

# Model uncertainty : the effect on robustness, estimation and stochastic optimisation

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## Chapter 6

# Valorisation

*“The policies with respect to the melting of the icebergs  
face the same problem of extrapolation on the extreme long end  
as those of pension funds.”*

-Anne Balter (Assertions accompanying the thesis)



In this addendum I outline the knowledge valorisation of this dissertation, by discussing the (social and economic) relevance of model uncertainty and the respective results, potential target groups, translated services, processes and activities, the innovativeness of the research and the implementation of the valorisation plans. Firstly, I discuss the relevance of this thesis to actuarial science, specifically to pension funds and insurance companies. Since the concepts derived are quite general, the usefulness extends to a wide variety of applications. After giving some examples in which misspecification plays a role, I highlight the general applicability once more by means of the section about climatology that serves both literally and figuratively as the tip of the iceberg.

## 6.1 Pension Funds

Since pension funds have liabilities on very long horizons, they need instruments with corresponding maturities in order to hedge the risk or at least to quantify the present value of all outstanding liabilities. The present value of the liabilities, together with the present value of the assets, is an indicator of the pension funds' health. The problem is that financial instruments are liquid up to maturities of 20 years whereafter the liquidity declines rapidly, while pensioners can live as long as a century. In the past, actuaries in The Netherlands used a fixed rate of 4% to discount their liabilities. However, soon one realised that this might not be market-consistent. Since then, discount curves have been used, but prices are not quoted at the long end. The ultimate forward rate (UFR) methodology, also proposed for insurance companies in Europe, states that in the long run, at a maturity of 60 years, the rates should converge to a fixed UFR. These fixed values seem to be artificial and should be investigated. The current debate is all about how to translate the obligations that have to be paid in the future into its value today. With other words "how much money is needed today to meet the future obligations?". In Chapter 2 the UFR method is implemented. Another standard in the industry, the Nelson-Siegel method, is also implemented. Both methods are compared with the Vasicek model.

Chapter 2 is about extrapolating the term structure of interest rates for maturities with declining liquidity and especially about measuring the uncertainty. We quantified the effect of parameter uncertainty in a one-factor affine term structure model in a Bayesian way. We applied this model to European and American data and found that the convexity term is an important factor whose role is often

neglected in practice. Our conclusion is that convergence happens very slowly, implying that the convexity effect does not vanish within a century. The other finding is that taking uncertainty into account results in an economically plausible, though rather wide range.

The societal impact of a high curve is a low present value of the liabilities. Therefore less is needed to save for the future and more can be spend today. This results in either no cutting of the pension payments or an increase in the indexation. Hence, this is beneficial for the current retirees and disadvantageous for the younger generations. Saving less might have a negative effect for the latter group if the model deviations are different than expected. Our simulations show the uncertainty explicitly. Therefore we do not propose a policy that advises a point estimate, but instead we quantify the uncertainty. The policy could use this information to reserve a buffer. Trivially, the effect is reversed if the expected rates are low. Moreover, irrespective of the funding ratio, which is the present value of the assets divided by the present value of the liabilities, different divisions among age groups harm specific cohorts at the expense of other cohorts.

So far, this has illustrated the social and economic relevance of Chapter 2 for employees and retirees. Another “target group” are the regulators and politicians. This research offers insight into the ongoing debate about the pension system. The paper on which this chapter is based has been used as input for the committee UFR. This committee<sup>1</sup> informed the minister on the UFR policy. The Dutch Central Bank (De Nederlandsche Bank) implemented the proposals from July 2015 onwards as mandatory discount method for pension funds. Moreover the paper *What does a term structure model imply about very long-term discount rates?* has been presented by the DNB to actuaries.

## 6.2 Insurance Companies

Chapter 3 specifies the effect of model uncertainty on pricing and hedging in incomplete markets. The set-up of the optimisation problem resembles a game in which an agent wants to maximise his surplus by choosing a hedging strategy whereas the worst-case scenario will be picked by a so called mother nature who minimises the surplus. This ensures a robust strategy which is the one that is least sensitive to perturbations of the model. Intuitively, the agent proposes a region of alternative models around his point estimate. We prove that the price of the liabil-

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<sup>1</sup>Prof. dr. A.A.J. Pelsser, my promoter, is a member of the committee UFR.

ity that may depend on both hedgeable and unhedgeable risk, is uniquely solvable. Moreover, we explain the economic interpretation of the hedging strategy which is identical to delta-hedging if the market is complete, i.e. risk-neutral pricing. In case of purely unhedgeable risk, the drift is adjusted in the prudent direction known as actuarial pricing. And in case of a mixed multivariate composition of tradeable and untradeable assets, the hedging strategy consists of a purely delta-hedging part, an extra delta-hedging part that captures the correlation between the hedgeable and unhedgeable risk and a speculative part.

A practitioner's methodology to price in incomplete markets is the industry standardised Cost-of-Capital method. Insurance companies use this quantifies the market value of the replicating portfolio plus a mark-up for the unhedgeable risk, which relies mostly on the subjective quantification of risk. The CoC method leads to a pricing operator that has similar characteristics as our result. The indifference pricing operator from Theorem 3.1 can be interpreted as a best estimate, which is the conditional expectation, plus a constant times the standard deviation of the unhedgeable component. The European Insurance and Occupational Pensions Authority (EIOPA) proposes the use of the CoC method. This is incorporated in the guidelines for Solvency II that is scheduled to come in effect on January 1, 2016 as mandatory pricing rule for insurance companies in Europe.

Consequently actuarial practices can be justified by the theorem developed in this chapter. Buffers imposed by regulators affect the financial behaviour of pension funds and insurance companies. But also any profit, or non-profit organisation can utilise this to support certain decisions concerning hedging and concerning the level of prudence or risk it wants to take. Moreover, the derivations in Chapter 3 are based on profit maximisation, resembling the core goal of many companies. Additionally, pricing in incomplete markets implies that the value for a non-traded item is deduced. Henceforth, not only insurance products benefit from this insight but one may think of *any* item to be priced. For instance, contracts that pay out during natural disasters, extreme low or high temperatures, the number of survivors, etcetera. Note that catastrophe bonds and mortality swaps are traded, which would imply the possibility to replicate cash flows. However the liquidity of these instruments is rather limited.

### 6.3 Misspecification

Chapter 4 is a theoretical chapter that serves the valorisation indirectly. It continues on the topic akin to model uncertainty. The idea that models might be misspecified is an improvement towards approaching real world examples by mathematical models. Chapter 4 deals with a general method for determining all alternative models that cannot be distinguished from each other. This set is widely applicable to various problems in different areas that allow for model uncertainty. Applying this to Chapter 3 leads to the quantification of the uncertainty bounds on the ellipsoid. Other literature that deals with uncertainty, but remains silent about a realistic choice of plausible models, can make use of these cutoff points.

Robust optimisation is relevant for both social and economic problems since the quantification of uncertainty can be implemented in many social questions that have been solved for an unknown ambiguity value. An example is the consumption and portfolio problem, where an agent wants to maximise his final wealth or the consumption during a specific time span and has to choose how much to consume, how much to save on the bank account and how much to invest in the risky assets. If an agent acknowledges that the underlying model might be misspecified, he would like to evaluate the optimal decision rule such that the strategy is least sensitive to perturbations of the model. As such a direct link with the constraint on the Kullback-Leibler divergence of the investment problem is established. Moreover, we can link this with a penalty on the entropy as well. Chapter 3 and 4 can also be used to measure uncertainty about interest rates. Affine deviations from the baseline model appear to be among the plausible stochastic alternatives and yield the transition to a mean-reverting model. Ben-Tal et al. (2009) consider a robust solution with respect to how much raw materials a company should buy to produce drugs, where the exact amount of raw material needed entails uncertainty. In another example they optimise the location of an antenna that transmits isotropic harmonic oscillator emitting spherical monochromatic electromagnetic waves. The objective is to send the electromagnetic field that is invoked by the oscillator, as close as possible to the target. Therefore uncertainty comes from both the positioning of the antenna, which is influenced by temperature, wind, etcetera, and the actuation errors, which emerge due to fact that invoking the oscillator cannot be implemented exactly.