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RECENT TRENDS IN ASSET AND LIABILITY MODELING FOR LIFE INSURERS

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ABSTRACT

Traditionally, asset and liability models are used by insurers to optimize their strategic risk and return profile given the objectives and constraints of their stakeholders. More recently, model developments are strongly driven by important changes in the fields of risk management, accounting and supervision. Spurred by these changes, insurers increasingly use ALM models for special purposes, such as solvency testing, risk-based capital calculations, market consistent valuation of embedded options, product development, pricing and so on. In this paper we describe how ORTEC's ALM model for life insurance companies can be applied for these purposes and enables life insurers to meet the latest requirements.

Keywords: scenario analysis, asset and liability management, life insurance, risk-based capital, embedded options, solvency testing, product pricing

JEL Classification: C15, C61, C88, G22, G32

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1 Introduction

ORTEC's models for Asset and Liability Management (ALM) have more than proven themselves over the years.[3] We show in this paper that, using these ALM models, insurance companies are also able to respond adequately to important changes in the fields of risk management, accounting and supervision. These changes include, for example, the market consistent valuation of liabilities, the International Financial Reporting Standards (IFRS), European Embedded Value (EEV), Solvency II and the introduction of local financial assessment frameworks.

Using ORTEC's ALM model for life insurers, insurers are up to many challenges and ready to answer questions like:

- What is the optimal strategic asset allocation and what is the optimal interest rate hedging policy?
- How can derivatives be used to optimize the strategic risk / return profile?
- Which guarantees and options are "embedded" in the liabilities?
- What is the economic value of these guarantees and embedded options (in a replicating portfolio) and how can we hedge these risks using swaps or swaptions?
- What is the impact of various reporting systems on the financial statements?
- What are the consequences of the introduction of a new financial assessment framework by the regulating authorities?

In Section 2 of this paper, we compare the approach used by ORTEC's ALM model for life insurers with the approach used by existing embedded value models. We argue that the ORTEC model is able to focus on all aspects relevant for ALM (assets, liabilities, scenarios, balance sheets, etc.) by using the output of embedded value models as input for its liability model. This way, a high calculation speed becomes possible without losing consistency with existing embedded value models. We then demonstrate in Section 3 that ORTEC's ALM model for life insurers is a flexible tool to investigate current issues like risk-based capital, solvency testing, market consistent valuation of embedded derivatives and product pricing. Section 4 concludes.

[3] We assume that the reader is familiar with the general concepts behind ALM. For an overview see for example Zenios and Ziemba (2006, 2007).

2 ALM models versus embedded value models

There are both similarities and differences between embedded value models, such as Prophet and Moses, and ORTEC's ALM model for life insurers. The most fundamental difference between these models is probably the purpose for which they were originally designed. The first version of the ORTEC model was developed more than 20 years ago for ALM and risk management analyses. Embedded value models, on the other hand, were originally designed for quite a different purpose: a detailed modeling of insurance liabilities that is used for example for profit testing and liability provisioning. Nowadays most embedded value models offer a kind of ALM module on top of the basic embedded value model. The detailed underlying actuarial modeling tends to slow down the ALM calculations considerably, however.

For major life insurance companies, with embedded value models already in place, the ORTEC model provides the best of both worlds by using deterministic cash flow projections of embedded value models as input for its liability model. Subsequently, the stochastic nature of the liabilities is modeled in two steps. First, based on the economic scenarios of interest rates and equity returns, the stochastic cash flows of the liabilities are simulated which typically originate from profit sharing or return guarantees. Second, the ORTEC model calculates the economic value of the liabilities for each year (say 10) and each scenario (say 1,000), including the value of the options embedded in the liabilities.

This way, consistency between the embedded value model and the ORTEC model is automatically achieved and the model can focus on all aspects relevant for ALM and related issues (assets, liabilities, scenarios, balance sheets, etc.). The focus of ORTEC's ALM model for life insurers thus clearly manifests itself in terms of:

- Simple linking to liability projections from embedded value or other existing liability models;
- Standard stochastic (market) valuations for a wide range of insurance products;
- Consistency between the valuation of (embedded) options and the underlying stochastic economic scenarios;
- High speed calculations, including stochastic valuation of guarantees and embedded options;
- Extensive modeling of asset classes, derivatives and investment strategies;
- Simultaneous stochastic analyses of balance sheets for various different reporting systems.
- Transparent and providing insight through many graphical and numerical reports.

These aspects allow the model to be truly used as a "management flight simulator" and support insurers when making strategic policy decisions.

3 Recent trends

Regulations and accounting for insurance companies are changing rapidly. Important developments are the emerging Solvency II guidelines for European insurance companies, the International Financial Reporting Standards (IFRS) and the establishment of local assessment frameworks in various countries.[4] These developments are linked to an increased awareness of the financial risks faced by insurance companies.

Responding to these issues, insurers are using existing ALM models to answer questions like:

- What is the required surplus given that we want avoid a negative surplus in (say) the next 5 years with a probability of 99.5%?
- What are the consequences of the introduction of a new financial assessment framework by the regulating authorities?
- Which options are “embedded” in our insurance contracts? Should we reserve funds on our balance sheet to cover these risks? Is it possible to properly hedge embedded insurance options with financial instruments?
- Can we use an ALM model to develop and price new products?

We will show in this section how ORTEC’s ALM model for life insurers can be used as a tool to investigate these challenging issues. Besides a short introduction to each topic, we also provide several examples.

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[4] Such as FTK (Financieel ToetsingsKader) in The Netherlands, Twin Peaks and ICA (Individual Capital Assessment) in the United Kingdom, SST (Swiss Solvency Test) in Switzerland and the Trafic Light System in Sweden. Van de Pas and Hilhorst (2005) give a short overview of ICA and FTK regulations and their importance for the Solvency II project.

3.1 Risk-Based Capital

The Risk-Based Capital (RBC) is the capital that is required to survive unexpected losses with a desired degree of confidence (probability), usually over a period of one year. Assets and liabilities are typically valued on an economic basis in this case (i.e., market value including embedded options). Risks are divided into different kinds of risk on the one hand (such as market risk, credit risk, insurance risk and operational risk) and product groups on the other hand. RBC results are used to calculate the required solvency, but are also an important component of the risk adjusted return on capital (RAROC) at the balance sheet -, portfolio - or product level. Furthermore, there is a strong parallel between the concepts of RBC and economic capital. The latter will very probably form the basis of the new Solvency II system that is under development. We will return to this in Section 3.2.

RBC calculations can be carried out on the basis of a number of deterministic shock scenarios as well as on the basis of comprehensive stochastic simulation techniques. ORTEC's ALM model for life insurers is perfectly suited for calculating the RBC because all components that are required for such calculations (like the market valuation of assets and liabilities as well as economic scenarios) are standard features of the model.

3.1.1 Example: Separated account

As an example, we show how the RBC of a so-called separated account can be determined. By separated account we mean an insured pension plan with a contract period of (typically) 5 to 10 years.[5] During this period, both the assets and the liabilities of the pension plan are on the balance sheet of the insurer as a separated account. At the end of the contract period, the client (i.e. the provider of the pension plan) often has the right (not the obligation) to leave all liabilities with the insurer even if at that moment the assets are insufficient to meet the liabilities. This right constitutes an embedded option: it would be rational to exercise this option if the market value of the liabilities is larger than the market value of the assets when the contract expires.[6]

Because the option value has a direct impact on the surplus of the insurance company (it is a liability of the insurance company), there should be sufficient capital to avoid the occurrence of a negative surplus over a certain period (with a certain probability). In the example given in Figure 3.1, the horizon is equal to 5 years (starting at the end of 2005). A negative surplus may only occur with a probability of 0.5% for one or more years. This risk criterion is just reached in Figure 3.1: for 25 out of 5,000 scenarios a negative surplus occurs. This means that the risk-based capital for this contract is equal to the surplus at the end of 2005 (approximately 120 as indicated).

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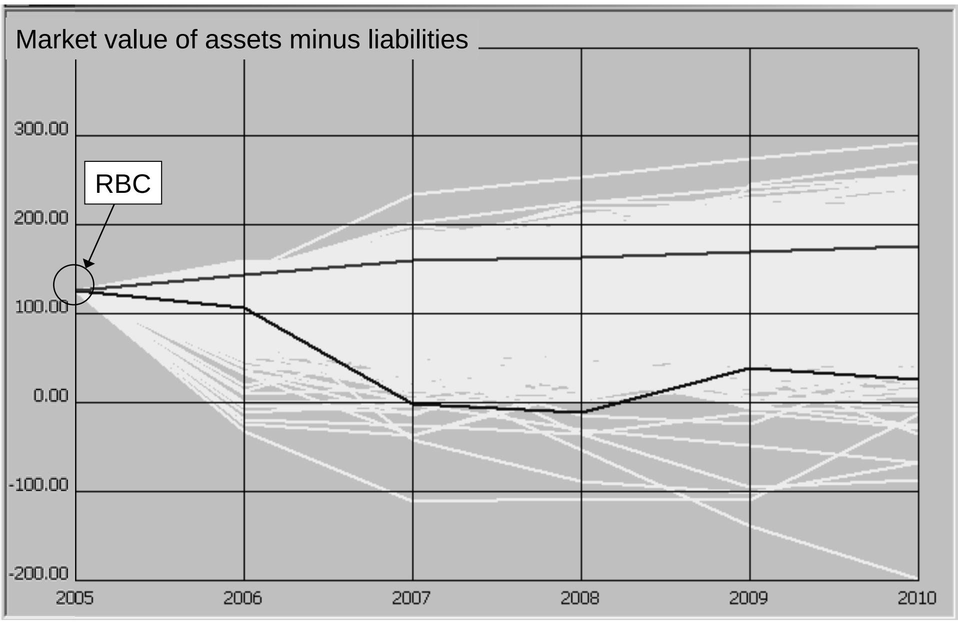
[5] This is a quite common form of insurance for large collective pension contracts in the Netherlands. In Dutch they are called "gesepareerde beleggingsdepots".

[6] This becomes even more attractive in case the pension fund continues to receive profit sharing (in case of high interest rates) after leaving the liabilities with the insurance company. This situation often occurs in practice.

Figure 3.1: Determining the RBC of a separated account



A common approach is to determine the RBC for all insurance products with the same scenario set. By comparing the RBC for the entire portfolio with the sum of RBC's for the individual contracts, the effect of diversification can then be determined. Diversification effects are in general not zero because the scenarios that constitute the risk need not be the same for all contracts.

The appropriate risk tolerance (for example 0.5% over a horizon of 5 years) is frequently determined using information about the insurer's rating. If available, this rating can be translated into an "acceptable" probability of experiencing a negative surplus over a certain period of time.

3.2 Solvency testing / Solvency II

A special case of RBC calculations is formed by, for example, the Dutch (FTK) solvency requirements. The Dutch regulating authority (the central bank) has developed this solvency testing framework as a predecessor of the upcoming Solvency II requirements, see De Nederlandsche Bank (2005). Although formally the FTK requirements have been postponed for Dutch insurers, the calculations are currently used by some insurers to justify their policy to the regulating authorities. Another reason for performing such calculations is that the Solvency II system will probably show strong similarities with systems like the FTK and insurers want to be prepared.

The required capital according to FTK is determined by evaluating the impact of different shocks (for instance, changes in the interest rates, inflations, stock prices, etc.) on the surplus of the insurer. The surplus is again measured using the economic (fair) value of the investments and liabilities. This procedure enables an insurer to determine how much capital should be available to survive (adverse) shocks for the different risk factors. The overall effect of the (combined) shocks is determined using simple assumptions regarding the correlations between the different factors.

These required capital calculations are available in ORTEC's ALM model for life insurers. An example is given below.

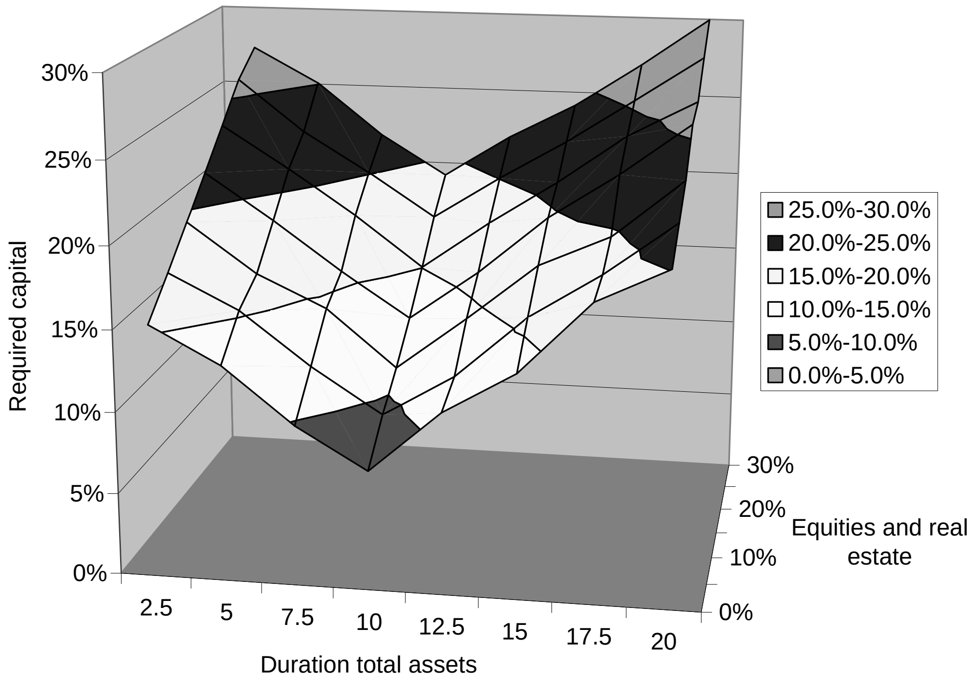
3.2.1 Example: Investment strategies

As an example, we will show the impact of the investment policy on the required capital for a life insurer. The liabilities of this insurer consist of the payment of funeral costs and therefore have a long duration. The policies are regular premium paying with profit sharing based on the interest rate level. We assume that this insurer only invests in equities, real estate and fixed income. We vary the asset allocation between 0% and 30% for equities and real estate versus 100% and 70% for fixed income.[7] We also vary the total duration of the assets between 2.5 and 20.[8]

Figure 3.2 shows the required capital (as a percentage of the market value of the liabilities) for these different investment policies.

[7] For purpose of exposition, we vary between only two (groups of) asset classes.
[8] We assume that the duration of equity and real estate is equal to zero.

Figure 3.2: Impact of investment policy on the required capital



The vertical axis represents the required capital, while the other two axes represent the amount of investments in equities and real estate and the total duration of the assets. This figure clearly shows that the required capital decreases when the amount of money invested in equities and real estate decreases. This is simply due to the diminishing effect of adverse equity and real estate shocks when the allocation to these categories decreases.

The required capital is clearly minimized in case of an asset duration of 10. This result also makes sense because the duration of the insurance liabilities is approximately equal to 10 in this example. The effect of interest rate shifts on the surplus is thus minimized (in first-order approximation) by matching the duration of the assets and liabilities.

It is important to note that the above methodology only yields information about *short-term* capital requirements (for a period of 1 year). It may well be the case that by reducing the short term risk (as measured by the required capital) the long term expected returns will also decrease. To investigate and optimize the risk-return tradeoff it remains necessary to perform multi-period calculations for different stochastic scenarios. Because ORTEC's ALM model for life insurers is able to determine the required capital for all future scenarios, it is possible to use the required capital as a benchmark for dynamic solvency testing in such multi-period studies.

3.3 Valuation of embedded options

Current IFRS (phase I) accounting rules offer the possibility to include (parts of) the market value of insurance liabilities on the balance sheet. Furthermore, it is expected that new accounting rules that are under development (IFRS phase II) will prescribe the market value liabilities as mandatory. Also for European Embedded Value (EEV) calculations or Liability Adequacy Testing (LAT) it is necessary to determine the market value of insurance liabilities. Identifying and subsequently correctly valuing insurance liabilities, including the contained guarantees and embedded options, is a very complex and highly specialized exercise. Fortunately, market valuations for a wide range of insurance products are available in ORTEC's ALM model for life insurers.

The model contains closed-form (risk-neutral or arbitrage free) option formulas for a variety of embedded options in insurance liabilities. Examples include interest-rate profit sharing options or return guarantees for unit-linked products. These option formulas are typically derived using simplifying assumptions. This is a feasible approach for ALM calculations because the market value does not have to be determined with 100% accuracy in this case. Furthermore, this approach offers huge reductions in calculation time which is crucial for performing ALM analyses.

On the other hand, it is also possible to carry out very precise one-off valuations with the model. For this purpose, a risk-neutral scenario generator has been developed. Using this generator, a risk-neutral scenario set can be produced with a combined Hull-White (interest rate) – Black-Scholes (equity) model.[9] With this scenario generator fully consistent risk-neutral scenarios can be generated for different interest rate curves (nominal, real, domestic and foreign curves), inflations, currencies, and total return series. Using these risk-neutral scenarios, even the most complex liability structures[10] can be valued with almost 100% accuracy by Monte Carlo simulation. Note that because a large number of simulations is required and also because the horizon of embedded options in insurance contracts can be rather long, this flexibility and accuracy comes at the cost of additional calculation time.

Additional (high-level) information on risk-neutral scenarios and Monte Carlo valuation in ORTEC's ALM model for life insurers is given in Appendix A.

[9] Users are able to calibrate the parameters of this model (volatilities, mean reversions, correlations) using historical or scenario data, or by using the market prices of relevant options.

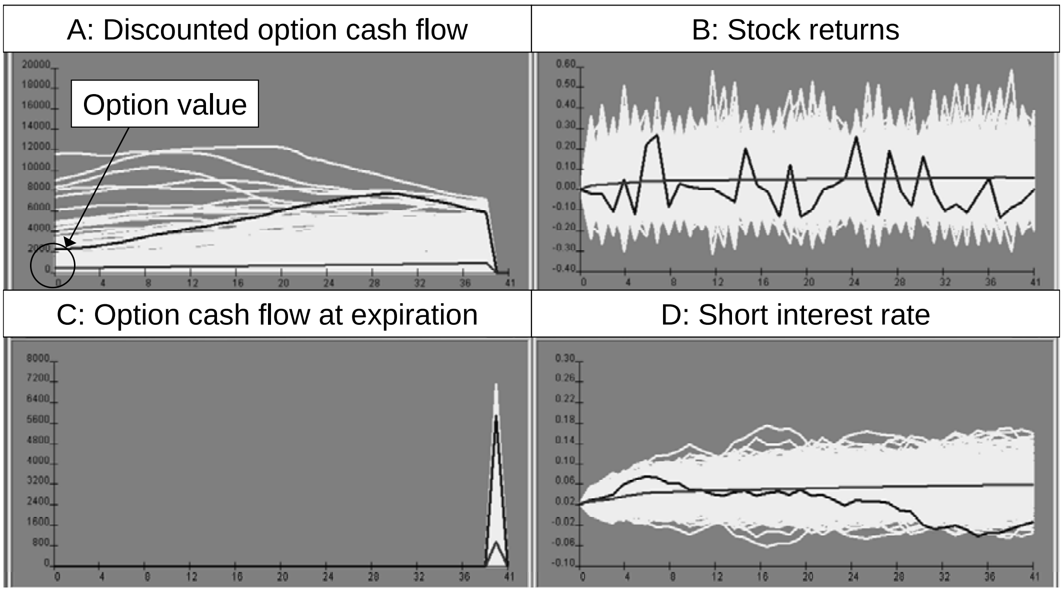
[10] Or more generally speaking, payoff patterns or so called contingent claims depending on one or more of these variables. Note that because also inflation is included, also pension fund options like conditional indexation, parent guarantee and the pension put as described in for example Kocken (2006) can be valued.

3.3.1 Example: Unit-linked guarantee

As an example we consider a premium-paying unit-linked (UL) product with a (terminal) return guarantee after 40 years. The value of the corresponding guarantee option (an equity put option with a strike equal to the guaranteed capital) can be determined with a closed-form approximation[11] or with Monte Carlo simulation. In both cases, the valuation is based on a risk-neutral Hull-White Black-Scholes model.

Figure 3.3 shows the Monte Carlo results for 500 scenarios. Panel B and D show the simulated risk-neutral scenarios from the combined Hull-White Black-Scholes model. Panel B shows the option cash flows that can occur at the expiration date when the accumulated fund value falls below the guaranteed capital after 40 years. Panel A shows these option cash flows as they are discounted back along the paths of the short interest rate scenarios. The darkest scenario represents one selected scenario which is (of course) the same in all panels. For this scenario, the guarantee expires in-the-money after 40 years due to the rather poor equity returns for this scenario (see panel B). The option cash flow is subsequently discounted back along the path of the short interest rate (see panel C). The option value is now equal to the mean value of these discounted option cash flows at time *t*=0, calculated as the average over all 500 scenarios as indicated in the figure.

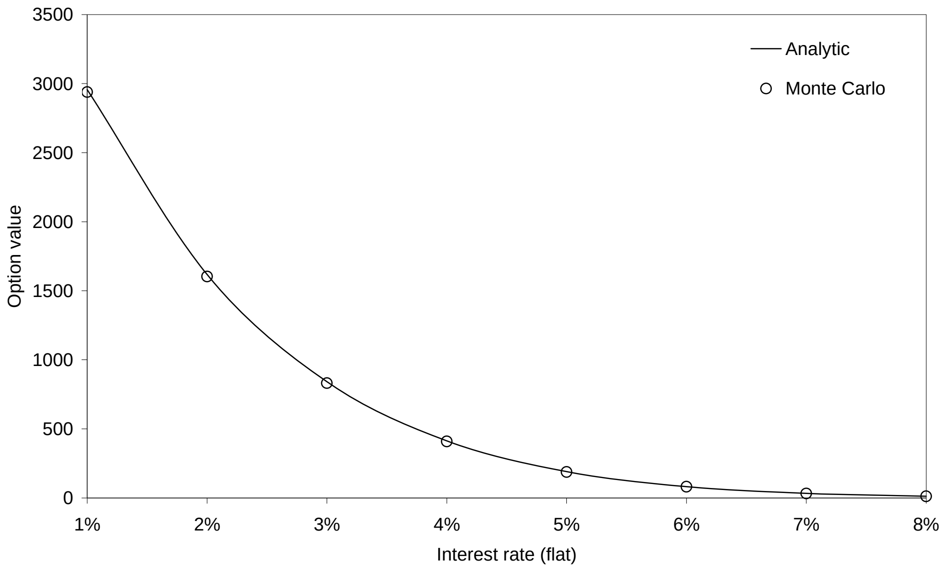
Figure 3.3: Valuation of a unit-linked guarantee through Monte Carlo simulation.



[11] Exact closed-form solutions do not exist in this case. An approximation is therefore used to derive an analytic formula. The interested reader is referred to for example Schrager and Pelsser (2004) for more information.

Monte Carlo results can also be used as a benchmark for approximating (closed-form) option formulas that in turn can be used in for example ALM modeling. An example of such an application for the UL product described above is show in Figure 3.4. The figure compares the value of the guarantee at different current (*t*=0) interest rate levels (for simplicity we assume flat yield curves) when calculated by means of Monte Carlo simulation with the (approximate) value given by the analytical formula. Note the excellent quality of the analytic approximation in this case. Also note the sharp increase in the value of the guarantee as the interest rate drops.

Figure 3.4: Testing an analytic option formula through Monte Carlo simulation.



3.4 Product development, pricing, and replicating portfolios

In practice, many product parameters need to be set when developing new insurance products. It may be important, for example, to determine which investment fee covers the cost of return guarantees for a unit-linked product. It may also be important to determine how financial risks of a product can be hedged efficiently with financial instruments. ORTEC’s ALM model for life insurers is well suited for performing such product development calculations because all required components are standard features of the model.

A recent development is to replicate insurance products with (liquid) financial instruments. In recent projects, the model has also been used for this purpose. The idea behind this approach is to replicate all cash flows associated with an insurance product (e.g., premiums, costs, guaranteed benefits, and profit sharing) as good as possible with a set of financial instruments (bonds, interest-rate derivatives, etc.). This way, it becomes possible to “convert” a portfolio of insurance products into an equivalent portfolio of financial products.

The advantage of this approach is twofold. First, it provides investors with a well-defined liability benchmark. This enables them to compare the returns on their investments with the return on the insurance products. Second, it also provides insurers with a useful pricing and risk management tool. An embedded option in an insurance product can, for example, be replicated with a derivative (say, a swaption) which has a measurable market price. This information can be used to determine an appropriate hedge and a proper surcharge when pricing the product.

4 Conclusions

This paper highlights several new developments in the field of asset and liability modeling (ALM) for insurance companies. Traditionally, ALM models are used by insurers to optimize their strategic risk and return profile given the objectives and constraints of their stakeholders. We show in this paper that, using the latest ALM models, insurance companies are also able to respond adequately to important changes in the fields of risk management, accounting and supervision.

These changes include, for example, the market consistent valuation of liabilities, the International Financial Reporting Standards (IFRS), European Embedded Value (EEV), Solvency II and the introduction of local financial assessment frameworks. Given the rapid and continuing developments it is likely that ALM models (and their application area) will further evolve in the next years. The key concepts behind current state-of-the-art models (stochastic scenario analysis, market consistent valuation of assets and liabilities, and integrated solvency testing facilities) will however remain at center stage in the years to come.

Appendix A: Risk-neutral scenarios and Monte Carlo valuation

ORTEC's ALM model for life insurers actually contains two kinds of economic scenario generators. The first one is used to generate real-world scenarios for ALM purposes. The second one is used to generate special arbitrage-free / risk-neutral scenarios. These scenarios are used to value for example complex embedded options in insurance contracts. Because of the particular and growing importance of these valuation methods for insurers, we give in this appendix some additional (high-level) information on the risk-neutral scenario and Monte Carlo facilities in the model.

Stated in (over)simplified terms, the real-world scenarios contain risk premiums for the various asset classes included, such as for example the equity risk premium. Risk-neutral scenarios, on the other hand, do not contain risk premiums.[12] In this case, all asset classes have the same expected return, which is based on the forward interest rates calculated from the zero coupon yield curve at the moment of valuation.

Embedded options in insurance products can be priced with great precision with a special-purpose Monte Carlo tool (see the examples given in Section 3.3.1). During each Monte Carlo run the model evaluates which insurance options are in-the-money at the expiration date and determines the corresponding "option cash flows" as the differences between the underlying variables and the strike levels. By discounting the option cash flows back along the simulated paths, the expected option value can be determined. A detailed description of this method is given in for example Hull (2005).[13] This combination of the actuarial module in which the insurance contracts are modeled, a risk-neutral scenario generator and the Monte Carlo method yields a very powerful tool for many liability valuation applications.

[12] By "risk-neutral" we mean that the market price of risk for investors is equal to zero, i.e. investors do not require a higher return for riskier investments (like risk-averse investors would). This assumption is often made when pricing derivatives because, based on replication (no-arbitrage) arguments, the value of an option does not depend on the risk attitude of the investor. Therefore, risk-neutral valuation yields the correct price of an option in all possible worlds (not only in the risk-neutral world).

[13] Besides European options, American options can also be valued in the model by means of Monte Carlo simulation. For this purpose the Least Squares Monte Carlo approach as described in Longstaff and Schwartz (2001) is used. An example of an American option in insurance contracts is the case in which policy holders can annually make the choice to surrender their policy. Surrendering the policy at a predetermined surrender value can be beneficial when interest rates are higher than the rate implied by the surrender value.

This Monte Carlo module requires risk-neutral scenarios. Such scenarios are generated with a combination of a two factor Hull-White (interest rate) model and a Black-Scholes (equity return) model.[14] This model generates arbitrage-free interest rate and equity scenarios.[15] This means that, by construction, arbitrage opportunities are excluded. Due to this property, interest rate and equity options are priced correctly when these scenarios are used in a Monte Carlo simulation. An advantage of the Hull-White Black-Scholes (HWBS) model is that analytical solutions can be derived for the pricing of many types of options. This greatly facilitates the calibration process to which we turn next.

The risk-neutral scenario generator has been extended with calibration tools to find the appropriate values of the different model parameters of the HWBS model (volatilities, mean reversion and correlation parameters). Calibrating the parameters of the HWBS model is the counterpart of the estimation of the parameters of a more conventional econometric time-series model. Calibration of a HWBS model on a given set of data is, in general, a highly non-linear optimization problem. Robust numerical techniques are therefore used to find the optimal parameter settings.

On what kind of data the model needs to be calibrated depends very much on the application of the model. Roughly speaking there are two types of applications:

1. A first possibility is to use (a version of) the HWBS model to value (embedded) options in assets and liabilities for reporting or regulatory solvency-testing purposes. In this case, the model needs to be consistent with the market prices of relevant traded financial instruments (options) at the moment of valuation. In this case, the model could be calibrated on the market prices of a set of swaptions (options on long term interest rates) and stock options.[16] Figure A.1 illustrates this approach. Panel A shows the zero coupon yield curve at the moment of valuation. Besides the volatilities, mean reversion and correlation parameters, this is in fact also an essential parameter of any valuation model. Panel B shows the results of the calibration process in terms of plotting the original market prices of a set of swaptions versus prices calculated with the calibrated Hull-White model. Prices are expressed as a percentage of the nominal amount of the underlying swap. In case of a 100% perfect calibration (which is not possible in most cases), all option prices will be exactly on the diagonal line. Panel C shows 1000 simulated scenarios of the short interest rate from the calibrated model[17]. The expected value of this interest rate follows from the forwards from the initial yield curve shown in panel A[18]. The mean reversion and volatility

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[14] For a description of the Hull-White and Black-Scholes models, see Hull (2004).

[15] Risk-neutral scenarios can be generated for nominal, real, domestic and foreign interest-rate curves, inflations, currencies and total return series.

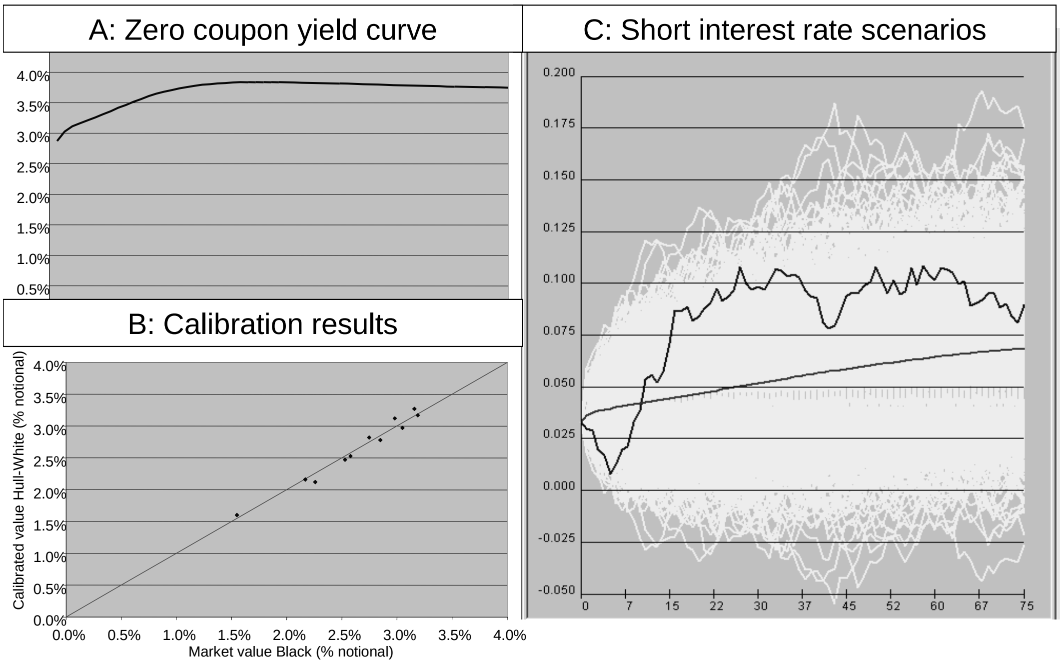
[16] For (embedded) options with a very long maturity, for which no actively traded counterparts exist, one might also want to calibrate the model (partly) on historical data. This method is similar to the second approach.

[17] In interest rate models like the Hull-White model, the process of the short rate completely specifies the process of the complete zero coupon yield curve.

[18] Plus a so called "convexity correction" which increases with the volatility and the maturity. This correction stems from a combination of on the one hand the martingale requirement which states

of the scenarios is obtained from the market prices of the swaptions on which the model is calibrated.

Figure A.1: Calibrating the risk-neutral scenario generator on option prices



2. A second possibility is to use (a version of) the HWBS model to value (embedded) options in assets and liabilities within a dynamic (ALM) scenario framework. In this case, it is important that the underlying dynamics of the HWBS model, as used for the valuation, is sufficiently consistent with the dynamics of the real-world scenarios, as used for ALM purposes. Otherwise, it becomes possible to optimize a strategic policy on model inconsistencies instead of true policy consequences. For example, think of what will happen when one values equity options with a volatility of 20% while using scenarios with a volatility of only 15%. To avoid these inconsistencies, the parameters of the HWBS model need to be chosen as consistent as possible with the statistical properties of the real-world scenarios (or the historical data set that was used to estimate the VAR model that generated the real-world scenarios).

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that in arbitrage free models, the expected return on all assets should equal the short forward rates and on the other hand the convexity in the price of (long term) bonds as a function of the interest rate.

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