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Dirk Broeders
Frank de Jong
Peter Schotman

DESIGN 56

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DESIGN PAPER 56

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Affiliations
Dirk Broeders – De Nederlandsche Bank and Maastricht University
Frank de Jong – Tilburg University
Peter Schotman – Maastricht University

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INTEREST RATE MODELS FOR PENSION AND INSURANCE REGULATION

Abstract
Liabilities of pension funds and life insurers typically have very long times to maturity. The valuation of such liabilities introduces particular challenges as it relies on long term interest rates. As the market for long term interest rates is less liquid, financial institutions and the regulator must rely, to some extent, on subjective parameters in regulation. An Ultimate Forward Rate is one way of dealing with the dependence on long term interest rates. We discuss two views with respect to the role of subjective parameters in regulation. These different views relate to the interpretation of a pension contract: a social contract or a financial contract. Furthermore, we assess the implications of different UFR proposals on managing liability risk.

1. Introduction

Liabilities of pension funds and life insurers typically have very long times to maturity. The valuation of such liabilities introduces particular challenges as it relies on long term interest rates. As the market for long term interest rates is less liquid, financial institutions and the regulator must rely, to some extent, on models and subjective parameters in regulation. This paper analyses the risks that using models for liability valuation and risk management entails.

The Ultimate Forward Rate (UFR) plays an increasing role in pension and insurance regulation. It is a practical and important example of both model and parameter risk for financial institutions with very long dated liabilities. It has important economic implications as it may, e.g. influence the distribution of wealth across a pension fund's or insurers' stakeholders. We discuss and compare four different UFR methods that are (being) introduced in different regulatory regimes. We compare the key characteristics of these models and assess their sensitivities with respect to convergence speed and UFR level.

One of the key implications of the UFR is that it raises a fundamental dilemma. It creates a multiple focus for the risk management of financial institutions: a regulatory versus an economic approach. Under regulatory hedging a pension fund optimizes its risk profile with respect to the regulatory framework including the UFR. Under economic hedging a pension fund optimizes its risk profile with respect to only market indicators. It is the responsibility of the board of trustees of a pension fund to balance both the regulatory and economic principles when choosing their preferred hedging strategy. In this paper we provide some insights on how the choice of the UFR affects these trade-offs.

The structure of this paper is as follows. We start this paper in Section 2 by identifying three types of risk: process risk, parameter risk and model risk. In Section 3 we turn to a practical and important example of both model and parameter risk, the Ultimate Forward Rate. The UFR has an important economic impact as it may affect the distribution of wealth across stakeholders and a pension fund's strategic asset allocation. Section 4 introduces four different UFR approaches that are or will be used in practice. In Section 5 we highlight some of the sensitivities of the UFR methods towards parameter sensitivity, specifically the speed of convergence and the UFR level. Section 6 discusses the implications for interest rate hedging. The final section offers the key conclusions.

2. Model and parameter uncertainty

From a conceptual point of view we identify three types of risk: process risk, parameter risk and model risk. Process risk involves the stochastic, or random, fluctuations in a specific variable under a correct model and the true parameter values. Parameter risk involves the uncertainty about the exact parameters given that the model is accurate and model risk is associated with modelling the probability distribution of the parameters. We discuss these risks in mainly the context of interest rate risk, although the same issues apply to other risks, such as longevity risk and inflation risk. These types of risks would not matter if the payoff of the pension contract can be exactly replicated by a portfolio of financial instruments. In this sense a pure Defined Contribution (DC) pension plan without any form of guarantees does not carry any risk for the pension fund. It simply pays the participants according to the financial returns. (For the participants the risks matter of course.)

Similarly, at the other extreme, a pure Defined Benefit (DB) pension plan that follows an exact immunization strategy has hedged all its financial (and actuarial) risk and does not care about the way interest rates move over time. This requires complete and liquid markets where all risks that the pension fund or the insurance company faces can be traded. In such a theoretical world of complete markets all risks can be allocated to different stakeholders ex ante and it will be possible to create a complete pension contract. Obviously, this is typically not the case. There are, e.g., no liquid markets for very long dated nominal bonds, and financial instruments that perfectly replicate inflation and mortality risks often do not exist. When markets are incomplete, risk management has to rely on models and parameter assumptions. Process risk, parameter risk and model risk are discussed in depth below.

2.1 Process risk

Process risk involves the stochastic, or random, fluctuations in a specific variable under a correct model and the true parameters values. In the case of interest rate risk a pension fund may be able to hedge this risk by following a dynamic trading strategy. As an example, the funding ratio of a pension fund with long duration liabilities holding a short duration bond portfolio, is exposed to interest rate fluctuations. With complete markets it may enter into an interest rate swap to hedge the interest rate risk. To that end, the pension fund agrees with a counterparty to pay the short-term rate over a certain principal amount in exchange for a long-term interest rate. If long-maturity bonds and swaps do not exist, the pension fund could still design a trading strategy that eliminates all interest rate risk. This would work if the pension fund exactly knows the process governing interest rates. If the yield curve would, e.g., only be subject to parallel shifts, the pension fund could create a synthetic bond with a 60 year maturity using a leveraged investment in 20 year bonds. In general, if interest rates are generated by a process with a small of number of risk factors, it is possible to construct a portfolio that has the same exposure to the risk factors as the liabilities, thus eliminating all interest rate risk. The big "if" in this analysis is the assumption that the model that drives interest rates is perfectly known. If there is any model error, synthetic risk management strategies involving leverage could become very risky. We will discuss model risk further in Section 2.3.

Another example of process risk is mortality risk. Each and every individual is uncertain about his remaining life expectancy after retirement. This is a diversifiable risk, because the actual mortality rate will converge to the expected mortality when individual pension contracts are pooled. The risk averages out due to the law of large numbers. But even for a pool of pension contract, each year the number of people that survives to the pool may be higher or lower compared to the expectation. This is also a form of process risk. The mortality risk is closely related to mortality credit or mortality yield. The contributions and accrued wealth of those who die earlier than expected contribute to gains of the overall pool. This delivers a higher yield to the survivors than could be achieved through individual investments in financial markets outside of a collective pool. Process risk is obviously a theoretical concept as in practice there is always parameter risk and model risk and a perfect model to build a hedge against these risks is not available.

2.2 Parameter risk

Parameter risk involves the uncertainty about the exact parameters given that the model is accurate. For instance, suppose we have an exact model describing interest rates for very long maturities including an UFR. So we know that the model representing reality indeed includes an Ultimate Forward Rate. Parameter risk in this example is the uncertainty about the level of the ultimate forward rate. If it is estimated too high, the liabilities will be undervalued. In this case a pension fund could choose to pay out more of its available assets to current retirees, but it would gradually over the course of a number years discover that its assets are insufficient to cover all liabilities. Another example is risk estimation (estimation error) for the parameter in the mortality trend. The mortality trend may be estimated too high or too low. Parameter risk is a systematic risk or non-diversifiable risk.

Pooling a larger number of participants does not lower the risk. This is true for both examples: the uncertainty about the UFR and the mortality trend.

2.3 Model risk

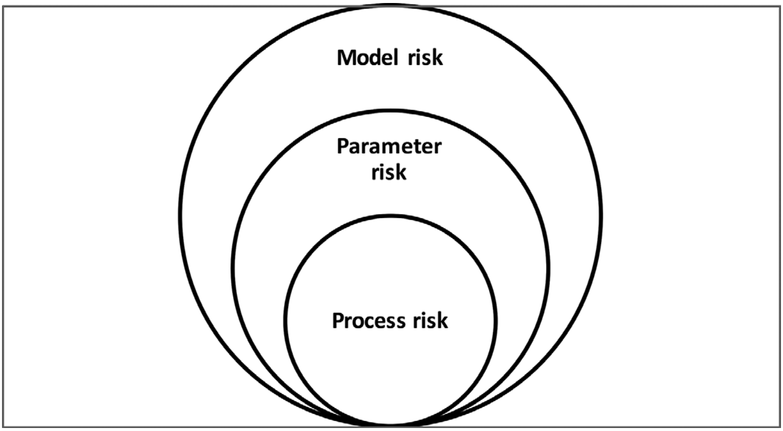
Finally, model risk is associated with modelling the probability distribution of the parameters. Examples are a misspecification of the UFR model or the wrong model for representing the mortality trend. Model risk can take a long time before being detected. Discounting very long-term liabilities at the UFR, for example, will only appear problematical if yields on 20-year bonds remain below the UFR for many years. The same holds for the mortality trend: deciding whether a deviation from the trend is temporary or a permanent shift to a different trend typically takes many years of data. More complex models typically rely on more assumptions and thus present the investor to higher model risk. It is therefore likely that model risk is priced in the market, Fender and Kliff (2005). An important form of model risk are hitherto unmodelled phenomena popularly denoted as 'black swans'.

2.4 Relation between model, parameter and process risk

Figure 1 shows a concentric visualization of the relation between the three types of risk. Model risk is the broadest concept. A model by definition is a simplification of reality. So this is by definition an unavoidable risk. Parameter risk assumes a correct model but involves uncertainty about the true economic parameters. Finally, process risk assumes the correct model and true parameters and leaves the stochastic variation in the variable under consideration.

It is important to realize that model risk is a real risk. Risk that is calculated conditional on a model and given the estimated

Figure 1: Relation between different types of risk



values of the parameters will often underestimate total risk. The effect of model and parameter risk can be particularly sizable over a long horizon. For equity markets this has been quantified in a study by Pastor and Stambaugh (2012), showing that for investors with a 30 years horizon, the per annum standard deviation of equity returns is about one and a half times the annual standard deviation. Contrary to conventional wisdom, stocks are more risky in the long run. The effect is especially notable in the long run, because getting the average return wrong by one or two percent will not have much of an effect on the risk of equity over a one year period, but getting it wrong for a long time will have a large cumulative effect. Hoevenaars, Molenaar, Schotman and Steenkamp (2014) find that parameter risk has an equally big effect on bond returns. For interest rates the mechanism is very different, as the main uncertainty is level of mean reversion of interest rates. When interest rates are as low as they are since the financial crisis, how will such an environment persist? The answer to that is hard to infer from empirical data, but has a strong effect on expected future interest rates and hence on long-term discount rates.

When model uncertainty is a seen as a real issue, the important question is how to deal with it. Building better models is an easy answer, but not very practical. Abandoning models is a radical answer, but not a solution, since it is hard to do valuations and risk assessments without a model. Bayesian decision making provides a coherent framework for dealing with parameter uncertainty. If prior beliefs are available and if a probability can be attached to all alternative models and parameters, it will be possible to combine the outcomes of different models. Forecasts would use a weighted average prediction of alternative models. And risk assessments would use the average variance plus an adjustment for the degree of dispersion among the different models.

In some cases there is no consensus on a reasonable prior. Different views may co-exist, and none of them is considered so unreasonable as to discard them. In such a case averaging may no longer work. Decision making will then rely on evaluating the costs of using the wrong model, with an optimal decision defined as the best choice against an imaginary opponent that will always select the worst possible model given our decision. Such decisions are called robust. In the application to hedging long-term liabilities this approach will require more capital in order to hedge the risk free claim the beneficiaries have on the pension fund or insurance company.

3. The UFR and the role of subjective parameters in regulation

As the market for long term interest rates is less liquid, financial institutions and the regulator must rely, to some extent, on subjective parameters in regulation. An Ultimate Forward Rate is one way of dealing with the dependence on long term interest rates. This involves both model and parameter risk as introduced in the previous section. In this section we first provide a general introduction to the UFR. Subsequently we discuss the impact the UFR may have on the redistribution of wealth and on strategic asset allocation. The last subsection entails a broader discussion on the pros and cons of an UFR in regulation.

3.1 General introduction to the UFR

Liabilities of life insurers and pension funds typically have very long times to maturity, up to 80 years. The valuation of such liabilities therefore poses particular problems. Specifically if it concerns defined benefit liabilities that are determined independent of the availability of financial instruments that can be used to hedge these liabilities. Instead, defined benefit pension liabilities are typically a function of a fixed accrual rate and years of service. Many supervisory frameworks prescribe discounting liability cash flows at market interest rates. Typically risk free market rates are derived from liquid financial instruments such as treasury bonds or swaps. According to market participants (see Kocken et al., 2012) the market for fixed income instruments up to 20 years maturity is extremely liquid, between 20 and 30 years there is good liquidity but beyond 30 years the market is less liquid. To solve this problem, a common solution is to extrapolate the term structure of interest rates from the liquid market segment into the illiquid segment. Obviously, this can be done in many ways. The current debate around Solvency II, and indeed some specific rules by, e.g., the Danish and Dutch regulator, propose extrapolating liquid market interest rates such that they converge in the long run to the Ultimate Forward Rate. The UFR is a measure of the one year forward rate for a very long duration. The UFR can either be a fixed value or derived from market prices of liquid instruments. Both the fixed UFR level as well as the function to derive the UFR from market prices can be adjusted discretionary. Both forms of the UFR contain therefore a subjective element. In what follows we discuss the relation between UFR and the redistribution of wealth across stakeholders and the relation between the UFR and strategic asset allocation. We then discuss the main advantages and shortcomings of an UFR.

3.2 The UFR and redistribution of wealth

The UFR is important because, through the valuation of the liabilities, it influences the financial position of the pension fund and the life insurer and therefore the allocation of wealth and risk across the different stakeholders. E.g., if changes in the UFR decrease the present value of liabilities a pension fund's funding ratio will increase. This increase is typically a signal that allows the pension funds' board of trustees to provide additional benefits to the participants, e.g. in the form of indexation. Ceteris paribus, this is a transfer of wealth from the young to the old participants. The following box elaborates on these points.

Note that there is fundamental uncertainty about these redistributive effects. In the examples in the Box the redistribution of wealth is measured against the market interest rates being the true measure for liability valuation. However, having an UFR is based on the assumption that the true market interest rates are inappropriate for the valuation of long duration liabilities. It is

Box

The UFR as a subjective parameter (or model) has an impact on discount rates, on expected returns and on cost effective contributions. In the pension debate two views exist with respect to the role of such subjective parameters in regulation. These different views relate to the interpretation of the pension contract: a social contract or a financial contract, Boender et al. (2013).

Under the 'social contract hypothesis' either (i) pension fund trustees, (ii) an independent committee or (iii) the regulator can have discretionary power to allocate wealth to different stakeholders. In this view having a subjective parameter like the UFR in the discount rate is considered an additional tool for (intergenerational) risk sharing. If the UFR is adjusted upward, the present value of liabilities will decrease and the funding ratio increases. This way the pension fund may grant more indexation to the benefit of the elder generations at the expense of the young generation. This will affect the wealth distribution between generations. Proponents of the social contract hypothesis consider these transfers legitimate.

Under the 'financial contract hypothesis' a redistribution of wealth between generations due to a change in the UFR is less rational. A change in the UFR does not affect the assets of the pension fund. The pension fund remains equally wealthy. Proponents of the financial contract hypothesis are therefore not in favour of value transfers between generations driven by (changes in) subjective parameters. To make sure that the introduction of an UFR and subsequent changes in the UFR have no effect on the wealth distribution across the participants in the pension fund, the following procedure should be followed. In determining the participants' benefits the UFR should also be used. Suppose for instance that an individual has a personal pension wealth of 100K euro. This is based on the promised benefits discounted at the term structure of interest rates including an UFR of 4.2 percent. If the UFR is altered, for instance to 3.2 percent, the promised benefits could be adjusted such that the personal pension wealth of the individual remains equal to 100K euro. This examples shows that implementing (changes in) the UFR can be executed without any redistributive effects between generations participating in the pension fund. This requires that the impact of changes in the denominator in the liability valuation is exactly compensated by offsetting adjustments in the promised benefits in the numerator.

therefore impossible to objectively judge whether or not redistribution really takes place. We will only know many years from now whether the chosen value of the UFR was "fair".

3.3 UFR and strategic asset allocation

The UFR could have an indirect impact on asset allocation through Asset and Liability Management (ALM). Although the promised pension benefits and actual market developments and prospects do not change with the introduction of an UFR, the projected development of the funding ratio over time may change. The funding ratio may, e.g., improve by applying an UFR. If as a consequence higher pension benefits are paid in the short run, the remaining assets need to yield a higher return to pay the (same) benefits in the long run. This may be an incentive for riskier investment strategies. Careful consideration should therefore be given to the impact of an UFR on long term projections of the funding ratio and its potential effect on asset allocation. Note however that the funding ratio may also deteriorate because of the UFR, creating a reverse effect.

3.4 Discussion of the UFR

In the previous sections we have shown that the UFR potentially has an important economic impact as it may affect the wealth distribution across stakeholders and strategic asset allocation. We now discuss some general pros and cons of the UFR. Advocates of the UFR argue that a potential advantage of an UFR is that it makes pension fund's funding ratios less susceptibility to potential market disturbances and that less liquid segments of financial markets are less prone to shocks in supply and demand of financial instruments. Under this view the UFR is an instrument to reduce potential pro-cyclical behaviour in financial markets. In times of strained financial markets, pension funds (and insurers) might feel the need to additionally hedge interest rate risks with the result that the interest rates for long maturities become under additional pressure. The UFR might help to prevent such pro-cyclical behaviour. The price to be paid for this is that the UFR introduces 'a basis risk' in hedging strategies. Pension funds cannot invest in market instruments that provide a perfect hedge against changes in the UFR curve.[1]

The application of an UFR reduces funding ratio or solvency ratio volatility. An UFR addresses the criticism of some market participants that, without an UFR, hedging demand of institutional investors is pushed towards the long end of the interest rate curve. As liquidity in this market segment is low and pension funds have a strong demand for hedging interest rate for long durations, there is downward pressure on market interest rates, potentially creating an inverse term structure of interest rates.

A contrasting view is that an inverse term structure is justifiable as it just represents the willingness of hedgers to pay for convexity. Convexity implies that the price appreciation when interest rates fall is greater than the price decline of a similar rise in interest rates. This attractive feature is more profound for longer maturities. As a result, investors are willing to pay more for long-term bonds and accept lower returns. Table 1 provides a simple example of the convexity effect for three different zero coupon bonds, maturing in 1, 30 and 60 years respectively. The table shows the price impact of a ±100 basis points change in

1 Note that Dutch pension regulation does not require to reduce risks in case of a funding shortfall. As such, they are always allowed to rebalance their portfolio towards their strategic asset allocation and hedging policy. Though pension funds are not allowed to increase their risk profile in excess of the strategic asset allocation in such a scenario. Although (Dutch) regulation therefore does not induce de-risking, pension funds might decide themselves on this.

Table 1: Price impact of a 100 basis points change interest rates on different zero coupon bonds

Maturity (in years)	-100bp	+100bp
1	+1%	-1%
30	+34%	-25%
60	+79%	-44%

interest rates. Initially it is assumed that the term structure is flat a 4 percent. The 1 year zero coupon bond does not show convexity. The price increase is roughly equal to the (absolute value) of the price decrease. Alternatively, for the 60 year zero coupon bond the convexity effect is very profound. The price increase following an interest rate decrease is significantly higher than the price decrease following an equivalent interest rate increase.

The UFR likely replaces continuous interest rate risk in the valuation of pension and insurance liabilities by discrete jumps in the applicable discount rate. It seems reasonable to assume that the UFR level over long horizons will, at least to some extent, follow market developments. If there are structural breaks in the economy and or market interest are high (low) for an extensive period, it is probable the UFR level will reflect this at some point. Note that in the UFR method recently introduced by De Nederlandsche Bank the UFR level already automatically reflects market conditions over time through the linkage to the 120 month moving average of the historical 20 year forward rate. In other UFR methods no procedures yet exist to periodically evaluate the UFR level. Discrete adjustments in the UFR level, or for that matter in the UFR methodology in general, may lead to discrete adjustments in hedging policies following any announcement of a change.

4. Models for implementing the UFR

There are multiple approaches for extrapolating the liquid interest rates into the Ultimate Forward Rate. The UFR can either be a fixed value or derived from market prices of more liquid instruments. How exactly this is calculated differs by proposal and implementation, and has consequences for the market. Below we discuss four different approaches: the Smith Wilson model under the Solvency II framework as developed by EIOPA, the old approach used in the Netherlands, the Swedish approach and a novel approach as advised by the UFR committee in the Netherlands and which recently has been adopted by De Nederlandsche Bank. Thereafter we provide insight into the parameter sensitivity in all four models.

4.1 The Smith-Wilson approach in Solvency II

The EIOPA (2010) approach is to calculate the interest rates from 20 years onwards as a weighted average of the 20 year forward rate and the UFR (this is called the Smith-Wilson method). The UFR itself is currently fixed at 4.2%. This value is an estimate of the sum of the long term averages of real interest rates and inflation. The 20 years market interest rate is considered to be the "last liquid point" on the term structure.

The interpolation used by EIOPA raises some concerns. First, no information on market rates beyond 20 years is used, and as a result this method puts a lot of weight on the twenty year yield. As a consequence, the twenty year market rate becomes very important in determining the present value of liabilities. A change in the 20 year market rate not only affects the present value of the 20 year cash flow but the present value of all consecutive cash flows too. This will lead to a large hedging demand exactly for the

20 year rate. The "**last** liquid point" may therefore become the "**least** liquid point" (Kocken et al., 2012). The large weight on the 20 year rate makes the value of the liabilities sensitive to market frictions at exactly this point, and these frictions may be precisely caused by the hedging demand stemming from the regulatory rule.

A second sensitivity relates to the mechanics of the extrapolation. The method calibrates a functional form that perfectly fits all maturities before the last liquid point. Due to this perfect fitting the functional form may be sensitive to small errors in forward rates close to the last liquid point. As has been pointed out in Kocken at al. (2013) this may lead, e.g., to an inverse demand for bonds and swaps with a 15 year maturity as the liability valuation becomes positively related to changes in 15 year market rate. For a smoother and more robust extrapolation one may want to leave room for some discrepancies ("avoid overfitting") in calibrating the functional form for extrapolating the forward curve.

4.2 Old DNB approach

In the Netherlands the first UFR for pension funds was introduced on 30 September 2012 by De Nederlandsche Bank (DNB), the prudential supervisor for Dutch pension funds. This method builds upon the Swith-Wilson method but it has some important differences. The UFR has been set at 4.2%, similar to EIOPA. For maturities of 21 years or more, the zero rate will be adjusted by extrapolating the underlying 1-year forward rates to the ultimate forward rate. The forward rate will be extrapolated by taking a weighted average of the forward rates in the market and the UFR. Market data affect the extrapolation, but the weights decrease with maturity such that forward rates for maturities 60 years and longer equal the risk-free rate. The weighting scheme is fixed and based on the Smith-Wilson extrapolation method using data from 2012. The adjustment aims to counteract interest rate sensitivity in and around the 20-year maturity range.

4.3 The Swedish approach

The Swedish supervisor (Finansinspektionen, 2013) has recently proposed a method where the UFR is fixed at 4.2% (like in the EIOPA approach) but the convergence to the UFR is gradual and mixed with market rates. For liabilities denominated in Swedish Kronor, market rates are used for maturities less than 10 years. For maturities between 10 and 20 years, the prescribed forward rate is a weighted average of the market forward rate and the UFR, where the weights increase linearly with the maturity. E.g., for the 11 year forward rate, the weight on the market rate is 0.9 and the weight on the UFR is 0.1 and for the 19 year forward rate, the weight on the market rate is 0.1 and the weight on the UFR is 0.9. For maturities beyond 20 years, the forward rate is equal to the UFR. For euro dominated liabilities, the Swedish proposal is to use market rates up to 20 years, then a linear convergence to the UFR over a 40 year period, and to use the UFR for liabilities longer than 60 years.

4.4 Current Dutch approach based on UFR Committee proposal

Apart from the choice of the last liquid point and convergence speed, another issue with the EIOPA approach is the exogenous determination of the UFR. This feature is also found in the old DNB approach and the Swedish approach. The exogenous determination of the UFR leaves scope for revisions of the UFR. This may lead unexpected changes in the UFR that will be reflected in changes in the liability value. EIOPA has indicated that it will review the methodology for deriving the UFR in 2016.[2] Supporters of the financial contract hypothesis may argue that these shocks are impossible to hedge for financial institutions. Advocates of the social contract hypothesis may however support this function of the UFR as an extra instrument for risk sharing.

To solve these two issues, an independent UFR Committee in the Netherlands has worked out an innovative method. It defines the UFR as the 10 year moving average of the twenty year historical market forward rate. Consequently for maturities in excess of 20 year, the discount rate is derived as a weighted average of the applicable market rate and the UFR, where the weight on the UFR increases for larger maturities and converges to one. The first element makes the UFR itself time varying to reflect changing economic environments. This variation comes in a smooth and predictable way, avoiding 'jumps' in liability value due to discrete changes in the UFR. The second element uses market rates as much as possible and avoids putting a lot of weight on the current 20 year rate.

The UFR Committee in the Netherlands has studied the market for long term interest rates. They conclude that the market up to 20 years maturity is very liquid and market prices are a reliable source of information for discount rates. The market liquidity between 20 and 30 years is less but still good enough to give market prices a substantial weight in determining discount rates. Beyond 30 years, the market is less liquid. The committee therefore proposes a methodology where a Last Liquid Forward Rate (LLFR) is determined as a weighted average of today's forward rates for maturities beyond 20 years, with declining weights on longer maturities. This LLFR can be seen as today's long term

2 *https://eiopa.europa.eu/Pages/News/Review-of-the-methodology-to-derive-the-ultimate-forward-rates.aspx* .

interest rate. The 20 year point is therefore a "first smoothing point" rather than a "last liquid point".

The proposal of the committee has been adopted by De Nederlandsche Bank as of July 15, 2015. DNB (2015) argues that the new UFR calculation takes better into account actual market rate developments. The more realistic UFR leads to more realistic price-setting.

4.5 A comparison of UFR methods

Table 2 discusses the main characteristics of the four different methods under consideration. We look at five features of the UFR model: the UFR level, the predictability of UFR adjustments, the hedgeability and the potential market impact.

The UFR level is fixed at 4.2 percent in three out of the four methods. Only the current DNB approach, as advised by the Dutch UFR committee, allows for a market based UFR level. A fixed UFR level in three models does not imply that the UFR will never change. It is not unlikely that at some point the UFR level might be adjusted upward or downward depending on structural changes in market conditions. Since this is a subjective discretionary adjustment, the predictability of changes in the UFR level is low. The predictability of UFR changes in the market-based approach as suggested by the Dutch UFR committee in contrast is high. As the level is a moving average of historical forward rates, its predictability is high. However, the same reasoning may apply here. The function to derive the UFR from market prices can be adjusted discretionary over time.

A comparison of the convergence speed is more challenging, since the mean reversion concepts differ. Smith-Wilson and the old DNB approach both have the same, relatively fast speed of convergence towards the UFR. The linear speed of Sweden

Table 2: Assessment of different UFR methods

UFR method	UFR level	Predictability of UFR adjustment	Speed of convergence	Hedgeability	Potential market impact
EIOPA	4.2	Low	Fast	Low	High
Old DNB	4.2	Low	Fast	Moderate	Low
Sweden	4.2	Low	Slow	Low	Low
Current DNB based on Dutch UFR Committee	10 year moving average of 20 year forward rate	High	Undefined	High	Low

is initially much slower than the Smith-Wilson and old DNB method. The first two steps in the linear method amount to 2/40 = 5% weight on UFR, while the Smith-Wilson/DNB weight for the 22 year maturity is already 19%. The current DNB approach adjusts to a moving target, hence the convergence speed is undefined.

The alternative extrapolation methods differ with respect to regulatory hedgeability of interest rate risk. This measures the extent to which pension funds are able to hedge regulatory interest rate risk, including possible changes in the UFR. The hedgeability under the EIOPA method depends on the liquidity of instruments with a 20 (and 15) year maturity. We already mentioned that the potential market impact of this method is that the "last liquid point" becomes the "least liquid point". The old DNB method reduces the sensitivity to the last liquid point. This may have the benefit that regulation itself does not distort the behavior of 20 year interest rates. The EIOPA, the old DNB and the Swedish method all have an unhedgeable feature, namely discrete adjustments in the UFR level. Such discrete jumps could cause large shocks in the value of their liabilities that could only be hedged with complex derivatives that provide protection against sudden jumps. The current DNB approach takes this one step further by taking away the risk of a discrete adjustment of the UFR. The economic hedgeability is the same under all methods as the economic interest rate risk does not depend on (changes in) the UFR. See Section 6 for a discussion of regulatory versus economic hedging.

5. Sensitivity of UFR methods to parameter assumptions

In this Section we highlight two important sensitivities of UFR methods. The speed of convergence and the UFR level itself. The speed of convergence involves how quickly the fitted term structure of interest rates reaches the UFR level. After that we discuss the impact of the UFR level itself.

5.1 Convergence speed

In all implementations of the UFR, the speed of convergence of the fitted term structure to the UFR is obviously important. A faster convergence implies less weight on market rates and more weight on the UFR value. This may impact the estimated solvency of pension funds.

In the Dutch UFR Committee proposal, the effects of the convergence speed can be easily quantified by varying the smoothing parameter a. The academic literature on term structure models typically finds that long term forward rates converge to an ultimate value at a very slow pace. Estimates are typically close to zero. For example, Balter et al. (2015) estimate a=0.02 with a standard error of 0.01. The choice of a=0.10 by the Dutch UFR Committee thus imposes a relatively quick convergence to the UFR. For example, for h=10 (the thirty year forward rate), the weight on the UFR is 0.37 and for h=30 (the fifty year rate), the weight on the UFR is 0.68. On the other hand, the UFR Committee lets the UFR level vary slowly over time. Actual forward rates therefore converge to a moving target. Fast convergence to a moving target could be very close to slow convergence to a fixed UFR target.
In terms of robustness issues, lower values of a can have some impact on discount rates. For example, using a=0.05 changes the weights on the LLFR in the 30 and 50 year to 0.21 respectively

Table 3: Impact of difference convergence parameter in the UFR Committee method

This table reports the funding level relative to the a=0.10 and UFR=4% case

UFR=4%	a=0.02	a=0.05	a=0.10	a=0.20
Average fund	98.5	99.2	100.0	101.0
"Green" fund	96.8	98.3	100.0	102.0
"Mature" fund	99.3	99.6	100.0	100.5

0.48; for the estimate in Balter et al. (a=0.02) we find weights on the UFR equal to 0.09 and 0.25, quite much lower than in the proposal of the UFR Committee. This can have an impact on the solvency of pension funds and insurance companies when there is a difference between the current LLFR and the UFR. For example, suppose today's LLFR is 2% but the UFR (based on a ten year moving average of twenty-year forward rates) is 4%. Then the discount curve based on a=0.02 will be lower than the curve based on a=0.10. We did a calculation on what impact this might have on the funding ratio. For these calculations, we use the same data on liabilities as the Dutch UFR Committee.[3] These data represent the average pension fund in the Netherlands. We also perform the calculations for a "green" and a "mature" pension fund.[4] The following table shows the results, where the funding ratio using a=0.10 is normalized to 100.

We see that the impact of a different convergence parameter is fairly small. A higher value (a=0.20) corresponding roughly

3 We are grateful to Henk-Jan van Well of De Nederlandsche Bank for providing these data.

4 The mature pension fund has the same cash flows as the average pension fund, but shifted 10 years forward. This means that the cash flows of the mature pension fund are earlier and hence have a shorter duration. The "green" fund's cash flow are the same as the average fund's cash flows, but shifted 10 years into the future (and the cash flows for the first 10 years are zero).

Table 4: Impact of different UFR level

This table reports the funding level relative to the a=0.10 and no UFR case

a=0.10	UFR=2%	UFR=3%	UFR=4%	UFR=4.2%
Average fund	100.0	101.1	102.1	102.3
"Green" fund	100.0	103.0	105.7	106.3
"Mature" fund	100.0	100.5	100.9	101.0

to a five year convergence period leads to a one percent higher funding ratio, whereas a lower value of *a* leads to lower funding ratios; in the most extreme case that we consider, *a*=0.02, corresponding to a fifty year convergence period, the impact on the funding ratio is –1.5% for the average fund and –3.2% for the green fund.

5.2 The UFR level

Obviously, the level of the UFR also has an impact on the value of the pension liabilities. Table 4 gives an idea of the impact of changing the UFR level (while keeping the convergence parameter fixed at a=0.10). This analysis uses exactly the same data that we used for Table 3.

Again, we observe that the effect of the UFR is relatively small for the average and the mature pension funds. The reason for this is that the UFR only affects the present value of liabilities dates 20 years or longer, and not the present value of liabilities with shorter maturities. The effects are larger for the green pension fund, with more long-dated liabilities.

The UFR level in various approaches is an estimate of the sum of the long term averages of real interest rates and inflation. The reasoning ignores risk premiums and convexity effects in long term interest rates. The argument implicitly assumes that these cancel out. To investigate these two effects, Balter, Pelsser and

Schotman (2015) construct a term structure model for long term swap rates (maturities between 5 and 20 years) and use the parameters to extrapolate the yield curve towards longer maturities. Their model is a one-factor Vasicek model. The Vasicek model is a special case of the more general class of affine term structure models, which has become the standard in the academic literature (see Joslin, Singleton and Zhu, 2011, for a review). In the Vasicek model forward rates converge to a fixed UFR. In that model the UFR is the sum of the long-run average spot rate, a risk premium and a (negative) convexity term. The convexity term increases with the volatility of interest rates and is inversely proportional to the mean reversion. The estimates reveal that it is very difficult to estimate the long run yield (or the UFR). The main reason for this is the slow pace of mean reversion. With slow mean reversion, the term structures converge to their long run value only very slowly and the long run yield is difficult to estimate from interest rates with maturities that go only up to 20 years. Uncertainty about the level of the UFR does not have a large effect on extrapolation up to maturities of 60 years. The UFR level is very sensitive to low values of mean reversion, but in the Vasicek model low mean reversion also implies a very small weight on the UFR. The combined effect of a tiny weight on an erratic UFR remains small.

The much bigger effect comes from convexity. With low mean reversion the forward curve has to become downward sloping for very large maturities. If we keep the UFR positive, while also fitting the 20 year rate on average, the model produces a significant hump-shaped convergence of the yield curve towards the UFR. After the 20 years maturity the yield curve tends to move upwards first and then slowly downwards toward the UFR. This means that for low interest rates the UFR is approached from above, contrary to standard extrapolation methods. According to estimates of Balter et al. (2014) the convexity effect would add around 2 percentage points to yields with a maturity of 60 years. One reason the convexity effect is so large is parameter uncertainty. Parameter uncertainty, in particular the mean reversion, causes additional uncertainty about long-run interest rate forecasts and this increases the estimated volatility and hence the convexity.

Large convexity effects at very long maturities have been noted before. Brown and Schaefer (2000) argue that long-term forward rates will likely be downward sloping in theoretical term structure models when mean reversion is low. Empirically they observe this effect for UK and US long-term forward rates.

6. Interest rate hedging implications

UFR methods raise an important question, namely the implications for interest rate hedging. Below we discuss two possible views on this issue, economic versus regulatory hedging. After that we describe the impact the UFR has on duration.

6.1 A discussion of economic versus regulatory hedging

An interest rate model in general, and the UFR in specific, involves model and parameter uncertainty. We now focus on the impact of the UFR on hedging. There are two ways to deal with the introduction and subsequent changes in the UFR from a hedging perspective: regulatory hedging and economic hedging. Under regulatory hedging a pension fund optimizes its risk profile with respect to the regulatory framework including the UFR. The UFR and the UFR model have a direct impact on the duration (interest rate sensitivity) of a pension funds' cash flows. Under economic hedging a pension fund optimizes its risk profile with respect to only market indicators. Earlier we wrote that a board of trustees has two ways to approach an UFR: as an instrument for intergenerational risk sharing under the social contract hypothesis or generational fair neutral under the financial contract hypothesis.

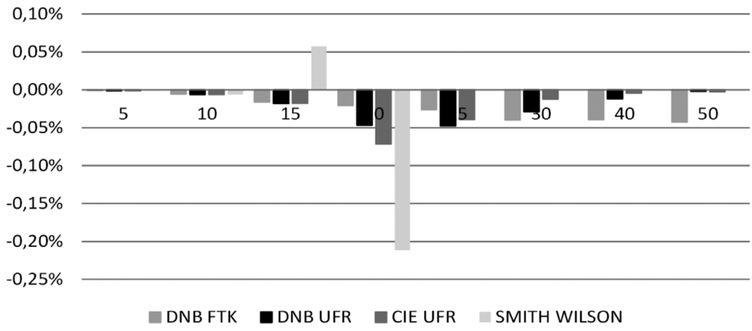
A similar trade off exists with respect to interest rate hedging. Regulatory and economic hedging are in principle not easy to combine as they have different objectives and require different strategies. It is therefore the responsibility of the board of trustees to balance both the regulatory and economic principles when choosing their preferred hedging strategy. But even when the board of trustees agrees with the economic consequences (redistribution of wealth and risk) of the regulatory framework, there is still model and parameter risk: the model used by the regulator may be wrong and lead to sub-optimal outcomes for members of the pension plan if the pension board hedges according to the regulatory rules.

In the short run a pension fund can decide to hedge its interest rate exposure based on the regulatory yield curve. But if the subjective UFR has been set too high, it will in the long run earn too little on its assets and the funding ratio will slowly deteriorate. On the other hand, if the pension fund has a good model for interest rate dynamics, it could construct a portfolio that synthetically replicates the long-term liabilities, such that it will be able to match all liabilities in the long run. This portfolio strategy will, however, be subject to short-term fluctuations in the funding ratio and hence look sub-optimal from a regulatory perspective.

6.2 The impact of UFR on duration

The UFR and the UFR model have a direct impact on the duration (interest rate sensitivity) of a pension funds' cash flows. As an example Figure 2 shows the impact four different UFR methods have on the duration of the cash flows. For the Smith-Wilson method, we notice a significant positive impact just before and an even more profound negative impact on the duration after the last liquid point. After the last liquid point the duration is absent in this method. Therefore, hedging activity will be concentrated around the last liquid point and might influences supply and demand, and therefore prices, directional. The Smith-Wilson method also has some perverse effects on the sensitivity of liabilities to the yields with maturity just shorter than 20 years, because the Smith-Wilson method extrapolates the forward rate, which is basically the difference between the 20 year yield and the 19 year yield. An increase in the 19 year yield (keeping the other yields constant) yield will therefore decrease the 20 year

Figure 2: Interest rate sensitivity of liabilities under different extrapolation methods



Note: The interest rate sensitivity of the liabilities is defined in terms of basis point values (in % of liabilities) at the level of the underlying swap rates. The horizontal axis shows maturity buckets. Maturities 1 to 5 are labeled '5', 6 to 10 years are labeled '10', and so on. Source of the figure: Commissie UFR (2013).

forward rate and hence all long rates. This will lead to an increase in the value of liabilities. This effect is visible in Figure 2 as the positive spike in the 15 year bucket (which includes the 19 year rate).

The current DNB method, based on the advice of the UFR Committee, (CIE UFR in the figure) shows a decrease of the duration at the last liquid point but also reveals some interest rate sensitivity after this point. This effect arises because in this method market information is taken into account also after the last liquid point. This will put less pressure on hedging demand at one or two maturities. In the figure above the green bars (DNB FTK) shows the interest rate sensitivity in a model without any UFR. Interest rate sensitivity increases for longer maturities.

7. Concluding remarks

The Ultimate Forward Rate plays an increasing role in pension and insurance regulation. It is a practical and important example of both model and parameter risk for financial institutions with long dated liabilities. It has important economic implications as it may, e.g., influence the distribution of wealth across a pension fund's or an insurers' stakeholders. In the pension debate two views exist with respect to the role of the UFR in regulation. These different views relate to the interpretation of the pension contract: a social contract or a financial contract. Under the 'social contract hypothesis' subjective parameters like the UFR can be used as an instrument to allocate wealth to different stakeholders. In this view having a subjective parameter like the UFR in the discount rate is considered an additional tool for (intergenerational) risk sharing. Under the 'financial contract hypothesis' a redistribution of wealth between generations due to a change in the UFR is less rational. If the subjective UFR changes the pension fund is equally wealthy. Proponents of the financial contract hypothesis are therefore not in favor of value transfers between generations driven by (changes in) subjective parameters.

Consequently, one of the key implications of the UFR is that it raises a fundamental dilemma. It creates a multiple focus for the risk management of financial institutions: a regulatory versus an economic approach. Under regulatory hedging a pension fund optimizes its risk profile with respect to the regulatory framework including the UFR. Under economic hedging a pension fund optimizes its risk profile with respect to only market indicators. It is the responsibility of the board of trustees to balance both the regulatory and economic principles when choosing their preferred hedging strategy.

In comparing four different UFR methods we find that the choice of UFR is not a big issue, if either the speed of convergence is slow or if the UFR is time-varying. An advantage of the Dutch proposal is that it reduces the risk of large discretionary changes in the discount rates, which will facilitate hedging the regulatory interest rate risk. In reviewing the UFR methodology, EIOPA (2016) proposes the possibility of small annual changes in the UFR.

Finally, we note that having a UFR is only one way of coping with the dependence on (illiquid) long term interest rates. An alternative solution is to redefine pension and life insurance liabilities in such a way that the reliance on discounting far out in the future is no longer needed. A simple example is to provide a defined contribution plan to young participants in a pension plan. The liabilities in such a plan by definition equal the value of the assets in the pension plan. Or put alternatively, defined contribution liabilities are by definition hedgeable as they are fully determined by investable assets. At a later age the accrued wealth in the defined contribution pension plan can be used to buy (deferred) annuities that need appropriate discounting for valuation purposes. However, for financial intermediaries to offer such long-dated annuities, they also need very long maturity market instruments, and in the absence of such instruments good models for their risk management.

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Interest rate models for pension and insurance regulation

Liabilities of pension funds and life insurers typically have very long times to maturity. The valuation of such liabilities relies on long term interest rates. As the market for long-term interest rates is less liquid, financial institutions and the regulator must rely on models and subjective parameters The Ultimate Forward Rate (UFR) plays an increasing role in pension and insurance regulation. This paper by Dirk Broeders (DNB), Frank de Jong (TiU) and Peter Schotman (UM) discusses and compares four different UFR methods that are (being) introduced in different regulatory regimes.

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Netspar
P.O. Box 90153
5000 LE Tilburg
the Netherlands
Phone +31 13 466 2109
E-mail info@netspar.nl
www.netspar.nl

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