big([w^+(j \cdot p) - w^+(j-1 \cdot p)]v(g_j)\big) \\ V^-(g,p) &= \sum_{j=k+1}^{n-1} \big([w^-((n-j+1)\cdot p) - w^-((n-j)\cdot p)]v(g_j)\big) + w^-(p)v(g_j) \end{aligned} \tag{B.1}$$

Here is the vector of the outcomes (g) is (6,4,2,-1,-3,-5), p is 1/6, n is 6 and k is 3. Filling in (B.1) we will have:

$$\begin{aligned} V^+(g,p) &= w^+(\frac{1}{6})v(6) + [w^+(2\cdot\frac{1}{6}) - w^+(1\cdot\frac{1}{6})]v(4) + [w^+(3\cdot\frac{1}{6}) - w^+(2\cdot\frac{1}{6})]v(2) \\ V^-(g,p) &= w^-(3\cdot\frac{1}{6}) - w^-(2\cdot 1/6)v(-1) + w^-(2\cdot\frac{1}{6}) - w^-(1\cdot 1/6)v(-3) + \\ &\quad w^-(\frac{1}{6})v(-5) \end{aligned} \tag{B.2}$$

Using the weighted function estimated by Prelec (1998) as shown in (5.8), the utility function shown in (5.3) and the parameters estimated by Doskeland and Nordahl (2008), (B.2) will become

$$\begin{aligned} V^+(g,p) &= 0.26\cdot 2.45 + (0.44-0.26)\cdot 2.00 + (0.59-0.44)\cdot 1.41 \\ &= 1.21 \\ V^-(g,p) &= (0.59-0.44)\cdot -2.25 + (0.44-0.26)\cdot -3.90 + 0.26\cdot -5.03 \\ &= -2.35 \end{aligned} \tag{B.3}$$

Filling the values of (B.3) in (5.4) we will have

$$V(g,p) = V^+(g,p) + V^-(g,p) = 1.21 + -2.35 = -1.14 \tag{B.4}$$

Appendix C

Symbols and abbreviations

Symbols

Age	i
Year	t
Gain	g
Bond	B
Asset	A
Equity	E
Benefit	b
Liability	L
Probability	p
Full benefit	bf
Real surplus	Sr
Contribution	c
Consumption	C
Time of death	D
Price inflation	inf
Wage inflation	$infw$
Nominal Surplus	Sn
Real interest rate	r

Sensitivity of loss	β
Sensitivity of gain	α
Mean stock return	μ
Time of Retirement	R
Real discount factor	CWr
yearly benefit accrual	$a\%$
Volatility stock return	σ
Nominal discount factor	CWn
Fraction invested in equity	θ
Sensitivity loss relative to gain	λ
Risk aversion parameter of EUT	γ
The utility per scenario for the CPT	G
Risk aversion parameter of CPT, $w(p)^+$	ψ
Risk aversion parameter of CPT, $w(p)^-$	δ
Risk aversion parameter of CPT, $w(p)^- = w(p)^+$	φ

Abbreviations

EUT	Expected Utility Theory
CPT	Cumulative Prospect Theory
CRRA	Constant Relative Risk Aversion
IDB	Individual Defined Benefit
CDB	Collective Defined Benefit
IDC	Individual Defined Contribution
CDC	Collective Defined Contribution
HS	Pension plan based on the plan of the Health sector
IHDB	Individual Defined Benefit with conditional indexation
CHDB	Collective Defined Benefit with conditional indexation
The first method	The technique where the contribution is calculated every year to be enough to cover the benefit accrual that year.
The second method	The contribution is calculated to be the average over the working lifetime.

Appendix D

Parameters

Population parameters	Symbol	Value
Time of death	D	55
Time of Retirement	R	40
Yearly benefit accrual	$a\%$	1.75%
Preference parameters EUT	**Symbol**	**Value**
Risk aversion	γ	5, 7, 9
Preference parameters CPT	**Symbol**	**Value**
Sensitivity of loss	β	0.5, 0.48, 0.88
Sensitivity of gain	α	0.5, 0.48, 0.88
Sensitivity loss relative to gain	λ	2.25
Risk aversion parameter of CPT, $w(p)^+$	ψ	0.61
Risk aversion parameter of CPT, $w(p)^-$	δ	0.69
Risk aversion parameter of CPT, $w(p)^- = w(p)^+$	φ	0.75, 0.74
Asset return parameters	**Symbol**	**Value**
Real interest rate	r	2%
Mean stock return	μ	7%
Volatility stock return	σ	15.2%
Price inflation	inf	2%
Wage inflation	$infw$	2.8%
Fraction invested in equity	θ	40%

Appendix E

Results

The full results of the sensitivity analysis are found in this appendix. Sensitivity analysis is executed for different horizons in which underfunding has to be brought back to the margin. Another mean investment return is taken on the basis of a current report done for the government (Don et al. (2009)). Next to changing the mean return, the standard deviation of the return will also be put to a robustness test. Since the initial funding ratio in collective pension plans can have a big influence, the analysis for the collective pension plans will be calculated using a random initial real funding ratio. The last assumption put to the test is the assumption of 40% invested in equity.

The results are depicted as CEC. The IDC pension plan does not settle his deficit. The pension plan gives less benefit instead. This gives a not available result for different time horizons. The HS pension plan is only calculated with the second method giving a not available result for the first method. The first method refers to the technique where the contribution is calculated every year to be enough to cover the benefit accrual that year. The second method represents the contribution calculated to be the average over the working lifetime. γ is the risk averse parameter, where the higher it is the more risk averse an individual is. The papers stand for combination of risk averse parameters. IDB stands for Individual Defined Benefit, IHDB stands for Individual Defined Benefit with conditional indexation, IDC stands for Individual Defined Contribution, CDB stands for Collective Defined Benefit, CHDB stands for Collective Defined Benefit with conditional indexation, CDC stands for Collective Defined Contribution and HS stands for pension plan of the health sector.

Deficit settled on a different horizon

The time horizon chosen to settle the deficit will have an impact on how volatile the contribution is. The shorter the horizon is the more volatile the contribution will be and conversely. The horizon in which the deficit is settled is decreased from 3 years to one year. We also increased the horizon. In the individual setting it is increased to the number of years left to retirement. In the collective setting the deficit is divided by 40, the total number of years in the workforce.

	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
Pension plan	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
$\gamma = 5$						
IDB	1.046	1.055	1.195	1.152	1.196	1.154
IHDB	1.095	1.094	1.226	1.185	1.229	1.189
IDC	1.252	1.208	N.A.	N.A.	N.A.	N.A.
CDB	1.258	1.224	1.293	1.253	1.268	1.222
CHDB	1.293	1.259	1.299	1.259	1.267	1.221
CDC	1.252	1.207	1.252	1.207	1.253	1.208
HS	N.A.	1.230	N.A.	1.233	N.A.	1.235
$\gamma = 7$						
IDB	0.931	0.943	1.111	1.064	1.110	1.059
IHDB	0.982	0.991	1.149	1.102	1.150	1.105
IDC	1.185	1.135	N.A.	N.A.	N.A.	N.A.
CDB	1.172	1.139	1.222	1.177	1.197	1.146
CHDB	1.220	1.179	1.227	1.182	1.197	1.146
CDC	1.185	1.135	1.185	1.135	1.185	1.135
HS	N.A.	1.151	N.A.	1.156	N.A.	1.157
$\gamma = 9$						
IDB	0.863	0.881	1.054	1.002	1.054	1.006
IHDB	0.924	0.931	1.099	1.051	1.101	1.051
IDC	1.139	1.087	N.A.	N.A.	N.A.	N.A.
CDB	1.118	1.079	1.172	1.124	1.149	1.096
CHDB	1.170	1.125	1.177	1.129	1.149	1.096
CDC	1.139	1.087	1.139	1.087	1.139	1.087
HS	N.A.	1.099	N.A.	1.104	N.A.	1.105
Doskeland and Nordahl (2008)						
IDB	1.546	1.565	1.557	1.568	1.566	1.576
IHDB	1.548	1.564	1.556	1.566	1.564	1.573
IDC	1.565	1.574	N.A.	N.A.	N.A.	N.A.
CDB	1.597	1.602	1.602	1.606	1.607	1.612
CHDB	1.584	1.591	1.583	1.589	1.583	1.589
CDC	1.575	1.582	1.575	1.581	1.581	1.588
HS	N.A.	1.594	N.A.	1.584	N.A.	1.590
Tversky and Kahneman (1992)						
IDB	1.581	1.591	1.580	1.589	1.581	1.591
IHDB	1.580	1.590	1.578	1.587	1.580	1.588
IDC	1.576	1.585	N.A.	N.A.	N.A.	N.A.
CDB	1.592	1.599	1.591	1.598	1.593	1.600
CHDB	1.589	1.597	1.589	1.597	1.589	1.597
CDC	1.588	1.595	1.588	1.595	1.588	1.596
HS	N.A.	1.597	N.A.	1.588	N.A.	1.597
Gonzales and Wu (1996)						
IDB	1.584	1.593	1.583	1.592	1.584	1.593
IHDB	1.583	1.592	1.581	1.589	1.582	1.591
IDC	1.579	1.587	N.A.	N.A.	N.A.	N.A.
CDB	1.591	1.598	1.591	1.598	1.592	1.599
CHDB	1.589	1.597	1.589	1.597	1.590	1.597
CDC	1.589	1.596	1.589	1.596	1.589	1.597
HS	N.A.	1.597	N.A.	1.589	N.A.	1.597

Mean return is 6%

Another mean investment return is taken on the basis of a current report done for the government (Don et al. (2009)). The mean return advised by the experts is 6%.

	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
Pension plan	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
$\gamma = 5$						
IDB	1.012	1.022	1.176	1.135	1.171	1.132
IHDB	1.064	1.069	1.217	1.177	1.222	1.181
IDC	1.251	1.206	N.A.	N.A.	N.A.	N.A.
CDB	1.225	1.196	1.280	1.241	1.264	1.218
CHDB	1.279	1.245	1.288	1.249	1.263	1.217
CDC	1.251	1.206	1.251	1.206	1.252	1.207
HS	N.A.	1.220	N.A.	1.225	N.A.	1.227
$\gamma = 7$						
IDB	0.890	0.898	1.087	1.039	1.080	1.035
IHDB	0.953	0.959	1.138	1.094	1.142	1.094
IDC	1.184	1.134	N.A.	N.A.	N.A.	N.A.
CDB	1.143	1.107	1.212	1.166	1.194	1.144
CHDB	1.209	1.167	1.220	1.174	1.194	1.144
CDC	1.184	1.134	1.184	1.134	1.185	1.135
HS	N.A.	1.143	N.A.	1.151	N.A.	1.152
$\gamma = 9$						
IDB	0.825	0.832	1.035	0.977	1.024	0.973
IHDB	0.883	0.895	1.085	1.039	1.091	1.042
IDC	1.139	1.087	N.A.	N.A.	N.A.	N.A.
CDB	1.083	1.042	1.164	1.116	1.147	1.094
CHDB	1.159	1.111	1.172	1.122	1.147	1.094
CDC	1.139	1.087	1.139	1.087	1.139	1.087
HS	N.A.	1.093	N.A.	1.100	N.A.	1.102
Doskeland and Nordahl (2008)						
IDB	1.529	1.545	1.540	1.549	1.547	1.555
IHDB	1.531	1.545	1.538	1.545	1.544	1.551
IDC	1.544	1.552	N.A.	N.A.	N.A.	N.A.
CDB	1.584	1.590	1.586	1.592	1.595	1.601
CHDB	1.570	1.576	1.568	1.574	1.570	1.576
CDC	1.566	1.572	1.566	1.572	1.576	1.583
HS	N.A.	1.581	N.A.	1.569	N.A.	1.575
Tversky and Kahneman (1992)						
IDB	1.575	1.586	1.573	1.583	1.574	1.584
IHDB	1.573	1.583	1.570	1.578	1.571	1.580
IDC	1.568	1.577	N.A.	N.A.	N.A.	N.A.
CDB	1.589	1.597	1.589	1.597	1.590	1.597
CHDB	1.587	1.595	1.587	1.595	1.588	1.596
CDC	1.586	1.593	1.586	1.593	1.587	1.595
HS	N.A.	1.594	N.A.	1.585	N.A.	1.594
Gonzales and Wu (1996)						
IDB	1.579	1.589	1.577	1.586	1.578	1.587
IHDB	1.578	1.587	1.574	1.582	1.575	1.584
IDC	1.573	1.581	N.A.	N.A.	N.A.	N.A.
CDB	1.589	1.597	1.589	1.597	1.590	1.597
CHDB	1.588	1.596	1.588	1.596	1.589	1.597
CDC	1.588	1.595	1.588	1.595	1.589	1.596
HS	N.A.	1.595	N.A.	1.586	N.A.	1.595

Mean return is 7.25%

Another mean investment return is taken on the basis of a current report done for the government (Don et al. (2009)). The social partners recommend a mean return of 7.25%.

Pension plan	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
	Method 1	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
$\gamma = 5$						
IDB	1.058	1.068	1.199	1.158	1.200	1.159
IHDB	1.098	1.103	1.230	1.187	1.233	1.191
IDC	1.253	1.208	N.A.	N.A.	N.A.	N.A.
CDB	1.264	1.230	1.296	1.257	1.269	1.223
CHDB	1.297	1.262	1.302	1.262	1.269	1.222
CDC	1.252	1.207	1.252	1.207	1.253	1.208
HS	N.A.	1.233	N.A.	1.235	N.A.	1.236
$\gamma = 7$						
IDB	0.940	0.952	1.114	1.065	1.115	1.069
IHDB	0.991	1.000	1.151	1.104	1.154	1.104
IDC	1.185	1.135	N.A.	N.A.	N.A.	N.A.
CDB	1.178	1.146	1.223	1.179	1.198	1.146
CHDB	1.223	1.183	1.229	1.183	1.198	1.147
CDC	1.185	1.135	1.185	1.135	1.185	1.135
HS	N.A.	1.152	N.A.	1.157	N.A.	1.158
$\gamma = 9$						
IDB	0.876	0.890	1.064	1.006	1.060	1.012
IHDB	0.926	0.937	1.098	1.051	1.102	1.055
IDC	1.139	1.087	N.A.	N.A.	N.A.	N.A.
CDB	1.128	1.085	1.174	1.126	1.149	1.096
CHDB	1.171	1.127	1.179	1.130	1.150	1.096
CDC	1.139	1.087	1.139	1.087	1.139	1.087
HS	N.A.	1.101	N.A.	1.106	N.A.	1.106
Doskeland and Nordahl (2008)						
IDB	1.551	1.570	1.562	1.573	1.571	1.581
IHDB	1.552	1.569	1.561	1.571	1.569	1.578
IDC	1.570	1.579	N.A.	N.A.	N.A.	N.A.
CDB	1.603	1.608	1.608	1.612	1.610	1.616
CHDB	1.587	1.594	1.587	1.593	1.586	1.592
CDC	1.577	1.584	1.577	1.583	1.582	1.589
HS	N.A.	1.597	N.A.	1.587	N.A.	1.593
Tversky and Kahneman (1992)						
IDB	1.582	1.592	1.582	1.591	1.583	1.592
IHDB	1.581	1.591	1.580	1.589	1.581	1.590
IDC	1.578	1.586	N.A.	N.A.	N.A.	N.A.
CDB	1.593	1.601	1.593	1.600	1.594	1.601
CHDB	1.589		1.589		1.590	
CDC	1.588	1.596	1.588	1.596	1.589	1.596
HS	N.A.	1.597	N.A.	1.589	N.A.	1.597
Gonzales and Wu (1996)						
IDB	1.585	1.594	1.584	1.593	1.585	1.594
IHDB	1.584	1.593	1.583	1.591	1.583	1.592
IDC	1.580	1.589	N.A.	N.A.	N.A.	N.A.
CDB	1.592	1.599	1.592	1.599	1.593	1.600
CHDB	1.589	1.597	1.589	1.597	1.590	1.598
CDC	1.589	1.597	1.589	1.597	1.589	1.597
HS	N.A.	1.597	N.A.	1.589	N.A.	1.597

Standard deviation is 20%

Next to changing the mean return, the standard deviation of the return will also be put to a robustness test. Since there has been no investigation of this by the Committee Parameters (Don et al. (2009)), extreme standard deviation of 20% was chosen.

	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
Pension plan	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
$\gamma = 5$						
IDB	0.910	0.950	1.155	1.124	1.155	1.122
IHDB	0.952	0.995	1.196	1.160	1.204	1.166
IDC	1.251	1.206	N.A.	N.A.	N.A.	N.A.
CDB	1.149	1.118	1.281	1.244	1.269	1.223
CHDB	1.252	1.215	1.295	1.256	1.268	1.222
CDC	1.250	1.205	1.250	1.206	1.252	1.207
HS	N.A.	1.204	N.A.	1.232	N.A.	1.236
$\gamma = 7$						
IDB	0.772	0.822	1.059	1.025	1.059	1.022
IHDB	0.826	0.869	1.109	1.070	1.115	1.073
IDC	1.184	1.134	N.A.	N.A.	N.A.	N.A.
CDB	1.046	1.013	1.208	1.166	1.198	1.147
CHDB	1.166	1.124	1.223	1.179	1.198	1.147
CDC	1.184	1.134	1.184	1.134	1.185	1.135
HS	N.A.	1.117	N.A.	1.154	N.A.	1.159
$\gamma = 9$						
IDB	0.710	0.751	1.006	0.962	1.001	0.960
IHDB	0.755	0.802	1.053	1.014	1.060	1.019
IDC	1.139	1.086	N.A.	N.A.	N.A.	N.A.
CDB	0.979	0.942	1.159	1.113	1.150	1.097
CHDB	1.109	1.067	1.172	1.125	1.150	1.097
CDC	1.139	1.086	1.139	1.087	1.139	1.087
HS	N.A.	1.062	N.A.	1.102	N.A.	1.107
Doskeland and Nordahl (2008)						
IDB	1.541	1.563	1.550	1.565	1.561	1.571
IHDB	1.542	1.562	1.549	1.562	1.558	1.568
IDC	1.560	1.568	N.A.	N.A.	N.A.	N.A.
CDB	1.587	1.594	1.589	1.596	1.603	1.608
CHDB	1.580	1.586	1.577	1.583	1.576	1.582
CDC	1.567	1.574	1.567	1.573	1.575	1.582
HS	N.A.	1.589	N.A.	1.577	N.A.	1.582
Tversky and Kahneman (1992)						
IDB	1.581	1.591	1.578	1.588	1.579	1.588
IHDB	1.579	1.589	1.576	1.585	1.577	1.586
IDC	1.572	1.581	N.A.	N.A.	N.A.	N.A.
CDB	1.590	1.598	1.589	1.597	1.591	1.598
CHDB	1.589		1.589		1.589	
CDC	1.586	1.594	1.586	1.594	1.587	1.595
HS	N.A.	1.596	N.A.	1.587	N.A.	1.595
Gonzales and Wu (1996)						
IDB	1.584	1.593	1.581	1.591	1.582	1.591
IHDB	1.583	1.592	1.579	1.588	1.580	1.589
IDC	1.576	1.584	N.A.	N.A.	N.A.	N.A.
CDB	1.590	1.597	1.589	1.597	1.590	1.598
CHDB	1.589	1.597	1.589	1.597	1.589	1.597
CDC	1.588	1.596	1.588	1.596	1.589	1.596
HS	N.A.	1.597	N.A.	1.588	N.A.	1.596

Standard deviation is 10%

Also, a standard deviation of 10% for the investment return is used for the analysis.

Pension plan	Surplus settled in 1 year Method 1	Surplus settled in 1 year Method 2	Surplus settled in 1 year Method 1	Surplus settled in 1 year Method 2	Surplus settled gradually Method 1	Surplus settled gradually Method 2
			$\gamma = 5$			
IDB	1.203	1.174	1.236	1.189	1.237	1.191
IHDB	1.219	1.189	1.251	1.207	1.251	1.208
IDC	1.254	1.209	N.A.	N.A.	N.A.	N.A.
CDB	1.295	1.259	1.298	1.255	1.267	1.220
CHDB	1.299	1.263	1.299	1.257	1.266	1.220
CDC	1.253	1.208	1.253	1.208	1.253	1.208
HS	N.A.	1.231	N.A.	1.231	N.A.	1.231
			$\gamma = 7$			
IDB	1.121	1.089	1.163	1.106	1.161	1.111
IHDB	1.145	1.109	1.181	1.130	1.180	1.130
IDC	1.185	1.135	N.A.	N.A.	N.A.	N.A.
CDB	1.225	1.182	1.226	1.178	1.196	1.144
CHDB	1.228	1.186	1.228	1.179	1.196	1.144
CDC	1.185	1.135	1.185	1.135	1.185	1.135
HS	N.A.	1.154	N.A.	1.154	N.A.	1.154
			$\gamma = 9$			
IDB	0.863	0.881	1.054	1.002	1.054	1.006
IHDB	0.924	0.931	1.099	1.051	1.101	1.051
IDC	1.139	1.087	N.A.	N.A.	N.A.	N.A.
CDB	1.118	1.079	1.172	1.124	1.149	1.096
CHDB	1.170	1.125	1.177	1.129	1.149	1.096
CDC	1.139	1.087	1.139	1.087	1.139	1.087
HS	N.A.	1.099	N.A.	1.104	N.A.	1.105
			Doskeland and Nordahl (2008)			
IDB	1.555	1.568	1.567	1.573	1.573	1.582
IHDB	1.557	1.568	1.566	1.571	1.571	1.580
IDC	1.572	1.582	N.A.	N.A.	N.A.	N.A.
CDB	1.611	1.617	1.617	1.621	1.609	1.616
CHDB	1.589	1.596	1.591	1.596	1.590	1.597
CDC	1.584	1.591	1.584	1.591	1.587	1.594
HS	N.A.	1.603	N.A.	1.590	N.A.	1.598
			Tversky and Kahneman (1992)			
IDB	1.582	1.591	1.583	1.591	1.584	1.593
IHDB	1.581	1.590	1.582	1.588	1.583	1.592
IDC	1.581	1.589	N.A.	N.A.	N.A.	N.A.
CDB	1.595	1.602	1.597	1.603	1.597	1.604
CHDB	1.590	1.597	1.590	1.598	1.591	1.598
CDC	1.589	1.597	1.589	1.597	1.589	1.597
HS	N.A.	1.598	N.A.	1.589	N.A.	1.597
			Gonzales and Wu (1996)			
IDB	1.584	1.593	1.585	1.593	1.586	1.594
IHDB	1.584	1.592	1.584	1.591	1.585	1.593
IDC	1.583	1.591	N.A.	N.A.	N.A.	N.A.
CDB	1.594	1.601	1.595	1.602	1.596	1.603
CHDB	1.590	1.597	1.590	1.598	1.592	1.599
CDC	1.589	1.597	1.589	1.597	1.589	1.597
HS	N.A.	1.598	N.A.	1.589	N.A.	1.597

CEC 100 years from now with EUT

Since the initial funding ratio in collective pension plans can have a big influence, the analysis for the collective pension plans will be calculated using a random initial real funding ratio. A random initial real funding ratio is calculated by simulating 100 years in advance before calculating the consumption path for an individual. The CEC is also calculated with an initial real funding ratio of 100%, but where the income is corrected for 100 years wage inflation. This is done to make a comparison with the results of the previous section.

	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
Pension plan	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
			$\gamma = 5$			
IDB	16.151	16.302	18.392	17.751	18.392	17.757
IHDB	16.790	16.876	18.886	18.240	18.939	18.306
IDC	19.278	18.592	N.A.	N.A.	N.A.	N.A.
CDB	19.324	18.862	19.898	19.296	19.518	18.805
CHDB	21.222	20.865	21.225	20.906	21.083	20.514
CDC	19.289	18.594	19.288	18.594	19.289	18.595
HS	N.A.	20.869	N.A.	20.883	N.A.	20.891
			Random initial real funding ratio			
CDB	18.999	18.292	19.890	19.187	20.613	19.882
CHDB	20.140	19.453	20.382	19.725	21.048	20.410
CDC	19.825	19.111	19.823	19.109	19.812	19.097
HS	N.A.	19.869	N.A.	19.940	N.A.	20.046
			$\gamma = 7$			
IDB	14.318	14.482	17.070	16.317	17.060	16.363
IHDB	15.141	15.266	17.684	16.970	17.722	16.978
IDC	18.238	17.466	N.A.	N.A.	N.A.	N.A.
CDB	18.060	17.533	18.802	18.110	18.423	17.634
CHDB	19.802	19.321	19.814	19.369	19.748	19.083
CDC	18.244	17.469	18.244	17.469	18.244	17.470
HS	N.A.	19.332	N.A.	19.352	N.A.	19.361
			Random initial real funding ratio			
CDB	17.574	16.814	18.756	17.976	19.473	18.684
CHDB	18.976	18.208	19.274	18.542	19.884	19.187
CDC	18.754	17.957	18.753	17.957	18.750	17.954
HS	N.A.	18.653	N.A.	18.748	N.A.	18.856
			$\gamma = 9$			
IDB	13.333	13.527	16.290	15.398	16.213	15.472
IHDB	14.133	14.281	16.859	16.139	16.915	16.199
IDC	17.534	16.729	N.A.	N.A.	N.A.	N.A.
CDB	17.189	16.625	18.041	17.300	17.682	16.865
CHDB	18.811	18.225	18.829	18.275	18.800	18.075
CDC	17.536	16.730	17.536	16.730	17.536	16.730
HS	N.A.	18.238	N.A.	18.262	N.A.	18.270
			Random initial real funding ratio			
CDB	16.628	15.856	17.988	17.178	18.701	17.892
CHDB	18.173	17.373	18.511	17.747	19.092	18.374
CDC	18.026	17.198	18.026	17.198	18.026	17.198
HS	N.A.	17.843	N.A.	17.955	N.A.	18.061

CEC 100 years from now with CPT

A random initial real funding ratio is also taken when the analysis is done for the CPT.

	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
Pension plan	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
Doskeland and Nordahl (2008)						
IDB	23.803	24.087	23.973	24.141	24.110	24.255
IHDB	23.832	24.083	23.956	24.099	24.070	24.211
IDC	24.093	24.232	N.A.	N.A.	N.A.	N.A.
CDB	24.580	24.662	24.660	24.728	24.734	24.820
CHDB	24.336	24.411	24.329	24.401	24.319	24.406
CDC	24.246	24.347	24.242	24.343	24.339	24.447
HS	N.A.	24.486	N.A.	24.286	N.A.	24.409
	Random initial real funding ratio					
CDB	25.882	25.891	25.850	25.852	26.451	26.388
CHDB	25.651	25.647	25.650	25.638	26.670	26.622
CDC	25.104	25.162	25.088	25.143	24.929	24.956
HS	N.A.	26.122	N.A.	26.095	N.A.	26.070
Tversky and Kahneman (1992)						
IDB	24.334	24.494	24.327	24.467	24.342	24.485
IHDB	24.317	24.470	24.294	24.424	24.313	24.451
IDC	24.265	24.393	N.A.	N.A.	N.A.	N.A.
CDB	24.501	24.614	24.495	24.605	24.522	24.630
CHDB	24.458	24.571	24.461	24.576	24.462	24.578
CDC	24.439	24.556	24.438	24.554	24.450	24.567
HS	N.A.	24.581	N.A.	24.406	N.A.	24.572
	Random initial real funding ratio					
CDB	26.929	26.877	26.828	26.757	27.327	27.211
CHDB	26.525	26.444	26.480	26.378	27.422	27.311
CDC	25.627	25.577	25.603	25.550	25.405	25.330
HS	N.A.	26.854	N.A.	26.821	N.A.	26.781
Gonzales and Wu (1996)						
IDB	24.381	24.528	24.367	24.502	24.376	24.516
IHDB	24.364	24.507	24.338	24.466	24.352	24.489
IDC	24.306	24.435	N.A.	N.A.	N.A.	N.A.
CDB	24.489	24.604	24.484	24.597	24.508	24.618
CHDB	24.463	24.580	24.465	24.582	24.466	24.584
CDC	24.456	24.574	24.455	24.573	24.460	24.578
HS	N.A.	24.584	N.A.	24.421	N.A.	24.581
	Random initial real funding ratio					
CDB	27.038	26.975	26.906	26.820	27.394	27.254
CHDB	26.574	26.475	26.500	26.376	27.494	27.359
CDC	25.791	25.726	25.768	25.701	25.580	25.486
HS	N.A.	26.854	N.A.	26.819	N.A.	26.771

Fraction invested in equity 50%

The last assumption put to the test is the fraction invested in equity. The analysis is done with the assumption that 40% is invested in equity, because the fraction invested in equity decreased after the economic crisis. However, in 2008 it was nearly 50%. To see what the effects are on CEC if the fraction invested in equity did not decreased, the analysis is done over with 50% invested in equity.

	Surplus settled in 1 year		Surplus settled in 1 year		Surplus settled gradually	
Pension plan	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
			$\gamma = 5$			
IDB	0.964	1.003	1.178	1.143	1.181	1.145
IHDB	1.004	1.042	1.212	1.173	1.218	1.179
IDC	1.252	1.208	N.A.	N.A.	N.A.	N.A.
CDB	1.210	1.177	1.293	1.256	1.272	1.226
CHDB	1.280	1.245	1.303	1.265	1.272	1.225
CDC	1.252	1.207	1.252	1.207	1.253	1.208
HS	N.A.	1.224	N.A.	1.239	N.A.	1.241
			$\gamma = 7$			
IDB	0.831	0.881	1.087	1.049	1.089	1.051
IHDB	0.885	0.926	1.128	1.086	1.133	1.089
IDC	1.185	1.135	N.A.	N.A.	N.A.	N.A.
CDB	1.109	1.082	1.220	1.177	1.200	1.148
CHDB	1.196	1.156	1.230	1.185	1.200	1.149
CDC	1.185	1.135	1.185	1.135	1.185	1.135
HS	N.A.	1.140	N.A.	1.159	N.A.	1.162
			$\gamma = 9$			
IDB	0.770	0.814	1.034	0.987	1.033	0.991
IHDB	0.814	0.860	1.071	1.031	1.079	1.035
IDC	1.139	1.087	N.A.	N.A.	N.A.	N.A.
CDB	1.047	1.011	1.169	1.123	1.151	1.098
CHDB	1.140	1.099	1.178	1.130	1.151	1.098
CDC	1.139	1.087	1.139	1.087	1.139	1.087
HS	N.A.	1.083	N.A.	1.106	N.A.	1.109
			Doskeland and Nordahl (2008)			
IDB	1.559	1.582	1.568	1.584	1.580	1.591
IHDB	1.560	1.582	1.568	1.582	1.578	1.588
IDC	1.580	1.589	N.A.	N.A.	N.A.	N.A.
CDB	1.602	1.607	1.608	1.611	1.613	1.618
CHDB	1.589	1.596	1.588	1.594	1.586	1.592
CDC	1.574	1.581	1.574	1.581	1.580	1.587
HS	N.A.	1.597	N.A.	1.587	N.A.	1.593
			Tversky and Kahneman (1992)			
IDB	1.585	1.595	1.584	1.593	1.585	1.594
IHDB	1.584	1.594	1.583	1.592	1.584	1.592
IDC	1.579	1.587	N.A.	N.A.	N.A.	N.A.
CDB	1.594	1.601	1.593	1.600	1.594	1.601
CHDB	1.590	1.597	1.590	1.597	1.590	1.597
CDC	1.588	1.595	1.588	1.595	1.588	1.596
HS	N.A.	1.597	N.A.	1.589	N.A.	1.597
			Gonzales and Wu (1996)			
IDB	1.587	1.596	1.586	1.594	1.586	1.595
IHDB	1.586	1.595	1.584	1.593	1.585	1.594
IDC	1.581	1.589	N.A.	N.A.	N.A.	N.A.
CDB	1.593	1.600	1.592	1.599	1.593	1.600
CHDB	1.590	1.597	1.590	1.597	1.590	1.597
CDC	1.589	1.596	1.589	1.596	1.589	1.597
HS	N.A.	1.597	N.A.	1.589	N.A.	1.597

Bibliography

Aaron, H.J. (1999). *Behavioural dimensions of retirement economics.* Brookings Institution Press.

AI (2010). Ag-tafels 2003-2008. Technical report, Actuarieel genootschap en actuarieel instituut, Groenewoudsedijk 80, 3528BK, Utrecht, The Netherlands.

Allais, P.M. (1953). Le comportement de l'homme rationnel devant le risque: critique des postulats et axiomes de lcole americaine. *Econometrica 21*(4), 503–546.

Ballotta, L. and S. Haberman (2006). The fair valuation problem of guaranteed annuity options: The stochastic mortality environment case. *Insurance: Mathematics and Economics 38*, 195214.

Beetsma, R.W.J. and P.C. Schotman (2001). Measuring risk attitude in a natural experiment: data from the television show lingo. *Economic Journal*, 821–848.

Black, F. and M. Scholes (1973). The pricing of options and corporate liabilities. *The journal of political economy 81*(3), 637–654.

Blommenstein, H., P. Janssen, N. Kortleve, and J. Yermo (2009). Moving beyond the 'db vs. dc' debate: The appeal of hybrid pension plans. *Rotman International Journal of pension management 2*(2).

Bodie, B., A. Kane, and A. Marcus (2009). *Investments.* McGraw-hill.

Cmaerer, C.F. and T. Ho (1994). Violations of the betweeness axiom and nonlinearity in probability. *Journal of risk and uncertainty 8*, 167–196.

Cui, J, F de Jong, and E. Ponds (2005). The value of intergenerational transfers within funded pension schemes. *Netspar*.

Cui, J, F de Jong, and E. Ponds (2006). Intergenerational risk sharing within funded pension schemes. *Netspar*.

Don, F., C. Driessen, C. van Ewijk, K. Knot, and K. van Popta (2009). Advies betreffende parameters pensioenfondsen. Commissie: Parameters, Government.

Doskeland, T.M. and A Nordahl, H (2008). Optimal pension insurance design. *Journal of Banking & Finance 32*, 382392.

ECB (2004). Executive board of the ecb. Technical report, European Central Bank, Kaiserstrasse 29, 60311 Frankfurt am Main, Germany.

Frijns, J., J. Nijsen, and L. Scholtens (2010). Pensioen:"onzekere zekerheid". Comissie:beleggingsbeleid en risicobeheer, Government.

Gollier, C. (2008). Intergenerational risk-sharing and risk-taking of a pension fund. *Journal of public economics 92*, 1463–1485.

Gonzales, R. and G. Wu (1996). Curvature of the probability weighting function. *management science 42*(12), 1676–1690.

Goudswaard, K., R. Beetsma, Th. Nijman, and P. Schnabel (2010). Een sterke tweede pijler. Commissie: Toekomstbestendigheid aanvullende pensioenregelingen, Government.

Hoevenaarsa, R. and E. Ponds (2008). Valuation of intergenerational transfers in funded collective pension schemes. *Insurance: Mathematics and Economics 42*, 578593.

Janssen, P. (2006). Welfare effects and robustness of generation specific pension deals. Master thesis, Universiteit van Tilburg.

Kahneman, D. and A. Tversky (1984). Choices, values and frames. *American psychologist 39*, 341–350.

Kakes, J. and D. Broeders (2006). De houdbaarheid van het nederlandse pensioenstelsel. *DNB Occasional Studies 4*(6).

Van der Lecq, S.G. and O.W. Steenbeek (2006). *Kosten en baten van collectieve pensioensystemen*. Kluwer.

Lee, R.D. and L.R. Carter (1992). Modelling and forecasting u.s. mortality. *Journal of the American Statistic Association 87*(419), 659–671.

OECD (2005). Private pensions, oecd classification and glossary. Technical report, Organisation for economic co-operation and development, rue Andr-Pascal, 75775 Paris Cedex 16, France.

Oficer, R. (1972). The distribution of stock returns. *Joutnal of the american statistical association 67*(340), 807–812.

PFZW (2009). Jaarverslag 2008. Technical report, Stichting Pensioenfonds Zorg en Welzijn.

Pinkse, C. and H. Bruijns (1992). *Financiele rekenkunde*. Noordhoff Uitgevers B.V.

Ponds, E. and B. Van Riel (2007). The recent evolution of pension funds in the netherlands: The trend to hybrid db-dc plans and beyond.

Prelec, D. (1998). The probability weighting function. *Econometrica 66*(3), 497–527.

van Rooij, M., A. Siegman, and P. Vlaar (2005). Palmnet: A pension asset and liability model for the netherlands. DNB Research memorandum WO 760, DNB.

Schuit, M. (2006). Collectief dc in opkomst. *Pensioen bestuur en management* (3), 46–48.

Tamerus, J. (2009). Durven we de nominale garanties los te laten? *Tijdschrift voor Pensioen vraagstukken*.

Teulings, C. and C. de Vries (2006). Generational accounting, solidarity and pension losses. *De economist 154*(1), 63–83.

Tversky, A. and D. Kahneman (1979). Prospect theory: An analysis of decision under risk. *Econometrica 47*(2), 263–274.

Tversky, A. and D. Kahneman (1986). Rational choice and the framing of decisions. *The journal of business 59*(4), 251–278.

Tversky, A. and D. Kahneman (1991). Loss aversion in riskless choice: a reference-dependent model. *The quarterly journal of economics 106*(4), 1039–1061.

Tversky, A. and D. Kahneman (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty* (5), 297–323.

Van Els, P., W. Van den End, and M. Rooij (2004). Pensions and public opinion: A survey among dutch households. *De Economist 152*(1), 101–116.

Van Hemert, O. (2005). optimal intergenerational tisk sharing. Technical report, Swedish institute for financial research, Universiteit van amsterdam.

Van Rooij, M., C. Kool, and H. Prast (2004). Risk-return preferences in the pension domain: are people able to choose? Discussion paper 04-05, Tjalling C. Koopmans Research Institute.

Varian, H.R. and R.H. Gordon (1988). Intergenerational risk sharing. *Journal of public economics 37*, 185–202.

VB (2009). Vragen en antwoorde:onderdekking pensioenfondsen. Technical report, Vereniging van Bedrijfstakpensioenfondsen.

Von Neumann, J. and O. Morgenstern (1953). *Theory of games and economic behavior.* Princeton university press.

Wijbenga, B. (2009). Intergenerational risk-sharing and changing demographics in a defined benefit pension scheme. Master thesis, RijksUniversiteit groningen.