Solvency Regulation and Contract Pricing in the Insurance Industry

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The President:

Prof. Ernst Mohr, PhD
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Ines Affolter
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Abstract

The purpose of this thesis is to analyze the factors influencing insurance policy valuation and pricing at both the insurance company level and the individual contract level. At the insurance company level, solvency and solvency regulation are of crucial importance in this regard. We therefore examine a selection of regulatory frameworks representative of those in effect around the world, investigating, in particular, how well each does at ensuring insurer solvency while avoiding market distortions.

Although the insurer’s solvency situation plays an important role in consumer insurance purchase decisions, other factors are also significant at the individual contract level. To discover what these factors are and their relative importance to consumers, we analyze participating life insurance policies and the influence of the underlying parameter combinations (i.e., annual guaranteed interest rate, annual surplus participation, and terminal bonus payment). We also take a look at the valuation of non-life insurance policies, with a particular focus on coinsurance policies.

The aim of this thesis is to be of both academic and practical value. On the academic front, it provides an overview of the effectiveness of different solvency systems. It also explains and illustrates the basics of insurance policy pricing using the concept of risk-neutral valuation and expected utility theory. On the practical front, the thesis is a useful primer on the different solvency systems in effect around the world and their differing requirements. Moreover, this thesis shows how insurers can potentially realize returns on equity above the risk adequate rate based on an analysis of customer value and willingness to pay.
1 Introduction

1.1 Motivation

Solvency regulation of insurers has changed substantially with the introduction of the Solvency II framework and the Swiss Solvency Test. These innovative models operate on the stochastic nature and distribution of capital requirements and make use of probability measures, such as value at risk and expected shortfall. In addition to these models, there is a variety of other approaches, including, among others, volume-driven capital requirements and rating-based frameworks.

Common to all of these frameworks is the goal of protecting the policyholder. Protecting the policyholder is deemed necessary due to information asymmetries between the policyholder and the insurance company that open the possibility of moral hazard. Another argument in this vein is that insurance company insolvencies can impose disproportionately high costs on policyholders or even on society. This can occur if the event the policyholder insured himself or herself against occurs simultaneously with the insurance company becoming insolvent. In this case, the policyholder will not receive any indemnification, which quite possibly could endanger his or her economic existence. Hence, from the policyholder’s perspective, the risk of insolvency is directly related to the quality of the insurance product and is therefore part of the decision to contract with a specific insurance company.

This thesis investigates two aspects of the insurance business: insurer solvency and contract pricing. The first part deals with a variety of solvency regulation standards in effect around the world. The standards differ widely in their approaches and in their effectiveness at protecting policyholders while avoiding market distortions. The second part addresses the valuation and pricing of insurance policies, looking at the practice from both the insurer and the policyholder perspective. The insurer perspective (supply side) provides the minimum policy price; the policyholder perspective provides maximum willingness to pay (demand side).

1.2 Areas of Research and Major Contributions

Figure 1 illustrates the areas of research and the major contributions of this thesis. The first area of research finds its motivation in the increasing awareness of solvency issues and the corresponding reforms of regulatory frameworks. Then, taking the
individual-contract-level perspective, we address the valuation/pricing of specific contracts under the assumption that policyholders follow a mean-variance approach to purchasing insurance.

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**Figure 1:** Areas of research and major contributions

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To our knowledge, there is very little literature providing detailed assessments of solvency systems structured along predefined criteria. Cummins et al. (1994) provide an appropriate conceptual framework, but the framework has been applied only twice to date. In the first of these, KPMG (2002) use a related set of criteria in their study of different methodologies to assess an insurer’s financial position. However, they do not explicitly consider existing solvency regulation systems. The second work in this area, Doff (2008), utilizes the Cummins et al. (1994) framework and does explicitly consider the Solvency II standards. Thus, there is a need for further evaluation of existing solvency frameworks using the Cummins et al. (1994) criteria, and we also believe that the framework itself should be reviewed for its applicability in the current environment. Hence, we make the following contributions to this area of research: (1) a descriptive overview of selected solvency frameworks representative of those in effect around the world; (2) an extension of the conceptual criteria catalogue of Cummins et al. (1994); and (3) a comparative assessment of three solvency systems using this extended criteria catalogue.

The second area of research investigates the insurance business from the individual contract level. In our opinion, appropriate pricing and valuation of these contracts depend on the perspective taken. From the insurer perspective, we assume claims to be replicable by means of financial instruments traded on the capital market and therefore application of the risk-neutral valuation technique is appropriate. The policyholders, on the other hand, are in general not able to replicate claims to the same extent and thus their valuation of insurance contracts is based on individual preferences. We are, to our knowledge, the first to apply and combine two different valuation approaches based on these two perspectives (contribution (4)). Combination of the two approaches results in the premium agreement range, bounded, on the lower end, by the minimum policy price the insurer is willing to accept (supply side) and, on the upper end, by policyholder willingness to pay (demand side). We analyze the size of this premium agreement range for participating life insurance policies for two cases, i.e., the policyholder either has or does not have diversification opportunities (5). We then apply the combined valuation approach to non-life insurance policies focusing on coinsurance as a special type (6).

1.3 Thesis Structure and Overview

The thesis is structured around the research areas and contributions outlined above in Chapter 1.2. The following Part 1 contains two chapters, both addressing solvency
regulation frameworks. Part 2 addresses pricing at the individual contract level, using an example from each of the life and the non-life insurance industries.

Chapter 2 of Part 1 provides an overview and comparison of risk-based capital requirements as currently in effect in the United States, the European Union, Switzerland, and New Zealand. These four systems are representative of capital standards around the world. Other systems, such as the Japanese and the Australian, are similar to the U.S. system, but also include some features of the Swiss and the forthcoming European Union systems. The four systems selected for this descriptive overview include one static factor model, two dynamic cash-flow-based approaches, and one supervisory process that operates almost entirely by means of private rating agencies.

Chapter 3 of Part 1 evolves around the conceptual framework of Cummins et al. (1994), which lays out seven criteria for effective solvency regulation of insurance companies. We extend this framework by four criteria to account for the dynamics of the insurance and capital markets and recent regulatory developments. Based on this extended framework, we provide an overview and critical analysis of risk-based capital requirements implemented in three different regions of the world (the United States, the European Union, and Switzerland).

Chapter 4 of Part 2 looks at valuation of participating life insurance contracts from the perspective of both the insurer and the policyholder. The insurer is assumed to set a minimum acceptable price for the contract by means of risk-neutral valuation. This price is the lower end of the premium agreement range and results in a net present value of zero for the insurance company’s equityholders. The policyholders, in our model, follow mean-variance preferences and determine a price for the policy at which they are indifferent between having or not having insurance. This price is the policyholders’ maximum willingness to pay and thus provides the upper bound of the premium agreement range. The size of the premium agreement range is used to analyze policyholder preferences for variations in the features of a participating life insurance contracts.

Chapter 5 of Part 2 takes a look at non-life insurance contracts and uses the same approach set out above to derive the minimum price the insurer will accept and the maximum price the policyholder is willing to pay, with a particular focus on coinsurance policies. Numerical examples are provided that identify situations characterized by a positive premium agreement range, meaning that both parties are willing to enter into the contract. How changes in the level of coinsurance and/or in the insurer’s safety level influence the premium agreement range is analyzed. Because,
from the insurer perspective, it is highly beneficial when policyholder willingness to pay exceeds minimum policy price, we conduct a maximization of the premium agreement range with regard to the level of coinsurance and the insurer’s safety level.
Part I: Solvency Regulation in the Insurance Industry

2 An Overview and Comparison of Risk-Based Capital Standards

2.1 Introduction

Since the beginning of the 1990s, most major economies have changed their regulatory framework for the insurance industry from not risk-based rules to a system of risk-based capital (RBC) standards. RBC standards are thus becoming increasingly the norm for capital regulation in the insurance industry. Canada and the United States (U.S.) were among the first countries to introduce RBC standards in 1992 and 1994. In 1996, Japan followed with the Solvency Margin Standard; Australia introduced its General Insurance Reform Act in 2001. Europe has been relatively slow to develop RBC requirements. The United Kingdom introduced its concept of an “enhanced capital requirement” and “individual capital assessment” in 2004 and Switzerland enacted the Swiss Solvency Test in 2006. Currently, the European Union (EU) is working toward harmonization across member countries, an effort that includes Solvency II—the implementation of RBC standards in all member countries.

On the topic of RBC standards, the literature to date addresses the economic effects of regulation in general, different methodologies for solvency regulation, and the predictive power of these models. Munch and Smallwood (1980), Rees et al. (1999), and Van Rossum (2005) discuss the economic effects of regulation on insurance markets. Most authors conclude with arguments against extensive solvency regulation. Munch and Smallwood (1980) find that minimum capital requirements reduce the number of insolvencies, but do so only because they reduce the number of small firms in the market, concluding that capital requirements are especially a burden for small insurers. Rees et al. (1999) show that insurers always provide enough capital to ensure solvency if consumers are fully informed of insolvency risk; they thus conclude that regulators should provide information rather than imposing capital requirements. Van Rossum (2005) points out the connection between the degree of regulation and costs, again highlighting the particularly strong effect on small insurers specialized in certain products and niches.

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1 This paper has been written jointly with Martin Eling. The Journal of Insurance Regulation has accepted this paper for publication.
Brockett et al. (1994), Carson and Hoyt (1995), Browne et al. (1999), Baranoff et al. (1999), Segovia-Vargas et al. (2003), and Chen and Wong (2004) analyze alternative factors and methodologies for predicting solvency. One important aspect within this body of literature is the suitability of different risk measures for solvency measurement, such as the value at risk and the expected shortfall (see, e.g., Artzner et al., 1999; Barth, 2000). Focusing on RBC models, Cummins et al. (1995, 1999), Grace et al. (1998), and Pottier and Sommer (2002) empirically analyze the predictive power of existing solvency models, e.g., the U.S. RBC standards and A.M. Best’s capital adequacy ratios. These authors conclude that the U.S. RBC ratios are not very effective in identifying financially weak insurers and that other measurers (e.g., those produced by the private sector) might be superior (see Pottier and Sommer, 2002).

This chapter contributes to the literature by providing an overview and comparison of four representative solvency systems. As a review of all models implemented around the globe is hardly feasible, we decided to focus on the U.S., the EU, New Zealand, and Switzerland. These four are good examples of different regulatory approaches implemented around the globe. Other systems, such as the Japanese or the Australian, are similar to the U.S. system, but also include some features of the Swiss and the forthcoming EU systems (see Eling et al., 2007, for an overview). Our results are relevant both for regulators, and for insurers that are required to implement the RBC measures in their risk management framework. Because we integrate measures of the private sector in our analysis, the results are also relevant for rating agencies. Our goal is to provide a compact overview of the variety of solvency systems implemented around the world and to encourage discussion on the future development of existing solvency systems.

The remainder of this chapter is organized as follows. In Section 2, we describe the four selected standards in detail, starting with the U.S. model (Section 2.1), followed by the RBC requirements implemented in the EU (Section 2.2), New Zealand (Section 2.3), and Switzerland (Section 2.4). In Section 3, we compare the four elements of each system: (1) general information, (2) definition of capital required, (3) definition of available capital, and (4) levels of intervention. We conclude in Section 4.

2.2 Overview

The RBC represents an amount of capital that an insurance company holds to be able to fulfill its obligations against policyholders in the future with a high probability. As we will show in this section, there are different ways of determining this amount. To
build a foundation for the comparison in Section 3, we will look at the same four elements of each system: (1) general information (i.e., basic model setting), (2) definition of capital required, (3) definition of available capital, and (4) levels of intervention.

### 2.2.1 U.S. RBC Standards

**General information**

The U.S. insurance market is the largest in the world. Approximately $1,170 billion, i.e., 31% of the worldwide premium volume, was generated in this market in 2006 (see Swiss Re, 2007; the data are for both life and non-life insurance and cover direct premiums before cession to reinsurers). Prior to the development of RBC standards, U.S. solvency regulation varied between the states and relied on fixed minimum capital. However, in 1994, the RBC standards, developed by the National Association of Insurance Commissioners (NAIC), were introduced. This new U.S.-wide standard for capital adequacy intended to more accurately reflect the size and risk exposure of a company (see Grace et al., 1998). The RBC standards have two main components: The first is a RBC formula that establishes a minimum capital level, which is compared to the actual level of capital. The second is a RBC model law that grants automatic authority to the state insurance regulator to take certain actions based on the company’s level of impairment (see NAIC, 2005). In addition to the RBC standards, each state still has its own fixed minimum capital requirements, which range from $0.5 million to $6 million (see Klein, 2005, p. 141). Furthermore, many state insurance regulators use their own measures to screen insurers (e.g., the Financial Analysis Solvency Tools, a scoring system consisting of 25 financial ratios and variables; see Grace et al., 1998). However, these are monitoring instruments only and do not impose capital requirements. Additional restrictions might be applied in individual U.S. states.

**Definition of capital required**

To take into account variations in the economic environments of different lines of business, there are three separate RBC models—one for life, property/casualty, and health insurance (see NAIC, 2005). All are based on the main principle that the variety of risks an insurer is exposed to must be assigned a corresponding equity capital. We consider the risk-based capital formula for a property/casualty insurer as an example:
The RBC covers two main types of risks: asset risks (factors R1, R2, and R3) and insurance risks (factors R4 and R5). Furthermore, there is a factor for the risk of default of affiliates and off-balance-sheet items, such as derivative instruments and contingent liabilities (R0). R1 models the fixed-income investment risk. Two factors are important when calculating R1. First, to determine the necessary RBC, the portion in each fixed-income investment (e.g., a bond) is weighted by a quality coefficient according to a NAIC classification. Second, large single exposures are modeled by an asset concentration factor, i.e., the weighting factors for the 10 largest exposures are doubled. R2 models risk associated with other investments, such as stocks or real estate, again weighted with a given coefficient. R3 represents credit risk, which is the risk associated with reinsurance contracts. R4 is the underwriting reserve risk. It contains factors for provisions on outstanding claims that differ between branches. R5 reflects the underwriting premium risk. It covers the risk that the premiums collected in a given business year may not be sufficient to meet the corresponding claims (see Feldblum, 1996; Klein and Wang, 2007).

To illustrate how all these different charges are determined, we use the underwriting premium risk R5 as an example. R5 is calculated by multiplying a volume number with a factor. The R5 volume number is the business written in the coming 12 months. However, as the future underwriting volume is unknown, the factor charge is applied to the underwriting volume of the last calendar year. The factor itself is derived using the average loss ratios for the last 10 years for the insurer and for the whole industry. Comparing individual insurer and total industry ratios leads to a reduction in a factor charge if the insurer’s average loss ratio is better than that of the industry and to an increase otherwise. The company's average expense ratio is then added to the loss ratio to form the so-called combined ratio. The combined ratio minus 1 provides the factor for calculating R5. If the combined ratio is less than 1, the capital charge is 0 (see Feldblum, 1996).

The RBC formula accounts for correlations between various types of risks, i.e., it includes a correlation adjustment in the formula. It reflects the fact that the total risk of a portfolio comprised of several different risks (if they are not perfectly positively correlated) is lower than the sum of the isolated risks. The factor for affiliate insurers and other off-balance-sheet risks (R0) is not included in the correlation adjustment.
Definition of available capital

The required RBC is compared to the amount of available capital. In the U.S. system, available capital is defined as the total adjusted capital, i.e., the insurer’s statutory capital and surplus. Furthermore, some other items as provided by the RBC instructions are added, e.g., half the dividend liability or a so-called asset valuation reserve (see NAIC, 2002, for more details).

Intervention

There are four intervention levels depending on the ratio of total adjusted capital to RBC (see Dickinson, 1997; Sandström, 2006, p. 170). A ratio larger than 200% represents the target situation. (1) If the ratio is between 150–200%, the company must submit a report (called company-action level). (2) If the ratio is between 100–150%, the insurer must submit an action plan (regulatory-action level). (3) If the ratio is between 70–100%, the regulator has the option of taking over management of the company (authorized-control level). (4) If the ratio is lower than 70%, the regulator is obligated to take over management of the company (mandatory-control level).

2.2.2 The EU Solvency I and Solvency II Framework

General information

Premiums for all 27 EU countries combined accounted for 37% of worldwide premiums in 2006 ($1,387 billion) and thus even exceeded the U.S. premium volume (see Swiss Re, 2007). In the EU, equity capital regulation is currently undergoing a reform. The European Commission (EC), the body responsible for proposing legislation in the EU, works toward harmonization across member countries as well as toward implementation of appropriate RBC standards. The implementation of the new regulatory framework follows a two-stage process: Solvency I and Solvency II. Solvency I, introduced in 2004, made modest modifications to the fixed ratios and rules-based capital standards that were already introduced in the 1970s (see EC, 2002a, for non-life insurers and EC, 2002b, for life insurers). Against it, Solvency II, intended to go into effect in 2012 for all EU insurance companies, will focus on an enterprise risk management approach. Further characteristics of the upcoming standards will be the use of internal models to calculate capital requirements and the consideration of two levels of capital requirements: The actual capital of a well capitalized insurer is
supposed to be equal or higher than the SCR (solvency capital requirement, also called target capital) and therewith also higher than the MCR (minimum capital requirement; see Figure 1).

**Definition of capital required**

We first present the current Solvency I rules, introduced in 2004, again taking a non-life insurer as an example. The Solvency I minimum capital requirement (MCR) is given by the maximum of the premium basis ($\text{PB}_t$) and the claims basis ($\text{CB}_t$). These two are calculated as ($P_t$ denotes the net premiums in period $t$; $C_t$ is derived on the basis of the average claim payments over the last three years net of reinsurance):

$$\text{PB}_t = 0.18 \cdot \min(P_t; €50 \text{ million}) + 0.16 \cdot \max(P_t - €50 \text{ million}; 0)$$

(2)

$$\text{CB}_t = 0.26 \cdot \min(C_t; €35 \text{ million}) + 0.23 \cdot \max(C_t - €35 \text{ million}; 0)$$

(3)

$$\text{MCR}_t = \max(\text{PB}_t; \text{CB}_t)$$

(4)

The calculation of the MCR for life insurers follows a similar approach. It is based on mathematical reserves, an indicator for market risk, and capital at risk, an indicator for insurance technical risk. Along with these relative capital requirement levels, there is a minimum guarantee fund, which is irrespective of the size of the insurer. For non-life insurers this is € 2 or € 3 million, depending on the lines of business (see EC, 2002a, p. 21). Life and reinsurers each are required to have a minimum guarantee fund of € 3 million (see EC, 2002b, p. 26). Obviously, Solvency I is comparatively crude and its theoretical foundation weak, but its application is very straightforward (see Farny, 1997). Perhaps the most important drawback to this system is that the capital requirements do not depend on the specific risk situation of the insurer, but mainly on its underwriting volume, which can lead to less than optimum practices by insurers, e.g., underpricing (the lower the premiums, the lower the MCR).

The Solvency II framework, as currently planned, is described in a directive published by the European Commission (see EC, 2007a). However, the process is ongoing and modifications are still possible. Similar to the solvency regulation for the banking industry (see Basel Committee on Banking Supervision, 2001), the Solvency II framework is based on three pillars: (1) quantitative requirements, (2) qualitative requirements and supervision, and (3) supervisory reporting and public disclosure (see Eling et al., 2007). In the following, we will focus on the first pillar, which is illustrated in Figure 1 (also see CRO and CEA, 2006).
Pillar I takes an integrated balance sheet approach, i.e., it considers assets, liability, and the interdependencies between them. The liabilities are subdivided in technical provisions and the solvency capital requirement (SCR). The MCR is a fraction of the SCR. The assets are subdivided in assets covering the technical provisions and the available solvency margin (to cover the SCR; if the available solvency margin is larger than the SCR, the residual is the excess capital). Both assets and liabilities are calculated at market value (see CEIOPS, 2007).

On the liability side, calculation of the technical provisions is based on their current exit value, i.e., the amount necessary to transfer contractual rights and obligations today to another undertaking (see Esson and Cooke, 2007; Duverne and Le Douit, 2007). The technical provisions are thus the sum of the best estimate of the liabilities and a risk margin, based on the cost-of-capital method. The SCR corresponds to the economic capital an insurer needs to limit the probability of ruin to 0.5%; it is determined as the value at risk at a 99.5% confidence level. To calculate the SCR, the insurer may choose between the standard approach and an internal model, the latter being subject to certain requirements and approval from the supervisor (see Liebwein, 2006). Larger undertakings will most likely use individual internal models. The internal models might then better reflect the true risk profile, lower the SCR and thus result in lower capital costs. Small insurers, which do not have sufficient personnel and financial re-sources to develop such models, might prefer the standard model. However, even this model allows for the use of personalized parameters and provides standardized simplifications for small and medium-size enterprises, in order to limit the disadvantages of small insurers (see EC, 2007b, p. 9). Solvency II also allows the
use of partial internal models, i.e., internal models that are applicable only to certain individual risk modules or submodules (see EC, 2007a, p. 111).

It is yet to be determined how the MCR will be calculated, that is, whether it will follow the so-called “modular approach” or “compact approach” (see CEIOPS, 2006). The modular approach considers the value at risk at 90% confidence level instead of 99.5% (the value used with the SCR). The compact approach sets the MCR at one-third of the SCR (EC, 2007a, p. 14). With either approach however, the MCR will have an absolute floor of € 2 million for life insurers and € 1 million for non-life and reinsurers (see EC, 2007a, p. 118).

**Definition of available capital**

As mentioned, Solvency II divides assets into two categories (see Figure 1): (1) assets covering the technical provisions and (2) assets covering the MCR and SCR (available solvency margin). To account for different capability of assets to absorb potential losses, a classification of own funds is made and certain limits are set. This classification is shown in Figure 2 (see EC, 2007a, p.12).

<table>
<thead>
<tr>
<th>Quality</th>
<th>Assets on the balance sheet</th>
<th>Off-balance-sheet assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Quality</td>
<td>Tier 1</td>
<td>Tier 2</td>
</tr>
<tr>
<td>Medium Quality</td>
<td>Tier 2</td>
<td>Tier 3</td>
</tr>
<tr>
<td>Low Quality</td>
<td>Tier 3</td>
<td>/</td>
</tr>
</tbody>
</table>

*Note: The three tiers indicate different quality and ability of own funds to absorb losses.*

**Figure 2:** Classification of own funds

The first distinction is made between own funds that are on the balance sheet and those that are not. On-balance-sheet funds comprise the excess of assets above liabilities plus subordinated liabilities, which can serve as capital in case of liquidation. Off-balance-sheet funds are, e.g., letters of credit or members’ calls, which the insurer can use to increase its own financial resources. The second distinction applies qualitative criteria, such as loss absorbency and permanence, and assesses the funds as being of high, medium, or low quality. The EC has yet to concretize those criteria via an implementing measure (see EC, 2007a, pp. 102-103). As a result the available capital is classified into three groups called “tiers,” with tier 3 items being less eligible to cover the MCR and the SCR than tier 2 and tier 1 items. The following limitations apply:
The MCR requirement can be met only with tier 1 and tier 2 items on the balance sheet. The proportion of tier 1 items thereby needs to be at least one-half.

With regard to the SCR requirement, the proportion of tier 1 items must be at least one-third, while the proportion of tier 3 items may not be higher than one-third.

**Intervention**

Two levels of intervention are possible, depending on the relation of available capital to the SCR and MCR. In the target situation the available capital is higher than the SCR. (1) If the available capital is lower than the SCR, the regulator will take action aimed at restoring the insurer to a healthy condition. (2) If the available capital is lower than the MCR, the regulator will revoke the insurer’s license. This will be followed either by the liquidation of the insurer’s in-force business or a transfer of the insurer’s liabilities to another insurer (see EC, 2007b, p. 5).

### 2.2.3 New Zealand’s Self-Regulatory Framework

**General information**

The life and non-life insurance premiums in New Zealand were approximately $5 billion for 2006 (0.15% of worldwide business; see Swiss Re, 2007). Regulation of the insurance industry in New Zealand is very different from the two approaches discussed above, in that the New Zealand market is one of the least regulated in the world. Insurers in that country are only required to comply with a self-regulatory framework, which intends to assure insurance customers of quality service. The framework, established by the Insurance Council in 1994, consists of three basic parts (see Insurance Council of New Zealand, 2007).

* The Fair Insurance Code is a contract between the insurer and the customer regarding ethical behavior on both sides. Customers should behave honestly by accurately disclosing all relevant information. The insurer should provide services and settle claims fairly and efficiently. Besides the obvious difficulty of identifying breaches of this code, sanctions are not well defined. An insurer’s breach of the code can lead to an investigation by the Insurance Council of New Zealand.
Zealand and, possibly, the taking of appropriate actions, which are not further specified.

- The Insurance and Savings Ombudsman Scheme (ISO) subjects the insurer to independent review by providing the customer with a point of contact in case of disputes. The ISO service is free of charge to the customer and uses the Fair Insurance Code as a basis for its decisions.

- The third part involves the Insurance Council’s Solvency Test. The requirement of being financially sound is ensured via the obligation to obtain a rating and renew the same annually. All ratings are published on the regulator’s web page (see http://www.isu.govt.nz). If a rating agency is considering downgrading an insurer, it may issue a credit watch warning that is also published on the regulator’s web page. There are three rating agencies approved to issues these ratings: A.M. Best, Standard & Poor’s (S&P), and Fitch Ratings.

As the third part of the framework is crucial in reviewing the New Zealand system, the rating procedure will be explained in more detail using A.M. Best ratings as an example. A.M. Best issues nearly half of all insurance ratings in New Zealand, whereas S&P performs most of the other ratings. Thus the most important differences between the A.M. Best ratings and the S&P ratings will be described below. Fitch plays only a minor role in New Zealand and therefore will not be detailed in this chapter (see Fitch Ratings, 2001, for more information on their rating).

Best’s Financial Strength Ratings are summary measures of the insurer’s ability to pay present and future claims (see Pottier and Sommer, 2002). The sources of information on which the ratings are based include financial statements and, in most cases, an interactive exchange of information with company management. Quantitative as well as qualitative analyses are conducted to assess the insurer’s financial strength. Three areas of Best’s Financial Strength Rating can be distinguished (see Zboron, 2006).

- A.M. Best measures the exposure of a company’s surplus to its operating and financial practices with the balance sheet strength. It takes into consideration a company’s underwriting, financial, operating, and asset leverage. The latter includes a company’s exposure to investment, interest rate, and credit risk associated with the assets held by the insurance company. The derivation of the balance sheet strength is further detailed below.
The analysis of operating performance is especially important for insurers writing long-tail business. The underlying assumption is that operating performance drives profitability and, therefore, long-term balance sheet strength. To assess the operating performance, A.M. Best performs various profitability tests, e.g., on loss ratio, expense ratio, and combined ratio (see Zboron, 2006; A.M. Best, 2007b).

An insurer’s business profile has an influence on current and future operating performance and, subsequently, on balance sheet strength, again especially for insurers writing long-tail business. The corresponding analyses comprise, e.g., the spread of risk, i.e., geographic, product, and distribution diversification, competitive market position, and management aspects (see A.M. Best, 2007b).

**Definition of capital required**

To assess balance sheet strength, the underwriting, financial, and asset leverage are summarized to Best’s capital adequacy ratio (BCAR). The BCAR is the ratio of the available capital (the adjusted surplus) divided by the net required capital (NRC). The insurer’s BCAR is then compared to the median of its peer group. It represents the most important measure in the rating process. The NRC formula for property/casualty looks comparable to the U.S. RBC formula (see A.M. Best, 2003):

\[
NRC = \sqrt{B1^2 + B2^2 + B3^2 + (0.5 \times B4)^2 + \left( (0.5 \times B4) + B5 \right)^2 + B6^2 + B7}
\]  

(5)

Three main types of risk are covered. The first is investment risk, including fixed income securities (B1), equities (B2), and interest rates (B3). B3 reflects the potential drop in the fixed income portfolio of an insurer as a consequence of rising interest rates. The second type of risk covered is credit risk (B4), which reflects third-party default risk originating from e.g., reinsurers or affiliates. The third type, underwriting risk, includes the risks inherent in an insurer’s loss reserves (B5) and the pricing risk inherent in a company’s mix of business (B6). Outside the covariance adjustment, the formula accounts for off-balance-sheet items (B7), which A.M. Best also calls the “business risk component” (see A.M. Best, 2003). As under the U.S. RBC standards, the capital charges (B1 to B7) are calculated by multiplying a volume number with a factor. Different from the U.S. regulation is that the factors are calibrated to correspond to a 1% expected policyholder deficit, defined as expected deficit divided
by the expected loss amount (see A.M. Best, 2007a; Butsic, 1994). Three adjustment factors are applied to the investment risk category. First, an asset concentration factor doubles the risk charge for all investments greater than 10% of the surplus. Compared to that the U.S. system doubles the charge for the 10 largest investments irrespective of their size. Second, the spread of risk factor is a portfolio-size adjustment. If the portfolio has less than $5 million in invested assets, this factor can go up to 50%. Third, the investment leverage factor concerns stock investments that represent more than 50% or 100% of the reported surplus. In this case, the normal risk charge of 15% for stocks is increased to 20% or 30% (see Towers Perrin, 2006).

The analysis of the balance sheet strength (the BCAR), operating performance, and business profile is then summarized to derive the insurer’s financial strength rating. These range from A++ (superior) to D (poor). Additional ratings are assigned to companies under review by the supervisory authority (E), companies in liquidation (F), and companies whose rating is suspended (S). The cut-off point between a vulnerable rating and a secure rating is located between B and B+. “Vulnerable” means that the company’s ability to meet obligations to policyholders is fair, instead of good as in the case of “secure” rated insurers (see A.M. Best, 2007b). As of October 2007, approximately 80% of all New Zealand insurers rated by A.M. Best have a rating of A+, A, or A–, approximately 10% have a B+ or B++. Less than 10% have a vulnerable rating of B or B– (see Ministry of Economic Development, 2007).

**Definition of available capital**

To derive the BCAR, the required capital is compared to an insurer’s adjusted surplus. The adjustments are intended to even out differences between insurers and to account for economic values not reflected in the statutory financials. They mainly correspond to an insurer’s equity and adjustments for unearned premiums, loss reserves, and reinsurance. Furthermore, potential catastrophe losses and future operating losses are considered. In contrast with the U.S. RBC model, qualitative factors, such as, for example, reinsurance quality, are also covered by those adjustments (see Pottier and Sommer, 2002; A.M. Best, 2003).

**Intervention**

There are no consequences for insurers who fall below a certain threshold rating or have been the subject of a credit watch warning. However, the implicit sanctions
imposed by the market, e.g., higher cost of capital or reduced willingness to pay for policies, are assumed to be effective (see Pottier and Sommer, 1999). All ratings and credit watch warnings are published on the regulator’s web page. Additionally, the ratings must be disclosed each time an insurer enters into or renews a contract. If the insurer fails to comply with the disclosure requirements, the insured has the right to cancel the contract. Thus, New Zealand regulators completely rely on market discipline, presuming that market participants themselves enforce appropriate insurer behavior. There is no empirical evidence on the strengths and effectiveness of market discipline in the New Zealand insurance market. However, there is some evidence for market discipline in the U.S. insurance industry, e.g., premium purchases decline after a rating down-grade (see Epermanis and Harrington, 2006).

Similarly to A.M. Best, the S&P capital adequacy model takes into consideration all major quantitative and qualitative factors that influence the probability of insurer failure. Although the A.M. Best and S&P models are not identical, their basic rating methodologies are quite similar. The equivalent to A.M. Best’s BCAR in the S&P model is the area capitalization, which employs a factor-based capital adequacy model (see S&P, 2007a). Historically, the main difference between A.M. Best’s BCAR and S&P’s capital model was that the latter did not explicitly account for diversification effects. However, with the new model introduced by S&P in May 2007, this is no longer true, albeit S&P still claims to handle diversification benefits more conservatively than do its competitors (see S&P, 2007b). Other differences between the two rating agencies include:

- Determination of A.M. Best’s BCAR is oriented at the expected policyholder deficit concept, whereas S&P uses a value at risk concept. It applies stress tests to each risk variable, using the potential movement expected over a one-year period. A rating is then assigned for the occurrence of a policyholder loss at a certain confidence level (see S&P, 2007a).

- A.M. Best and S&P use different cut-offs when rating companies as either vulnerable or secure. A.M. Best sets this border between B+ and B ratings, whereas for S&P it is located between BBB and BB (see A.M. Best, 2007a; S&P, 2002). Above this cut-off point, A.M. Best distinguishes six rating categories, S&P four. There is no information available on the equivalence of the rating scales across rating agencies. Even if, such would be of questionable value, due to the differing methodologies (see Pottier and Sommer, 1999). Furthermore, no clear indications could be found that one rating agency’s method is systematically
more rigid than the other’s, or that one of them is consistently better at predicting insurer insolvency. However, Pottier and Sommer (1999) note that S&P ratings tend to be lower on average than the ratings given by A.M. Best.

- The importance assigned to the S&P capital model and the BCAR model by the respective rating agencies is different. A.M. Best claims the BCAR to very often be a “minimum requirement to support a certain rating” (A.M. Best, 2007a). Contrary, S&P emphasizes that strength or weakness in capital adequacy can be more than offset by strength or weakness in other key areas, such as a company’s market position, management, and strategy (see S&P, 2007a).

- Both agencies make adjustments to their ratings based on size and concentration of invested assets. In contrast to A.M. Best, S&P makes no adjustment for high volumes of stock investment (see Towers Perrin, 2006).

### 2.2.4 Swiss Solvency Test

**General information**

Accounting for 1.1% of the worldwide life and non-life insurance business, the 2006 premium volume of Swiss insurance companies was approximately $42 billion (see Swiss Re, 2007). This volume is eight times higher than that of New Zealand, although the Swiss population is only double that of New Zealand. The relatively high volume is explained by the extremely high share of overseas activities conducted by Swiss insurers, e.g., which amounted to 42% of their life and non-life insurance business in 2006 (see Swiss Federal Office of Private Insurance, 2006).

The Swiss Solvency Test (SST) went into force for large insurers in 2006, and will be mandatory for all Swiss insurance companies beginning in 2008. However, there is a grace period for compliance that will last until 2011, a time period insurers can use to ensure that they meet the requirements set forth by the new system. The SST is comparable to Solvency II in that determination of the capital requirements follows a two-level approach. The first level is a rules-based minimum capital analogue to the Solvency I rules. The second level is a required “target capital” based on market value, which we discuss in more detail below. The SST also includes a quality assessment that focuses on internal processes and risk control (similar to pillar II of Solvency II; see Swiss Federal Office of Private Insurance, 2007).
Definition of capital required

Under the SST, standardized factor models are used to calculate market, credit, and insurance risks. Other risk categories such as, e.g., catastrophes are covered by scenario analyses. Figure 3 illustrates the modular structure of the SST (see Swiss Federal Office of Private Insurance, 2004). To determine target capital, the results of the standard models are aggregated with the results of the scenario analyses. Accompanying this aggregation is an extensive SST report, in which the insurer’s exposure in the different risk categories is summarized. As with Solvency II, the SST allows the use of internal risk models instead of standard models (including the use of partial internal models for different risk categories).

![Figure 3: Structure of the SST](image)

Interest rates, stock prices, currencies, and real estate prices are considered in the market risk model. It is based on risk metrics developed by J.P. Morgan, the most widespread approach for calculating value at risk in the field of banking. The risk factors are multivariate normally distributed and aggregated using a variance-covariance approach. The factors are estimated using ten years of monthly returns of selected indices. Note that not all parameters are determined by the regulator. Several are estimated by the insurer itself based on its own portfolio, which illustrates a main difference of the SST compared to other approaches (principles instead of fixed rules).

The Basel II credit risk approach is used under the credit risk standard model. In contrast to Basel II, operational risks are not considered in the model. Instead these risks are considered on a qualitative basis within the SST report. Applying the Basel II
approach within the SST framework has the advantage of being easy to implement and
to reduce incentives for regulatory arbitrage between banking and insurance.

Three separate insurance risk models were developed for life, non-life, and health
insurance. There is no standard model for reinsurers, as these should employ adequate
internal risk models for calculating insurance risk.

- The standard model for life insurance consists of seven risk factors such as
  mortality, lapse rate, exercising of product options, and costs. All risks are
  modeled using a normal distribution and aggregated under given assumptions on
  correlations between these risks.

- In the non-life insurance model, risk is subdivided into three groups: small
  claims, large claims, and change in provisions (resulting from previous years’
  claims). Catastrophe risks are included as part of the scenario analyses. The sum
  of the small claims is modeled using a normal distribution, whereas for large
  claims, number and size are modeled separately. The number of claims is Poisson
  distributed. Each line of business has a specific distribution, e.g., a Pareto
  distribution, and given parameters for the claim size (see Luder, 2005).

- The health insurance standard model considers three lines: nursing expenses,
  individual per diem allowance, and collective per diem allowance. For each line,
  a mean and a standard deviation is estimated on the basis of historical data. The
  lines are aggregated using assumptions on the correlations between them (see

Risks not covered by these standard models are covered by quantitative and qualitative
scenarios. The qualitative scenarios are included in the SST report, while the quantita-
tive scenarios are considered in calculating the target capital. Among the quantitative
scenarios are, e.g., natural disasters or a financial market crash. For these scenarios,
probability of occurrence and resulting effect on the solvency level are estimated.

To calculate the target capital, the results of the standard models and of the scenarios
are aggregated using a weighted average of the loss distribution of the standard models
and the loss distribution of the scenarios (using the scenario probabilities as weights;
see Swiss Federal Office of Private Insurance, 2004). The target capital should
 correspond to the economic capital an insurance company needs for running its
business within a given safety level. It is calculated as the tail value at risk (also
known as expected shortfall or conditional value at risk) of the aggregated loss distribution within a year at a confidence level of 99%.

**Definition of available capital**

Under the SST, the available capital is called risk-bearing capital and is defined as the difference between the market value of the assets and the best estimate of the liabilities. The regulator does not provide a method for estimating the market value of the liabilities. However, the embedded options and guarantees must be taken into account when determining the best estimate of the liabilities. Several different methods for present value calculation are deemed acceptable, for example, risk-neutral valuation.

**Intervention**

The SST’s provisions for intervention are still under construction, but will probably be in place by 2011, the end of the transition period. Current planning is going in the direction of Solvency II. There will be different intervention levels depending on the relation of available capital to target capital and minimum capital.

### 2.3 Comparison

In this section we compare the four systems described in Section 2 and analyze the main differences between them. Table 1 provides a summary of this comparison. The structure of the table reflects that of Section 2, i.e., it covers (1) general information, (2) definition of capital required, (3) definition of available capital, and (4) levels of intervention. The subsections below follow the structure of Table 1.

#### 2.3.1 General Information

**Country of application/year of introduction**

The U.S. RBC standards have been in effect since 1994 without major revisions. In the same year, New Zealand’s Fair Insurance Code was introduced. However due to its reliance on different rating agencies, the underlying models were adapted continuously. The two youngest models are the SST (introduced in 2006) and Solvency II (currently developed, expected to be effective in 2012). The Solvency I
rules currently in use in the EU have been implemented in the 1970s, with a minor revision in 2004.

Transferring the task of model revision to rating agencies as done in New Zealand seems to be a flexible way of ensuring that a system reflects recent developments in the insurance and financial markets and recent findings in academic research. The fact that only a few rating agencies (selected by the Ministry of Economic Development) are authorized to issue ratings reduces incentives for moral hazard by the rating agencies, e.g., to systematically provide better ratings than other rating agencies. Additionally, inaccurate or wrong ratings by a rating agency might be punished not only by the regulator, but also by the market, which would lose faith in the agency’s ratings. Thus the demand for ratings from that rating agency would decrease. This also reduces incentives for moral hazard by the insurance companies, e.g., to exert pressure on the rating agency. Another idea in the context of flexibility, which we will address below, is to use principles-based approaches instead of strict rules, as done in the SST.
<table>
<thead>
<tr>
<th>System</th>
<th>RBC standards</th>
<th>Solvency II</th>
<th>Self-Regulatory Framework</th>
<th>Swiss Solvency Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. General information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country of application</td>
<td>USA</td>
<td>European Union</td>
<td>New Zealand</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Year of introduction</td>
<td>1994</td>
<td>2012 (expected)</td>
<td>1994</td>
<td>2006</td>
</tr>
<tr>
<td><strong>Main pillars</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulated companies</td>
<td>Insurers (domestic &amp; foreign); no reinsurers</td>
<td>Insurers and reinsurers (domestic &amp; foreign)</td>
<td>P&amp;C insurers (domestic &amp; foreign); no re-/life insurers</td>
<td>Insurers and reinsurers (domestic &amp; foreign)</td>
</tr>
<tr>
<td>Consideration of management risk</td>
<td>No</td>
<td>Rudimentarily addressed by pillar II</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Public disclosure requirements</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>2. Definition of capital required</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model typology</td>
<td>Static factor model</td>
<td>Static factor model</td>
<td>Static factor model</td>
<td>Static factor model</td>
</tr>
<tr>
<td>Total balance sheet approach</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time horizon</td>
<td>1 year</td>
<td>1 year</td>
<td>1 year</td>
<td>1 year</td>
</tr>
<tr>
<td>Risk measure/calibration</td>
<td>No risk measure</td>
<td>Value at risk/99.5% confidence level</td>
<td>A.M. Best: Expected policyholder deficit</td>
<td>Expected shortfall/99% confidence level</td>
</tr>
<tr>
<td>Consideration of operational risk</td>
<td>Not explicitly (implicit via off-balance sheet items—R0)</td>
<td>Quantitatively</td>
<td>A.M. Best: No explicit consideration</td>
<td>Qualitatively</td>
</tr>
<tr>
<td>Consideration of catastrophe risk</td>
<td>No</td>
<td>Yes (as part of underwriting risk)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Use of internal models</td>
<td>No</td>
<td>Appreciated</td>
<td>No</td>
<td>Appreciated for insurers; required for re-insurers</td>
</tr>
<tr>
<td><strong>3. Definition of available capital</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definition based on market or book values</td>
<td>Book values</td>
<td>Market values</td>
<td>Market values</td>
<td>Market values</td>
</tr>
<tr>
<td>Classification of available capital</td>
<td>No</td>
<td>Yes (three tiers)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Consideration of off-balance-sheet items</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>4. Intervention</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levels of intervention</td>
<td>4</td>
<td>2</td>
<td>No intervention by regulator, but market discipline</td>
<td>2</td>
</tr>
<tr>
<td>Clarity of sanctions</td>
<td>Strict, clear rules</td>
<td>Not clear yet</td>
<td>No direct sanctions</td>
<td>Not clear yet</td>
</tr>
</tbody>
</table>

**Table 1: Comparison of Solvency Systems**
Basic setting

The 1994 U.S. standards consist of a formula for determining an amount of necessary capital. Younger systems, as the SST and Solvency II, take a more holistic approach and take both quantitative and qualitative aspects into consideration. Based on an analysis of failures and near-failures of insurance companies, it appears that the root of most insurance company failure is inexperienced management (see Conference of Insurance Supervisory Services of the Member States of the European Union, 2002; Ashby et al., 2003). Regulators thus also should include qualitative criteria, such as assessment of management capabilities, in the review process. This might then result in several segments of regulation with different criteria as can be seen under Solvency II: Pillar I addresses quantitative requirements and pillar II qualitative aspects. The U.S. system, in contrast, does not focus on qualitative aspects; however, these can be addressed by additional rules in individual states. Another interesting difference between the systems is that, some regulatory authorities do not rely completely on their own assessment, but also take the opinion of the market into consideration. This is the third pillar of Solvency II and the main foundation of New Zealand’s self-regulatory approach.

Regulated companies

Solvency II and the SST are effective for all insurance undertakings, i.e., property/casualty, life, health, and reinsurers. In contrast, the U.S. RBC standards do not apply to reinsurers (these are subject to regulation in their state of domicile). New Zealand’s framework applies neither to reinsurers nor to life insurers. Regulation of life insurance in New Zealand is conducted by way of several legislative frameworks, of which the Life Insurance Act of 1908 is the most important. However, an extensive review of life insurance regulation in New Zealand is currently in process (see Law Commission of New Zealand, 2004).

Another question in this context is how to regulate third-country insurers and insurance groups. All four systems studied here apply the country-of-destination principle. This makes all insurers conducting business in the country, domestic or foreign, subject to national legislation. An alternative is the country-of-origin principle. Solvency II aims to facilitate compliance with regulation for foreign insurers with affiliates active in the EU when the home country’s solvency regime is at least
equivalent to that of the EU (see EC, 2007a, p. 238). However, cross-country operations would be best facilitated by global harmonization of solvency frameworks.

**Consideration of management risk**

As mentioned, regulators have recently begun to include qualitative aspects in their review processes, an important part of which is assessment of management capability. Rating agencies (e.g., A.M. Best and S&P), as compared to regulators, have a great deal of experience with this type of assessment, and an important part of it is the interactive exchange of information with management. This type of evaluation is not even a part of the U.S. RBC system. However, Solvency II addresses management capabilities, in that it specifies that board members, senior management, and people in key management positions must be “fit and proper” (EC, 2007b, p. 8). More precisely, an insurer is required to demonstrate that its board collectively has sufficient knowledge and expertise to exercise effective supervision (see EC, 2007b, p. 8). Insurers are also obligated to provide the regulator with certain information concerning board members (see EC, 2007a, p. 73).

**Public disclosure requirements**

A new aspect of insurance regulation is market transparency, especially via public disclosure requirements. A transparent process should result in less regulation as market participants themselves ensure appropriate behavior. Academic evidence highlights the advantages of public disclosure (see, e.g., Rees et al., 1999; Epermanis and Harrington, 2006). Market discipline thus might be a building block in creating a strong and solvent insurance industry. Extensive disclosure requirements are the main foundation of New Zealand’s regulatory system. Under Solvency II, market discipline is addressed within pillar III, which obliges insurers to issue an annual public report on their solvency and financial condition (see EC, 2007a, p. 77). U.S. insurers are required to report the RBC and their available capital in their annual statements; however, the detailed calculations remain confidential (see Klein, 2005, p. 143). Currently, there are further no disclosure requirements under the SST. Rating agencies have recently been criticized for the lack of transparency of their rating assignment methodologies (see Doherty et al., 2007). The publicly available rating information serves as advertising material and thus cannot be relied on for insight into the objectivity of the rating procedures. An insurer’s rating might be of some use in comparing companies, but it is difficult to understand why an insurer received the
rating it did. Furthermore, mainly due to recent failures of rating agencies to provide adequate information (e.g., U.S. mortgage crisis, Enron, Worldcom), the concentration of market power in a small number of rating agencies has been questioned (see Doherty et al., 2007).

2.3.2 Definition of Capital Required

Model typology

The regulatory models used in practice can be classified as either static factor-based models or dynamic cash-flow-based models (see Eling et al., 2007). Static factor-based models apply a certain factor to a static accounting position. Dynamic cash-flow-based models, on the contrary, use projected future cash flows as a basis for calculation (see CEA and Mercer Oliver Wyman, 2005). The U.S. and the rating agencies use static factor models. Solvency II and the SST are risk-based factor models combined with scenarios, e.g., for financial market crisis and natural disasters. Both allow the use of dynamic cash flow models.

Rules- versus principles-based approach

The U.S. RBC standards is a rules-based approach, with a precisely defined solvency formula and no built-in flexibility to handle individual situations (see Klein and Wang, 2007). On the one hand this simplifies supervision. However on the other hand, it is not a very effective way of assessing the wide range of insurance risk profiles. Against it, principles-based approaches provide the insurer the opportunity of integrating regulatory requirements into its own risk management processes. The resulting alignment of business and regulatory objectives leads to more efficient insurance regulation (see FSA, 2007). The EU Solvency II framework, the SST, and the New Zealand model are all principles-based approaches.

Total balance sheet approach

Under a total balance sheet approach, capital requirements are calculated based on a comprehensive analysis of risks, taking into account the interaction between assets and liabilities, risk mitigation, and diversification (see CEA, 2007). The U.S. RBC standards do not follow this approach. These standards e.g. do not adequately account for
correlation between different risks because they employ a simple covariance formula (see Farny, 1997). Even though A.M. Best applies a similar covariance formula, its rating model achieves more of total balance sheet assessment because it considers risk mitigation techniques and diversification effects, among others. Solvency II, the SST, and the model used by S&P include all relevant activities of the insurance companies and its risk-driving factors and thus can be considered total balance sheet approaches (see Liebwein, 2006).

**Time horizon**

The models use different lengths of data history as input for the calculations—the U.S. model, e.g., includes the loss ratios of the past 10 years; in the Solvency II model, the data encompass the past 15 years (see Klein and Wang, 2007; CEIOPS, 2007). For long-tail business, future cash flows are generally calculated using historical payout patterns. For example, in the SST, payout patterns derived for the next 25 years are used in long-tail lines such as liability and transport (see Bundesamt für Privatversicherungen, 2006, p. 20). The future cash flows are discounted in order to obtain a best estimate of the liabilities. The resulting capital requirements should then cover the risks that the insurer faces within a one-year time horizon, i.e., the capital required is calculated as the capital the insurer needs for running its business at a given safety level for the next year. This seems generally appropriate, especially for non-life insurers as these mainly write annual contracts. However, some lines of business have long-term character. For example, in liability the claim settlement may take decades. Life insurance business also has long-term nature. When modeling liabilities, the (stochastic) trend of mortality must therefore be taken into consideration. Asset modeling for life insurance is also different from that of non-life insurers because of the different investments horizon. Therefore, especially in the life insurance business, a longer time horizon might be more appropriate. However, to date, this would be possible only under internal models in the SST and Solvency II.

**Risk measure/calibration**

There has been a long and intense discussion in academia and practice regarding the use of different risk measures in regulation (see, e.g., Artzner et al., 1999; Barth, 2000). Solvency II relies on the value at risk at a 99.5% confidence level. Statistically, regulators thus deem acceptable a 1 in 200 chance of the insurer becoming insolvent (see EC, 2007b, p. 5). In contrast, the SST uses the expected shortfall, which
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corresponds to the tail value at risk, at a 99% confidence level. The main difference between value at risk and tail value at risk is that the latter takes the expected tail loss into consideration while the first approach relies on ruin probability. The tail value at risk is thus more relevant to policyholders since it is they who have to bear the loss in case of insolvency. Shareholders, who have a limited downside risk (in case of limited liability), might be more interested in the ruin probability. Another advantage of the tail value at risk is that it has a number of desirable mathematical features, such as additivity and convexity (see Artzner et al., 1999; McNeil et al., 2005, p. 243). One drawback, however, is its reliance on a precise estimation of the costs in case of insolvency, which are difficult to obtain in practice. The value at risk approach has the further advantage that it is widely used in practice and is possibly one of the best understood risk measures.

The Swiss, the New Zealand, and the EU systems all have in common that they determine a stochastic distribution of the future outcomes (or cash flows) and then apply a risk measure to derive the capital requirements. For example, one might consider the 0.5% quantile of this stochastic distribution, which leads to the value at risk at a 99.5% confidence level (as considered under Solvency II). In contrast, the U.S. system does not operate on the stochastic nature and distribution of capital requirements and therefore does not apply any risk measure when deriving the RBC.

**Consideration of operational risk**

Operational risk is the risk of loss resulting from inadequate or failed internal processes, people, and systems or from external events (see Basel Committee on Banking Supervision, 2001). Although this definition originates in the banking sector, operational risk is also highly relevant in the insurance industry. Solvency II follows Basel II by using various quantitative approaches to measure operational risk (i.e., basic indicator approach, standardized approach, advanced measurement approach). Against it, the designers of the SST argued that it is impossible to properly quantify operational risk. They thus decided to include it on a qualitative basis. Under the SST, management must complete a qualitative statement, which becomes part of the SST report. The U.S. system does not explicitly address operational risk, but it could be interpreted as part of the off-balance sheet items (R0). Rating agencies vary in the way they take operational risk into consideration. A.M. Best does not explicitly assess them. S&P includes them on a quantitative basis using a factor-based approach with premiums written and total liabilities as variables.
Consideration of catastrophe risk

Catastrophe risk has become important in recent years due to adverse developments such as, e.g., climate change (see Klein and Wang, 2007). Accordingly, of the systems under evaluation here, only the older U.S. standards do not incorporate catastrophe risk. The Solvency II directive explicitly states that extreme events should be considered within the underwriting risk category (see EC, 2007a, pp. 107–108). Within A.M. Best’s rating process, catastrophe stress tests are conducted. These tests not only evaluate the insurer’s financial resilience, but also their overall catastrophe risk management process (see A.M. Best, 2007b). S&P only partially includes catastrophe risk in that it applies a catastrophe capital charge to property/casualty insurers, but not to life insurers (see S&P, 2007a). The SST includes catastrophe risk via predefined scenarios (see Swiss Federal Office of Private Insurance, 2004).

There are various ways to include catastrophe risk in regulation and these also should reflect the multiple alternatives for catastrophic risk financing, including reinsurance, options, swaps, catastrophe bonds, and weather derivatives. With regard to regulation, it is important to ensure that insurers will be motivated to use these devices and techniques in an appropriate manner. An extensive study on alternative means of catastrophic risk financing, its current status in the U.S. and EU solvency systems, and various proposals for improvement can be found in Klein and Wang (2007).

Use of internal models

Another recent innovation in regulation is the use of internal, instead of standard, risk models in determining the solvency capital required. On the one hand, those internal models result in more accurate analysis, control, and management of the insurer’s financial situation than do the more generic standard models. On the other hand, the regulatory authorities need resources to review all the different sophisticated models. The use of internal models is allowed under Solvency II and the SST, but not under the U.S. RBC standards. Under the SST and Solvency II, regulators can even require the use of an internal model if the insurer’s particular conditions are substantially different from standard model assumptions (see EC, 2003, p. 39; Bundesamt für Privatversicherungen, 2006). Furthermore, reinsurers are required to use internal models under the SST (see Swiss Federal Office of Private Insurance, 2004). In New Zealand, an insurer’s internal model is considered as add-ons to the rating agencies’ models (see S&P, 2007a).
2.3.3 Definition of Available Capital

Market/book values

One of the main criticisms on the U.S. system relates to its use of book values (see Grace et al., 1998). Market values are considered a more appropriate and accurate indicator of an insurer’s risk profile. However, it is difficult to derive these market values. The SST states that observable market prices are to be used wherever possible (so-called marking-to-market). If not available, comparable market values, taking into account liquidity and other product-specific features, or values derived on a model basis (marking-to-model) should be used (see Swiss Federal Office of Private Insurance, 2004). Solvency II stipulates a mixture of marking-to-market and marking-to-model valuation (see Sandström, 2006, p. 152). A.M. Best and S&P both rely on market values and make adjustments when these are not available (see A.M. Best, 2007a; S&P, 2007a).

Classification of available capital

There are different ways to ensure that an insurer has sufficient assets to fulfill policyholder obligations. One involves restrictive investment rules for insurers. However, these rules also reduce investment return, which in turn increases policy prices (see Klein, 1995). Another approach is to limit the eligibility of certain asset classes to offset capital requirements. Solvency II follows this approach and identifies three tiers of capital, along with clear guidelines for the accountability of each tier against capital requirements (see EC, 2007a, p. 12). The SST, the U.S. RBC standards, and the rating agencies only identify one overall amount of available capital. However, they also differentiate between the quality of different asset classes (e.g., subordinated debt or hybrid instruments) by either limiting or adjusting the value of these assets when calculating the available solvency margin.

Consideration of off-balance-sheet items

In addition to capital recorded on the balance sheet, Solvency II, S&P, and A.M. Best also consider off-balance-sheet items when determining an insurer’s available capital. Those can e.g. be letters of credit, which the insurer can call upon and therewith gain additional financial resources to meet policyholder obligations. Off-balance-sheet items that decrease the amount of available capital include, e.g., guarantees for
affiliates issued by the insurer itself. Only A.M. Best makes deductions based on off-balance-sheet items from available capital. Solvency II and S&P, in contrast, consider only those off-balance-sheet items that increase the available capital. The SST and the U.S. standards do not consider off-balance-sheet items at all when determining an insurer’s available capital. However, the U.S. standards and the A.M. Best model consider off-balance-sheet items, such as derivative instruments or contingent liabilities, when calculating the insurer’s required capital. One goal of Solvency II is to coordinate the recognition of off-balance-sheet items with the development of the International Financial Reporting Standards (see Duverne and Le Douit, 2007).

2.3.4 Intervention

Levels of intervention

There is a fair amount of variation in the intervention approaches of the four systems. The U.S. system has four different levels of intervention, whereas the Solvency II system planned for the EU and the SST have only two. The New Zealand system has no levels of intervention.

Clarity of sanctions

The U.S. system has relatively strict rules with clear sanctions for each of the five levels of solvency it encompasses. Interventions are relatively soft in the Swiss and EU systems, where it is vaguely specified what intervention should take place at each of the solvency levels. The less detailed system of intervention can again be characterized as a principle-based approach—that is, the essential purpose of intervention is the minimization of policyholder loss (see Klein, 1995). There is no evidence as to whether the relatively strict U.S. rules, the soft rules of the SST, or the New Zealand system of sole reliance on market forces has the best outcome as to protecting policyholders.

2.4 Conclusion

The aim of this chapter was to provide an overview and comparison of the risk-based capital (RBC) requirements implemented in the U.S., the EU, New Zealand, and Switzerland. Differences in the time of introduction, industrial environment, and regulatory philosophy have resulted in very different kinds of regulation. Some
systems impose very clear and strict rules (the U.S.); others simply provide a few principles, leaving the insurers with a great deal of discretion in conducting their businesses (Switzerland). Another extreme is to provide nothing else than the requirement to obtain a rating (New Zealand). It is as yet unclear exactly what form and direction regulation will take in the EU, where regulators are currently in the process of developing the new Solvency II framework. However, the three-pillar structure (I. Quantitative requirements; II. Qualitative requirements; III. Public disclosure) on which the new regulations will be based shows that the regulators have considered and been influenced by all the different types of solvency regulation examined in this chapter.

In summary, the three most important differences between the solvency systems analyzed in this chapter are as follows.

(1) Two different risk measures—value at risk and expected shortfall—are used. Whereas value at risk is the simpler and more widespread approach, expected shortfall takes into consideration the severity of a possible insolvency, which is important from a policyholder and thus also from a regulatory point of view. In addition, expected shortfall has some valuable mathematical features that the value at risk has not. Each measure has its advantages and disadvantages and it is difficult to say which one is better. However, academic evidence suggests that expected shortfall might be more appropriate (see Artzner et al., 1999).

(2) Solvency II and the Swiss Solvency Test (SST) encourage the development and use of internal risk models to calculate RBC. Internal models provide a more accurate and individualized assessment of an insurer’s solvency position compared to the standardized models that are the foundation of the U.S. system and of the private ratings agencies. Developing internal models can foster innovation in insurance companies and provide the insurer with the opportunity to integrate regulatory requirements into its risk management process. However, it remains to be seen whether regulatory authorities will have the resources to deal with a large number of different and highly sophisticated models.

(3) The importance of accounting for operational and catastrophic risk is unquestioned, but how to best measure it, is contested. There are great differences in the way the four systems cover operational risk: There is no explicit consideration in the U.S. standards or in the A.M. Best model. The SST makes a qualitative assessment, whereas under Solvency II, operational risk is a quantitative factor. Similarly, catastrophe risk is variously integrated into the different models, including by way of catastrophe stress.
tests (in the SST), submodules to underwriting risk covering extreme events (planned under Solvency II), simple capital charges (S&P), and quantitative stress tests in combination with qualitative assessment of catastrophe risk management processes (A.M. Best).

This comparison of the various systems reveals that there is not one single capital standard in the insurance industry; indeed, there is a fair amount of variation in how the insurance industry is regulated around the world. Thus, comparing the systems provides an opportunity to learn from other countries. There is only limited empirical evidence on the outcome of the different models in terms of costs and benefits, and it is thus not obvious which system is the best and/or most efficient. Therefore comparing the different approaches and recognizing differences is important, especially as a basis for identifying the best way to determine RBC standards.
3 The United States RBC Standards, Solvency II, and the Swiss Solvency Test: A Comparative Assessment

3.1 Introduction

Insurance company insolvency may have disproportionately high costs for the customer, and even for society as a whole, compared to insolvency in other industries. This is partly because policyholders buy insurance to protect themselves against a particular loss, so when the loss occurs and the insurance company becomes insolvent and unable to pay the claim, it is possible that the policyholder’s very economic existence is jeopardized. The insolvency of an insurance company can also affect the economic existence of a third party, for example, in the case of liability insurance. The quality of an insurance contract is thus directly linked with the solvency level of the offering insurer. Unfortunately, it would be very expensive, if even possible, for policyholders to monitor the solvency status of their insurance companies. This situation of asymmetric information, combined with the severe consequences of insurance company failures, makes regulation of the insurance industry, with the aim of decreasing the risk of insolvency, of great public interest (see Klein, 1995). However, regulation comes at a cost. Although a well-designed regulatory framework can reduce the risk of insurer insolvency, it can also distort the decisions of financially sound insurers. These distortions create market inefficiencies, leading to an eventually even lower safety level and higher premium prices (see Cummins et al., 1995). Also, ineffective regulatory frameworks can give insurance companies, the regulator, and policyholders a false sense of security.

Cummins et al. (1994), among others, analyze this regulatory tradeoff. They review major criteria affecting an insurer’s insolvency risk and discuss the rationale and objectives of solvency regulation in the form of risk-based capital (RBC) standards. The main contribution of their work is a conceptual framework that stakeholders of insurance companies can use to evaluate RBC standards. To our knowledge, two applications of these criteria have been published to date. KPMG (2002) use a related set of criteria in their study of different methodologies for assessing an insurer’s
financial position. However, they do not explicitly consider existing solvency regulation systems. Doff (2008) utilizes the Cummins et al. (1994) framework and explicitly considers the Solvency II standards. Doff (2008) encouraged us to engage in research that would extend the contributions of his paper and also that of Cummins et al. (1994).

Since the publication of Cummins et al. (1994), capital regulation has changed dramatically; the former volume-driven capital requirements have, for the most part, been replaced by risk-sensitive capital requirements. This change was a response to underlying changes in the insurance and capital markets, including, for example, the convergence of the banking and the insurance business, and the increasing complexity and interdependence of insurer assets and liabilities (see van Rossum, 2005). We account for these changes and trends in that we add four new criteria to the original framework of Cummins et al. (1994). These new criteria put special emphasis on the dynamics of insurance and capital markets, as well as on recent developments in regulation. This extension of Cummins et al.’s list of criteria is the chapter’s first contribution.

Our second contribution is an application of this extended framework. Using all (now) eleven criteria, we analyze the RBC requirements of the United States (U.S.), of the Solvency II framework of the European Union (EU), and of the Swiss Solvency Test (SST) of Switzerland. We consider the U.S. RBC requirements and the Solvency II framework as most important, as these regulations cover the two largest insurance markets in the world, accounting for almost 70% of the global life and non-life premiums in 2006 (see Swiss Re, 2007). We further integrate the SST in our analysis to allow for a comparison of the SST with Solvency II against the background of a set of predefined criteria. This provides the opportunity to assess the compatibility of the SST with Solvency II, which is an explicit goal of the Swiss regulator. This chapter’s contributions are of value for both regulators and insurers, perhaps most especially for those insurers engaged in activities in more than one of the three geographic regions.

The remainder of this chapter is organized as follows. Section 2 provides a short overview of the three systems. A critical analysis, structured along the individual criteria, is conducted in Section 3. In Section 4, we provide a summary of the results as well as an integrated assessment of each of the three systems.
3.2 RBC Standards: An Overview

This section provides a short overview of the three systems under consideration. The requirements of each system are quite different, ranging from a pure risk-based capital formula (implemented in the U.S.) to a comprehensive analysis of quantitative and qualitative criteria, including disclosure requirements, as planned in the EU. For a more detailed overview of the three systems, the reader is referred to Eling and Holzmüller (2008).

3.2.1 U.S. RBC Standards

The National Association of Insurance Commissioners (NAIC) introduced the U.S. RBC standards in 1994. This framework aims to incorporate the size and risk profiles of insurers when determining capital requirements. To account for the differences between lines of business, the framework contains three separate formulas to calculate the required capital for property/casualty, life, and health insurance (see Grace et al., 1998).

Each of the three RBC formulas is an aggregation of individual risk charges for prescribed risk categories. The property/casualty formula, for example, includes charges for underwriting, credit, asset, and growth risk. The aggregation of the risk charges includes a covariance adjustment in order to account for the diversification between the risk categories. The individual risk charges are factor-based. More precisely, the risk charges are calculated by multiplying a certain factor with a volume number. For example, the volume number employed to calculate the underwriting risk charge is comprised of the insurer’s reserves and the insurer’s premiums written within one year (see Cummins et al., 1995). In addition to the capital requirements based on these RBC formulas, each insurer must comply with state-specific rules (see Klein and Wang, 2007).

Comparing an insurer’s available capital with the amount of capital required provides information on the insurer’s financial strength. Under the U.S. standards, the available capital corresponds to the total adjusted capital, which equals total surplus for most insurers (see Grace et al., 1998). Depending on how total surplus compares to RBC, the regulator applies one of five action levels to the company: (1) no action is required; (2) the insurer must submit a corrective plan to the regulator; (3) the regulator may issue a corrective order against the insurer; (4) the regulator may require the liquidation or rehabilitation of the insurer; or (5), and most severe, the regulator must require the liquidation or rehabilitation of the insurer (see Dickinson, 1997).
3.2.2 Solvency II in the European Union

EU insurance regulation is in a transition phase. Solvency I has been in effect since 2004. This framework is a rules-based approach, under which capital requirements are calculated by applying fixed ratios to measures for risk exposures. Those measures can be technical provisions, premiums, or claims (see Linder and Ronkainen, 2004). Solvency I is a transitional regulatory scheme that will be abandoned when Solvency II comes into effect, which is expected to occur in 2012.

The goal of the Solvency II framework is to harmonize insurance regulation across the EU member countries, improve policyholder protection, and increase the stability of the financial system as a whole. To achieve these goals, Solvency II follows a three-pillar structure: capital requirements (Pillar I), qualitative requirements (Pillar II), and public disclosure rules (Pillar III) (see EC, 2007b). Within Pillar I, the determination of capital requirements follows a two-level approach. The solvency capital requirement (SCR) is the target capital level the insurer should aim for; the lower level, the minimum capital requirement (MCR), is the minimum capital necessary to protect policyholder interests (see EC, 2007a).

Under Solvency II, there are two main ways to determine an insurer’s SCR. First, and new to insurance regulation, insurers can calculate the SCR using their own internal models, provided those models have been approved by the regulator (see CEIOPS, 2007b; van Rossum, 2005). The internal models are, of course, entity-specific and hence reflect an insurer’s actual risk situation more accurately than is possible using a generic model. The second way of determining the SCR is by use of a standard model, a one-size-fits-all approach. The Solvency II standard model is still to be finalized, which is expected to occur in the second half of 2009 (see EC, 2007b). Further discussion in this chapter thus will be reference to the current proposal, detailed in CEIOPS (2007a). In addition to these two possibilities for determining SCR, insurers can use a combination method comprised of the standard model supplemented with internally developed components (see EC, 2007b).

Under Solvency II, an insurer’s available is measured according to its ability to absorb losses. This measurement results in three classes of capital, each of which have differing eligibility to offset the MCR and the SCR. The European Commission still has to finalize this classification system via implementing measures (see EC, 2007a).

Depending on the ratio of available capital to SCR and MCR, three levels of intervention are possible. (1) No intervention when the insurer’s available capital is
equal to or greater than the SCR. (2) If the insurer’s available capital falls between the SCR and the MCR levels, the regulator will take action with the goal of restoring the insurer to situation (1). (3) If the insurer’s available capital is less than the MCR, the regulator will withdraw the insurer’s license. The insurer’s ongoing business is then liquidated, or its liabilities are transferred to another insurance entity (see EC, 2007a, 2007b).

3.2.3 Swiss Solvency Test

The Swiss Federal Office of Private Insurance developed the Swiss Solvency Test (SST) in close cooperation with the Swiss insurance industry and academic representatives from the field of insurance (see Luder, 2005). The project began in 2003 and was field tested in 2004 and 2005. In 2006, the new framework became applicable for large insurers and, since the beginning of 2008, is now in effect for all insurers (see Keller, 2007).

The main goal of the SST is similar to that of Solvency II: protection of policyholder interests. Furthermore, the SST has increased the transparency of the insurance industry by, for example, the introduction of consistent valuation techniques. Apart from these two main objectives, the SST aims to be compatible with its European counterpart Solvency II (see Swiss Federal Office of Private Insurance, 2004).

The SST consists of two parts: the SST target capital (based on quantitative elements) and the SST report, which addresses qualitative items. Within the first part, the SST follows a two-level approach similar to that of Solvency II. The higher target capital is risk-based and relies on a market-consistent valuation. The lower level, which is the minimum solvency allowed, is a volume indicator based on statutory values (see Swiss Federal Office of Private Insurance, 2004; Schweizerischer Bundesrat, 2005). Overall, the SST includes a number of models that take into consideration market risk, insurance risk, and credit risk. Additionally, predefined scenario analyses are used (see Luder, 2005).

Also in line with Solvency II, the SST target capital can be calculated using a standard model, an insurer-specific internal model, or a combination of the two (see Luder, 2005). Internal models and partially internal models are subject to supervisory approval in Switzerland, too—details on the requirements for internal models are provided in Swiss Federal Office of Private Insurance (2006a). Under the SST, reinsurers and other insurers conducting business too specialized to allow for a
standardized procedure are actually required to develop and apply internal models (see von Bomhard and Frey, 2006).

The SST will likely encompass three levels of regulator intervention, based on the relation of available capital to SCR and MCR, but these are as yet under construction and their precise design is somewhat contingent on the development of Solvency II.

3.3 Critical Analysis of RBC Standards

3.3.1 Overview of Criteria Catalogue

In this section we assess the three systems presented in Section 2. Our aim is to evaluate the advantages and disadvantages of the different approaches based on a broad criteria framework. Our framework builds on the seven criteria provided by Cummins et al. (1994), which are as follows:

1. Getting the appropriate incentives: The risk-based capital formula should provide incentives for weak companies to hold more capital and/or reduce their exposure to risk without significantly distorting the decisions of financially sound insurers.

2. Formula should be risk-sensitive: The risk-based capital formula should reflect the major types of risk that affect insurers and be sensitive to how these risks differ across insurers.

3. Formula should be appropriately calibrated: The risk-based capital charges (or weights) for each major type of risk should be proportional to their impact on the overall risk of insolvency.

4. Focus on the highest insolvency costs for economy as a whole: The risk-based capital system should focus on identifying those insurers likely to impose the highest costs of insolvency.

5. Focus on economic values: The formula and/or the measurement of actual capital should reflect the economic value of assets and liabilities whenever practicable.

6. System should discourage misreporting: To the extent possible, the risk-based capital system should discourage underreporting of loss reserves and other forms of manipulation by insurers.
7. Formula as simple as possible: The formula should avoid complexity that is of questionable value in increasing accuracy of risk measurement.

We extend this framework with four additional criteria. The aim of this extension is to integrate the dynamics of insurance and capital markets observed in the last several years. The intention behind each criterion will be detailed separately in Section 3.3.

8. Adequacy in economic crises and anticipation of systematic risk\(^3\): Solvency regulation should anticipate systematic risk and prevent the insurance industry from being trapped in a vicious cycle when economic crises occur.

9. Assessment of management: A solvency system should take into consideration “soft” factors, including, particularly, management capabilities.

10. Flexibility of framework over time: A model should be flexible with regard to its general concept and to its parameters. Empirical insights and theoretical development, such as new models and concepts, should lead to continuous improvement.

11. Strengthening of risk management and market transparency: Solvency regulation should require insurers to handle the predominantly quantitative risks with sound risk management. Increased market transparency will, in the long run, reduce the need for regulation.

### 3.3.2 Comparison of the Three Systems Under the Existing Criteria

**Criterion 1: Getting the appropriate incentives**

In general, insurance markets are prone to a moral hazard with regard to insolvency risk. On the one hand, it is in the interest of the policyholder that the insurance company holds a high capital cushion. The insurance company, on the other hand, has an incentive to reduce the safety level, as it will be rather the policyholders, not itself, who will be hurt most by a possible insolvency (see Klein, 1995; different for mutual insurers). The existence of state guarantee funds further reinforces the incentive to reduce the safety level, as solvent insurers—by means of non-risk-based premiums—

\(^3\) The definition of systematic risk used within this thesis corresponds to the risk associated to a plan or system. It does not address systemic risk as handled within market portfolio theory.
pay the losses of insolvent insurers (see Cummins et al., 1995). Based on these market imperfections, the goal of RBC systems should be to provide incentives for weak companies to hold more capital and/or reduce their exposure to risk. At the same time, the system should minimize distorting the decisions of financially sound insurers (see Cummins et al., 1994).

The U.S. RBC framework fails to satisfy this criterion. On the contrary, it provides incentives to insurers to charge lower premiums, as this reduces their capital requirements. This dependency originates in the factor-based calculation of the underwriting risk charge, which uses premiums and reserves as volume indicators. Cautious rate making thus results in higher capital requirements, although the company is, ceteris paribus, safer if it collects higher premiums. The same relationship holds with regard to the reserving practices of insurers. The RBC formula “rewards” insurers holding lower reserves—having a higher risk of insolvency—with relatively lower capital requirements (see Feldblum, 1996). In addition to the RBC requirements, U.S. state statues define absolute minimum capital levels between $0.5 million and $6 millions. The level depends on the state and the insurer’s lines of business, but not on its actual risk profile (see Klein, 2005, p. 141). However, even though these capital requirements fail to provide the right incentives according to Criterion 1, they are not significant due to their low absolute level.

In principle, Solvency II does satisfy Criterion 1. The standard approach to determine the SCR is in its main parts risk-sensitive—higher risk exposures lead to higher capital requirements. However, some risks are too complex to be addressed by a one-size-fits-all standard approach. Accordingly, the non-life and health underwriting risks are only included in the form of factor-based calculations using gross premiums (and claims expenditure) of the accounting year as variables. This simplification allows the inclusion of those risks in the standard approach, but it reduces the risk-sensitivity of the resulting capital requirement. The incentives based on these two risk categories thus do not satisfy Criterion 1, as higher premiums, and not necessarily higher risk exposures, lead to higher capital requirements (see Doff, 2008; CEIOPS, 2007b). The alternative method of calculating the SCR—by use of internal models—is discussed below for Solvency II and the SST together. As for calculation of the MCR under Solvency II, two approaches are currently under discussion. First, the modular approach calculates the MCR with a simplified version of the standard approach calibrated to a 90% confidence level. This simplified version will include the non-life underwriting risk module of the standard approach, which is factor-based using gross premiums as variables. The modular approach therefore inherits the previously
mentioned problem that the capital requirement increases with increasing premiums, not with increasing risk, and therefore fails to satisfy Criterion 1 (see EC, 2007a). Second, the compact approach simply requires the MCR to be one-third of the SCR. The SCR, which needs regulator approval, ought to reflect the actual risk situation of the insurer. Hence, the MCR calculated by means of the compact approach is risk-based as well and thus satisfies Criterion 1 (see Doff, 2008; EC, 2007a). Irrespective of the MCR approach selected, an absolute minimum capital floor, € 2 million for life insurers and € 1 million for non-life and reinsurers, is required under Solvency II (see EC, 2007a). Again, even though not compliant with Criterion 1, this minimum capital floor is too low to have a significant effect.

As for the SST, Criterion 1 is generally satisfied. The target capital calculated under the standard approach increases with increasing risk and thus sets the right incentives for insurers. The use of internal models to calculate target capital is discussed below, for Solvency II and the SST together. Not in line with Criterion 1 is the factor-based calculation of minimum solvency under the SST, which is determined through the multiplication of a specific factor with premiums or claims for non-life insurers and with mathematical provisions for life insurers. This approach is model-independent and objective, but it does not reflect the insurer’s specific risk exposures and therefore does not provide the right incentives (see Swiss Federal Office of Private Insurance, 2004; Schweizerischer Bundesrat, 2005).

Internal models for calculating the SCR, under Solvency II, and target capital, under the SST, must be approved by the regulator and therefore are assumed to satisfy Criterion 1. Their development and use is encouraged by the European Commission and the Swiss Federal Office of Private Insurance as the effort will force insurance companies to focus on risk management, which also supports Criterion 1 (see EC, 2004; Swiss Federal Office of Private Insurance, 2004). However, for the benefits provided by internal models to pay off, some conditions will have to be met. First, the regulator needs to have enough capacity to assess a large number of different and sophisticated models developed by insurers (see, e.g., Eling and Holzmüller, 2008). Second, the regulator ought to accept the internal model results and avoid imposing arbitrary capital add-ons, which could lead to requiring insurers to hold more capital than is economically sensible (see Doff, 2008; von Bomhard and Frey, 2006). Third and last, for internal models to reflect the actual risk situation of an insurer, the models need to be embedded in the company’s business processes. Also, responsibility for the models should be assigned to senior management (see von Bomhard and Frey, 2006).
Empirical evidence on the effectiveness of the internal model approach is still lacking, but it seems likely that this approach will satisfy Criterion 1 (see Eling et al., 2007).
Criterion 2: Formula should be risk-sensitive

Criterion 2 stipulates that solvency frameworks should cover all major types of risk, as this reduces the possibility for system arbitrage. Additionally, to the degree possible, RBC requirements ought to be sensitive to how these risks differ across insurers. Risk-sensitivity reduces the extent of undesirable distortions and the likelihood of discrimination against certain segments of the industry, particularly against small insurers (see Cummins et al., 1994). Compliance costs that are too high can eat into the profitability of small insurers, who are often specialized in certain products or niches. If those insurers are pushed out of the market, the result will be less competition and less choice for customers (see van Rossum, 2005). Hence, as a third aspect within Criterion 2, we test the models for potential discrimination against small insurers.

Most RBC systems incorporate the main types of risks—market, credit, and underwriting—which is in line with the first part of Criterion 2. The systems differ, however, in how they recognize operational and catastrophe risk. Operational risk is not explicitly considered within the U.S. RBC standards; instead, it is subsumed under business risk. Solvency II chooses a quantitative approach to account for operational
risk. It applies a factor-based charge, using premiums and technical provisions as variables (see EC, 2007a). The SST covers this risk category qualitatively within the SST report (see Sandström, 2006; Swiss Federal Office of Private Insurance, 2004). Hence, none of the three approaches is truly sensitive toward operational risk. However, operational risk is, indeed, difficult to measure and it is thus questionable whether more sophisticated models would lead to a better recognition of this type of risk. A good solution might be a factor-based charge, similar to Solvency II, complemented with qualitative organizational requirements (see Doff, 2008).

The three systems also differ in their treatment of catastrophe risk. The U.S. RBC formula does not cover catastrophe risk at all. Under Solvency II, catastrophe risk—extreme or exceptional events—is considered within underwriting risk (see EC, 2007a). The SST includes catastrophe risk via predefined scenarios (see Swiss Federal Office of Private Insurance, 2004). There are several ways to incorporate catastrophe risk into solvency regulation and in today’s globalized world, which appears to be experiencing ever more frequent extreme events, doing so is essential (see Eling and Holzmüller, 2008). Accordingly, Klein and Wang (2007) provide recommendations on how the U.S. system could integrate catastrophe risk and hence be improved.

There are two other risk categories that we will discuss only briefly at this point. The first of these is liquidity risk, which is less important for insurers than it is for banks, as an insurer’s financial business model is not based on a liquidity mismatch (see Doff, 2008). Consideration of liquidity risk is thus absent from most solvency systems, unless mentioned in the connection with the liquidity of an asset position. The second type is business/strategic risk, which can be important in explaining insurance company failures (see Conference of Insurance Supervisory Services of the Member States of the European Union, 2002; Doff, 2008). In this chapter, this type of risk is included within operational risk and addressed in more detail in our discussion of Criterion 9, i.e., management risk.

The second aspect of Criterion 2 specifies that capital requirements be sensitive to how these risks differ across insurers. The U.S. RBC standards are for many risk categories not risk-sensitive. An example is the asset concentration factor within the category of investment risk, which arbitrarily stipulates doubling the capital charges of the 10 largest investments, independent of their absolute size or riskiness. Another example is a fixed 10% charge on all reinsurance recoverables within the category of credit risk (see Feldblum, 1996). Solvency II is generally more risk-sensitive. Limitations are the factor-based charges for operational risk, non-life, and health underwriting risk.
Similarly, the capital requirements under the SST reflect different levels of risk, except for operational risk, which is considered only qualitatively (see Swiss Federal Office of Private Insurance, 2004).

The third aspect of Criterion 2 is that RBC frameworks should not unfairly and inefficiently disadvantage small insurers (Munch and Smallwood, 1980, provide a more detailed discussion). Solvency II and the SST impose high introductory costs on insurers and thereby the potential for discrimination. To counteract this possibility, Solvency II applies the principle of proportionality, which aims to facilitate compliance for small and young insurers. More precisely, simplifications are provided, including, for example, the calculation of technical provisions or the length of data input requirements (see CEIOPS, 2007a; EC, 2007b). Furthermore, the SST and Solvency II offer a standard model that can be used to determine capital requirements in cases where the insurer’s operations are relatively straightforward (see EC, 2007b; Bundesamt für Privatversicherungen, 2006). However, even though using the standard model avoids the high development cost of an internal model, it can result in higher capital requirements (see Swiss Federal Office of Private Insurance, 2004).

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<th>Criterion</th>
<th>United States</th>
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<th>Switzerland</th>
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<tr>
<td>2. Formula</td>
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<tr>
<td>should be risk-sensitive</td>
<td>- No integration of operational risk</td>
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<td></td>
<td>- No integration of catastrophe risk</td>
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<td></td>
<td>- Measurement of asset concentration is arbitrary</td>
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<td></td>
<td>- No adequate consideration of credit risk</td>
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<tr>
<td></td>
<td>+ Framework covers all major risk categories</td>
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<td></td>
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<td></td>
<td>+ Factor-based approach for operational risk (variables: premiums and technical provisions)</td>
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<td></td>
<td>+ Standard approach mostly risk-sensitive, except for non-life and health underwriting risk modules</td>
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<td>- Potential discrimination against small insurers (high investments for the transition to Solvency II and the development of internal models)</td>
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<td></td>
<td>+ Standard model provided</td>
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<td></td>
<td>+ Additional alleviations for SMEs</td>
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<td></td>
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<tr>
<td></td>
<td>+ Framework covers all major risk categories</td>
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<tr>
<td></td>
<td>+ Qualitative consideration of operational risk</td>
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<td></td>
<td>+ Risk-sensitive standard approach</td>
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<td></td>
<td>- Potential discrimination against small insurers (high investments for introduction of SST and the development of internal models)</td>
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<tr>
<td></td>
<td>+ Standard model provided</td>
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*Legend:  + Satisfies criterion - Does not satisfy criterion +/- Assessment not possible (yet)*

*Table 2: Overview Criterion 2*


**Criterion 3: Formula should be appropriately calibrated**

According to Criterion 3, solvency systems should reflect the impact of the individual risks on the overall risk of insolvency. This implies appropriate calibration of the respective solvency models. We thus examine the three systems as to whether they account for (1) the dependencies between the different risk categories, (2) the time horizon, and (3) the confidence level applied. Due to the fact that the U.S. framework does not operate on the stochastic nature and distribution of capital requirements, the third aspect is valid only for Solvency II and the SST (see Eling and Holzmüller, 2008).

Under the U.S. system, the individual risk charges are aggregated by means of a covariance formula. This aggregation method follows Butsic (1993), who argued that not all risks will occur simultaneously. Whereas deductions for diversification are justified, the U.S. RBC formula goes further and omits any correlation or covariance terms, that is, it assumes the individual risks to be independent. However, because in practice there is at least partial dependence, this leads to an underestimation of capital requirements (see Feldblum, 1996). Hence the dependencies between the different risk categories are not well accounted for under the U.S. system.

The Solvency II aggregation method for the individual risks, as proposed by the European Commission, makes use of a square root formula. The formula contains predefined correlation coefficients that account for the dependencies between the risks (see EC, 2007a). The SCR calculated by means of this formula thus considers diversification effects, which is in line with Criterion 3. However, calibration of the formula is not yet final and thus Solvency II’s satisfaction of the first aspect of Criterion 3 will need to be reassessed when the formula is published. The internal models under Solvency II need to be tested on an individual case level.

In contrast to the U.S. framework, the dependencies between the risk categories are well accounted for under the SST standard approach. The standard risk models—asset, liability, and credit—are therein aggregated by means of assumed correlations between the individual risks, yielding to one probability distribution of the insurer’s capital. In addition, evaluation of each scenario within the SST results in one probability distribution, which are then aggregated with the distribution of the standard models. This aggregation corresponds to a weighted average, with the weights given by the respective probability of each scenario (see Swiss Federal Office of Private Insurance,
2004). As with Solvency II, whether dependencies are given adequate consideration within the SST’s internal models needs to be assessed on an individual case level.

The second aspect of model calibration has to do with the time horizon applied. All three systems identify capital requirements based on the risks the insurer faces within one year. This seems justified in the case of non-life insurers, who usually write annual contracts. However, considering, for example, the uncertain extent of incurred but unreported losses, or the potentially lengthy processes of claims settlement, a time horizon of one year might not be sufficient. Also, for life insurers a longer time horizon would possibly produce more reliable results (see Eling and Holzmüller, 2008).

Third, with regard to confidence level, Solvency II applies a value at risk on a confidence level of 99.5% (see EC, 2007a). In light of the fact that higher confidence reduces the risk of insolvency but also imposes a higher capital burden on insurers and thus eventually increases policy prices, the choice of 99.5% is in line with Criterion 3 (see CEIOPS, 2007b). The SST uses the expected shortfall at a confidence level of 99%. In an extensive field test, the Swiss Federal Office of Private Insurance identified the value at risk for Swiss life and non-life insurers that would be equivalent to a 99% expected shortfall. At the minimum it corresponded to 99.5%, at maximum to 99.7%, and for the median to a 99.63% value at risk (see Swiss Federal Office of Private Insurance, 2005). Thus, the confidence level applied by the SST is approximately equivalent to that of Solvency II and therefore in line with Criterion 3.

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<th>Criterion</th>
<th>United States</th>
<th>European Union</th>
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<tbody>
<tr>
<td>3. Formula should be appropriately calibrated</td>
<td>+ Covariance adjustment - Assumption of independence between different risks in general not justified</td>
<td>+/- Calibration of standard approach not final yet—if too early to assess +/- Individual assessment necessary for internal models + Value at risk (99.5%, 1 yr) as reference point satisfies Criterion 3</td>
<td>+ Aggregation of individual risks within standard approach under consideration of possible correlations +/- Individual assessment necessary for internal models + Expected shortfall (99%, 1 yr) as reference point satisfies Criterion 3</td>
</tr>
</tbody>
</table>

Legend:  
+ Satisfies criterion  
- Does not satisfy criterion  
+- Assessment not possible (yet)

Table 3: Overview Criterion 3
Criterion 4: Focus on the highest insolvency costs for economy as a whole

Based on an analysis of approximately 200 insurance company failures, Cummins et al. (1994) find that the major part of insolvency costs is induced by a small number of large insurer insolvencies. Hence, the objective of reducing total insolvency costs for the economy as a whole can best be achieved through an increased regulatory focus on large insurers’ solvency situations (see Cummins et al., 1994).

With the capital requirements more dependent on company size than on an insurer’s risk profile, the U.S. RBC system results in relatively higher capital requirements for large insurers. In light of the fact that most insolvency costs are induced by large insurance company failures, this would in principle appear to satisfy Criterion 4. However, the U.S. RBC requirements lack information about the insurer’s actual risk profile, and thus do not allow the regulator to focus on the highest potential insolvency costs. In its main parts, the U.S. RBC standards are thus not in line with Criterion 4. This statement is backed up by the results of an empirical analysis on the relationship between property liability insurers’ insolvency risk and their capital adequacy conducted by Cummins et al. (1995), who find that the solvency ratio used under the U.S. RBC framework is significantly less successful in predicting large insurers’ insolvency than in predicting small insolvencies.

In contrast to the U.S. RBC formula, Solvency II and the SST are not factor-based, but rely on probabilistic risk measures to identify the necessary capital requirements. Solvency II is based on the value at risk; the SST applies the expected shortfall (tail value at risk). The expected shortfall corresponds to the average loss in case of insolvency, as compared to the value at risk, which represents the threshold loss beyond which an insurer is insolvent. Of the two risk measures, only the expected shortfall and thus the SST satisfies Criterion 4, as it incorporates the severity of the insolvency beyond the threshold case (see Doff, 2008). Despite the conceptual advantage of using the expected shortfall, the European Commission decided in favor of the value at risk, mainly because it is less complex and more widespread in practice (see CEA, 2006). For detailed discussions on the choice of the risk measure, the reader is referred to Artzner et al. (1999), McNeil et al. (2005), and Filipovic and Vogelpoth (2008).

The internal model approach, under both Solvency II and the SST, does not completely satisfy Criterion 4. In particular, regulators motivate the use of internal models with reduced capital requirements as compared to when insurers would apply
the standard approach (note that this is not definite in the case of Solvency II, but seems likely) (see EC, 2007b; Steffen, 2008; Swiss Federal Office of Private Insurance, 2004). As mainly large insurers have the resources to develop internal models, they face relatively lower capital requirements. Nevertheless, the internal model approach is generally in line with Criterion 4, as those reduced capital requirements are based on a more accurate reflection of the insurer’s risk profile.

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<th>Criterion</th>
<th>United States</th>
<th>European Union</th>
<th>Switzerland</th>
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<tbody>
<tr>
<td>4. Focus on the highest insolvency costs for economy as a whole</td>
<td>+ Capital requirements proportional to insurer’s size rather than risk profile</td>
<td>- Value at risk rather than tail value at risk as risk measure does not satisfy Criterion 4</td>
<td>+ Tail value at risk as risk measure satisfies Criterion 4</td>
</tr>
<tr>
<td></td>
<td>- Empirical evidence shows limited adequacy</td>
<td>+ Internal models in general satisfy criterion 4, due to accurate reflection of the insurer’s risk profile</td>
<td>+ Internal models in general satisfy Criterion 4, due to accurate reflection of the insurer’s risk profile</td>
</tr>
</tbody>
</table>

Legend:  + Satisfies criterion  - Does not satisfy criterion  +/- Assessment not possible (yet)

**Table 4: Overview Criterion 4**

**Criterion 5: Focus on economic values**

According to Cummins et al. (1994), any solvency system that ignores the potentially large difference between balance sheet data and market values has only limited ability to assist regulators. Even though balance sheet data in the U.S. are considered to be relatively close to market values, the U.S. RBC standards have been criticized for their use of a factor-based approach applied to historic statutory values (see Sandström, 2006; Klein, 2005, p. 151). The framework is thus not designed to identify the true net worth and therefore does not satisfy Criterion 5. Cummins et al. (1994) define the true net worth as the difference between the economic values of the assets and the liabilities.

Solvency II satisfies Criterion 5. Calculation of capital requirements under Pillar I is based on an economic total balance sheet approach (see EC, 2007a). This implicates the use of market-consistent values of assets and liabilities, whenever possible (see CEA, 2007). To reduce the administrative burden for insurance companies, an alignment of Solvency II with the International Financial Reporting Standards (IFRS) is intended (see Duverne and Le Douit, 2007; Flamée, 2008; EC, 2007a). However, these standards are still works in progress and thus the use of market-consistent values is still not definite. Further areas of discussion relevant for Solvency II include accounting for discretionary bonuses within participating contracts and the role of the
insurer’s own credit standing within the valuation of insurance liabilities (see Flamée, 2008). Solvency II’s ultimate compliance with Criterion 5 therefore still depends on the development of IFRS and the level of convergence between the two standards (see Doff, 2008).

The SST is based on a market-consistent valuation of assets and liabilities (see Swiss Federal Office of Private Insurance, 2007). The assets should represent market values, whenever possible; otherwise, an appropriate model to estimate the asset’s current value must be applied. Liabilities have to be valued under the principle of best estimate (see Swiss Federal Office of Private Insurance, 2004). These procedures are in line with Criterion 5; but, they only apply to the determination of target capital. Calculation of the minimum solvency requirement is based on the statutory balance sheet (see Swiss Federal Office of Private Insurance, 2007). However, because not all balance sheet data are subject to market distortions (e.g., premiums) and because insurers will more likely focus on the target capital level rather than on the minimum solvency, the SST still satisfies Criterion 5.

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<th>Criterion</th>
<th>United States</th>
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<th>Switzerland</th>
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<tbody>
<tr>
<td>5. Focus on economic values</td>
<td>- Reliance on balance sheet data does not satisfy Criterion 5 (though U.S. reporting partly adopts market values)</td>
<td>+ Market-consistent techniques satisfy Criterion 5</td>
<td>+ Market-consistent values satisfy Criterion 5</td>
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<td></td>
<td></td>
<td>+/- Convergence with IFRS still leaves some uncertainty</td>
<td>+ Valuation of assets in principle according to marking to market; otherwise according to marking to model</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Minimum solvency based on statutory balance sheet values</td>
</tr>
</tbody>
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Legend:  
+ Satisfies criterion  
- Does not satisfy criterion  
 +/- Assessment not possible (yet)

Table 5: Overview Criterion 5

Criterion 6: System should discourage misreporting

The problem of potential misreporting is not explicitly mentioned in any of the solvency systems. Moreover, the stated goals of the regulatory frameworks do not touch upon this pitfall and instead focus their attention on policyholder security and market efficiency. Even though insurers might be tempted to manipulate data in order to lower capital requirements, it is questionable prohibiting this behavior should be part of the solvency regulation or better covered by other laws and regulations.
Within a factor-based solvency framework, misstatements of financials can cause an equivalent reduction of capital requirements. An exemplary U.S. insurer who states a lower-than-actual combined ratio will receive a reduced written premium risk charge (see Feldblum, 1996). The factor-based approach of the U.S. RBC standards thus does not encourage correct reporting and therefore does not satisfy Criterion 6. However, certain national legislation has been enacted to address this problem. For example, the Sarbanes-Oxley Act was enacted in response to several major accounting scandals in 2001 and 2002 and aims to improve the accuracy and reliability of corporate disclosures (see Kagermann et al., 2008).

Under Solvency II, the SCR is not factor-based, which makes it less easy to use misreporting to lower capital requirements. Furthermore, Solvency II does address, if only rudimentarily, the issue of potential manipulations by insurers within Pillar II, which contains, among other things, specifications on corporate governance, the supervisory review process, and the empowerment of the supervisory authority (see EC, 2007a). However, to ensure that these “soft” requirements are effective, the sanctions following a breach would need to be more clearly defined and transparent for all market participants. Also, some countries within the EU have their own laws on this subject, which could complement Solvency II, with regard to Criterion 6. For example, the German “Gesetz zur Kontrolle und Transparenz im Unternehmensbereich” details the requirements for financial reporting systems and the responsibilities of the internal audit function (see Kagermann et al., 2008).

The SST does not address potential misreporting. The relevant national legislation is the “Bundesgesetz betreffend die Aufsicht über Versicherungsunternehmen” (Schweizerische Bundesversammlung, 2004) and the corresponding implementing measure is the “Verordnung über die Beaufsichtigung von privaten Versicherungsunternehmen” (Schweizerischer Bundesrat, 2005). Consequently, Criterion 6 is at least partly satisfied by the SST. Solvency II and the SST are principle- rather than rules-based regulatory systems, a characteristic that becomes evident with regard to Criterion 6, where both systems rely more on the individual responsibility of the insurer than on strict rules (see, e.g., EC, 2007a).
### Table 6: Overview Criterion 6

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<th>Criterion</th>
<th>United States</th>
<th>European Union</th>
<th>Switzerland</th>
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<tbody>
<tr>
<td>6. System should discourage misreporting</td>
<td>- Risk-based capital requirements in general and factor-based approaches in particular provide incentive for underreporting + The national Sarbanes-Oxley Act partly fulfills Criterion 6</td>
<td>- Risk-based capital requirements in general provide incentive for underreporting + Pillar II—corporate governance, on-site monitoring powers, etc.—partly satisfies Criterion 6 + National legislation partly fulfills Criterion 6 + Principle of individual responsibility applied</td>
<td>- Risk-based capital requirements in general provide incentive for underreporting + National legislation partly fulfills Criterion 6 + Principle of individual responsibility applied</td>
</tr>
</tbody>
</table>

Legend:  + Satisfies criterion  - Does not satisfy criterion  +/- Assessment not possible (yet)

**Criterion 7: Formula as simple as possible**

The solvency system should avoid complexity. If, however, complexity is increased, the additional costs for the insurers and for the regulator should at the very least be offset by improvement of the system to predict and avoid potential failures of insurance undertakings. An inappropriate level of complexity will otherwise result in increased premiums for the insurance customers and in decreasing innovation for the insurance market as a whole (see van Rossum, 2005). One limitation to Criterion 7 is the difficulty of accurately measuring, or even defining, “complexity” and “system improvement”. The following discussion is thus, in some parts, mostly theoretical.

The U.S. RBC formula looks very simple at first glance, but some of the calculations of individual risk charges are complex and require long data histories—10 years for most risk charges (see Feldblum, 1996; Klein and Wang, 2007). Because the foundation of the formula is theoretically weak, this complexity does not serve to enhance policyholder security (see Farny, 1997). Overall, however, especially compared to Solvency II and the SST, the U.S. RBC formula is relatively simple and thus at least partly satisfies Criterion 7.

In principle, Solvency II satisfies Criterion 7. The market-consistent valuation of assets and liabilities and the overarching value at risk concept do increase complexity compared to the Solvency I framework, but this increase is justified by the capital requirements becoming more risk-sensitive (see Doff, 2008). As for Pillars II and III of the Solvency II framework—the qualitative requirements and the rules on public disclosure—it is not yet known if or how well they will satisfy Criterion 7. Only time
will tell how the practical application of these pillars will affect the administrative burden of insurers; however, there is potential misalignment with Criterion 7 due to e.g. requirements necessitating the documentation of internal control mechanisms, internal audit procedures, and outsourcing activities (see EC, 2007a).

The SST is considered even more complex than Solvency II (see von Bomhard and Frey, 2006). Complexity arises, for example, from the application of the tail value at risk and the performance of scenario analyses. The tail value at risk, though, has the advantage that it considers not only the probability but also the cost of potential insurer insolvency. The scenario analyses make it possible to adequately consider the fat tails inherent in the distribution of insurance risks (see Bundesamt für Privatversicherungen, 2006). Consequently, the complex characteristics of the SST improve the accuracy of the model and are therefore in line with Criterion 7.

As for the underlying calculation of capital requirements under Solvency II and the SST, the internal and the standard models are the extremes at each end of the spectrum. At one end are the internal models, which are very complex, but have great predictive power and high risk-sensitivity (see Eling et al., 2007). Their complexity may thus be justified and the internal model approach is widely regarded as a major step forward in insurance regulation and risk management (see Linder and Ronkainen, 2004; Klein and Wang, 2007). At the other end of the spectrum is the one-size-fits-all standard model. The standard model’s role as a simple alternative to resource-intensive internal models may justify the corresponding but unfortunate side effect of reduced risk-sensitivity, but this will not be known for certain in the case of Solvency II until the design of the standard model is finalized. For the SST, satisfaction of Criterion 7 is doubtful due to the complexity inherent in the standard model. This complexity arises from, for example, the requirement that insurers determine the sensitivity of their assets and liabilities to market risk factors and use these sensitivities within the model. According to the Swiss regulator, this level of complexity is appropriate and necessary to ensure that those insurers using the standard approach establish risk management capabilities. Furthermore, this personalization shall ensure that the capital requirements, identified by means of the standard model, are adequately risk-sensitive (see Swiss Federal Office of Private Insurance, 2006b).
### Table 7: Overview Criterion 7

+ Simple formula
- Complex modeling of risk categories not offset by increased accuracy due to inappropriate aggregation of risks
- Complex framework
+ More complex valuation of insurance liabilities adds value—satisfies Criterion 7
+/- Pillar II and III provide potential for misalignment with Criterion 7 (too early to assess)
+/- Complexity of standard formula not assessable yet

- Complex framework
+ Complexity of tail value at risk offset by possibility of including cost of insolvencies
+ Complexity of scenario analysis offset by possibility of capturing extreme events
- Complexity of standard approach questionable

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<th>United States</th>
<th>European Union</th>
<th>Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Formula as simple as possible</td>
<td>+ Simple formula</td>
<td>- Complex framework</td>
<td>- Very complex framework</td>
</tr>
<tr>
<td></td>
<td>- Complex modeling of risk categories not offset by increased accuracy due to inappropriate aggregation of risks</td>
<td>+ More complex valuation of insurance liabilities adds value—satisfies Criterion 7</td>
<td>+ Complexity of tail value at risk offset by possibility of including cost of insolvencies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+/- Pillar II and III provide potential for misalignment with Criterion 7 (too early to assess)</td>
<td>+ Complexity of scenario analysis offset by possibility of capturing extreme events</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+/- Complexity of standard formula not assessable yet</td>
<td>- Complexity of standard approach questionable</td>
</tr>
</tbody>
</table>

Legend:  
+ Satisfies criterion  
- Does not satisfy criterion  
+/- Assessment not possible (yet)

### 3.3.3 Comparison of the Three Systems Under the Extended Criteria

**Criterion 8: Adequacy in economic crises and systematic risk**

Historically, systematic risk was primarily associated with the occurrence of a bank run (see Swiss Re, 2003). However, increasing securitization and globalization have led to an increased relevance of systematic risk to the insurance industry also, which is sharply illustrated by the recent U.S. mortgage crisis. We thus see a need to introduce a new RBC criterion addressing adequacy in economic crisis situations and systematic risk aspects.

Deficient regulation is one potential source of systematic risk (see Nebel, 2004). If all insurers use the same risk models, they will all have similar risk exposures and will be affected equally by an unusual event in the capital or insurance markets. Consequently, they will all take the same counteractive measures, which can, in a worst case, again enforce the primary cause. In recognition of these dynamic aspects, insurers should employ different models, e.g., internal models (see Swiss Federal Office of Private Insurance, 2004). Hence the SST and Solvency II, which motivate insurers to develop and apply internal models, satisfy Criterion 8. In addition, the principle-based approach of the SST and Solvency II give insurers more discretion than does a strict rules-based system. Thus, insurers apply a variety of models and the potential for systematic risk decreases (see Nebel, 2004). The U.S. RBC formula, in contrast, may expose U.S. insurers to a high level of systematic risk and is therefore not in line with Criterion 8.
Sanctions are another critical factor with regard to Criterion 8. Their design should follow the objective of regulatory action, which can include anything from penalizing the insurer, to financial recovery, to the minimization of insolvency costs in case of winding-up. To fully exploit these regulatory possibilities, the potential of being sanctioned should occur early on and have multiple intervention levels. All three systems under investigation here satisfy that need: the U.S. framework applies five levels; Solvency II and the SST three each—including the level of “no intervention” in the case of a financially sound insurer (see Dickinson, 1997; EC, 2007b; Swiss Federal Office of Private Insurance, 2004). Depending on the severity of the insurer’s financial situation, different sanctions are implemented under the U.S. framework and Solvency II. Among others, these include discussions with the authorities, submission of recovery plans, issuance of corrective orders, and the requirement for liquidation. The SST’s three levels of intervention are still in development, but it is likely they will mirror those of Solvency II (see Eling and Holzmüller, 2008).

<table>
<thead>
<tr>
<th>Criterion</th>
<th>United States</th>
<th>European Union</th>
<th>Switzerland</th>
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<tbody>
<tr>
<td>Adequacy in economic crises and systematic risk</td>
<td>- In the U.S. all insurers apply the same model, which may lead to high systematic risk + Interventions are well designed</td>
<td>- High adequacy intended, however systematic risk is possible + Internal models decrease systematic risk + Principle-based approach decreases systematic risk + Interventions are well designed</td>
<td>- High adequacy intended, however systematic risk is possible + Internal models decrease systematic risk + Principle-based approach decreases systematic risk +/- Interventions are still under construction</td>
</tr>
</tbody>
</table>

Legend:  
+ Satisfies criterion  
- Does not satisfy criterion  
+/− Assessment not possible (yet)

Table 8: Overview Criterion 8

Criterion 9: Assessment of management

In an analysis of insurance company failures and near-misses, the Sharma Report found that inexperienced management was at the root of most insurance company failures (see Conference of Insurance Supervisory Services of the Member States of the European Union, 2002; Ashby et al., 2003). Based on this insight, we introduce Criterion 9—the assessment of management. Solvency systems should thus not solely rely on a quantitative assessment of the insurer’s solvency level, but encompass the full casual chain of insurance failures, including requirements for management team experience, early warning indicators, and an emphasis on forward-looking information...
such as, for example, business plans (see Conference of Insurance Supervisory Services of the Member States of the European Union, 2002).

The call to include management risk in solvency systems is not new. As early as 1997, Dickinson reported that management risk is omitted in the U.S. RBC formula, a situation that has not changed and thus the U.S. RBC system does not satisfy Criterion 9.

Solvency II rudimentarily addresses management risk in Pillar II, which details qualitative requirements and rules on supervision. As part of the qualitative requirements, the European Commission sets out governance principles in general and the “fit and proper” standard in particular (see EC, 2007a). The latter stipulates that people effectively running the undertaking or people in other key functions must be fit with regard to their professional qualification, experience, and knowledge, and proper with regard to their personal integrity (see EC, 2007a; Eling and Holzmüller, 2008).

The SST does not address management risk and therefore does not satisfy Criterion 9. However, this need is partly fulfilled by the “Versicherungsaufsichtsgesetz” and the corresponding initiative, which is called Swiss Quality Assessment. According to the legislative act, insurance licenses will be granted only if certain management positions are filled by persons having a good reputation and who can warrant sound business practices (see Schweizerische Bundesversammlung, 2004). The corresponding initiative addresses corporate governance, risk control, and internal processes, but fails to concretize the requirements for good reputation and sound business practices (see Swiss Federal Office of Private Insurance, 2007).

<table>
<thead>
<tr>
<th>Criterion</th>
<th>United States</th>
<th>European Union</th>
<th>Switzerland</th>
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<tbody>
<tr>
<td>9. Assessment of management</td>
<td>- No assessment of management capabilities</td>
<td>+ Rudimentarily addressed by Pillar II (governance, fit and proper requirement)</td>
<td>- No assessment of management capabilities + National legislation addresses suitability of management team</td>
</tr>
</tbody>
</table>

Legend: + Satisfies criterion - Does not satisfy criterion +/- Assessment not possible (yet)

Table 9: Overview Criterion 9

**Criterion 10: Flexibility of framework over time**

History shows that solvency systems can live a long life before they are replaced or adjusted to changed market conditions. An example is the European solvency margin system, the predecessor of Solvency I. Despite general agreement on the need for
change, the system was in force for approximately 30 years (see Dickinson, 1997). Similarly, Solvency I, originally designed as a stop-gap approach, will be in force within the EU for at least 10 years—from 2002 to presumably 2012 (see EC, 2007a, 2007b). However, in light of how fast financial markets can change, this system longevity can result in major gaps within regulatory frameworks and to adverse effects on policyholder protection. We thus propose Criterion 10, which requires that new or improved-upon solvency systems are designed flexible toward changes and do not ask for bureaucratic processes in case of reform.

Wide geographic scope, multiple stakeholders, and slow political processes are among the most common reasons for inflexible solvency systems. All three systems under evaluation here have legislative characteristics that can hinder modification. The U.S. and the EU frameworks face the additional complexity of being applicable to a federation of states/countries with a concomitant increase in the number of stakeholders. Switzerland, in contrast, benefits from its reduced geographical scope. For example, the SST framework was developed in a relatively short time period, going from project start in 2002 to introduction in 2006 (see Schweizerischer Bundesrat, 2005). In contrast, Solvency II, which covers the entire EU, also began in 2002 and is not expected to finalize until 2012.

Although the geographic scope of the EU or the U.S. is more or less a given, it is within the power of the regulator to design the solvency framework itself as flexible as possible. A rather radical approach is implemented in New Zealand, which relies almost entirely on private rating agencies to regulate the insurance industry. Those private companies, such as A.M. Best and Standard & Poor’s, have proven to be extremely adaptable to changing circumstances due to their lack of external commitments and information supply duties (see Eling and Holzmüller, 2008). Less radical is a principles-based framework, like Solvency II and the SST. As long as the underlying principles are not affected, small changes and updates are easy to implement in a system like this as compared to a rules-based system, where even small modifications can involve a lengthy process.
Criterion 11: Strengthening of risk management and market transparency

The last criterion focuses on the qualitative elements of supervision and evaluates whether the regulator promotes internal risk management and market discipline. The idea behind the latter is that transparent processes will require less regulation in the long run as market participants themselves force appropriate insurer behavior (see Eling et al., 2007). Hence internal risk management and market discipline should be addressed by regulation.

Both Solvency II and the SST view strengthening risk management as one of their main goals (see EC, 2007b; Swiss Federal Office of Private Insurance, 2004). Both systems thus provide a strong incentive for insurers to develop and apply internal models to determine capital requirements, which process forces the insurers to focus on risk. Even when it is the standard model that is used, though, both systems incorporate risk management. For example, Solvency II requires all insurers to perform the “Own Risk and Solvency Assessment”, during which insurers have to assess their overall solvency need under their specific risk profile on a regular basis and report the results to the supervisory authority (see EC, 2007a). As for the SST, the design of the standard approach as a rather complex model instead of as a simple formula has the explicit goal of ensuring adequate risk management capabilities of all insurers (see Swiss Federal Office of Private Insurance, 2006b). In contrast, the U.S. RBC system contains no provisions for assessing the adequacy, or even existence, of insurer risk management (see Eling and Holzmüller, 2008).

Of the three systems being compared here, Solvency II best satisfies Criterion 11. It not only strengthens risk management but also fosters market transparency by requiring a public disclosure of the insurer’s solvency and financial condition (Pillar
III) (see EC, 2007a). The SST and the U.S. RBC standard do not require public disclosure and thus do not make use of market forces.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>United States</th>
<th>European Union</th>
<th>Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Strengthening of risk management and market transparency</td>
<td>- Application of formula, no recognition of risk management - No disclosure requirements</td>
<td>+ Strengthening of risk management is one of the main objectives + Possibility of using internal models increases incentive to develop risk management competences + Own risk and solvency assessment within Pillar II + Annual public disclosure of solvency and financial condition (Pillar III)</td>
<td>+ Strengthening of risk management is one of the main objectives + Possibility of using internal models increases incentive to develop risk management competences + Standard model approach instead of standard formula - No disclosure requirements</td>
</tr>
</tbody>
</table>

Legend: + Satisfies criterion - Does not satisfy criterion +/- Assessment not possible (yet)

Table 11: Overview Criterion 11

3.4 Summary

With the introduction of new solvency frameworks such as Solvency II and the SST, insurance regulation has entered a new era. Compared to the significantly older U.S. RBC system, the newer Solvency II and SST go in the direction of an integrated asset and liability perspective, principles- instead of rules-based regulation, and an additional consideration of qualitative aspects. In this chapter, we compare all three systems on the basis of the broad criteria framework provided by Cummins et al. (1994). In recognition of the dynamics in the insurance industry, we then extend the framework with four new criteria.

Table 12 summarizes our analysis. A “full” moon indicates satisfies criterion; an “empty” moon indicates does not satisfy criterion.
Our main findings are as follows.

(1) The EU Solvency II framework and the SST score significantly better than the U.S. RBC formula, disclosing that the U.S. framework is the system most in need of reform (see, e.g., Klein and Wang, 2007). To be fair, however, it should be remembered that the U.S. framework was introduced more than 10 years before the other two, and at that time was viewed as a major advance in solvency regulation (see Feldblum, 1996; Farny, 1997). Nevertheless, the reform movement afoot in the U.S. toward a principles-based solvency framework similar to that of the EU is a good sign and currently gaining some momentum (see IAIS, 2007; Iuppa, 2006).

(2) We agree with Doff (2008) that Solvency II satisfies the seven criteria of Cummins et al. (1994). Based on our extended analysis, we can further attest that Solvency II satisfies our additional criteria (8-11), and that also the SST is in line with the requirements. Remaining concerns with regard to Solvency II are the factor-based calculations within parts of the standard approach, the use of the value at risk concept, which ignores the cost of insolvency, and the inadequate consideration of management risk. As for the SST, areas of concern relate to the derivation of the minimum solvency level, which is not risk-based and relies on statutory financials, as well as its high level of complexity and disregard of management risk.
(3) A comparison between Solvency II and the SST does not lead to an obvious answer to the question of which system is superior. Each has a few deficiencies, but both incorporate some of the most recent and most promising findings from the fields of risk management and insurance regulation (e.g., internal model approach, total balance sheet approach). It will no doubt be how well each system protects policyholders, which is stated to be their chief goal, that determines which system works best, but such a judgment will have to await the passage of time before appropriate empirical evidence can be gathered and analyzed.
Part II: Pricing of Insurance Contracts

4 Creating Customer Value in Participating Life Insurance

4.1 Introduction

Participating life insurance contracts generally feature a minimum interest rate guarantee, guaranteed participation in the annual return of the insurer’s asset portfolio, and a terminal bonus payment. Appropriate pricing of these features is crucial to an insurance company’s financial stability. Risk-neutral valuation and other premium principles based on the duplication of cash flow serve well to valuate contracts from the insurer’s perspective. However, these techniques are only relevant, if insurance policies priced according to them actually meet customer demand. Since policyholders may not be able to duplicate their claims via capital market instruments for valuation purposes, they will often judge its value based on individual preferences. Thus, their willingness to pay—referred to here as “customer value” of the contract—may be quite different from the fair premium calculated by the insurance company. The aim of this chapter is to combine the insurer’s perspective with that of the policyholders, which is done by identifying those fair contract parameters (guaranteed interest rate and annual and terminal surplus participation rate) that, while keeping the fair value fixed for the insurer, maximize customer value.

Combining these two approaches is new to the literature; however, there is a fair amount of previous research on each individual perspective. From the insurer perspective, the relevant area is option pricing theory and its application to participating life insurance contracts. Among this literature, we find Briys and de Varenne (1997), Grosen and Jørgensen (2002), Bacinello (2003), Ballotta, Haberman, and Wang (2006), and Gatzert (2008). All these papers use option pricing models to determine the price of life insurance policies, but their objectives are various. Briys and de Varenne (1997), for example, use a contingent claims approach to derive prices for life insurance liabilities and to compare the durations of equity and liabilities in the insurance and banking industries, respectively. In contrast, Gatzert (2008) analyzes the

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4 This paper has been written jointly with Nadine Gatzert and Hato Schmeiser. It has been submitted and is currently under review.
influence of asset management and surplus distribution strategies on the fair value of participating life insurance contracts.

From the policyholder perspective, the literature on utility theory and, in particular, on the demand for insurance, is relevant. In our research work, the demand for insurance is derived by assuming that the policyholders follow mean-variance preferences, a common assumption in the literature. For example, Berketi (1999) assumes mean-variance preferences in an analysis of insurers’ risk management activity, finding that although such activity does reduce the risk of insolvency, it also reduces the expected payments to the policyholders when considering participating life insurance contracts. Berketi (1999) applies a mean-variance framework to analyze policyholder preferences with regard to these activities, but does not derive their willingness to pay. Various other research has been conducted to analyze the demand for insurance by corporate entities (see, e.g., Mayers and Smith, 1982; Doherty and Richter, 2002; Doherty and Tinic, 1981).

Generally, demand for insurance depends not only on an individual’s preferences, but also on the person’s economic situation. Accordingly, Mayers and Smith (1983) examine insurance holdings as one of many interrelated portfolio decisions. Inspired by this paper, Showers and Shotick (1994) conduct an empirical analysis and verify the interdependence between individuals’ demand for insurance and household characteristics (e.g., income, number of family members, number of working family members). Ehrlich and Becker (1972) combine expected utility theory with consumption theory and analyze substitution effects. In particular, they examine the relationship between insurance, self-insurance (reduction of the loss extent), and self-protection (reduction of the loss probability). To account for the findings of this research, we consider the special case in which the policyholder’s wealth develops stochastically and thus there are diversification opportunities between the private wealth and investment in a life insurance contract.

The theoretical results on insurance demand—ours among them—build on and complement important previous empirical studies. Wakker, Thaler, and Tversky (1997) use the so-called prospect theory, developed by Kahneman and Tversky (1979), to explain experimental data on the demand for probabilistic insurance. Probabilistic insurance is a type of insurance policy that indemnifies the policyholder with a probability only strictly less than one due to the insurer’s default risk. Recent experimental research on demand for insurance under default risk includes Zimmer,
Schade, and Gründl (2007), who show that awareness of even a very small positive probability of insolvency hugely reduces customer willingness to pay.

In this chapter we combine the insurer and policyholder viewpoints in the context of participating life insurance contracts. The insurer conducts (preference-independent) risk-neutral valuation and arrives at the fair price of the insurance contract. This fair price is the minimum premium the insurance company needs to charge in order for its equityholders—who could also and simultaneously be policyholders—to receive a risk-adequate return on their investment. Policyholders, who generally cannot duplicate cash flows to the same extent as the insurance company, possibly will not base their decision on risk-neutral valuation. Instead, it is likely that their willingness to pay depends on their individual degree of risk aversion and, in our model, is thus based on mean-variance preferences. On this basis, we derive explicit expressions for policyholder willingness to pay and analyze its sensitivity for changes in the payoff structure of the participating life insurance policy.

Our findings show how an insurance company can alter policy characteristics to increase customer value, while, at the same time, keeping the fair premium value fixed. Furthermore, we investigate whether existing regulatory specifications regarding the design of participating life insurance contracts actually fulfill their intended purpose of protecting policyholder interests. If, by disregarding those specifications, the insurance company can increase customer value, this justification comes into doubt. Our findings are relevant for both the insured and insurance companies, who may be able to realize premiums above the fair premium level by increasing policyholder willingness to pay. Taking the lead from Mayers and Smith (1983), Showers and Shotick (1994), and Ehrlich and Becker (1972), we also aim to investigate the effects on insurance demand when policyholder basis wealth is stochastic and the policyholder thus has diversification possibilities.

The remainder of this chapter is organized as follows. In Section 2, the basic setting is introduced. In Section 3, we present the valuation procedures, both those one used by the insurer and those employed by policyholders. Keeping the fair (from the insurer’s perspective) premium value fixed, we optimize customer value in Section 4. Section 5 provides numerical examples. Policy implications and a summary are found in Section 6.
4.2 Basic Setting

We analyze participating life insurance contracts similar to those offered in many European countries, including Germany, Switzerland, the United Kingdom, and France. The insurance company’s initial assets are denoted by $A_0$. At inception of the contract, policyholders pay a single up-front premium $P_0 (=\beta \cdot A_0)$ and the insurance company equityholders make an initial contribution of $Eq_0 (= (1-\beta) \cdot A_0)$. Here, $\beta = P_0 / A_0$ can be considered as the leverage of the company. The total value of initial payments $A_0 = P_0 + Eq_0$ is then invested in the capital market, which leads to uncertainty about the value of the insurer’s assets $A(t)$ at time $t = 1, 2, \ldots, T$, where $T$ denotes the fixed maturity of the contract(s). Having the assets follow a geometric Brownian motion captures this uncertainty. Under the real-world measure $P$, this stochastic process is characterized by drift $\mu_d$ and volatility $\sigma_d$, leading to

$$A(t) = A(t-1) \cdot \exp \left[ \mu_d - \frac{\sigma_d^2}{2} + \sigma(W_d(t) - W_d(t-1)) \right],$$

with

$$A(0) = A_0 = P_0 + Eq_0,$$

where $W_d$ is a standard $P$-Brownian motion. At time $t = T$, the assets $A(T)$ should exceed the liabilities to the policyholders. The amount of liabilities at maturity $T$ is determined by three parameters. The first is a guaranteed minimum annual interest rate $g$ regarding the policyholder reserves. In several European countries, this minimum interest rate is determined by law and changed periodically—depending on capital market conditions.

The second parameter is the annual surplus distribution rate $\alpha$. In general, this rate is regulated, too, similar to the minimum annual interest rate (e.g., Germany, Switzerland, and France). Hence, in the case of positive market developments, the policyholders participate in the insurer’s investment returns above the guaranteed interest rate. The participation rate is applied to earnings on book values, which can differ considerably from earnings on market values. We therefore introduce a constant parameter $\gamma$, as is done in Kling, Richter, and Ruß (2007), to capture the difference between book and market values. In this sense, the factor $\gamma$ also serves as a smoothing parameter as it allows the insurance company to build up reserves and thus to even out
policyholder payments between years of “low” and “high” investment returns. The parameter $\gamma$ takes values between 0 and 1.

The third contract parameter is the optional terminal surplus bonus $\delta$. This terminal bonus is not guaranteed, but is optionally credited to the policyholder account according to the initial contribution rate $\beta = P_0 / A_0$ at maturity. As we are mainly interested in the financial risk situation, we do not take early surrender and deaths into account. Under the assumption that mortality risk is diversifiable, it can be dealt with using expected values when writing a sufficiently large number of similar contracts. However, we presume that any additional options are priced adequately and paid for separately.

Thus, the policyholder account $P(t)$ in our model is as follows:

$$P(t) = P(t-1) \cdot (1 + g) + \max\left[ \alpha \cdot \gamma \cdot (A(t) - A(t-1)) - g \cdot P(t-1), 0 \right], \tag{3}$$

where $P(0) = P_0$ and $\gamma$ is the relation of book value to market value. The interest rate and the annual participation payment are locked in each year and thus become part of the guarantee (so-called cliquet-style guarantee). The terminal bonus is denoted by $B(T)$, where

$$B(T) = \max(\beta \cdot A(T) - P(T), 0). \tag{4}$$

The total payoff to the policyholder at maturity $L(T)$ thus consists of the policyholder’s guaranteed accumulated account $P(T)$—including guaranteed interest rate payments and annual surplus participation—as well as an optional terminal surplus participation payment $B(T)$. The policyholder will receive the guaranteed payoff only if the insurance company is solvent at maturity, i.e., if the market value of assets $A(T)$ is sufficient to cover the guaranteed maturity payoff $P(T)$. If the company is insolvent—$P(T) > A(T)$—policyholders receive only the total market value of the insurer’s assets. Hence, the expected cost of insolvency is represented by the default put option $D(T)$:

$$D(T) = \max(P(T) - A(T), 0). \tag{5}$$
The default put option is deducted from the policyholder claims (see, e.g., Doherty and Garven, 1986), leading to a total policyholder payoff \( L(T) \), with

\[
L(T) = P(T) + \delta \cdot B(T) - D(T). 
\] (6)

The insurance company equityholders have limited liability, which means that they either receive the residual difference between the market value of the assets and the policyholder payoff at time \( t = T \) or, in the case of insolvency, nothing:

\[
Eq(T) = A(T) - L(T) = \max(A(T) - P(T), 0) - \delta \cdot B(T). 
\] (7)

The first term on the right-hand side of Equation (7) represents a call option on the insurer’s assets with strike price \( P(T) \), which illustrates the equityholders’ limited liability.

### 4.3 Valuation from the Perspective of Insurers and Policyholders

We now turn to the valuation and determination of fair premiums, which will be different, depending on the perspective taken—policyholder or insurer (equityholder). Since we believe that policyholders generally cannot duplicate cash flows to the same extent as can an insurance company, their valuation and thus their willingness to pay for the contract depends on individual preferences. In this chapter, policyholder willingness to pay is referred to as the “customer value” of the insurance contract. From the insurance company point of view, we assume that claims are replicable in order to derive fair (or minimum) premiums. Thus, a preference-free valuation approach, for a given combination of the parameters \( g, \alpha, \) and \( \delta \), can be applied to provide a risk-adequate return for the company’s equityholders. If the customer value exceeds the minimum premium derived, we obtain a positive premium agreement range. If this range is negative, it is not likely the contract will find a buyer.

#### 4.3.1 Insurer Perspective

Assuming an arbitrage-free capital market, the insurer evaluates claims under the risk-neutral measure \( Q \). Under \( Q \), the drift of the asset process changes from \( \mu_A \) to the risk-free interest rate \( r \),
\[ A(t) = A(t-1) \cdot \exp \left[ r - \sigma^2 / 2 + \sigma (W_A(t) - W_A(t-1)) \right] \]  

(8)

where \( W_A^Q \) is a \( Q \)-Brownian motion. The values of the policyholder (\( \Pi^* \)) and the equityholder claim (\( \Pi^E \)) under the risk-neutral measure are then given by:

\[ \Pi^* = E^Q \left( e^{-\gamma T} \cdot L(T) \right) = E^Q \left[ e^{-\gamma T} \cdot \left( P(T) + \delta \cdot B(T) \right) \right] - E^Q \left( e^{-\gamma T} \cdot D(T) \right) \]

\[ = \Pi - \Pi^{DPO} \]  

(9)

and

\[ \Pi^E = E^Q \left( e^{-\gamma T} \cdot E(T) \right). \]  

(10)

An up-front premium \( P_0 \) is called “fair” if it equals the market value of the contract under the risk-neutral measure at time \( t = 0 \). This is expressed as

\[ \Pi^* = P_0, \]  

(11)

which, due to no arbitrage, is equivalent to solving

\[ \Pi^E = Eq_0. \]  

(12)

The value of the policyholder claim is determined by the guaranteed interest rate \( g \), the annual surplus participation \( \alpha \), and the terminal surplus bonus \( \delta \). Keeping all else equal, a decrease in any one of the three parameters—e.g., of \( g \)—decreases the fair contract value \( \Pi^* (g, \alpha, \delta) < P_0 \). However, by increasing the remaining parameters—in this example, \( \alpha, \delta \), or both—the value of the contract can be kept constant at \( \Pi^* = P_0 \). Hence, there are an infinite number of contract specifications that all have the same fair value but, because of their different payoff structures, will vary in the degree to which policyholders find them attractive, that is, each variant, although of equal value to the insurer, may have a different customer value.
Any fair premium provides a net present value of zero for the insurance company equityholders. The fair premium $P_0$ thus provides the lower end of the premium agreement range.

### 4.3.2 Policyholder Perspective

The upper end of the premium agreement range is determined by policyholder willingness to pay, denoted by $P_0^\phi$. We employ one of the most common forms of preference dependent valuation—mean-variance preferences (see, e.g., Berketi, 1999; Mayers and Smith, 1983). The policyholder’s order of preferences under the real-world measure $P$ is given by the difference between expected wealth and the variance of the wealth multiplied by the policyholder’s individual risk aversion coefficient $a$ (times one-half; see, e.g., Doherty and Richter, 2002):

$$\Phi = E(Z_T) - \frac{a}{2} \cdot \sigma^2(Z_T).$$

(13)

Here, $Z_T$ denotes the policyholder’s wealth at maturity. Since the focus of this analysis is on demand for life insurance, we assume that policyholders are risk averse; hence only positive values for $a$ are considered.

To determine policyholder willingness to pay, we compare the preference function for the case of no insurance ($NI$) to the one with insurance ($WI$) (see Eisenhauer, 2004). The maximum willingness to pay is exactly the price at which the customer becomes indifferent between the two cases:

$$\Phi^{WI} = \Phi^{NI}$$

(14)

with

$$\Phi^{NI} = E(Z_T^{NI}) - \frac{a}{2} \cdot \sigma^2(Z_T^{NI})$$

(15)

and
The policyholder’s initial wealth is denoted by $Z_0$, where $Z_0 > 0$. In the case without insurance, $Z_0^{NI} = Z_0$. Alternatively, $Z_0^{WI} = Z_0 - P_0^\phi$. The remainder of the initial wealth is either compounded with the risk-free interest rate (if the policyholder has no chance to diversify) or is invested in a stochastic portfolio (i.e., the policyholder can diversify). We distinguish between these two cases below.

**Part A—Deterministic wealth of policyholder**

In the case of deterministic wealth, the policyholder must choose between investing in the risk-free asset and using at least part of the wealth to purchase the life insurance contract. If the policyholder invests all the wealth in the risk-free investment opportunity, his or her future wealth is given by $Z_0 e^{rT}$. If the policyholder decides to purchase life insurance, initial wealth is reduced by the premium he or she is willing to pay, $P_0^\phi$, i.e., $Z_0^{WI} = Z_0 - P_0^\phi$. Furthermore, a variance term is deducted from the preference function to account for the risk associated with the life insurance policy’s payback. For the two cases, the following holds true:

\[
\Phi^{NI} = Z_0 \cdot e^{rT} 
\]

and

\[
\Phi^{WI} = E\left(\left(Z_0 - P_0^\phi\right) \cdot e^{rT} + L(T)\right) - \frac{\alpha}{2} \cdot \sigma^2 \left(\left(Z_0 - P_0^\phi\right) \cdot e^{rT} + L(T)\right).
\]

According to Equation (14), the policyholder solves

\[
Z_0 \cdot e^{rT} = \left(Z_0 - P_0^\phi\right) \cdot e^{rT} + E\left(L(T)\right) - \frac{\alpha}{2} \cdot \sigma^2 \left(L(T)\right).
\]
Hence, maximum willingness to pay does not depend on the policyholder’s initial wealth:

\[ P_0^\phi = e^{-rT} \cdot \left[ E(L(T)) - \frac{\alpha}{2} \cdot \sigma^2(L(T)) \right]. \]  

(20)

**Part B—Stochastic wealth of policyholder**

Following Mayers and Smith (1983), who emphasize the interaction between demand for insurance and other portfolio decisions, we introduce a stochastic investment opportunity. The policyholder may now invest his or her total initial wealth at time \( t = 0 \) in the stochastic asset process, or use parts of it to purchase life insurance. We assume that the stochastic asset process of the investment opportunity evolves according to a geometric Brownian motion with drift \( \mu_z \) and volatility \( \sigma_z \). Under the objective measure \( P \), \( W_z \)—in analogue to the assets process of the insurance company—is a standard \( P \)-Brownian motion. Development of the investment opportunity is thus given by

\[ Z(t) = Z(t-1) \cdot \exp \left[ \mu_z - \sigma_z^2 / 2 + \sigma_z \left( W_z(t) - W_z(t-1) \right) \right], \]  

(21)

with \( Z(0) = Z_0^{WI} \) (with insurance) or \( Z(0) = Z_0^{WI} \) (without insurance). Furthermore, the two Brownian motions of the insurer’s asset process \( A(t) \) and the private investment opportunity \( Z(t) \) are correlated with a constant coefficient of correlation \( \rho \):

\[ dW_A dW_Z = \rho dt. \]  

(22)

As before, if the policyholder chooses not to purchase life insurance, the initial investment sum equals the initial wealth \( (Z_0^{WI} = Z_0) \). If the policyholder decides to take out an insurance contract, his or her investment sum equals the initial wealth reduced by a premium payment, \( Z_0^{NI} = Z_0 - P_0^\phi \).

Again, the policyholder’s marginal willingness to pay \( P_0^\phi \) is derived by comparing the policyholder’s preference function for the case with and without insurance (see Equations (14)–(16)). The policyholder thus solves
\[ E(Z_T^{NI}) - \frac{a}{2} \cdot \sigma^2(Z_T^{NI}) = E(Z_T^{WT} + L(T)) - \frac{a}{2} \cdot \sigma^2(Z_T^{WT} + L(T)), \] (23)

with

\[ Z_0^{WT} = Z_0 - P_0^\phi = Z_0^{NI} - P_0^\phi \] (24)

and

\[ \tilde{Z}_T = \exp\left[\left(\mu_Z - \sigma_Z^2 / 2\right) \cdot T + \sigma_Z \cdot (W_Z(T) - W_Z(0))\right], \] (25)

which can be rewritten as \( Z_T^{WT} = (Z_0^{NI} - P_0^\phi) \cdot \tilde{Z}_T \), and \( Z_T^{NI} = Z_0^{NI} \cdot \tilde{Z}_T \). Solving Equation (23) leads to an explicit formula for policyholder willingness to pay, hence for the customer value \( P_0^\phi \) of the life insurance contract (see Appendix A for the detailed derivation):

\[
P_0^\phi = \left[ \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \right] \cdot \frac{1}{2} \left[ \frac{\sigma^2(\tilde{Z}_T)}{\sigma^2(\tilde{Z}_T) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))} \right]^{-\frac{1}{2}}.
\] (26)

Hence, this premium \( P_0^\phi \) stands for the upper end of the premium agreement range in the case where the policyholder has, in addition to the life insurance contract, a second stochastic investment opportunity.
4.4 Creating Customer Value for Fair Contracts

This section combines the two valuation approaches presented above so as to discover how customer value can be maximized and, at the same time, ensure fair contract conditions for the insurer.

The participating life insurance policy under investigation here has three features that affect the policyholder payoff. Even if contracts are calibrated to be fair according to Equation (11), the value to the customer (see Equations (20) and (26)) can differ substantially. From the insurer perspective, maximizing customer value \( P_0^{\Phi} \) (hence the policyholder willingness to pay) is a worthwhile undertaking toward increasing the chances of obtaining a positive net present value on the insurance market. The corresponding optimization problem can be described as follows:

\[
P_0^{\Phi} \rightarrow \max_{g, \alpha, \delta}

\text{such that } P_0 = \Pi^*(g, \alpha, \delta) = E_Q \left( e^{-rT} \cdot L(T) \right).
\]  

Hence, for a fixed nominal premium \( P_0 \), a fair parameter combination \((g, \alpha, \delta)\) is chosen that leads to the highest customer value, while providing, at a minimum, risk-adequate returns for company’s equityholders. A higher customer value increases the premium agreement range and thus may enable the company to realize a higher rate of return for its equityholders. However, these optimal contracts may not comply with regulatory restrictions on minimum interest rates or other legal requirements. We will examine this hypothesis for the case of Germany in the numerical examples conducted in Section 5.

We now use some specific model cases to demonstrate the procedure required by Equation (27). We focus on the case of deterministic wealth (see Section 3.2, Part A) and aim to derive explicit expressions for the customer value of fair contracts. The procedure is, in principle, the same for the case of stochastic wealth (Part B); however, derivation of explicit expressions is far more complex.

For participating life insurance contracts with all three features, that is, \( g, \alpha, \) and \( \delta \), the accumulated policy reserve at maturity, \( P(T) = f(g, \alpha) \), is a function of \( g \) and \( \alpha \). For a given \( g^* \) and \( \alpha^* \), the fairness condition in Equation (11) is satisfied if \( \delta \) is given by
\[ \delta^* = \frac{P_0 - e^{-rT} \cdot E \left( P(T) \right) + \text{Put}}{\text{Call}} = h\left(g^*, \alpha^*\right), \]  

(28)

where \( \text{Call} = e^{-rT} \cdot E \left[ \max(A(T) - P(T), 0) \right] \) and \( \text{Put} \) is the corresponding put option value \( e^{-rT} \cdot E \left[ \max(P(T) - A(T), 0) \right] \). In Equation (28), \( \delta^* \) is a function of \( g^* \) and \( \alpha^* \) (denoted by \( h\left(g^*, \alpha^*\right)\)). Thus, \( (g^*, \alpha^*, \delta^*) \) represents a fair parameter combination that serves as a starting point for further calculation of customer value using Equations (20) and (26). Our final goal is to find an optimal fair parameter combination that maximizes customer value as expressed by Equation (27).

### 4.4.1 The General Case

For the case of deterministic wealth, we replace \( \delta^* \) with the expression in Equation (28) and rewrite the second term in Equation (20)—the variance term—as

\[ \sigma^2(L(T)) = \sigma^2(P(T) + \delta^* \cdot \max(A(T) - P(T), 0) - \max(P(T) - A(T), 0)) \]

\[ = f\left(g^*, \alpha^*, h\left(g^*, \alpha^*\right)\right). \]

Hence, the variance of the policyholder payoff \( L(T) \) depends on the functions \( f \) and \( h \).

The customer value \( P_0^\phi \) under fair contract conditions is thus given by

\[ P_0^\phi = e^{-rT} \cdot \left[ E(L(T)) - \frac{\alpha}{2} \cdot \sigma^2(L(T)) \right] \]

\[ = e^{-rT} \cdot E\left( P(T) \right) + h\left(g^*, \alpha^*\right) \cdot \text{Call}^\phi\left(g^*, \alpha^*\right) \]

\[ - \text{Put}^\phi\left(g^*, \alpha^*\right) - e^{-rT} \cdot \frac{\alpha}{2} \cdot f\left(g^*, \alpha^*, h\left(g^*, \alpha^*\right)\right), \]  

(30)

where

\[ \text{Call}^\phi = e^{-rT} \cdot E\left[ \max(A(T) - P(T), 0) \right], \text{Put}^\phi = e^{-rT} \cdot E\left[ \max(P(T) - A(T), 0) \right]. \]  

(31)

Equation (30) shows that \( P_0^\phi \) is a function of \( g^* \) and \( \alpha^* \) only, since the fair \( \delta^* \) is a function of these two parameters as well. Thus with \( \delta \) being replaced by the function \( h\left(g^*, \alpha^*\right) \), \( g^* \) or \( \alpha^* \) can be increased and still satisfy the fairness constraint.
Further, with an increasing risk aversion parameter $a$, $P^\phi_0$ is decreasing if

$$f(g^*, \alpha^*, h(g^*, \alpha^*)) > 0.$$  (32)

The optimization problem in Equation (29) can be solved using the Lagrange method. If, for instance, the guaranteed interest rate is fixed by the regulatory authorities, the annual surplus participation parameter $\alpha$ that maximizes $P^\phi_0$ is given by the implicit solution of the equation

$$\frac{\partial P^\phi_0}{\partial \alpha} = 0$$  (33)

if the second derivative is negative. The partial derivatives can also be used to see how customer value will change when increasing or decreasing $g$ or $\alpha$ given fair contracts. However, more general statements regarding the impact of each contract parameter cannot be derived due to the complexity of the expression. For instance, one cannot be sure that an increasing guaranteed interest rate will raise the customer value under fair contract conditions. This is likely to be the case only for certain intervals, which we will illustrate in numerical examples in Section 5.

### 4.4.2 Contracts with One Option

We now consider the special case of contracts that contain only one of the three parameters: either a guaranteed interest rate, or annual surplus participation, or terminal bonus. Our goal is to derive explicit expressions for willingness to pay for all three contract types and to see which of them generates the highest customer value. Furthermore, these simple types of contracts may generally imply a higher customer value than the more complicated contracts that include all three parameters.

For simplicity, we assume that the equity capital is sufficiently high for a default put option value of approximately zero. This allows derivation of explicit expressions for each fair contract parameter and for the customer value (for a detailed derivation, see Appendix B).
Guaranteed interest rate

For a contract that features only a guaranteed interest rate and does not include annual or terminal surplus participation, i.e., \( g > 0, \alpha = 0, \delta = 0 \), we proceed as in the general case and first calibrate \( g \) to be fair under the risk-neutral measure \( Q \), resulting in

\[
(1 + g^*)^T = e^{rT}.
\] (34)

Given \( g^* \), we obtain the following expression for the customer value:

\[
P_0^* = e^{-rT} \cdot P_0 \cdot (1 + g^*)^T = P_0.
\] (35)

This outcome is intuitive since this contract carries no risk. Therefore, the guaranteed interest rate must be equal to the risk-free rate in order to ensure no arbitrage possibilities in the insurance market. Hence, a policyholder would be willing to pay only the nominal value \( P_0 \) for a contract that guarantees the risk-free rate.

Annual guaranteed surplus participation

Second, we examine a contract with annual guaranteed surplus participation and a money-back guarantee that, at a minimum, returns the premiums paid into the contract, i.e., \( g = 0, \alpha > 0, \delta = 0 \). In this case, the fair annual surplus participation rate is given by

\[
\alpha^* = \frac{P_0 \cdot (1 - e^{-rT})}{\sum_{i=1}^{T} \gamma \cdot e^{-rT} \cdot E^Q \left( \max \left[ \left( A(i) - A(i-1) \right), 0 \right] \right)}.
\] (36)

The customer value for this fair \( \alpha^* \) results in
Part II: 4 Creating Customer Value in Participating Life Insurance

Terminal bonus payment and money-back guarantee

We finally consider a contract with a terminal bonus payment and a money-back guarantee, \( g = 0, \alpha = 0, \delta > 0 \). Similar to the previous case, the fair terminal surplus participation rate is

\[
\delta^* = \frac{P_0 \cdot (1 - e^{-rT})}{e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)}.
\]  

(38)

Inserting this participation rate into the customer value formula yields

\[
P^0_0 = e^{-rT} \cdot P_0 + P_0 \cdot (1 - e^{-rT}) \cdot \frac{e^{-rT} \cdot E \left( \max(\beta \cdot A(T) - P_0, 0) \right)}{e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)}
\]

\[-e^{-rT} \cdot \frac{a}{2} \cdot \sigma^2 \left[ P_0 \cdot (1 - e^{-rT}) \cdot \frac{\max(\beta \cdot A(T) - P_0, 0)}{e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)} \right].
\]

(39)

We can reformulate Equation (39) by using the fact that

\[
\beta \cdot e^{-rT} \cdot E \left( \max(A(T) - A(0), 0) \right) = \beta \cdot e^{-rT} \cdot E \left[ \sum_{i=1}^{T} \max(A(i) - A(i-1), 0) \right].
\]

(40)

However, even though
a general ranking between Equations (37) and (39) cannot be derived due to the ratios of expected values under the real-world and risk-neutral measures contained in these equations. For the same reason, they cannot be explicitly compared to Equation (35) for the contract with a guaranteed interest rate only. It is not clear whether the customer values of the fair contracts with annual or terminal surplus participation are below or above the premium $P_0$ and thus preferable compared to a contract that contains only a guaranteed interest rate. However, we believe the explicit formulas in Equations (35), (37), and (39) to be useful for practical implementation, as numerical inputs will deliver comparable results.

### 4.5 Numerical Examples

We now illustrate application of the explicit formulas derived in the previous section using numerical examples. In particular, we demonstrate how contract parameters in a participating life policy can be adjusted to lead to fair contracts and, at the same time, increase customer value.

**Input parameters**

Until otherwise stated, we use the following input parameters as the basis for all our numerical analyses. The case considered reflects the condition of the German market; however, the analysis can easily be adjusted to meet conditions prevalent in other countries.

$$r = 4.46\%, \mu_A = 7\%, \sigma_A = 6\%, P_0 = 100, Eq_0 = 30, \gamma = 50\%, T = 10.$$ 

For the risk-free interest rate $r$ we use 4.46%, which corresponds to the return on German 10-year government bonds as of 2007 (see Bafin, 2008, p. 38). The assets of the insurance company $A(t)$ are invested in a portfolio with mean annual return of 7% ($\mu_a$), and a standard deviation of the annual return of 6% ($\sigma_a$). Further, the fair premium and thus the starting value of the policyholder account is set to 100 ($P_0$). The contribution of the equityholders is set to $Eq_0 = 30$. As in Kling, Richter, and Ruß (2007), the relation of book to market values, which at the same time is an (inverse)
flexibility parameter for the insurance company to build up hidden reserves, is set to $\gamma = 50\%$. The input parameters ensure a high safety level for the insurance company. Numerical results are derived using Monte Carlo simulation, where necessary, on the basis of 100,000 simulation runs.

Currently, e.g., German regulations concerning policy reserves require a minimum annual interest rate of 2.25% until maturity ($= g$) for all German life insurance contracts issued after January 2007. Furthermore, German law ensures that at least 90% of the investment earnings on book values are credited to the policyholder account ($\alpha$). In the base case, we use these preset parameters and calculate the terminal surplus participation rate ($\delta$) such that the fairness condition of Equation (11) is satisfied. Hence, the present value of the policyholder payoff is equal to the initial nominal premium of $\Pi^* = 100$. This is achieved by setting $\delta = 68\%$.

Table 1 contains numerical results for the cases of deterministic and stochastic wealth. The left part of the table displays parameter combinations that lead to a fair contract value of $\Pi^* = 100$ (fair premium from the insurer perspective in order to achieve a risk-adequate return). To provide an indication of the risk associated with the contracts, we list the corresponding default put option value (DPO) and the shortfall probability. The right part of the table contains the corresponding customer value based on the policyholders following mean-variance preferences for the case of deterministic (first column in the right part) and stochastic wealth (second to seventh column in the right part). Customer values are calculated using the expressions in Equations (20) and (26).

Panel A of Table 1 displays the base case, i.e., the contract satisfying regulatory restrictions. For better comparison, we adjust the risk-aversion parameter $a$ such that the customer value in this base case is equal to the fair policy price of 100 ($= P_0^\phi = \Pi^*$). Thus, we start the analysis with standardized parameters. For the cases of deterministic and stochastic wealth, these values are given by $a = 0.0685$ and $a = 0.0105$, respectively. In all examples, we first calibrate contract parameters to have the same fair value from the insurer perspective using risk-neutral valuation. Second, we calculate the corresponding customer value for these contracts by using the explicit expressions for deterministic and stochastic wealth derived in the previous sections.

Table 1 shows that even though all contracts in the left column have the same fair value ($\Pi^*$) of 100 for the insurer, they do not have the same value to a risk-averse customer with mean-variance preferences. On the contrary, we find that customer value varies substantially. Hence, it is possible for insurers to design contracts such
that customer value and, hence, policyholder willingness to pay considerably exceed the minimum premium required to achieve a risk-adequate return on equity.
Table 1: Fair premium, maximum willingness to pay, and premium agreement range for policies with different coinsurance levels and no exposure to default risk.

<table>
<thead>
<tr>
<th>Guaranteed interest rate ($g$)</th>
<th>Terminal participation rate ($\delta$)</th>
<th>Annual participation rate ($\alpha$)</th>
<th>$\Pi^*$</th>
<th>DPO</th>
<th>Shortfall probability</th>
<th>Part A: deterministic ($a = 0.0685$)</th>
<th>Part B: stochastic ($a = 0.0105$)</th>
<th>$\rho = 0.9$</th>
<th>$\sigma_Z = 8%$</th>
<th>$\sigma_Z = 4%$</th>
<th>$Z_0 = 200$</th>
<th>$a = 0.0685$</th>
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<td>Panel A: Contract with regulatory restrictions:</td>
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<td>Panel B: Simple contracts with one parameter only:</td>
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<td>Panel C: Maximizing customer value:</td>
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Part A: Numerical results for deterministic wealth of policyholder

We look first at the results for the case of deterministic wealth. As mentioned above, the risk-aversion parameter for this case is set to $a = 0.0685$ so that the customer value $P_0^\phi$ will be equal to the fair premium $P_0 = 100$ in Panel A of Table 1. When considering fair contracts with only one of the three contract parameters $(g, \alpha, \delta)$—as discussed in Section 4—we find that the customer value can be increased above this level (see Panel B of Table 1). In particular, the highest value for deterministic wealth ($P_0^\phi = 101.3$) among the three simple contracts is achieved when offering a contract with an annual surplus participation rate and a money-back guarantee ($g = 0\%$) only. To ensure fair contract conditions, this fair annual rate even exceeds 100%. A contract with a guaranteed interest rate on the premium paid is also more valuable to a customer with mean-variance preferences than the fair contract that complies with regulatory restrictions (Panel A of Table 1). In particular, this result demonstrates that the premium agreement range can be increased by freely adjusting contract parameters with the aim of maximizing customer value while continuing to keep the contracts fair from the insurer perspective.

To illustrate this process, Panel C in Table 1 contains customer values for different choices of $g$, $\alpha$, and $\delta$. As discussed in Section 4, the results show that customer value is a complex function of these three parameters. For lower fixed values of $g$ (1\%, 2\%, 3\%, 4\%), customer value is highest if the terminal bonus participation rate is zero. At the same time, customer value is increasing with increasing guaranteed rate. This pattern changes, however, when the guaranteed rate approaches the risk-free rate. Here, policyholders prefer higher terminal bonus with low annual surplus participation. The highest customer value in the examples considered is obtained for $g = 4.4\%$, $\alpha = 5\%$, and $\delta = 27\%$. However, this combination represents maximum customer value regarding fair contracts only for these numerical examples. Since there are an infinite number of parameter combinations leading to one specific fair contract value, analyzing a larger set of contracts may lead to a further increase in customer value.

Part B: Numerical results for stochastic wealth of policyholders

We next consider the case of stochastic wealth. In this case, we assume that the drift and volatility of the investment open to the policyholders are given by $\mu_z = 7\%$ and $\sigma_z = 6\%$, which are the same parameters applicable to the policyholder account. For
simplicity, we start by assuming that policyholder and insurer investments are uncorrelated ($\rho = 0$) and then consider the case of positively correlated cash flows ($\rho = 0.9$). Results are exhibited in Part B of the right-hand side customer value area in Table 1. In contrast to the case of deterministic wealth, we now find the maximum customer value of $P_0^\phi = 104.1$ for a simple contract with a terminal bonus participation rate only.

For a positive correlation coefficient of 0.9 between policyholder and insurer investments, customer value is reduced compared to the contract with uncorrelated cash flows. This is due to a lower diversification effect achieved when investing in the life policy. A higher volatility of the wealth process $\sigma_z = 8\%$ makes (ceteris paribus) the less volatile life insurance contract ($\sigma_d = 6\%$) more attractive from the policyholder perspective and, hence, $P_0^\phi$ is increasing. The opposite is observed for a lower wealth process volatility of $\sigma_z = 4\%$. We further find that a higher initial wealth of 200, compared to 150, increases the customer value of the contract. In addition, if the risk-aversion coefficient is the same as in the case of deterministic wealth ($a = 0.0685$), customer value increases substantially. However, the differences in customer value for different fair parameter combinations are quite small for $a = 0.0685$.

Overall, we find that restrictions on contract parameters can—at least in our model setup—seriously depress customer value. The extent of the loss in utility depends on the preference function of the policyholders.

### 4.6 Summary and Policy Implications

Most literature on participating life insurance focuses on pricing from the insurer perspective and does not take into consideration how policyholders might value the contract. In this chapter, we examine how insurers can generate customer value for participating life insurance contracts by combining their perspective with that of the policyholders. Participating life insurance contracts feature a minimum interest rate guarantee, a guaranteed annual participation in the surplus generated by the asset portfolio of the insurer, and a terminal bonus. In this chapter, customer value is defined as policyholder willingness to pay and is calculated based on mean-variance preferences. We compare the cases of policyholders with deterministic wealth and those with stochastic wealth, i.e., with and without diversification opportunities.

For the insurer, we assume that the preference-free approach of risk-neutral valuation is used (hence, cash flows of an insurance contract can be replicated by means of
assets traded on the capital market). We combine customer value and insurer valuation by first calibrating contract parameters so that all contracts have the same fair risk-neutral value from the insurer perspective. In the second step, we derive explicit expressions for the customer value of these same contracts.

Our findings show that customer value varies substantially, even though all contracts have the same value from the insurer perspective. The results suggest that customer segmentation is a viable tool for increasing insurer profit and achieving a shareholder return above the risk-adequate rate. If insurers know how particular segments of the customer population value contracts, they can design contracts (by adjusting the guaranteed interest rate and/or annual and terminal surplus participation rate) to specifically increase customer value compared to standard contracts. In particular, preferred contracts may be simple contracts with, e.g., only one of the three parameters, as illustrated by our numerical example for stochastic policyholder wealth. In particular, a change from the regulatory parameter combination to the case with terminal participation rate only increases customer value by approximately 4%, given our input assumptions.

Customer value may be even further increased for higher default put option values (or shortfall probability). Hence, policyholders may prefer a fair product parameter combination that is associated with higher shortfall risk. Regulatory authorities, however, in general penalize this. Future steps in the customer value analysis should take behavioral aspects into consideration. If the safety level is a main decision variable for policyholders, results may differ and default put option values could have a much more negative impact on customer value.
Appendix A

Derivation of the customer value given the case of stochastic wealth

\[ E(Z_{\tau}^{NI}) - \frac{a}{2} \cdot \sigma^2 (Z_{\tau}^{NI}) = E(Z_{\tau}^{WI}) + E(L(T)) - \frac{a}{2} \cdot \sigma^2 (Z_{\tau}^{WI} + L(T)) \]

\[ \Leftrightarrow P_0^\phi \cdot E(\tilde{Z}_\tau) - E(L(T)) - \frac{a}{2} \cdot \sigma^2 (Z_{\tau}^{NI}) + \frac{a}{2} \cdot \sigma^2 (Z_{\tau}^{WI} + L(T)) = 0, \]

(A1)

with

\[ \tilde{Z}_\tau = \exp \left[ (\mu_z - \sigma^2 z^2/2) \cdot T + \sigma_z \cdot (W_z(T) - W_z(0)) \right]. \]

Calculation of the last variance term in Equation (A1):

\[ \sigma^2 (Z_{\tau}^{WI} + L(T)) \]
\[ = \sigma^2 (Z_{\tau}^{NI} - P_0^\phi \cdot \tilde{Z}_\tau + L(T)) \]
\[ = \sigma^2 (Z_{\tau}^{NI}) + \sigma^2 (P_0^\phi \cdot \tilde{Z}_\tau) + \sigma^2 (L(T)) - 2 \cdot Cov(Z_{\tau}^{NI}, P_0^\phi \cdot \tilde{Z}_\tau) \]
\[ + 2 \cdot Cov(Z_{\tau}^{NI}, L(T)) - 2 \cdot Cov(P_0^\phi \cdot \tilde{Z}_\tau, L(T)) \]
\[ = \sigma^2 (Z_{\tau}^{NI}) + P_0^{\phi^2} \cdot \sigma^2 (\tilde{Z}_\tau) + \sigma^2 (L(T)) - 2 \cdot P_0^\phi \cdot Cov(Z_{\tau}^{NI}, \tilde{Z}_\tau) \]
\[ + 2 \cdot Cov(Z_{\tau}^{NI}, L(T)) - 2 \cdot P_0^\phi \cdot Cov(\tilde{Z}_\tau, L(T)) \]
\[ = P_0^{\phi^2} \cdot \sigma^2 (\tilde{Z}_\tau) - 2 \cdot P_0^\phi \cdot Cov(Z_{\tau}^{NI}, \tilde{Z}_\tau) - 2 \cdot P_0^\phi \cdot Cov(\tilde{Z}_\tau, L(T)) \]
\[ + \sigma^2 (Z_{\tau}^{NI}) + \sigma^2 (L(T)) + 2 \cdot Cov(Z_{\tau}^{NI}, L(T)). \]

(A2)

Replacing the variance term in Equation (A1) with the result derived in Equation (A2) leads to
\[ P_0^\phi \cdot E(\tilde{Z}_T) - E(L(T)) = \frac{a}{2} \cdot \sigma^2(\tilde{Z}_T) + \frac{a}{2} \cdot P_0^{\phi_2} \cdot \sigma^2(\tilde{Z}_T) - a \cdot P_0^\phi \cdot \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - a \cdot P_0^\phi \cdot \text{Cov}(\tilde{Z}_T, L(T)) + \frac{a}{2} \cdot \sigma^2(L(T)) + a \cdot \text{Cov}(Z_T^{NI}, L(T)) = 0 \]

\[ \Leftrightarrow \frac{a}{2} \cdot P_0^{\phi_2} \cdot \sigma^2(\tilde{Z}_T) - a \cdot P_0^\phi \cdot \text{Cov}(Z_T^{NI}, \tilde{Z}_T) + P_0^\phi \cdot E(\tilde{Z}_T) - a \cdot P_0^\phi \cdot \text{Cov}(\tilde{Z}_T, L(T)) - E(L(T)) + \frac{a}{2} \cdot \sigma^2(L(T)) + a \cdot \text{Cov}(Z_T^{NI}, L(T)) = 0 \]

\[ \Leftrightarrow P_0^{\phi_2} \left( \frac{a}{2} \cdot \sigma^2(\tilde{Z}_T) \right) + P_0^\phi \left[ E(\tilde{Z}_T) - a \cdot \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - a \cdot \text{Cov}(\tilde{Z}_T, L(T)) \right] + \left[ \frac{a}{2} \cdot \sigma^2(L(T)) + a \cdot \text{Cov}(Z_T^{NI}, L(T)) - E(L(T)) \right] = 0 \]

\[ \Leftrightarrow P_0^{\phi_2} + P_0^\phi \cdot \frac{2}{\left( \sigma^2(\tilde{Z}_T) \right)} \left[ \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \right] + \frac{1}{\left( \sigma^2(\tilde{Z}_T) \right)} \left[ \sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T)) \right] = 0 \]

\[ \Leftrightarrow P_0^{\phi_2} + 2 \cdot P_0^\phi \cdot \frac{\frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T))}{\sigma^2(\tilde{Z}_T)} \cdot \frac{\sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))}{\sigma^2(\tilde{Z}_T)} = 0 \]
\[ P_0^{\phi^2} + 2 \cdot P_0^\phi \cdot \frac{\frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T))}{\sigma^2(\tilde{Z}_T)} \]

\[ = \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \]

\[ + \frac{\sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))}{\sigma^2(\tilde{Z}_T)} \]

\[ \Rightarrow P_0^\phi = \left[ \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \right] \]

\[ \pm \left[ \frac{\sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))}{\sigma^2(\tilde{Z}_T)} \right]^{\frac{1}{2}} \]

\[ - \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \]

\[ \frac{\sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))}{\sigma^2(\tilde{Z}_T)} \]

\[ \Rightarrow P_0^\phi = \left[ \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \right] \]

\[ \pm \left[ \frac{\sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))}{\sigma^2(\tilde{Z}_T)} \right]^{\frac{1}{2}} \]

\[ - \frac{1}{a} \cdot E(\tilde{Z}_T) - \text{Cov}(Z_T^{NI}, \tilde{Z}_T) - \text{Cov}(\tilde{Z}_T, L(T)) \]

\[ \frac{\sigma^2(L(T)) + 2 \cdot \text{Cov}(Z_T^{NI}, L(T)) - \frac{2}{a} \cdot E(L(T))}{\sigma^2(\tilde{Z}_T)} \]

\[ (A3) \]
Appendix B

Derivation of formulas in Section 4.2 (Contracts with one option—deterministic wealth)

i) \( g > 0, \alpha = 0, \delta = 0 \).

This implies that

\[
L(T) = P(T) + \delta \cdot B(T) - D(T) = P(T) = P_0 \cdot (1 + g)^T,
\]

and that the contract is fair if

\[
P_0 = E^Q \left( e^{-rT} \cdot L(T) \right) = e^{-rT} \cdot P_0 \left( 1 + g^* \right)^T.
\]

Hence, from the insurer perspective, the fair guaranteed interest rate satisfies

\[
\left( 1 + g^* \right)^T = e^{rT}.
\]

For the customer value, Equation (20) implies that

\[
P_0^\phi = e^{-rT} \cdot E \left( L(T) \right) - e^{-rT} \cdot \frac{\alpha}{2} \cdot \sigma^2 \left( L(T) \right)
= e^{-rT} \cdot E \left( P_0 \cdot \left( 1 + g^* \right)^T \right) - e^{-rT} \cdot \frac{\alpha}{2} \cdot \sigma^2 \left( P_0 \cdot \left( 1 + g^* \right)^T \right)
= e^{-rT} \cdot P_0 \cdot \left( 1 + g^* \right)^T = P_0 \cdot e^{-rT} \cdot e^T = P_0.
\]

ii) \( g = 0, \alpha > 0, \delta = 0 \).

For the policy reserves, one obtains
\[ P(t) = P(t-1) \cdot (1 + g) + \max \left[ \alpha \cdot \gamma \cdot (A(t) - A(t-1)) - g \cdot P(t-1), 0 \right] \]
\[ = P(t-1) + \alpha \cdot \gamma \cdot \max \left[ (A(t) - A(t-1)), 0 \right] \]
\[ = P(t-2) + \alpha \cdot \gamma \cdot \max \left[ (A(t-1) - A(t-2)), 0 \right] + \alpha \cdot \gamma \cdot \max \left[ (A(t) - A(t-1)), 0 \right] \]
\[ = P_0 + \alpha \sum_{i=1}^{T} \gamma \cdot \max \left[ (A(i) - A(i-1)), 0 \right]. \]  
(B5)

For the payoff to the policyholder, the money-back guarantee is added, leading to

\[ L(T) = P(T) + \delta B(T) - D(T) = P_0 + \alpha \sum_{i=1}^{T} \gamma \cdot \max \left[ (A(i) - A(i-1)), 0 \right]. \]  
(B6)

The insurance contract is fair, if

\[ P_0 = E^Q \left( e^{-rT} \cdot L(T) \right) = e^{-rT} \cdot E^Q \left( P_0 + \alpha^* \sum_{i=1}^{T} \gamma \cdot \max \left[ (A(i) - A(i-1)), 0 \right] \right) \]
\[ = e^{-rT} \cdot P_0 + \alpha^* \sum_{i=1}^{T} \gamma \cdot e^{-rT} \cdot E^Q \left( \max \left[ (A(i) - A(i-1)), 0 \right] \right), \]  
(B7)

which implies a fair annual surplus participation rate of

\[ \alpha^* = \frac{P_0 \left( 1 - e^{-rT} \right)}{\sum_{i=1}^{T} \gamma \cdot e^{-rT} \cdot E^Q \left( \max \left[ (A(i) - A(i-1)), 0 \right] \right)} . \]  
(B8)

The customer value for the fair \( \alpha^* \) results in
The formula shows that the ratio of the sum of the value of \( \max[(A(i) - A(i-1)), 0] \) under the real-world measure \( P \) and under the risk-neutral measure \( Q \) is an important factor in determination of customer value.

\[ P_0^\phi = e^{-rT} E(L(T)) - e^{-rT} \frac{a}{2} \sigma^2(L(T)) \]
\[ = e^{-rT} E\left(P_0 + \alpha^* \cdot \sum_{i=1}^{T} \gamma \max[(A(i) - A(i-1)), 0]\right) \]
\[ -e^{-rT} \frac{a}{2} \sigma^2 \left(P_0 + \alpha^* \cdot \sum_{i=1}^{T} \gamma \max[(A(i) - A(i-1)), 0]\right) \]
\[ = e^{-rT} P_0 + P_0 (1 - e^{-rT}) \sum_{i=1}^{T} \gamma \cdot e^{-rT} \cdot E\left(\max[(A(i) - A(i-1)), 0]\right) \]
\[ -e^{-rT} \frac{a}{2} \sigma^2 \left(P_0 (1 - e^{-rT}) \sum_{i=1}^{T} \gamma \cdot e^{-rT} \cdot E^Q\left(\max[(A(i) - A(i-1)), 0]\right) \right) \]
\[ = e^{-rT} P_0 + P_0 (1 - e^{-rT}) \sum_{i=1}^{T} E\left(\max[(A(i) - A(i-1)), 0]\right) \]
\[ -e^{-rT} \frac{a}{2} \sigma^2 \left(P_0 (1 - e^{-rT}) \sum_{i=1}^{T} \max[(A(i) - A(i-1)), 0] \right) \]
\[ e^{-rT} \sum_{i=1}^{T} E^Q\left(\max[(A(i) - A(i-1)), 0]\right) \] 

(B9)

iii) \( g = 0, \alpha = 0, \delta > 0 \).

For the policy reserves, we adjust the up-front premium and the terminal bonus accordingly:

\[ P(t) = P(t-1) \cdot (1 + g) + \max[\alpha \cdot \gamma \cdot (A(t) - A(t-1)) - g \cdot P(t-1), 0] = P_0 \]  

(B10)

\[ B(T) = \max(\beta \cdot A(T) - P(T), 0) = \max(\beta \cdot A(T) - P_0, 0) \]  

(B11)
Therefore, the policyholder payoff is given by

\[
L(T) = P(T) + \delta \cdot B(T) - D(T) = P_0 + \delta \cdot \max(\beta \cdot A(T) - P_0, 0)
\]  
(B12)

and the contract is fair, if

\[
P_0 = E^Q \left( e^{-rT} \cdot L(T) \right) = e^{-rT} \cdot E^Q \left( P_0 + \delta^* \max(\beta \cdot A(T) - P_0, 0) \right)
\]

\[
= e^{-rT} \cdot P_0 + \delta^* \cdot e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)
\]

\[
= e^{-rT} \cdot P_0 + \delta^* \cdot \beta \cdot e^{-rT} \cdot E^Q \left( \max \left( A(T) - \frac{P_0}{\beta}, 0 \right) \right)
\]

\[
= e^{-rT} \cdot P_0 + \delta^* \cdot \beta \cdot e^{-rT} \cdot E^Q \left( \max \left( A(T) - A(0), 0 \right) \right).
\]  
(B13)

Hence,

\[
\delta^* = \frac{P_0 \left(1 - e^{-rT}\right)}{e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)}.
\]  
(B14)

The customer value is given by

\[
P_0^\phi = e^{-rT} \cdot E(L(T)) - e^{-rT} \frac{a}{2} \sigma^2(L(T))
\]

\[
= e^{-rT} \cdot E \left( P_0 + \delta^* \cdot \max(\beta \cdot A(T) - P_0, 0) \right)
\]

\[
= e^{-rT} \cdot P_0 + \frac{a}{2} \sigma^2 \left( P_0 + \delta^* \cdot \max(\beta \cdot A(T) - P_0, 0) \right)
\]  
(B15)

\[
- e^{-rT} \cdot \frac{a}{2} \cdot \sigma^2 \left( P_0 + \delta^* \cdot \max(\beta \cdot A(T) - P_0, 0) \right)
\]

\[
= e^{-rT} \cdot P_0 \left(1 - e^{-rT}\right) \frac{e^{-rT} \cdot E \left( \max(\beta \cdot A(T) - P_0, 0) \right)}{e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)}
\]

\[
- e^{-rT} \cdot \frac{a}{2} \cdot \sigma^2 \left( P_0 \left(1 - e^{-rT}\right) \frac{\max(\beta \cdot A(T) - P_0, 0)}{e^{-rT} \cdot E^Q \left( \max(\beta \cdot A(T) - P_0, 0) \right)} \right).
\]
5 Comparison of Policyholder and Insurer Perspectives on Property-Liability Insurance Policies

5.1 Introduction

Property-liability insurance policies can be priced on the basis of option pricing theory. We believe that, in general, risk-neutral valuation, one of the chief tools of option pricing, is appropriately employed by insurers, but that such is not the case for policyholders because policyholders cannot replicate claims in the financial market to the same extent as can insurers. The policyholders therefore evaluate claims based on individual preferences. This difference in valuation may make policy pricing more complex, but it also provides insurers with an opportunity to realize returns on equity above the risk-adequate rate. The aim of this chapter is to examine the difference between policyholder and insurer perspectives as regards general property-liability insurance policies with full coverage. We further introduce three special cases: deductibles, coinsurance, and stop-loss policies. In the numerical analysis, we concentrate on coinsurance policies, as closed-form solutions for the respective policyholder and equityholder claims can be found using the Fischer (1978) and Margrabe (1978) formula.

Deductible policies receive the most attention in the literature. In general, deductibles stipulate that no loss below the deductible limit will be paid by the insurer, whereas each loss in excess of this limit will be paid in full by the insurer (see Duvall and Allen, 1973). This type of policy is common, for example, in the automobile insurance industry, as analyzed by Pashigian, Schkade, and Menefee (1966), Schkade and Menefee (1966), von Lanzenauer (1971), and Murray (1971). Additional research in this area is conducted by Arrow (1963), who determines the optimal insurance policy within the medical care industry and finds that a positive deductible is optimal in case of a fixed percentage loading of insurance contracts. Literature that looks at the demand for insurance with deductibles in light of background risk or stochastic initial wealth includes Hoy and Robson (1981), Doherty and Schlesinger (1983), and Meyer and Meyer (1998).

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5 This paper has been submitted and is currently under review.


Coinsurance policies specify a percentage proportion of each loss to be borne by the insured and are common, for example, in health insurance contracts. In contrast to policies with deductibles, there is no upper limit on the possible amount the policyholder will have to pay. Arrow (1963) investigates coinsurance policies, finding that this type of policy is optimal if loadings of insurance contracts are not fixed, but dependent on the uncertainty incorporated in the contract, i.e., if the insurer is risk-averse itself. Similarly, Raviv (1979) states the optimality of coinsurance contracts to be due either to risk or cost sharing between the policyholder and the insurer. Young and Browne (1997) find that it is adverse selection that explains the optimality of coinsurance policies.

Stop-loss policies, also known as maximum or upper-limit coverage, are common, for example, in the liability insurance industry. This feature can mean either that above a predefined loss level the indemnity payment stays constant, or that no indemnification is paid above that level (see, e.g., Huberman, Mayers, and Smith, 1983). Huberman, Mayers, and Smith (1983) explain the existence of upper limits on coverage as due to the limited liability of individuals granted by bankruptcy statutes. Raviv (1979) finds that upper limits are not optimal when maximizing expected utility and argues that their existence is due to specifics in insurance regulation.

The literature contains a fair amount of discussion as to when and why deductibles, coinsurance, and/or stop-loss features in insurance contracts are optimal. For example, it is generally agreed that the chief reason for a deductible is to reduce moral hazard for the insurer. In this respect, Schmidt (1961) analyzes the hypothesis that deductibles can effectively keep an automobile insurance policyholder from deviating from generally accepted principles, such as carefulness. An intuitively appealing reason for the existence of stop-loss insurance is regulation, solvency regulation of insurance companies in particular (see, e.g., Raviv, 1979). Considering a risk-sensitive solvency framework, the disclaimer of liabilities above a certain threshold can substantially lower the insurer’s risk and, hence, its capital requirements.

In this chapter, we define optimality by comparing policyholder and insurer perspectives on insurance prices, which results in the premium agreement range between the two parties. The insurer provides the lower end of this range, applying, we

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6 Other interpretations of coinsurance are contained in Chami, Shama, and Shim (2004), who use coinsurance in the sense of mutual insurance between countries and Brusco and Castiglionesi (2007), who address liquidity coinsurance between banks.
assume, risk-neutral valuation. This lower end premium ensures a risk-adequate return for the insurer’s equityholders. The policyholder maximum willingness to pay is the upper end of this range and is, in this chapter, derived under the assumption of the policyholders having mean-variance preferences (see, e.g., Mayers and Smith, 1983). Combining the pricing of property-liability insurance policies under the risk-neutral measure with the valuation from the policyholder perspective, which is based on individual preferences, is new to the literature, as far as we know. Application of the risk-neutral valuation technique allows incorporation of the insurer’s default risk when determining the optimal policy type. We thus contribute to the extant literature as we maximize the premium agreement range with regard to the level of coinsurance and the insurer’s safety level.

Our results for the optimum coinsurance level in the absence of default risk support previous findings; namely, it is not coinsurance, but full insurance contracts that produce the largest premium agreement ranges when policies are offered at their actuarial fair value. Coinsurance is optimal when the fair price according to capital market theory deviates from the actuarial value of the policy. Introducing default risk, our numerical results indicate that under the assumptions made and for the case of risk-averse policyholders, the premium agreement ranges are largest for full coverage policies and high safety levels. High safety levels, hence large premium agreement ranges, provide insurers with the possibility of realizing returns on equity above the risk-adequate rate. This suggests that solvency regulation appears to be unnecessary if there is a certain level of market transparency. Furthermore, we find that with decreasing safety levels, the largest premium agreement ranges occur for increasing levels of coinsurance, with the optimal coinsurance level increasing as the safety level decreases.

This chapter is structured as follows. Section 2 introduces the model framework. It sets out the details of the general case of full insurance coverage and distinguishes between policyholder and insurer perspectives. The model framework is generally applied to the cases of deductibles, coinsurance, and stop-loss insurance policies in Section 3. This section provides the indemnity schedules of the different policy types on an illustrative basis and discusses the individual elements of the maximum willingness to pay formula. Section 4 concentrates more deeply on coinsurance policies and maximizes the premium agreement range with regard to the level of coinsurance in the absence of default risk. For the case with default risk, we rephrase the optimization problem in Section 4 and conduct a bounded numerical search for the optimum level
of coinsurance, and a search for the optimum safety level in Section 5. Section 6 concludes.

5.2 Model Framework

This section introduces the model framework for the general case of full insurance coverage. First, we adopt the insurer perspective. We assume that the insurer is able to replicate claims in the financial market and can therefore use the risk-neutral valuation technique to determine the fair policy price that will provide a risk-adequate return on equity. In short it is the minimum price the insurer is willing to accept for the policy. Second, we assume that policyholders cannot replicate claims in the financial market to the same extent as can the insurer and thus individual preferences influence valuation of the policy. This valuation, which is based on the assumption that the policyholder follows mean-variance preferences, results in the policyholder maximum willingness to pay. The policy’s actual price must be within the range thus bounded, that is, on the lower end by the minimum amount the insurer will accept—the fair policy price under the risk-neutral measure—and on the upper end by the maximum amount the policyholder is willing to pay.

5.2.1 Insurer Perspective on Full Insurance Contract

The following one-period model for full coverage property-liability insurance policies is based on Doherty and Garven (1986) and is the foundation of the analysis.

The policyholders today dispose of their wealth $Z_0$, which they can either invest in the risk-free investment opportunity or spend on insurance that protects them against uncertain future losses $L_0$, with nominal value $L_0$. The premium for the insurance contract is denoted by $P_0$. The equityholders invest the amount $Eq_0$ in the insurance company, which, for them, is simply an investment opportunity and they thus require, at the very least, a risk-adequate return. In the following, the insurer (the equityholders) and the policyholders are disjunctive groups in respect to their valuation procedures. For time $t = 0$, this leads to initial assets for the insurance company of:

$$A_0 = Eq_0 + P_0$$ (1)
The assets and the liabilities develop according to geometric Brownian motion under the objective measure $P$, with

$$A_t = A_0 \cdot \exp \left[ \left( \mu_A - \sigma_A^2 / 2 \right) + \sigma_A (W_A (1) - W_A (0)) \right],$$  \hspace{1cm} (2)

$$L_t = L_0 \cdot \exp \left[ \left( \mu_L - \sigma_L^2 / 2 \right) + \sigma_L (W_L (1) - W_L (0)) \right],$$  \hspace{1cm} (3)

where $\mu$ and $\sigma$ denote the drift and volatility of the stochastic processes. The two $P$-Brownian motions, $W_A$ and $W_L$, are correlated with the correlation coefficient $\rho$.

To identify the values of stochastic future payoffs from the insurer perspective, we use risk-neutral valuation because we assume that the insurers—or, more precisely, their owners—are able to replicate claims in the arbitrage-free capital market. The evolution of the assets and the liabilities under the risk-neutral measure $Q$ follow

$$A_t = A_0 \cdot \exp \left[ \left( r - \sigma_A^2 / 2 \right) + \sigma_A (W_A^Q (1) - W_A^Q (0)) \right],$$  \hspace{1cm} (4)

$$L_t = L_0 \cdot \exp \left[ \left( r - \sigma_L^2 / 2 \right) + \sigma_L (W_L^Q (1) - W_L^Q (0)) \right],$$  \hspace{1cm} (5)

with $r$ as the deterministic risk-free interest rate and $W_A^Q$ and $W_L^Q$ as $Q$-Brownian motions.

The payoffs at time $t = 1$ to the policyholders and the equityholders depend on the stochastic values $A_t$ and $L_t$. If liabilities are greater than assets, the insurer becomes insolvent. For the policyholders, who have preferential claims, the payoff is $L_t$ if the insurance company is solvent and $A_t$ otherwise. The net present value of the policyholders’ payoff is therefore given with

$$\Pi^p = e^{-r} \cdot E^Q \left[ \min(A_t, L_t) \right],$$  \hspace{1cm} (6)
and it equals the initial premium in case of a “fair” contract, i.e., $\Pi^P = P_0$. The payoff to the equityholders is the remainder of the assets after indemnification of the losses, if the insurer is solvent; zero otherwise. Due to no-arbitrage, fair premiums are those where the net present value of the equityholders’ claims is equal to their initial contributions, i.e., $\Pi^E = Eq_0$.

### 5.2.2 Policyholder Perspective on Full Insurance Contract

We now consider a policyholder whose target value is his wealth at $t = 1$. He has the following order of preferences

$$\Phi = E(Z_1) - \frac{a}{2} \sigma^2(Z_1), \quad (7)$$

with $a > 0$ as the individual risk-aversion coefficient. Hence we assume that the policyholder is risk averse with mean-variance preferences (see, e.g., Mayers and Smith, 1983).

If the individual decides not to buy insurance, his expected utility is given by his expected wealth minus the stochastic future losses ($NI$—no insurance). The uncertainty (variance) in his wealth is driven by the stochasticity of the losses. It follows that

$$\Phi^{NI} = E(Z_{1}^{NI} - L) - \frac{a}{2} \sigma^2(Z_{1}^{NI} - L) = e^r \cdot Z_0 - E(L) - \frac{a}{2} \sigma^2(L). \quad (8)$$

If the individual decides to buy full insurance, which is not exposed to default risk (consider, e.g., insurance with a state guarantee), his future wealth is not stochastic. The variance in this case thus equals zero. The expected utility then consists solely of the future wealth. In $t = 0$, however, the policyholder needs to pay a premium $P_0^{\text{default-free}}$ for this insurance. His preference function is given with ($WI$—with insurance):

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7 The policyholder invests his wealth in the risk-free asset with deterministic payout.
\[ \Phi_{\text{WT}}(\text{default-free}) = E(Z) = E\left[ e^r \cdot \left( Z_0 - P_0^{\text{default-free}} \right) \right] = e^r \cdot \left( Z_0 - P_0^{\text{default-free}} \right). \tag{9} \]

However, in general, insurance companies do face default risk. This leads, on the one hand, to a reduction in the expected payback from the insurance policy and, on the other hand, to uncertainty (variance) about the future wealth of the policyholder. The policyholder preference function for default-stressed insurance is:

\[ \Phi_{\text{WT}} = E\left[ e^r \cdot (Z_0 - P_0^\Phi) \right] - E\left[ L - \min(A, L) \right] - \frac{a}{2} \sigma^2 \left[ L - \min(A, L) \right] = e^r \cdot (Z_0 - P_0^\Phi) - E\left[ L \right] + E\left[ \min(A, L) \right] - \frac{a}{2} \sigma^2 \left[ L - \min(A, L) \right]. \tag{10} \]

To identify an individual’s willingness to pay for an insurance contract, the potential customer needs to be indifferent between the situation with no insurance and the situation with this specific insurance contract. We thus introduce \( P_0^\Phi \) as the policyholder maximum willingness to pay. Setting the preference functions of the case with insurance equal to the one without insurance and solving for \( P_0^\Phi \) leads to the maximum premium the policyholder would be willing to pay for the insurance policy:

\[ P_0^\Phi = e^{-r} \cdot E\left[ \min(A, L) \right] + e^{-r} \cdot \frac{a}{2} \sigma^2 \left( L \right) - e^{-r} \cdot \frac{a}{2} \sigma^2 \left[ L - \min(A, L) \right]. \tag{11} \]

A customer with mean-variance preferences will buy the insurance if it is cheaper than \( P_0^\Phi \) and will not purchase it if the premium is higher. As for the insurance company, it will only sell a policy for at least the fair premium \( P_0 \). This leads to the premium agreement range of \([ P_0, P_0^\Phi ]\), with \( P_0^\Phi \geq P_0 \).

### 5.3 Special Types of Property-Liability Insurance Policies

This section introduces three different types of policies: one with a deductible, one providing for coinsurance, and one containing a stop-loss agreement. Due to their basic similarity to the full coverage policy, the description of each policy is brief (corresponding equations can be found in Appendix A). Figure 1 shows the indemnity schedules, \( I(L) \), of the three contract types.
We first look at insurance policies with deductibles. Although deductibles can come in a variety of forms, for our simplified example of a two-period model, the deductible \((X)\) works as follows: the policyholder at time \(t=1\) faces a loss at the random level \(L_1\), with \(L_1 > 0\), or no loss, i.e., \(L_1 = 0\). If the loss is less than the deductible agreed to in the contract, i.e., \(L_1 < X\), the policyholder must cover the loss. If the loss is more than the deductible, i.e., \(L_1 > X\), and provided the insurance company is solvent, the policyholder will be indemnified with the difference between the actual loss \(L_1\) and the deductible, i.e., with \(L_1 - X\). If the insurance company is insolvent, \(A_1 < (L_1 - X)\), policyholders will receive the value of the assets \(A_1\). The policyholder’s indemnity payment thus is given by \(\min(A_1,\max(L_1 - X,0))\).

We next look at coinsurance policies. Under this type of policy, the policyholder must pay part of the loss, \(\theta\%\) with \((0 < \theta < 1)\), himself. The remaining amount of loss, \((1-\theta)\%\), is paid by the insurance company, provided it is solvent. In the event of insurer insolvency, policyholders receive the value of the assets. The indemnity payment to the policyholder for the case of coinsurance is given by \(\min(A_1,(1-\theta)\cdot L_1)\).
And lastly, we investigate *stop-loss* policies that feature a maximum indemnification. The maximum indemnification $I(L)$ is paid for all losses of a predefined level $L$ or above, i.e., for $L_i \geq L$. However, this is only the case if the insurance company is solvent. If an insolvency occurs, policyholders will receive the values of the assets, i.e., $A_i$. The indemnity payment to the policyholder is given by $\min(A_i, \min(L_i, L))$.

For all three policy types, the policyholder ($\Pi^p$) and the equityholder ($\Pi^e$) claims are given with:

$$\Pi^p = e^{-r} \cdot E^q[I(L)]$$

$$\Pi^e = e^{-r} \cdot E^q[A_i - I(L)]$$

The policyholder maximum willingness to pay for the different policy types can in general be calculated with:

$$P^* = \frac{e^{-r} \cdot E^q[I(L)] + e^{-r} \cdot \frac{a}{2} \sigma^2(L) - e^{-r} \cdot \frac{a}{2} \sigma^2[L - I(L)]}{\text{Net reduction of variance of policyholder wealth.$$}

Maximum willingness to pay is comprised of three basic elements. First, willingness to pay is dependent on expected payback from the insurance policy. The expected indemnity payment depends on the contract types (see Figure 1) and on whether the insurer is solvent. Second, willingness to pay increases with increasing variance of the policyholder’s wealth without insurance (with the assumption of a risk-averse policyholder, $a > 0$). This means that a policyholder with a higher initial risk exposure is willing to pay more for an insurance contract. This second element is independent of the type of policy investigated. Third, even with insurance, however, the policyholder might not be able to eliminate all the risk he faces. The policyholder willingness to pay, therefore, is reduced by variance in the wealth he has after contracting the insurance policy. The variance of wealth in the situation without insurance minus the variance of wealth in the situation with insurance is the net reduction in the variance of
the policyholder’s wealth. It is this variance that the policyholder can eliminate by purchasing insurance. Both variance terms—terms two and three—are weighted with the risk-aversion of the policyholder \( (\alpha) \).

5.4 Coinsurance Policies

This section focuses on coinsurance policies. We choose this policy type for more detailed examination because closed-form solutions for equityholder and policyholder claims can be derived using the Fischer (1978) and Margrabe (1978) formula. The precondition for using this formula is that the strike price of the corresponding option is lognormally distributed, and this is indeed the case for coinsurance policies, \( (1-\theta) \cdot L_1 \), but not for policies with deductibles, \( \max(L_1 - \bar{L}, 0) \), or stop-loss indemnification, \( \min(L_1, L_{\bar{T}}) \). For these two types of policies, an approximation of the payoff can be derived using, e.g., a Monte Carlo simulation, but, in general, there are no closed-form solutions.

5.4.1 Fair Pricing

The indemnity payment in case of coinsurance is \( \min(A, (1-\theta) \cdot L_1) \). The policyholder \( \Pi^P(\theta) \) and the equityholder \( \Pi^E(\theta) \) claims are thus given with:

\[
\Pi^P(\theta) = E^Q \left[ e^{-r} \cdot \min(A, (1-\theta) \cdot L_1) \right],
\]

\[
\Pi^E(\theta) = E^Q \left[ e^{-r} \cdot \max(A - (1-\theta) \cdot L_1, 0) \right].
\]

As in the case of full insurance coverage, these claims are representative of European options with stochastic strike price. The liabilities at \( t = 1 \) are lognormally distributed, i.e., \( L_1 \sim LN(m, \nu^2) \). For linear transformations of \( L_1 \) to \( L_1^\theta \), with factor \( (1-\theta) \), the lognormality remains with \( L_1^\theta \sim LN(\ln(1-\theta) + m, \nu^2) \). The derivation of the mean and variance of the transformed distribution (with only the drift \( \mu_1 \) and volatility \( \sigma_L \) of the stochastic liability process given) can be found in Appendix B. The nominal value of the liabilities is the same as in the standard case with full insurance \( (L_0) \). Hence, applying the Fischer (1978) and Margrabe (1978) formula, we obtain the following closed-form solution for Equation (16).
\[ \Pi^E(\theta) = E^Q \left[ e^{-r} \cdot \max \left( A_i - (1 - \theta) \cdot L_i, 0 \right) \right] = A_0 \cdot N(d_1) - (1 - \theta) \cdot L_0 \cdot N(d_2) \]

\[ = A_0 \cdot N \left( \frac{\ln \left( \frac{A_0}{(1 - \theta) \cdot L_0} \right) + \frac{\hat{\sigma}^2}{2}}{\hat{\sigma}} \right) - (1 - \theta) \cdot L_0 \cdot N \left( \frac{\ln \left( \frac{A_0}{(1 - \theta) \cdot L_0} \right) + \frac{\hat{\sigma}^2}{2}}{\hat{\sigma}} \right) - \hat{\sigma}, \]

with \( \hat{\sigma} = \sqrt{\sigma^2 + \sigma^2 - 2 \cdot \rho \cdot \sigma \cdot \sigma_A} \). (17)

To obtain fair prices, we set the initial contribution from the equityholders equal to the value of their future claim, i.e., \( \Pi^E(\theta) = Eq_0(\theta) \). This is equivalent to \( \Pi^P(\theta) = P_0(\theta) \). The fair price \( P_0(\theta) \) represents the lower end of the premium agreement range for coinsurance policies.

### 5.4.2 Maximum Willingness to Pay

Policyholder maximum willingness to pay is the upper end of the premium agreement range. As done previously, the preference functions for the situations with and without insurance need to be set equal. We do not repeat the procedure here, but simply apply the indemnity function for the case of coinsurance, \( \min(A_i, (1 - \theta) \cdot L_i) \), to Equation (14). Thus policyholder maximum willingness to pay for a coinsurance contract \( P_0^\phi(\theta) \) is given by

\[ P_0^\phi(\theta) = e^{-r} \cdot E \left[ \min(A_i, (1 - \theta) \cdot L_i) \right] + e^{-r} \cdot \frac{a}{2} \cdot \sigma^2(L_i) - e^{-r} \cdot \frac{a}{2} \cdot \sigma^2 \left[ L_i - \min(A_i, (1 - \theta) \cdot L_i) \right]. \] (18)

### 5.4.3 Maximization of Premium Agreement Range

The premium agreement range \( PAR(\theta) \), with \( PAR(\theta) > 0 \), results if we combine policyholder maximum willingness to pay with what the insurer considers a fair price.

\[ PAR(\theta) = P_0^\phi(\theta) - P_0(\theta). \] (19)
We then maximize the premium agreement range in order to identify the optimum level of coinsurance. In a first step, the optimization problem is given for the case without default risk:

$$\text{PAR}(\theta) \rightarrow \max_{\theta} \text{ with } \text{PAR}(\theta) = P_{0}^{\phi}(\theta) - P_{0}(\theta).$$

$$\text{PAR}(\theta) = e^{-r} \left[ (1-\theta) \cdot E(L_1) + \left(1 - \theta^2\right) \cdot \frac{a}{2} \cdot \sigma^2(L_1) - (1-\theta) \cdot E(L_1) \right]. \quad (20)$$

We obtain the optimum level of coinsurance ($\theta$) if we differentiate Equation (20) with respect to the level of coinsurance ($\theta$) and subsequently set the term equal to zero:

$$\frac{\partial \left( \text{PAR}(\theta) \right)}{\partial \theta} = 0 \quad (21)$$

This results in

$$-e^{-r} \cdot E(L_1) + e^{-r} \cdot E(L_1) - a \cdot \text{PAR}^{\phi}(\theta) \cdot e^{-r} \cdot \sigma^2(L_1) = 0, \quad (22)$$

which leads to the optimal level of coinsurance of

$$\theta^{\phi}(\theta) = \frac{P_{0} - P_{0}^{\text{actuarial}}}{e^{-r} \cdot a \cdot \sigma^2(L_1)}, \quad (23)$$

with

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8 Doherty (1975) examines a similar problem. Different to here, he uses the actuarially fair premium. The actuarially fair premium is multiplied with the percentage participation born by the insurer in case of coinsurance.
The result implies that a positive coinsurance level will be optimal if the fair premium price according to capital market theory is higher than the actuarial value of the policy. In principle, this is in line with existing theorems stating that full coverage is never optimal in case of an actuarially unfair premium and a policyholder without stochastic basis income (see Mossin, 1968; Doherty, 1975).

In a second step we introduce default risk, represented by the default-value-to-liability ratio \( d \). The default-value-to-liability ratio can be applied as a safety level for insurance policies or lines of business (see, e.g., Butsic, 1994; Barth, 2000; Gründl and Schmeiser, 2007; Gatzert, 2008). The default-value-to-liability ratio \( d \) for coinsurance policies is defined as

\[
d(\theta) = \frac{\Pi^{DPO}(\theta)}{\Pi^*(\theta)} = \frac{E^Q \left[ \max((1-\theta) \cdot L_1 - A_t, 0) \right]}{E^Q \left( e^{-r} \cdot (1-\theta) \cdot L_1 \right)},
\]

where \( \Pi^*(\theta) \) is the fair premium without default risk and \( \Pi^{DPO}(\theta) \) is the net present value of the default put option. The default put option is the value by which the default-free premium \( \Pi^*(\theta) \) is reduced in order to obtain the fair premium with default risk. This premium is fair with regard to the possibility that the insurer might not satisfy the policyholder claim due to being insolvent.

The premium agreement range under default risk is given with:

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\(^9\) Equation (23) is only defined for individual risk-aversion coefficients different from zero. As we assume risk-averse policyholders, the coefficient is strictly positive, i.e., \( \alpha > 0 \).
\[ \text{PAR}(\theta) = e^{-r} \cdot E\left[ \min\left(A_i, (1-\theta) \cdot L_i\right) \right] + e^{-r} \cdot \frac{a}{2} \cdot \sigma^2 \left( L_i \right) \]

\[ -e^{-r} \cdot \frac{a}{2} \cdot \sigma^2 \left[ L_i - \min\left(A_i, (1-\theta) \cdot L_i\right) \right] - E^Q \left( e^{-r} \cdot (1-\theta) \cdot L_i \right) \]

\[ + E^Q \left( e^{-r} \cdot \max\left((1-\theta) \cdot L_i - A_i, 0\right) \right) \]

\[ = e^{-r} \cdot E\left[ \min\left(A_i, (1-\theta) \cdot L_i\right) \right] + e^{-r} \cdot \frac{a}{2} \cdot \sigma^2 \left( L_i \right) \]

\[ -e^{-r} \cdot \frac{a}{2} \cdot \sigma^2 \left[ L_i - \min\left(A_i, (1-\theta) \cdot L_i\right) \right] \]

\[ -(1-\theta) \cdot L_0 + \left((1-\theta) \cdot L_0 \cdot N\left(d_1\right) - A_0 \cdot N\left(d_2\right)\right) \]

\[
\ln\left(\frac{(1-\theta) \cdot L_0}{A_0}\right) + \hat{\sigma}^2 / 2 \]

with \( d_1 = -\frac{(1-\theta) \cdot L_0}{A_0} \), \( d_2 = d_1 - \hat{\sigma} \), \( \hat{\sigma} = \sqrt{\hat{\sigma}_L^2 + \hat{\sigma}_r^2 - 2 \cdot \rho \cdot \hat{\sigma}_L \cdot \hat{\sigma}_r} \).

The optimization problem with default risk aims to maximize the premium agreement range with regard to the level of coinsurance and the insurer’s safety level, represented by the default-value-to-liability ratio \( (d) \):

\[ \text{PAR}(\theta) \rightarrow \max_{\theta, d} \quad \text{with} \quad \text{PAR}(\theta) = P_0^d (\theta) - P_0 (\theta) \quad (28) \]

General statements regarding the size of the premium agreement range, as were made for the case without default risk, cannot be derived at this point due to the complexity of Equation (27). However, it is possible to conduct a bounded numerical search for the optimum level of coinsurance and the optimum safety level, and just such a search is conducted in the following section.

### 5.5 Numerical Analysis of Coinsurance Policies

In the following, numerical examples illustrate application of the explicit formulas so as to maximize the premium agreement range without default risk. The case with default risk is also examined. We conduct a numerical search for the optimum level of
coinsurance and the optimum level of default risk that will maximize the premium agreement range.

### 5.5.1 Identification of Maximum Premium Agreement Range without Default Risk

The numerical example set out in Table 1 approximates the situation with no default risk based on a default-value-to-liability ratio of 0.0001%. We compare insurance policies without coinsurance and with coinsurance at different levels—policyholder participation is varied from 0% (full coverage) to 50%, in steps of 10%. We generate the data employing a Monte Carlo simulation technique with 10,000 iterations. The nominal value of the liabilities is set to 1,000 \( (= L_0) \) in all following examples.

To illustrate the result of the optimization problem (see Equation (23)), the drift of the liability process and the risk-free interest rate are initially set equal to 2% \( (= \mu_L = r) \). The respective maximum willingness to pay and the premium agreement range are set forth in Columns 4 and 5 of Table 1. Then, the risk-free rate is increased to 10% so as to increase the fair premium compared to the actuarially determined one.\(^{10}\) This second case is shown in Columns 6 and 7. In both cases, the volatility of the liability process is 40% \( (= \sigma_L) \). Furthermore, the stochastic asset process is characterized by a drift of 5% \( (= \mu_A) \) and a volatility of 25% \( (= \sigma_A) \). Since it is the insurer’s aim to align assets and liabilities, we assume a positive correlation between the two processes of 0.3 \( (= \rho) \). The policyholder’s risk aversion is assumed to be 0.005 \( (= a) \).

With the default-value-to-liability ratio chosen to be sufficiently low, the fair premium price \( P_0 \) is equal to the nominal liabilities \( P_0 = L_0 \).\(^{11}\) According to the fairness condition (Equation (16)) and with the assets as the sum of equity and premium price \( (A_0 = Eq_0 + P_0) \), the initial equity level \( (Eq_0) \) is uniquely defined.

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\(^{10}\) The rather extreme risk-free interest rate of 10% is needed to illustrate the effect on the optimum level of coinsurance.

\(^{11}\) This is due to the martingale characteristic of the liabilities (discounted at the risk-free interest rate \( r \)) under the risk-neutral measure \( Q \).
Part II: 5 Pricing of Property-Liability Insurance Policies

Table 1: Fair premium, maximum willingness to pay, and premium agreement range for policies with different coinsurance levels and no exposure to default risk.

<table>
<thead>
<tr>
<th>Coinsurance level ($\theta$)</th>
<th>Equity ($E_0$)</th>
<th>Fair premium ($P_0$)</th>
<th>$r = \mu_L = 2%$</th>
<th>$r = 10%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>4,664</td>
<td>1,000</td>
<td>1,442</td>
<td>1,332</td>
</tr>
<tr>
<td>10%</td>
<td>4,198</td>
<td>900</td>
<td>1,338</td>
<td>1,235</td>
</tr>
<tr>
<td>20%</td>
<td>3,731</td>
<td>800</td>
<td>1,225</td>
<td>1,131</td>
</tr>
<tr>
<td>30%</td>
<td>3,265</td>
<td>700</td>
<td>1,103</td>
<td>1,018</td>
</tr>
<tr>
<td>40%</td>
<td>2,798</td>
<td>600</td>
<td>972</td>
<td>897</td>
</tr>
<tr>
<td>50%</td>
<td>2,264</td>
<td>500</td>
<td>832</td>
<td>768</td>
</tr>
</tbody>
</table>

In the example with risk-free interest rate and drift of liabilities equal to 2%, the policyholder is willing to pay 1,442 for the policy with full coverage and (almost) no default risk. This is more than the fair premium price of 1,000, resulting in a positive premium agreement range of 442 (=1,442–1,000). Across all levels of coinsurance, the size of the premium agreement range (for the case of risk-free interest rate equal to drift of stochastic liability process) is largest for the case of full insurance, i.e., for $\theta = 0$. With the drift of the liability process equal to the risk-free interest rate, the policy price, according to capital market theory, ($P_0$), is the same as the actuarial value of the policy ($P_{actuarial}^0$). Hence, the optimality of full coverage is in line with the results of Section 4.3, implying that if insurance policies with different coinsurance levels are offered at their fair price, the policyholder will, under the assumptions made here, choose the policy with full coverage. From the insurer perspective, offering full coverage insurance policies provides the best opportunity to realize premiums above the fair price of the contract and hence to realize a return on equity above the risk-adequate rate. This result is in line with existing literature, such as Arrow (1963) and Mossin (1968), who state that in the absence of costs and in the existence of fair prices full insurance is optimal.

In Columns 6 and 7 of Table 1, the maximum willingness to pay and the premium agreement range are given for the case of a risk-free rate of 10% and a drift of the liabilities of 2%. This increase in the risk-free rate compared to the drift of the liabilities results in the fair premium price under the risk-neutral measure being higher than the actuarial value of the policy ($P_0 > P_{actuarial}^0$). According to Equation (23), it is not full coverage, but a positive coinsurance level of 10% that leads to the highest
premium agreement range for this parameter combination. This is in line with the information given in Table 1, where the largest premium agreement range of 335 was obtained for a coinsurance level of 10% (see Column 7).

### 5.5.2 Identification of Maximum Premium Agreement Range with Default Risk

We now introduce default risk into the analysis. Table 2 provides the first step of the numerical search for the optimum level of coinsurance and the optimum level of default risk that will maximize the premium agreement range (see Equation (28)). The parameters are chosen as follows.

The stochastic liability process is characterized by a drift of 1% \((= \mu_L)\) and volatility of 40% \((= \sigma_L)\). The asset process develops with drift 5% \((= \mu_A)\) and volatility 25% \((= \sigma_A)\). The risk-free interest rate is 3% \((= r)\). The two processes are correlated with 0.3 \((= \rho)\) and the policyholder is risk averse, having an individual risk-aversion coefficient of 0.005 \((= a)\). This parameter combination will be the standard in the following.

To illustrate the numerical search for the optimum level of coinsurance \((\theta)\) and the insurer’s optimum safety level \((d)\), the premium agreement range is calculated for different choices of the two parameters. Each panel of Table 2 is characterized by a fixed default-value-to-liability ratio and varying level of coinsurance (0% to 50%, in steps of 10%). For relatively low safety levels \((d = 0.4\%, 0.5\%)\), a coinsurance level of 10% leads to the highest premium agreement range (see Panels D and E). In contrast, the premium agreement range is highest for the case of full coverage if the safety level increases \((d = 0.1\%, 0.2\%, 0.3\%—Panels A–C)\). Overall, the premium agreement range increases with an increasing insurer safety level. Accordingly, the highest premium agreement range is achieved for full insurance coverage and the highest safety level of the insurer (405 in Panel A for \(\theta = 0\%)\).
<table>
<thead>
<tr>
<th>Contract parameters</th>
<th>MWP</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Default-to-</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>liability ratio</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(d)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coinsurance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>level $(\theta)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Equity</strong> $(E_0)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fair premium</strong> $(P_0)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_0^\theta$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_0^\theta - P_0$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Panel A**

| 0.1% | 0% | 1,845 | 999 | 1,404 | 405 |
| 10%  | 1,661 | 899 | 1,301 | 402 |
| 20%  | 1,476 | 799 | 1,193 | 394 |
| 30%  | 1,292 | 699 | 1,074 | 374 |
| 40%  | 1,107 | 599 | 946  | 347 |
| 50%  | 923 | 500 | 809  | 310 |

**Panel B**

| 0.2% | 0% | 1,583 | 998 | 1,398 | 400 |
| 10%  | 1,425 | 898 | 1,297 | 399 |
| 20%  | 1,266 | 798 | 1,190 | 392 |
| 30%  | 1,108 | 699 | 1,072 | 373 |
| 40%  | 950 | 599 | 944  | 345 |
| 50%  | 791 | 499 | 806  | 307 |

**Panel C**

| 0.3% | 0% | 1,433 | 997 | 1,393 | 396.3 |
| 10%  | 1,290 | 897 | 1,293 | 395.9 |
| 20%  | 1,146 | 798 | 1,188 | 390 |
| 30%  | 1,003 | 698 | 1,070 | 372 |
| 40%  | 860 | 598 | 942  | 344 |
| 50%  | 716 | 499 | 804  | 306 |

**Panel D**

| 0.4% | 0% | 1,328 | 996 | 1,389 | 392.5 |
| 10%  | 1,195 | 896 | 1,290 | 393.3 |
| 20%  | 1,062 | 797 | 1,186 | 389 |
| 30%  | 930 | 697 | 1,068 | 371 |
| 40%  | 797 | 598 | 940  | 343 |
| 50%  | 664 | 498 | 802  | 304 |

**Panel E**

| 0.5% | 0% | 1,247 | 995 | 1,384 | 389 |
| 10%  | 1,123 | 896 | 1,286 | 391 |
| 20%  | 998 | 796 | 1,183 | 387 |
| 30%  | 873 | 697 | 1,067 | 370 |
| 40%  | 748 | 597 | 938  | 341 |
| 50%  | 624 | 498 | 800  | 302 |

Notation: $MWP = maximum willingness to pay; PAR = premium agreement range.$

**Table 2:** Fair premium, maximum willingness to pay, and premium agreement range for fixed default-value-to-liability ratios and varying levels of coinsurance.
Two hypotheses can be derived from the results in Table 2 under the respective parameter assumptions. First, risk-averse policyholders prefer full insurance coverage with no default risk. To further examine that finding, the numerical search in a second step comprises the space of $d = 0.02\%$ to $0.08\%$ in steps of $0.02\%$ for coinsurance levels of $\theta = 0\%$ to $50\%$ (Table 3). Second, it appears that the higher the default risk, the higher the optimum level of coinsurance. We thus extend the numerical search for the optimum premium agreement range for default-value-to-liability ratios of $d = 5\%$, $10\%$, and $25\%$, and again test coinsurance levels of $\theta = 0\%$ to $50\%$ (Table 4). The other parameters remain unchanged.
<table>
<thead>
<tr>
<th>Contract parameters</th>
<th>MWP</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default-to-liability ratio ($d$)</td>
<td>Coinsurance level ($\theta$)</td>
<td>Equity ($E_0$)</td>
</tr>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.02%</td>
<td>0%</td>
<td>2,484</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>2,236</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>1,987</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>1,739</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>1,491</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>1,242</td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
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<td></td>
</tr>
<tr>
<td>0.04%</td>
<td>0%</td>
<td>2,204</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>1,984</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>1,763</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>1,543</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>1,322</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>1,102</td>
</tr>
<tr>
<td><strong>Panel C</strong></td>
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<td></td>
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<tr>
<td>0.06%</td>
<td>0%</td>
<td>2,044</td>
</tr>
<tr>
<td></td>
<td>10%</td>
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<td></td>
<td>30%</td>
<td>1,431</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>1,226</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>1,022</td>
</tr>
<tr>
<td><strong>Panel D</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.08%</td>
<td>0%</td>
<td>1,931</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>1,738</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>1,545</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>1,352</td>
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<td></td>
<td>40%</td>
<td>1,159</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>966</td>
</tr>
</tbody>
</table>

Notation: $MWP = maximum willingness to pay; PAR = premium agreement range.$

**Table 3**: Fair premium, maximum willingness to pay, and premium agreement range for very low default-value-to-liability ratios and varying levels of coinsurance.

Table 3 further reduces the default-value-to-liability ratio ($d = 0.02\%$ to $0.08\%$ in steps of $0.02\%$). Of the four panels with different safety levels, the highest premium agreement range is obtained for $d = 0.02\%$ and full insurance coverage, i.e., $\theta = 0\%$. 
This result supports our first hypothesis that policyholders under the given assumptions prefer full coverage policies with no default risk. The numerical analysis could be continued within a space of even less default risk, but we do not do so here and the following implications are drawn from the available information set. Risk-averse policyholders in this setting generally seem to not be happy about increases in the default-value-to-liability ratio, even if the price of the policy remains fair and is reduced to reflect the decreased the safety level. Practically, this means that solvency regulation of property-liability insurers appears to be unnecessary if there is sufficient market transparency. This finding is in line with current solvency systems, which, among other measures intended to guarantee sufficient insurer solvency, aim to increase market transparency (see Solvency II or the solvency system implemented in New Zealand). The finding is also in accord with academic evidence, which emphasizes the effectiveness of market transparency (see Epermanis and Harrington, 2006). In absence of market transparency, however, higher policy prices based on higher safety levels are difficult to explain and hence to realize. If policyholders are not aware of insurer safety levels, they will purchase the cheapest policy offered, forcing the “safer” insurer to lower its prices and hence its safety level.

According to our second hypothesis, the optimum level of coinsurance increases when the insurer’s safety level decreases. For default-value-to-liability ratios of $d = 0.1\%$ to $0.5\%$, the optimum levels of coinsurance were $0\%$ and $10\%$, respectively. In Table 4, we further test default-value-to-liability ratios of $5\%$, $10\%$, and $25\%$. All other parameters are unchanged from the standard case.
### Table 4: Fair premium, maximum willingness to pay, and premium agreement range for high default-value-to-liability ratios and varying levels of coinsurance.

<table>
<thead>
<tr>
<th>Panel A</th>
<th>5%</th>
<th>0%</th>
<th>472</th>
<th>950</th>
<th>1,241</th>
<th>291</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>425</td>
<td>855</td>
<td>1,186</td>
<td>331</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>378</td>
<td>760</td>
<td>1,110</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>331</td>
<td>665</td>
<td>1,013</td>
<td>348</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>283</td>
<td>570</td>
<td>891</td>
<td>321</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>236</td>
<td>475</td>
<td>752</td>
<td>277</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B</th>
<th>10%</th>
<th>0%</th>
<th>274</th>
<th>900</th>
<th>1,122</th>
<th>222</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>247</td>
<td>810</td>
<td>1,096</td>
<td>286</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>219</td>
<td>720</td>
<td>1,043</td>
<td>323</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>192</td>
<td>630</td>
<td>963</td>
<td>333</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>164</td>
<td>540</td>
<td>852</td>
<td>312</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>137</td>
<td>450</td>
<td>715</td>
<td>265</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel C</th>
<th>25%</th>
<th>0%</th>
<th>74</th>
<th>750</th>
<th>838</th>
<th>88</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>66</td>
<td>675</td>
<td>865</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>59</td>
<td>600</td>
<td>860</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>52</td>
<td>525</td>
<td>822</td>
<td>297</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>44</td>
<td>450</td>
<td>750</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>37</td>
<td>375</td>
<td>650</td>
<td>275</td>
<td></td>
</tr>
</tbody>
</table>

**Notation:** MWP = maximum willingness to pay; PAR = premium agreement range.

In line with our second hypothesis, the optimum level of coinsurance does, indeed, increase as the insurer’s safety level decreases—the premium agreement range is largest for 20% coinsurance with \( d = 5\% \), for 30% with \( d = 10\% \), and for 40% with \( d = 50\% \). This numerical search could be extended to default-to-liability ratios of even more than 25%. But buying insurance from a company with such a low safety level is more in the nature of taking a risk than guarding against one and, moreover, probably not even possible as such a company would not meet the solvency guidelines or regulations of any licensing authority. So, we will confine ourselves to more realistic
scenarios and end by saying that decreasing safety levels lead to a policyholder preference for partial coverage with increasing coinsurance levels.

5.6 Summary

The aim of this chapter was to evaluate property-liability insurance policies from a combination of policyholder and insurer perspectives. We assume, on the one hand, that insurers can replicate financial claims in the market and can therefore in general use risk-neutral valuation to set prices. Policyholders, on the other hand, evaluate the claims under individual preferences. The two reference values—policy value under a risk-neutral measure from the insurer perspective and maximum willingness to pay from the policyholder perspective—provide the premium agreement range between the two parties. When the premium agreement range is positive, both parties will be willing to enter into the contract. The actual price positions within the range are dependent on factors such as intensity of competition or density of price regulation in the market. Given that the larger the range, the better the insurer’s chance of realizing returns on equity above the risk-adequate rate, we conduct a maximization of the premium agreement range with regard to the level of coinsurance and the insurer’s safety level.

We examine property-liability insurance contracts, which are either characterized by full coverage, a deductible, coinsurance, or a stop-loss agreement. We find that policyholder maximum willingness to pay for each of these policy types is comprised of three basic elements: the expected payback of the policy, and the variance of policyholder wealth with and without insurance coverage. The variance of the wealth with insurance coverage represents the variance that the policyholder cannot eliminate despite the insurance purchase and it therefore enters the formula with a negative sign.

Our numerical analysis focuses on coinsurance, as, in contrast to policies with deductibles or stop-loss agreements, closed-form solutions for equityholder and policyholder claims exist. When we maximize the premium agreement range with regard to the level of coinsurance in the absence of default risk we find support for existing theorems. In particular, coinsurance will be optimal only if the fair premium price according to capital market theory is higher than the actuarial value of the policy. Introducing default risk, we maximize the premium agreement range with regard to the optimum level of coinsurance and the insurer’s safety level. We find that full coverage insurance policies together with high safety levels are optimal. With a decreasing safety level, the premium agreement ranges are largest for policies with partial
coverage, with the optimum level of coinsurance increasing as the safety level decreases. Given that, overall, the premium agreement range—in this setting—is largest for high safety levels, solvency regulation appears to be unnecessary as long as there is sufficient market transparency.

Even though closed-form solutions for claims related to deductible or stop-loss policies do not exist in general, values for them can be approximated using, e.g., Monte Carlo simulation. Together with the basics provided in this chapter, the optimal deductible and stop-loss value can thus be derived by maximizing the respective premium agreement ranges. We consider the execution of this analysis an opportunity for further research. Another question remaining to be answered has to do with the robustness of the results against the influence of background risk or stochastic initial wealth (see, e.g., Meyer and Meyer, 1998). Furthermore testing the findings against empirical data, including the potential effect of coinsurance on moral hazard, would be interesting avenue for future research to explore.
Appendix A

i) Insurance policies with deductibles \( (X) \).

Policyholder claim:

\[
\Pi^p(X) = E^0 \left[ e^{-r} \cdot \min(A, \max(L - X, 0)) \right]. \tag{A1}
\]

Equityholder claim:

\[
\Pi^e(X) = E^0 \left[ e^{-r} \cdot \max(A - \max(L - X, 0), 0) \right]. \tag{A2}
\]

Preference function of the policyholder, following mean-variance preferences, for an insurance contract with deductible:

\[
\Phi(X) = E \left[ Z^0 - L + \min(A, (L - X)) \right] - \frac{\alpha}{2} \sigma^2 \left[ \min(A, (L - X)) - L \right] =
\]

\[
= \left( Z_0 - P^\phi_0(X) \right) \cdot e^{-r} - E \left[ \min(A, (L - X)) \right] - \frac{\alpha}{2} \sigma^2 \left[ L - \min(A, (L - X)) \right]. \tag{A3}
\]

With \( Z^0_1 \) as the policyholder wealth at \( t=1 \) in case of a deductible \( (D) \) insurance purchase at \( t=0 \).

Equalizing Equation (A3) with the preference function of no insurance (Equation (8)), leads to the policyholder maximum willingness to pay \( P^\phi_0(X) \) for an insurance contract with deductible:

\[
P^\phi_0(X) = e^{-r} \cdot \left[ E \left( \min(A, L - X) \right) + \frac{\alpha}{2} \cdot \sigma^2(L) - \frac{\alpha}{2} \cdot \sigma^2 \left[ L - \min(A, L - X) \right] \right]. \tag{A4}
\]
ii) Policyholder maximum willingness to pay for a coinsurance policy ($\theta$).

Policyholder claim:

$$\Pi^P (\theta) = E^Q \left[ e^{-r} \cdot \min (A_i, (1-\theta) \cdot L_i) \right]. \quad (A5)$$

Equityholder claim:

$$\Pi^E (\theta) = E^Q \left[ e^{-r} \cdot \max (A_i - (1-\theta) \cdot L_i, 0) \right]. \quad (A6)$$

Preference function of the policyholder, following mean-variance preferences, for a coinsurance contract:

$$\Phi^{\Pi} (\theta) = E \left[ Z_t^{CI} - L_t + \min (A_i, (1-\theta) \cdot L_i) \right] - \frac{a}{2} \sigma^2 \left[ \min (A_i, (1-\theta) \cdot L_i) - L_i \right] =$$

$$= \left( Z_0 - P_0^{\Pi} (\theta) \right) \cdot e^{-r} - E(L_i) + E \left[ \min (A_i, (1-\theta) \cdot L_i) \right] -$$

$$- \frac{a}{2} \sigma^2 \left[ L_i - \min (A_i, (1-\theta) \cdot L_i) \right]. \quad (A7)$$

With $Z_t^{CI}$ as the policyholder wealth at $t = 1$ in case of a coinsurance ($CI$) purchase at $t = 0$.

Equalizing Equation (A7) with the preference function of no insurance (Equation (8)), leads to the maximum willingness to pay, given with Equation (18).

iii) Policyholder maximum willingness to pay for a stop-loss policy ($\bar{L}$).

Policyholder claim:

$$\Pi^P (\bar{L}) = e^{-r} \cdot E^Q \left[ \min (A_i, \min (L_i, \bar{L})) \right]. \quad (A8)$$

Equityholder claim:
\[ \Pi^E(L) = e^{-r} \cdot E^Q \left[ \max\left( A_i - \min(L_i, L), 0 \right) \right]. \] (A9)

Preference function of the policyholder, following mean-variance preferences, for a stop-loss insurance contract:

\[ \Phi(L) = E\left(Z_{sl}^t - L_t\right) + E\left[ \min\left(A_i, \min(L_i, L)\right) \right] - \frac{a}{2} \sigma^2 \left[ \min\left(A_i, \min(L_i, L)\right) \right]. \] (A10)

With \( Z_{sl}^t \) as the policyholder wealth at \( t = 1 \) in case of a stop-loss (SL) insurance purchase at \( t = 0 \).

Equalizing Equation (A10) with the preference function of no insurance (Equation (8)), leads to the policyholder maximum willingness to pay \( P^\phi_L(L) \) for an insurance contract with stop-loss indemnification:

\[ P^\phi_L(L) = e^{-r} \cdot E \left[ \min\left(A_i, \min\left(L_i, L\right)\right) + \frac{a}{2} \sigma^2 \left(L_t\right) \right] \] (A11)

**Appendix B**

Transformation of the distribution of liabilities in the case of full coverage to the distribution of liabilities in the case of coinsurance (see Casella and Berger, 2002):

The drift and volatility of the stochastic liability process \( L_t \) are given with \( \mu_L \) and \( \sigma_L \). The liabilities follow

\[ L_t = L_0 \cdot \exp\left[\left(\mu_L - \frac{\sigma^2_L}{2}\right) + \sigma_L \left(W_t(1) - W_t(0)\right)\right]. \] (B1)

The expected value and the variance of the liabilities \( L_t \) at time \( t = 1 \) can be calculated as follows:

\[ E(L_t) = L_0 \cdot \exp(\mu_L), \] (B2)
\[ \sigma^2(L) = L_0^2 \cdot \exp(2 \cdot \mu_L) \cdot \left( \exp(\sigma^2_L) - 1 \right). \] \hspace{1cm} \text{(B3)}

Knowledge about the expected value and the variance of the liabilities allows the calculation of the mean \( m \) and variance \( v^2 \) characterizing the lognormal distribution. The distribution of \( L \sim LN(m, v^2) \), is characterized by

\[ m = \ln\left(E(L)\right) - \frac{1}{2} \cdot v^2, \text{ and} \]

\[ v^2 = \ln\left(1 + \frac{\sigma^2(L)}{E(L)^2}\right). \hspace{1cm} \text{(B4)} \]

\[ v^2 = \ln\left(1 + \frac{\sigma^2(L)}{E(L)^2}\right). \hspace{1cm} \text{(B5)} \]

With values for these two parameters we can derive the distribution of the transformed liabilities:

\[ L_\theta = (1 - \theta) \cdot L \sim LN(\ln(1 - \theta) + m, v^2) = LN(m^\theta, v^2) \] \hspace{1cm} \text{(B6)}

The expected value and variance of the liabilities in the case with coinsurance are given with:

\[ E(L_\theta) = \exp\left(m^\theta + \frac{1}{2} \cdot v^2\right) = \exp\left(\ln(1 - \theta) + m + \frac{1}{2} \cdot v^2\right) = \]

\[ = \exp\left(\ln(1 - \theta)\right) \cdot \exp\left(m + \frac{1}{2} \cdot v^2\right) = (1 - \theta) \cdot \exp\left(m + \frac{1}{2} \cdot v^2\right) = \]

\[ = (1 - \theta) \cdot E(L), \hspace{1cm} \text{(B7)} \]
\[ \sigma^2(L_t^\theta) = \exp(2 \cdot m^\theta + v^2) \cdot \left( \exp(v^2) - 1 \right) = \]
\[ = \exp(2 \cdot \ln(1 - \theta) + m^\theta + v^2) \cdot \left( \exp(v^2) - 1 \right) = \]
\[ = \exp(2 \cdot \ln(1 - \theta) + 2 \cdot m + v^2) \cdot \left( \exp(v^2) - 1 \right) = \]
\[ = \left[ \exp(\ln(1 - \theta)) \right]^2 \cdot \exp(2 \cdot m + v^2) \cdot \left( \exp(v^2) - 1 \right) = \]
\[ = (1 - \theta)^2 \cdot \left( \exp(v^2) - 1 \right) \cdot E(L_t)^2. \]
6 Conclusion

This thesis contains two main parts, one dealing with solvency regulation, the other with insurance contract pricing. The research gave rise to the following findings.

Chapter 2 provides a descriptive overview of selected solvency systems representative of systems in effect around the world. The four systems chiefly differ with regard to use of different risk measures, with value at risk and expected shortfall being the most common. Another difference has to do with recognition of operational and catastrophe risk, which ranges from omission, to qualitative, to quantitative. One important innovation in insurance regulation is the option for insurers to develop and apply their own internal models. This is a great opportunity for insurers, but could be an equally great challenge for insurance regulators.

Our comparative assessment of regulatory systems using the extended criteria catalogue of Cummins et al. (1994) (Chapter 3 of Part 1) revealed the U.S. framework as the one in greatest need of reform. In principle, Solvency II and the Swiss Solvency Test satisfy the criteria. The Swiss Solvency Test was designed to be fully compatible with Solvency II but there are some differences between the two. Whether those differences make one system superior to the other will only be assessable after the passage of some time and empirical analysis.

Chapter 4 of Part 2 combines policyholder and insurer perspectives on life and non-life insurance contracts, resulting in a premium agreement range between the two parties. With regard to participating life insurance contracts, we find that the insurer can increase policyholder willingness to pay by changing the underlying contract parameters in ways that do not actually change the policy value. Our results suggest that it would be very worthwhile for insurance companies to engage in customer segmentation based on the different ways customers evaluate life insurance contracts and embedded investment guarantees as doing so could result in substantial increases in policyholder willingness to pay.

With regard to non-life insurance contracts, we derive the premium agreement range between the policyholder and the insurer for policies with full coverage, and for those with a deductible, coinsurance, or a stop-loss agreement. For our numerical analysis, we focus on the coinsurance policy type, as it is possible to derive closed-form solutions for equityholder and policyholder claims in this case. Our results generally
support existing theorems, indicating that in the absence of default risk, the premium agreement range is largest for full coverage policies. Additionally, we find that in the case of positive default risk, the premium agreement range is largest for full coverage policies and high insurer safety levels, even if the policy price rises accordingly. With a decreasing insurer safety level, the largest premium agreement ranges occur for partial coverage policies, with increasing coinsurance levels. Given that, overall, the premium agreement range—in this setting—is largest for high safety levels, and taking into consideration market transparency, insurers have a great incentive to operate at a high level of safety.
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