The consequences of changes in the term structure methodology

A study on the consequences of introducing the UFR-methodology for Dutch pension funds

A thesis submitted in partial fulfillment of the requirements for the degree of Master in Quantitative Science and Actuarial Science

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Abstract

The yield curve methodology used by the Dutch Central Bank for the term structures for pension funds has changed as of September 2012. Low market rates, a persistent economic crisis and assumed illiquidity of the swap market beyond 20 years have cleared the way for the implementation of the UFR-methodology in the yield curve. A direct consequence for Dutch pension funds is a sudden increase in the funding ratios. In this thesis the consequences of the changed yield curve methodology for Dutch pension funds are further illustrated. Looking at the effects on the coverage ratio and cost-effective contribution, the implementation of the new methodology improved the financial situation of pension funds. The coverage ratio has increased, and the volatility seems to decrease with the new methodology.

Higher coverage ratios will prevent or lower rights cuts in 2015, when the new financial assessment framework is likely to be fully operational. The new methodology will be in favor of the older participants of the funds, as a large part of their financial capital is put into the pension fund and their human capital has diminished. The full effect for the younger participants is not clear at this moment in time.

In the new methodology, choices have to be made regarding a number of key input parameters. A solid theoretical and empirical basis on which these choices are made seems to be missing at this moment in time. At the end, when the interest rates cannot meet their expectations in the long run (i.e. the ultimate forward rate), pension funds can be in trouble. Pension funds then have paid higher pension benefits to the pensioners and assigned more pension accrual to the participants then they could afford ex post. An overestimation of the financial status at this moment in time can cause for a (more) asymmetric distribution of capital over generations within pension funds.
Acknowledgements

First I want to express my gratitude towards my supervisor, Dr. R.J. Mahieu, for his help in the process of writing my thesis. His quick responses to my questions and clear communication allowed for a smooth process, which prevented unnecessary delays. He guided me through the process with helpful comments and interesting questions, which inspired me to think even more thoroughly about my thesis subject.

Then I would like to thank my supervisor from PwC, Dirk-Symon Siesling, for his helpful comments and suggestions during my internship. His help made the process run quicker and his suggestions resulted in a thesis which is besides theoretical, also practical. Thanks also to everyone from PAIS for allowing for pleasant working conditions and valuable suggestions.

My studies would not have been the same without my close friends and fellow students. Working with you and enjoying my study time in Tilburg with you was great.

Last, but certainly not least, I would like to thank my parents and sister who supported and motivated me unconditionally during my studies.
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Chapter 1

Introduction

Pension plans are a popular topic of discussion in the Netherlands, because of demographic changes (e.g. aging population), the financial crisis, the sovereign debt crisis and currently low interest rates. Pensions were not considered to be very interesting until one realized how much money is invested and what is at stake for the Dutch working (and retired) population. In pension funds alone, approximately €873bn\(^1\) is invested in financial markets, which is more than 145% of the Dutch Gross Domestic Product (GDP).

The valuation method of Dutch pension funds until 2006 was straightforward; all cash flows (independent of the maturity of the cash flow) were valued at a constant interest rate of 4%\(^2\). This resulted in coverage ratios which were only dependent on the financial market through the assets. As of 2006, pension funds had to value their liabilities using a fair-value approach (market valuation) (see Ewisk 2005), resulting in coverage ratios which were a better representation of the financial situation of the fund. An advantage of this method is that both assets and liabilities are valued using the same yield curve which creates more insight. The disadvantage of using the fair-value approach is that the coverage ratios become much more volatile (see Rebel 2012). Another disadvantage of valuing pension liabilities using market-valuation emerged when the interest rate decreased. The value of the pension liabilities increased rapidly, resulting in higher pension liabilities which led to decreasing coverage ratios. Pension fund became underfunded mainly because of the market conditions at that moment in time. To cope with the lower interest rate, the economic crisis and an assumed illiquidity of the swap market beyond 20 years maturity, the valuation method for pension liabilities is adapted again. As of September 2012, the valuation of pension fund liabilities became a mix between market valuation and a (fixed) stability factor, in anticipation of the new financial assessment framework (ftk) for Dutch pension funds (see Ministry of Social Affairs and Employment 2012).

\(^1\)At the end of 2011

\(^2\)Pension funds could value their liabilities using a lower interest rate when they asked for dispensation. However, since a lower interest rate would yield a lower funding ratio, not many pension funds used this opportunity.
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Figure 1.1: Funding ratio largest 5 pension funds before and after the introduction of the UFR-methodology

<table>
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<tr>
<th></th>
<th>ABP</th>
<th>ZW</th>
<th>PMT</th>
<th>Bouwnijverheid</th>
<th>PME</th>
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<tr>
<td>Avg. June, July and August</td>
<td>91.7%</td>
<td>93.3%</td>
<td>88.1%</td>
<td>98.1%</td>
<td>88.1%</td>
</tr>
<tr>
<td>Avg. September, October and November</td>
<td>97.0%</td>
<td>99.3%</td>
<td>91.4%</td>
<td>104.6%</td>
<td>93.5%</td>
</tr>
<tr>
<td>Difference</td>
<td>5.3%</td>
<td>6.0%</td>
<td>6.3%</td>
<td>6.5%</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

Table 1.1: 3-Month average funding ratio five largest pension funds in the Netherlands before and after the introduction of the UFR-methodology

The modification to the yield curve results in higher coverage ratios (at this moment in time), from which some think they are artificially high. According to the Dutch Central Bank (DNB), the data used to calculate the interest rate curve is not reliable beyond 20 years maturity because the illiquidity of the market after that moment in time.

Therefore, DNB calculates the yield for long durations differently, constructing the long-term interest rates using a linear combination of market forward rates and a fixed (long-term) forward rate, called the ultimate forward rate (UFR). Artificial or not, the result of the policy change is that the coverage ratio of Dutch pension funds have risen after the introduction of the new yield curve methodology, as shown in Figure 1.1 and Table 1.1 for the five largest pension funds in the Netherlands.

In the end, if the newly introduced yield curve ex post appears to be too high, the policy change now will result in pensions which are paid to the pensioners that pension funds cannot afford. The bill of paying too high pensions now will ultimately have to be paid by the younger generations, as intergenerational value transfers take place from the younger to the older generations.

3Opinion of Werker, van Wijnbergen, de Jong and Kocken (2012) in Financieel Dagblad: DNB speelt hoog spel met introductie van rekenrente die niet bepaald risicovrij is; Noodzakelijke aanpassing van de nieuwe rekenrente voorkomt ongewenste bijeffecten

4The largest five pension funds in the Netherlands are respectively Algemeen Burgerlijk Pensioenfonds (ABP), Zorg en Welzijn (ZW), Metaal en Techniek (PMT), Bouwnijverheid and Metaelektro (PME)
1.1 Bases of the new methodology

Knowing the main reasons of the DNB to adapt the yield curve, one can form an opinion about the new term methodology. The illiquidity presumption of the swap market after 20 years is disputable, since the size of the trading volume of 15-20 years swaps is not so different from the 20-30 year swaps as can be seen in Table A.1 and in Blake et al. (2012). In Carlin (2010) this is also discussed; where it is stated that illiquidity is not defined uniformly. Liquidity of the market can be defined as the ability to transact normal market sizes without moving the price, but also as the ability of the entire insurance industry to undertake large scale hedging without moving the price. These two definitions could lead to two different conclusions regarding the liquidity of the financial market after 20 years. Besides this, when the long term interest rate based on less swap contracts still represents a proper expectation of the long term interest rate, a less liquid market after 20 years is not a problem at all. In light of this, the difference between supply and demand for these long term contracts is more important.

Low interest rates can be observed from the market the last years, as can be seen for the Eurozone in Figure 1.2. During this period Europe faces the credit crisis, the sovereign debt crisis and political crises (in several countries). These are probably the main drivers behind the low interest rates and the trigger for the DNB to artificially raise the long-term interest rate to correct for these extreme market conditions and to make the yield curve more consistent with the long-term average. In the new methodology, the forward rate in the euro zone for the long run (from 60 years on) is fixed to the ultimate forward rate of 4.2%. Note that at 60 years maturity the UFR is about 134 basis points (bp) higher than the observed forward rate from the market. The UFR is set to this percentage being the sum of the long-term expected inflation rate (2.0%) and the expected real rate (2.2%). Introducing the UFR to correct for current market conditions implicitly...

On 31 August 2012
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assumes that the long-term forward rate will ultimately revert to this level again and is thus based on a mean reversion assumption of the long-term forward rate. The expected long-term inflation rate is set to the explicit target for the inflation rate of the European Central Bank (ECB), which seems to be appropriate. The expectation of the real rate of return is less trivial, since this value is based on historical data. The estimation of the expected real rate is based on historical averages of the real rate of 19 economies obtained from earlier work of Dimson et al. (2000). The average real rate of the whole 20th century according to this publication is equal to 1.7%. In an earlier publication of the same author, the averages of the real rate are obtained of the first half of the 20th century (-1.1%) and the second half of the 20th century (2.3%). Based on these averages, it is stated in the Quantitative Studies 5 (QIS5) report (see European Insurance and Occupational Pensions Authority, 2010) that the long term expected real rate of 2.2% is an adequate estimate. This decision is criticized by (among others) Nobel Laureate Robert Merton and Blake (see Blake et al., 2012), because of the way it is constructed and its rather high value. Blake et al. (2012) state that no clear mean reversion patterns are observed in historical interest rates and that a stationary value of the long-term forward rate should be adjusted over time as interest rates fluctuate considerably. Note that this would mean that the ultimate forward rate should be constructed in a different manner.

Interest rates can be low for a long period of time as is the case in Japan (see Figure 1.3), where the interest is low for over a decade.

Pension funds are important participants in the financial (swap) market, and have the ability to influence the swap market when there is a sudden shock in the demand for interest rate swaps with a particular duration. A policy decision of DNB can cause such a shock, as the demand for 20 year swap would increase when the method described in QIS5 would have been introduced. This would happen when pension funds try to cover their interest rate risk as illustrated by Kocken et al. (2012). However, DNB chose to adapt this method which prevents large distortions in the hedging demand of pension funds.

In the next section, the research questions which will be answered throughout this thesis are stated. In the last section of the introduction the outline of the remainder of this thesis is illustrated.

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6The average is the weighted average (by GDP) of the real rates of the individual countries

7The following 19 economies are used in the comparison: Belgium, Italy, Germany, Finland, France, Spain, Ireland, Norway, Japan, Switzerland, Denmark, Netherlands, New Zealand, UK, Canada, US, South Africa, Sweden and Australia

8The following 12 economies are used for the comparison: Italy, Germany, France, Japan, Switzerland, Denmark, Netherlands, UK, Canada, US, Sweden and Australia

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1.2 Research questions

Throughout this thesis, the answers to the following research questions will be given:

1. What has changed in the valuation method of the liabilities of Dutch pension funds?
2. Are the effects for pension fund participants and sponsors positive, if there are any effects?
3. Will the new valuation method lead to intergenerational value transfers?
4. Why has DNB changed the valuation method for pension liabilities?
5. What are the funding consequences for Dutch pension funds of the changed methodology?
6. What are the consequences for the cost-effective contribution of Dutch pension funds?

I will concentrate solely on the interest rate risk of Dutch pension funds. To be able to isolate the effects of the change in interest rate methodology, all other risks are assumed to be constant and left out of the scope of this thesis.

1.3 Outline of this thesis

The remainder of this thesis will be organized in the following way. First, the regulatory framework surrounding Dutch pension funds will be discussed in Chapter 2, after which the technical background of this thesis will be given in Chapter 3. The methodology used to create the term structure to value pension liabilities of Dutch pension funds before September 2012, as well as the new methodology which is currently used to value the liabilities of Dutch pension funds is treated in Chapter 4. In Chapter 5, the consequences of the new methodology for Dutch pension funds regarding the level and volatility of the funding ratio as well as the consequences for the cost-effective contribution pension funds have to charge the sponsors and participants are illustrated. After Chapter 5, all findings are summarized in the conclusion in Chapter 6 after which in Chapter 7 recommendations for further research are given.
Chapter 2

Regulating pension funds

In this chapter, after a general introduction of pensions, the regulatory framework for pension funds will be discussed. This framework will be adapted in the near future. An elaboration will be made on the consequences for pension funds and pension fund participants of the transition from ftk, with full market-valuation for liabilities and ex post recovery plans, to the new financial assessment framework (ftkII). In the new financial assessment framework, the UFR-methodology is implemented in the valuation for liabilities and ex ante recovery plans are used to recover from an underfunded position. With these recovery plans it is clear in advance what will happen when a pension funds reaches an underfunded position.

2.1 Pensions in the Netherlands

Pensions can be divided into three pillars. The first pillar is a state pension called the AOW in the Netherlands, that Dutch citizens receive irrespective of their contribution to the system and is on a pay-as-you-go (PAYG) basis. The second pillar is a work-based pension, dependent on the contributions of participants and sponsors (employers) and insures against standard of living risk. This second pillar is funded, and pension funds manage a large part of these pensions. Pension fund can be divided into company pension funds and industry-wide pension funds, and aim at a pension level based on a fixed percentage of the average salary or final salary of the participants (e.g. 70%). When the funding ratio of the pension fund is not high enough to guarantee this pension, the sponsor bears a large part of the risk. The sponsor then has to pay for (a large part of) the deficit. So the benefits are defined and the contributions are not fixed in advance (defined-benefit pension plans). Insurance companies also manage a large part of the second pillar pensions. These contracts are often based on a fixed contribution level. The pension payment depends on the results on the financial market over the years (defined-contribution pension plans). The third pillar is a funded private (voluntary) pension, and is meant for the self-employed who do not have a second pillar pension and for individuals who want to save for an additional pension. Insurance companies have to follow the regulations in the solvency framework, and pension funds have their own
regulatory framework: the financial assessment framework.

2.2 The financial assessment framework

2.2.1 Current financial assessment framework

The regulatory framework used to be rather decorative because of the large returns on assets and high interest rates, creating a high value of the assets and a low value of the liabilities resulting in sky high coverage ratios of pension funds. Surpluses were even sufficiently high to reduce contribution levels (premium holidays). The ftk is introduced in January 2007 in the Netherlands and was designed to cope with situations in which coverage ratios would drop and critical decisions regarding the pensions of pension fund participants had to be taken. This framework becomes effective whenever a nominal coverage ratio drops below the minimum required buffer of approximately 20% (minimum required capital level), or the probability that next years nominal coverage ratio is below 100% is higher than 2.5%. Note that a nominal coverage ratio below 100% means that a pension fund has less money than it expects that it is obliged to pay out in the future in nominal terms, and that a pension fund cannot correct the pension benefits for inflation. Pension funds often have the ambition to correct for inflation to protect participants against inflation risk and standard-of-living risk. The most important rules regarding the coverage ratio are:

- Below a nominal coverage ratio of 105% a recovery plan has to be made with a recovery period of maximum 3 years.
- Between a nominal coverage ratio of 105% and 120% a recovery plan has to be made with a recovery period of maximum 15 years.

Figure 2.1: Average coverage ratio of Dutch pension funds
Shortcomings financial assessment framework

When the crisis started to develop and coverage ratios dropped below 105% for many pension funds, pension funds thought that they would recover within a couple of years. Therefore many pension funds asked permission at the Dutch Central Bank to delay their obligatory submission date for a recovery plan, and most funds got it. Recovering from an underfunded position can take place on the asset side of the balance sheet and on the liability side. A higher value of the assets can be established for example by increasing the contribution rate, and the goal of a lower value of the liabilities can be reached when less (or no) indexation is applied or when pension rights are cut. Note that the Dutch population is aging and that the effect of an increased contribution rate is small due to the large amount of capital of pension fund compared to the sum of the pension premiums. To recover from an underfunded position, pension funds often provide no full indexation (or no indexation at all) to the pension rights of participants, depending on the financial situation of the fund. A possible indexation policy of a pension fund is illustrated in Figure 2.2. Below a nominal funding ratio of 100% no indexation is applied on the pension rights, above a real funding ratio of 100% (corresponding to a nominal funding ratio of approximately 140%-150%), full indexation is applied and partial indexation is provided in between. However, some pension funds choose to provide full indexation above the minimum required capital level, reached at a nominal funding ratio of approximately 120%. As the crisis stayed and the interest rates remained

![Figure 2.2: Possible indexation policy pension fund](image)

at their low levels, pension funds became continuously underfunded (see Figure 2.1) and the methodology used to construct the yield curve became a topic of discussion. The Dutch Central Bank had to design a new framework which was better equipped to cope with the dynamic economic environment. One problem this new framework had to tackle was the allocation of the funding surplus of pension funds. When the nominal funding ratio is below 100%, pension benefits are higher than the pension fund can afford. When the real funding ratio is above 100%, the buffer is larger than needed and the pension
benefits could be higher. When in the first half of this century the real funding ratios were larger than 100%, no explicit decisions were made regarding the (positive) funding surplus, but because of the luxury nature of the problem no one pointed attention to this. When the nominal coverage ratio lies between 105% and 120% a pension fund could adjust the level of indexation to make sure the buffer is reached within 15 years and no funding surplus is present. Below a nominal coverage ratio of 105% however a problem occurs, since the expected pension benefits are too high compared to the assets of the pension fund and the pension fund board has to decide who pays for the shortfall. Implicitly, making no decision regarding the underfunded position hurts the young participants as more money is paid out than the pension fund has, which ultimately leads to a burden for the younger generation. Another possibility is to apply cuts to the pension entitlements, but this is a measure a pension fund board only uses as a last resort. However, due to the continuously underfunded position of many pension funds the last years, 60 pension funds applied this measure in January 2013. Out of the five largest pension funds of the Netherlands, three pension funds had to cut into the pension rights of their participants. ABP, PMT and PME had to apply rights cuts of respectively 0.5%, 6.3% and 5.1%. The indexation mechanism works, but only leads to a slow increase in the coverage ratio.

As it became clear that the financial assessment framework could not deal with the economic situation at that time, the Dutch government (ministry of Social Affairs and Employment) asked two committees to look at the pension system and come up with possible improvements of the assessment framework for pension funds. The results of these committees are discussed in the next section of this thesis.

The most important findings of the committees Frijns and Goudswaard

The first committee was under supervision of Prof. Dr. J. M. G. Frijns and reported in January 2010 (see Frijns et al., 2010). Its goal was to look at the risk management and investment policy of Dutch pension funds. The most important results from the Frijns committee were

- due to demographic changes pension funds are becoming more vulnerable;
- pension funds pay too less attention towards their risk management and investment policy;
- the financial assessment framework focuses too much on the nominal coverage ratio where it should focus primarily on the real coverage ratio;
- a socially responsible investment policy is not an integrated part of the risk management and investment policy of Dutch pension funds.

So regarding the risk management and investment policy of pension funds, improvements could be made and implemented in an improved assessment framework according to the committee Frijns. The second committee was under supervision of Prof. Dr. Goudswaard

\footnote{The pension fund for the concrete mortar industry, since 2006 merged into Bouwnijverheid, also had to cut rights with 4.4%}
and reported in October 2010 (see Goudswaard et al., 2010). This committee looked at the sustainability of the Dutch second pillar, and divided the pension rights into hard pension rights and soft pension rights. Soft pension rights can be seen as an ambition, and hard pension rights are far more certain; a pension fund only default on this promise with a small probability (i.e. 2.5%). The findings of the committee dealing with the governance of pension funds were

- the Dutch pension system with its ambitions and guarantees is insufficiently sustainable due to demographic changes;
- a new balance has to be found between ambition, certainty and pension costs to maintain a pension system which is based on collectiveness and solidarity;
- contribution rates are at their limits;
- a more sustainable pension system can be obtained when the life expectancy is included in the pension arrangements;
- moving from hard to soft pension rights would improve the sustainability of the pension system;
- allocating the funding surplus in the funding rate should be done on an ex ante basis, leading to a complete and fully specified contract;
- communication is a key tool in a changing pension system, making sure that participants do not face surprises at pensionable age;
- an adapted pension law should be made, opening ways to conditional pension rights in order to be more flexible in risk sharing. This would increase the sustainability of the pension system.

This committee stated that the ambition level and the level of risk that pension fund participants face should be transparent in advance and communicated clearly.

### 2.2.2 The new financial assessment framework

After the reports of Frijns and Goudswaard a new financial assessment framework is constructed, still to be implemented but expected to be introduced in January 2015\(^2\). The new framework is a product of the debate of the government and social parties following the recommendations of the reports of Frijns and Goudswaard. The renewed financial assessment framework has the goal to maintain a pension system in the Netherlands which is sustainable in both execution and regulation. In this new framework there is also a possibility for a real contract with accompanying regulatory boundaries. The most important changes between the current financial assessment framework and the new financial assessment framework for a nominal contract are stated below.

- The discount curve will be based on the risk free interest rate curve adapted with the ultimate forward rate methodology for long durations. This curve is still based on the three month average of the interest rates.

\(^2\)Source: planning of bills (wetsvoorstellen)
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- The minimum buffer is increased on average from approximately 20% to 25%, leaving the certainty measure the same. So the probability that the (nominal) coverage ratio next year is below 100% should still be smaller than 2.5%.
- For the financial assessment framework, the 12-month moving average of the coverage ratio is used. This will lead to more stability in the coverage ratio used in the decision making process.
- The ambition level will be compared with the expected outcome in the worst case scenario, and the ability of the fund to recover from an underfunded status will be measured.
- Pension funds should make an \textit{ex ante} recovery plan (before: \textit{ex post} recovery plan). Below a coverage ratio of 105%, benefits are cut using a maximum of 3 years. Above a nominal coverage ratio of 105%, an additional 12 year recovery period is allowed to regain a healthy financial situation.
- The pensionable age can be adapted and current pension rights can be lowered optionally.

The primary target of the ftkII is to protect the sustainability of the pension system and to keep the intergenerational balance. The new ftk will give more stability in the financial situation of pension funds, since shocks in single coverage ratios are absorbed by the usage of 12-month averages. An important difference in the new framework compared to the old framework is the recovery plan changing from an \textit{ex post} plan to an \textit{ex ante} plan. Below a nominal coverage ratio of 105% benefit cuts will be used during a maximum period of 3 years, cutting in the first two years a maximum of 7% of the rights per annum. When the coverage ratio is below the minimum required capital level an additional recovery period of 12 years is allowed. Another important change is that positive and negative surpluses in the coverage ratio have to be made explicit. This will improve the transparency of the pension system, as was recommended by the Goudswaard committee (see Goudswaard et al., 2010). As pointed out earlier in this chapter, one component of the new assessment framework is a changing discount curve. Since one effect of the new discount curve leads to an increase in the coverage ratio, this can cause intergenerational transfers for the pension fund participants when the market does not meet the expectations which are implicit in the new methodology. On the other hand, since the buffers have to be increased in ftkII, the pension benefits of current generations are not corrected for inflation which also causes for intergenerational value transfers since future generations will benefit from this. Because the earlier introduction of the new discount curve leads to increased coverage ratios of Dutch pension funds (see Figure 1.1 and Table 1.1), the 12-month average at the time ftkII becomes operational will be fully based on the new (higher) coverage ratios. Thereby, additional rights cuts which would have taken place when the new methodology had not been introduced at this moment may have been prevented. Possibly, this causes transfers from the young to the old generations when the long-term interest rate used for the valuation is too high. It is not quite clear why the new methodology is introduced before ftkII is launched. However, it seems to be the result of extensive lobbying of pension funds and politicians.
2.3 Implications new financial assessment framework

Pensions of many Dutch workers are influenced by ftkII, mainly because of the new term structure methodology but also because of the recovery plan shifting from \textit{ex post} to \textit{ex ante}. The interest rate hedging consequences of the new methodology are already illustrated by Kocken et al. (2012) and Rebel (2012); distortions in the swap market around the 20 year point are prevented with the implemented recommendation of Rebel (2012), who slightly adapted the methodology proposed in QIS5. The new methodology is further discussed in Chapter 4. Furthermore, the funding rate and premium consequences in level and volatility of the new methodology are illustrated in this thesis in Chapter 5.
Chapter 3

Technical background

In this chapter the technical background behind the discount curve, the yield curve and the forward curve is described which will be used for the calculations in further chapters. Both the continuous and discrete (annual) representation of the curves will be given. This is useful, because the tool provided by the Committee of European Insurance and Occupational Pension Supervisors (CEIOPS) switches from discrete time representation to continuous time representation and back creating the term structure. DNB uses the same method to create the new term structure for insurance companies and pension funds. Note that continuous time interest rates can easily be composed (approximated) out of discrete time interest rates by:

\[ \tilde{R}_T = \ln(1 + R_T), \]  

where \( \tilde{R}_T \) is the continuously compounded rate and \( R_T \) is the discretely compounded interest rate.

3.1 Information distillation

Gathering information in the financial market can be done in different ways. Approximations of risk free interest rates can be found in the bond market as well as the swap market. A bond is a promise by a government or corporation of a certain amount, the principal, to the holder of the bond. This promise expires at a given date, which is called the time to maturity, at which the principal has to be paid back. Two kinds of bonds exist; bonds that pay coupons (coupon-paying bonds), which are interest rate payments, and bonds which have no payments in between (zero-coupon paying bonds). Neglecting mortality, pension payments can be seen as series of zero-coupon bonds, since they are payments at given points in time without intermediate payments. The valuation of bonds is thereby similar to the valuation of pension payments and that is why prices of bonds can be used to value pension promises of pension funds. Zero-coupon bonds are sold for less than the principal, so at a discount. From the prices of these bonds with different maturities the discount curve can be distilled. Since bonds are traded for a given (small) set of maturities, only a given set of discount rates is available in
The consequences of changes in the term structure methodology

The risk free prices for every maturity are given by the discount curve and can be interpreted in the following way: The current market value (at time $t = 0$) of one unit of currency $T$ periods from now is represented by the discount curve in period $T$. The value of the discount curve starting in period $t$ maturing in period $T$ is given by $P_t(T)$. The discount curve is given by the values of the discount factor for different maturities at given value of $t$. Throughout this thesis, the price of one unit of currency today $T$ periods from now is given by $P_T$ for simplification purposes (so $P_0(T) = P_T$). The currency which will be used in this thesis is euro and the periods are in years. The discount curve should be non-increasing and nonnegative for all maturities to prevent arbitrage opportunities. The discount factor with zero maturity should be equal to 1 for the same reason, so $P_0 = 1$.

In reality, there is a risk that the issuer defaults on the promise. This risk will typically be higher for corporate bonds than for government bonds, and higher for corporations or governments with a lower rating. However, as several European countries are on a life-support machine of the Trojka\(^2\) some corporate bonds are now considered to be less risky than some government bonds. Although normally government bonds were assumed to be riskless, this has changed with the start of the sovereign debt crisis in Europe in October 2009\(^2\) when rating agencies lowered the credit ratings of several European countries. For the valuation of pension obligations a term structure has to be used based on high quality bonds, which triggers the discussion about how high a rating should be in order to be of high quality. The term structure can also be obtained using information from the swap market, which is done in the Netherlands. A disadvantage of using the swap market instead of the bond market as a basis for the risk free term structure of interest rates is that the information in the swap market is available for longer maturities. Interest rates can be obtained from the swap market by looking at the swap contracts in the financial market. Swap contracts are contracts in which one party pays a fixed interest rate ($C$) and the other party pays a floating (variable) interest rate over a notional principal $A$. The fixed rate, the notional principal and a set of intermediate dates (tenor dates) are agreed upon in the contract and the floating rate is observed in the market. At every tenor date, party one pays the accrued interest over the notional principal in the time between the previous tenor date and the current. Since both the tenor dates and the interest rate are fixed for party one this amount is already known in advance. The other party also pays the accrued interest over the same period, but this interest payment depends on the level of the interest rate at that moment. At the time of the initiation of the contract, the market value of the contract in theory is equal to zero (otherwise no party will agree with the contract in a perfect world). The value of the interest payments of the fixed side of the contract (the fixed leg) is given in Equation (3.2) and the value of the interest payments of the floating side of the contract (the floating leg) is given in Equation (3.3) for a contract with $n$ tenor dates for both

---

\(^2\)The Trojka consists of the International Monetary Fund (IMF), the European Commission and the European Central Bank (ECB)

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legs (number of payments can be different in reality) and a notional principal $A$.

$$\sum_{i=1}^{i=n} P_i CA$$

$$\sum_{i=1}^{i=n} (P_{i-1} - P_i) A = (1 - P_{tn}) A$$

Where $C$ is the swap rate or coupon rate, $P_i$ is the discount factor and $P_{t0} = P_0 = 1$. The value of the fixed rate is chosen in such a way that the value of the floating leg is equal to the value of the fixed leg at the initiation of the swap contract. The coupon rate determines the size of coupon payments for a loan with coupon paying dates equal to the tenor dates and the same maturity as the swap contract. The agreed swap rate in swap contracts can however be different from the equilibrium rate, which can be interpreted as a term premium or as a risk premium. This topic will be elaborated in Chapter 4. Using the coupon rate, the yield curve can be constructed. Swap contracts also exist for a given set of durations so the construction of the full curve also involves interpolation for intermediate durations and extrapolation for very long durations. As already mentioned, an advantage of using swap contracts as a basis for the risk free term structure over government bonds is that swap contracts typically have longer durations than bonds, which is one of the reasons DNB uses swap contracts as a basis to construct the yield curve. The method DNB uses will be discussed in Chapter 4.

3.2 The yield curve

Where the discount rate is used to calculate the value of a future cash flow at this moment in time, the yield curve is used to value a cash flow from which the value is known at this moment $T$ periods from now. The yield curve, which is also sometimes called the term structure of interest rates or interest rate curve, is the solution of one of the following equations:

$$\tilde{P}_T = e^{-R_T T}$$;

$$P_T = \frac{1}{(1 + R_T)^T}.$$  \hspace{1cm} (3.4)  \hspace{1cm} (3.5)

Where Equation (3.4) uses continuous compounding and Equation (3.5) uses discrete compounding. Solving these equations, the following explicit form can be obtained:

$$\tilde{R}_T = -\frac{1}{T} \log [P_T];$$

$$R_T = \left[ \frac{1}{P_T} \right]^\frac{1}{T} - 1.$$  \hspace{1cm} (3.6)  \hspace{1cm} (3.7)
So the yield curve represents the yield for different values of $T$. To obtain the yield curve, one has to interpolate for intermediate durations and extrapolate for very long durations using methods like for example Nelson-Siegel (1987). As can be seen in Equation (3.6) the yield cannot be calculated for $T=0$. In the limit when $T$ tends to 0 this yield is defined as the instantaneous rate of growth of riskless capital, or short rate (see Schumacher 2011):

$$R_0 = -\lim_{T \downarrow 0} \log \left[ \frac{P_T}{T} \right] = -\frac{P_T'}{P_T} \bigg|_{T=0} = -P_0'$$

(3.8)

Since discount factors should lie between 0 and 1, interest rates should be nonnegative (see Equation (3.4)). Note that when interest rates would not be positive, $P_\infty = 0$ would not hold and there would be arbitrage opportunities. A drawback of the Smith-Wilson (SW) method however, is that the prices could become negative for some cases. This will be further elaborated in Subsection 4.2.3. The Smith-Wilson method is used for the construction of the term structure as of September 2012. For an elaboration of the SW method see Section 4.2.1.

### 3.3 The forward curve

In the new methodology for the construction of the term structure of interest rates (TSIR), the forward rates will be converging to the ultimate forward rate for long durations. The forward rate is the link at this moment in time between two terms to maturity in the future $t_1$ and $t_2$. When one would trade at this moment one unit of currency maturing at time $t_2$, and trade one unit of currency till $t_1$ and at $t_1$ trade the resulting amount till $t_2$ (with time to maturity $t_2 - t_1$), the forward rate is the rate between $t_1$ and $t_2$. In formulae, the continuously compounded forward rate $\tilde{F}_{t_1,t_2}$ from $t_1$ to $t_2$, is given by Equation (3.9).

$$e^{\tilde{R}_{t_1,t_1} t_1} e^{\tilde{F}_{t_1,t_2} (t_2-t_1)} = e^{\tilde{R}_{t_2,t_2} t_2},$$

(3.9)

This equation is equivalent to Equation (3.10), which is the discretely compounded representation. Rewriting Equation (3.9) leads to the representation given in (3.11).

$$(1 + R_{t_1})^{t_1} (1 + F_{t_1,t_2})^{t_2-t_1} = (1 + R_{t_2})^{t_2}$$

(3.10)

$$\tilde{F}_{t_1,t_2} = \frac{\tilde{R}_{t_2, t_2} - \tilde{R}_{t_1, t_1}}{t_2 - t_1}.$$  

(3.11)

In practice, the forward rate is derived in discrete time. For example, the link between the one year interest rate and the two year interest rate is given by Equation (3.12).

$$(1 + R_1)(1 + F_{1,2}) = (1 + R_2)^2$$

(3.12)

Rewriting gives an explicit expression for the forward rate $F_{1,2}$:

$$F_{1,2} = \frac{(1 + R_2)^2}{(1 + R_1)} - 1$$

(3.13)
The yield curve can be seen as a weighted average of the forward rate. To obtain the yield at time $T$ out of the forward curve, one has to integrate the forward rate from 0 to $T$ and divide by $T$, as in Equation (3.14) where $F_s$ represents the forward rate from 0 to $s$.

$$R_T = \frac{1}{T} \int_0^T F_s \, ds$$

(3.14)

Given the yield curve, the one-year forward rates can be constructed using:

$$F_{t-1,t} = \frac{(1 + R_t)^t}{(1 + R_{t-1})^{t-1}} - 1,$$

(3.15)

where $t = 1, 2, ...$ and $R_0 \equiv 0$. 

Chapter 4

Term structure of interest rates in practice

In this chapter the construction method of the term structure will be discussed. First, the methodology is discussed which is used to compute the market curve in Section 4.1. In Section 4.2.2 the construction of the yield curve is discussed as it is used as of September 2012 by DNB (hereafter: DNB 20-60 curve), using the UFR-methodology. Possible governance issues for pension funds will also be briefly discussed.

One could use three different yield curves for the valuation of pension fund liabilities: a nominal term structure, a real term structure and the DNB 20-60 curve which is used in ftkII. One could use the nominal term structure to value pension fund liabilities resulting in a coverage ratio that reflects the financial situation of the pension fund in the current market. A real term structure could be used to value the liabilities resulting in a coverage ratio which reflects the pension funds position in real terms, since the real term structure gives the value of the liabilities corrected with inflation. When a pension contract has a real ambition, the real term structure can be used as this gives a coverage ratio assuming full indexation (with hard pension rights). For a further elaboration on hard and soft pension rights I refer to Goudswaard et al. (2010). The DNB 20-60 curve can be used to value the liabilities to meet the conditions within the second regulatory framework.

Two different term structures will be used in this thesis: the market curve (nominal term structure), and the DNB 20-60 curve. The latter curve includes the UFR-methodology and this methodology is used by both insurance companies and pension funds. However, the curve insurance companies are allowed to use is not completely the same as pension fund are allowed to use. The difference between the two curves will be explained in this chapter.

4.1 The market curve

As mentioned in Section 3.1 the Dutch Central Bank uses swap rates as a basis to construct the term structure of interest rates (TSIR) pension funds have to use to value
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<table>
<thead>
<tr>
<th>Year</th>
<th>Coupon rate $C_i$</th>
<th>Zero-coupon rate $R_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.321%</td>
<td>0.321%</td>
</tr>
<tr>
<td>2</td>
<td>0.360%</td>
<td>0.360%</td>
</tr>
<tr>
<td>3</td>
<td>0.459%</td>
<td>0.460%</td>
</tr>
<tr>
<td>4</td>
<td>0.594%</td>
<td>0.596%</td>
</tr>
<tr>
<td>5</td>
<td>0.746%</td>
<td>0.750%</td>
</tr>
</tbody>
</table>

Table 4.1: Swap rates example

their liabilities. Since the term structure should represent the interest rates in the Eurozone, the DNB uses European swap rates which represent a market average. London composite rates (CMPL) from Bloomberg are chosen with durations of respectively 1-10, 12, 15, 20, 25, 30, 40 and 50 years. Bloomberg offers these rates in a 2 basis point (bp) spread, and the DNB uses the lower bid-rate to construct the term structure. This is a prudent choice, since this will result in a higher value of the pension liabilities. Bloomberg also offers intermediate swap rates up to 30 years and a 35 and 45 year swap rate, but they are not used as input for the TSIR of the DNB as the swap market for these maturities is assumed to be not liquid enough.

In these European swap contracts the swap rate (fixed rate) is exchanged against the 6 month Euro Interbank Offered Rate (EURIBOR). At the time of initiation the market value of the swap is close to nil as already mentioned in Section 3.1. Because of the way swap contracts are constructed, the yields observed from the market are par yields, which are the coupon rates for which the price of a bond is equal to its nominal value. The swap contract is on a 30/360 basis, so the length of a month and year are fixed to respectively 30 and 360 days.

Let $C_t$ denote the coupon rate for a contract with duration $t$. A bond maturing at time $t$ has an annualized cash flow equal to $C_t$ every year up to time $t-1$ and equal to $1+C_t$ at time $t$, assuming a notional value equal to 1. The DNB uses bootstrapping for the construction of the (zero-coupon) yield curve (see [De Nederlandse Bank 2005]). Starting at the 1-year swap rate, the zero-coupon rate is derived, followed by the 2-year zero-coupon rate, etcetera.

\[
\frac{1+C_1}{1+R_1} = 1 \Rightarrow R_1 = C_1
\]

\[
\frac{C_2}{1+R_1} + \frac{1+C_2}{(1+R_2)^2} = 1 \Rightarrow R_2 = \sqrt{\frac{1+C_2}{1+R_1} - 1}
\]

\[
\vdots
\]
Numerical example

Suppose we want to construct zero-coupon rates for the first five years using coupon rates given in the second column in Table 4.1. Following the method described above, the zero-coupon yields can be calculated, resulting in zero-coupon rates as in the third column in Table 4.1:

\[
R_1 = C_1 = 0.321\% \\
R_2 = \sqrt{1 + \frac{C_2}{1 + R_1}} - 1 = 0.360\% \\
R_i = \sqrt{1 + \frac{C_i}{1 - \sum_{j=1}^{i-1} \frac{C_j}{(1+R_j)^j}}} - 1 \text{ for } i = 3, 4, 5
\]

For all interest rates up to and including 10 years the yield curve can be constructed in this way, since all intermediate swap rates are available and used for the construction of the TSIR. Beyond 10 years, not for every year the swap rate is available (or used), and an interpolation method is necessary for the construction of the full term structure. For the interpolation between intermediate data points the DNB uses a straightforward method, assuming that all intermediate one-year forward rates are constant. For example, for the calculation of the interest rates for durations 11 and 12 the assumption is made that

\[
F_{10,11} = F_{11,12} = F_{10,12}, \text{ so } (1 + R_{11})^{11} = (1 + R_{10})^{10}(1 + F_{10,11}) = (1 + R_{10})^{10}(1 + F_{10,12}), \\
(1 + R_{12})^{12} = (1 + R_{11})^{10}(1 + F_{11,12}) = (1 + R_{10})^{10}(1 + F_{10,12})^2.
\]

Similarly, the one-year forward rates between 30 and 40 years and between 40 and 50 years are assumed to be constant. The last forward rate (i.e. \(F_{40,50}\)) can also be used for extrapolation purposes, which is done by the DNB for the construction of the long term interest rate. Using the known cash flows, one can numerically solve for the forward rates \(F_{10,12}, F_{12,15}, F_{15,20}, F_{25,30}, F_{30,40}\) and \(F_{40,50}\). For example, the value of \(F_{10,12}\) can be found solving the equation

\[
\frac{C_{12}}{1 + R_1} + \frac{C_{12}}{(1 + R_2)^2} + \cdots + \frac{C_{12}}{(1 + R_{11})^{11}} + \frac{1 + C_{12}}{(1 + R_{12})^{12}} \times \left[ \sum_{t=1}^{10} \frac{1}{(1 + R_t)^t} + \frac{1}{(1 + R_t)^{10}} \sum_{t=1}^{2} \frac{1}{(1 + F_{10,12})^t} \right] + \frac{1}{(1 + R_t)^{10}(1 + F_{10,12})^2} = 1.
\]

The TSIR which follows from these calculations can be seen as the (nominal) market curve. That is, the zero-coupon rates that follow from financial contracts with little risk in the market. These interest rates are updated every month by the DNB to represent the current (riskless) market conditions.
Figure 4.1: Term structure of interest rates (solid) based on swap rates (scatter)

An example of the market curve (end-of-year 2012) is presented in Figure 4.1. Zero-coupon rates are used as input for the construction of the new TSIR, to be used by pension funds as explained in the next section, the DNB 20-60 curve.

4.2 Changing the yield curve

As a result of a policy change in September 2012 (see Ministry of Social Affairs and Employment, 2012), the valuation method of pension fund liabilities has been changed. DNB adapted the TSIR discussed in the previous section with the Ultimate Forward Rate methodology. The TSIR insurance companies have to use for the valuation of their liabilities was already adapted in a similar way back in June 2012. This adaption is made in anticipation of the changing capital requirements for insurance companies, Solvency II, expected to be fully operational in 2014 (see Ministry of Finance and Ministry of Security and Justice, 2012). However, the TSIR insurance companies use is not entirely equal to the TSIR pension funds use. The method used for the construction is similar, but adaptions are made for the yield curve of pension funds to guarantee smoother coverage ratios over time and to establish a closer link to the financial market. The differences and the similarities between the two curves will be discussed in this section.

4.2.1 The UFR-methodology

In this subsection the methodology of the yield curve with the UFR is discussed. The method used by DNB (see De Nederlandse Bank, 2012) is similar to the method used in the Quantitative Impact Study 5 (QIS5) of the European Insurance and Occupational Pensions Authority (EIOPA). This method was originally proposed by Smith and Wilson (2001).
The consequences of changes in the term structure methodology

The input for the method are zero-coupon rates, which are the rates calculated in Section 4.1 using European data following the DNB methodology. In the Smith-Wilson (SW) method a last liquid point (LLP) has to be chosen; a point in time after which the swap market is assumed to be not liquid enough anymore. So, after the LLP the (average) swap rates are assumed to represent the market conditions not well enough to use these rates for the composition of the risk free prices (discount curve). In QIS5, the forward rates after the LLP are constructed as a weighted average of the forward rate at the last liquid point and the UFR. The value of the weight assigned to the UFR increases with time, up to a known point in time (i.e. $T_2$) in which the new forward rate equals the UFR (with an allowed deviation of 3 basis points). The LLP is chosen to be 20 years for the Netherlands and the point in time in which the forward rate should be (approximately) equal to the UFR is chosen to be 60 years. The notation in this thesis is consistent with QIS5 and Smith and Wilson (2001). Since zero-coupon rates are the input for the SW method, the market term structure has to be composed up to 60 years (i.e. $T_2$) in the Netherlands. The Smith-Wilson method produces the prices for each maturity, from which the TSIR can be calculated directly. The SW method will be discussed in the next part of this subsection.

Smith-Wilson method

The Smith-Wilson method (see Smith and Wilson, 2001) uses zero-coupon rates as input for the calculation and provides an extrapolation method for (risk free) interest rates. The zero-coupon rates up to $T_2$ are constructed in the same way as described in Section 4.1. Furthermore, choices have to be made regarding the LLP, the speed of convergence towards the ultimate forward rate and the value of the ultimate forward rate. The following notation will be used:

- $P_t$ = the discount factor
- $t$ = the maturity
- $UFR$ = the chosen ultimate forward rate ($UFR = 4.2\%$)
- $N$ = the number of known zero-coupon prices
- $LLP$ = last liquid point (chosen to be 20 yrs)
- $ξ$ = parameter to fit the known yield curve
- $u_i$ = tenors of the known prices
- $α$ = measure for the speed of convergence (in default, $α = 0.1$), and smoothness of the forward curve
- $T2$ = point in time in which the forward rate lie within predefined boundaries from the UFR (chosen to be 60 yrs).

The default value of $α = 0.1$ is chosen because it ensured sensible, and economically appropriate yield curves in a qualitative assessment of the model performance by Thomas and Maré (2007), where historical data ensured a consistently smooth set of forward rates for $α = 0.1$. However, this assessment is done for South-African data and thus the implicit assumption is made in QIS5 that the performance level of the model using this default value of $α$ will be similar using European data.

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The speed of convergence from the LLP towards the UFR can be adjusted. The value of $\alpha$ will be recalibrated (increased) when the forward rate at T2 does not lie within the allowed 3 bp of the UFR. The convergence criterion is specified, as the value of $\alpha$ has to be increased whenever the 3 bp criterion is not met. However, the size of the adjustment of $\alpha$ which has to be made when the criterion is not met is not specified in QIS5. The recalibration of $\alpha$ can be done with different step sizes. DNB chooses for example to increase the value of $\alpha$ with 0.1 when the 3 bp criterion is not met, and an available tool of the CEIOPS (by comparison) chooses to adjust the value of $\alpha$ with 0.001 at the time.

For pension funds with durations larger than the LLP, large adjustment steps of $\alpha$ can result in shocks in the present value of future liabilities when a period in which the value of $\alpha$ is stable is followed by a period in which the value of $\alpha$ has to be adjusted. A smaller step size of $\alpha$ seems to be more desirable.

A smaller step size of $\alpha$ seems to be more desirable. The range in which $T_2$ should lie according to the CEIOPS report (see European Insurance and Occupational Pensions Authority, 2010) is between 70 and 120 years, so a convergence period between 50 and 100 years. Other convergence periods which are mentioned are 10 years and 40 years (see European Insurance and Occupational Pensions Authority, 2012). DNB chooses a convergence period of 40 years, which is equal to the proposal of EIOPA. With a default value of $\alpha = 0.1$, the forward rate at 60 years lies within the 3 bp boundary for the current market conditions[^1] in the Netherlands, as can be seen in Figure 4.2.

The pricing function of the SW method is given by:

$$P_t = e^{-UFRt} + \sum_{j=1}^{N} \xi_j \cdot W_{t,u_j}, \; t \geq 0.$$  \hspace{1cm} (4.1)

In the function above, $W_{t,u_j}$ is a (symmetric) Smith-Wilson function defined by:

$$W_{t,u_j} = e^{-UFR(t+u_j)} \cdot \left\{ \alpha \cdot \min(t,u_j) - 0.5 \cdot e^{-\alpha \cdot \max(t,u_j)} \cdot \left( e^{\alpha \cdot \min(t,u_j)} - e^{-\alpha \cdot \min(t,u_j)} \right) \right\}. \hspace{1cm} (4.2)$$

In equation (4.1), it can be seen that the prices in the Smith-Wilson method are given by the sum of a factor solely based on the UFR and the multiplication of the SW function with $\xi$. The multiplication is added to ensure a perfect fit up to the last liquid point, and a smooth transition between the LLP and T2. The prices of the known tenors are given by:

$$P_{u_j} = e^{-UFRu_j} + \sum_{j=1}^{N} \xi_j \cdot W_{t,u_j}, \; t \geq 0.$$  

Define the vector of known tenor prices by $p = (P(u_1) \ldots P(u_N))^T$, and the vector of prices based on the UFR by $\mu = (e^{UFRu_1} \ldots e^{UFRu_N})^T$. The vector $\xi$ can now be derived:

$$p = \mu + W\xi$$

$$\implies \xi = W^{-1}(p - \mu)$$

[^1]: Swap rates dd 31-12-2012
The vector $\xi$ is composed in such a way that the prices up to the LLP are equal to the prices of the market. After the LLP, the forward rates are a linear combination of the UFR and the market forward rate at the LLP ($F_{19,20}$). Thereby, the forward rates after the last liquid point can be presented by the expression given in Equation (4.3).

The forward rates composed by DNB for insurance companies are equal to the forward rates composed by the SW method.

$$F_{SW}^{t-1,t} = (1 - \tilde{w}_t) F_{19,20} + \tilde{w}_t UFR, \text{ for } t = 21, \ldots, 60$$ (4.3)

Before the last liquid point, the weight $\tilde{w}_t$ is equal to zero and at $T2$ the weight on the UFR is close to 1. When the forward rates $F_{SW}^{t-1,t}$ are known, the value of the SW weights can be calculated using the expression in Equation (4.4).

$$\tilde{w}_t = \frac{F_{SW}^{t-1,t} - F_{19,20}}{UFR - F_{19,20}}, \text{ for } t = 21, \ldots, 60$$ (4.4)

### 4.2.2 DNB 20-60 curve

A disadvantage of the SW approach is that the market is not taken into account anymore after the LLP. A combination of the SW approach and the market is introduced in Rebel (2012) and chosen by the DNB, where the construction of the forward rate after the LLP is a weighted average of the market forward rate (of the same maturity) and the UFR, as can be seen below.

$$F_{t-1,t}^* = \begin{cases} F_{t-1,t} & 1 \leq t \leq 20 \\ (1 - w_t) \cdot F_{t-1,t} + w_t \cdot UFR & 21 \leq t \leq 60 \\ UFR & 61 \leq t. \end{cases}$$

Where $w(t)$ are the weights composed in the following way:

$$w_t = \frac{F_{SW}^{t-1,t} - F_{19,20}}{F_{60,61}^{SW} - F_{19,20}}, \text{ for } t = 21, \ldots, 60$$ (4.5)

Note that the forward rate calculated using the SW method at $T2$ is within 3 bp of the UFR, and that the forward rate at duration 61 of the DNB curve, hereafter DNB 20-60 curve, is automatically equal to the UFR. With the constructed forward rates, the yield curve can be derived using the following relationship between forward rates and interest rates:

$$(1 + R_t^*)^t = \prod_{j=1}^{t} (1 + F_{j-1,t}^*), \text{ for } t = 1, 2, \ldots$$ (4.6)

The DNB 20-60 curve is not different from the market curve up to 20 years to maturity. After that term to maturity, the forward rates for higher durations are adapted in such a way that the new forward rates are a weighted average of the known one-year forward rate from the market and the UFR. The weights on the UFR increase with duration until the forward rate is equal to the UFR for durations from 61 years on. With these newly constructed forward rates the TSIR can be calculated.
Yield curve differences between pension funds and insurance companies

One difference between the term structures of insurance companies and pension funds regards the input; where the input for the construction of the market curve for insurance companies is based on current market conditions, the input for the TSIR for pension funds is based on the average of the daily curves of the past three months. As a result, the term structures for pension funds are smoother than the term structures for insurance companies. Shocks in the interest rate thus have a smaller effect on the term structure for pension funds. Another difference between the curves used by pension funds and insurance companies regards the convergence period of the market forward rate at the chosen last liquid point (LLP) towards the UFR, which is reached at a predefined moment in time (i.e. T2). For the construction of the TSIR for insurance companies forward rates are used which follow from the SW method, so forward rates that are a weighted average of the forward rate at the LLP \( F_{19,20} \) and the UFR. For the construction of the TSIR for pension funds forward rates are used that are a weighted average of the market forward rate and the UFR. So for the term structure of pension funds market information is used up to T2, whereas no market information after the last liquid is used for insurance companies. As a result, the forward rates used to construct the TSIR for pension funds have a closer link to the financial market up to T2. This is in line with a recommendation of Rebel (2012), who states that liquid market information is ignored in the QIS5 methodology for the valuation of pension liabilities for the very maturities that are relevant for pension funds, since the bulk of the liabilities are due at the assumed last liquid point. However, note that it is not clear whether the prices observed at those long terms to maturity are correct because of possible distortions due to differences in supply and demand.

The resulting forward curves

In Figure 4.2, the one-year forward rates for 31 December 2012 of the market curve, insurance companies and pension funds are illustrated. The forward rates of the market curve are stationary between two different (used) data points. From 40 years on, the forward rate remains constant as the last used forward rate for the market curve is \( F_{40,50} \), as described in Section 4.1. The forward curve corresponding to the yield curve of insurance companies is equal to the forward curve of the market curve up to 20 years (the last liquid point). Between 20 and 60 years the forward rate converges smoothly to the ultimate forward rate, remaining constant to the UFR after 60 years. The forward curve of pension funds is equal to the curve of the market and insurance companies up to the LLP. After the last liquid point the forward rate converges to the UFR, but maintaining a link with the market curve. In the convergence period, a more irregular pattern is followed by the forward rate because a weight is attached to the market forward rate, but from 60 years on the forward rate also remains constant at 4.2%.
4.2.3 Theoretical and practical comments

In long-term investments, investors expect an additional return as a compensation for their investments for the long term. This additional return is often referred to in the literature as the term premium, and could be positive or negative dependent on the investor. From the point of view of an investor, locking a part of the investments lowers the possibility to react to up-to-date market conditions and thus the term premium should be positive. However, long-term investments can also be used to cover risk and some investors will allow for a negative term premium when the investments offer a closer link to match their liabilities. This reasoning is intuitively clear for bonds, but not less clear for the swap market. The lack of empirical data on the term premium was the main reason to decide to take the term premium not into account in the QIS5 research. This is a logical decision as the impact of the term premium is not clear and reliable models using reliable data are not available (yet). The Dutch Central Bank agreed with this as they implemented the SW method as presented in QIS5. Carlin (2010) notes that the term premium may already be included in the swap rate, where the fixed rate may differ from the equilibrium rate acting as a term premium. Further research however is necessary on this topic before the term premium could be included in the term structure methodology. Another missing factor in the modelling of the term structure as it is presented in QIS5 is the implementation of the convexity effect. This effect should be implemented from a theoretical point of view because of the non-linear (convex) relationship between bond prices and interest rates, and would result in a negative component. This effect could also not be robustly and credibly quantified and is thus not taken into account in QIS5. Note that this effect should be taken into account when one uses zero-coupon prices derived from bond data as input for this method, and that DNB uses zero-coupon prices derived from swap rates. Not taking the convexity effect into account will thereby probably have a negligible effect for the Netherlands. Moreover, Carlin (2010) argues that the CEIOPS has chosen the term premium such
that the convexity is cancelled out. Since real interest rates and inflation levels differ within the euro zone, one can argue whether a country specific ultimate forward rate would provide a more accurate estimate of the long-term forward rate. For example, in QIS5 the average inflation rate in the Netherlands was 2.15% and the average real rate was equal to 1.1% which would lead to an UFR of the Netherlands equal to 3.25%. However, the economies of individual countries are correlated with each other which would support QIS5 in looking at the euro zone as a whole. Allowing for discrepancies in the ultimate forward rate within the euro zone could however lead to more reliable estimates for the long-term interest rate and could be the topic of further research. Besides this, historical estimates of the inflation rate and real rate are not necessarily a good estimate for the long-term expectation. When one chooses to implement a long-term (ultimate) forward rate in the term structure it seems to be a good choice to base this forward rate solely on the long-term expectations of the inflation rate and the real rate and to neglect the term premium and convexity effect in the quantification as they demand further research before a possible implementation. However, the quality of these long-term expectations could be the topic of further research, as well as the long-term forecasting power of historical averages for individual countries in the euro zone. This research however probably will face a problem, as little data is yet available.

The choice of the Smith and Wilson method by QIS5 and the Dutch Central Bank has several more advantages and disadvantages. The most important arguments supporting, as well the critics on the method used by QIS5 to create the term structure and the method the DNB uses to adapt that term structure are denoted below.

Supporting arguments:

- The SW method is in the open domain, so transparent and fully accessible for everyone who is interested. Formulae and a computing tool are published on the website of the CEIOPS (open source) as also recommended by Bovenberg et al. (2012).
- The method is flexible concerning the input, and easy to implement. Prices for different maturities can be used as input.
- A perfect fit of the term structure is established up to the last liquid point, causing no distortion until that point. After the LLP, a smooth transition from the market forward rate to ultimate forward rate is established.
- The SW method can be applied directly to raw financial market data, so no bootstrapping is needed. Note however that DNB does uses bootstrapping to generate the input.
- Adapting the SW yield curve by the Dutch Central Bank as recommended by Rebel (2012) ensures less distortion in interest rate hedging, since the usage of market data beyond the last liquid point removes the large weight on 20 year swaps (see Kocken et al. 2012). In the SW method, the interest rates after the LLP are insensitive to change in market rates. This leads to extreme interest rate sensitivity to the 20 year interest rate.
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**Critical arguments:**

- The value of the convergence parameter $\alpha$ has to be chosen outside the model, and expert judgment will still be needed to control for possible odd term structures. More work has to be done in order to see if a default value smaller than 0.1 could also be appropriate as starting value. Since the current default value is based on an assessment done outside the euro zone, it would be recommendable to check whether this value is also the minimum for the euro zone. The calibration criteria of $\alpha$ are also not fully specified, as the step size with which $\alpha$ should be corrected (when needed) is not defined. Objective criteria for setting the value of $\alpha$ are also not specified yet.

- There is no constraint in the SW method forcing the discount function to decrease. This could lead to strange results in the liquid part of the assessed term structure. For example that $P_T$ is decreasing function on the given liquid market data points, but locally increasing at that point in the interpolated curve. When two neighbouring market points are almost equal to each other this can happen. Many other methods would have the same problems however (see European Insurance and Occupational Pensions Authority, 2010).

- Prices can become negative after the last liquid point, when the last known (liquid) forward rate is high compared to the sum of $\alpha$ and the UFR. To prevent this, higher values of $\alpha$ can be chosen to resolve the problem. Expert judgment is still needed to monitor the results of the SW method to generate proper term structures.

- Weights which are calculated by DNB to attach a weight towards the UFR can explode when the denominator in Equation (4.5) is close to zero. Expert judgment of DNB will be needed when the weights are large in absolute value. In Chapter 5 this problem is solved by taking the SW curve when the weights which have been calculated using Equation (4.5) are large. Note that a small denominator implies that the distance between the forward rate at the last liquid point and the UFR is small.

---

1Example provided by QIS5: take for example $P(0) = 1, P(1) = 0.95001, P(2) = 0.95000$ and $P(3) = 0.9$. A smooth curve through these points will force the curve down between $P(1)$ and $P(2)$. However, for some $1 < t < 2$, $P(t) < P(2) = 0.95$. 

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Chapter 5
Consequences of changes in methodology

In this chapter, the consequences for pension funds replacing the market curve with the DNB 20-60 curve will be discussed. This is measured looking at the effect on the coverage ratio and the cost-effective contribution. For the effect on the coverage ratio, the change in average value and annualized volatility of the funding level are compared when the market curve is replaced by the DNB 20-60 curve. The consequences for the cost-effective contribution are measured looking at level and volatility of the cost of one year pension accrual.

Interest rates are historically low at this moment in time, resulting in underfunded pension funds. Besides that, there is an active discussion about the accuracy of the long-term interest rate calculated today. To look at the influence of the introduction of the UFR-methodology in periods with high interest rates and in periods with low interest rates, the sample period used in this thesis is divided into two periods representing a high interest period and a low interest rate period.

In this thesis, the consequences of the new term structure methodology for Dutch pension funds will be illustrated both ex post and ex ante. The ex post study will be done using the data set described in Section 5.1. For the ex ante study a method designed by Diebold and Li (2006) will be used, which is based on the extrapolation of Nelson-Siegel parameters and provides good results for out-of-sample forecasting (see Diebold and Li, 2006). Future interest rates are not known and hard to forecast, and frequently used models based on no-arbitrage (e.g. Hull and White (1990)) and equilibrium models (e.g. Vasicek (1977)) often have a strong theoretical background and a strong fit to the current term structure, but perform poorly in an out-of-sample performance test. The method of Diebold and Li (2006) will thereby be used to simulate future yield curves, and with these results the effects on the funding level and the cost-effective contribution of the changed methodology in possible extreme events in the near future are illustrated.

Since the DNB 20-60 curve is only different from the (old) market curve for durations longer than 20 years, it would be interesting to look at the consequences for pension funds...
The consequences of changes in the term structure methodology

with different average durations. Three model pension funds will be used to illustrate the
differences for young (green), average and old (grey) pension funds. The model pension
funds all have a total liability cash flow equal to €10bn but differ in average duration.
The average durations of the model pension funds are respectively 11, 20 and 32 years
for the young, average and old fund. Cash flows of the three model pension funds can
be found in figures A.1, A.2 and A.3. This thesis focuses solely on the interest rate
risk that pension funds face; all other risks (e.g. financial market risk, mortality risk,
longevity risk, etcetera) are assumed constant and out of the scope of this thesis. Note
that interest rate risk is an important risk for pension funds because of the length of the
cash flows and the height of the pension obligation. The risk pension funds face, is that
the interest rate drops in the future, raising the present value of the pension liabilities.
To cover this, pension funds engage for example in interest rate swaps (they receive the
fixed leg and pay the floating leg) and invest in bonds to protect themselves against some
of the interest rate risk. When the interest rate then drops the present value of future
liabilities increases but the effect on the coverage ratio is lowered due to an increasing
value of the assets. In this thesis, it is assumed that the three pension funds succeed in
covering 50% of their interest rate risk. Note that the 50% interest rate covering is a
realization of the target of pension funds, and that the target probably was higher since
a perfect replication of the liabilities is often impossible. In practice, pension funds cover
on average about 35%-40% of their interest rate risk. The results in this thesis thus
reflect the minimum impact of the changed term structure methodology. In the analysis,
an asset cash flow is set to 50% of the cash flow of the liabilities to reflect the interest
rate covering. The change in the interest rate is the only risk pension funds face in this
thesis, and the value of the stocks is assumed to remain constant. At the beginning
of each data period, the nominal coverage ratio of the pension funds is set to 100% by
choosing a proper value of the stocks (assets cash flow is valued using the market curve).
The fluctuations in the coverage ratio are solely due to fluctuations in the interest rate.

5.1 Data description

The data that will be used for the composition of the term structures will be the published
end of the month risk free interest rates by the Dutch Central Bank (due to financial
constraints). Because the new methodology is already implemented in the last three
months of 2012 the data for the end of these months are subtracted out of the Bloomberg
database. The DNB uses 3 month averages for the financial assessment framework, based
on daily data. To approximate these interest rates, the average will be calculated each
month for the past three months. For example, the rates of December will be based on
the averages of the months October, November and December. Since in this thesis the
transition and the differences going from the old methodology to the new methodology
is important, this will have no influence on the results presented in this thesis. Note
that the rates that will be used are a close approximate of the real data that are used

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by the DNB. The sample period that will be used is the period from 31-12-2003 up to and including 31-12-2012. Monthly data will be used for the analysis. The sample period will be divided into two parts; a high rate period and a low rate period. The high interest rate period is defined in this thesis as the period from 31-12-2003 up to and including 31-12-2007. The low rate period is defined as the period between 31-1-2008 up to and including 31-12-2012. To give an impression of the values of the interest rates in these periods, the average yield curves for the periods are presented in Figure 5.1 and descriptive statistics of both periods are presented in Table 5.1. The difference between the two periods at the last liquid point and at $T_2$ are respectively 77 and 120 basis points.

5.2 Ex post consequences

5.2.1 Effect on the coverage ratio

The Coverage ratio columns in the tables below represent the average change in the (nominal) coverage ratio changing the methodology of the yield curve from full market valuation (market curve) to the new valuation using the UFR-methodology (DNB 20-60

<table>
<thead>
<tr>
<th>Descriptive</th>
<th>High rate period</th>
<th>Low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>1.98%</td>
<td>0.32%</td>
</tr>
<tr>
<td>Maximum</td>
<td>5.36%</td>
<td>5.36%</td>
</tr>
<tr>
<td>Mean (1 yr.)</td>
<td>3.15%</td>
<td>1.92%</td>
</tr>
<tr>
<td>Mean (20 yrs.)</td>
<td>4.50%</td>
<td>3.69%</td>
</tr>
<tr>
<td>Mean (60 yrs.)</td>
<td>4.43%</td>
<td>3.20%</td>
</tr>
<tr>
<td>Volatility (1 yr.)</td>
<td>0.95%</td>
<td>1.37%</td>
</tr>
<tr>
<td>Volatility (20 yrs.)</td>
<td>0.43%</td>
<td>0.81%</td>
</tr>
<tr>
<td>Volatility (60 yrs.)</td>
<td>0.44%</td>
<td>0.61%</td>
</tr>
</tbody>
</table>

Table 5.1: Descriptive statistics of the data periods
The consequences of changes in the term structure methodology

curve). The two-sided p-values of the t-test are provided between brackets, and the accompanying test statistic is also provided. The null hypothesis underlying this test is that the average coverage ratio under the DNB 20-60 methodology ($\bar{X}$) is equal to the average coverage ratio using the market term structure (the true coverage ratio $\mu$). The test statistic is provided in Equation (5.1), in which $S$ denotes the sample standard deviation of the coverage ratio using the DNB 20-60 curve and $n$ denotes the number of observations. A p-value smaller than 0.05 indicates that the average coverage ratio using the DNB 20-60 curve for the valuation of pension fund liabilities is statistically different from the average coverage ratio using full market valuation.

$$T = \frac{\bar{X} - \mu}{S/\sqrt{n}}$$

(5.1)

An argument supporting the introduction of the UFR-methodology is that the volatility of the coverage ratio would be reduced after the introduction of the new methodology (see De Nederlandse Bank, 2012a). The volatility of the old coverage ratio (based on the changing interest rate) will be compared to the volatility of the coverage ratio using the new term structure. In the Volatility columns the annualized volatility of the coverage ratio after the replacement is given, as well as the (one-sided) p-values between brackets indicating whether the volatility has reduced using the new methodology. The accompanying test statistic is also provided. The null hypothesis underlying this test is that the standard deviation under the new methodology ($S_m$) is at least as large as the standard deviation under the old (market) methodology ($S_{ufr}$), and the test statistic is provided in Equation (5.2). Note that a p-value smaller than 0.05 indicates that the volatility of the coverage ratio reduces when the DNB 20-60 curve is used for the valuation of pension fund liabilities.

$$W = \frac{S_m^2}{S_{ufr}^2}$$

(5.2)

The results are provided in Table 5.2. The average coverage ratio replacing the DNB market curve with the DNB 20-60 curve for the valuation in a period where the interest rate is high, is lower for all pension funds. However, this change is statistically insignificant ex post. The volatility of the coverage ratio for the young fund has decreased significantly in the high rate period. A replacement in a period where the interest rate is low causes a significant difference in the coverage ratio for the young and average fund. Because the new methodology adapts the market curve after 20 years, pension funds with an average duration below that point are affected less, which is the old fund in this case. Since the average duration of the old pension fund is lower than the last liquid point, the transition from the old to the new yield curve methodology has a low impact on the old pension fund. The coverage ratios of the young and average fund have increased significantly on average with respectively 3.28% and 1.27%. Overall the impact for the old fund is insignificantly small for both sample periods.

2On a 95% significance level
3On a 95% significance level
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Table 5.2: Funding level and volatility for pension funds. In the Coverage ratio columns the average change of the coverage ratio is displayed when the market curve is replaced by the DNB 20-60 curve. Between brackets the p-value is presented which follows from a two sided t-test indicating whether the average coverage ratio has changed. The accompanying test statistic (see Equation (5.1)) is also provided. In the Volatility columns the sample standard deviation of the coverage ratio is given using the DNB 20-60 curve for the valuation. Between brackets the p-value is presented which follows from a one-sided test indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.2)) is also provided.

<table>
<thead>
<tr>
<th>Fund Type</th>
<th>Coverage ratio</th>
<th>Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High rate period</td>
<td>Low rate period</td>
</tr>
<tr>
<td>Young fund</td>
<td>-0.84%</td>
<td>3.28%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-1.19</td>
<td>3.36</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.12)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Average fund</td>
<td>-0.30%</td>
<td>1.27%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.67</td>
<td>1.74</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.25)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Old fund</td>
<td>-0.07%</td>
<td>0.28%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.25</td>
<td>0.57</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.40)</td>
<td>(0.28)</td>
</tr>
</tbody>
</table>

The impact for the young fund is quite high, decreasing the volatility in the high rate period and increasing the coverage ratio in the low rate period. Because the average fund has an average duration of 20 years, the impact of replacing the term structure for the valuation is rather small, only resulting in a significant increase in the height of the coverage ratio in the low rate period.

5.2.2 Effect on the cost-effective contribution

Pension funds have to ask at least a pension premium which is enough to cover their costs and the pension rights they guarantee. This is the so-called cost-effective pension contribution. The actual contribution paid by the sponsor and participants can however be lower than the cost-effective contribution. When the long term expectations of the investment return and the interest rate are respectively high and low enough, pension funds could charge a lower contribution level. In that case, a premium reduction is given to the sponsor and participants.

Because premium is paid for active participants, the average duration of the cash flow of the cost-effective contribution is often larger than the average duration of the pension payments. To illustrate the effects of the changed term structure methodology on the height and volatility of the cost-effective contribution, the same data periods will be used as described in Section 5.1 to value the cash flow of the assumed cost-effective contribution (see Figure 5.2). A pension fund assigns pension accrual based on the age, pensionable salary, years of service and part-time percentage of the participant for the retirement pension and spouse pension (and possible orphans pension and disability

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4Possibilities to ask for lower premiums are possibly limited in ftkII
5Pension based salary is equal to the yearly salary (holiday allowance) minus a deductible
6Only in a final-pay pension contract
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Figure 5.2: The cash flow of the cost-effective contribution belonging to one year pension accrual.

pension), dependent on the pension contract. Using the age of the participants and demographic assumptions\(^7\), expected cash flows can be generated. These cash flows are needed for the pension accrual each year, and one cash flow (see Figure 5.2) will be used to study the effects of the changed term structure methodology. These are the costs of one year pension rights accrual of active participants of a pension fund. When the active participants of different funds have the same characteristics, the cost-effective contribution will also look similar. Despite having very different liability cash flows, the young, average and old fund could for example all have a similar active population. Note that the pension premium level is important for the sponsor and the employees, since they have to pay for a possible increase in the cost-effective contribution. For the pension funds the premium income is an important factor, since it has a large impact in the Profit and Loss (P&L) account. It is in the interest of pension funds to ask for a premium high enough to be able to make the pension payments which they promise, but employers and employees have other interests. Employers do not want that their pension premium becomes too high and that the pension premium is very volatile. Employees on the other hand want to have a large amount of certainty in the height and volatility of their pension and would like to have hard pension rights\(^8\). The analysis below assumes that the cash flow in Figure 5.2 is fixed and that the present value is only dependent on the yield curve. When the total present value of the cash flow increases, it means that the cost of the pension rights which are accrued rise and thus the contribution rate should rise or the accrual should decrease when the contribution level remains unchanged. Higher values of the total present value of the cash flow have thereby a negative effect for both employers and employees. A lower premium yields a positive effect, since the pension accrual can then increase or the contribution level can become lower. A small volatility over time of the cost-effective contribution is preferable, since a volatile contribution rate and pension accrual increases uncertainty and lowers the confidence level. The average change in the present value of the total cash flow replacing the market curve

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\(^7\) Assumptions regarding for example mortality, disability, marriage of the participants

\(^8\) In the new financial assessment framework, hard pension rights are probably softened to ensure a more sustainable pension system.
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Table 5.3: The average change (%) of the sum of the present value of the cash flow of the cost-effective contribution using the market curve compared to the valuation using the DNB 20-60 curve. Between brackets the p-value is presented indicating whether the total value of the cost-effective contribution has changed. The accompanying test statistic (see Equation (5.1)) is also provided.

<table>
<thead>
<tr>
<th></th>
<th>High rate period</th>
<th>Low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td>% difference total present value</td>
<td>-1.58%</td>
<td>7.90%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.82</td>
<td>3.32</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.21)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

Figure 5.3: Present value of the cash flow of the cost-effective contribution presented (see Figure 5.2) using respectively the market-curve and the DNB 20-60 curve.

by the DNB 20-60 curve is presented in Table 5.3. A p-value below 0.05 indicates that the present value of the cost-effective contribution using the market curve differs from the present value of the cost-effective contribution using the DNB 20-60 curve with a 95% confidence level. In Figure 5.3, the average present value of the cash flow of the cost-effective contribution in the high rate period and the low rate period using the two different curves are presented. In the high rate period, the present value of the cash flow of the cost-effective contribution has not changed significantly. The sum of the present values of the cash flow calculated with the market curve are on average 1.58% lower than the total present value calculated with the DNB 20-60 curve. The new methodology will thus result in a worse outcome for the pension funds. There is however a significant change observable in the low-rate period, where the present value of the total cash flow calculated with the market curve yields on average a value which is 7.90% higher than the present value calculated with the DNB 20-60 curve. For the cash flows with durations beyond 20 years, the present value is observable higher in this period as can be seen in Figure 5.3. Using the DNB 20-60 curve to value the cost-effective contribution will thus have a positive effect, assuming the long-term forward rate used for the construction ex post proves to be accurate. The volatility of the total present value of the cost-effective contribution seems to decrease when the market curve is replaced by the DNB 20-60 curve as can be seen in Table 5.4.
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<table>
<thead>
<tr>
<th>Volatility total cash flow (amounts in €1,000.-)</th>
<th>High rate period</th>
<th>Low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Market</td>
<td>DNB 20-60</td>
</tr>
<tr>
<td>Test statistic</td>
<td>4.517</td>
<td>3.598</td>
</tr>
<tr>
<td>p-value</td>
<td>1.58</td>
<td>1.67</td>
</tr>
</tbody>
</table>

Table 5.4: The volatility of the total cash flow using the market-curve and using the DNB 20-60 curve. Between brackets the p-value is presented which follows from a one-sided test indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.3)) is also provided.

In both the high rate period as the low rate period a significantly lower volatility of the total present value of the cost-effective contribution is observed (using a confidence level of 94%). The p-values are corresponding to a F-test with a test statistic as in Equation (5.3), where $S_{marketC}^2$ is the volatility of the sum of the cash flow using market valuation and $S_{ufrC}^2$ is the volatility of the total cash flow using the DNB 20-60 curve.

$$W = \frac{S_{marketC}^2}{S_{ufrC}^2}$$

(5.3)

5.3 Sensitivity with respect to important parameters

Since the new yield curve is subject to a number of important assumptions, a sensitivity analysis will be performed to reveal the sensitivity of the height and volatility of the coverage ratio and the cost-effective contribution with respect to important parameters. The most important assumptions used in the SW method are about the choice of the last liquid point, the speed of convergence and the value of the ultimate forward rate.

5.3.1 Sensitivity of the coverage ratio

Since the swap market is still quite liquid up to 30 years, it is interesting to look at the influence of the choice regarding the last liquid point on the level of the coverage ratio and volatility of pension funds. In Table 5.5 the influence of a changing term structure is depicted replacing the market curve with a UFR 30-60 curve. Note that the length of the convergence period is automatically adapted because of the newly chosen last liquid point. Because the term structure is adapted after 30 years, the influence of a changing term structure has become smaller for the three pension funds, and almost negligible for the average and old fund. However, there is still a significant increase for the young period in the average coverage ratio of 1.80%. Other effects are small and insignificant, implying that the replacement of term structure using a last liquid point of 30 years by this new term structure would have almost no effect on the value and volatility of the coverage ratio of pension funds covering half of their interest rate risk.

Since the default value of the convergence parameter is set to 0.1, and is only adapted upwards because this is assumed to be the minimum value for $\alpha$, the sensitivity with respect to the default value of $\alpha$ is only practical relevant for higher default values of $\alpha$.
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Table 5.5: Sensitivity with respect to the last liquid point. The consequences for the coverage ratio when the market-curve is replaced by an UFR 30-60 curve. In the Coverage ratio columns the average change of the coverage ratio is displayed when the market curve is replaced by an UFR 30-60 curve. Between brackets the \( p \)-value is presented indicating whether the average coverage ratio has changed. The accompanying test statistic (see Equation (5.1)) is also provided. In the Volatility columns the sample standard deviation of the coverage ratio is given using an UFR 30-60 curve for the valuation. Between brackets the \( p \)-value is presented indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.2)) is also provided.

<table>
<thead>
<tr>
<th></th>
<th>High rate period</th>
<th>Low rate period</th>
<th>High rate period</th>
<th>Low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LL = 20</td>
<td>LL = 30</td>
<td>LL = 20</td>
<td>LL = 30</td>
</tr>
<tr>
<td>Young fund</td>
<td>-0.84%</td>
<td>-0.23%</td>
<td>3.28%</td>
<td>1.80%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-1.19</td>
<td>-0.32</td>
<td>3.36</td>
<td>1.84</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(0.12)</td>
<td>(0.07)</td>
<td>(0.00)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Average fund</td>
<td>-0.30%</td>
<td>-0.05%</td>
<td>1.27%</td>
<td>0.56%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.67</td>
<td>-0.11</td>
<td>1.74</td>
<td>0.76</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(0.25)</td>
<td>(0.45)</td>
<td>(0.04)</td>
<td>(0.22)</td>
</tr>
<tr>
<td>Old fund</td>
<td>-0.07%</td>
<td>-0.01%</td>
<td>0.28%</td>
<td>0.08%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.25</td>
<td>-0.02</td>
<td>0.57</td>
<td>0.17</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(0.40)</td>
<td>(0.49)</td>
<td>(0.28)</td>
<td>(0.43)</td>
</tr>
</tbody>
</table>

Since for the analysis in Table 5.2 the value of \( \alpha \) is only revised for a couple of months, a higher default value of \( \alpha \) implies a lower value of \( T^2 \) and thus a steeper increase of the forward rate after the last liquid point. The results of changing the default value of \( \alpha \) from 0.1 to respectively 0.15 and 0.20 are shown in Table 5.6 and Table 5.7.

Increasing the default value of \( \alpha \) steepens the forward curve after the last liquid point towards the ultimate forward rate and thus increases the resulting yield curve. This results in larger effects in the coverage ratios of the three pension funds. A shorter convergence period leads to larger effects replacing the market curve with the new curve; the effects that can be observed in tables 5.6 and 5.7 are larger than the effects in Table 5.2. In periods where the interest rate is high, the volatility of the coverage ratio decreases significantly and in periods where the interest rate is low the average coverage ratio rises significantly. This effect becomes stronger and the level of significance increases when the speed of convergence increases, so when the default value of \( \alpha \) is larger.

The value of the UFR can considered to be high compared to market interest rates. Some say that the ultimate forward rate should be adapted and has to be dependent of the market. However, the UFR is used as a stabilizing factor to correct for very high and very low interest rate levels and should therefore be stable over time and only change due to fundamental changes in the long term expectations of the inflation and the real rate. Sensitivity with respect to the value of the ultimate forward rate is interesting, because of the criticised value of 4.2%. The sensitivity of the coverage ratio with respect to the ultimate forward rate plus and minus 10 and 20 basis points will be checked. The results are visualized in Table 5.8, Table 5.9, Table 5.10 and Table 5.11.
### Coverage ratio

<table>
<thead>
<tr>
<th></th>
<th>High rate period</th>
<th>Low rate period</th>
<th>High rate period</th>
<th>Low rate period</th>
<th>High rate period</th>
<th>Low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Young fund</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α=0.10</td>
<td>-0.84%</td>
<td>-0.84%</td>
<td>3.28%</td>
<td>3.67%</td>
<td>3.94%</td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td>-1.19</td>
<td>-1.20</td>
<td>3.36</td>
<td>3.76</td>
<td>4.04</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>(0.12)</td>
<td>(0.12)</td>
<td>(0.09)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td><strong>Average fund</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α=0.10</td>
<td>-0.30%</td>
<td>-0.31%</td>
<td>1.27%</td>
<td>1.44%</td>
<td>1.56%</td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.67</td>
<td>-0.69</td>
<td>1.74</td>
<td>1.97</td>
<td>2.14</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>(0.25)</td>
<td>(0.25)</td>
<td>(0.21)</td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.02)</td>
</tr>
<tr>
<td><strong>Old fund</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α=0.10</td>
<td>-0.07%</td>
<td>-0.07%</td>
<td>0.28%</td>
<td>0.32%</td>
<td>0.35%</td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.25</td>
<td>0.66</td>
<td>0.57</td>
<td>0.66</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>(0.40)</td>
<td>(0.40)</td>
<td>(0.38)</td>
<td>(0.28)</td>
<td>(0.25)</td>
<td>(0.23)</td>
</tr>
</tbody>
</table>

Table 5.6: Sensitivity with respect to the convergence parameter $\alpha$. The consequences for the coverage ratio when the market curve is replaced by the new yield curve. The average change of the coverage ratio is displayed when the market curve is replaced by the new yield curve. Between brackets the $p$-value is presented indicating whether the average coverage ratio has changed. The accompanying test statistic (see Equation (5.1)) is also provided.

### Volatility

<table>
<thead>
<tr>
<th></th>
<th>High rate period</th>
<th>Low rate period</th>
<th>High rate period</th>
<th>Low rate period</th>
<th>High rate period</th>
<th>Low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Young fund</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α=0.10</td>
<td>12.39%</td>
<td>12.47%</td>
<td>22.26%</td>
<td>21.56%</td>
<td>21.01%</td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.89</td>
<td>1.86</td>
<td>1.38</td>
<td>1.47</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.07)</td>
<td>(0.05)</td>
<td></td>
</tr>
<tr>
<td><strong>Average fund</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α=0.10</td>
<td>9.48%</td>
<td>9.50%</td>
<td>17.81%</td>
<td>17.50%</td>
<td>17.23%</td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.31</td>
<td>1.31</td>
<td>1.21</td>
<td>1.25</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>(0.17)</td>
<td>(0.18)</td>
<td>(0.24)</td>
<td>(0.20)</td>
<td>(0.17)</td>
<td></td>
</tr>
<tr>
<td><strong>Old fund</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α=0.10</td>
<td>6.25%</td>
<td>6.25%</td>
<td>12.53%</td>
<td>12.44%</td>
<td>21.37%</td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.07</td>
<td>1.07</td>
<td>1.07</td>
<td>1.09</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>(0.41)</td>
<td>(0.41)</td>
<td>(0.39)</td>
<td>(0.39)</td>
<td>(0.37)</td>
<td>(0.35)</td>
</tr>
</tbody>
</table>

Table 5.7: Sensitivity with respect to the convergence parameter $\alpha$. The consequences for the coverage ratio when the market curve is replaced by the new yield curve. The sample standard deviation of the coverage ratio is given using the new yield curve for the valuation. Between brackets the $p$-value indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.2)) is also provided.
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### Coverage ratio high rate period

<table>
<thead>
<tr>
<th></th>
<th>UFR -20bp</th>
<th>UFR -10bp</th>
<th>UFR</th>
<th>UFR +10bp</th>
<th>UFR +20bp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young fund</td>
<td>-1.42%</td>
<td>-1.12%</td>
<td>-0.84%</td>
<td>-0.56%</td>
<td>-0.26%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-2.02</td>
<td>-1.59</td>
<td>-1.19</td>
<td>-0.80</td>
<td>-0.38</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.02)</td>
<td>(0.06)</td>
<td>(0.12)</td>
<td>(0.21)</td>
<td>(0.35)</td>
</tr>
<tr>
<td>Average fund</td>
<td>-0.05%</td>
<td>-0.40%</td>
<td>-0.30%</td>
<td>-0.21%</td>
<td>-0.11%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-1.12</td>
<td>-0.89</td>
<td>-0.67</td>
<td>-0.46</td>
<td>-0.24</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.13)</td>
<td>(0.19)</td>
<td>(0.25)</td>
<td>(0.32)</td>
<td>(0.41)</td>
</tr>
<tr>
<td>Old fund</td>
<td>-0.11%</td>
<td>-0.99%</td>
<td>-0.01%</td>
<td>-0.05%</td>
<td>-0.03%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.41</td>
<td>-0.33</td>
<td>-0.25</td>
<td>-0.18</td>
<td>-0.10</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.34)</td>
<td>(0.37)</td>
<td>(0.40)</td>
<td>(0.43)</td>
<td>(0.46)</td>
</tr>
</tbody>
</table>

Table 5.8: Sensitivity with respect to the UFR in the high rate period. The consequences for the coverage ratio when the market curve is replaced by the new yield curve. The average change of the coverage ratio is displayed when the market curve is replaced by the new yield curve. Between brackets the $p$-value indicating whether the average coverage ratio has changed. The accompanying test statistic (see Equation \[5.1\]) is also provided.

### Volatility high rate period

<table>
<thead>
<tr>
<th></th>
<th>UFR -20bp</th>
<th>UFR -10bp</th>
<th>UFR</th>
<th>UFR +10bp</th>
<th>UFR +20bp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young fund</td>
<td>11.91%</td>
<td>12.12%</td>
<td>12.39%</td>
<td>12.43%</td>
<td>12.55%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>2.04</td>
<td>1.97</td>
<td>1.89</td>
<td>1.84</td>
<td>1.87</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Average fund</td>
<td>9.34%</td>
<td>9.40%</td>
<td>9.48%</td>
<td>9.47%</td>
<td>9.49%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.35</td>
<td>1.34</td>
<td>1.97</td>
<td>1.31</td>
<td>1.31</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.15)</td>
<td>(0.16)</td>
<td>(0.17)</td>
<td>(0.17)</td>
<td>(0.17)</td>
</tr>
<tr>
<td>Old fund</td>
<td>6.23%</td>
<td>6.24%</td>
<td>6.25%</td>
<td>6.24%</td>
<td>6.24%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.08</td>
<td>1.08</td>
<td>1.07</td>
<td>1.08</td>
<td>1.07</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.40)</td>
<td>(0.40)</td>
<td>(0.41)</td>
<td>(0.40)</td>
<td>(0.40)</td>
</tr>
</tbody>
</table>

Table 5.9: Sensitivity with respect to the UFR in the high rate period. The consequences for the coverage ratio when the market curve is replaced by the new yield curve. The sample standard deviation of the coverage ratio is given using the new yield curve for the valuation. Between brackets the $p$-value is presented indicating whether the volatility has decreased. The accompanying test statistic (see Equation \[5.2\]) is also provided.

Author: Tom van der Vorst  
Supervisor: Dr. Ronald Mahieu
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<table>
<thead>
<tr>
<th></th>
<th>Coverage ratio low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UFR -20bp</td>
</tr>
<tr>
<td><strong>Young fund</strong></td>
<td>2.67%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>2.74</td>
</tr>
<tr>
<td><em>p</em>-value</td>
<td>(0.00)</td>
</tr>
<tr>
<td><strong>Average fund</strong></td>
<td>1.05%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.44</td>
</tr>
<tr>
<td><em>p</em>-value</td>
<td>(0.08)</td>
</tr>
<tr>
<td><strong>Old fund</strong></td>
<td>0.23%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>0.47</td>
</tr>
<tr>
<td><em>p</em>-value</td>
<td>(0.32)</td>
</tr>
</tbody>
</table>

Table 5.10: Sensitivity with respect to the UFR in the low rate period. The consequences for the coverage ratio when the market curve is replaced by the new yield curve. The average change of the coverage ratio is displayed when the market curve is replaced by the new yield curve. Between brackets the *p*-value indicating whether the average coverage ratio has changed. The accompanying test statistic (see Equation [5.1]) is also provided.

<table>
<thead>
<tr>
<th></th>
<th>Volatility low rate period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UFR -20bp</td>
</tr>
<tr>
<td><strong>Young fund</strong></td>
<td>21.89%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.07</td>
</tr>
<tr>
<td><em>p</em>-value</td>
<td>(0.09)</td>
</tr>
<tr>
<td><strong>Average fund</strong></td>
<td>17.76%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.21</td>
</tr>
<tr>
<td><em>p</em>-value</td>
<td>(0.23)</td>
</tr>
<tr>
<td><strong>Old fund</strong></td>
<td>12.54%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.07</td>
</tr>
<tr>
<td><em>p</em>-value</td>
<td>(0.39)</td>
</tr>
</tbody>
</table>

Table 5.11: Sensitivity with respect to the UFR in the low rate period. The consequences for the coverage ratio when the market curve is replaced by the new yield curve. The sample standard deviation of the coverage ratio is given using the new yield curve for the valuation. Between brackets the *p*-value is presented indicating whether the volatility has decreased. The accompanying test statistic (see Equation [5.2]) is also provided.
A higher value of the ultimate forward rate results in a steeper yield curve in the low rate period and a less steep curve in the high rate period, and thus a larger effect in the low rate period and a smaller effect in the high rate period compared to the curve with an UFR of 4.2%. Lowering the value of the UFR will have the opposite effect of increasing the value of the UFR. The value of the ultimate forward rate does have an impact on the increase (or decrease) of the average coverage ratio. In a period where the interest rate is high, the effect of a larger UFR reduces the effect on the average coverage ratio, but in a period where the interest rate is low the difference in average coverage ratio becomes larger. The effect on the volatility of the coverage ratio depends on the period in which you are interested; in periods where the interest rate is high (good times for pension funds) the volatility seems to be reduced, and only a small effect is observed in a period where the interest rate is low (worse times for pension funds). For pension funds with a higher average duration, the effects on both the difference in average coverage ratio as well as the reduction in the volatility of the coverage ratio are larger.

### 5.3.2 Sensitivity of the cost-effective contribution

A sensitivity analysis for the height and volatility of the present value of the cost-effective contribution is constructed in the same way as described above for the coverage ratio. Throughout the rest of this section, $S_{\text{new}}$ will denote the volatility of the present value of the cost-effective contribution valued with the new yield curve. The sensitivity with respect to the choice of the last liquid point for Dutch pension funds will be illustrated below. In Table 5.12, the influence of a changing term structure is depicted, replacing the market curve with an UFR 30-60 curve.

Replacing the market curve with an UFR 30-60 curve has a smaller effect on the cost-effective contribution than when the market curve is replaced by the DNB 20-60 curve. The effect of shifting the last liquid point from 20 to 30 years leads to a small

<table>
<thead>
<tr>
<th>% difference total present value</th>
<th>LLP=20</th>
<th>LLP=30</th>
<th>LLP=20</th>
<th>LLP=30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test statistic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_{\text{new}}$ (amounts in €1,000.-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test statistic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.12: Sensitivity with respect to the last liquid point of the cost-effective contribution. The consequences for the cost-effective contribution when the market curve is replaced by an UFR 30-60 curve. The average change (%) of the sum of the present value of the cash flow of the cost-effective contribution using the market curve compared to the valuation using an UFR 30-60 curve. The $p$-values correspond to a two-sided $t$-test indicating whether the total value has significantly changed. The accompanying test statistic (see Equation (5.1)) is also provided. The volatility of the total cash flow using the new yield curve for the valuation is also presented, along with the $p$-value indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.3)) is also provided.
The consequences of changes in the term structure methodology

<table>
<thead>
<tr>
<th></th>
<th>High rate period</th>
<th></th>
<th></th>
<th>Low rate period</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha=0.10$</td>
<td>$\alpha=0.15$</td>
<td>$\alpha=0.20$</td>
<td>$\alpha=0.10$</td>
<td>$\alpha=0.15$</td>
</tr>
<tr>
<td>% difference total present value</td>
<td>-1.58%</td>
<td>-1.61%</td>
<td>-1.87%</td>
<td>7.90%</td>
<td>8.81%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>-0.82</td>
<td>-0.81</td>
<td>-0.99</td>
<td>3.32</td>
<td>3.71</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.21)</td>
<td>(0.20)</td>
<td>(0.16)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$S_{\text{new}}$ (amounts in €1,000.-)</td>
<td>3,598</td>
<td>3,596</td>
<td>3,488</td>
<td>8,529</td>
<td>8,203</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.58</td>
<td>1.58</td>
<td>1.68</td>
<td>1.67</td>
<td>1.80</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.0594)</td>
<td>(0.0588)</td>
<td>(0.0382)</td>
<td>(0.0258)</td>
<td>(0.0126)</td>
</tr>
</tbody>
</table>

Table 5.13: Sensitivity with respect to the convergence parameter $\alpha$ of the cost-effective contribution.

The consequences for the cost-effective contribution when the market curve is replaced by the new yield curve. The average change (%) of the sum of the present value of the cash flow of the cost-effective contribution using the market curve compared to the valuation using the new yield curve. The $p$-values correspond to a two-sided $t$-test indicating whether the total value has changed significantly. The accompanying test statistic (see Equation (5.1)) is also provided. The volatility of the total cash flow using the new yield curve for the valuation is also presented, along with the $p$-value indicating whether the volatility has decreased when the new yield curve is used. The accompanying test statistic (see Equation (5.3)) is also provided.

impact on the total value of the cash flow and the volatility when the market curve is replaced by the new curve. Replacing the market curve with an UFR 30-60 curve leads to insignificant changes in the present value of the cash flow in the high rate period and a small difference in the low rate period of 4.28%. The volatility of the present value is not reduced significantly in both periods. Thus, when the last liquid point is set to 30 years, the introduction of the UFR-methodology would result at best in a small decrease in the value of the cost-effective contribution. However, this result is only obtained when the market interest rate is at a low level.

As in the previous subsection, it would be interesting to look at the sensitivity with respect to the convergence parameter $\alpha$. The effect on the cost-effective contribution probably will be large since the average duration of the cash flow is high. The result of changing the default value of $\alpha$ from 0.1 to respectively 0.15 and 0.20 are shown in Table 5.13. Increasing the default value of $\alpha$ will lead to larger differences between the results of the valuation using the market curve and the new curve. In the high rate period a small increase is observed in the total value of the cash flow of the cost-effective contribution when the new curve is introduced by 1.87% at most. This increase is however small and insignificant. The volatility has decreased in the high rate period significantly, which is preferable for both employers as employees. The results in the low rate are significant; both the present value as the volatility of the cash flow of the cost-effective contribution have decreased when the market curve is replaced by the new curve. The total value of the cash flow of the cost-effective contribution is at most 9.42% higher when the market curve is used.

The last parameter for which the sensitivity of the total value of the cost-effective contribution is considered, is the sensitivity with respect to the value of the ultimate forward rate. The effect on the present value of the cash flow for values of the UFR plus and minus 10 and 20 basis points will be calculated. The results can be found in Table 5.14 and Table 5.15.
### High rate period

<table>
<thead>
<tr>
<th>% difference total present value</th>
<th>UFR -20bp</th>
<th>UFR -10bp</th>
<th>UFR</th>
<th>UFR +10bp</th>
<th>UFR +20bp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test statistic</td>
<td>-2.32%</td>
<td>-2.18%</td>
<td>-1.58%</td>
<td>-1.00%</td>
<td>-0.59%</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.06)</td>
<td>(0.12)</td>
<td>(0.21)</td>
<td>(0.32)</td>
<td>(0.47)</td>
</tr>
<tr>
<td>$S_{\text{new}}$ (amounts in €1,000.-)</td>
<td>3.563%</td>
<td>3.574%</td>
<td>3.598%</td>
<td>3.564%</td>
<td>3.543%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.61</td>
<td>1.60</td>
<td>1.58</td>
<td>1.61</td>
<td>1.63</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.0518)</td>
<td>(0.0541)</td>
<td>(0.0594)</td>
<td>(0.0520)</td>
<td>(0.0479)</td>
</tr>
</tbody>
</table>

Table 5.14: Sensitivity with respect to the value of the UFR of the cost-effective contribution in the high rate period. The consequences for the cost-effective contribution when the market curve is replaced by the new yield curve. The average change (%) of the sum of the present value of the cash flow of the cost-effective contribution using the market curve compared to the valuation using the new yield curve. The p-values correspond to a two-sided t-test indicating whether the change has changed significantly. The accompanying test statistic (see Equation (5.1)) is also provided. The volatility of the total cash flow using the new yield curve for the valuation is also presented, along with the p-value indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.3)) is also provided.

### Low rate period

<table>
<thead>
<tr>
<th>% difference total present value</th>
<th>UFR -20bp</th>
<th>UFR -10bp</th>
<th>UFR</th>
<th>UFR +10bp</th>
<th>UFR +20bp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test statistic</td>
<td>6.66%</td>
<td>7.07%</td>
<td>7.90%</td>
<td>8.20%</td>
<td>8.94%</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$S_{\text{new}}$ (amounts in €1,000.-)</td>
<td>8.653</td>
<td>8.558</td>
<td>8.529</td>
<td>8.322</td>
<td>8.188</td>
</tr>
<tr>
<td>Test statistic</td>
<td>1.62</td>
<td>1.66</td>
<td>1.67</td>
<td>1.75</td>
<td>1.83</td>
</tr>
<tr>
<td>p-value</td>
<td>(0.0330)</td>
<td>(0.0273)</td>
<td>(0.0258)</td>
<td>(0.0165)</td>
<td>(0.0108)</td>
</tr>
</tbody>
</table>

Table 5.15: Sensitivity with respect to the value of the UFR of the cost-effective contribution in the low rate period. The consequences for the cost-effective contribution when the market curve is replaced by the new yield curve. The average change (%) of the sum of the present value of the cash flow of the cost-effective contribution using the market curve compared to the valuation using the new yield curve. The p-values correspond to a two-sided t-test indicating whether the change has changed significantly. The accompanying test statistic (see Equation (5.1)) is also provided. The volatility of the total cash flow using the new yield curve for the valuation is also presented, along with the p-value indicating whether the volatility has decreased. The accompanying test statistic (see Equation (5.3)) is also provided.
As pointed out earlier in this thesis, a higher value of the ultimate forward rate will lead to a steeper yield curve in the low rate period and a less steep curve in the high rate period. Similar effects as seen in the sensitivity for the coverage ratio can be seen in tables 5.14 and 5.15. In the high rate period, a lower value of the UFR will lead to larger differences between the valuations using the two different yield curves whereas the opposite is observed in the low rate period. The results in the high rate period are less significant, but with a reasonable confidence level one can conclude that the volatility of the total cash flow decreases irrespective of the values of the UFR which are considered. When the interest rate observed in the market is low, the new yield curve will lead to a lower present value of the total cash flow. High market rates will lead to higher values of the total cash flow, but these effects are smaller. Overall the results are strongly dependent on the choices which are made regarding the new yield curve. The effect on the coverage ratio and the cost-effective contribution are sensitive to choices which are made regarding the last liquid point, the speed of convergence and the value of the UFR. Thus, when the market curve is replaced by a new curve, these choices should be supported by valid arguments.

5.4 Ex ante consequences: modelling future scenarios

In the previous section, the influence of implementing the ultimate forward rate methodology was illustrated ex post. Because it would also be interesting to look at the consequences of the new term structure methodology in the future, possible future term structures will be simulated. Using these term structures, the consequences of a changing methodology in the extreme events in the near future can be simulated. Extreme events will be defined as the top 2.5% of the simulated term structures as well as the bottom 2.5% of the simulated term structures ordered at the last liquid point based on a total of 2,000 simulations. To give a realistic impression of the consequences the new methodology has on the coverage ratio and cost-effective contribution of pension funds, a model is needed which generates realistic results for the term structure in the near future. Forecasting the term structure is a difficult task, and often the choice is made between the fit of the model on the term structure at a given point in time, and model dynamics. The aim of the first model is to ensure no arbitrage opportunities and the aim of the second model is to focus on the dynamics of the short rate, after which various assumption make it possible to derive the yield curve. However, in the arbitrage free term structure literature, little attention is paid towards the dynamics or forecasting of the term structure. The drawback of the work done in the affine equilibrium term structure literature, as illustrated by Duffee (2002), is that equilibrium models perform rather poorly in out-of-sample forecasts. Since for this thesis out-of-sample forecasting is needed to simulate possible future term structures, I will use the work of Diebold and Li (2006) which primarily focuses on this topic. In their model, the Nelson and Siegel (1987) framework is used as a basis to extrapolate for future term structures. In the next subsection this method will be further elaborated.
5.4.1 Model

In the exponential components framework designed by Nelson and Siegel (1987), the forward curve is modelled using a three component exponential, which can be interpreted as a Laguerre function plus a constant. A Laguerre function is a polynomial times an exponential decay function, and is often used for approximation purposes (for a further elaboration I refer to Courant and Hilbert (1953)). The forward curve at time \( t \) for maturities \( T \) is given in Equation (5.4).

\[
F_t(T) = \beta_1 t + \beta_2 t e^{-\lambda_1 T} + \beta_3 t \lambda_1 T e^{-\lambda_1 T}
\]  

Using Equation (3.14) the corresponding yield curve can be obtained, resulting in (5.5).

\[
R_t(T) = \beta_1 t + \beta_2 t \left( \frac{1 - e^{-\lambda_1 T}}{\lambda_1 T} \right) + \beta_3 t \left( \frac{1 - e^{-\lambda_1 T}}{\lambda_1 T} - e^{-\lambda_1 T} \right)
\]

The yield curve is fitted period-by-period, creating a three-dimensional parameter that evolves dynamically over time. In Diebold and Li (2006) it is shown that these three time-varying parameters may be interpreted as factors representing the level, slope and curvature of the term structure over time. These factors are modelled in three autoregressive models which allow for extrapolation over time of the factors. Using this extrapolation, possible future term structures can be obtained when the extrapolated factors are put into Equation (5.5). The exponential decay rate is governed by the parameter \( \lambda_t \); a higher value allows for a better fit at short maturities, where a lower value ensures a better fit for long maturities. The interpretation of \( \beta_1 t \) is straightforward, since the term structure for larger values of \( T \) converges to the value of \( \beta_1 t \) as the loadings on \( \beta_2 t \) and \( \beta_3 t \) converge to 0 for large values of \( T \) and the loading on \( \beta_1 t \) remains constant over time at 1. Thus, in the Nelson-Siegel model the first factor \( \beta_1 t \) can be interpreted as the long-term factor. The loading on the second factor \( \beta_2 t \) reduces over time, starting at 1 for the instantaneous rate and converges monotonically to 0 over time. Hence, \( \beta_2 t \) can be interpreted as the short term factor. The interpretation of the third factor is less straightforward as it starts at 0, increases at first, and decreases then again converging to 0 again for large maturities. The third factor can thereby interpreted as a medium-term factor (see Diebold and Li 2006). The time of maturity for which the loading on the third factor reaches it maximum depends on the value of \( \lambda_t \). As in Diebold and Li (2006), I will assume that the loading on the third factor reaches it maximum at 30 months, hence 2.5 years is defined as the medium-term. The value of \( \lambda_t \) corresponding to a maximum of the loading on the third factor at 30 months is equal to 0.0598. For simplification purposes I will keep the value of \( \lambda \) constant over time (so \( \lambda_t = \lambda = 0.0598 \)), which allows for least squares estimation of \( \{\beta_1 t, \beta_2 t, \beta_3 t\} \). The loadings on the three factors for different maturities are illustrated in Figure 5.4.
The consequences of changes in the term structure methodology

Figure 5.4: The factors loadings

Data

Because the number of observations of term structures available on the DNB website is too low to perform the analysis described above, another dataset has to be used to provide the dynamics of the parameters in the framework. For the estimation of the autoregressive models of the parameters, spot rates of the Eurozone will be used which are provided by the *European Central Bank* (ECB). Daily data is available from 6 September 2004 up to 28 February 2013, which are 2214 observations based on AAA government bonds. In this period, both the level of the interest rate as the shape of the term structure have changed as can be seen in Figure 5.5. The changing shape over time of the term structure is an argument to follow the methodology from Diebold and Li, since this method copes with the fact that the shape, curvature and level of the term structure change over time. I will assume that the dynamics of the parameters representing the short-, middle- and long-term in the yield curve based on interest rate swaps and the dynamics of the yield curve based on AAA government bonds are the same. For the simulations of the term structures in the Netherlands these dynamics will be used with starting values equal to the estimates of the Nelson-Siegel parameters of the Dutch term structure of 31 December 2012.

9The ratings are provided by Fitch Ratings
The consequences of changes in the term structure methodology

5.4.2 Estimation and forecasting

The Nelson-Siegel curve is fitted period-by-period, resulting in three series, \( \{ \hat{\beta}_1 \} \), \( \{ \hat{\beta}_2 \} \) and \( \{ \hat{\beta}_3 \} \) each with length 2214. The overview of the descriptive statistics of the estimates are depicted in Table 5.16. For the Augmented Dickey-Fuller (ADF) test the Schwarz Information Criterion is used to choose the number of lags. Note that there is no unit root present according to the ADF test in the three series.

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \hat{\beta}_1 )</td>
<td>4.305</td>
<td>0.550</td>
<td>2.750</td>
<td>5.400</td>
</tr>
<tr>
<td>( \hat{\beta}_2 )</td>
<td>-2.288</td>
<td>1.446</td>
<td>-4.940</td>
<td>0.201</td>
</tr>
<tr>
<td>( \hat{\beta}_3 )</td>
<td>-3.560</td>
<td>1.774</td>
<td>-7.705</td>
<td>0.591</td>
</tr>
</tbody>
</table>

MacKinnon (1996) critical values for the rejection of a unit root are -3.43 at a 1% level, -2.86 at the 5% level and -2.57 at the 10% level.

Table 5.16: Descriptive factors

As can be seen in Figure 5.6 the Nelson-Siegel curve performs well in replicating the actual curve for very different kind of shapes. The parameter values should thereby give a realistic and practical insight in the dynamics of the term structure. The three series are modelled in an autoregressive model with one lag and a constant, as can be seen below.

\[
\begin{align*}
\hat{\beta}_1 &= \hat{c}_1 + \hat{\eta}_1 \hat{\beta}_{1t-1}; \\
\hat{\beta}_2 &= \hat{c}_2 + \hat{\eta}_2 \hat{\beta}_{2t-1}; \\
\hat{\beta}_3 &= \hat{c}_3 + \hat{\eta}_3 \hat{\beta}_{3t-1}.
\end{align*}
\]
The consequences of changes in the term structure methodology

Figure 5.6: Fit Nelson-Siegel for different shapes of the term structure. The solid line represents the actual curve and the dotted line the fitted Nelson-Siegel curve.

<table>
<thead>
<tr>
<th>$c$</th>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\beta_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>(0.07)</td>
<td>(0.48)</td>
<td>(0.05)</td>
</tr>
</tbody>
</table>

Table 5.17: Estimates autoregressive models

Using the estimates of the regression, as well as the estimates of $\beta_{it}$ for the Dutch market curve of 31 December 2012, simulations of possible future term structures can be generated assuming that the level, slope and curvature have the same dynamics in yield curves based on interest rate swaps as in the yield curves based on AAA government bonds. The estimates of the autoregressive models can be found in Table 5.17. Note that the estimates of $\eta$ are statistically different from zero and that successive parameter values (on a daily basis) can thus be explained by their predecessors.

Possible future term structures can now be generated as in Equation (5.6), using the estimates of $\beta_{it}$ of the Dutch market curve which are depicted in Table 5.18.

$$\hat{R}_{t+h}(T) = \hat{\beta}_{1,t+h} + \hat{\beta}_{2,t+h} \left( 1 - \frac{e^{-\lambda_i T}}{\lambda_i T} \right) + \hat{\beta}_{3,t+h} \left( \frac{1 - e^{-\lambda_i T}}{\lambda_i T} - e^{-\lambda_i T} \right)$$ (5.6)

The generated term structures are ordered based on the value at the last liquid point.
The consequences of changes in the term structure methodology

<table>
<thead>
<tr>
<th></th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \beta_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimate</strong></td>
<td>3.2843</td>
<td>-0.5951</td>
<td>-9.7795</td>
</tr>
</tbody>
</table>

Table 5.18: Estimates Dutch market curve

The highest 2.5% and lowest 2.5% of the yield curves are defined as the top and bottom 2.5% for the analysis. On the extremes, the new DNB 20-60 methodology will be applied to get a better understanding on what the consequences are of the new methodology of the three model pension funds. The average change in the funding ratio replaces the market curve with the DNB 20-60 curve will be calculated and tested for significance. The results of the analysis, which is the average change in funding ratio for the simulated extreme cases in the near future, are depicted in Table 5.19. Using this methodology, the interest rate will increase the upcoming period converging to a 60-year interest rate of approximately 3.90%. This is a drawback of the chosen method, since the top 2.5% of the simulated term structures are not very extreme term structures. However, the top 2.5% of the simulated term structures are on average approximately 180 bp higher in year 1 and end up 50 bp higher at 60 years to maturity than the term structure published by DNB in 31 March 2013. Thus, the simulated term structures will still give an impression of the possible consequences of the new term structure methodology in the near future. The simulated term structures, as well as the extremes adapted for the new methodology are illustrated in Figure 5.7.

![Simulated yield curves](image)

Figure 5.7: Simulated term structures. The term structures in dark orange are the extreme events using the DNB 20-60 methodology.
The consequences of changes in the term structure methodology

### Table 5.19: Impact on the funding ratio in possible future events. In the table the average change of the coverage ratio is displayed when the simulated extreme curves are replaced by the DNB 20-60 curve. Between brackets the \( p \)-value is presented indicating whether the average coverage ratio has changed. The accompanying test statistic (see Equation (5.1)) is also provided.

<table>
<thead>
<tr>
<th></th>
<th>Coverage ratio top 2.5%</th>
<th>Coverage ratio bottom 2.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young fund</td>
<td>0.54%</td>
<td>3.21%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>2367.00</td>
<td>29.02</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(1.00)</td>
<td>(1.00)</td>
</tr>
<tr>
<td>Average fund</td>
<td>0.17%</td>
<td>1.05%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>5988.68</td>
<td>13.10</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(1.00)</td>
<td>(1.00)</td>
</tr>
<tr>
<td>Old fund</td>
<td>0.03%</td>
<td>0.21%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>171.05</td>
<td>3.78</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(1.00)</td>
<td>(1.00)</td>
</tr>
</tbody>
</table>

When the market interest rate rises the coming years as simulated, the introduction of the DNB 20-60 methodology leads to a small but significant rise of the funding ratio. The high level of the test statistic is the result of the low volatility in the top 2.5% of the simulated term structures. A drop of the interest rate as simulated could cause a significant increase of the term structure for all three pension funds. The effects are of similar size as the effects observed in the low rate period in Section 5.2. This indicates that following the simulation methodology used in this thesis, the interest rate will not drop any further in the near future. In reality however, the interest rate can stay at this low level quite a long time. For the young fund, the effect of a change in yield curve of the market curve to the DNB 20-60 curve can become as large as 3.21%. For the average and old fund this will also lead to a significant increase in the coverage ratio, although the size of the change in the coverage ratio will be much smaller with respectively 1.05% and 0.21%. The simulated term structures are also used to look at the effect of the changed term structure methodology in possible future events on the cost-effective contribution. Using the top and bottom 2.5% of the simulated term structures, the cash flow of the cost-effective contribution will be valued. The results are depicted in Table 5.20.

### Table 5.20: Impact on the cost-effective contribution in possible future events. The average change (%) of the sum of the present value of the cash flow of the cost-effective contribution using the simulated curves compared to the valuation using the DNB 20-60 curve. Between brackets the \( p \)-value is presented indicating whether the total value of the cost-effective contribution has changed. The accompanying test statistic (see Equation (5.1)) is also provided.

<table>
<thead>
<tr>
<th></th>
<th>Top 2.5%</th>
<th>Bottom 2.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>% difference total present value</td>
<td>0.91%</td>
<td>5.01%</td>
</tr>
<tr>
<td>Test statistic</td>
<td>2306.47</td>
<td>24.00</td>
</tr>
<tr>
<td>( p )-value</td>
<td>(1.00)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

Author: Tom van der Vorst Supervisor: Dr. Ronald Mahieu
The consequences of changes in the term structure methodology

When the market curve is used to value the cash flow of the cost-effective contribution, it will give on average higher values than when the DNB 20-60 curve is used. For the top 2.5% of the term structure this is a 0.91% higher value on average. Again, the high level of the test statistic can be explained by the low volatility of the term structure in the top 2.5% of the simulated term structures. Using the bottom 2.5% of the simulated term structures, the valuation based on the market curve yields on average a 5.01% higher value, which is statistically different from the present value of the cost-effective contribution using the DNB 20-60 curve. So, in times when the interest rate is low the new methodology will cause for lower premiums. When there is a higher term structure in the near future, the change yield curve will have a small effect. From this point of view, the introduction of the UFR-methodology has a positive effect for Dutch pension funds, sponsors and participants. However, when the long-term forward rate in the long run does not converge to 4.2%, many participants of pension funds have paid too little for the pension rights than they have by then. As a result, pension funds will be in financial distress when that happens. Ultimately, this will be the problem of sponsors and participants. The sponsor will have to make an extra deposit, and the participants could face less than full (or no) indexation or even pension benefit cuts.

The results found in this section are in line with the results obtained in Section 5.2. Consequences for the coverage ratio of pension funds are positive when the interest rate is low. The young fund does profit the most of the changing term structure methodology, because of the higher average duration of its liabilities. Pension funds with a lower average duration will experience a smaller effect on their coverage ratio and cost-effective contribution. The cost-effective contribution is also affected the most when low interest rates are observed in the financial market. Based on the methods used in this thesis, replacing the yield curve has a similar effect ex ante as was observed ex post. Note however that the size of the ex ante effect is dependent of the chosen model.
Chapter 6

Conclusion

All results found in this thesis are summarized in this concluding chapter. The consequences of the changed term structure methodology for pension funds are illustrated focusing on the effect on the coverage ratio and the cost-effective contribution. All other risks but interest rate risk were out of the scope on this thesis. The replacement of the market curve by the DNB 20-60 curve for the valuation of cash flows of Dutch pension funds is a correction of the low interest rate in the market and results in higher funding ratios and lower values of the cost-effective contributions. These effects are large for young pension funds, which have a large average duration of the liabilities, and small for pension funds with a lower average duration, the older funds. Constructing the yield curve with an implicit correction for possible economic extreme scenarios could be valuable for pension funds, as their obligations are due over 15 years from now on average. However, the new yield curve is sensitive to choices which have to be made outside the term structure model and the financial market.

The value of the ultimate forward rate, the choice of the last liquid point and the choice of the converge parameter $\alpha$ deserve extra attention. The UFR is partly based on historical averages, and one has to wonder whether a historical average is a proper estimate for the future. The illiquidity presumption of the market after 20 years can also be discussed, because the financial market up to 30 years is still quite liquid. Moreover, the choice of the convergence parameter is based on a study done with South-African data and is not verified for European data. The effects on the coverage ratio and the cost-effective contribution are sensitive to the choice of the parameters described above, so a careful look towards these choices is necessary. The new methodology, introduced to correct for extreme economic scenarios and reduce the volatility of the coverage ratio, only has a significant effect on the level of the coverage ratio when the interest rate is low. However, the volatility of the coverage ratio is reduced in the sample period where the interest rate on average was high. The difference in the size of the effect on the level of the coverage ratio between the high rate period and the low rate period is probably caused by the fact that the difference between the interest rates used in the analysis and the ultimate forward rate is larger in the low rate period than they are in the high rate period. Pension funds with a high average duration, so with young average participants,
The consequences of changes in the term structure methodology

are affected the most by the change of the yield curve methodology. Old pension funds are hardly affected because the yield curve is only adapted for long durations, behind the bulk of the liabilities of pension funds with a high average participant age. Effects on the cost-effective contribution are in line with the findings for the young pension fund. Pension funds are able to ask lower contributions when the DNB 20-60 curve is used for the valuation of the cash flow of the cost-effective contribution. The cost-effective contribution level will also become less volatile after the introduction.

However, when the interest rates do not meet their expectations implemented in the new yield curve, this causes problems for pension funds. Underestimating the economic present value pension fund liabilities and cost-effective contributions will result in a more asymmetric distribution of capital over generations within pension funds. Valuing the liabilities and cost-effective contributions with an artificial increased yield curve could prevent serious rights cuts, but putting off benefit cuts today means passing on the problem of underfunding to next generations in case market rates and UFR rates do not converge in the long-term. In case the gap between market rates and UFR rates remains present in the long run, the distorted view of the financial position of the fund has disastrous consequences. Basically, younger generations participating in pension funds are bearing this risk.
Chapter 7

Further research

In this final chapter, recommendations for further research are given on the topic of this thesis. As mentioned earlier, some of the external input factors of the new yield curve are based on only a small theoretical and empirical basis. The value of the ultimate forward rate is partly based on historical averages, and one has to wonder whether a historical average is a proper estimate for the future. A solid theoretical argumentation supported by empirical results regarding the value of the UFR is an important topic of the further research as the coverage ratio and value of the cost-effective contribution are sensitive to this value.

Since there is discussion about the point in time after which the market is not liquid anymore to use for the term structure, a solid argumentation has to be given supporting the argument that the financial is not liquid anymore after 20 years. Further research could be necessary, as no clear definition is used for market illiquidity and there could be a difference between the results following different market liquidity definitions. The default value of the convergence parameter $\alpha$ is now based on a study with South-African data. A qualitative assessment regarding the performance of the Smith-Wilson model for different values of $\alpha$ using European data has to confirm that smaller values of $\alpha$ will not yield sensible results. However, because the Eurozone is relatively a young currency zone, there could be a data problem because of the relatively small amount of zero-coupon curves which can be used for the qualitative assessment. A qualitative assessment based on data from the UK or US may also provide more information about the performance of the Smith-Wilson method with lower values of $\alpha$. Nevertheless, when lower values of $\alpha$ would also give sensible results for European data, the default value of $\alpha$ DNB uses has to be lowered to prevent artificial high coverage ratios.

In the Smith-Wilson methodology, the term premium is not included. It could be valuable to do further research on this topic, as this could affect the yield curve for pension funds. However, as pointed out in this thesis, it could be that the term premium is already implemented in swap contracts in the financial market. A study on the reason why the swap rate in practice differs from the equilibrium rate could be interested because of that reason too. It could be for example that the term premium is not implemented, but there is a risk premium embedded in the swap contracts.
Bibliography


De Nederlandse Bank (2005), ‘Vaststelling van de methodiek voor de rentetermijnstructuur’.


De Nederlandse Bank (2012b), ‘Vaststelling UFR methodiek voor de berekening van de rentetermijnstructuur’.


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The consequences of changes in the term structure methodology


Appendix A

Trading volume swap market and model pension funds

A.1 Trading volumes

Below the volume size and the number of trades in the Interest Rate Swap (IRS) market are presented. The figures are obtained from the Interest Rate Trade Repository Report of TriOptima. Data as of close of business: 20 April 2012.

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Gross Notional (BUSD Eqv.)</th>
<th>Maturity (years)</th>
<th>Maturity (years)</th>
<th>Maturity (years)</th>
<th>Maturity (years)</th>
<th>Maturity (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5-10</td>
<td>10-15</td>
<td>15-20</td>
<td>20-30</td>
<td>30+</td>
</tr>
<tr>
<td>IR - Basis Swap</td>
<td>Notional</td>
<td>694</td>
<td>121</td>
<td>54</td>
<td>61</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Trade Count</td>
<td>4,327</td>
<td>1,020</td>
<td>651</td>
<td>831</td>
<td>79</td>
</tr>
<tr>
<td>IR - Swap</td>
<td>Notional</td>
<td>45,683</td>
<td>8,436</td>
<td>4,637</td>
<td>8,745</td>
<td>876</td>
</tr>
<tr>
<td></td>
<td>Trade Count</td>
<td>518,302</td>
<td>90,817</td>
<td>74,573</td>
<td>176,714</td>
<td>15,732</td>
</tr>
<tr>
<td>Grand Total</td>
<td>Notional</td>
<td>46,288</td>
<td>8,551</td>
<td>4,690</td>
<td>8,807</td>
<td>886</td>
</tr>
<tr>
<td></td>
<td>Trade Count</td>
<td>522,629</td>
<td>91,837</td>
<td>75,224</td>
<td>177,545</td>
<td>15,811</td>
</tr>
</tbody>
</table>

Table A.1: Trading volumes and sizes

A.2 Model pension funds

The cash flows of the three model pension funds are presented below. The young, average and old pension fund have average durations of respectively 11, 20 and 32 years.
Figure A.1: Cash flow young fund

Figure A.2: Cash flow average fund

Figure A.3: Cash flow old fund