CARL VON OSSIETZKY universität OLDENBURG
FAKULTÄT V
MATHEMATIK UND NATURWISSENSCHAFTEN

The impact of asset-hedging on insurance companies

Von der Fakultät für Mathematik und Naturwissenschaften der
Carl von Ossietzky Universität Oldenburg
zur Erlangung des Grades und Titels eines

Doktors der Philosophie (Dr. phil.)

angenommene Dissertation

von Herrn Anton S. Wittl
geboren am 31. Dezember 1990 in München

Gutachterin:	Prof. Dr. Angelika May
Weitere Gutachter:	Prof. Dr. Jörg Prokop
Tag der Disputation:	17. Dezember 2020

Acknowledgement

Writing a dissertation while concurrently honoring other duties and responsibilities is a challenge. Fortunately, there are people who support you with words and deeds. Without these people in my life, the completion of this dissertation would not have been achieved.

My heartfelt thanks go to my supervisor Prof. Dr. Angelika May. I am grateful for her advice and support. Her kindness and the joy she has in her work gave me great motivation for mine.

Furthermore, I would like to thank Prof. Dr. Jörg Prokop for his scientific support as second reviewer.

In addition, I have my colleagues and friends to thank for bearing with me. Christoph, thank you for answering all of my questions. Justin, thank you for pushing me and also giving me balance. And Katharina, thank you for being there for me.

My extraordinary gratitude goes to my parents for their love and support. Thank you for keeping me on the right path, for always having my back and for making this accomplishment possible.

Abstract

In order to assess the effect of hedging mechanisms in insurance companies – in particular the hedging of equity positions – key parameters of risk and earnings management are observed and analyzed over a medium-term accounting and planning period. This takes into account the regulatory and economic interdependencies between the investment management and the management of the portfolio of insurance risks. Asymmetrical profit distribution mechanisms between policyholders and shareholders, depending on the insurance line, are shown, whereby the analysis of the tails of the profit and loss distribution is of particular interest. This differentiated consideration of the parameters with their respective line-specific interdependencies is achieved by using stochastic modeling with 10,000 capital market scenarios. The simulations and analyses are carried out for both a life insurance model firm and a property/casualty insurance model firm.

Zusammenfassung

Zur Beurteilung der Wirkung von Hedgingmechanismen bei Versicherungsunternehmen – hier speziell die Absicherung von Aktienpositionen – werden wesentliche Kenngrößen der Risiko- und Ertragssteuerung über eine mittelfristige Rechnungslegungs- und Planungsperiode beobachtet und analysiert. Dies erfolgt unter Einbeziehung der regulatorisch und ökonomisch gegebenen Interdependenzen zwischen dem Kapitalanlagenmanagement und dem versicherungstechnischen Portfoliomanagement. Versicherungsspartenabhängige asymmetrische Gewinnverteilungsmechanismen zwischen Versicherungsnehmern und Aktionären werden aufgezeigt, wobei die Untersuchungen der Ränder der Ergebnisverteilungen von besonderem Interesse sind. Diese differenzierte Betrachtung der Kenngrößen mit ihren jeweils spartenspezifischen Wirkungszusammenhängen erfolgt durch die Verwendung einer stochastischen Modellierung mit 10.000 Kapitalmarktszenarien. Die Simulationen und Analysen werden einerseits an einer Modell-Lebensversicherung und andererseits an einer Modell-Schaden- /Unfallversicherung vorgenommen.

Table of content

1. General introduction

According to Section 124 subsection 1 of the German insurance supervision act (*Versicherungsaufsichtsgesetz VAG*) all assets of an insurance company should be invested under the principle of entrepreneurial prudence, so that the security, quality, liquidity, profitability and availability of the portfolio is ensured. Moreover, it should avoid over-concentration of risks, while maintaining an appropriate level of diversification. To do so, only investments in assets, whose risks can be identified, assessed, monitored, controlled, and supervised, are allowed. Additionally, it must be ensured that the assets can be sufficiently considered when assessing the solvency requirements and that the solvency capital requirements under Solvency II are fulfilled at any given time. It is implied that appropriate governance structures with sufficient risk controlling mechanisms are put in place, to ensure the previously described qualities of the asset portfolio.

One part in the collaborative process of controlling risk and ensuring a well working asset liability management, is covered by the asset management. A way to maintain security in an asset portfolio while generating profitability, is to use derivative financial instruments to control risks and secure profits already earned. The rational for securing profits already earned is threefold: Firstly, it affects the assurance of required current income for the achievement of certain minimum income measures. These current income requirements stem from the interest guarantees from commitments on the liability side. Secondly, it affects the build-up of buffers in form of valuation reserves, which strengthen the financial flexibility of the firm. And thirdly, it positively influences the risk-bearing capacities over time.

Derivative financial instruments that are relevant in this context are covered in the insurance supervision law. Section 15 subsection 1 and Section 124 subsection 1 sentence 5 of the *VAG* allow the usage of derivative financial instruments, should they serve as hedges against price or interest rate changes for existing assets, or for the acquisition of securities in the future, or to generate additional income from existing securities, without the possibility of shortfall of the security assets on the date of the delivery obligation. These criteria have been concretized by the German financial supervisory authority (BaFin) in the circular letters R 3/2000 (BaFin, 2000) and R 3/1999 (BaFin, 1999). These circulars however are omitted since January 1st, 2016 for companies under the Solvency II regime. Until extensive experience with the management of derivative financial instruments and structured products under this new supervisory regime has been obtained, insurance companies still orientate themselves towards the circulars R 3/2000 and R 3/1999. The later has recently been replaced with the circular R 08/2017 (BaFin, 2017b).

Derivative financial instruments include all transactions, whose prices are derived from an underlying asset, such as stocks, securities or currencies, reference price, reference rate or reference index. Derivative financial instruments consist either of two binding contracts (forward transactions feature) or of an unilateral legal transaction (option feature). A hedging transaction is given when derivative financial instruments are used to protect the portfolio of assets and liabilities partially or in full against price or interest rate change risks. In this context, the price or interest rate change risks include both the risk of change in value of the assets to be hedged and the risk of fluctuations of future cash flows. During the entire term of the derivative financial instrument used for hedging, there must be respective balance sheet positions opposing it in the corresponding volumes. Should the asset to be hedged be terminated, the hedging instrument must be sold or be closed out, as well, unless it is used for other hedging purposes or can be used as a forward transaction.

A summary of derivative financial instruments permitted by the German supervisory authority (BaFin) can be seen in the circular R 3/2000 section A. Accordingly, suitable hedging strategies for the assets of an insurance company are (1) the purchase of a seller's option (long-put), (2) the selling position in futures contracts, and (3) interest rate swaps or currency swaps (or a combination of both).

This regulatory situation with its practical realizations stimulates a closer analysis of the implications for asset liability management of insurance firms from an academic point of view. The reasoning behind hedging asset portfolios in general, as well as its benefits and pitfalls, are well researched, especially from the perspective of financial portfolio management. However, in the complex accounting and regulatory schemes, which insurance companies need to handle and manage, the effects of hedging strategies are not as apparent. How does the usage of certain hedging strategies affect the profitability of an insurance firm? In what way does the asymmetry in the profit distribution under regulatory law affect the effectiveness of hedging? Is it appealing for investors and shareholders to encourage the firm's management to apply hedging mechanisms in the asset management? If so, how are the company's customers, the insured, affected by such measures? Is there a trade-off between profitability and security for the insurance company?

Since the earlier mentioned asymmetry in the profit distribution in life insurance is a key aspect of this study, the main mechanism should be discussed before going into the detailed analysis. Section 139 *VAG* addresses the surplus participation in the life insurance business. This concept was introduced in part due to the fact that insurance firms are required to calculate premiums prudently and it is therefore only fair to let the insured participate in profits, which result from this notion. The rules for this surplus participation are defined in Section 6 et. seq. of the *Mindestzuführungsverordnung*. The regulation dictates that profits from the three main sources of income for the insurance firm need to be allocated towards the insured. At least 90 percent of the capital investment result, at least 90 percent of the risk result and at least 50 percent of the other result are therefore directed towards the insured. This mechanism affects only positive results. Losses are fully carried by the insurance company. This means that profits only partially go to the firm, while losses go in full. In practice, this effect is referred to as the asymmetry in the profit distribution. This complex issue is explained in detail in the legal commentaries of the *VAG* by Prölss et al. (2018) on Section 138 et. seq. and in the works of Zimmermann et al. (2006), Basedow (1992) and Lorenz (1993).

In the past, several authors have researched hedging in general, as well as aspects of the proposed research questions. Nevertheless, the focus of academic literature has mostly been on hedging risks that occur on the liability business of insurance companies. In the work of Kling et al. (2014) it is shown how policyholder behavior, and faulty assumptions of it, affect hedging efforts of the insurance company. Gründl et al. (2006) analyze hedging efficiency for a different liability risk: demographic risk; while Golden et al. (2010) put hedging effectiveness into yet another liability risk context, weather-related risks. And further, an analysis of hedging mortality risk is conducted by Gaillardetz et al. (2012).

Applied to the German insurance market Bartels and Veselcic (2009) study the effects of various strategies in the context of business with guarantees and compare them with results from applying Constant Proportion Portfolio Insurance (CPPI) to the portfolio. Furthermore, the works of Coleman et al. (2007) and Tse et al. (2008) contribute to the theoretical assessment of hedging in the context of insurance.

Apparently, in academic literature there exists no analysis of the trade-off between shareholder interests and the interests of the insured when applying derivative financial instruments to hedge risks in the asset portfolio of an insurance firm. Instead, a heavily researched field is the hedging of risks that stem mainly from the liability side of the insurance business. Bernard and Kwak (2016) find an optimal hedging strategy for variable annuities relying on semi-static hedging strategies. Coleman et al. (2006), Coleman et al. (2007) and Kolkiewicz and Liu (2012) choose similar approaches using options to hedge variable annuities. Alternatively, dynamic delta-hedging can be applied to address the issue of finding optimal hedging strategies for risks in variable annuities, as shown by Kling et al. (2011) and Kling et al. (2014). In the field of dynamic hedging, there have also been studies on approaches using mean-variance criteria, which have been published by Papageorgiou et al. (2008) and Hocquard et al. (2012). And next to semi-static and dynamic hedging there is the area of static hedging. Studies here have been published by Hardy (2000) and Marshall et al. (2012), in which put options are used in a static position to replicate maturity guarantees.

As mentioned before, research on these specific questions has been sparse, nonetheless there have been highly interesting publications on different relatable topics. Hedging in the extended field of insurance with focus on financial risks has been researched by various authors. Pézier and Scheller (2013) compare constant proportion portfolio insurance (CPPI) with option-based portfolio insurance strategies. Møller (1998) discusses risk-minimizing trading strategies with respect to unit-linked contracts. Liu and Yang (2004) derive optimal investment strategies for reducing an insurer's probability of ruin.

This work contributes to academic literature by conducting the analysis in a realistic setting within the framework of the actual regulatory rules and practical business conducts. Applying academic research methods, while using a state-of-the-art stochastic simulation tool, allows for scientifically sound answers to questions proposed by practitioners. The stochastic is crucial for this topic, since it allows to analyze the behavior of the key figures in the context of the previously explained asymmetry of the profit distribution. It is the superior way for evaluating key figures in the decision-making process because the distributions of results make the complexity of the insurance business' accounting and regulatory framework feasible. This is one reason why over the past years, stochastic analysis has become the advanced standard for asset-liability management. Ideally, such an analysis is done dynamically over several projection years. By doing so, this work complementarily creates value for research orientated practitioners, as well.

The remainder of this work sets out to analyze the proposed research questions in the following structure. Firstly, an introduction to asset-liability management simulations and stochastic capital market scenarios is given. Secondly, the proposed research questions are analyzed along the model of a German life insurance company. Thirdly, the life insurance results are challenged in a scenario analysis with differing capital market settings. This enhances the conclusions drawn from the life insurance chapter and adds an additional perspective – the one of the capital markets – to the analysis. Afterwards, hedging in the German property/casualty insurance is modeled and examined. As property/casualty insurance is subject to a widely different set of challenges and regulations, this makes for a suitable comparison within the same financial sector. Lastly, the work is concluded with a summary and an outlook for possible further studies is presented.

2. Technical framework

This chapter introduces the used asset-liability-management-software as well as the technical foundation for this analysis. It further describes the simulation algorithm, in which the hedging strategy is integrated. Since the hedging mechanism is kept unchanged throughout the whole analysis, the general mechanism and parametrization is also established in the chapter.

2.1. Asset-liability management and stochastic simulations

Asset-liability management is a management approach, which gives the targeted steering of assets and liabilities coherence, while taking interdependences into account. Both the assets in form of the investment portfolio and the liabilities, meaning the technical insurance obligations including the implied financial guarantees and options, entail risks. These risks need coordinated steering under the premise of including the company-specific requirements from the individual (equity) capital situation and risk orientation.

This company-specific management approach also serves to meet regulatory requirements. These can be financial risk factors on the asset side with their liquidity and return characteristics. But also, the benefit obligations on the liability side with their insurance-specific risk characteristics count towards such regulatory requirements. The attributes are characterized by other liquidity requirements, financing needs and the specific risk character. This in turn is significantly impacted by the insurance sector, the respective product, and the country with its local accounting standards.

The existing interdependencies between assets and liabilities are mainly derived from the product level or the structure of benefit obligations. In principle, products with high provision intensity and longer settlement periods induce correspondingly intensive interdependencies. A prominent example is life insurance, where, in addition to biometric risks, extensive financial risks such as interest rate guarantees, and surplus commitments are typically implicitly included in the insurance product.

A simultaneous cross-company analysis and consideration of relevant control and performance indicators in asset-liability management requires probabilistic interpretations. This is made possible by means of stochastic simulations. In the asset-liability management tools used for this purpose, an integrated depiction of risks taken in the insurance operations and the financial areas is thus achieved. This depiction is further automatically linked with the control algorithms of accounting and hypotheses on situation-dependent management decisions within the framework of the company's target system.

Asset-liability management therefore enables the management to gain the cross-company control over the financial stability, as well as the control over the risks taken within the entire impact structure of complex interdependencies. It allows for the steering of profitability depending on risks taken and enables the evaluation risk/return positions on both the product and investment level. It even facilitates the optimization of decisions on risk, return and capital at the level of the entire company.

This holistic approach makes asset-liability management tools ideal for analyzing and evaluating of a mechanism like hedging, since hedging leads to exactly the interdependences mentioned before. Therefore, the analyses in this work are done using the asset-liability management software PLA.NET[1], which is a stochastic simulation tool used by many insurance firms in Germany. For this work, two model companies are built in the asset-liability management software, one typical German insurance company with “classic” guarantee business[2] in the current portfolio and one typical German property/casualty insurance firm.

The following chapters provide details of the model specifics and the presumed assumptions. A holistic view of the whole model and the interactions of its modules is visualized in Figure 1. Considering the general build of the model company, the assumptions can be grouped into four main parts: the capital market model on the left (which actually is not part of the main asset-liability management model), the asset model, the liability model (including the external inputs for policyholder behavior) and the management model, which interacts with each module. The evaluation and control model does not require any assumptions as it solely serves the purpose of processing and displaying the inputs and results.

[1] PLA.NET is a product of ROKOCO GmbH. All rights reserved.

[2] Examples for “classic” guarantee business are pension insurance, endowment insurance or term insurance with guaranteed calculation bases (interest and biometry) over the contract term, with surplus participation and the storing of the policy holder funds in the coverage assets. Reuß et al. (2015) give a technical example for such a traditional insurance product and Klotzki (2018) lists numerous examples of current insurance products, while addressing the development of new product categories in recent years.

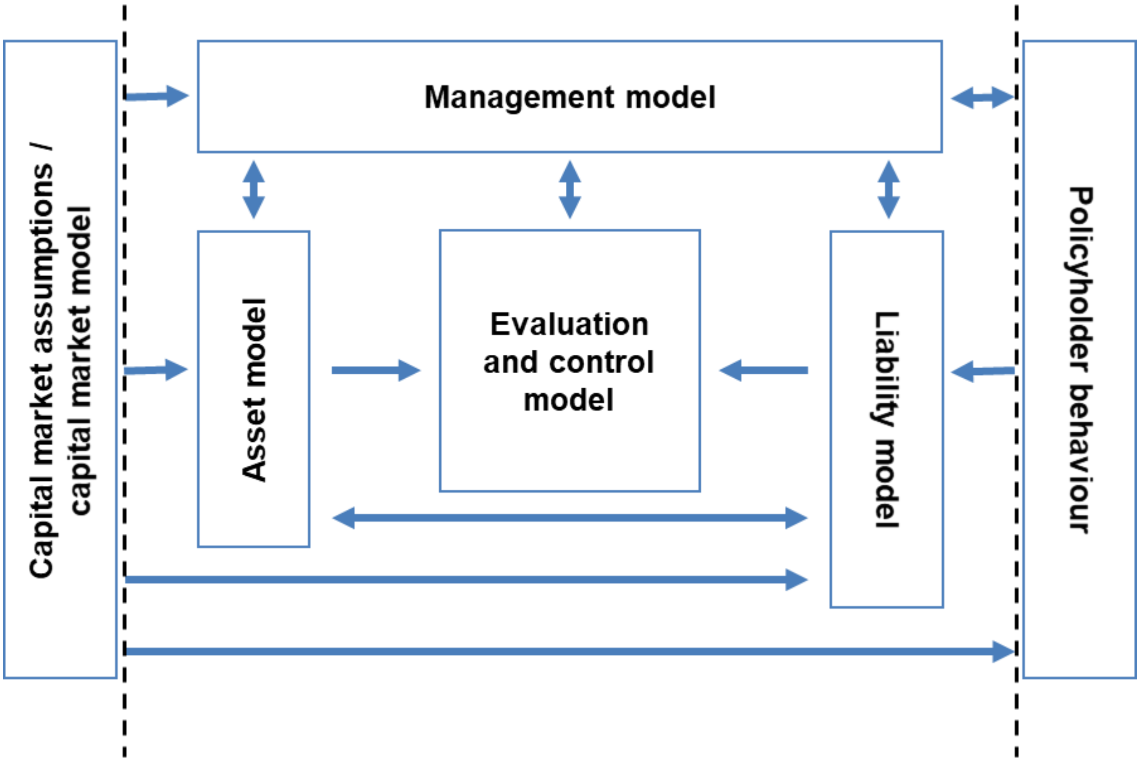

Figure 1: Asset-liability management model.[3]

2.2. Stochastic economic scenarios

A necessity for the stochastic capital market simulations in an asset-liability management tool are the stochastic economic scenarios. They make up the capital market model of the asset-liability management model and are used as assumptions for the performance of the asset classes relevant for the asset portfolio. The scenarios are input data to the asset-liability management simulation, which must be determined using suitable methods. They are generated using an economic scenario generator (ESG) and are independent of the model company.

There are two types of economic scenarios: risk-neutral scenarios and real-world scenarios. Risk-neutral scenarios are needed for valuations and mostly regulatory purposes, for example the calculation of solvency ratios. Real-world scenarios, on the other hand, are used for corporate planning and corporate management. They included actual assumptions (expected value and volatility) for the performance of the asset classes. As this work strives to shed light on the advantages and drawbacks of hedging from different perspectives (policyholder and shareholder), real-world scenarios are used for the simulations.

[3] Based on figures in Jaquemod (2005, p. 48).

The economic scenarios typically have 1,000 to 10,000 stochastic paths. The number of paths should be as high as possible, however with an increasing number of scenarios, the runtime of the already highly time-intensive simulation process increases even further. In this work, 10,000 stochastic paths are used. The generation of the economic scenarios is a simulation process of its own and consists of four key steps: the capital market research, the calibration process, the simulation process, and the validation of the results.

The first step, the capital market research, starts with a look at the asset portfolio of the company that is to be projected in the asset-liability management simulation. For each risk factor represented in that asset portfolio, the economic scenarios need to provide stochastic paths, which means that each of these risk factors needs a simulation model and inputs for its simulation parameters. Once the risk factors and the corresponding simulation models are established, benchmark indices or interest rate curves for each risk factor are determined, which the calibration process is performed on. The selection of the simulation models depends on the desired characteristics of the outputs. The model selection in this work is based on market standards. The capital market data for calibration process is typically either historic time series or interest rate curves with implied volatility information. The data for the scenario calibration used in this work was obtained from Bloomberg Finance L.P.

The calibration process derives the model parameters from the capital market data and the simulation process uses these calibration parameters for the implemented models to generate the economic scenarios. In this work, the Hull-White interest rate model, the Geometric Brownian motion model, and the spread model with normally distributed gains are used. To improve the quality of the random numbers in the simulation process, the volatility reducing techniques of stratified sampling and antithetical variables are used.

After the economic scenarios have been generated, the scenario data is typically validated to verify the quality of the random numbers and the simulation algorithms. Such tests include checks in which the expected value and the volatility of generated data is cross-checked with the actual input parameters or the resulting interest curve is mapped against the initial interest rate curve of the simulation input. Provided the validation is successful, the economic scenarios can be imported into the asset-liability management software and used by the simulation algorithm.

2.3. Hedging mechanism

The term "hedging mechanism" not only describes the parametrization of the hedging strategy, but also includes the embedding of the hedging strategy in the complex algorithms of the simulation model.

The asset-liability management simulation basically is a repetition of forward projections of assets, liabilities, and costs, as well as readjustments and rebalancing mechanisms at certain points of the projection. The simulation model chosen for this analysis has the unit years as time steps. Therefore, the steps from the starting date to the end of the first projection year are as follows: First, the assets including market values, book values, cash, credit defaults, etc., are projected forward based on the underlying assumptions from the capital market model. Subsequently, the liabilities with its reserves, premiums, payouts, solvency requirements, etc. are projected. Afterwards, the same is done with the costs. The next step is where the rebalancing of the assets takes place: cash flows are used to achieve a good fit to the selected target allocation. The management rules, which are defined in the management model, are also applied in this step. Due to the management rules and possible target figures or constraints, the rebalancing step can be repeated more than once. Finally, the annual accounts are complied. All these steps are repeated in a loop over all projection years and then in another loop over all capital market scenarios.

The hedging mechanism as seen with a put-options-based hedging strategy is part of the projection of the assets. Therefore, the put options' gains and losses/costs are calculated at the end of the projection year, just before the rebalancing takes place.

To calculate the gains of the options, firstly, the price of the puts P needs to be calculated. This is done using the Black-Scholes formula:

$$P = MV_{j-1} * \left(X * e^{-r(j-1)} * \Phi(-d_2) - e^{-dividend_j} * \Phi(-d_1)\right)$$

$$with\ d_1 = \frac{\ln\left({}^{1}/_{X}\right) + r_{j-1} - dividend_j + {}^{\sigma^2}/_{2}}{\sigma}$$

$$and\ with\ d_2 = d_1 - \sigma$$

The dividends of the stocks $dividend_j$ are drawn from the projection, while the short rate r_j is derived from the spot rates. X is the strike of the asset, σ the volatility of the underlying asset, Φ the standard normal cumulative distribution function, MV_j the current market value from the asset portfolio in projection year j and MV_{j-1} represents the old market value from the balance sheet in the year j–1.

Secondly, the actual costs of the puts are equal to the price of the puts multiplied with the hedged portion of the equities $Portion_{hedged}$.

$$Puts_{costs} = P * Portion_{hedged}$$

Thirdly, the profit from the put option is calculated by multiplying the market value of the equity at the beginning of the projection year with the hedged portion and the maximum of the difference of the strike and the equity performance including the dividends, and zero.

$$Puts_{profits} = MV_{j-1} * Portion_{hedged} * \max\left(X - \max\left(1 + r_j; 0\right) + dividend_j; 0\right)$$

Finally, the gain from put options is the profit from puts minus the costs for the puts compounded over the projection year.

$$Puts_{gain} = Puts_{profits} - Puts_{costs} * (1 + R(j; 1))$$

2.4. Hedging parametrization

There are four variables that must be defined in the simulation model when using put options as a hedging strategy. The first one is rather straightforward, as it is the selection, which equity positions in the asset portfolio should be hedged. It is important here to consider that the asset portfolio typically includes *Spezialfonds*, which can have an equity portion. In this analysis, all equities, both directly held and in the *Spezialfonds* are subject to the hedging strategy. Even though all positions are hedged, it is common to not hedge the full position, but much rather smaller portions of each position depending on the individual risk bearing capacities. In the published corporate reports of insurance firms are no adequate disclosures concerning the gross and net equity quotas. It is refrained from using a percentage of 100 percent, as the hedging costs would drastically distort the median results, while providing no substantial advantage in the observation of results. Instead, a percentage of 30 percent is chosen for the portion of the hedged position. This way the effects of the hedge can be observed, while keeping the costs for the hedge limited. For further research, a separate analysis could be conducted to determine the optimal percentage to be hedged based on individual risk preferences of the management, however would exceed the limits of this work at this point. The risk bearing capacity is also of relevance here, especially when it is influenced by the solvency regime in terms of certain quotas that need to be fulfilled. Moreover, a partial hedging is often motivated by the wish and/or the need for security, but also the necessity for profit generation. The smaller the hedged portion is, the fewer options need to be purchased and the fewer costs are incurred due to the hedging instruments – at least in the planning scenario of most managers.

The third and fourth variables are both relevant for the put options themselves, as they define the strike and the volatility of the options. This analysis sets the strike with the purpose of securing current levels of the equity developments. The parameter is therefore fixed at 100 percent. This parametrization can also be discussed further in terms of finding the optimal level. Nevertheless, 100 percent is a valid assumption to facilitate the analysis of the results. To be consistent within the model, the volatility is set to be the same as in the capital market model. This parametrization is intended to represent the typical behavior of insurance companies, although the approach to hedging is a very company-specific issue. In the market, it is strongly influenced by a company's risk bearing capacity, its profit expectations as well as its profit necessities, and needs to be designed accordingly.

Now that the technical framework is set, the general simulation model for this work is established, and the examined hedging strategy is defined, the first of three main result chapters is presented.

3. Life insurance

3.1. Introduction life insurance

As mentioned before, life insurance is a predestined example for a business model, which needs asset-liability management. The interdependences between the two sides of the balance sheet are extensive. Not only the asset portfolio is impacted by the capital markets, but also the liability portfolio with its interest rate guarantees, which are often incorporated in the insurance policies. This intensifies the role of asset management in this particular insurance sector. Furthermore, the amount of assets under management in the average German life insurance portfolio makes investment management a major topic for these financial institutions. As hedges are frequently used in practice in this sector, this work is not only interesting from a theoretical point of view but is also relevant for practitioners.

The regulatory framework for the German life insurance business addressed in the introductory chapter of this work has been growing in complexity and steering a company within the set boundaries of this regulation is a challenge. This complexity paired with multidimensional interdependencies of the business model itself makes the hedging strategy's mode of action non intuitive. Therefore, this analysis is conducted to further the understanding of the effects from asset-hedging on a German life insurance company.

For this work, a model company is built in the asset-liability management software, which represents a typical German life insurance company with "classic" guarantee business in the current portfolio. The model excludes new business. The presumed assumptions for the model company are based on industry averages and are described in the following paragraphs.

3.2. Model description

3.2.1. Capital market model

The capital market inputs significantly influence the performance of the simulated asset portfolio. The interest rate development is one of the key factors, as it also influences the liability side of the simulation. In Figure 2 the assumed development of the 10-year spot rates for Euro fixed income rates is depicted. The capital market assumptions are derived from historic data time series of corresponding major benchmark indices. The calibration date is December 31st, 2015.

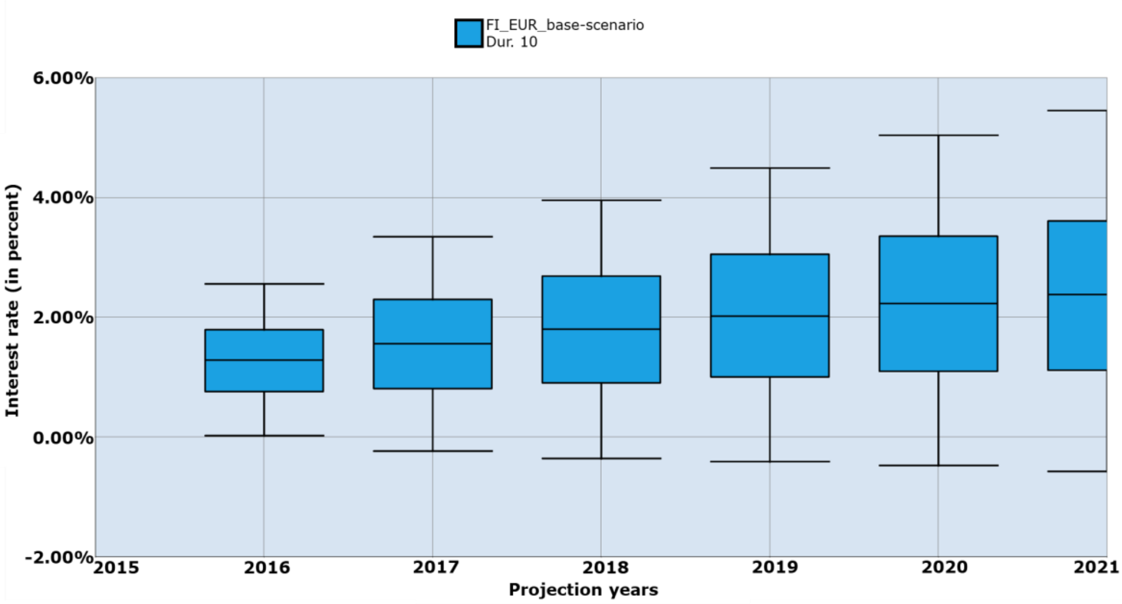

Figure 2: Capital market assumptions (life insurance). Box plot of interest rates for 10-year EUR spot rates.

For the equity, real estate, and private equity scenarios the geometric Brownian motion is used. The spread model is based on normally distributed gains. The Hull-White interest rate model is calibrated using the Euro swap curve at the reference date and the matching at-the-money swaption volatilities. Table 1 summarizes the capital market assumptions made for the scenarios and the projection. They are given here to show that the scenarios used for the simulation are based on realistic inputs derived from actual market data:

Risk factor	**Expected value**	**Volatility**
Equity Europe	6.400%	16.750%
Equity Global	5.500%	13.490%
Real Estate Europe	3.500%	3.640%
Private Equity	6.800%	17.750%
Spreads EUR AAA	0.000%	0.000%
Spreads EUR AA	0.370%	0.330%
Spreads EUR A	0.160%	0.130%
Spreads EUR BBB	0.240%	0.170%

Table 1: Capital market assumptions (life insurance). Parameters for risk factors. Spreads are additive towards the spot rates resp. the next better rating. These risk factors are used for the benchmarking of the simulated asset classes.

3.2.2. Asset model

The asset model is one of the key components of this analysis. In the simulation system it is possible to create a numerous amount of asset classes to represent the company asset portfolio as precisely as possible. For each class, there are properties to be set for creating a realistic representation of the displayed company assets. The most important properties usually are the accounting method (current assets / fixed assets), reference index, issuer & rating (for bonds only), purchase date and date of expiration, market value, book value, nominal value, purchase price, coupon, spread, accrued interest and J-curve. Most of these properties need to be set, but it is possible to let the software automatically calculate the remaining properties, for example given a specific capital market situation (interest rates) and a given coupon, the spreads are calculated within the asset-liability management software using a market-consistent closed formula.

The model portfolio for this analysis is meant to depict a German life insurance company, which is active in classical business with profit participation. Therefore, the asset portfolio will consist of the common asset classes such as equity, real estate, registered bonds, and promissory notes. Furthermore, as other asset classes have become more popular with insurers, the model portfolio also includes instruments like callable bonds, annuities, and multi-tranche bonds as well as private equity investments. All mentioned capital market instruments can be held either directly or in specialized mixed funds.

The investments are not limited to European investments, however, to reduce complexity and to keep the focus on equity hedges, all investments are made in Euros (€). For an analysis of currency hedges, the asset portfolio would require changes here.

As this work focuses on hedging of asset portfolio positions, the model company is given a detailed asset portfolio. The asset structure at the beginning of the projection is modeled along market averages from the annual market report 2016 by BaFin (2017a) and the annual reports of most German life insurance companies[4].

The reference date of the portfolio is December 31st, 2015, which makes 2016 the first year of projection. The portfolio does not consist of any assets issued or bought before January 1st, 2002. Therefore, there are no issues with the currency-conversion from Deutsche Mark to Euro. It is further assumed that all assets are denoted in Euro.

The overall book value of the asset portfolio is set to be ten billion Euros. The assets are divided into direct holdings (*Direktbestand)* and indirect holdings through the *Spezialfonds*. 30 percent of total assets are allocated towards the *Spezialfonds*. The 70 percent held directly are split into twelve *Assetmäntel*. Seven fixed income groups: annuity bonds, callable bonds, multi tranche bonds, registered bonds

---

[4] Unpublished study of annual reports of German life insurance companies 2015, ROKOCO GmbH. The study covers more than 98 percent of the German life insurance market.

(*Namensschuldverschreibungen*), promissory notes (*Schuldscheinforderungen*), swaption bonds and zero bonds. And five other asset groups: European stocks, stocks "world", cash, real estate, and private equity. Within the *Assetmantel Spezialfonds* two *Spezialfonds* are modelled: one mixed fund, which covers stocks, cash, corporate bonds and government bonds, and one bond fund, which solely consists of corporate and government bonds.

The pie chart in Figure 3 displays the model company's asset allocation based on book values at the reference date December 31st, 2015:

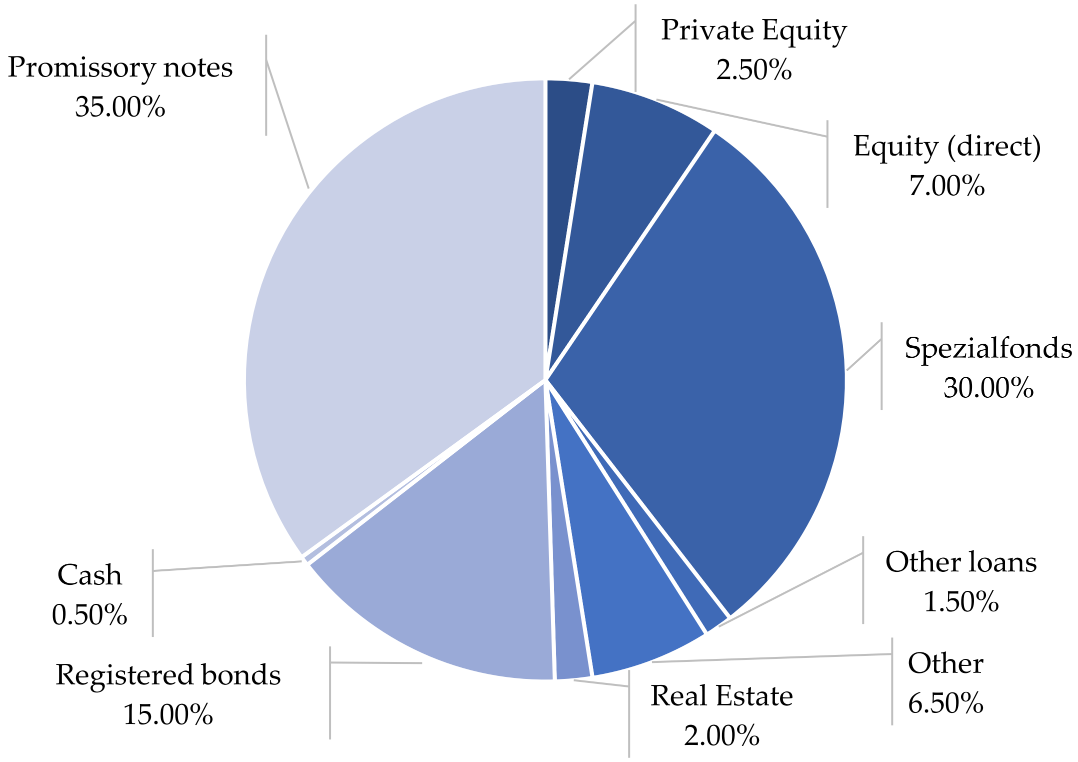

Figure 3: Pie chart of asset portfolio book values at beginning of projection (life insurance). Reference date December 31st, 2015. Total book value of ten billion Euros.

The subsequent paragraphs discuss the composition of assets within each *Assetmantel* and their underlying assumptions.

The total exposure of equity in the portfolio is ten percent. Of these stocks 70 percent are held directly as *Direktbestand* and 30 percent are part of the mixed *Spezialfonds*. The directly held stocks are 60 percent European stocks and 40 percent world-wide. These stocks are usually traded throughout one year and therefore do not have substantial amounts of capital gains (measured by the market to book ratio of each position). According to the industry average for valuation reserves on stocks as published in the annual reports, the market value of stocks exceeds the book value on average by 12.450 percent. The book to market ratios in the portfolio are modeled accordingly.

The proportion of real estate investments is also based on average market figures and comes to 1.500 percent of the total book value of the portfolio. It is distributed across three assets in the *Direktbestand*. Due to the positive performance of the German real estate market in recent years, the market value of the total real estate investments is set to be 38 percent higher than its book value.

The underlying asset portfolio further includes private equity. The purchases of alternative investments have been rising in the past years and therefore a portion of 2.500 percent is allocated towards private equity in this portfolio. This *Assetmantel* is split into ten private equity holdings. For the past ten years each year another investment has been made, each with a holding period of 14 years. Each investment is assumed to have the same underlying J-curve. This is done to smooth the effects of these types of investments in order to avoid extreme effects in later results.

To make the model company a realistic representation of the German life insurance industry, the portfolio includes special fixed income instruments, which have become popular with insurers, even though they are only held in minor amounts. These include multi tranche bonds and callable bonds. The multi tranche bonds make up 0.500 percent of the total book value. Callable bonds are set to one percent as these assets have proven to be a way to earn slightly higher coupons compared to regular fixed income investments with an acceptable risk-return trade-off. With 1.500 percent of total book value zero borrower's note loans (*Zero-Schuldscheindarlehen)* are another "uncommon" fixed income instrument included in the portfolio. This asset class can be seen in more and more portfolios of insurers and is therefore also added to the model company.

Annuity loans (*Annuitätendarlehen*) make up five percent of total book value and thus are one of the larger parts of the enormous portion of fixed income investments of the model company. The actual investments inside the *Assetmantel* are set up with maturities evenly spread out over the next 20 years to create a steady stream of income. The valuation reserves on the annuity loans are about 14 percent at the reference date.

The second largest asset class in the *Direktbestand* consists of registered bonds with a portion of 15 percent of total book value. The assets under this *Assetmantel* are divided into "Euro" and "Global" and are further separated into rating groups AAA, AA and A. The average rating lies between AA and A. The valuation reserves on all registered bonds are about 21 percent of the book value. The respective coupons of each asset are determined by adding average spreads to the actual market interest curves at the respective date of issuance. It is assumed that all assets are bought at par. The average Macaulay-duration comes to about ten years. At the reference date, the total number of registered bonds is 68.

The largest group of assets is comprised of promissory notes and makes up 35 percent of the total portfolio. The approach for finding adequate coupons and market values equals the one used for to the registered bonds. The assets have ratings ranging from AAA to BBB and can also be divided into "Euro" and "Global", with 27 positions in total.

The remaining part of the asset portfolio is held in *Spezialfonds*. One makes up for 10 percent of total book value and is a mixed fund, while the other fund (20 percent) is a bond fund. The bond fund mixes corporate bonds and government bonds. The bonds have both European and global issuer and are rated between AA and A. The mixed fund adds stocks and cash to corporate and government bonds. The portion of thirty percent of total book value allocated towards *Spezialfonds* appears high at first sight, however, thirty percent and more are not uncommon anymore in the industry.

The last part of the asset model is the target allocation. It is used to control the investment strategy for the future by defining the portfolio’s asset distribution for each year of projection. To eliminate unwanted effects in the results due to reallocations, the asset allocation is set to be constant over time. If necessary, a passive reallocation mechanism is applied, which solely uses access cash to reach the wanted quotas for each asset class.

3.2.3. Liability model

The liabilities of the model company are displayed in the liability model. The insurance portfolio is represented through the rate structures (*Tarifwerk*), the actuarial calculation assumptions (*Rechnungsgrundlagen*), the portfolio structure (*Bestandsstruktur*) and the cost structure (*Kostenstruktur*).

The rate structure includes the actuarial interest rate generations, the first-order costs, and the necessary tables such as mortality tables for premium calculation and reservation. The actuarial calculation assumptions (second order) cover the second-order mortality tables and second-order lapse tables. Probabilities for premium exemption and lump-sum options are also defined here. For the portfolio structure, a mixture of model points representing the typical age structure in German guarantee business is used for the portfolio structure. The second-order cost structures are derived from industry averages.

By excluding new business, while maintaining the cost structure of a going-concern model, the result from other income will be overvalued. Since this phenomenon will be stable over the projection time, it will not lead to a distortion of the general results. Nonetheless, it strongly reduces complexity and is therefore a viable assumption. It might however make sense to keep this in mind, when looking at absolute profit figures. Another simplification is the omission of building the *Zinszusatzreserve* in the projection. The resulting increased gross surplus leads to an increased *RfB-Zuführung* (*Zuführung zur Rückstellung für Beitragsrückerstattung*) and a high rate of retention of equity reserves, but the respective liquidity will still stay in the firm.

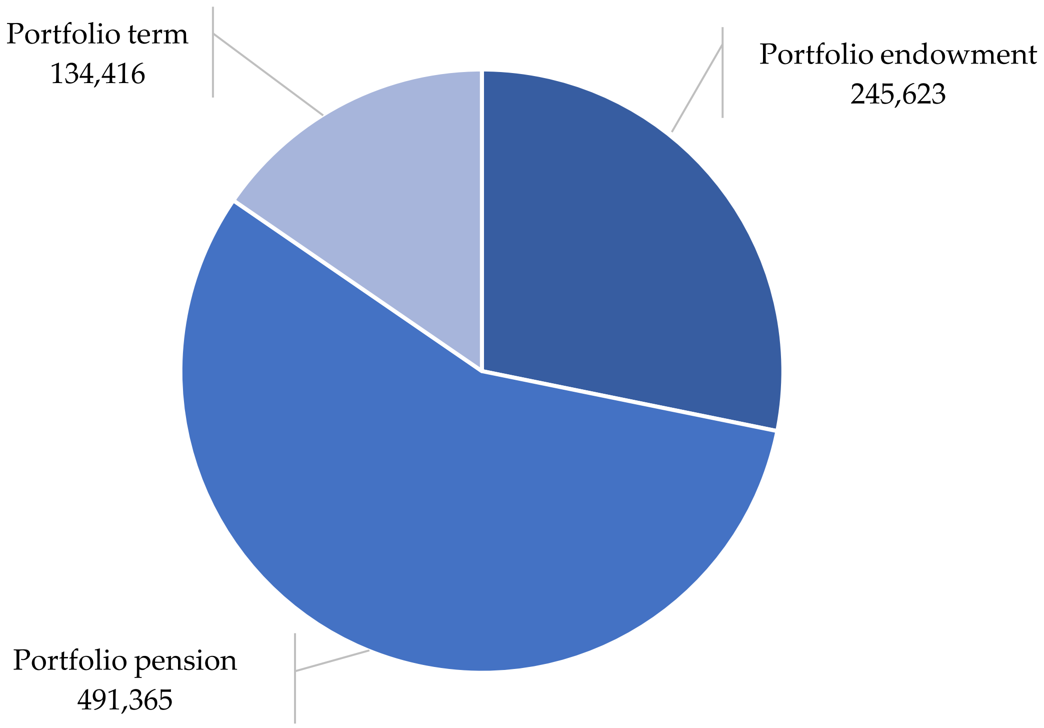

Figure 4: Pie chart of the liability portfolio structure based on the type of insurance by number of contracts (life insurance).

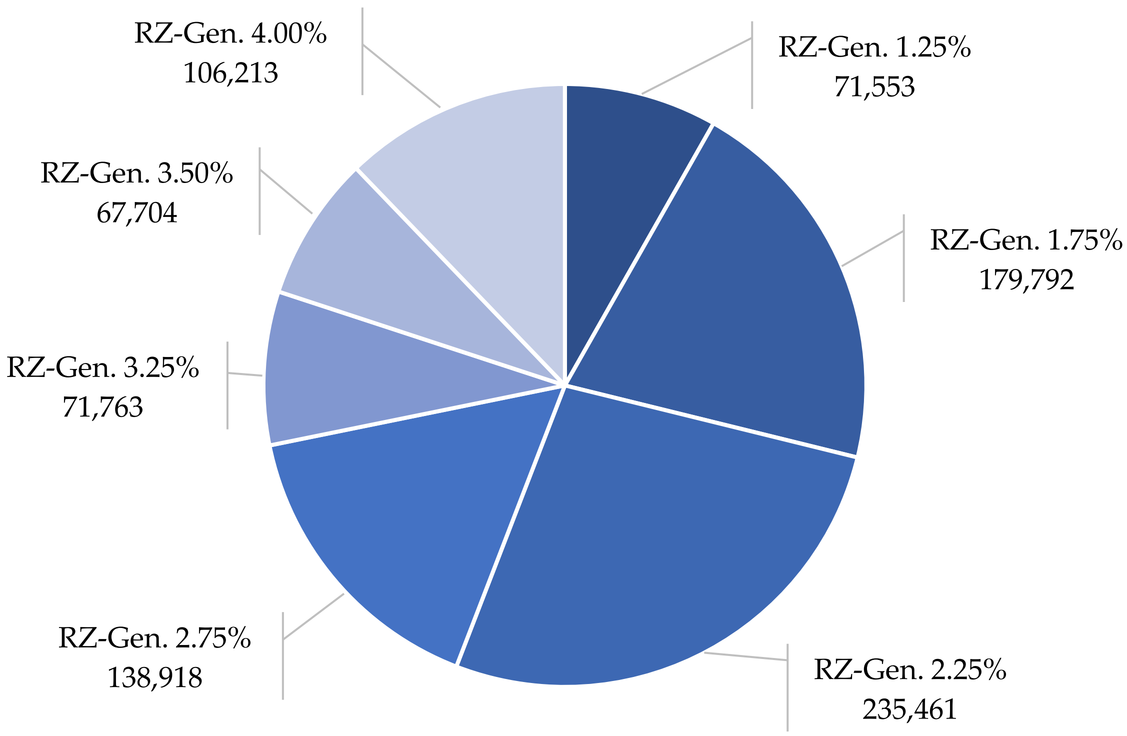

Figure 5: Pie chart of the liability portfolio structure based on the interest rate generations (life insurance).

The portfolio is assumed to consists of three types of insurance:[5] 56.400% pension insurance (*Rentenversicherung*), 28.200% endowment assurance (*Kapitalversicherung*) and 15.400% term insurance (*Risikoversicherung*). The percentages are by number of contracts, which are displayed in Figure 4. Additionally, Figure 5 sorts the portfolio by the interest rate generations (*Rechnungszins-Generationen*).

3.2.4. Management model

The management model is used to specify the regulatory framework and to establish the management strategies for the company. There is a pre-defined set of management rules, which can be extended when needed. The structure of the management model allows for the implementation of "hooks". Hooks can be applied to the simulation in general or to the asset model only. The asset-liability management software categorizes the settings into four groups: general management rules, asset-rules, liability-rules and other parameters.

For this work, a set of rules is applied, which concerns all workings of the model company and matches the typical characteristics of a German life insurer. The exception here are rules, which are omitted to simplify the model, but do not have effects on the analysis of the hedging strategies and the according research questions. The management rules are kept unchanged to ensure the comparability of the results and therefore establish a "base-case" simulation scenario. The only changes to the management rules are the activation of the hedging mechanisms. This makes the handling of the model much easier and allows for the simple usage of checkboxes to activate and deactivate the hedging strategies during the analysis.

The following paragraphs define and describe the applied set of management rules. In the general management rules five rules are activated. The minimum annual income (before taxes) (#M1) is set to € 0. In case the limit is not reached, the *RfB-Zuführung* is reduced at first and then the valuation reserve. The minimum equity capital (#M2) is set to € 100,000,000. The probability of failing this target in stochastic simulations is documented in the results. The dividend (#M3) is held at 6.000% of the annual profits after taxes for the entire simulation and is payed to the shareholder at the end of each period. The loss carried forward (#M5), that can be put on the balance sheets, is set to not be higher than € 10,000,000. Equity injection (#M7) is active and triggered by two events: if the solvability ratio falls below 100%, equity is injected to the point of raising the solvability ratio to 100%, and alternatively, if the equity capital becomes negative, it is set back to € 0.

[5] Based on industry averages from unpublished study of annual reports of German life insurance companies 2015, ROKOCO GmbH.

For the asset model the base-case comprises of 13 activated management rules. The type of target allocation (#A1) defines what the values in the target allocation reference to and how the allocation is conducted. For the model company the reference value is the book value and the reallocation style is passive. Therefore, only available cashflows are used to gradually reach the desired book value. In *Zielverzinsung* (#A2) the disintegration of hidden reserves is controlled. They will be used when the guaranteed interest rate is too low and the *Zuführung zur ZZR* would be considered there, if it were in place. However, hidden reserves will not be used when the *Zielverzinsung* is missed. The *Zielverzinsung* is predetermined to start at 4.000% in the first year and gradually declining to 2.000% over ten years, where it will remain constant. The minimum valuation reserves (#A3) will be taken into account, which are defined for each asset class in the asset portfolio. The systematic disintegration of agios and disagios within fixed assets (#A4) is set be linear. This goes for fixed income assets, which are either accounted for according to German GAAP §341c (*Handelsgesetzbuch HGB*) or § 253 (*HGB*). Depreciation is conducted according to German GAAP §341b (*HGB*) (#A5). If hidden losses occurred, they would be left standing for one year. Should they remain in the next year, the value of the extraordinary depreciation results from the minimum of the current hidden losses and the ones from the previous year. Further, depreciation on tangible assets and fixed income assets will be avoided if possible. The rate for depreciation on real estate (#A6) is 2.000% of the purchase value. Asset rule #A8 activates the usage of put options for hedging the selected equity positions of the asset portfolio. This rule is later used to distinguish between the base-case without hedging and the "hedge-case", in which the hedging strategy is applied. This rule further defines the risk-free rate used for the valuation of the put options. The credit default model (#A10) uses rating migration, which is defined in the capital market model. Within *Spezialfonds* the attributed market value is managed in rule #A11. The sustainability factor for stocks is 25% and the lowest rating for which a sustainable market value can be set is BBB. Valuation reserves on *Spezialfonds* (#A13) will be dissolved by returning shares of the fund, instead of extraordinary appreciation. Since both callable bonds and annuities are included in the asset portfolio, rules #A17 and #A18 are active, which set the parameters for these two asset classes. The volatility of callable bonds is ten percent and the calls take place after three years. The repayment rate for annuities is 15%.

There are six active management rules concerning the liabilities. The *RfB-Zuführung* (#P3) happens according to the *Mindestzuführungsverordnung (MindZV)* (*Verordnung über die Mindestbeitragsrückerstattung in der Lebensversicherung*). Reductions of the injection can be used to offset negative investment results in accordance with §5 *MindZV*. Before this offset applies, valuation reserves are dissolved to reach the required level. The injection quotes for capital investment, risk and other are 90%, 90% and 50%. The surplus participation (#P4) is declared so that the *freie RfB* equals the last five injections. The maximum *freie RfB-Quote* is ten percent of the actuarial reserve and the maximum declaration is ten percent. The model does not take the *Zinszusatzreserve*

(#P5) into account. §56b *VAG* is applied (#P6), which allows for the offset of negative investment results. However, an offset only as far as it stems from a reduction of the injection to the *Zinszusatzreserve*, in case it incurs. These withdrawals will not be compensated the following year. The method for conversion to second order (#P8) is differentiation before expected value, which differentiates the insurance year from the calendar year before the expected value is calculated. The outstanding acquisition costs are recalculated. Since the model company is assumed to have no new business, rule #P9 is not active, which inhibits new business from being written.

With the selection of these parametrizations, rule settings and simplifications, it is possible to achieve a plannable depiction of a representable life insurance company with reduced complexity. It further lays the foundation for a dynamic stochastic simulation with sufficient stochastic paths for the thorough analysis of the respective hedging strategy.

3.3. Results

3.3.1. Structure of the analysis

To evaluate the effects of the hedging strategy using put options to hedge the equity positions in the asset portfolio, a pyramidal structure with three layers is used. It is further distributed into vertical segments, which help allocate the various elements of each layer towards a goal. These segments address two key aspects of operating a business: profitability and security. The top horizontal layer represents the target variables for this analysis. These variables exemplify the final figures, on which the economic results for the two main stakeholders, insured and shareholders, are evaluated. For the life insurance part, the target variables are the gross surplus, the net profit and the *Schlussüberschussanteilfonds (SÜA-Fonds)*. The key figures are selected in a way so that the measurement of hedging-effects can be done both before and after asymmetric mechanisms in the model.

The gross surplus is the sum of the three sources of profits: investment result, risk result and other result. It is the main key figure, which determines what is available for distribution among the insured and the shareholders. The regulation requires a minimum portion of this figure to be attributed towards the policyholders, while a residual goes to the shareholders in form of the net profit.

This net profit represents the next target variable of this analysis. The link between these two variables is especially interesting, as between these two figures the asymmetry, which was described earlier, comes into play. The net profit is the key figure for measuring the shareholders' perspective of the firm's operations in terms of the classical German GAAP. Certainly, risk-based elements require consideration, too. However, in this analysis these risk-based factors will be addressed in the other layers of the pyramidal scheme, as well as in relation to the vertical segmentation of the pyramid. Net profit describes the company's result net of all transfers to and from the insured and is the key determinant of the value of the shareholders' distributable benefits.

The third target variable is the *Schlussüberschussanteilfonds*. This variable characterizes a perspective of the insured, as it is the important additional figure next to the guarantees in the underlying low interest rate environment, in which the ongoing profit participation is minimized. The *Schlussüberschussanteilfonds* is a maturity payment towards the insured and is part of the *Rückstellung für Beitragsrückerstattungen (RfB)*. The *Schlussüberschussanteilfonds* is not just an additional source of payment at maturity of the insurance contract, but also serves as an increase of solvability of the insurance company. In negative scenarios, in which the insurer's solvability is low, the *Schlussüberschussanteilfonds* supports the solvability of the firm. This mechanism is beneficial towards the insured, since solvability is needed for the ability to fulfill the given contractual guarantees and denotes the regulatory risk-bearing capacity. Moreover, it is a key aspect for the establishment of market reputation against competitors.

The second layer of the pyramidal analysis structure is the control variable layer. It captures the variables, which can be changed and optimized in order to reach the goals established for the target variables. This layer is typically made up of various management rules, which allow the company to control mechanism for profit, risk or solvency optimization. Since this analysis focuses on the effects of hedging strategies, the only "changeable" control variable is the strategic decision whether to use put options in order to hedge the downside risks of the equity in the asset portfolio, or not.

Surplus utilization is the first control variable. It observes the distribution of the net income with focus on the dividends paid. This control variable mainly focuses on profitability, as the shareholders are the recipients of the dividend payments. The control variable serves to check the continuity of profitability under the introduction of the hedging strategy.

The second control variable is the *RfB-Zuführung*, which is balanced between the two aspects of profitability and security. A higher *Rückstellung für Beitragsrückerstattung* represents higher future profits for the insured, but also has components such as the *freie RfB* that can serve as a buffer for volatile years. The *RfB-Zuführung* is determined using the *Mindestzuführungsverordnung*, which allocates certain percentages of the three sources of income towards the *Rückstellung für Beitragsrückerstattung*. This is one of the most asymmetric aspects of the profit and loss allocation in the insurance business, as profits are allocated to the *Rückstellung für Beitragsrückerstattung* for the most part, while losses are carried by the firm alone.

The strategic asset allocation (SAA) is determined before the simulation and is held constant over time. It serves as a control variable for the purpose of ensuring that observed effects do not appear due to changes in the strategic asset allocation, but solely due to the applied hedging strategy.

Another control variable is the costs, more precisely the cost-ratio. It is defined as the costs incurred for insurance business divided by the gross income. Since the hedging strategy should only apply to the assets of the insurer, this control variable checks that there are no effects of the hedges on the insurance business on the liability side.

The last control variable is hedging. This is the variable that is changed between the base-case and the hedge-case in order to observe the changes on the model company's results when using a specific hedging strategy. It is controlled by the settings in the management model.

To comprehend the full mechanisms behind the analyzed effects, a third layer with observatory variables is added to the pyramidal structure. This cluster of variables comprises of several key figures relevant to the target variables. Since the complex structure of an insurance firm heavily relies on interactions between both assets and liabilities, including asymmetries due to regulatory and contractual constraints, the workings of the analyzed hedging strategy are not linear and solely observable in the three target variables gross surplus, net profit and *Schlussüberschussanteilfonds*. In fact, a complete understanding of the effects can only be achieved through the inclusion of additional key figures, which are defined in this bottom layer of analysis pyramid.

The first additional key figure is the gross income (*gebuchte Bruttoerträge*). It is the main generator of income from the actuarial business. Since the model company does not write any new business, it is expected to decrease slightly each year as more contracts transition from the accumulation phase to the pension phase.

Another observatory variable is the valuation reserve. The level of the valuation reserve gives indications on the financial flexibility of the firm, as higher levels allow for the possibility of compensating losses with extraordinary proceeds from the dissolution of the respective valuation reserves. Furthermore, the valuation reserve lets one draw conclusions on the risk-bearing capacity, for the same reasons as the financial flexibility.

The net return on capital investments (*Nettoverzinsung*) is the third observatory variable in the analysis. Net returns solely measure the hedging effectiveness on the asset side of the company's balance sheets, separated form interactions with the liabilities, making it a figure especially relevant from a German-GAAP-perspective, as well as the gross surplus management.

The fourth observatory variable is equity capital. It is a major determinant of how financially stable an insurance company is. The notion of going-concern is more likely for a financially secure firm than it is for an "under-financed" company. This is one of the foremost interests of the insured. The equity capital also is a key figure for the shareholders, since parts of the annual profit can be allocated towards equity capital growth and therefore profit the shareholders.

Lastly, the *freie RfB*, which is a component of the *Rückstellung für Beitragsrückerstattung,* is added as an observatory variable. It is the residual left after the declared components and the *SÜA-Fonds* have been allocated. The funds in the *freie RfB* belong to the insured and will be distributed in the future. However, they remain on the firm's balance for quite some time and have an equity-like character, since the *freie RfB* can be used as a buffer in volatile times to ensure the rest of the *Rückstellung für Beitragsrückerstattung*. It therefore represents an aspect of security for the firm and the insured.

Figure 6 displays the schematic of the analysis pyramid:

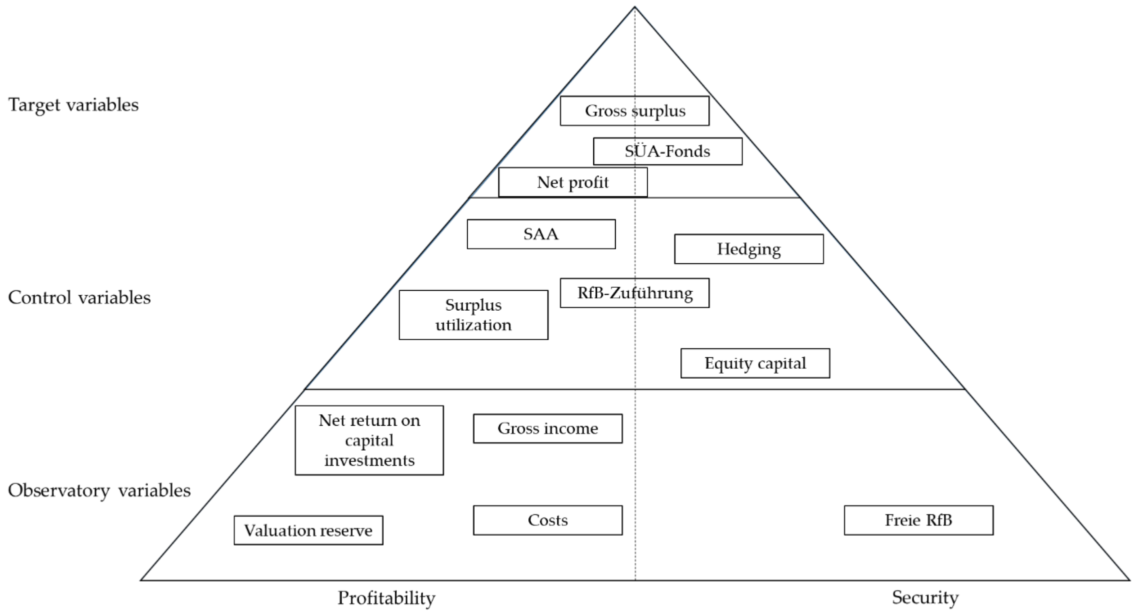

Figure 6: Pyramidal analysis structure with key figures (life insurance). Own representation.

3.3.2. Analysis of results

For a meaningful analysis of the effects of the hedging strategy in the context of a German life insurance firm, a stochastic simulation within an asset-liability-management-software is done. The stochastic simulation of the numerous key figures of the company allows for a closer look on the different quantiles of the result distributions and provides the important additional information for a risk-based analysis. The analysis puts focus not only on the expected values derived from the deterministic simulation, but also on the tails of the distributions. The one percent quantile is examined extensively, as it serves as an indication for a “worst-case” scenario. Throughout this work, the term worst-case scenario is used to describe the one percent quantile. Theoretically, the one percent quantile can stem from a different capital market scenario at every point in time, however, the one percent quantile is still addressed as the worst-case scenario in this work. The analysis of the tails of the distribution allows for a deeper understanding of the median and expected value figures. Especially for the management of an insurance company, it is of interest to know the downside potential of any given decision that is undertaken in the second layer of the analysis pyramid. The same principle applies to the "upside" of the distribution, for which the 99 percent quantile is the indication, representing a "best-case" scenario of the decision. Therefore, all observatory and target variables are analyzed using distribution plots, allowing for the essential risk-based view needed for conclusive assessment of the analyzed effects. In the presented plots the corresponding results are displayed in the same color scheme: the hedge-case is red, and the base-case is blue. The upper line represents the best-case, while the lower ones represent the worst-case. The results of this stochastic analysis are presented in the following subchapters.

3.3.2.1. Observatory variables

3.3.2.1.1. Net return on capital investments

The net return on capital investments is the first key figure of the observatory variables in the analysis of the benefits and disadvantages of the underlying hedging strategy. As the net return on capital investments represents the capital gains from the firm's assets it most clearly captures the effects of the hedge on the performance generated through the assets. As gains from puts are declared as extraordinary income, the *laufende Durchschnittsverzinsung* cannot be used in this case.

Figure 7 displays the distribution of the net return on capital investments. There is next to no visible difference in the median level of the results. However, the outer percentiles of the distribution clearly show the effects of the hedging strategy.

The bottom blue line represents the one percent quantile of the base-case (without hedging). In year four it is at 2.320 percent, while it is at 0.930 percent in the fifth projection year. This steep decrease is caused by strongly negative capital market scenarios. In comparison, the bottom red line displays the same quantile of the hedge-case. It can be clearly seen that the hedge-case is always higher than the base-case. In the fourth year it is 22.0 basis points higher at 2.540 percent. And with 1.186 percent in the last projection year it is even 25.6 basis points above the level of the base-case's one percent quantile. These positive differences show that the application of the hedging strategy reduces the downside risk by generating additional returns from the put options in case of significant downturns of the markets.

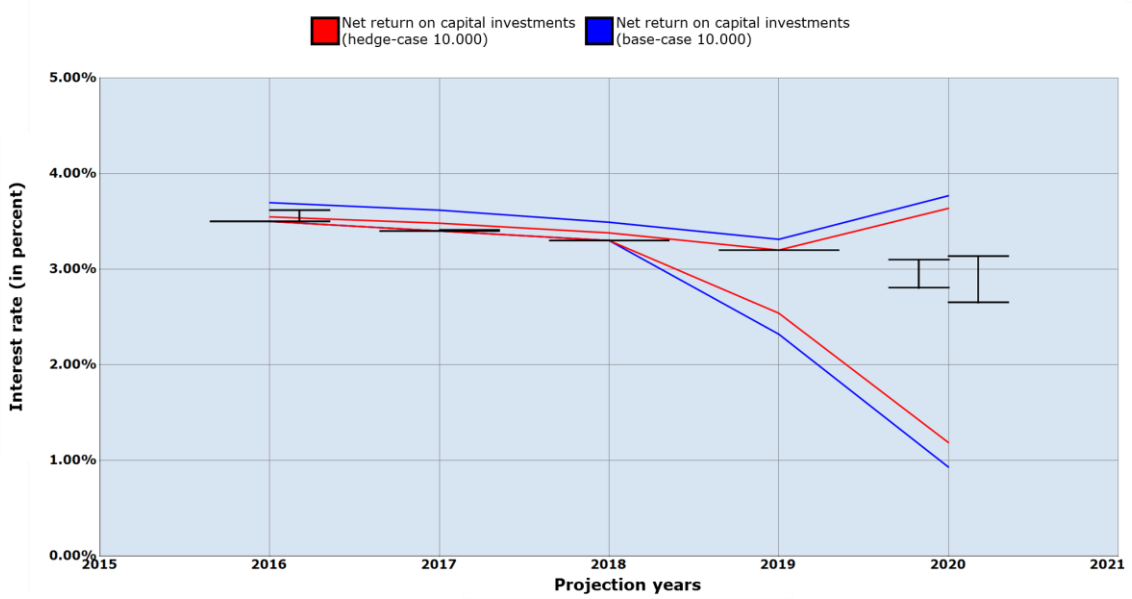

Figure 7: Box plot of net return on capital investments (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

As the puts are in-the-money in negative capital market scenarios, they are out-of-the-money in positive scenarios. In these cases, the puts have a valuation of zero and therefore only contribute to the profit and loss statement with its costs of the purchase. Thus, it is plausible, that in the 99 percent quantile the roles of the base-case and the hedge-case are reversed. The upper red line (hedge-case) is now below the blue line of the base-case. In the fifth projection year the difference is -13.2 basis points, with 3.637 percent compared to 3.769 percent. As the hedging strategy leads to the positive effect of reducing the downside risk, this reduction of volatility also automatically leads to a reduction in upside potential, as the costs of purchasing the hedge are deducted from the capital gains in positive capital market situations.

3.3.2.1.2. Valuation reserve

The next observatory variable with focus on the profitability perspective in the analysis pyramid is the valuation reserve. The distribution of the valuation reserve within the 25 percent and 75 percent quantile shows a reduction in volatility when the hedging strategy is applied. It can be measured by subtracting the two quantiles and comparing the differences between the two cases. In the base-case the difference equals 1,048.444 € million whereas the difference for the hedge-case only comes to 1,020.567 € million in the fourth projection year. However, the position of the red box (base-case) compared to the blue box (hedge-case) shows that the general level of the valuation reserve as well as the median (middle line in each box) is lower in the hedge-case. The effect grows stronger with each projection year. The rationale behind this effect lies within the reallocation mechanism of cash in each period. In case the capital gains of one period surpass the capital losses, the remaining cash position is (partially) invested in new assets. In positive capital market conditions higher investment amounts lead to higher valuation reserves. The logic of compound interest contributes to this effect. So, when the cash position used for new investments is reduced by the costs of purchasing hedges, the base-case with a slightly higher investment amount each year, starts to raise a gap towards the hedge-case's valuation reserve. This effect can be seen most clearly in the 99 percent quantile. The difference is an amount of 98.644 € million (3,382.622 € million in the base-case and 3,283.978 € million in the hedge-case).

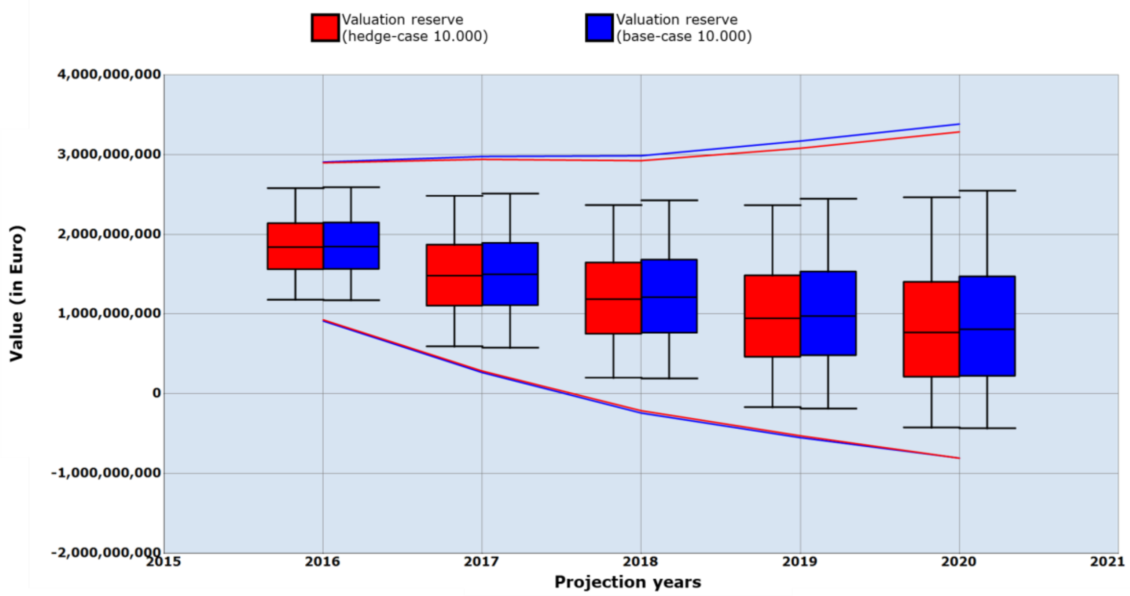

Figure 8: Box plot of valuation reserve (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

As the difference between the two 99 percent quantiles grows larger with every projection year, the effects for the downside risk are not as large in amount. The difference grows to 29.522 € million in the third year, but then decreases again. In the last projection year, the base-case even surpasses the hedge-case, however by merely 0.528 € million. Since the level of the valuation reserve at this point is strongly negative, it is likely that there are not many equity positions left in the portfolio, making the effect of the equity hedge negligible here.

3.3.2.1.3. Gross income

As expected, the level of the gross income decreases slightly with each projection year. Since no new business is written and the tariffs are established with the start of the projection, the development of this key figure is deterministic without any volatility. The overall decline can be attributed towards the expiration of old policies and the absence of new business. Furthermore, there is no difference between the base-case and the hedge-case. This is a positive result, as it indicates that the simulation software works: a hedging strategy, which is applied towards the assets of the model firm, should not have any effects on the generated gross income from the actuarial business. This is also done with similar key figures to check for the same effect. The level of the gross income in the first year is 1,024.788 € million and decreases towards 982.130 € million in the fifth projection year.

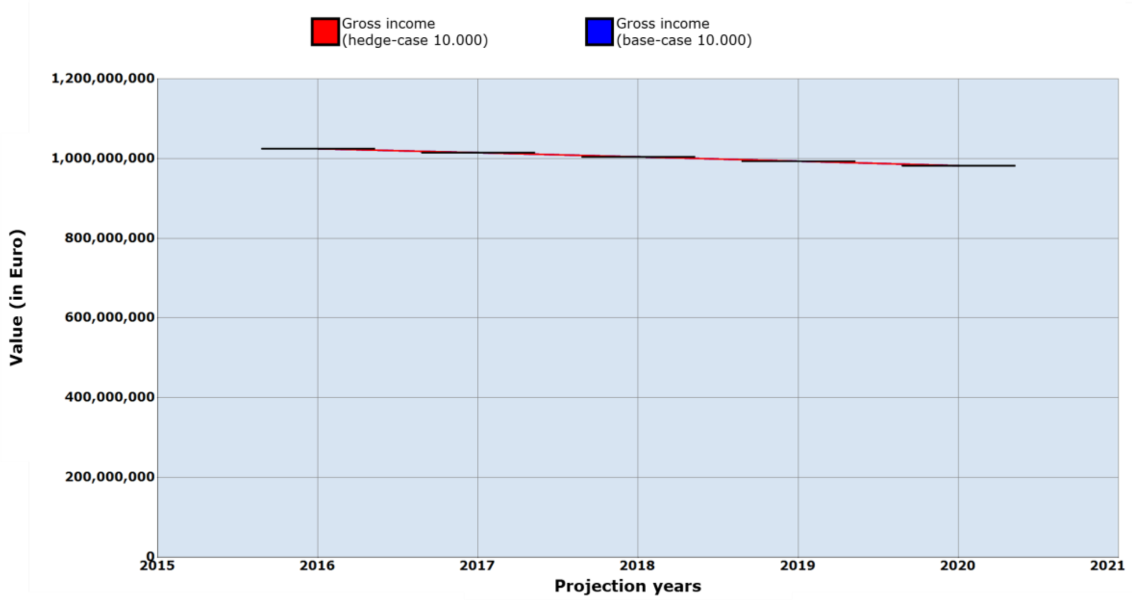

Figure 9: Box plot of gross income (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario. All lines overlap here.

3.3.2.1.4. Costs

As defined earlier, the costs (of the insurance business) should stay unchanged when applying the hedging strategy because the costs for the purchase of put options are modelled in the asset model, not in the cost model. Figure 10 shows that the cost-ratio is identical in both cases. The control variable therefore verifies that the hedging strategy is implemented correctly in the model. Just as with the previous key figure, this result is included to control for unwanted effects and because practitioners would always include these parameters, when making a holistic analysis of this topic.

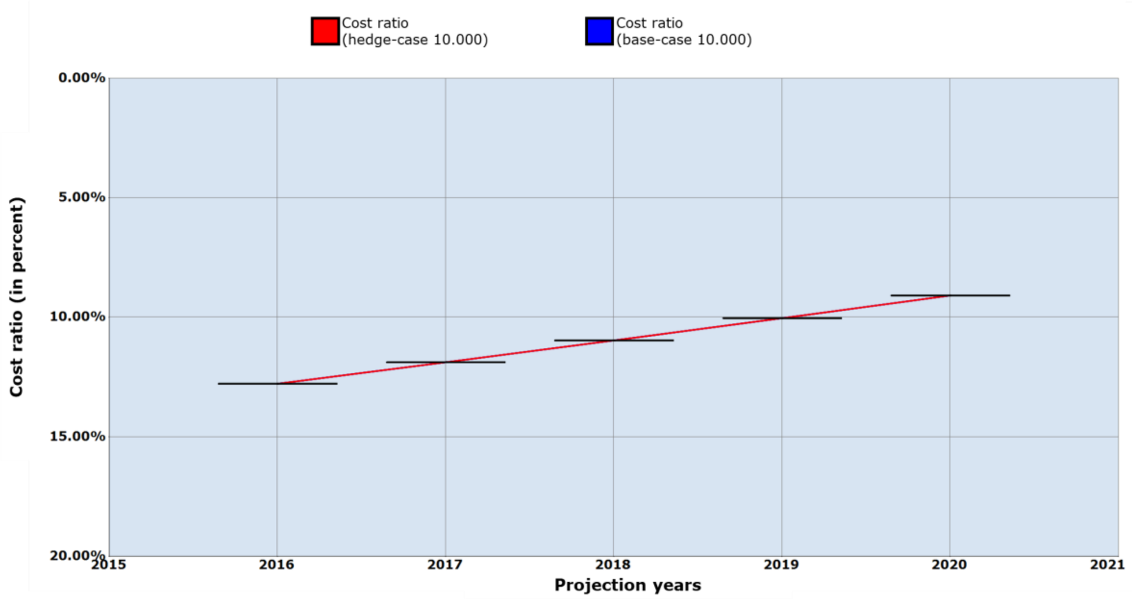

Figure 10: Box plot of cost ratio (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario. All lines overlap here. The vertical axis is inverted.

3.3.2.1.5. Freie RfB

The *freie RfB* decreases constantly over the time of the projection. It almost halves from 404.584 € million in the first year to 206.085 € million in the fifth year. In the median, there is no substantial difference between the base-case and the hedge-case. The downside risk is also equal between the two cases, but only in the first three years. In the fourth year, the *freie RfB* in the hedge-case is still 229.100 € million, while the base-case is 7.431 € million lower at 221.669 € million. This shows that the hedging strategy reduces the downside risk for the *freie RfB*. Interestingly, the quantile values start to converge again in the last year to a difference of 4.934 € million, suggesting only a short-term effect of the hedge.

The upside potential displays a different mechanic. Over all projection years, the upside potential for the *freie RfB* is reduced by the hedging strategy by 14 to 17 € million and even 22.732 € million in the last projection year.

These results display the asymmetry of the earnings distribution in the German life insurance perfectly. Due to the *Mindestzuführungsverordnung* 90 percent of both the investment income and the risk result, and 50 percent of the other comprehensive income are allocated towards the *Rückstellung für Beitragsrückerstattung*, of which the *freie RfB* is a residual figure. Therefore, in the positive scenarios, the reduction of capital gains due to the incurred costs of the hedging strategy substantially reduces the basis for the *Mindestzuführungsverordnung*.

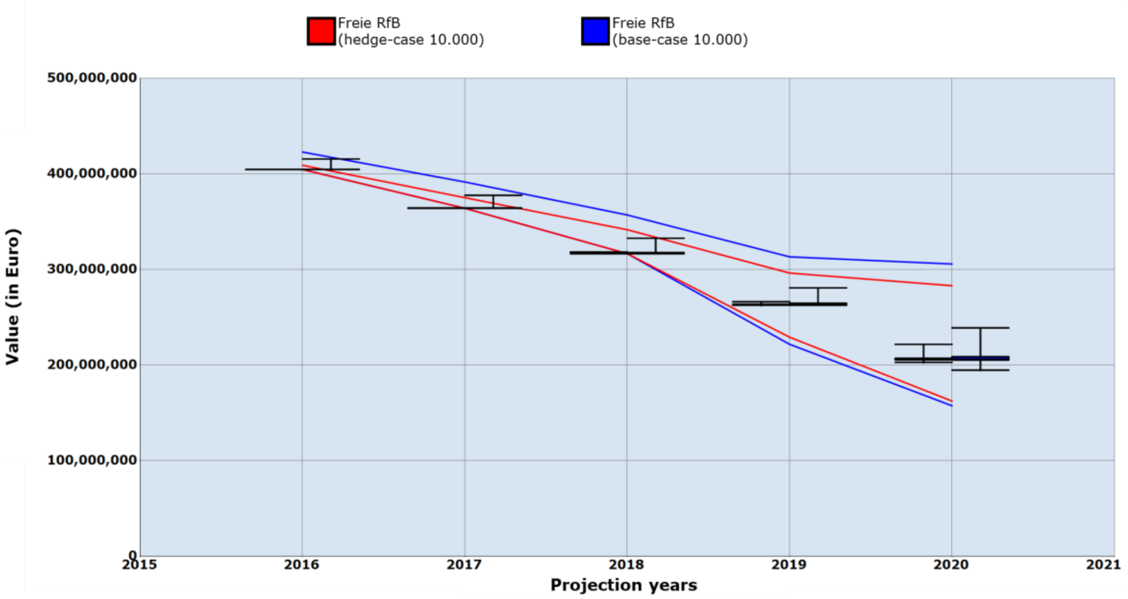

Figure 11: Box plot of *freie RfB* (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

In negative scenarios, the lack of participation of the *Rückstellung für Beitragsrückerstattung* at the carrying of losses makes the existence of the hedging strategy next to irrelevant in comparison to the reduction in upside potential. The difference in the one percent quantile in the fourth projection year is the effect of the management rules for the *Rückstellung für Beitragsrückerstattung*. In accordance with the *Mindestzuführungsverordnung*, the increase of the reserve can be reduced to a certain degree in order to offset negative investment results. This effect is triggered here and thus explains this difference between the base-case and the hedge-case.

3.3.2.2. Control variables

3.3.2.2.1. Surplus utilization

In the management model, the yearly dividend is set to be at a constant percentage. Since this percentage does not depend on the hedging strategy, no differences between the two scenarios should be visible.

Indeed, the dividend percentage stays fixed at the set level over the course of the projection both with and without the hedging strategy

3.3.2.2.2. Strategic asset allocation

Both the base-case and the hedge-case use the same setting for its strategic asset allocation. The reallocation is done passively, which leads to a gradient transition of the asset portfolio towards the target portfolio. In both the base-case and the hedge-case, the allocation of assets within the portfolio in percent of total market value is the same, showing that the allocation process is independent from the application of the hedging strategy.

3.3.2.2.3. RfB-Zuführung

The *RfB-Zuführung* shows similar results as seen in observatory variable *freie RfB*. The median values of the base-case and hedge-case lie at around 42.500 € million. The downside risk in the first three projection years is almost at the exact same level as the median, however in the third year, it starts to drop rapidly. The downside quantile for the hedge-case, however, declines much slower than the case without hedging. In the fourth year this difference amounts to 11.087 € million. This difference is due to the management rules, analogously to the *freie RfB*. In year five, both are at zero and seem to converge. But this is simply because the *freie RfB* cannot be negative and the simulation has annual time steps. With more time steps, the base-case would reach zero a lot earlier than the hedge-case.

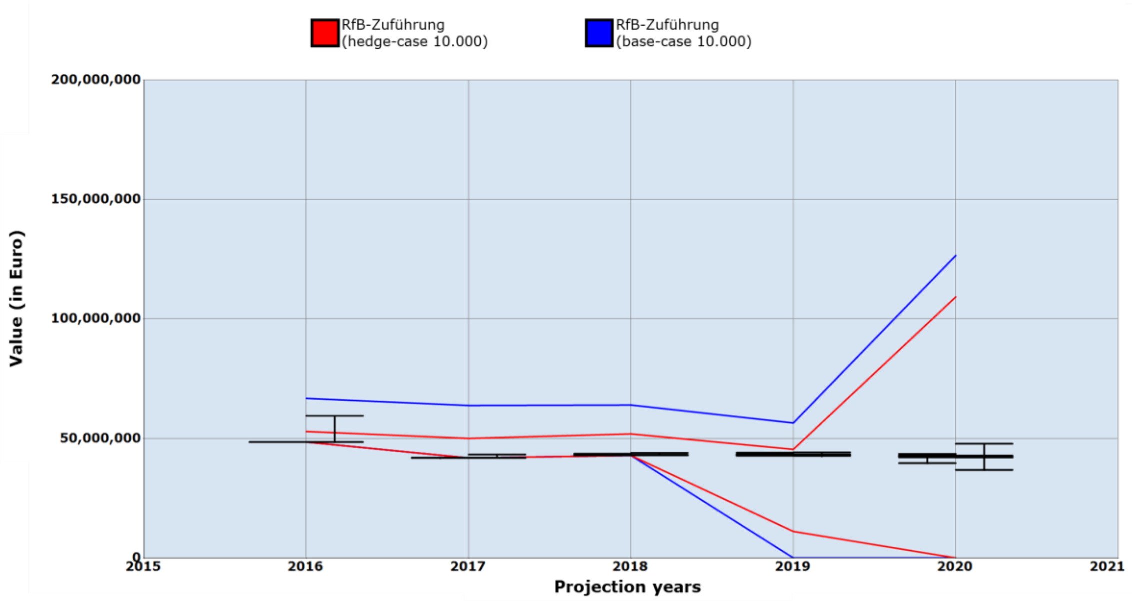

Figure 12: Box plot of *RfB-Zuführung* (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

The upside risk displays the already established pattern, in which the hedge-case has lower upside potential than the base-case. The reasoning is linked to the asymmetry of the *Mindestzuführungsverordnung* as explained earlier for the *freie RfB.*

3.3.2.2.4. Equity capital

The observatory variable equity capital is highly dependent on the control variable net return. Nevertheless, it serves well to give an indication of the financial stability of the model firm. It also allows to control for possible capital injections by the shareholders in case of undercapitalization of the firm.

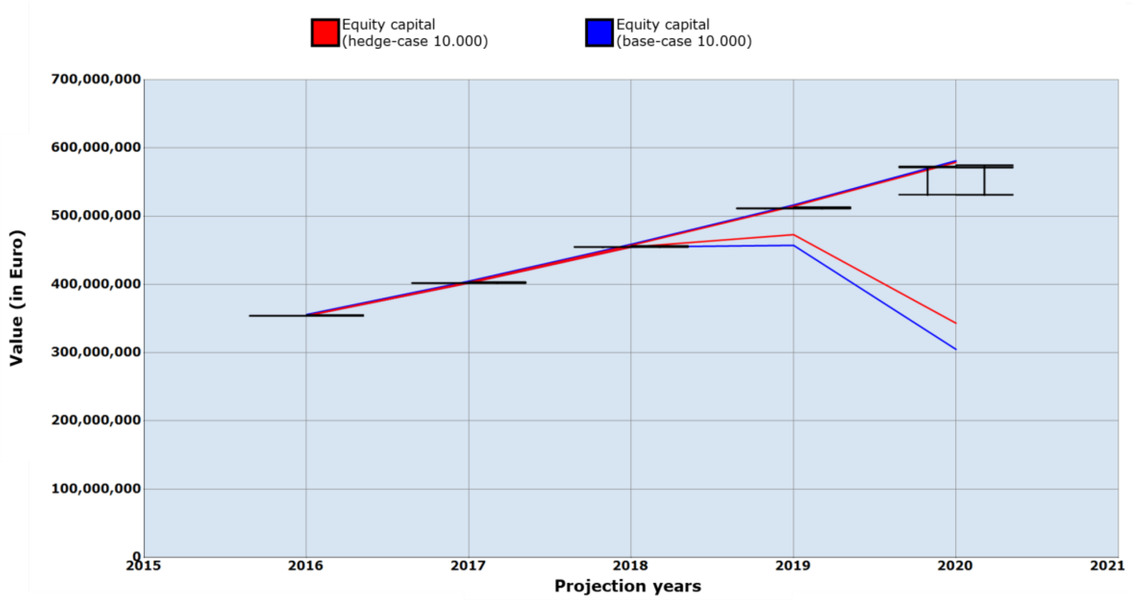

Figure 13: Box plot of equity capital (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

The model firm's equity capital continues to rise over the projection time, mostly due to the approximation form omitting a portion of the *Zinszusatzreserve*. The graph shows similar effects as seen before: The hedge reduces the downside risk, but also slightly decreases the upside potential. Since the equity capital is mostly a residual key figure, the effects are slightly smaller than seen with other key figures. This is due to the many mechanisms that come into play for insurance firms' accounting, where the hedging effects are one of many. Nevertheless, these effects are clearly visible.

3.3.2.2.5. Hedging

In this analysis the applied hedging strategy is the usage of put options to hedge equity risk. The base simulation does not use any hedging strategy, while the hedge-case utilizes such put options. As described in the first part of this chapter, this is the variable that is actively changed to distinguish between the base-case and the hedge-case.

3.3.2.3. Target variables

3.3.2.3.1. Gross surplus

To evaluate the profitability of the hedging strategy, gross surplus is the key target variable to be analyzed. The model firm's median gross surplus shows a rather constant level of around 140-150 € million. There are no visible effects of the hedging strategy within the projection years, here. In the fifth projection year the distribution of the gross surplus starts to widen, seen by the lowering and heightening of the box-plot-tails.

However, with hedging the five percent quantile lies around 21.524 € million above the base-case. Same can be seen with the 95 percent quantile, which stays 4.857 € million below the base-case quantile. This is the first clear indication, that the applied hedging strategy leads to a reduction in volatility from a shareholder perspective.

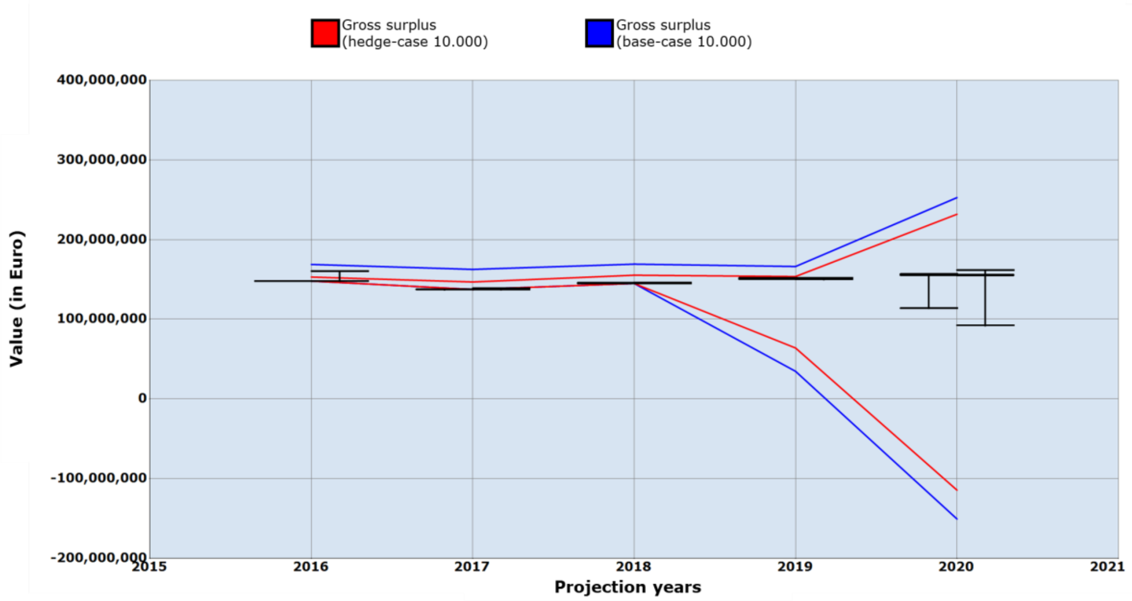

Figure 14: Box plot of gross surplus (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

The hedging effects become much clearer in a value-at-risk-analysis. In the gross surplus plot above, both the downside and upside risk are represented by the respective value-at-risk-quantiles of one percent and 99 percent. In Figure 14, the bottom blue line depicts the one in one hundred years loss event of the base-case. In projection year five, this value equals -150.754 € million. Compared to the base-case, the hedge-case (red line) is at a substantially higher level throughout the whole projection. In comparison, the value in the fifth year equals -114.539 € million. The application of puts towards the equity portions of the portfolio clearly reduce the downside risk from a profitability perspective by more than 36 € million. As stakeholders are required to compensate such negative results in case they occur, the massive reduction of potential losses could be highly beneficial from their perspective.

To evaluate whether the hedging effects on the gross surplus are symmetrical, the upside risk also needs to be examined. Over the full projection it is easy to see that the base-case (top blue line) lies substantially higher than the red line of the hedge-case. This is caused by the costs of purchasing the hedging instruments. When puts are bought to hedge the equity investments, costs are incurred, which reduces the assets in total. Therefore, there are less assets, which can generate income. This is particularly apparent in very positive capital market scenarios (such as the 99 percent quantile in this case). The difference between the blue line and the red line lies at around 15 € million. In the last projection year, the base-case stands at a gross surplus of 252.690 € million, while the hedge-case totals in 231.829 € million, leading to a difference of 20.861 € million.

As expected, the reduction in the downside risk scenarios comes at the price of a reduction in the upside potential. Nevertheless, looking at the corresponding quantiles of the distribution (one percent and 99 percent) the reduction on the downside of 36.215 € million represents a substantially larger monetary value than the reduction in the upside scenario (20.861 € million).

3.3.2.3.2. Net profit

The second target variable helps to understand the profitability aspect of this analysis. Net profit is the company's result net of all transfers to and from the insured, and thus is the key determinant of the value of the shareholders' distributable benefits. Since this key figure is calculated at the very end of the income statement, all asymmetric distribution mechanisms have already been applied. Therefore, a stronger effect on the downside compared to the upside is expected.

The median net profit in the first projection year is 53.894 € million and increases to 63.787 € million in the fifth year. The difference to the hedge-case is negligible. In general, the first three projection years show next to no effects from hedging. The fact that net profit is one of the last result figures explains this. There are a lot of management rules that have smoothed the results in order to reach stable result figures. Consequently, the effects of the hedging mechanisms do not appear right away in the net profit. The only directly visible effect of the hedging strategy appears in the 99 percent quantile. In this best-case scenario, an effect is visible, which was observed and explained in other variables before: Due to the costs that are incurred when purchasing the hedging instruments, the available funds for reinvesting are reduced. With fewer assets invested in the capital markets, which are performing very well in this best-case scenario, the result is a smaller positive gain. In the fifth projection year this leads to a net profit in the hedge-case of 70.234 € million, which is 1.888 € million lower than in the base-case.

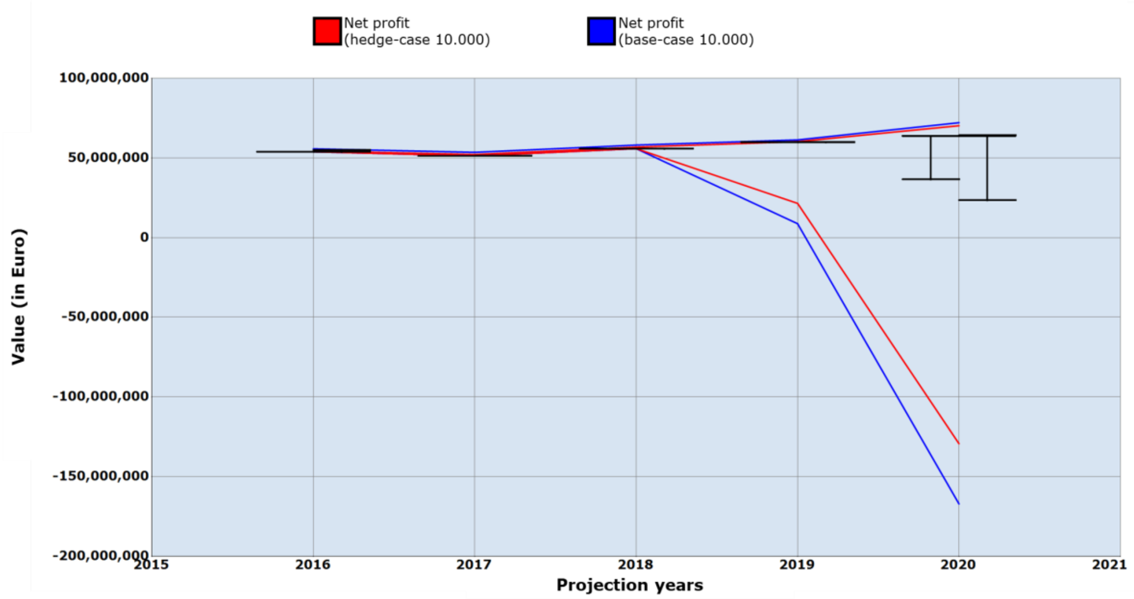

Figure 15: Box plot of net profit (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

Nevertheless, in the last two projection years the effects from the hedging strategy become clear. Already the five percent quantile shows substantial differences in the fifth year of the projection, but in the one percent quantile the difference is highly apparent. The net profit for the base-case in the last projection year is -167.194 € million, so a net loss. With hedging however, this loss is reduced to -129.395 € million. This is a difference of 37.799 € million.

The reason for the late appearance of these effects is manifold, but one main reason is the general state of profitability the company is in during the different scenarios. When the solvency of the company is not in jeopardy and there are still valuation reserves that can be resolved when needed, the net profit figures can be held stable with the necessary management rules. But when all valuation reserves are gone and returns from assets are weak due to dismal performance of the capital markets, the shareholders' equity needs to finance the business operations, which is equal to a negative net profit.

This circumstance makes the observed effects in the simulation even more crucial. While the reduction in profits in the best-case scenario is 1.888 € million, the hedging strategy compensates with a 37.799-€-million-reduction of the possible loss in the worst-case scenario. This equals more than 20 times the value of the profit reduction. Seeing that too many negative net returns bring equity injections from the shareholders with them, it is difficult to rationalize not to apply the hedging strategy from this profitability perspective.

3.3.2.3.3. Schlussüberschussanteilfonds

Analyzing the last target variable, the *Schlussüberschussanteilfonds*, the perspective of the insured is incorporated into the study. Since the *Schlussüberschussanteilfonds* was previously determined to be a main contributor towards the firm's solvability, which is a major criterion for the likelihood of future guarantees being fulfilled, this key figure represents the security component of the analysis pyramid. It is expected that not all hedging mechanisms have positive effects for all stakeholders of the insurance company.

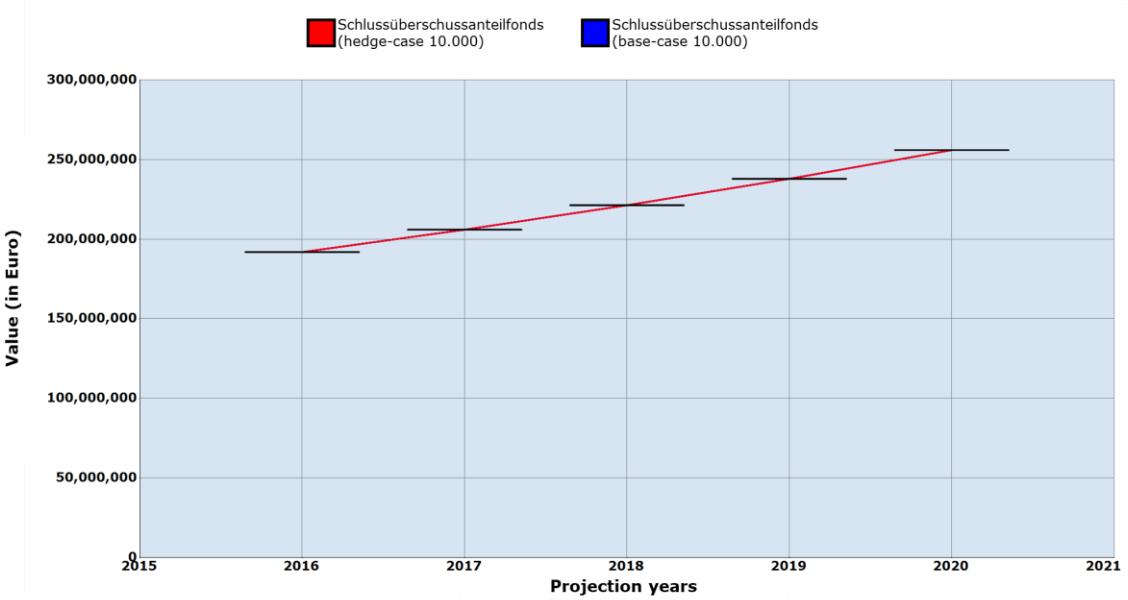

Figure 16: Box plot of *Schlussüberschussanteilfonds* (life insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario. All lines overlap here.

As depicted in Figure 16, there is no volatility in the results for the *Schlussüberschussanteilfonds*. Not only do the quantiles of the base-case overlap exactly, but also does the hedge-case not stray away from the path of the base-case. The development of the *Schlussüberschussanteilfonds* appears to be deterministic without any interference from the application of the hedging strategy. This was to be expected because the purchase of put options for hedging purposes merely reduces the capital gains of the company, which are independent of the actuarial business. The various mechanisms surrounding the *Rückstellung für Beitragsrückerstattung*, of which the *Schlussüberschussanteilfonds* is a component, filter out all fluctuations on the capital market side of business.

The results from the *Schlussüberschussanteilfonds* suggest no measurable changes in the solvability, in terms of financial security, of the firm. It therefore follows that the applied hedging strategy has no negative effects on the insured, yet leads to a considerable positive effect for the shareholders.

3.3.3. Sensitivity analysis

After the results have been analyzed, this section serves the purpose of evaluating the sensitivity of the target variable results towards changes in the parametrization of the hedging instruments. It is tested if changes lead to the expected consequences based on the mechanisms observed previously. Therefore, the results of the three target variables are compared in two sensitivity analyses: Firstly, the hedged portion of the equity investments is altered. Secondly, the strike for the put options is varied. Both alterations are commonly practiced by management boards, when factors like the risk bearing capacity influence the decision-making process of the company's asset management.

	(1)	(2)	(3a)	(4a)
	Base case No hedging in Mio. €	Hedge case Strike at 100% in Mio. €	Hedged portion reduced 10% hedged in Mio. €	Hedged portion increased 50% hedged in Mio. €
1,00% quantile				
Gross surplus	-150.754	-114.539	-139.229	-97.351
Net profit	-167.194	-129.395	-156.304	-109.367
Schlussüberschussanteilfonds	255.956	255.956	255.956	255.956
99,00% quantile				
Gross surplus	252.690	231.829	243.199	225.927
Net profit	72.122	70.234	71.370	69.799
Schlussüberschussanteilfonds	255.956	255.956	255.956	255.956

Table 2: Results table for the hedging portion sensitivity (life insurance). The results of the three target variables gross surplus, net profit and *Schlussüberschussanteilfonds* in the fifth projection year are displayed. All numbers are displayed in € millions.

Table 2 displays the results for the change in the hedged portion of equity investments. Column (3a) shows the results of the simulation when the hedged portion is reduced from 30 percent to ten percent. In column (4a) the results of an increase to 50 percent are displayed. The upside reduction caused by the hedging strategy is visible for the gross surplus as well as for the net profit. The results of the lower hedged portion lie between the figures of column (1) and (2), whereas the increased hedged portion leads to the strongest upside reduction of the four cases. A similar effect is visible for the downside reduction. This shows that increased hedging activities lead to increased safety for these key figures but comes at a higher price in terms of upside reduction. Interestingly, in comparison with the hedge-case of column (2), the difference in net profit between the reduced hedge (26.909 € million) and the increased hedge (20.028 € millions) is not equal. This could be a sign for a diminishing marginal utility of this hedging instrument when increasing the hedged portion of the equity investments. The results for the *Schlussüberschussanteilfonds* do not change with the adjustment of the hedging strategy, which was also observed in the main analysis.

The second sensitivity analysis is done by adjusting the strike of the put options used to hedge the equity investments. The outcomes are summarized in Table 3. For column (3b) and (4b) the strike is gradually reduced to 90 percent respectively 80 percent. The results for the *Schlussüberschussanteilfonds* stay unchanged as previously observed in the main analysis and the first sensitivity analysis. The results of the gross surplus and the net profit both show the expected changes: With a lower strike, the number of scenarios, in which the options become in-the-money, decreases. Therefore, in fewer scenarios the hedging decreases the downside for these key figures. Additionally, the costs for the option decrease with a lower strike, which reduces the upside reduction. The lower the strike goes, the closer the result figures will approach the base-case without hedging.

	(1)	(2)	(3b)	(4b)
	Base case No hedging in Mio. €	Hedge case Strike at 100% in Mio. €	Hedged portion reduced Strike at 90% in Mio. €	Hedged portion increased Strike at 80% in Mio. €
1,00% quantile				
Gross surplus	-150.754	-114.539	-137.162	-146.847
Net profit	-167.194	-129.395	-149.410	-159.168
Schlussüberschussanteilfonds	255.956	255.956	255.956	255.956
99,00% quantile				
Gross surplus	252.690	231.829	244.807	251.230
Net profit	72.122	70.234	71.477	72.014
Schlussüberschussanteilfonds	255.956	255.956	255.956	255.956

Table 3: Results table for the strike sensitivity (life insurance). The results of the three target variables gross surplus, net profit and *Schlussüberschussanteilfonds* in the fifth projection year are displayed. All numbers are displayed in € millions.

3.4. Interim conclusion

These results show the asymmetry in the profit and loss distribution caused by the regulatory framework of the German life insurance business. And this makes the implicit costs for a hedging strategy with puts smaller in terms of reduction in upside potential compared to betterment in the downside potential. In the model, the gross surplus' worst-case level, i.e. the one percent quantile, is reduced from -150.754 € million to -114.539 € million, while the upside reduction is only 8.256 percent resp. 20.861 € million. The other target variable, net profit, improves in the worst-case from a loss of -167.194 € million by 22.608 percent. Compared with this, its best-case reduction of 2.618 percent is minimal. This effect can be traced back to the staggered accounting scheme of the German GAAP, which amplifies the asymmetry the further it comes towards the end of the profit and loss statement.

One way for corporate financial management to steer a company is to manage and achieve certain levels for German-GAAP-based key figures. This includes generating the necessary returns, reaching the targeted risk bearing capacities, ensuring an adequate diversification, upholding sufficient solvability, and ensuring a competitive financial strength, along the general growth of the firm.

There are several conceivable instruments to aid the management in their doing. Hedging instruments for the asset portfolio count towards them. These hedging instruments in correspondence with the distinct accounting rules of the German life insurance business have been analyzed here. Due to the staggered accounting scheme of the German GAAP, the analyzed key figures have an embedded hierarchy, which leads to differential intensities of the effects from applying the examined hedging strategies. Looking at the differences between the base-case and the hedge-case, while sorting the key figures in accordance with the staggered accounting process, it can be observed that the intensity of the hedging effects increases. Starting from the net return on capital investments the spread between base-case and hedge-case grows larger towards the gross surplus, and even further when the net profit is finally reached. This observation corresponds well with the assumption that there are asymmetric mechanisms through the German life insurance regulation, which unfold the closer it comes towards result figures.

The conducted analysis further shows that the applied hedging strategy not only substantially reduces the downside risk of the firm as seen in various key figures, but also suggests that the price for the hedge in the upside is considerably smaller in amount than the reduction (or rather the gain) on the downside.

The answer towards the proposed question of profitability for the company when applying hedging strategies depends on the perspective of the management. The results of the analysis show a clear opportunity for reducing possible losses in the downside, though a reduction (although smaller in amount) in the most positive scenarios is given. Considering the implications for the shareholders, which the management represent, a smaller possible gain is likely to be accepted more easily than the outlook on equity injections due to massive losses. And since the median of the net profits experiences next to no effects from the application of the hedging strategy, investors and shareholders will likely call for adequate hedging to be implemented by the management.

Looking at these findings from the perspective of the insured, the question was raised, whether the decision to use hedging in the asset portfolio represents a trade-off between the perspectives of the insured and the shareholders. To address this question, the preferences of the insured are captured by the notion of security. Security here is meant in terms of the predominant interest in having the long-term obligations of the pension schemes fulfilled at maturity and having their anticipated wealth accumulation process realized. As this type of security is crucially dependent on the solvency situation of the company, this analysis considers key variables that contribute towards the solvency and found no substantial deteriorations due to the appliance of the examined hedging strategies. At this point it can therefore be concluded that hedging has no considerable negative effects on the insured in this study. Consequently, the assumption that there is a trade-off between profitability and security or between shareholder interests and the interests of the insured does not hold.

4. Capital market situation sensitivities

4.1. Introduction capital market situation sensitivities

As mentioned earlier in the introduction to stochastic economic scenarios, the capital market performance is an input for the asset-liability management simulation that is independent of the simulated company. In an analysis, which is mostly impacted by the asset portfolio, it is obvious that the capital market assumptions play a considerable role. With the unprecedented development of the interest rates in the past years as well as the ever-growing importance of stress scenarios in the regulatory context, this next chapter puts its focus on the effects of hedging during different capital market situations. In the previous chapter the capital market is treated as an exogenous input. Now, the focus shifts more towards a capital market analysis in terms of how a change of these market assumptions affects the proposed research questions within the established model.

In insurers’ asset portfolios, especially in the life insurance sector, a main driver is the fixed income market. It impacts both the asset side and the liability side. Therefore, shifting and adjusting the interest rate curve works ideally for this examination of capital market situation sensitivities. The examined capital market situations are inspired by both real-world manifestations of the previously mentioned unprecedented interest rate curve levels, and capital market scenario assumptions, with which insurers typically approach similar asset-liability management calculations. The analysis aims to evaluate the effectiveness of the hedging strategy in situations, in which key figures relevant to the company results are impaired or boosted, such as, for example, the net return on capital investments or the valuation reserve.

Moreover, this analysis strengthens the results from the previous chapter, as it gives a deeper understanding of the effects seen in the life insurance chapter. It addresses the question whether the effects measured earlier also hold in different capital market surroundings and may establish other factors that influence the magnitude and effectiveness of the applied hedging strategy.

4.2. Model description

The analysis compares the three capital market sensitivities to the original capital market situation used in the first part of this analysis. Accordingly, the model life insurance company is the same as in the previous chapter.

The analysis comprises of four capital market situations, one "base-scenario" and three stress scenarios. As the starting point of the simulation (t=0) remains the same for each of them, the model can stay unchanged. The assumption is that during the first projection year a stress event happens, so that at the end of the first projection year the interest rate curve is at the correspondingly stressed level. With this approach no adjustment to asset portfolio like market values are necessary. Moreover, since the starting point of all four scenarios is equal, a reliable comparison can be drawn.

4.3. Definition of capital market situation scenarios

The starting point and basis of comparison is the interest rate curve from December 31st, 2015, which is also used for the previous life insurance part. This capital market situation is referred to as the base-scenario in the following chapter. Its box plot as well as the best estimate path are plotted in orange color in Figure 17.

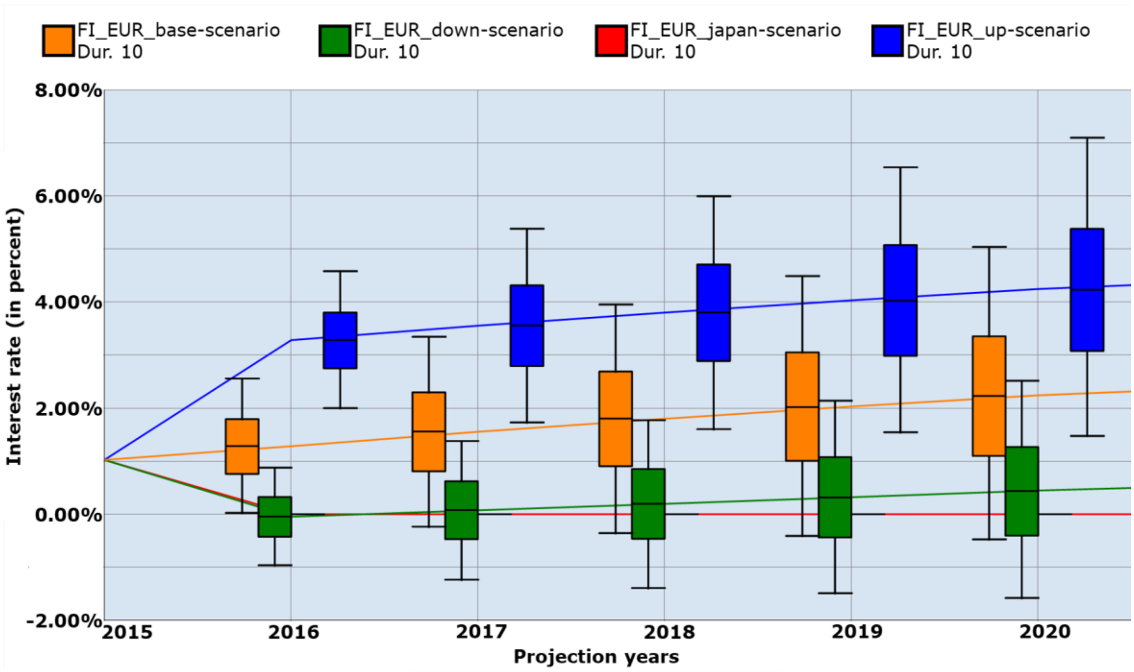

Figure 17: Capital market assumptions (capital market sensitivities). Box plot of interest rates for 10-year EUR spot rates. The order of the box plots corresponds to the order of the legend from left to right.

The first capital market situation that is compared to the base-scenario is the "down-scenario". It represents a sudden drop in the interest rate curve. At the beginning of 2020, the lowest observed Euro swaps interest rate curve ever was the September 30th, 2019. This interest rate curve serves as the foundation of this down-scenario.

Stemming from a time in which specific deterministic capital market scenarios used to be calculated for business analyses in insurance firms, the "Japan-scenario" represents a fixed income world in which the interest rate curve is flat at the zero percent level and stays at this level for the rest of the projection. The name is derived from the interest rate policy in Japan, which has led to interest rates just above zero over many years. This scenario has no volatility in the interest rate development, hence the "missing" box plots around the red line in Figure 17.

The third capital market situation is referred to as the "up-scenario". Its derivation is inspired by European Insurance and Occupational Pensions Authority's (EIOPA) approach for calculating the upward stress of the EIOPA risk free interest curve, which is used for solvency calculations required by the regulatory framework of Solvency II. The interest rate curve of the up-scenario is calculated by shifting the interest rate curve of the base-scenario upwards by 200 basis points. This scenario's corresponding color in Figure 17 is blue.

4.4. Results

4.4.1. Structure of the analysis

To evaluate the effects of the capital market situations on the effectiveness of the hedging strategy, the same pyramidal structure as seen before is used. In order to ensure clarity, the number of key figures to control for profitability and security within the model company is reduced to eight. The key figures are drawn from the pyramidal analysis structure introduced in the life insurance chapter. The following figures are used for the analysis: three observatory variables, the valuation reserve, the *freie RfB* and the net return on capital investments, the equity capital and the *RfB-Zuführung*, both control variables, and from the target variable level the gross surplus, the net profit and the *Schlussüberschussanteilfonds (SÜA-Fonds)*.

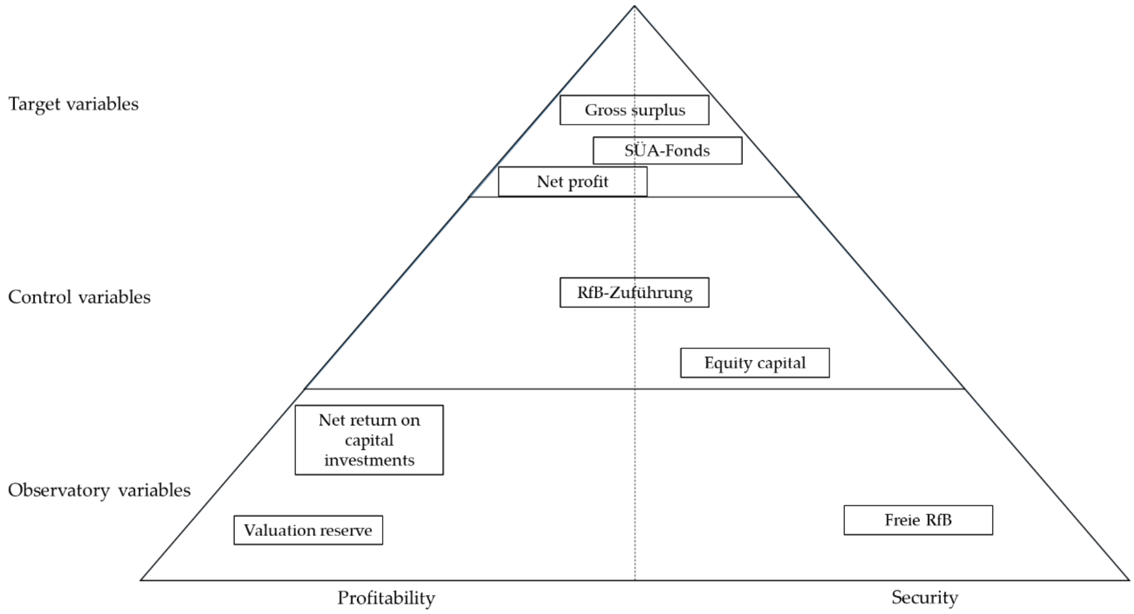

Figure 18: Pyramidal analysis structure with key figures (capital market sensitivities). Own representation.

Figure 18 displays the schematic of the analysis pyramid for each of the three analyzed capital market sensitivities. The analysis of the capital market sensitivities uses the same format as the analysis in the first part of this work: an assessment of the result distributions from a stochastic simulation within an asset-liability-management-software. Special focus is put on the tails of the distribution represented by a worst-case value (exemplified by the one percent quantile) and a best-case value (the 99 percent quantile).

In order to give a holistic view of the effects during the different capital market situations, for each of the capital market sensitivity all eight key figures are discussed and compared to the results from the standard situation. After all three sensitivities have been compared to the standard situation, an overall comparison is made. The plotted figures use the following coloring scheme: the hedge-case in the down-/Japan-/up-scenario is orange and its base-case is green, the hedge-case in the base-scenario is red and its base-case is blue. For these four cases, the figures show a box plot and two lines each, where the lower line represents the worst-case and the upper line the best-case.

Result box plot / BE-path	**Color**
Hedge-case down-/Japan-/up-scenario	Orange
Base-case down-/Japan-/up-scenario	Green
Hedge-case base-scenario	Red
Base-case base-scenario	Blue

Table 4: Color scheme of result plots for the capital market sensitivities chapter.

4.4.2. Analysis of the down-scenario

4.4.2.1. Net return on capital investments

Representing the capital gains from the firm's assets the net return on capital investments serves well to display the effects of the hedge on the performance of the assets.

In the median the results are the same in each case, declining constantly from 3.500 percent to 3.100 percent in the last year. The worst-case results are interesting as to how the hedge works in the down-scenario vs. the base-scenario: In the first three years, there are no differences between the hedge-case and its respective base-case. In the base-scenario, year four is then the first year, which shows a substantial positive effect of the hedge in the amount of 22.0 basis points. At this point, the down-scenario is still not showing a difference between the cases, however, is at a much higher level (3.200 percent). In year five, the down-scenario also displays a considerably positive effect from the hedge, in the amount of 25.2 basis points. At the same time, the base-scenario continues with a difference of 25.6 basis points. This shows that once the hedge generates returns, the effect is similar in amount, hence rather independent of the scenario. The time of its appearance most likely depends on factors discussed later on.

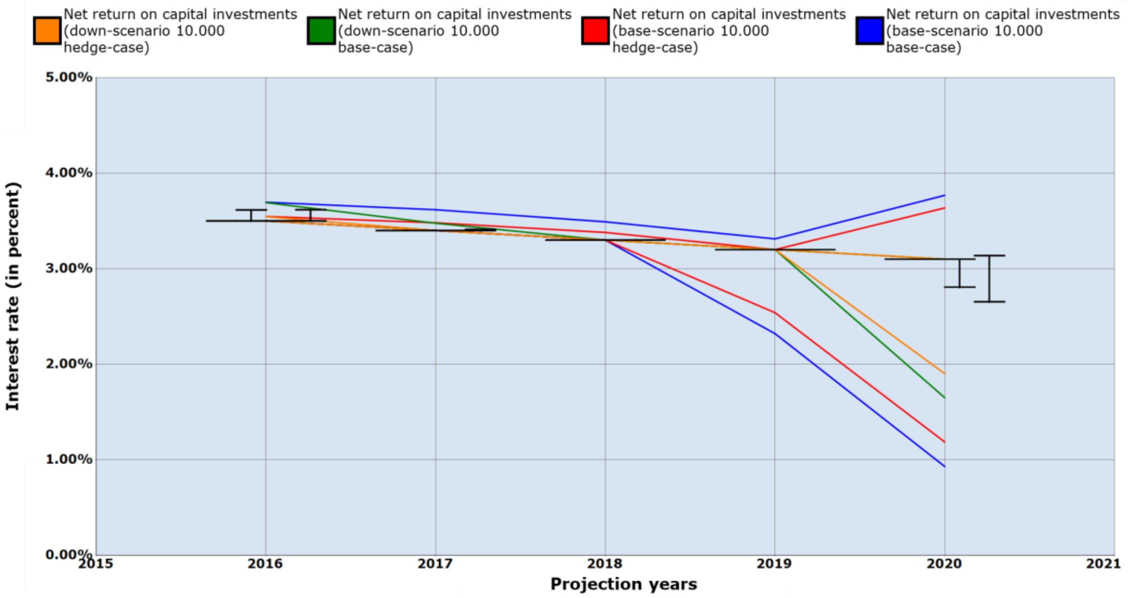

Figure 19: Box plot of net return on capital investments (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

On the upside, the base-scenario appears to have a constant negative effect from the hedge, ranging from 11-15 basis points. This effect is present from the start of the projection, however, is lower in amount than the positive effect on the downside. In the down-scenario, the negative effect is also 14.8 basis points in the first year, but declines to zero over time. This means that in years four and five, there is no negative effect in the best-case scenario, yet a substantial positive effect in the worst-case scenario.

4.4.2.2. Valuation reserve

The valuation reserve shows substantial differences between the down-scenario and the base-scenario. Due to the lower level of the interest rates in the down-scenario there are more valuation reserves available and over a longer period.

In the worst-case the values in the down-scenario show that the hedged company has valuation reserves of 1,668.797 € million, 16.893 € million more than the base-case. The difference grows to 38.315 € million at first, and then decreases again to 16.473 € million. At this point the valuation reserve has become negative in both cases. The base-scenario draws a similar picture, however at an even lower level. Here, the base-case is 0.528 € million higher than the hedge-case in the last year.

The results for the best-case scenario display the same dynamic in both the down and the base-scenario. In both of them, the hedge has the expected negative effect, which grows larger with time. The amount of the difference exceeds the positive effects on the downside by far (with exception of the first projection year). In year five, the down-scenario difference in the best-case is -149.225 € million, while the difference in the worst-case is 16.473 € million.

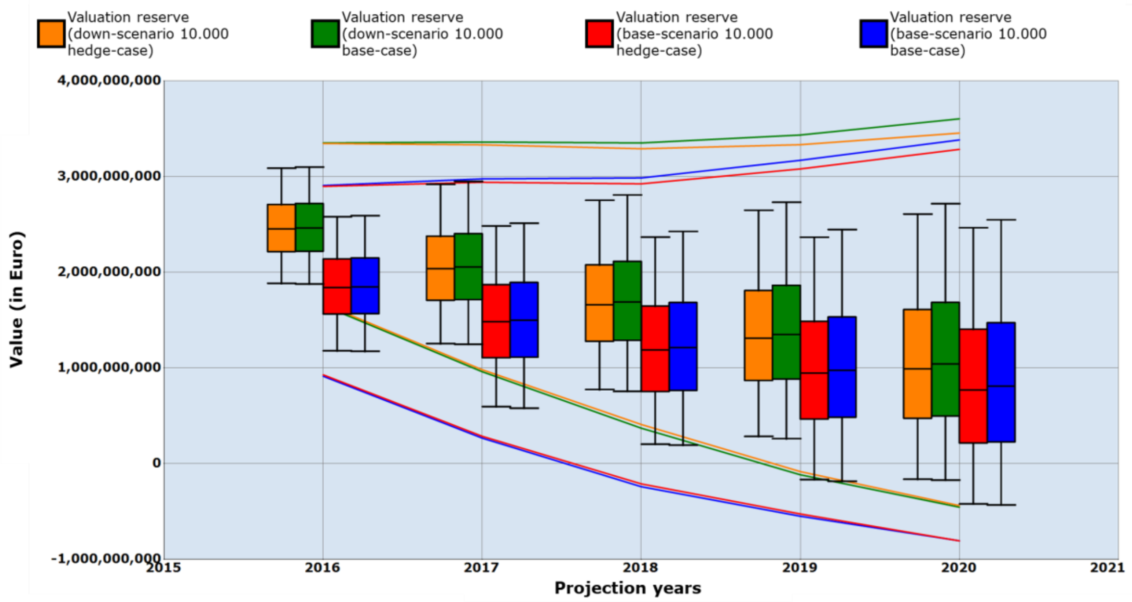

Figure 20: Box plot of valuation reserve (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.2.3. Freie RfB

The *freie RfB* shows an overall downward trend. The median decreases from 404.584 € million to a level of just above 200.000 € million in the fifth projection year. In the best-case the general trend is similar in both capital market scenarios: The hedge lowers the upside over all periods. Looking at the last projection year, the difference of the respective hedge- and base-case is -15.168 € million in the down-scenario and -22.732 € million in the base-scenario.

In the worst-case scenario the first three years are identical in both scenarios and both cases. In the fourth year the base-scenario starts decreasing more rapidly and the hedge manages to slow down the decrease by 4.934 € million in the last year. In the down-scenario, the downturn appears one year later, nevertheless ending up at 164.269 € million – just slightly higher than in the base-scenario. Interestingly, in the down-scenario the difference between the hedge-case and the base-case is marginal (0.103 € million). This suggests that for this key figure the hedge generates almost no positive effect in the lower capital market scenario.

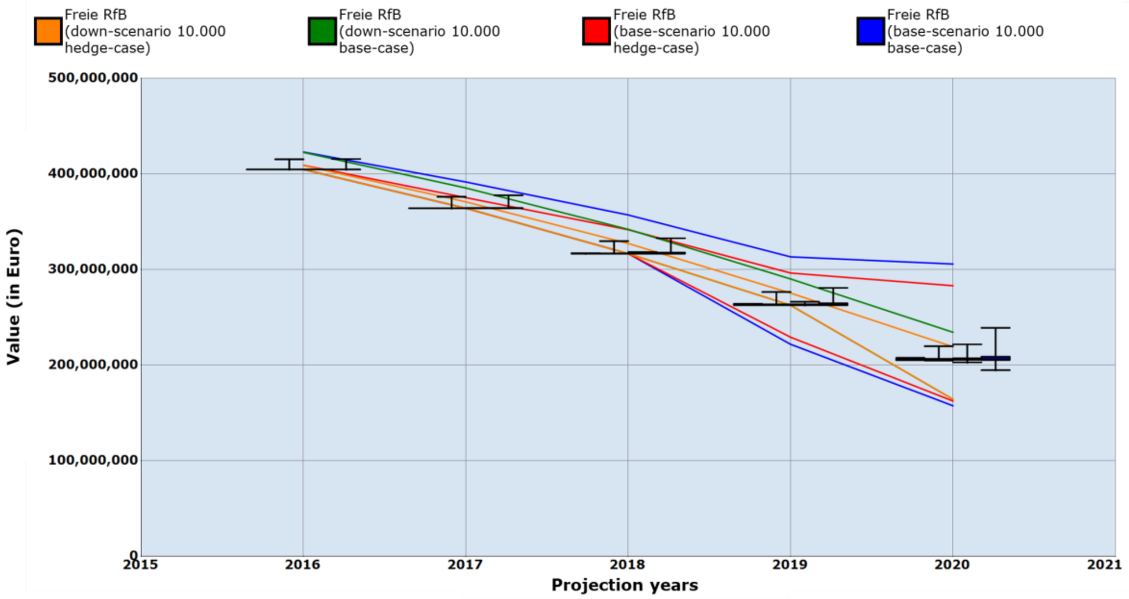

Figure 21: Box plot of *freie RfB* (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario. Bottom orange and bottom green line overlap here.

4.4.2.4. Equity capital

Although the equity capital's development is intricately linked to the net profit, it is a key determinant of financial stability of the firm and is therefore controlled for here.

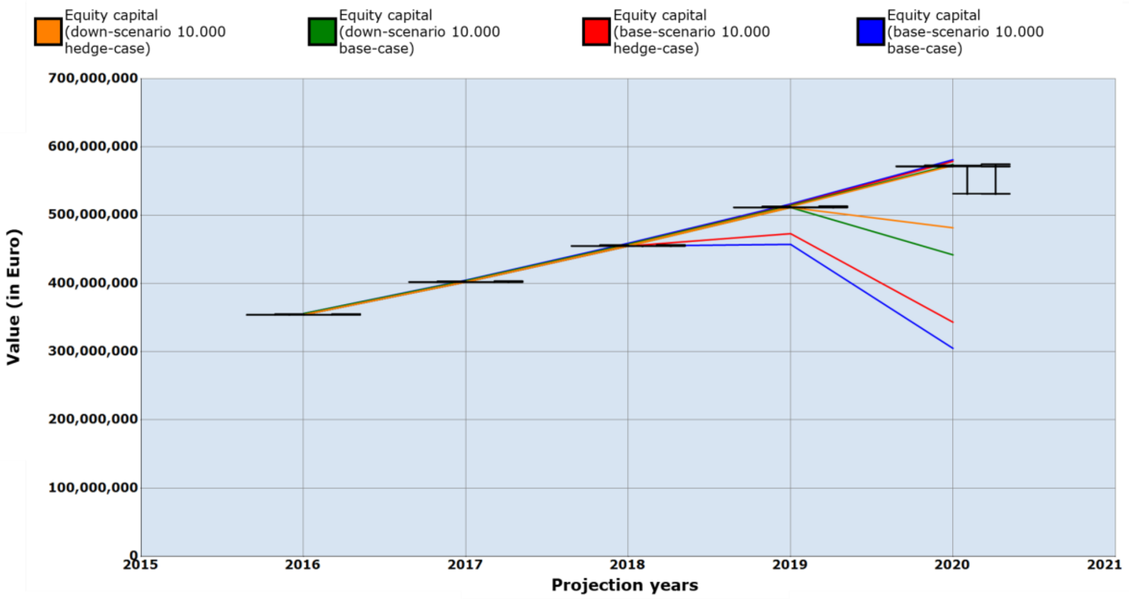

Figure 22: Box plot of equity capital (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

With a positive median net profit, the equity capital continues to rise over the projection years from 353.894 € million to 571.450 € million. The differences between the scenarios and the cases are negligible in the median.

In the worst-case scenario the positive effect of the hedge becomes visible as in the last projection year the hedge-case is 39.701 € million higher than the base-case (in the down-scenario); in the base-scenario the difference is 38.321 € million.

4.4.2.5. RfB-Zuführung

After being reduced from 48.512 € million in the first year, the median level of the *RfB-Zuführung* stays at a relatively constant level of around 42.500 € million in all cases. The worst-case scenario only differs in the last projection years. In the down-scenario it drops to zero in the last projection year, while the same happens one year earlier in the base-scenario, being only slightly prolonged by the hedge.

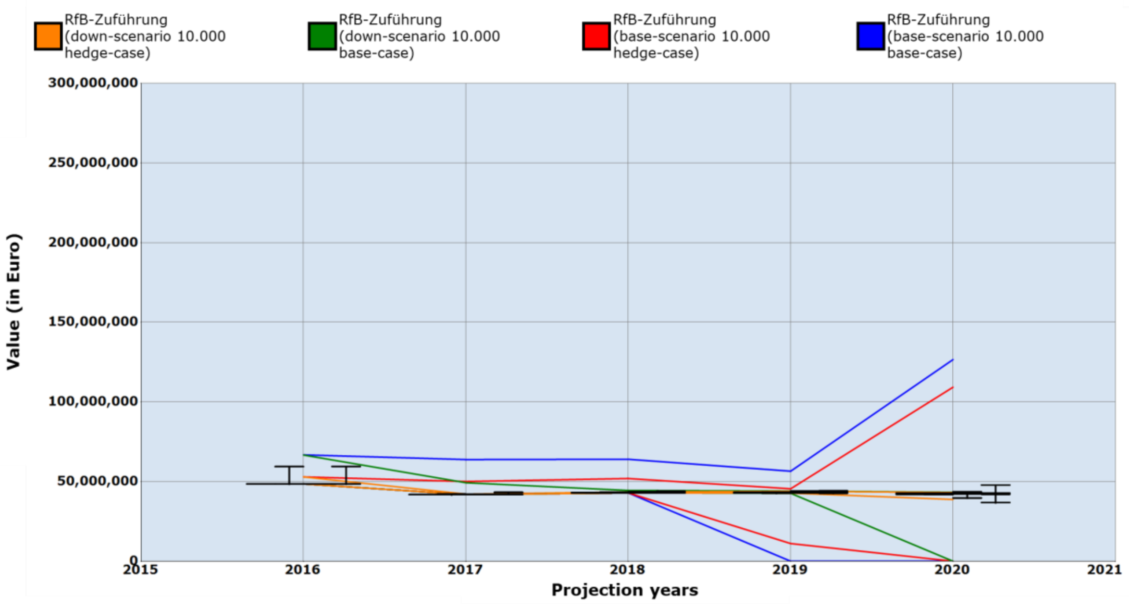

Figure 23: Box plot of *RfB-Zuführung* (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

In the upside, the development between the two capital market scenarios differs. The base-scenario shows the expected difference between the hedge-case and the base-case, which stays rather constant and is -17.338 € million in the last year. However, in the down-scenario the difference, which starts out at -13.736 € million, is reduced to -0.076 € million in the last projection year. This suggests that the hedge is no longer financed within the *RfB-Zuführung*. The rationale behind this is that at a certain (negative) level of the company's results, the mechanism, with which the *Mindestzuführung* is managed, is unable to uphold the costs for the hedge. The problem is then shifted to the valuation reserve, which is then even more stressed as the company already is in turmoil.

4.4.2.6. Gross surplus

The model firm's median gross surplus shows a rather constant level for both capital market situations and regardless of the hedge. However, in the quantile analysis effects both capital market situation and the hedge appear to make a difference.

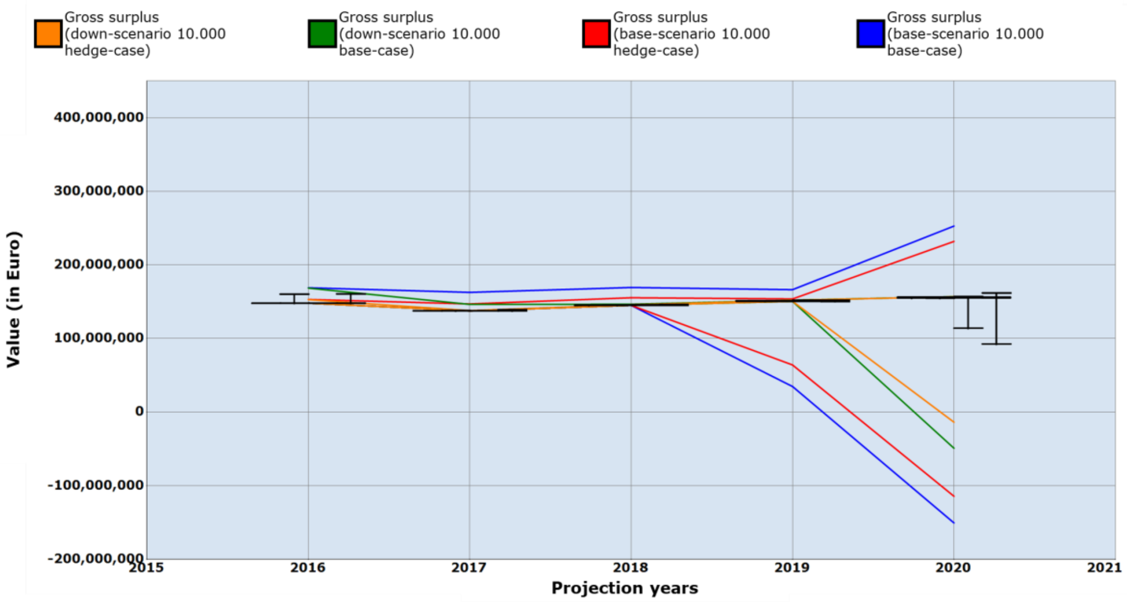

Figure 24: Box plot of gross surplus (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

In the worst-case, the first three projection years are exactly the same for all four cases. In the fourth projection year, the base capital market scenario drops substantially, while the down-scenario holds the previous level. A year later, the latter also drops. The severity of the drop in the last year is quite similar according to the amount, ranging from 160-200 € million. The one-year-delay of the drop can be traced back to the prolonged existence of valuation reserves in the down-scenario.

The hedge reduces the downfall in the worst-case by similar amounts in both capital market scenarios. In the base-scenario, the hedging strategy reduces the drop by 29.300 € million in the fourth projection year and by 36.215 € million in the fifth. For the down-scenario, the gross surplus is -49.266 € million and with the hedge -13.847 € million, making a difference of 35.419 € million.

Interestingly, there is a considerable difference visible between the two market situations in the worst-case scenario. While the spread between the worst-case and the respective base-case starts out with around 15.8 € million for both capital market situations, this difference is reduced to 0.110 € million in the down-scenario and widened in the base-scenario to 20.861 € million. This effect is attributed to the substantially lower number of capital market scenarios with highly positive developments.

4.4.2.7. Net profit

Representing the profitability component of the business, the net profit is the second target variable in this analysis. Since this key figure is calculated at the very end of the income statement, all asymmetric distribution mechanisms have already been applied. Therefore, a stronger effect on the downside compared to the upside is expected in either of the two capital market situations.

Same as with the gross surplus, the downfall in the worst-case appears one year earlier in the base-scenario than in the down-scenario. In the base-scenario, the net profit falls to -167.194 € million without hedging and to -129.395 € million with the hedging strategy, a difference of 37.799 € million. In the down-scenario this difference is similar with 35.419 € million, but the level of the net profit is much higher, meaning less negative. With this capital market situation and the application of the puts, the one in one hundred loss event can be reduced to -25.863 € million. This is half of the respective loss without the hedging strategy (-61.282 € million).

Figure 25: Box plot of net profit (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

While the downside-reduction is substantial, yet similar in amount regardless of the capital market situation, the "cost" on the upside is unalike. When the markets turn positive, it is favorable that the invested amount is as high as possible. The costs for the hedge reduce this investable amount and therefore the hedge-case performs worse than the base-case in the best-case scenario. This is visible in the difference of up to 1.888 € million (projection year five, base-scenario). However, in the down-scenario, in which the markets perform worse than in the base-scenario, the difference between the hedge-case and the base-case reduces to 0.042 € million. Compared to the -25.863 € million reduction on the downside, this is an exceedingly small "cost".

4.4.2.8. Schlussüberschussanteilfonds (SÜA-Fonds)

With the *Schlussüberschussanteilfonds* the perspective of the insured is incorporated into the study. Since the *Schlussüberschussanteilfonds* was previously determined to be a main contributor towards the firm's solvability, which is a major criterion for the likelihood of future guarantees being fulfilled, this key figure represents the security component of the analysis pyramid. In the first part of this work, the analyzed hedging strategy did not have any effect on the *Schlussüberschussanteilfonds*. This is confirmed here. Furthermore, the results show that the different capital market situation also does not affect the value development of the *Schlussüberschussanteilfonds*.

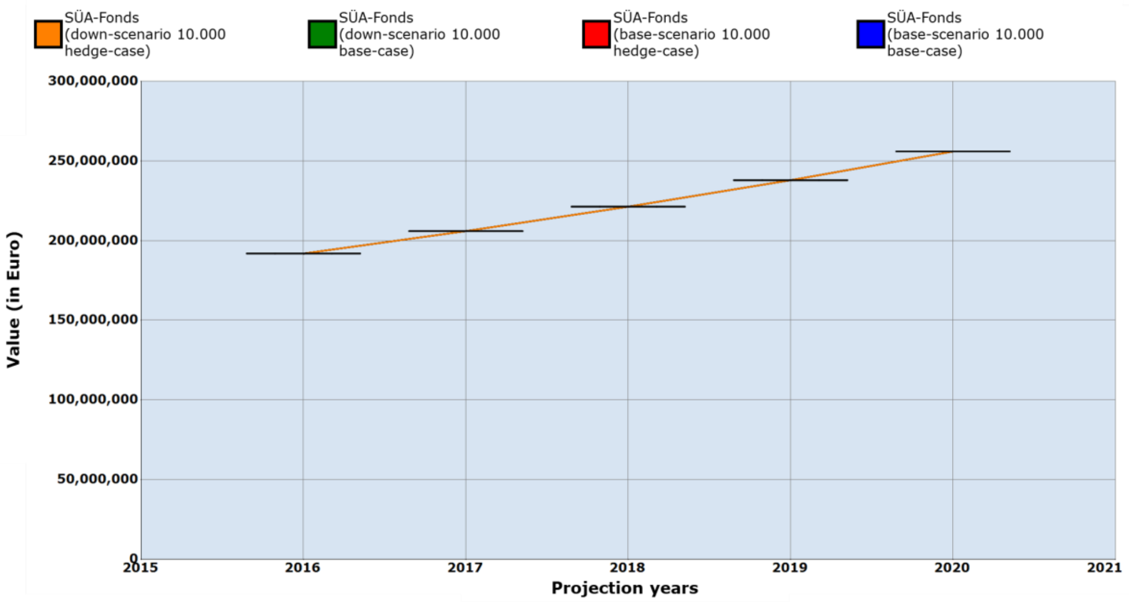

Figure 26: Box plot of *Schlussüberschussanteilfonds* (down-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario. All lines overlap here.

These results suggest that while for the profitability figures there are effects from the change in the capital market situation, the security perspective stays unchanged.

4.4.3. Analysis of the Japan-scenario

4.4.3.1. Net return on capital investments

The first observatory variable in the analysis of the Japan-scenario is the net return on capital investments. It is expected to see similar results as in the down-scenario, since the overall performance of the interest market has similar characteristics in this scenario. Declining from 3.500 percent to 3.100 percent over the five projection years, the median shows no differences between the analyzed cases.

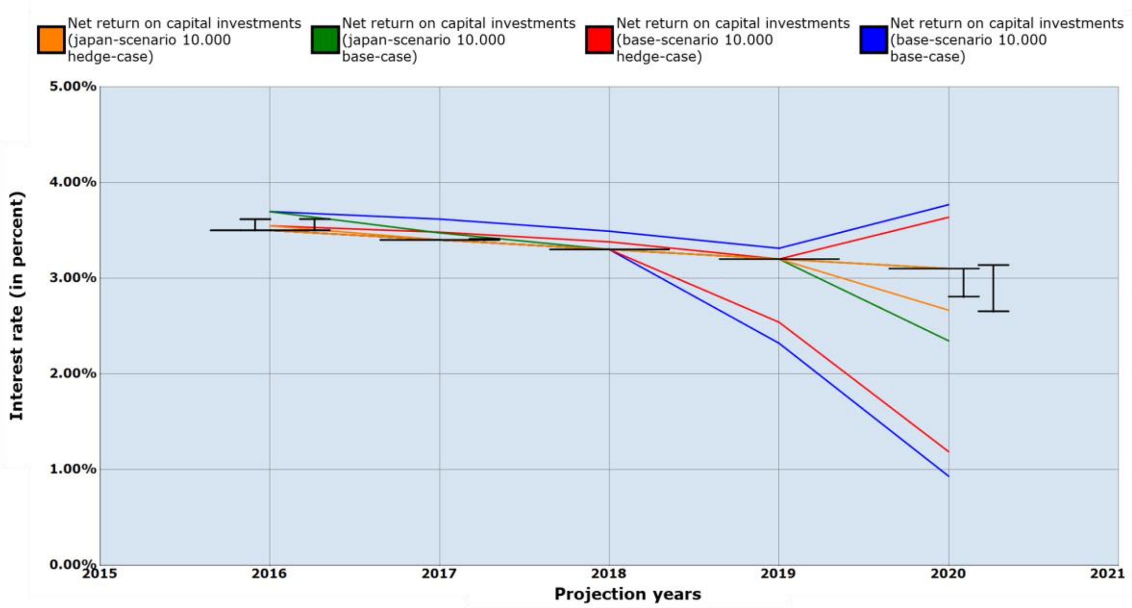

Figure 27: Box plot of net return on capital investments (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

The hedge shows its effect in the worst-case scenario only in the last year with a 32.0 basis points higher net return on capital investments than its respective scenario without the hedge, which ends up at 2.345 percent. In the best-case scenario the Japan-scenario shows a different effect than in the base-scenario. While the hedge leads to a rather constant loss of upside in the base-scenario, this loss declines to zero over time in the Japan-scenario. This is the same pattern as seen previously in chapter 4.4.2.1 of the down-scenario.

4.4.3.2. Valuation reserve

The results of the valuation reserve show that a low, flat interest rate curve can in certain situations be better for the company’s key figures than a normal interest rate curve with an extremely low short end, at least for a few years. Compared with the down-scenario, the 25 percent quantile never falls below zero, whereas in the down-scenario this happens in the fifth projection year.

The valuation reserve in the worst-case scenario is 1,882.784 € million in the first year and decline to -206.339 € million in the fifth year, crossing the zero-line during the last year. The respective base-case is lower at every point in time, with a difference of 31.048 € million in the last year. This shows that the hedge reduces the downside as planned. The best-case furthermore shows the expected effect for the hedge: in the fifth year the valuation reserve with the hedge is at 3,437.743 € million, so 109.513 € million lower than without the hedge.

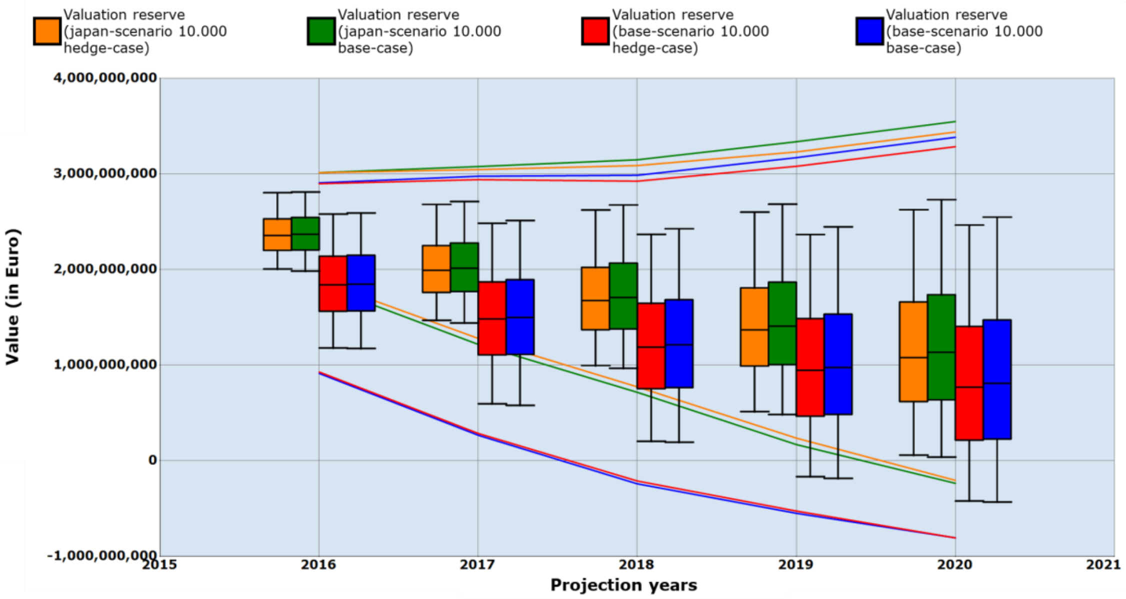

Figure 28: Box plot of valuation reserve (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.3.3. Freie RfB

The overall downward trend of the freie RfB is visible in all cases of both scenarios, as the median grows smaller from 404.584 € million to a level of just above 200.000 € million. In the Japan-scenario the hedge's effect is substantial and much higher than in the base-scenario as well as in the down-scenario. In the worst-case of the Japan-scenario the base-case cannot hold the level of the median in the fifth year anymore and falls to 168.810 € million. With the hedging strategy, the freie RfB can manage to not experience this drastic decline, but instead maintain the median level at 202.554 € million.

Regarding the best-case scenario, the hedge reduces the upside constantly by around 15 € million. Compared to the 33.744 € million advantage on the downside, the hedge appears to have a positive effect, however only in the last year. The four previous years, the negative effect on the upside outweighs the downside reduction.

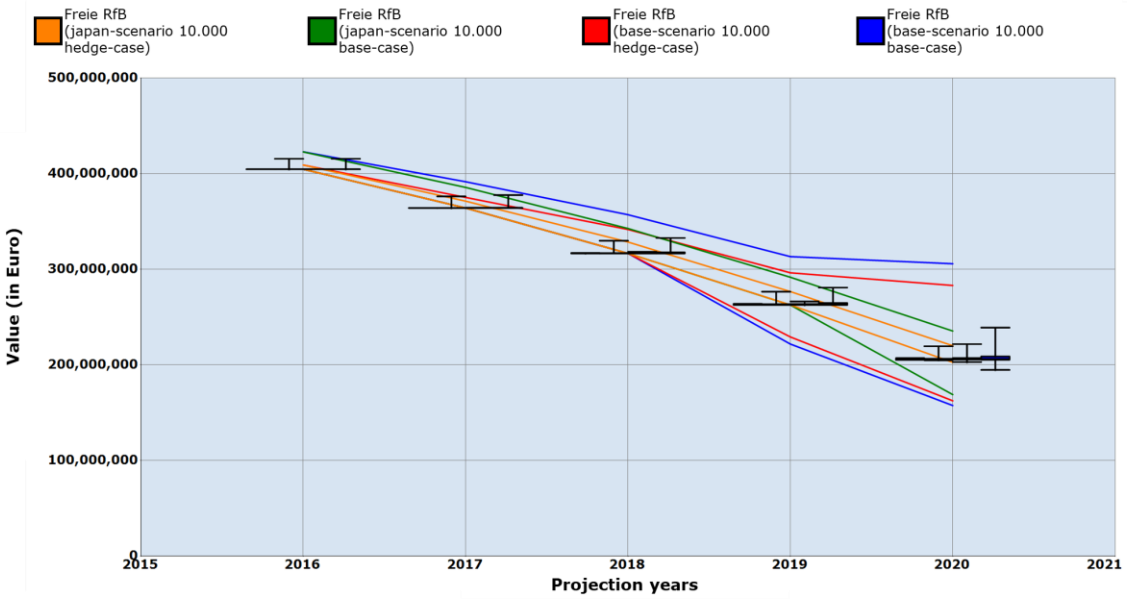

Figure 29: Box plot of *freie RfB* (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.3.4. Equity capital

The median equity capital grows steadily with positive net returns over the five-year projection. In the best-case scenario the hedge leads to a slight reduction in the upside by around 1.5 € million. In the base-scenario this difference is equal in direction, yet slightly higher in each year with -2.282 € million in the fifth year versus -1.553 € million in the down-scenario's hedge-case.

In the worst-case analysis, the hedge's effect unfolds in the fifth projection year with a downside reduction of 9.046 € million. In value this clearly outweighs the loss in upside, however it only appears in the last year, whereas the upside reduction is constantly present throughout all years.

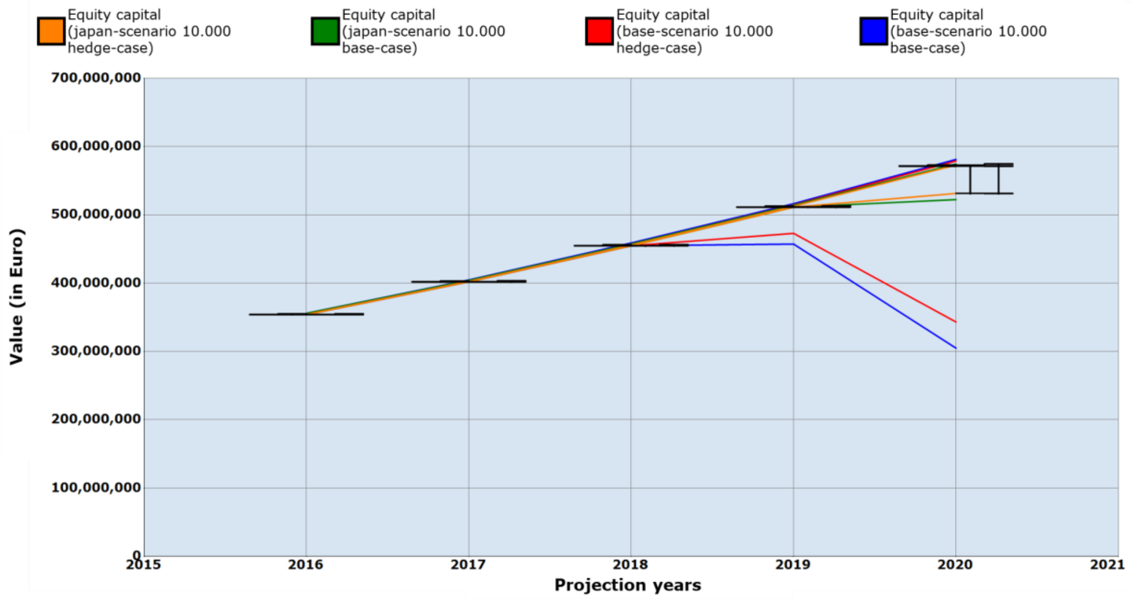

Figure 30: Box plot of equity capital (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.3.5. RfB-Zuführung

The median *RfB-Zuführung* is held at a constant level of around 42-45 € million regardless of the capital market scenario and regardless of the application of the hedge.

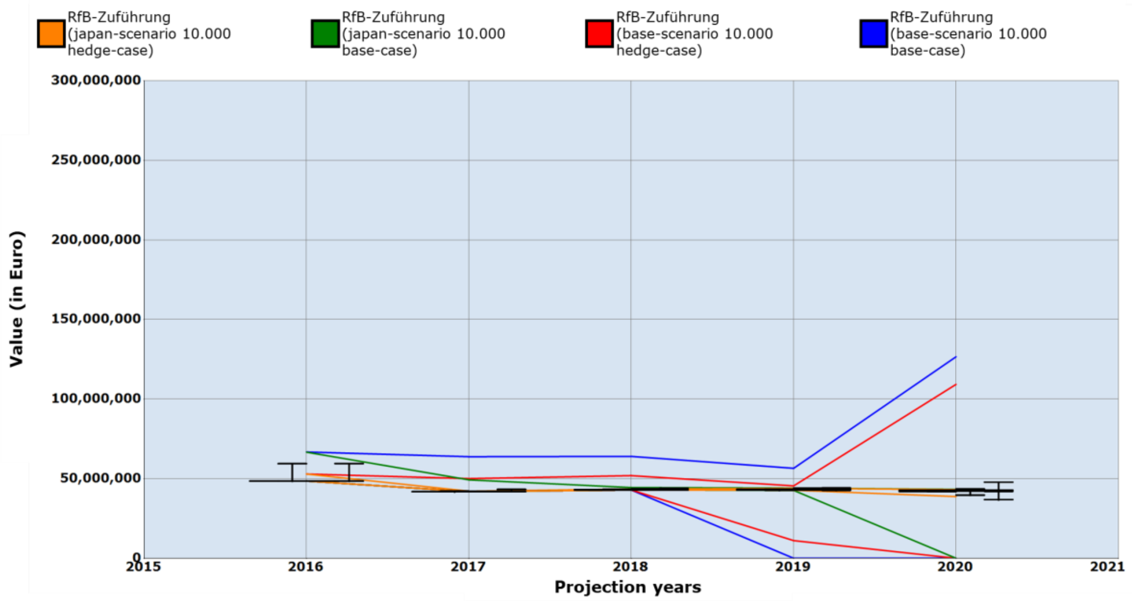

Figure 31: Box plot of *RfB-Zuführung* (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

While the *RfB-Zuführung* is both beneficial for the shareholder as well as for the insured, the results in the Japan-scenario speak clearly for the hedge. As the *RfB-Zuführung* drops to zero without the hedge in the last projection year, the hedge helps maintain a level of 38.753 € million. The results from the best-case analysis reinforces this result. While the upside reduction is 13.736 € million in the first year, this “loss” on the upside decreases to a mere 0.167 € million in the last year. According to the amount in the fifth year, this makes the benefit 231 times higher than the disadvantage on the upside.

4.4.3.6. Gross surplus

The gross surplus results serve well to show the asymmetry in the distribution of gains stemming from the *Mindestzuführungsverordnung*. In the last year of the worst-case scenario the base-case gross surplus drops to 48.722 € million. With the hedge, it only drops to 94.394 € million. This makes the hedge worth 45.672 € million on the downside. In comparison, the loss of upside in the same year is 0.171 € million. In such a low-return-environment as the Japan-scenario, the upside represented by the 99 percent quantile is only 0.919 € million higher than the respective median value. The loss on the upside is therefore almost negligible, however the downside is much more sensitive towards the hedge.

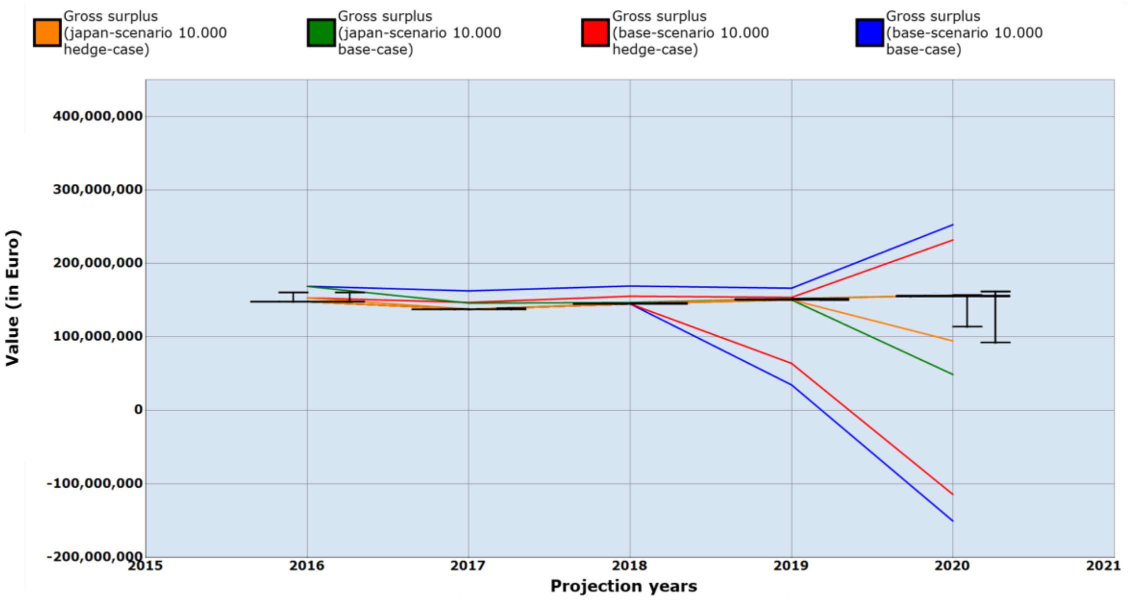

Figure 32: Box plot of gross surplus (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

4.4.3.7. Net profit

Being the foremost result figure, the net profit mostly represents shareholders' interests. Due to the asymmetric distribution of profits as dictated by the *Mindestzuführungsverordnung*, it is expected that the hedge shows larger effects on the downside than on the upside.

In the Japan-scenario the worst-case result shows effects from the hedge only in the last two years. In the last year, the hedge-case stands at 23.538 € million and the base-case at 18.694 € million, making a difference of 4.844 € million. In the best-case the respective difference comes to -0.036 € million. This clearly shows the expected asymmetry.

A notable result is also that in the Japan-scenario the net profit does not fall below zero, whereas the net profit in the down-scenario did indeed fall below zero. This again shows that with the constantly low interest rates, the valuation reserves hold longer than with a normal interest curve and therefore let the company continue business without net losses in the lower quantiles.

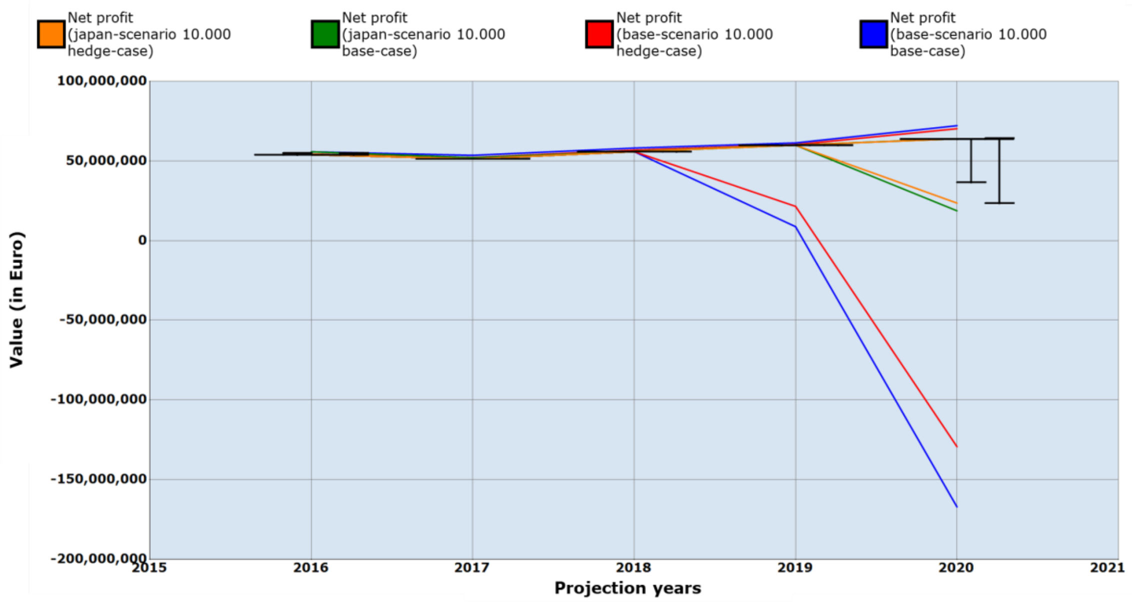

Figure 33: Box plot of net profit (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Top orange and top green line overlap here. Bottom four lines display worst-case scenario.

4.4.3.8. Schlussüberschussanteilfonds (SÜA-Fonds)

As established in previous chapters, the *Schlussüberschussanteilfonds* should not be affected by the hedging strategy. The results do not show any differences between the scenarios and cases, fulfilling the expectation.

Focusing just on the last two target variables, the hedge shows positive results from the shareholders' perspective and no negative effect on the figure representing the interest of the insured.

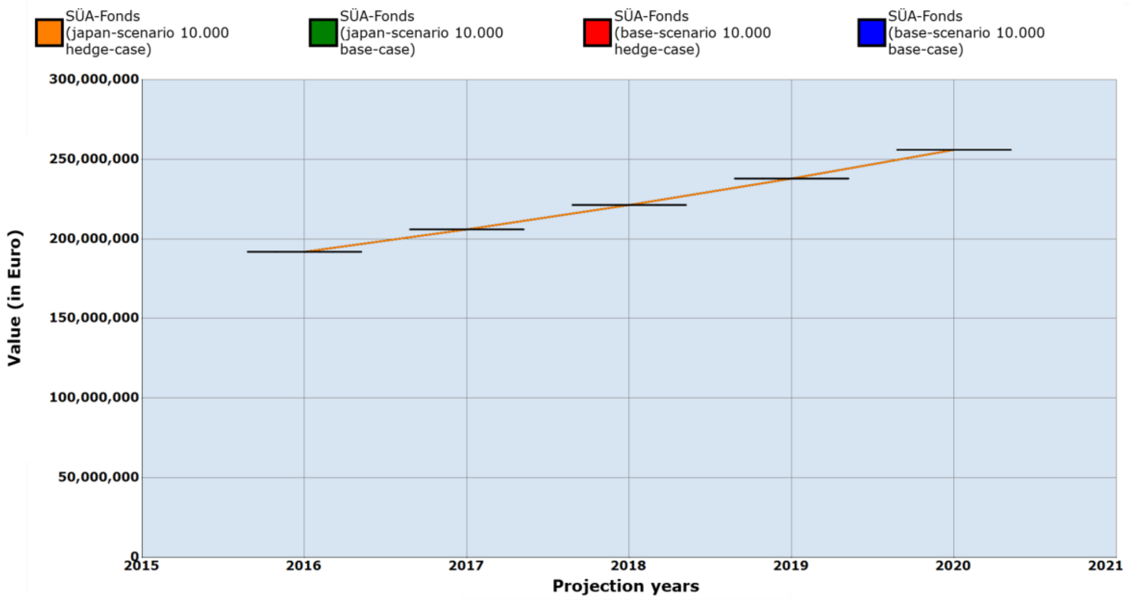

Figure 34: Box plot of *Schlussüberschussanteilfonds* (Japan-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario. All lines overlap here.

4.4.4. Analysis of the up-scenario

4.4.4.1. Net return on capital investments

The up-scenario is characterized by a higher level of the interest rate curve, which naturally leads to higher returns from the asset portfolio. This effect however takes some time as the reallocation into higher return assets is not forced but done naturally through the free cash.

In the median all cases form both scenarios are equal throughout the projection, however already in the 75 percent and the 95 percent quantiles differences appear in the second year. Because of the higher interest rates, the up-scenario can generate 3.410 percent in the 75 percent quantile, while the base-scenario is 31.0 basis points lower (both without hedge). Naturally, in the best-case analysis the difference is even stronger. Without hedge the net return on capital investments is 4.908 percent in the fifth year, whereas the base-scenario can only generate 3.769 percent. With regards to the hedging strategy, the already established pattern also appears in the up-scenario. Since the hedge leads to costs, there is less capital to be invested. With compound interest this has a negative effect on the performance especially in exceedingly positive market situations. With the hedge, and therefore the related costs, the net return on capital investments comes to 4.775 percent in the fifth year. This is 13.3 basis points less than without the hedge.

This negative effect on the upside is compensated by a positive reduction in downside as seen in the worst-case analysis. Starting in the third year, the hedge allows for a higher return than without the hedge. This difference is 34.7 basis points in the third year, 24.1 basis points in the fourth year and 26.5 basis points in the last projection year.

The fact that the one percent quantile lines of the up-scenario and the base-scenario cross in the fifth year can be explained through the valuation reserve. As the valuation reserves vanish rapidly with the increased rates at the fixed income market, the net returns on capital investments start falling almost immediately after the start of the projection. However, once the reallocation into higher return investments leads to higher portions of the portfolio, the net returns stabilize, whereas the ones in the base-scenario keep falling.

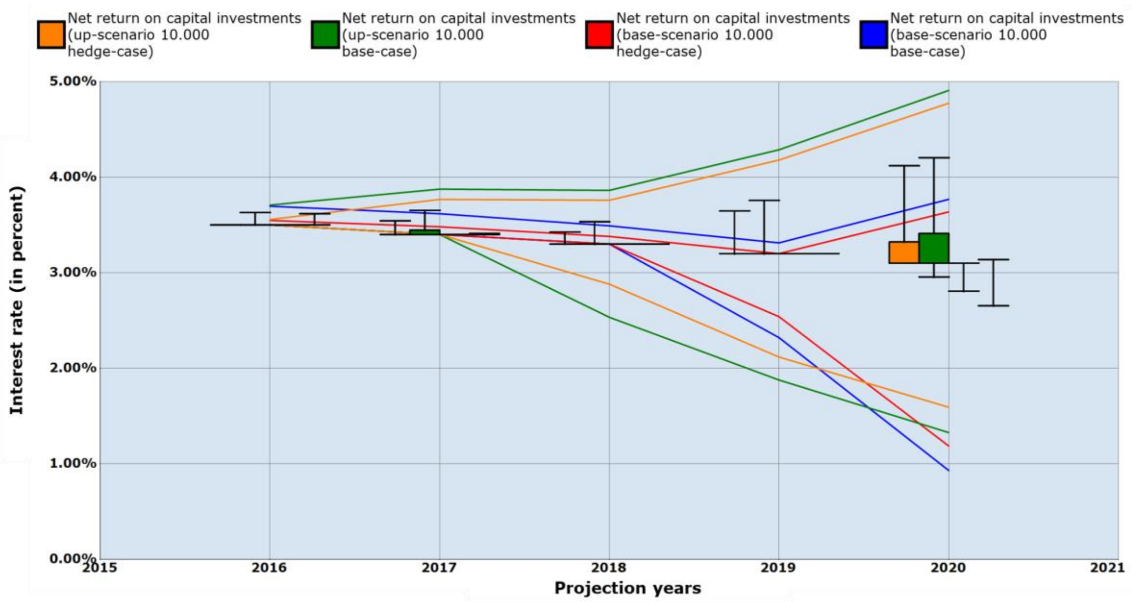

Figure 35: Box plot of net return on capital investments (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.4.2. Valuation reserve

As the interest rate shock appears at the beginning of the projection, the valuation reserve is reduced drastically in the first projection year. From then, reinvestments can be made at higher interest rate levels, therefore the median declines only by 247.910 € million to 659.979 € million in the last year, while the drop over five years in the base-scenario is 1,038.003 € million.

In the worst-case the valuation reserve declines from 81.066 € million to -910.439 € million. The hedging effect is 24.880 € million in the last projection year, showing that the direction of the hedge is still the same even at such negative levels of the valuation reserve.

The upside reduction is higher in value than the downside reduction. In the fifth projection year the hedge-case is 47.090 € million lower than the base-case, which then is at 3,144.369 € million.

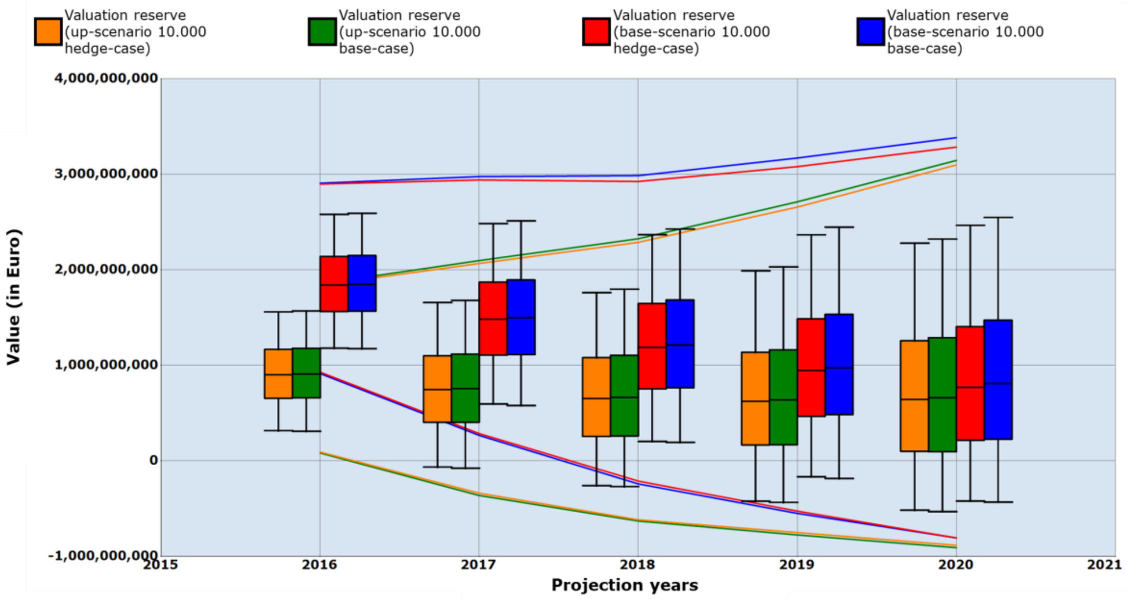

Figure 36: Box plot of valuation reserve (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.4.3. Freie RfB

The overall downward trend of the *freie RfB* is visible in all cases of both scenarios. The worst-case behaves similarly in all four results, starting at 404.584 € million and ending up at a level just above 150.000 € million. The hedge-case in the last year is 3.656 € million (up-scenario) and 4.934 € million (base-scenario) higher than the respective base-case.

Figure 37: Box plot of *freie RfB* (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

In the best-case, a much stronger diversion appears, which can already be seen in the middle 50 percent of the result distribution, the boxplot. While the up-scenario shows a constantly growing spread between the 50 and the 75 percent quantile (i.e. the upper half of the box), the base-scenario has little to none. This means that there are not just a few, but many paths, in which the decline in the *freie RfB* is slowed down or even turned around. This is especially visible in the best-case, where the orange line (457.914 € million) and the green line (486.181 € million) end up at a higher level in year five then in the years before. Nevertheless, in both scenarios the hedge-case is substantially lower than their respective base-case. In the up-scenario, this difference is 28.267 € million in the fifth projection year.

4.4.4.4. Equity capital

Being the ultimate profitability key figure in the property loss statement, the net profit results are of special interest in this analysis. As its development is strongly driven by the results from the gross profit, the differences between the base-scenario and the up-scenario are again clearly visible.

The median level as well as the best-case show a similar upward trend over the time of the projection. Nevertheless, the base-case in the up-scenario increases most over time. It finally ends up at 599.537 € million in the last year. The corresponding base-scenario figure ranges lower at 581.174 € million.

The worst-case results show a similar development as seen before in the net return on capital investments. While the base-scenario results increase up until the fourth year, the up-scenario results have their turning point a year earlier. However, the following decrease is much less in magnitude. This ultimately leads to the lines crossing, with the hedge-case of the up-scenario ending up at the highest level of the four (381.244 € million), while the base-case of the base-scenario is the lowest at 304.728 € million. Furthermore, it can be observed that the hedge has a stronger effect in the up-scenario with a difference of 69.099 € million in the fifth year, than in the base-scenario, where the difference is 38.321 € million.

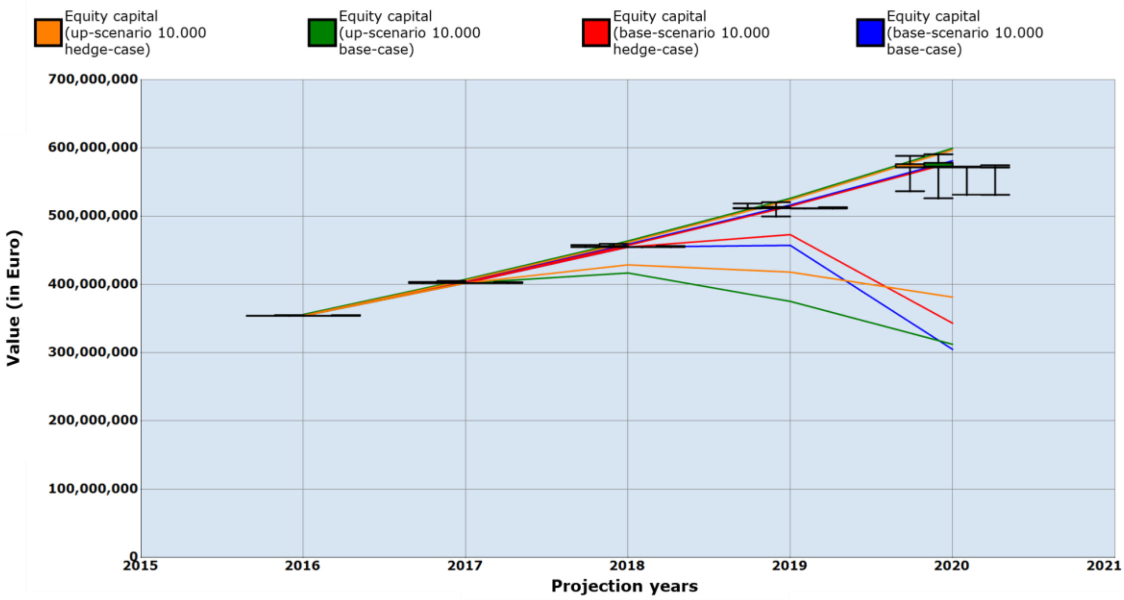

Figure 38: Box plot of equity capital (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.4.5. RfB-Zuführung

As the *RfB-Zuführung* is heavily dependent on the gross surplus, Figure 39 foreshadows the results from the gross surplus presented in the next paragraph. The up-scenario diverges considerably from the base-scenario. In the best-case, a *RfB-Zuführung* of up to 268.343 € million become possible with the substantial increase that was seen in the corresponding result of the net returns on capital investments. As expected, the hedge-case falls short of the base-case by 16.421 € million. This difference is comparable to one seen in the base-scenario, although here the *RfB-Zuführung* ends up at a much lower level at 126.567 € million.

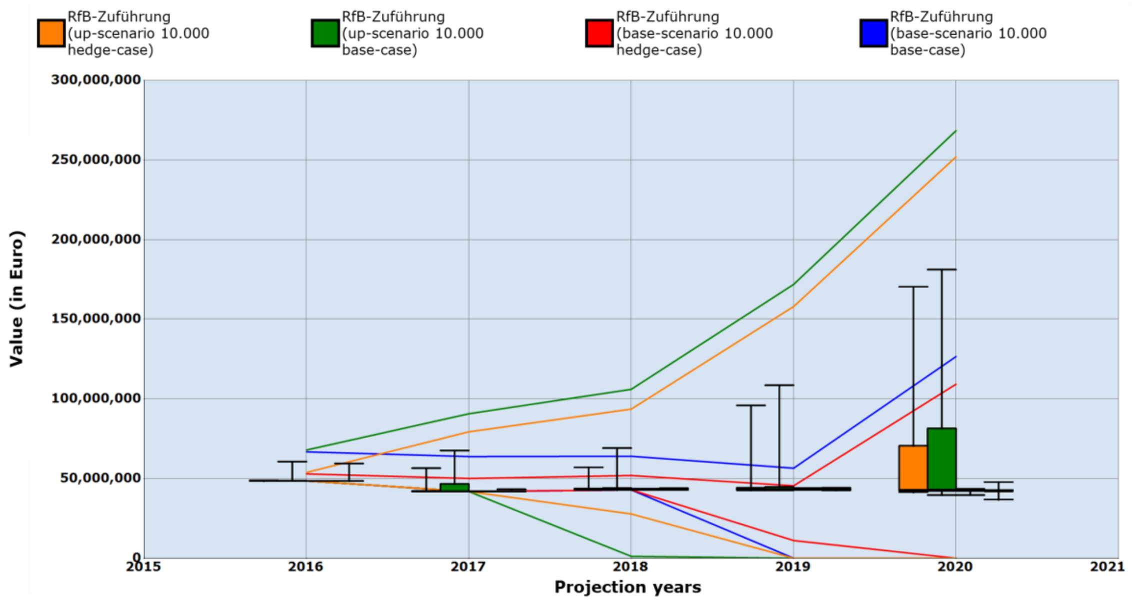

Figure 39: Box plot of *RfB-Zuführung* (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

In the worst-case, the natural limitation at the level zero is reached in both scenarios. Yet, both the scenario and the hedge affect the time of when the zero-level is reached. The first result to almost reach zero, more specifically 1.176 € million, is the base-case of the up-scenario in the third projection year. With the absence of valuation reserves so early in the projection this was expected. The hedge helps here maintain at least a *RfB-Zuführung* of 27.777 € million. A year later, three of the four cases are at zero with the exception of the hedge-case of the base-scenario, where the hedge again was able to maintain a slightly higher level. Ultimately, all cases are at zero in the last projection year.

4.4.4.6. Gross surplus

The model firm's median gross surplus shows a rather constant level for both capital market situations and regardless of the hedge. However, in the quantile analysis effects both capital market situation and the hedge appear to make a difference.

The effects seen here are strongly linked to the presence of valuation reserves and the creation of new ones, respectively. In the worst-case, the gross surplus starts at 147.921 € million in all four simulations. While the base-scenario holds this level until year three, the decline of the up-scenario already starts in the third year. Its base-case drops to 51.062 € million and ends up at -93.846 € million in year five. With the hedging strategy the values are considerably more positive. In year five this equals a difference of 35.316 € million (with the hedge-case at -58.530 € million).

The base-scenario experiences a later, yet more drastic reduction. While having held the starting level a year longer than the up-scenario, the base-scenario ends up lower in the last projection year, with -114.539 € million in the hedge-case and -150.754 € million in the base-case. Here the positive hedging effect measures to 36.215 € million, so roughly the same amount as in the down-scenario. The reason for the more drastic downfall of the gross surplus in the base-scenario is linked to the wave motion of the valuation reserve. The upward shock of the fixed income market leads to an almost immediate vanishing of the accumulated valuation reserve, which lets the figures drop faster. However, the new investments are then made with higher returns, leading to a faster accumulation of "new" valuation reserves. These help reduce the losses in the later years of the projections.

This matches the results seen in the best-case figures. While the level of the base-scenario figures stays relatively close to the media level, the ones for the up-scenario rise tremendously. The effect is even visible in the 95 percent and 75 percent quantile as the box of the boxplot starts to widen in the last projection years.

Figure 40: Box plot of gross surplus (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

4.4.4.7. Net profit

Being the ultimate profitability key figure in the property loss statement, the net profit results are of special interest in this analysis. As its development is strongly driven by the results from the gross profit, the differences between the base-scenario and the up-scenario are again clearly visible.

The worst-case results of the up-scenario start declining earlier than the ones of the base-scenario, are however overtaken in the last projection year. In year five, the base-case of the base-scenario is at -167.194 € million, while the respective hedge-case is 37.799 € million less negative at -129.395 € million. The up-scenario results in less negative numbers (-107.711 € million base-case; -70.546 € million hedge-case). The "gain" from applying the hedging strategy leads to 37.165 € million, a similar difference as seen in the base-scenario.

Figure 41: Box plot of net profit (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario.

The asymmetry in the German life insurance can also be seen here. The differences from using the hedging strategy are substantially smaller in the best-case scenarios. Here the spread between the base-case and the hedge-case is around 1-2 € million for both capital market situations. The level of the up-scenario is higher as already seen in the gross surplus figures. Therefore, the usage of the hedging strategy appears reasonable as the downside reduction clearly outweighs the upside reduction according to amount.

4.4.4.8. Schlussüberschussanteilfonds (SÜA-Fonds)

The results of the *Schlussüberschussanteilfonds* appear to be unaffected neither by the change in the capital market situation nor by the application strategy. This matches the results previously seen for this key figure, suggesting no negative or positive effects for the security perspective of this analysis.

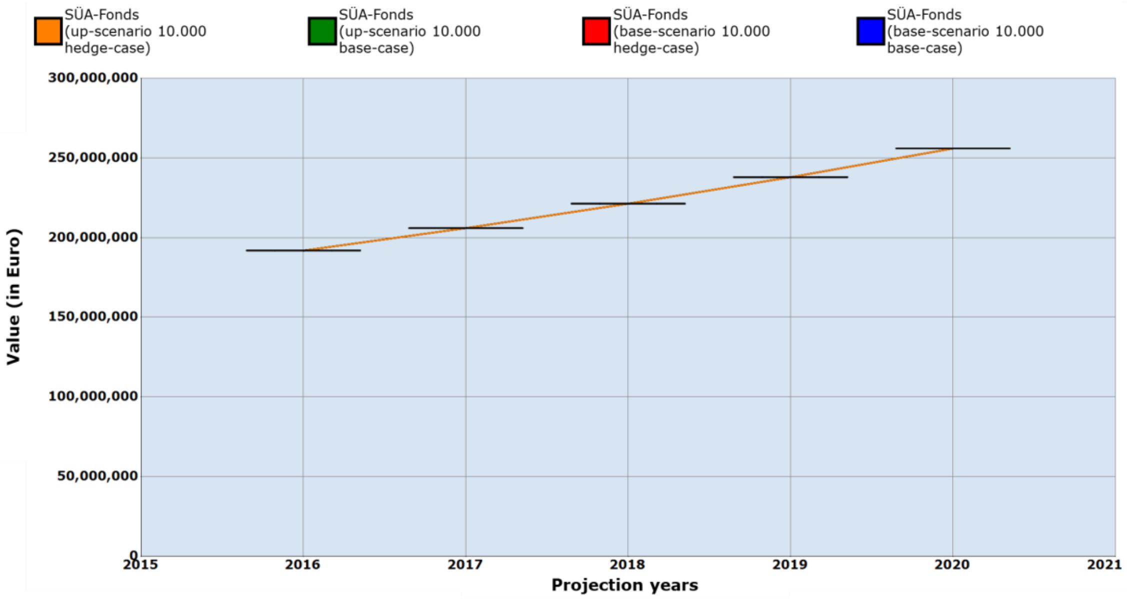

Figure 42: Box plot of *Schlussüberschussanteilfonds* (up-scenario). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top four lines display best-case scenario. Bottom four lines display worst-case scenario. All lines overlap here.

4.5. Interim conclusion

The analysis of all three capital market situations shows the presence of asymmetric effects of the applied hedging strategy on the observed key figures. This confirms the results from the previous part, i.e. the base-scenario. Another finding is that the intensity and the speed of the effects is influenced by the general situation of the capital markets. The mechanism of action takes effect through the various buffer positions in the balance sheet and the profit and loss statement such as the valuation reserve or the *freie RfB* for example. The results suggest that in market settings with higher interest rate levels the hedge effectiveness is robust. In low interest rate settings, the asymmetric mechanisms grow stronger and that is when the hedge effectiveness increases even further.

So in a preliminary summary, these recent two chapters set out to deepen the understanding of the effects of using hedging instruments in the complex context of asset-liability management in German life insurance. For another validation of these results and a suitable comparison, the analysis of an example, in which the accounting principles typically do not induce these types of significant buffering positions and generally do not have such a drastic mechanism like the *Mindestzuführungsverordnung*, would provide further insights.

Within the German insurance sector as a whole, one does not have to look far, for such an example. Many insurance corporations with life insurers are also active in the non-life insurance business. Depending on the corporate structure, the divisions responsible for managing and controlling the insurance firm's investments, are also responsible for the assets of the property/casualty branch. To understand whether the documented effects of hedging drawn from the life insurance part of this work is translatable to property/casualty insurance, the following chapter analyzes the same hedging strategy within a second model company representing a typical German property/casualty insurance company.

5. Property/casualty insurance

5.1. Introduction property/casualty insurance

In recent years, insurance companies have been experiencing noticeable changes in the composition of their sources of income. A major influencing factor has been the development of the capital markets. The intensity of this influence depends on the lines of business and the respective product lines. In the non-life business two dynamics are of special interest: underlying the technical reserves with sufficient assets and the presumably high independence of volatilities of the assets and of the liabilities. This generally allows for a differentiated strategic asset allocation in comparison to the life and health insurance. Regarding this, the German financial supervisory authority's (BaFin) annual market report 2017 (BaFin, 2018) shows that non-life insurers have significant portions of their portfolios not invested in fixed income assets, but rather equity, real estate, etc. Since non-life insurers typically do not have interest guarantees as for example life insurers do, their asset managers normally are not as invested in fixed income assets as their life insurance counterparts. This is also due to the fact that on average, the duration of their liability portfolios is rather low, hence a smaller need for long-term interest rate investments and the slightly different risk-appetite concerning their investment strategy.

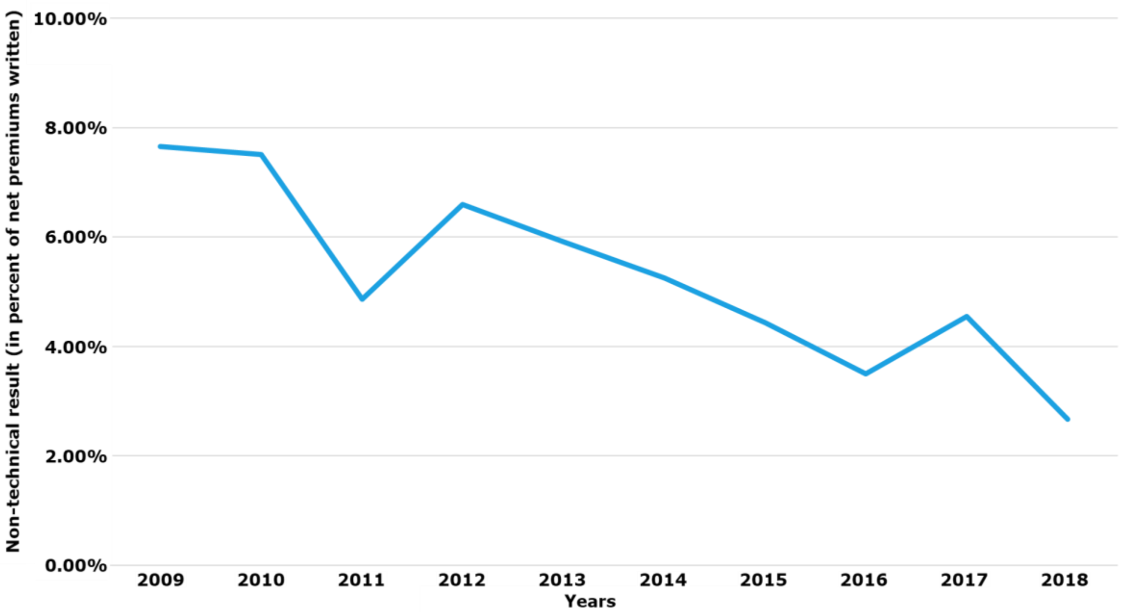

Figure 43: Timeline of non-life insurance industry average of the non-technical result in relation to net premiums written from 2009 to 2018. Own representation based on unpublished study of annual reports of German property/casualty insurance companies 2018, ROKOCO GmbH.

Over the past years, the non-technical results (in relation to net premiums earned) have declined considerably in the German non-life insurance industry, as can be seen in Figure 43.[6] Decreasing margins and periods of increased volatility at the capital markets have been made out to be main drivers of this development.

A common method for reducing such volatility is hedging. This in combination with non-life insurers' significant exposures to equites in their asset portfolios as well as the decreasing non-technical results observed in the industry, makes it an interesting research topic in the context of the research questions raised in this work. Now the model for the property/casualty insurance company is introduced, before the results of the conducted analysis are presented.

5.2. Model description

5.2.1. Capital market model

Overall, the capital market model is identical to the one of the life insurance part of this work. However, as this part of the work was done more recently, the used interest rate curve and the corresponding calibration for the Hull-White model refers to a more recent date. In Figure 44 the assumed development of the 10-year spot rates for Euro fixed income rates is depicted. The calibration date is December 31st, 2017.

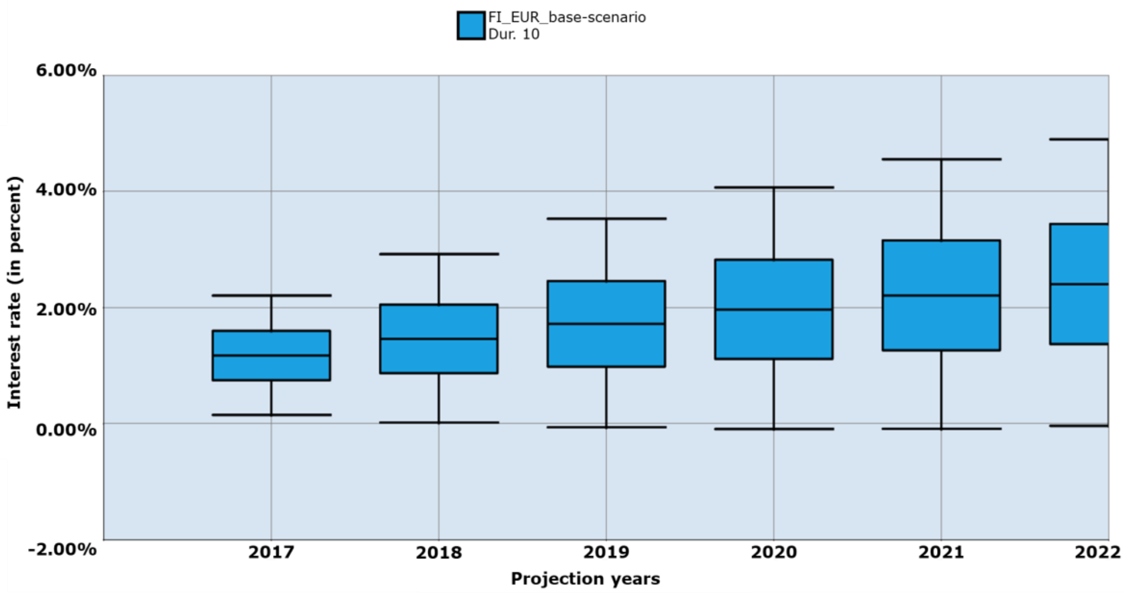

Figure 44: Capital market assumptions (property/casualty insurance). Box plot of interest rates for 10-year EUR spot rates.

[6] Unpublished study of annual reports of German property/casualty insurance companies 2018, ROKOCO GmbH.

The capital market assumptions are derived from historic data time series of corresponding major benchmark indices. For the equity, real estate, and private equity scenarios the geometric Brownian motion is used. The spread model is based on normally distributed gains. The parameter assumptions except for the interest rate model are identical to the parameters used in the life insurance part:

Risk factor	Expected value	Volatility
Equity Europe	6.400%	16.750%
Equity Global	5.500%	13.490%
Real Estate Europe	3.500%	3.640%
Private Equity	6.800%	17.750%
Spreads EUR AAA	0.000%	0.000%
Spreads EUR AA	0.370%	0.330%
Spreads EUR A	0.160%	0.130%
Spreads EUR BBB	0.240%	0.170%

Table 5: Capital market assumptions (property/casualty insurance). Parameters for risk factors. Spreads are additive towards the spot rates resp. the next better rating. These risk factors are used for the benchmarking of the simulated asset classes.

5.2.2. Asset model

The general structure of the asset model is the same as in the life insurance model, however, some changes are made in order to give credit to the specialties of the property/casualty insurance business. The model portfolio for this analysis is meant to depict a German property/casualty insurance company, which is active with a diversified insurance portfolio. Therefore, the asset portfolio will consist of the following asset classes: equity, real estate, bearer debentures, registered bonds and promissory notes, as well as callable bonds, annuities, borrower's note loans, multi-tranche bonds and private equity investments. All mentioned capital market instruments can be held either directly or in specialized mixed funds.

The asset structure at the beginning of the projection is modeled along market averages from the annual market report 2017 by BaFin (2018) and the annual reports of most German property/casualty insurance companies.[7] To reduce complexity and to keep the focus on equity hedges, all investments are made in Euro.

The overall book value of the asset portfolio is set to be 75 million Euros. The assets are divided into direct holdings (*Direktbestand)* and indirect holdings through the

[7] Unpublished study of annual reports of German property/casualty insurance companies 2018, ROKOCO GmbH. The study covers more than 98 percent of the German life insurance market.

Spezialfonds. 45 percent of total assets are allocated towards the *Spezialfonds*. The 55 percent held directly are split into twelve *Assetmäntel*. Seven fixed income groups: annuity bonds (*Annuitätendarlehen*), callable bonds, multi tranche bonds, registered bonds (*Namensschuldverschreibungen)*, promissory notes (*Schuldscheinforderungen)*, bearer debentures (*Inhaberschuldverschreibungen*), and borrower's note loans (*Zero-Schuldscheindarlehen*). And five other asset groups: stocks (Europe), stocks (world), cash, real estate, and private equity. The *Assetmantel Spezialfonds* contains one *Spezialfonds*, which is a mixed fund covering stocks, cash, corporate bonds and government bonds.

The pie chart in Figure 45 displays the model company's asset allocation based on book values at the reference date December 31st, 2017:

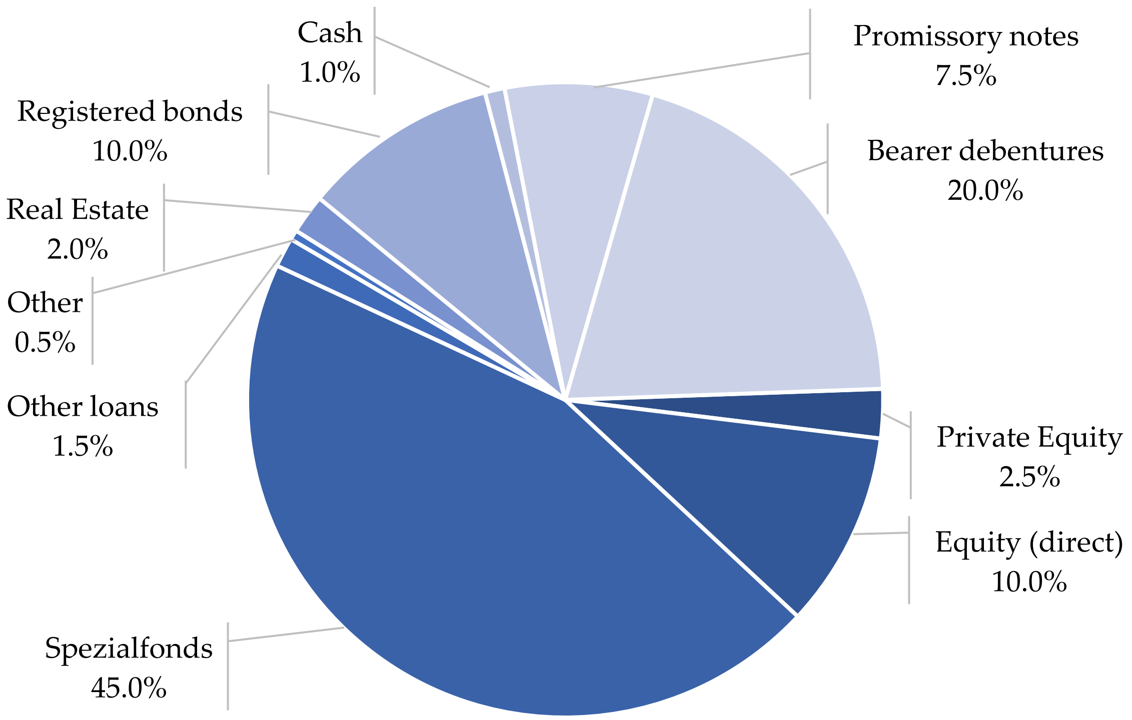

Figure 45: Pie chart of asset portfolio book values at beginning of projection (property/casualty insurance). Reference date December 31st, 2017. Total book value of 75 million Euros.

As mentioned before, for the most part the asset model uses the same *Assetmäntel* as the life insurance model in chapter 3.2.2. However, the portfolio shares may differ as well as the assumed ratios for valuation reserves. Additionally, some *Assetmäntel* were added, which are especially popular investments in the property/casualty insurance sector. If not stated otherwise, the assumptions from chapter 3.2.2 are used.

The total exposure of equity in the portfolio is 20 percent, which is much higher compared to the average life insurer. Of these equities, 50 percent are held directly as *Direktbestand* and 50 percent are part of the mixed *Spezialfonds*. The directly held stocks are 60 percent European stocks and 40 percent world-wide listings. According to the industry average for valuation reserves on stocks as published in the annual reports, the market value of stocks exceeds the book value on average by ten percent.

The proportion of real estate investments is also based on average market figures and comes to 2.0000 percent of the total book value of the portfolio. 2.500 percent have been allocated towards private equity. Multi tranche bonds, callable bonds, borrower's note loans, and annuity loans each make up for 0.5000 percent of the portfolio. These four are marked as "Other" and "Other loans" in Figure 45.

The registered bonds make up for 10.000 percent of total book value, while the promissory notes are given 7.500 percent of the portfolio share. The largest group of fixed income assets is comprised of bearer debentures and makes up 20 percent of the total portfolio. These assets have ratings ranging from AA to BBB and can also be divided into "Euro" and "Global". The total number of positions is 60. The approach for finding adequate coupons and market values equals the one used for the registered bonds.

The remaining part of the asset portfolio is held in the *Spezialfonds*. *Spezialfonds* are even more popular with property/casualty insurers than with life insurers and therefore make up for 45 percent of total book value. The bonds again have both European and global issuer, are a mixture of corporate bonds and government bonds, and are rated between AA and A. Stocks and cash are also added to the fund. The portion of 45 percent of total book value allocated towards *Spezialfonds* appears high at first sight, however, over the past years insurers have put more and more capital into *Spezialfonds* for a number of reasons such as different accounting methods than for direct holdings.

The target allocation is treated the same way as in the life insurance model. It is set to be constant over time. If necessary, a passive reallocation mechanism is applied, which solely uses access cash to reach the wanted quotas for each asset class. This eliminates unwanted effects in the results due to reallocations.

5.2.3. Liability model

The liability model for the property/casualty insurance company primarily defines and parameterizes the lines of business, in which the company operates, as well as the corresponding claims information. The structure of the insurance portfolio is set up to represent a typical German property/casualty insurance business. The majority of the portfolio is composed of long-tail business, which has a relatively high claims reserve compared with its premiums written. This gives the company a larger asset portfolio, which helps with the analysis of the hedging strategy. Furthermore, the liability portfolio does not include any characteristics known form life insurance, such as premium refund for personal accident insurance. This allows for the omittance of a *Rückstellung für Beitragsrückerstattung*.

The claims information is represented through the claims data. For the claims analysis the claims analysis tool RisKey[8] is used. The basic information for each line of business is defined in the gross scenarios (*Bruttoszenarien*) and the reinsurance scenarios (*RV-Szenarien*) define the implemented reinsurance mechanisms for each line of business. Typically, the stochastic claims are defined using probability distributions for both the claims amount and the number of claims. It is further distinguished between basic claims and major claims.

The model company is assumed to operate in seven lines of business. Figure 46 displays the composition of the portfolio by their premiums at the beginning of the projection:

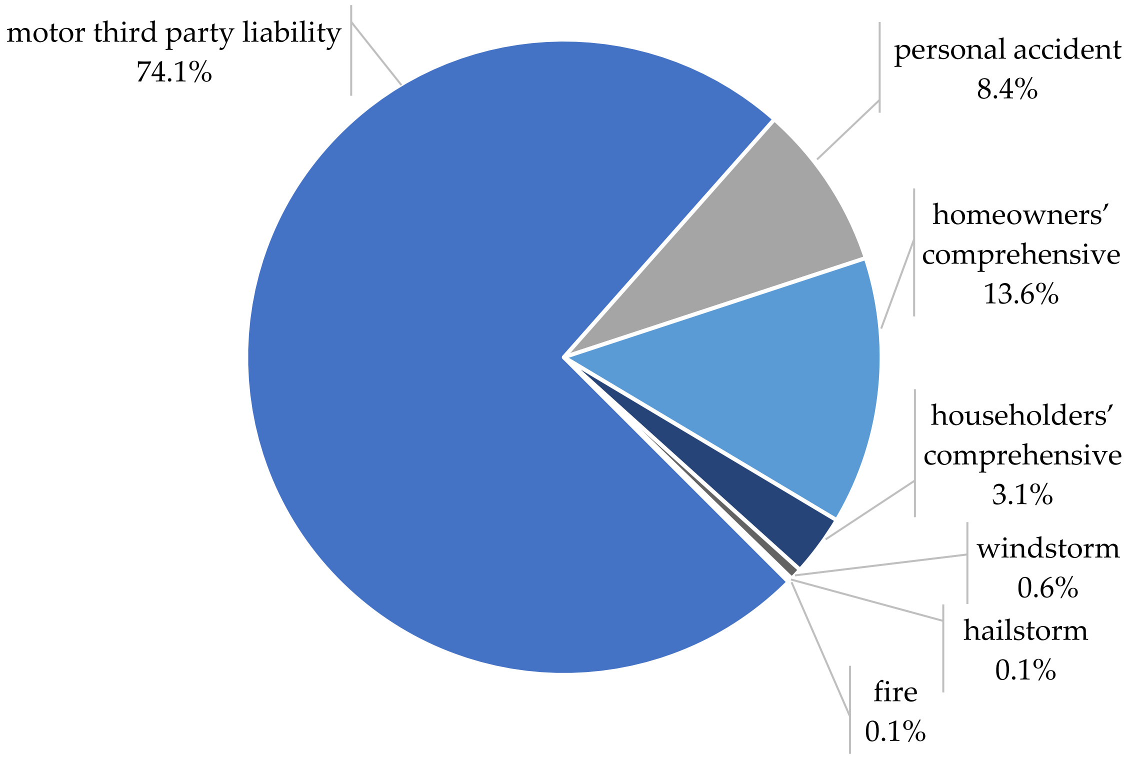

Figure 46: Pie chart of the liability portfolio structure based on the net premiums written at the start of the projection (property/casualty insurance).

The basic motor third party liability insurance claims are modelled with the gamma distribution. Its major claims use the lognormal distribution for the amount, while the distribution for the number of claims is the Poisson distribution. The same goes for the personal accident insurance, although here, the amount uses the Weibull distribution. The lognormal distribution is used to model the basic claims of the homeowners' comprehensive insurance. The underlying distributions for the amount and number of claims are pareto and negative binomial. The claims for the homeowners' comprehensive are the only claims in this sample claims set, which use predefined

[8] RisKey is a product of ROKOCO GmbH. All rights reserved.

claims and claims payments. It therefore does not use any underlying probability distribution. The last three lines of business (windstorm, hailstorm, and fire) are not modelled to have basic claims, only major claims. The distribution for the number of claims is the Poisson distribution for all three of them, however the claims amount is different for each of them. While the windstorm has a Burr distribution for the stochastic simulation, the hailstorm uses a pareto distribution. Lastly, the fire insurance is modelled with a lognormal distribution.

It is possible to use different distributions for each of these lines of business. Pfeifer (2003) describes the various distributions used for claims modelling in the industry, as well as the possible impact of choosing non-ideal ones for the different types of claims. The asset-liability management software has various distributions to choose from, when setting up the claims for each data set. The distributions chosen in the previous paragraph are chosen in accordance with actual settings in the industry and are in line with the analysis of Pfeifer (2003). Nevertheless, in order to keep the focus of this analysis on the asset portfolio, the used distributions are not changed throughout the analysis and are assumed to be given here. Analyzing the effects of changing the distributions could be interesting, however it is omitted here, as it is not the topic of this analysis.

Finally, the model company is assumed to have several typical reinsurance coverages. These include stop loss contracts, quota share reinsurance and surplus reinsurance. This is done to keep the focus on the effects of the hedging strategy and to prevent catastrophic claims events from disrupting the result figures.

5.2.4. Management model

The property/casualty insurance also requires the definition of management rules in the management model. For this work, a set of rules is applied, which concerns all workings of the model company and matches the typical characteristics of a German property/casualty insurer. The exception here are rules, which are omitted to simplify the model, but do not have effects on the analysis of the hedging strategies and the corresponding research questions. As in the previous parts, the management rules will be kept unchanged to ensure the comparability of the results and therefore establish a base-case simulation scenario. The only changes to the management rules will be the activation of the hedging mechanism. There are two types of rules for the property/casualty model: general management rules and rules for the asset model. In the property/casualty model the liability rules are defined through the parametrization of the lines of business in their respective gross scenarios and reinsurance scenarios.

In the general management rules five rules are activated. The minimum annual income (before taxes) (#M1) is set to € 0. In case the limit is not reached, valuation reserves are dissolved. The minimum equity capital (#M2) is set to € 10,000,000. The probability of failing this target in stochastic simulations is documented in the results. 50 percent of the annual profits after taxes are distributed as dividends to the shareholders (#M3). The loss carried forward (#M5), that can be put on the balance sheets, is set to zero. Equity injection (#M7) is active and triggered by the following event: if the solvability ratio falls below 125%, equity is injected to the point of raising the solvability ratio to 135%.

For the asset model the base-case comprises of eleven activated management rules. The type of target allocation (#A1) defines what the values in the target allocation reference to and how the allocation is conducted. For the model company the reference value is the book value and the reallocation style is passive. Therefore, only available cashflows are used to gradually reach the desired book value quotas from the target allocation. The minimum valuation reserves (#A3) will be taken into account, which are defined for each asset class in the asset portfolio. The systematic disintegration of agios and disagios within fixed assets (#A4) is set to be linear. This goes for fixed income assets, which are either accounted for according to German GAAP §341c (*HGB*) or § 253 (*HGB*). Depreciation is conducted according to German GAAP §341b (*HGB*) (#A5). If hidden losses occurred, they would be left standing for one year. Should they remain in the next year, the value of the extraordinary depreciation results from the minimum of the current hidden losses and the ones from the previous year. Further, depreciation on tangible assets and fixed income assets will be avoided if possible. The rate for depreciation on real estate (#A6) is two percent of the purchase value. Asset rule #A8 activates the usage of put options for hedging the selected equity positions of the asset portfolio. This rule is later used to distinguish between the base-case without hedging and the hedge-case, in which the hedging strategy is applied. This rule further defines the risk-free rate used for the valuation of the put options. The credit default model (#A10) uses rating migration, which is defined in the capital market model. Valuation reserves on *Spezialfonds* (#A12) will be dissolved by returning shares of the fund, instead of extraordinary appreciation. Cash is not given any interest during the year (#A14). Since both callable bonds and annuities are included in the asset portfolio, rules #A15 and #A16 are active, which set the parameters for these two asset classes. The volatility of callable bonds is ten percent and the calls take place after three years. The repayment rate for annuities is 15 percent. The tax rate is defined in the other parameters. It is held constant at 30 percent.

5.3. Results

5.3.1. Structure of the analysis

The general outlay and approach of the analysis is equivalent to the previous parts, using a pyramidal structure with three layers. It also features the vertical segments, which help allocate the various elements of each layer towards a goal. These again address the two key aspects of operating a business: profitability and security. As this analysis is done for the property/casualty insurance sector, the used key figures differ compared with the ones used for the life insurance model. The main key figures are the target variables, the underwriting result, the non-technical result, the net profit, and the combined ratio.

The underwriting result is the result of insurance operations from all lines of business combined. It includes reinsurance effects and the change in the equalization reserve (*Veränderung der Schwankungsrückstellung)*. Hedging in the asset portfolio is not expected to affect these insurance operations.

The non-technical result represents the results from asset management operations and interest. In this key figure the effects of the hedging mechanisms should be visible.

The analysis also focuses on the target variable net profit. It describes the company's result net of all transfers to and from the insured and is the key determinant of the value of the shareholders' distributable benefits.

The last target variable is the combined ratio. This key figure describes the relation between underwriting expenses and claims incurred to written premiums. This ratio is one of the most commonly used key figures when analyzing property-casualty insurances as it gives an indication for the profitability of the insurance company.

The second layer of the pyramidal analysis structure consists of the following control variables: The strategic asset allocation (SAA) is determined before the simulation and is held constant over time. It serves as a control variable for the purpose of ensuring that observed effects do not appear due to changes in the strategic asset allocation, but solely due to the applied hedging strategy.

The change in the equalization reserve is also controlled for. The equalization reserve itself is a reserve for buffering fluctuations in claims experiences. Property-casualty insurances are regulated on how to build these reserves for the various lines of business, however, there is a margin for management decisions. This margin is acted out in the change in the equalization reserve. Management can influence the company results with this key figure in the profit and loss statement, therefore, it is an important control variable for this analysis.

Another control variable is equity capital. It is a major determinant of how financially stable an insurance company is. The notion of going-concern is more likely for a financially secure firm than it is for an "under-financed" company. This is one of the foremost interests of the insured. The equity capital also is a key figure for the shareholders, since parts of the annual profit can be allocated towards equity capital growth and therefore profit the shareholders.

The last control variable is hedging. This is the variable that is changed between the base-case and the hedge-case in order to observe the changes on the model company's results when using a specific hedging strategy. It is controlled by the settings in the management model.

For further insights into the working mechanisms of this analysis, the third pyramidal layer is added, which features the following observatory variables:

The first additional key figure is the net premiums written (*verdiente Netto-Beiträge*). It is the main generator of income from the insurance business. The model company was given some typical reinsurance contracts for the various lines of business in order to smooth effects from major claims. Since the focus of this analysis lies on the asset side of the company, this is viewed as given. Consequently, it makes sense to look at the net figure after reinsurance.

Another observatory variable is the valuation reserve. The level of the valuation reserve gives indications on the financial flexibility of the firm, as higher levels allow for the possibility of compensating losses with extraordinary proceeds from the dissolution of such valuation reserves. Furthermore, the valuation reserve lets one draw conclusions on the risk-bearing capacity, for the same reasons as the financial flexibility.

The net return on capital investments (*Nettoverzinsung*) is the third observatory variable in the analysis. Net returns solely measure the hedging effectiveness on the asset side of the company's balance sheets, separated form interactions with the liabilities, making it a figure especially relevant from a German-GAAP-perspective.

The fourth observatory variable is the costs, more precisely the cost-ratio. It is defined as the costs incurred for insurance business divided by the net premiums written. Since the hedging strategy should only apply to the assets of the insurer, this control variable checks that there are no effects of the hedges on the insurance business on the liability side.

Further, the claims reserve is analyzed among the observatory variables. Being the major reserve on the balance sheet of the company, this reserve should be observed during the analysis.

Lastly, the equalization reserve is added as an observatory variable. As described earlier, the equalization reserve is a reserve for buffering fluctuations in claims experiences. This mandatory reserve is flexible to some degree and can "breathe" depending on its management. It represents an aspect of security for the firm and the insured and is therefore added to the variable selection.

Figure 47 displays the schematic of the analysis pyramid:

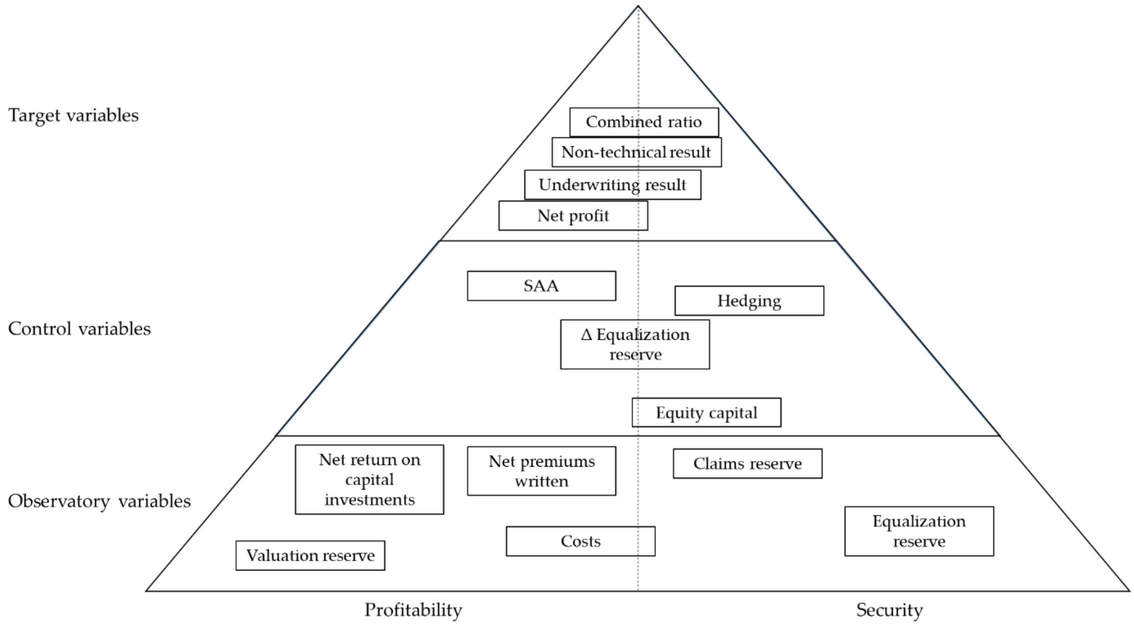

Figure 47: Pyramidal analysis structure with key figures (property/casualty insurance). Own representation.

5.3.2. Analysis of results

Following the approach used in the life insurance chapter, the results of this property/casualty insurance analysis display comparisons between a hedge-case and the results without the hedging strategy, the base-case. The results show the boxplots of the result distributions as well as a best-case scenario and a worst-case scenario, which was already defined in chapter 3.3.2 of this work. In the following, the results of the property/casualty insurance model are presented.

5.3.2.1. Observatory variables

5.3.2.1.1. Net premiums written

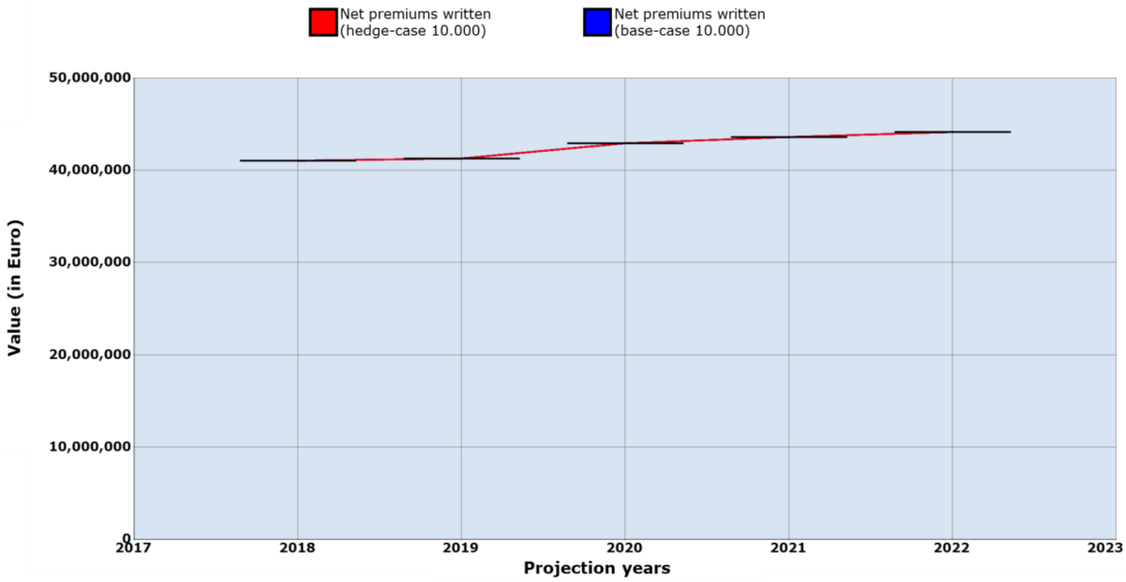

Figure 48: Box plot of net premiums written (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario. All lines overlap here.

As expected, the level of the net premiums written increases slightly with each projection year. Since the various lines of business are modelled with some small growth, the development of this key figure is deterministic without any volatility. There is no difference between the base-case and the hedge-case. This is a positive result, as it indicates that the simulation software works: a hedging strategy, which is applied towards the assets of the model firm, should not have any effects on the generated income from the actuarial business. In order to control for the same effect, this check is also done with similar key figures, which are not described further here. Also, the hedges do not affect the reinsurance contracts. This should be stated, since the looked-at key figure is net of reinsurance effects. The level of the net premiums written in the first year is 41.049 € million and increases towards 44.154 € million in the fifth projection year.

5.3.2.1.2. Costs

As defined earlier, the costs (of the insurance business) should stay unchanged when applying the hedging strategy because the costs for the purchase of put options are modelled in the asset model, not in the cost model. Figure 49 shows that the cost-ratio is identical for both scenarios. The control variable therefore verifies that the hedging strategy is implemented correctly in the model.

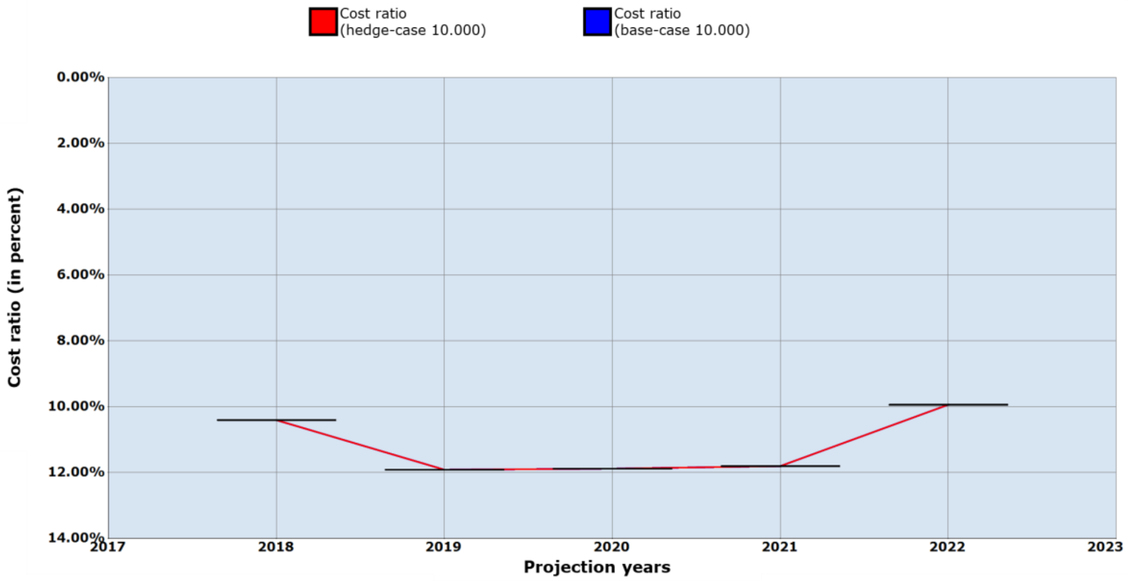

Figure 49: Box plot of cost ratio (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario. All lines overlap here. The vertical axis is inverted.

5.3.2.1.3. Valuation reserve

The next observatory variable with focus on the profitability perspective in the analysis pyramid is the valuation reserve. The distributions of the valuation reserve within the 25 percent and 75 percent quantile shows a slight reduction in volatility when the hedging strategy is applied. It can be measured by subtracting the two quantiles and comparing the differences between the two cases. In the base-case, the difference equals 11.575 € million, whereas the difference for the hedge-case only comes to 11.139 € million in the fifth projection year. This is 0.436 € million less in the hedge-case.

However, this reduction in volatility comes at the price of lower potential upside, as can be seen when looking at the upper lines, the best-case scenario. The rationale behind this effect lies within the reallocation mechanism of cash in each period. In case the capital gains of one period surpass the capital losses, the remaining cash position is (partially) invested in new assets. In positive capital market conditions higher investment amounts lead to higher valuation reserves. The logic of compound interest contributes to this effect. Consequently, when the cash position used for new investments is reduced by the costs of purchasing hedges, the base-case with a slightly higher investment amount each year, starts to raise a gap towards the hedge-case's valuation reserve. In the second year, the base-case is at 20.793 € million, while the hedge-case is 0.053 € million lower. In the last projection year, the valuation reserve in the base-case reaches a level of 36.670 € million, while the hedge-case is 0.244 € million lower, at 36.426 € million.

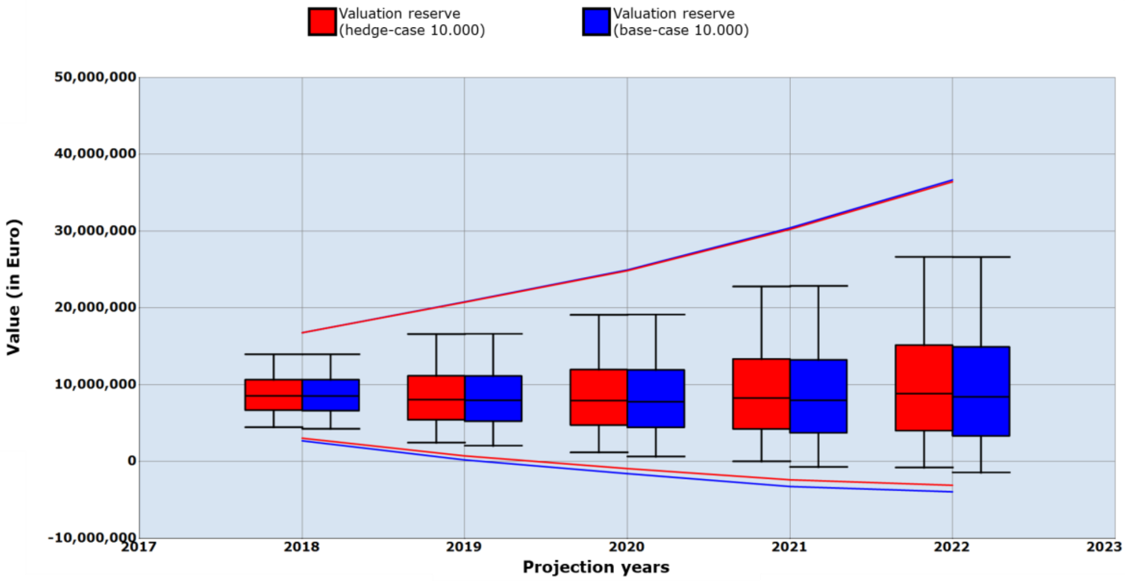

Figure 50: Box plot of valuation reserve (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

From the worst-case perspective, the hedging strategy appears to help considerably in stabilizing the valuation reserve. The hedge-case level is constantly above the respective base-case level and the gap between the two (bottom two lines) grows larger over the time of the projection. While the valuation reserve is still positive in the first two years, they become negative in both cases from the third year on. Finally, in the fifth year, the base-case is at -3.945 € million. With the application of the hedging strategy, the hedge-case is able to come in 0.851 € million higher, at -3.094 € million.

5.3.2.1.4. Net return on capital investments

The fourth key figure of the observatory variables in the analysis of the benefits and disadvantages of the underlying hedging strategy is the net return on capital investments. It is preferred over the *laufende Durchschnittsverzinsung* here, since gains from puts are declared as extraordinary income, which are only included in the net return on capital investments. It most clearly captures the effects of the hedge on the performance generated through the assets.

Comparing the box plots in Figure 51, it is clearly visible that the median value as well as the adjacent quantiles are lower in the hedge-case in each projection year. Furthermore, it can be observed that the volatility in the base-case is higher than in the hedge-case: While the spread between the five percent and the 95 percent quantiles is 1.458 percentage points (first projection year), it is 0.510 percentage points lower in the corresponding hedge-case.

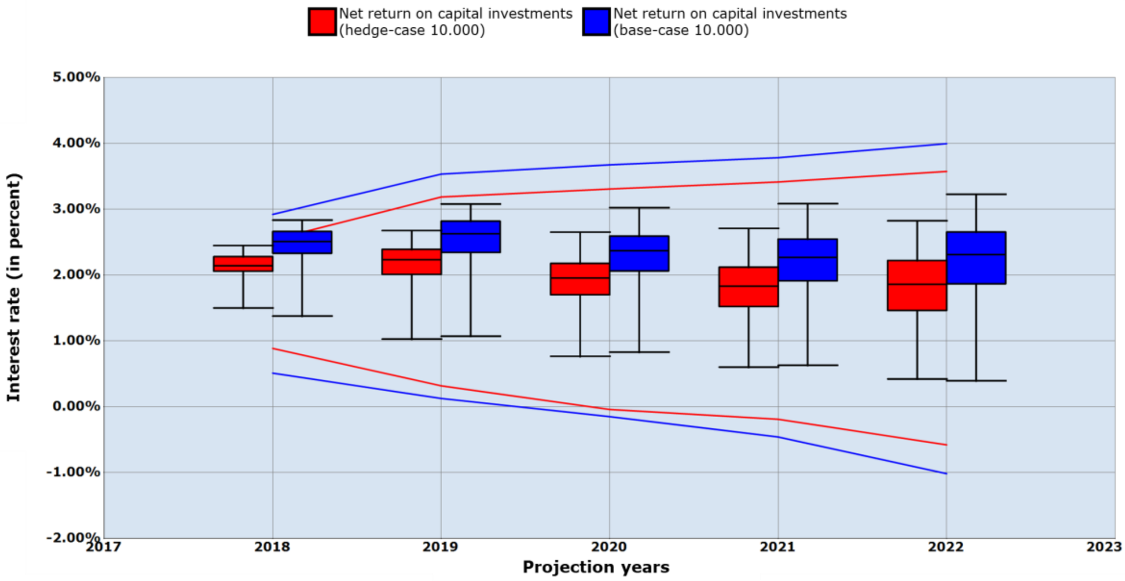

Figure 51: Box plot of net return on capital investments (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

Looking at the worst-case scenario, the bottom blue line represents the one percent quantile of the base-case. In year one, it is at 0.509 percent, while it is at -1.018 percent in the last projection year. In comparison, the red line displays the same quantile of the hedge-case. It can be clearly seen that the hedge-case is always higher than the base-case. In fact, it is at least 10.8 basis points higher in every single projection year. These positive differences show that the application of the hedging strategy reduces the downside risk by generating additional returns from the put options in case of significant downturns of the markets.

As the puts are in-the-money in negative capital market scenarios, they are out-of-the-money in positive scenarios. In these cases, the puts have a valuation of zero and therefore only contribute to the profit and loss statement with its costs of the purchase. Thus, it is plausible, that in the 99 percent quantile the roles of the base-case and the hedge-case are reversed. The red line (hedge-case) is now below the blue line of the base-case. In the fifth projection year the difference is -42.2 basis points, with 3.573 percent compared to 3.995 percent. As the hedging strategy leads to the positive effect of reducing the downside risk, this reduction of volatility also automatically leads to a reduction in upside potential, as the costs of purchasing the hedge are deducted from the capital gains in positive capital market situations.

5.3.2.1.5. Claims reserve

Due to the high portion of long-tail business in the portfolio mixture of the model company, level of the claims reserve is relatively high (in relation to net premiums written). In the first projection year the median claims reserve is 51.283 € millions, which is 125 percent of the net premium. Over the time of the projection, the claims reserve fluctuates slightly and reaches a median level of 48.153 € million in the fifth projection year, as shown in Figure 52.

Figure 52: Box plot of claims reserve (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Top two lines overlap here. Bottom two lines display worst-case scenario. Bottom two lines overlap here.

A difference between the claims reserve in the base-case and in the hedge-case is neither visible in the median, nor in any of the quantiles. It appears that the capital market situation does not affect the claims reserve. As its calculation is solely dependent on the insurance activities and the calculation parameters set by the law maker, this is a positive result showing the correct workings of the simulation mechanism.

Although, the hedging strategy does not affect the claims reserve, the level of the reserve has an implicit impact on this asset-focused analysis. The higher the claims reserve is, the higher are the total liabilities and the balance sum, respectively. This lengthening of the balance sheet leads to more assets for the company. And through the increased amount of assets, the non-technical result, which basically is the result from asset management, gains in importance compared with the underwriting result. Also, the size of the claims reserve has effects on the cash flows of the company and its liquidity. Therefore, with a growing portion of long-tail business and consequently an increase in claims reserves, asset management mechanisms, such as hedging strategies, grow in significance for the final profit figures of the insurance company.

5.3.2.1.6. Equalization reserve

The equalization reserve is a reserve that is typically built to compensate volatility of the insurance activities. And the fact that the equalization reserve is tax balance relevant, makes this reserve even more interesting for companies. The calculation formula for the reserve is specified by the regulator and does not include any interest related parameters. The equalization can be influenced by historic data and reinsurance, but not through asset strategies. Therefore, it is not expected to see effects form the application of the hedging strategy in the results.

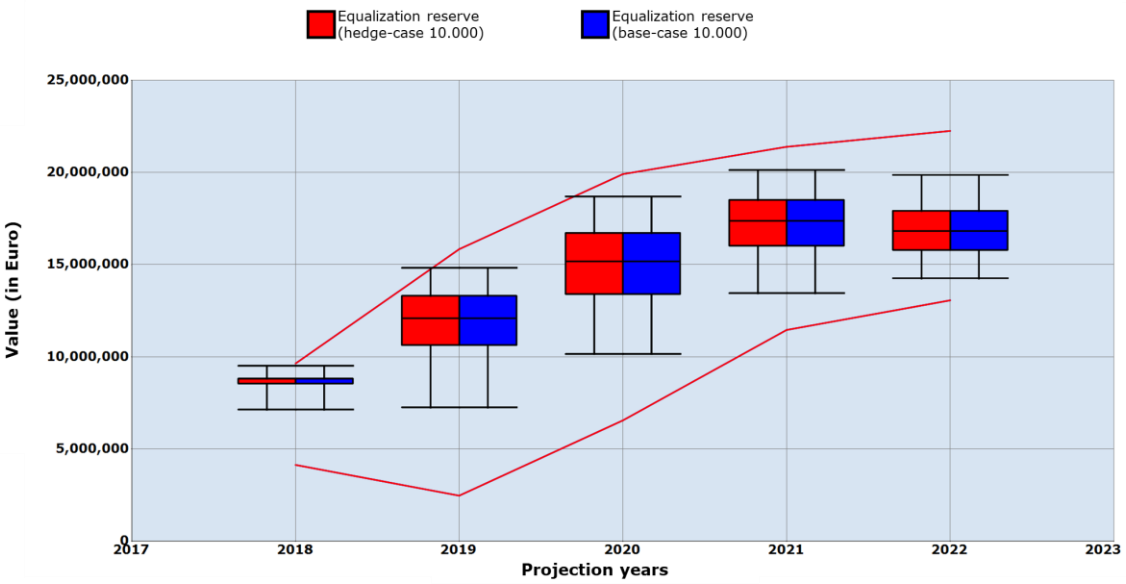

Figure 53: Box plot of equalization reserve (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Top two lines overlap here. Bottom two lines display worst-case scenario. Bottom two lines overlap here.

In the first projection year, the median reserve is at 8.810 € million. It increases up to around 17 € million in the last two projection years. The range between the worst-case and best-case scenario is as large as 13.374 € million in the second projection year, which shows the substantial effects of loss events towards the calculation of the equalization reserve.

However, same as for the claims reserve, the equalization reserve has an implicit consequence for the general role of hedging in the profit figures of the company: An insurance firm that writes significant portions of its business in very volatile lines of business such as storm insurance, the equalization reserve is typically high. The higher this reserve, the higher the total liabilities. With higher liabilities, there are more assets to manage and therefore, the significance of the non-technical result grows larger in comparison to the underwriting result.

5.3.2.2. Control variables

5.3.2.2.1. Strategic asset allocation

Both the base-case and the hedge-case use the same setting for its strategic asset allocation. The reallocation is done passively, which leads to a gradient transition of the asset portfolio towards the target portfolio. In both the base-case and the hedge-case, the allocation of assets within the portfolio in percent of total market value is the same, showing that the allocation process is independent from the application of the hedging strategy.

5.3.2.2.2. Change in the equalization reserve

The change in the equalization reserve is an important control variable, due to its importance in classical corporate management for property/casualty insurers. When extreme loss events occur, substantial impact on the property and loss statement can follow, because it includes the change in the equalization reserve. In such cases, this can have an impact on capital measures. A typical example would be the triggering of a measure that leads to the dissolution of valuation reserves in order to prevent negative net profits. In the model company, management rule #M1 is set for this scenario.

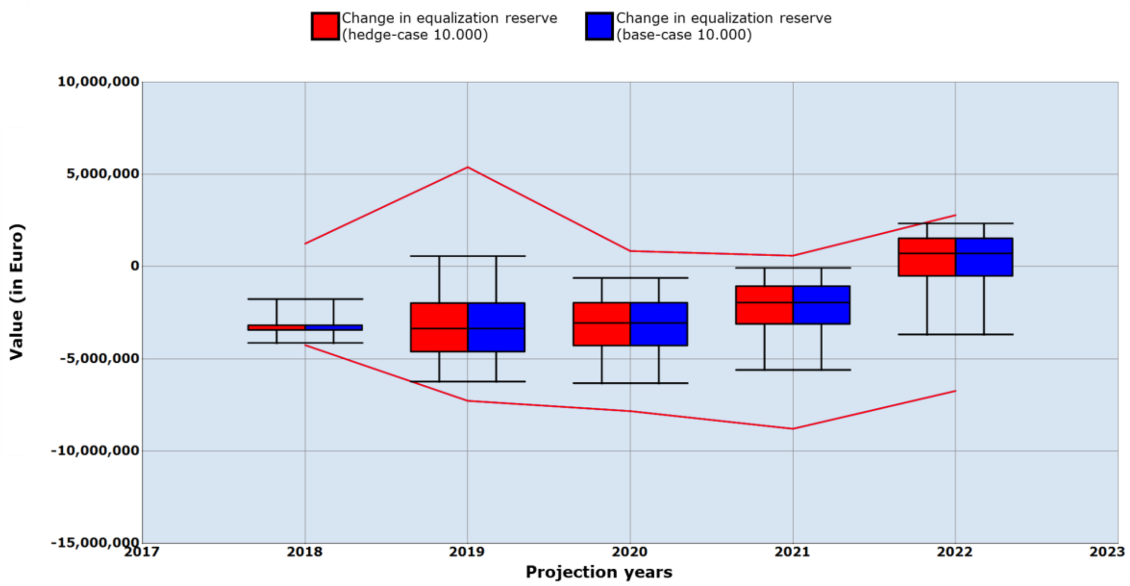

Figure 54: Box plot of change in the equalization reserve (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Top two lines overlap here. Bottom two lines display worst-case scenario. Bottom two lines overlap here.

Visible in Figure 54, there are no differences between the hedge-case and the base-case simulation. This is in accordance with the observatory variable equalization reserve.

The median change in the first projection year is -3.435 € million. The following years the median change becomes less negative and finally becomes positive in the last year. The quantiles show no other substantial movements that are not in line with the expected development.

5.3.2.2.3. Equity capital

The observatory variable equity capital is highly dependent on the control variable net profit. Nevertheless, it serves well to give an indication of the financial stability of the model firm. It also allows to control for possible capital injections by the shareholders in case of undercapitalization of the firm.

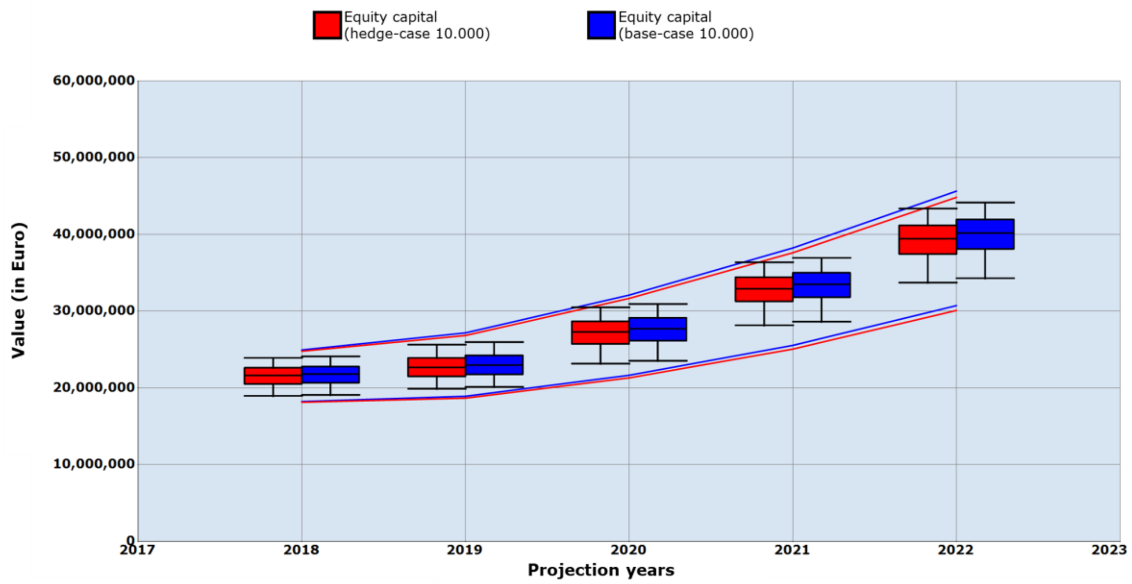

Figure 55: Box plot of equity capital (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

The model firm's equity capital continues to rise over the projection time. The volatility appears to not be affected substantially by the hedging strategy. The first-year median level of the equity is at 21.796 € millions (base-case) and rises to 40.181 € million over the time of the projection. This increase in equity capital is caused by the always positive net return during the projection.

Since the equity capital is mostly a residual key figure, the effects are slightly smaller than seen with other key figures. This is due to the many mechanisms that come into play for insurance firms' accounting, where the hedging effects are one of many. Nevertheless, these effects are clearly visible.

5.3.2.2.4. Hedging

In this analysis, the applied hedging strategy is the usage of put options to hedge equity risk. The base simulation does not use any hedging strategy, while the hedge-case utilizes such put options. As described in the first part of this chapter, this is the variable that is actively changed to distinguish between the base-case and the hedge-case.

5.3.2.3. Target variables

5.3.2.3.1. Underwriting result

The underwriting result is the result, which stems from the insurance business. It combines all lines of business and aggregates them. It includes the written premiums, the reported losses, run-off results of the reserves, injections and withdrawals to them, as well as changes in the equalization reserve. And it is net of all reinsurance effects. It basically sums up the activities on the liability side of the insurance company.

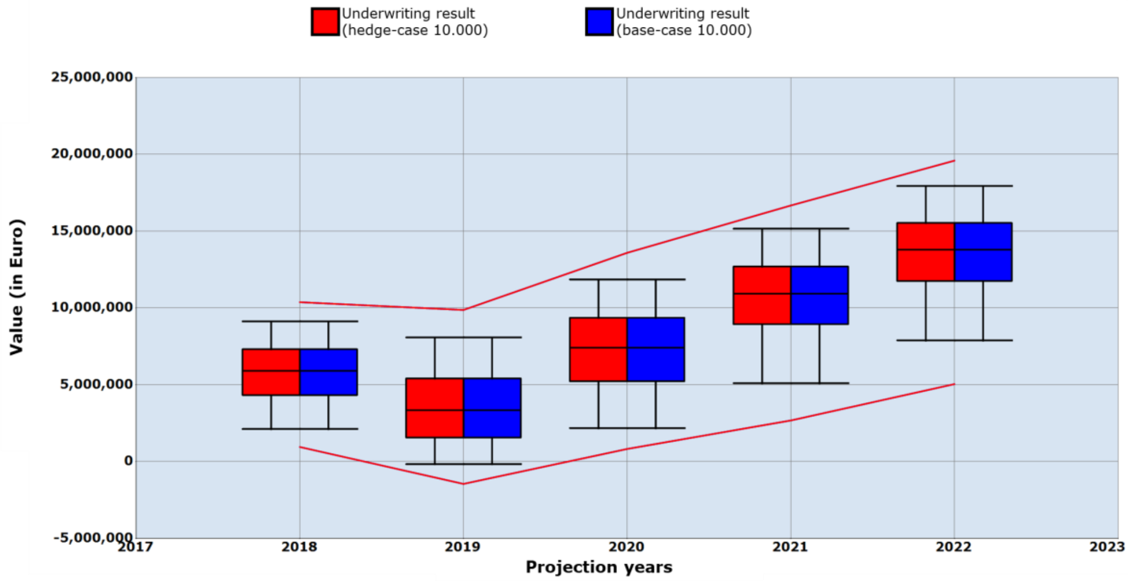

Figure 56: Box plot of underwriting result (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Top two lines overlap here. Bottom two lines display worst-case scenario. Bottom two lines overlap here.

In the first projection year, the underwriting result is 5.903 € million at the median, while the worst-case and the best-case scenarios are at 0.946 € million and 10.373 € million, respectively. In the second projection year, there is a downturn with a worst-case result of up to -1.459 € million. This negative development is due to extreme losses in the stochastic simulation. For example, in the worst-case scenario (scenario number 7,999) the projection year 2019 had a massive hailstorm combined with a devastating year in the motor third-party liability business. While the hailstorm line of business booked a line-of-business-specific underwriting result of -1.976 € million, the motor third-party liability result was -0.369 € million. The model company was only slightly able to compensate these results through the other lines-of-business. However, the following years all had positive underwriting results with a median result in the last projection year of 13.789 € million.

Figure 56 does not show any differences between the base-case and the hedge-case, which makes sense. As stated before, the underwriting result solely focuses on the liability side of the company and therefore hedging strategies for the asset portfolio do not show up in these result figures.

Nevertheless, there are some interactions with the asset side: In line with the management rule, which addresses issues around a minimum net profit, negative underwriting results can trigger the dissolution of valuation reserves. As commonly seen in practice, this rule is set for the conducted simulations, which means that in scenarios, in which the underlying result is negative enough to overweight the anticipated non-technical result, valuation reserves are used to try to at least reach the minimum net profit. For the model company, the minimum net profit is set to be zero.

5.3.2.3.2. Non-technical result

The non-technical result is where the hedging strategy shows its effects. In general, the non-technical result includes the income and expenses from capital investments as well as other income and expenses. Since the latter two do not apply to the model company, the non-technical result is equal to a result from capital investments and therefore corresponds well to the earlier discussed net return on capital investments. Since the hedging strategy with puts for the equity positions in the asset portfolio is solely based on the assets, it is expected to appear in these results.

After this position in the property and loss statement, there is only the aggregation with the underwriting result left until the result form ordinary business activity is derived. This means that just as with the underwriting result, the non-technical result goes directly into the net return (after taxes), without any redistribution mechanisms like the ones known from the life insurance business.

The median value for the base-case in the first projection year is 1.992 € million and 2.466 € million in the fifth year. In comparison, the hedge-case values are 1.696 € million and 1.970 € million, respectively. These differences are due to the fact that the hedging instruments cost money and are not in-the-money in the median scenarios. Nevertheless, the positive aspect of the hedges can already be seen solely looking at the box plots: With the hedging strategy in place, the volatility of the results clearly reduces. The spread between the crow feet of the box plot (between the five percent and the 95 percent quantile) is much smaller compared to the base-case. In the projection year 2018, this spread is 1.162 € million for the base-case, while it only is

0.756 € million in the hedge-case. The difference is more than 400.000 € and while it decreases during the projection, it peaks in the last year at 0.477 € million.

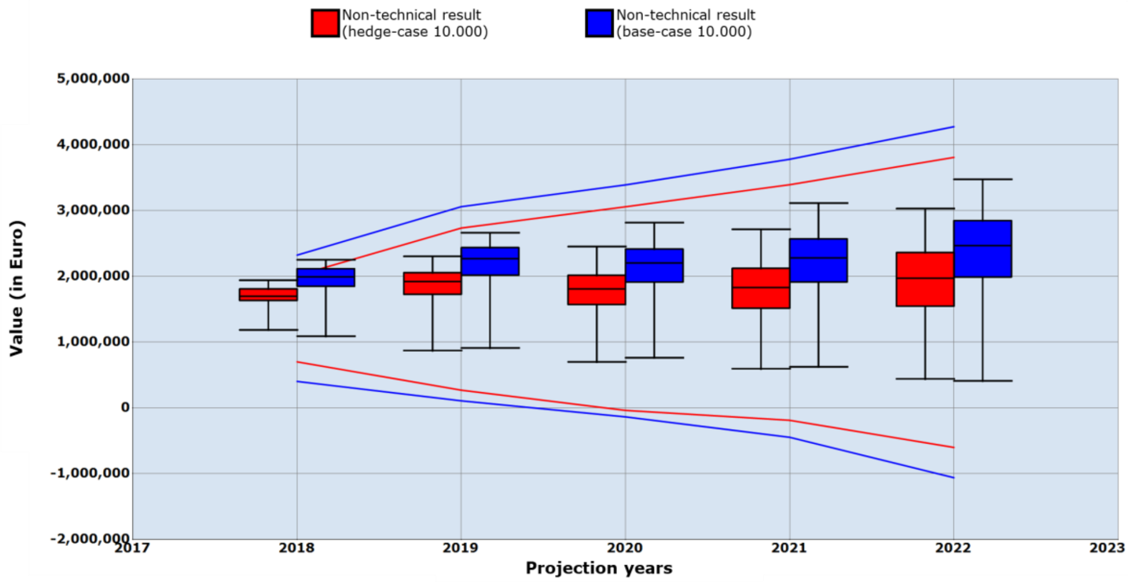

Figure 57: Box plot of non-technical result (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

In the worst-case scenario this effect is seen even clearer. The hedge reduces the worst-case result by 0.297 € million in 2018 and by 0.460 € million in the last projection year. This shows that the hedges indeed reduce the downside risk for this result figure, but the cost of it can be seen in the best-case scenario: the hedges not only lead to expenses from the purchase, but also reduce the investable cash, which is especially unfortunate in scenarios with very positive capital market developments. In the last projection year, the hedge-case only lies at 3.808 € million, whereas the base-case result is 0.466 € million higher at 4.274 € million. Interestingly, the absolute value difference is higher in the best-case scenario than in the worst-case scenario, which means that the hedge is quite expensive.

5.3.2.3.3. Net profit

The net profit of the model company is the third target variable of the analysis, as it is after all the ultimate result figure and the representation of the firm's profitability. It combines the result from insurance activities over all lines of business and the non-technical result.

Overall, the model company is able to grow its net profits over the projection time, with a set-back in the second projection year, which nonetheless is still a positive profit. In the base-case, the lowest median net profit (in the year 2019) is 3.829 € million, while the highest median net profit is 11.264 € million.

The first observation drawn from Figure 58 is that the hedge-case is lower than the base-case in all of the quantiles of the box plot as well as in the best-case and the worst-case scenario. In the best-case scenario, the net profit of the base-case simulation starts at 8.616 € million and increases to 15.540 € million over time, while with hedging the values are at least 0.163 € million lower in any of the projection years. The lowest worst-case net profit for the base-case is 0.284 € million in the second projection year and even here, the hedge-case is 0.141 € million lower at a level of 0.144 € million.

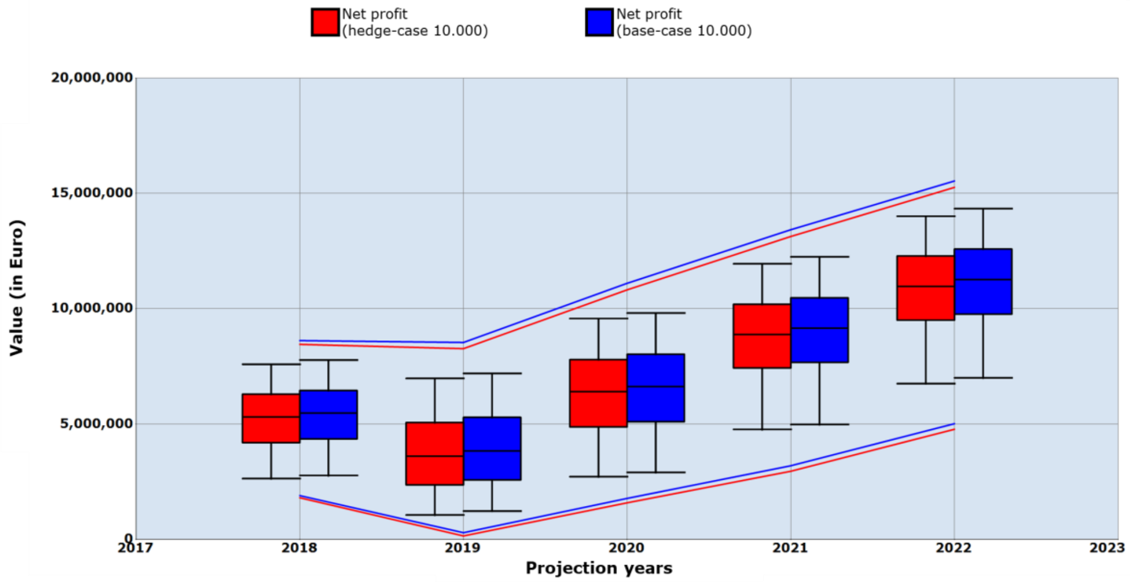

Figure 58: Box plot of net profit (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Bottom two lines display worst-case scenario.

The rationale behind these results is twofold: Firstly, it is important to point out the dimensions of the non-technical results in comparison with the underwriting results. For the model company displayed in this analysis, the underwriting result is much more significant than the non-technical result. In the last projection year, it actually is more than five times as large. In the underwriting results, the hedging effects do not surface. In the non-technical result, they were visible, but the scale of the y-axis is four times larger in the net profit, so the small differences in the non-technical result become even smaller in the net profit.

Secondly, the mechanism of simulation and the structure of the box plots and quantile displays can lead to false interpretations when simply looking at the three result plots. As mentioned before, the here defined best-case and worst-case scenarios are not each one specific scenario of the 10,000 simulations. They are the depiction of the respective quantile result in each projection year. This for example means that the median value in the underwriting result is not from the same capital market scenario as the same median value in the non-technical result. It is therefore not correct to simply add the values seen in Figure 56 from the underwriting result and Figure 57 from the non-technical result together to get to the net profit in Figure 58. The simulation software calculates the net profit for each scenario and then displays the resulting distribution of these results. As all negative capital market scenarios do not necessarily fall together with all the extreme loss events, this differentiation should be stressed here.

The results of this analysis suggest that for a property/casualty insurer an extreme loss event, which is not fully covered by reinsurance, is worse than a capital market crash. In this analysis, the lowest observed worst-case *Marktwertverzinsung* is at around -10 percent. At approximately 80 million assets this would mean a loss of 10 € million. In comparison, the worst-case loss event was at around -60 € million.

In the worst-case scenario, when the risk-bearing capacity is significantly impaired, the company dissolves valuation reserves. Among these valuation reserves are the equity positions, which are hedged with the put options. If the need is strong enough however, the equity positions are also sold and thus there can be worst-case scenarios, in which there are not any equity positions left that can be hedged. Which then explains, why there are no substantial positive effects from the hedges in the downside.

5.3.2.3.4. Combined ratio

The combined ratio provides information on the claims and cost intensity of the underwriting business and allows for comparison with competitors. If the combined ratio is below 100 percent, the underwriting business is profitable. Since the underwriting result is the predominant figure in property/casualty insurance, the combined ratio is the premier key figure for practitioners, especially in market comparisons.

Since the combined ratio is solely related to the underwriting side of the insurer, it is expected to not reflect any activities in the asset portfolio, including the analyzed hedging strategy. Nevertheless, it is essential for ensuring a realistic set-up of the model firm.

Figure 59 is displayed with an inverted vertical axis, since it is beneficial for the company to have a low combined ratio and thus the best-case scenario is at the top. Overall, the median combined ratio is at a very healthy level. Its lowest value is in the last projection year at 69.537 percent, while the highest median value is at 82.537 percent in the second year. In none of the quantiles is a difference between the base-case and the hedge-case, which matches the initially stated expectation.

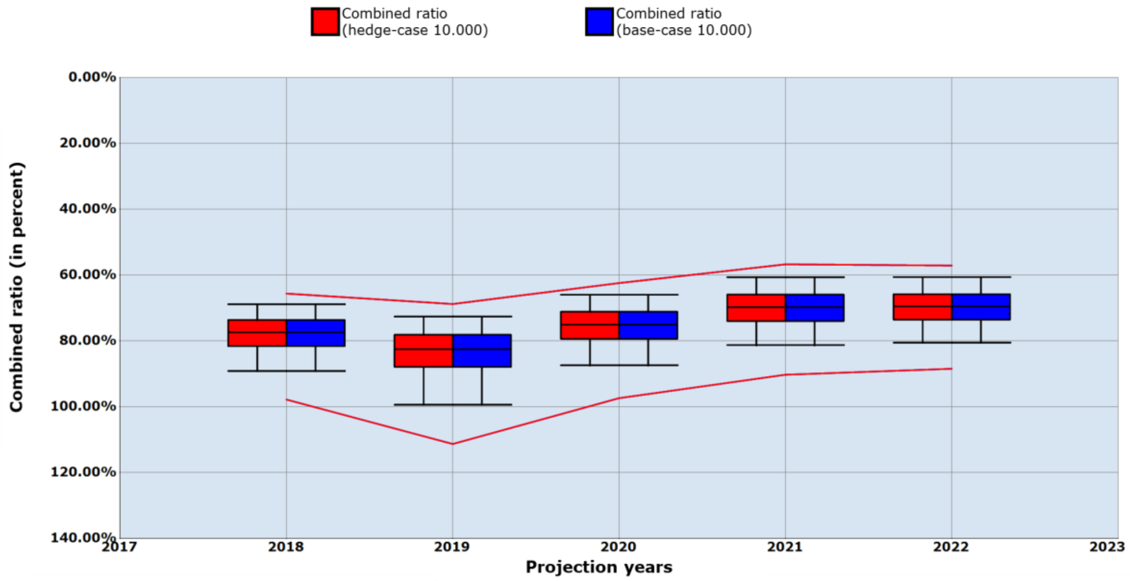

Figure 59: Box plot of combined ratio (property/casualty insurance). The bold black lines display box plots, in which the quantiles (5%, 25%, 50%, 75%, 95%) (partially) overlap. The order of the box plots corresponds to the order of the legend from left to right. Top two lines display best-case scenario. Top two lines overlap here. Bottom two lines display worst-case scenario. Bottom two lines overlap here. The vertical axis is inverted.

5.4. Interim conclusion

This analysis shows that using put options to hedge equity risks in the asset portfolio of a property/casualty insurer is a valid approach to reduce down-side risk in the non-technical result. However, the costs for this type of hedging strategy have negative effects on both the median and the best-case scenarios of the general result figures. This could make the hedging strategy unattractive for management boards, which have to fulfil certain profit targets.

It is further found that the effectiveness of the hedging strategy depends on the importance of the non-technical result for the company. Especially for non-life insurers with short-tail business the technical result generally outweighs the non-technical result, which then makes equity hedging with put options insignificant from a general company perspective. The more the business shifts to long-tail business (taking on characteristics and challenges life insurers must deal with), the more relevant the results from the asset management become for the company's net profits. This then makes hedging strategies, which specifically target the assets, more relevant and possibly effective.

Another major finding is that in comparison with extreme loss events on the liability side, an equity market crash appears to be not as severe for the analyzed property/casualty insurer. Even with reinsurance, the models for catastrophic underwriting risks generate losses that strongly outweigh comparable turmoil at the stock market even though the equity proportion of the model company was set to be quite high. Furthermore, it is very likely that in the event of two simultaneous catastrophic events both on the liability and the asset side, the liquidation mechanisms for assets and their valuation reserves would most likely have led to the sale of the equity portfolio, making its hedging strategy obsolete.

6. General conclusion

A key aspect of managing an insurance company is handling the interdependencies that asset-liability management entails. This means that while enabling the firm to grow and ensuring a competitive financial strength, returns from both the insurance operations as well as the investment activities have to be generated, risk bearing capacities have to be reached and sufficient solvability has to be upheld. Since all these factors are linked with each other, the interdependencies need to be accounted for at all times. In this work, the role of the interdependencies is made out to be a major factor for the effectiveness and direction of action for the examined hedging strategy. In a setting, where the asset side and the liability side are intricately connected, hedging presents itself as an effective tool for the management to meet their targets and ensure them.

In this context, this work raises questions on the effectiveness and the direction of action for this management tool and answers these questions with a scientifically sound approach in a realistic and practical environment. Two dimensions are defined, under which the effects of the hedging strategy are evaluated: profitability, representing the shareholder perspective, and security, which represents the perspective of the insured.

The first result chapter on life insurance shows that from a profitability perspective, the gain on the downside from using the hedging strategy clearly exceeds (by factor 20) the loss on the upside. At the same time, the security perspective is unaffected by the hedge. With regards to the proposed research questions, these results clearly indicate that the usage of the hedging strategy is beneficiary for shareholders and investors. It should further be unopposed by the insured, since they do not experience negative effects along the security perspective. This concludes that between these two parties there is no trade-off to be decided.

The results from the capital market sensitivities chapter contribute additional information on the effectiveness of the hedging strategy. The intensity and the speed of the effects is influenced by the general situation of the capital markets. In situations with higher overall returns generated at the capital markets, i.e. a higher interest rate level like in the up-scenario, the effectiveness of the hedging strategy is comparable to the base-scenario. In low interest rate situations, as examined in the down- and the Japan-scenario, the hedge becomes more effective from a profitability perspective. The effectiveness here is measured on the net profit, more specifically on the magnitude of the loss in the upside compared to the gain on the downside due to the hedge. The results of this second analysis endorse the answer towards the research question concerning an asymmetric mechanism of action for the hedging strategy stemming from the *Mindestzuführungsverordnung* of the German life insurance regulation. In capital market situations, in which (net) profits are vanishing even in the best-case scenarios, the asymmetry in the profit distribution under regulatory law protects the insured and bundles the losses at the shareholder side. As the hedging strategy takes its effect on the key figures attributed to the profitability perspective, the hedge becomes more effective, the more losses are incurred here. Therefore, shareholders will want the management to use such hedging strategies, because they will not expect high capital returns anyway, are typically more interested in stable results, and more importantly will want to limit their risk of capital injections, or at least the size of these injections. This leads one to conclude that the desire for more hedging will rise with a worsening of the profit situation of the company.

The chapter surrounding the property/casualty insurance set out to validate the results from the previous two chapters and to check whether similar effectiveness is measurable in a setting, in which the regulatory framework does not dictate such an asymmetric profit distribution as seen in life insurance. The results show that the hedge indeed reduces the downside risk in the non-technical results. However, this comes with a reduction of both its upside potential and its median. This differs from the results in the life insurance, as there are no indications for asymmetries here. The magnitude of the downside-reduction does not clearly outweigh the loss in upside. This makes the hedge simply an instrument for reducing volatility, while the costs for the hedge reduce not only the upside, but also the median result. Furthermore, the results help understand, for which type of business this hedging strategy is effective. For property/casualty insurer the asset management does not play as much of a dominant role as it does for life insurance companies. The difference depends on whether the business model is focused on long-tail business or on short-tail business. The longer it is, the more important the results from investment activities become. For a short-tail focused property/casualty insurer, the underwriting results outweigh the non-technical result by a multiple. Small nuances of betterment in the asset performance just do not matter for the net profit compared to significant loss events in the underwriting results. However, for long-tail business, which life insurance is the ultimate form of, the impact of the asset management becomes more and more relevant to the overall company performance. So here, hedging can grow in importance, as the magnitude of changes on the non-technical results become more relevant overall. And when finally the long-tail business is operated under a regulatory regime with profit distribution asymmetries like from the *Mindestzuführungsverordnung*, the relevance and effectiveness of the hedging strategy grows to be the effective instrument as seen in the life insurance chapter of this work.

The proposed research questions of this work can therefore be answered with the following: The German regulatory framework for life insurance makes the profit distribution asymmetric. This asymmetry makes the analyzed hedging strategy effective for reducing downside risk from a profitability perspective, while maintaining the same level of security for insured. It is further appealing for investors and shareholders to encourage the firm's management to apply hedging mechanisms in the asset management, since the asymmetry makes the gain from reducing the downside risk much greater in magnitude than the loss on the upside because here, the asymmetry takes away most of the profit anyway. Since the perspective of the insured, the security of one's guarantees being paid at some point in the future, is not affected and the profitability perspective of the shareholders is strengthened by the hedging strategy, the management is not unreasonably burdened with a trade-off between the two perspectives. Nevertheless, should the regulation not entail such an asymmetry, the management has to decide whether lower volatility and smaller potential losses in a worst-case scenario are worth giving up upside potential for profits or even a reduction in the mean result figures.

Naturally, the made assumptions influence the results of this work. The take-away from the life insurance model that shareholders favor the hedge, while the insured are unaffected, significantly depends on the one-dimensional interest orientation of the two parties. For certain, the insured will not only have the security aspect at heart, but also others like for example profitability in case their insurance policies include profit participation. And also the shareholders might not only think financially rational, but wish for other factors to be incorporated than just profitability.

Furthermore, the results elaborated on in this work generally offer three other possibilities for further research. It would be interesting to study the tactical implementation of hedging strategies with regards to an optimization of the observed effects. From the sensitivity analysis in chapter 3.3.3 it can already be inferred that the magnitude of the hedging effects can be controlled by the put options' strike and the portion of the hedged portfolio. Finding the ideal hedging parametrization as well as the optimal moment of time for entering the option positions could be worthwhile. Secondly, an analysis of the hedging instruments considering dependences on the individual financial situation of a firm (for example the firm's current levels of valuation reserves) would especially be thought-provoking for research-interested practitioners. Finding a decision rule for the stochastic simulations when to enter into the hedging positions and when to refrain from hedging, would set new standards for the asset management controlling process. Thirdly, it could also be interesting to study the effects of other hedging instruments like interest rate futures. Fixed income is the predominant asset class for insurers for multiple reasons and with the prolonged reality of ultra-low interest rate levels, this could be interesting to study.

For the management, the decision-making process can not only rely on the results from analyses under the German GAAP regulation. A major influencing factor is omitted from the examination in this work, which is the regulatory framework of Solvency II. Here, an additional set of key figures as well as a new set of constraints and limitations comes into play, which also needs to be regarded by management boards today. The role of capital requirements and finding an optimal asset allocation under this additional regulatory framework provides extensive material for research. The complexity of this framework leaves a lot of room for an extension of this research topic.

List of figures

List of tables

Bibliography

BaFin (1999) *Rundschreiben R 3/1999*. Bundesaufsichtamt für das Versicherungswesen. https://www.bafin.de/DE/RechtRegelungen/AufgehobeneDokumente/AufgehobeneRundschreiben/aufgehobeneRundschreiben_node.html. Version: September 1999. Latest access: 04.11.2018.

BaFin (2000) *Rundschreiben R 3/2000*. Bundesaufsichtamt für das Versicherungswesen. https://www.bafin.de/SharedDocs/Downloads/DE/Rundschreiben/dl_rs0003_derivate_pdf_va.pdf?__blob=publicationFile&v=4. Version: October 2000. Latest access: 25.09.2020.

BaFin (2017a) *Jahresbericht 2016 der Bundesanstalt für Finanzdienstleistungsaufsicht*. Bundesaufsichtamt für das Versicherungswesen. https://www.bafin.de/SharedDocs/Downloads/DE/Jahresbericht/dl_jb_2016.pdf?__blob=publicationFile&v=10. Version: May 2017. Latest access: 25.09.2020.

BaFin (2017b) *Rundschreiben R 08/2017*. Bundesaufsichtamt für das Versicherungswesen. https://www.bafin.de/SharedDocs/Veroeffentlichungen/DE/Rundschreiben/2017/rs_1708_ derivate_finanzinstrumente_va.html. Version: August 2017. Latest access: 25.09.2020.

BaFin (2018) *Jahresbericht 2017 der Bundesanstalt für Finanzdienstleistungsaufsicht*. Bundesaufsichtamt für das Versicherungswesen. https://www.bafin.de/SharedDocs/Downloads/DE/Jahresbericht/dl_jb_2018.pdf?__blob=publicationFile&v=6. Version: May 2019. Latest access: 25.09.2020.

Bartels, H.-J. and Veselcic, M. (2009) 'Zinsgarantien und Modellrisiko in Lebensversicherungen', *Blätter der DGVFM*, 30(2), pp. 327-361.

Basedow, J. (1992) 'Die Kapitallebensversicherung als partiarisches Rechtsverhältnis', *Zeitschrift für die gesamte Versicherungswissenschaft*, 81(3), pp. 419-455.

Bernard, C. and Kwak, M. (2016) 'Semi-static hedging of variable annuities', *Insurance: Mathematics and Economics*, 67, pp. 173-186.

Brigo, D. and Mercurio, F. (2006) '*Interest Rate Models - Theory and Practice*', 2nd ed. Berlin/ Heidelberg: Springer.

Coleman, T.F., Li, Y. and Patron, M.-C. (2006) 'Hedging Guarantees in Variable Annuities Under Both Market and Interest Rate Risks', *Insurance: Mathematics and Economics,* 38, pp. 215-228.

Coleman, T. F., Kim, Y. and Patron, M.-C. (2007) ‘Robustly hedging variable annuities with guarantees under jump and volatility risks’, *Journal of Risk and Insurance*, 74(2), pp. 347-376.

Farny, D. (2011) *'Versicherungsbetriebslehre'*, 5th ed. Karlsruhe: Verlag Versicherungswirtschaft GmbH.

Gaillardetz, P., Li, H. Y. and MacKay, A. (2012) ‘Equity-linked products: evaluation of the dynamic hedging errors under stochastic mortality’, *European Actuarial Journal*, 2(2), pp. 243-258.

Golden, L. L., Yang, C. C. and Zou, H. (2010) ‘The Effectiveness of Using a Basis Hedging Strategy to Mitigate the Financial Consequences of Weather-Related Risks’, *North American Actuarial Journal*, 14(2), pp. 157-175.

Gründl, H., Post, T. and Schulze, R. N. (2006) ‘To Hedge or not to Hedge: Managing Demographic Risk in Life Insurance Companies’, *The Journal of Risk and Insurance*, 73(1), pp. 19-41.

Hardy, M.R. (2000) 'Hedging and Reserving for Singel-Premium Segregated Fund Contracts', *North American Actuarial Journal,* 4(2), pp. 63-74.

Hocquard, A., Papageorgiou, A. and Rémillard, B. (2012) 'Optimal Hedging Strategies With an Application to Hedge Fund Replication', *Wilmott magazine,* pp. 62-65.

Hull, J. (2019) *'Optionen, Futures und andere Derivate*', 10th ed. Boston: Pearson.

Jaquemod, R. (2005) ‘Stochastisches Unternehmensmodell für deutsche Lebensversicherungen’, *Schriftenreihe Angewandte Versicherungsmathematik*, Heft 33.

Kling, A., Ruez, F. and Ruß, J. (2011) ‘The Impact of Stochastic Volatility on Pricing, Hedging, and Hedge Efficiency of Withdrawal Benefit Guarantees in Variable Annuities', *Astin Bulletin,* 41(2), pp. 511-545.

Kling, A., Ruez, F. and Ruß, J. (2014) ‘The impact of policyholder behavior on pricing, hedging, and hedge efficiency of withdrawl benefit guarantees in variable annuitites’, *European Actuarial Journal*, 4(2), pp. 281-314.

Kolkiewicz, A. and Liu, Y. (2012) 'Semi-Static Hedging for GMWB in Variable Annuities', *North American Actuarial Journal,* 16(1), pp. 112-140.

Klotzki, U. (2018) 'New life insurance products and product complexity in Germany', *Zeitschrift für die gesamte Versicherungswissenschaft*, 107(2), pp. 143-161.

Liu, C. S. and Yang, H. (2004) ‘Optimal investment for an insurer to minimze its probability of ruin’, *North American Actuarial Journal*, 8(2), pp. 11-31.

Lorenz, E. (1993) 'Rechtsfragen zur Überschussbeteiligung in der Kapitallebensversicherung', *Zeitschrift für die gesamte Versicherungswissenschaft,* 82(3), pp. 283-323.

Marshall, C., Hardy, M. and Saunders, D. (2012) 'Measuring the Effectiveness of Static Hediging Strategies for Guaranteed Minimum Income Benefit', *North American Actuarial Journal,* 16(2), pp. 143-182.

Møller, T. (1998) ‘Risk-minimizing hedging strategies for unit-linked life insurance contracts’, *ASTIN Bulletin*, 28(1), pp. 17-47.

Papageorgiou, N., Rémillard, B. and Hocquard, A. (2008) 'Replicationg the Properties of Hedge Fund Returns', *The Journal of Alternative Investments,* 11(2), pp. 8-39.

Pézier, J. and Scheller, J. (2013) 'Best portfolio insurance for long-term investment strategies in realisitic conditions', *Insurance: Mathematics and Economics,* 52(2), pp.263-274.

Pfeifer, D. (2003) 'Möglichkeiten und Grenzen der mathematischen Schadenmodellierung', *Zeitschrift für die gesamte Versicherungswissenschaft*, 92(4), pp. 665-696.

Prölss, E., Dreher, M. and Präve, P. (2018) '*Versicherungsaufsichtsgesetz mit Nebengesetzen*', 13th ed. München: C. H. Beck.

Reuß, A., Ruß, J. and Wieland, J., 'Participating Life Insurance Contracts under Risk Based Solvency Frameworks: How to Increase Capital Efficiency by Product Design', in: Glau, K., Scherer, M. and Zagst, R. (eds.), (2015) '*Innovations in Quantitative Risk Management*', Volume 99, pp. 185-208, Springer Proceedings in Mathematics & Statistics, Berlin: Springer.

ROKOCO (2016) '*Geschäftsberichtsanalyse Lebensversicherung 2015*' Unpublished.

ROKOCO (2019) '*Geschäftsberichtsanalyse Kompositversicherung 2018*' Unpublished.

Tse, W.-M., Chang, E., Li, L.-K. and Mok, H. (2008) ‘Pricing and Hedging of Discrete Dynamic Guaranteed Funds’, *The Journal of Risk and Insurance*, 75(1), pp. 167-192.

Zimmermann, J., Chevtchenko, G. and Schweinberger, S. (2006) ‘Der Einfluss des Versicherungskapitalanlagen-Bewertungsgesetzes (VersKapAG) auf Überschüsse und Überschussbeteiligung in der Lebensversicherung — Eine empirische Untersuchung‘, *Zeitschrift für die gesamte Versicherungswissenschaft,* 95(1), pp. 91-124.

Curriculum Vitae

Personal details

Name	Anton Silvester Wittl
Date of birth	December 31st, 1990
Place of birth	Munich, Germany

Education

10/2017 – 12/2020	Carl von Ossietzky Universität Oldenburg Doctoral studies
09/2014 – 11/2015	University of Edinburgh Master of Science in Financial Management (with Distinction)
07/2013 – 09/2013	University of California, Los Angeles (UCLA) Guest student for courses in economics and accounting
09/2010 – 03/2014	Ludwig-Maximilians-Universität München Bachelor of Science in Economics

Professional experience

Since 08/2019	ROKOCO GmbH Managing partner
12/2015 – 07/2019	ROKOCO GmbH Analyst and consultant
04/2014 – 08/2014	Allianz SE Intern at Group Risk

Erklärung

Hiermit versichere ich, dass ich diese Arbeit selbstständig verfasst und keine anderen als die angegebenen Hilfsmittel und Quellen verwendet habe.

Anton S. Wittl
Oldenburg, den 01. Oktober 2020

Current status of publication of research papers

Research paper	**Part of dissertation**	**Status of publication**	**Journal**
The impact of hedging on life insurance companies	Chapter 3	Accepted; published March 27th, 2019	Zeitschrift für die gesamte Versicherungswissenschaft (German Journal of Risk and Insurance)