Safety Versus Affordability as Targets of Insurance Regulation: A Welfare Approach

Rayna Stoyanova
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Printed in the United States of America

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Safety Versus Affordability as Targets of Insurance Regulation: A Welfare Approach

Rayna Stoyanova*
Sebastian Schlütter**

Abstract

Insurance regulation is typically aimed at policyholder protection. On the one hand, regulators attempt to ensure the financial “safety” of insurance firms, for example, by means of capital regulation; on the other hand, they are concerned about the “affordability” of insurance and thus impose restrictions on insurance pricing. Using a model that incorporates a bias of insurance buyers' perception of the insurer's solvency level, this paper weights up the welfare benefits and costs of the two regulatory tools. We demonstrate that capital requirements will only be effective when consumers have a significantly optimistic perception of the solvency level; significant frictional costs of equity capital and insurance risks are additional drivers for the effectiveness of capital regulation. Interestingly, the drivers for effective price regulation point in the opposite direction: A realistic or pessimistic consumer perception of solvency, low frictional costs of equity capital and a low riskiness of the portfolio make price regulation more effective.
1. Introduction

In attempting to meet their overall objective of protecting policyholder interests, insurance regulators employ different techniques aimed at two subordinate objectives. First, insurance regulators want to ensure that insurance companies are sufficiently capitalized to meet policyholder claims. In this context, they develop sophisticated regulatory regimes imposing risk-based capital (RBC) requirements. For example, under the future regulatory regime Solvency II in the European Union, capital requirements are designed to restrict the insurer's annual default probability at 0.5%. In addition, Solvency II contains qualitative requirements regarding insurers' risk management practices, as well as transparency and disclosure standards for insurer risk profiles. Implementing such a regulatory regime comes at a high cost: Ernst & Young (2011) estimate that the implementation of Solvency II in the United Kingdom (UK) costs the insurance companies £1.8bn; government expenditure to set up the regulatory regime and establish appropriate regulatory authorities comes on top. Second, regulators frequently employ measures aimed at making insurance more affordable. For example, in some U.S. states, rate regulation is in force for workers' compensation, automobile and medical malpractice insurance. Even though the insurance markets in the European Union (EU) were deregulated in 1994, there is also some degree of price regulation in the EU: In Germany, for example, private health insurers are required to offer a basic tariff (Basistarif) whose premium is limited in accordance with the maximum rate in the statutory health insurance. Typically, those insurance pricing restrictions are independent of the insurer's capitalization.

Although these two regulatory objectives—safety and affordability—appear to be in conflict, there is little theoretical work on how insurance regulators should act in order to effectively protect policyholders' interests. Klein et al. (2002) demonstrate empirically that stringent price ceilings induce insurers to attain higher leverage ratios and thus reduce their safety level. This finding is in line with the (not insurance-specific) theoretical argument that firms use debt as a strategy to influence the regulator to increase the regulated price (Taggart, 1981; Spiegel and Spulber, 1994; Dasgupta and Nanda, 1993). In the context of insurance, there is another, simpler explanation for this observation: Because the regulated premium influences the insurers' expected profits per insurance contract, it affects their incentive for attracting customers with a strong financial position (Schlüter, 2014). A significant price ceiling, therefore, is accompanied by relatively high

1. A general overview of regulatory theories and tools and the related literature is provided by Lorson et al. (2012).
2. A global overview of the introduction of risk-based capital standards is provided by Eling and Holzmüller (2008).
3. Lorson et al. (2012) give an overview of several studies estimating the Solvency II-related implementation costs and the additional costs for raising capital.
insolvency risk. Vice versa, there are theoretical arguments that stringent solvency regulation might increase insurance premiums. First, solvency regulation affects the insurer’s default put option, which is reflected by insurance premiums (Doherty and Garven, 1986; Gründl and Schmeiser, 2002; Gatzert and Schmeiser, 2008). Second, to attain a higher safety level, insurers face additional risk management costs, such as costs of reinsurance or frictional costs of equity capital (Froot, 2007), that may be passed on to the consumer in higher insurance premiums.

This article investigates how regulatory requirements designed to meet the objectives of “safety” and “affordability” influence an insurer’s optimal capital and pricing strategy, and how these decisions affect policyholder welfare. Based on these results, we investigate in which situations regulators should focus either more on “safety” or, alternatively, on “affordability.” Throughout our analysis, we employ a model with a heterogeneous group of policyholders whose preferences are represented by an insurance demand function, depending on the insurance premium and the insurer’s safety level. The insurer decides on its shareholder-value-maximizing equity-premium combination by anticipating the consequences for insurance demand. The model incorporates frictional costs of the insurer's equity capital endowment, such as corporate taxes. Insurance buyers may have an overly optimistic or pessimistic perception of the insurer's safety level, and the insurer could make wrong assumptions about this perception bias.

In a benchmark case, we first derive the insurer’s optimal strategy in the absence of regulation. We determine the insurer’s optimal safety level by balancing its incentives resulting from demand reaction against the default put option and the frictional costs of equity. Next, we analyze the influence of RBC requirements. Here, the regulator can specify the insurer’s safety level, to which the insurer reacts by adjusting the insurance premium. We find that the regulator cannot enhance welfare by means of solvency regulation as long as policyholders perceive default risk realistically. However, when policyholders cannot perfectly monitor the solvency level, capital regulation can enhance consumer welfare, even though it causes an increase of insurance premiums. Strictly speaking, given that the insurer could make wrong assumptions about consumers’ solvency perception, the most relevant factor is what the insurer believes about consumers’ perception and reaction to the solvency level: Capital requirements will be effective if the insurer believes that consumers have an optimistic solvency level perception. Moreover, our numerical examples demonstrate that the effectiveness of capital regulation is positively related to the level of capital-related frictional costs and the severity of underwriting risks.

Finally, we study the consequences of regulatory price ceilings. We demonstrate that the net effect of enhancing the affordability of insurance, on the one hand, and reducing the insurer’s optimal safety level, on the other hand, can be


5. This result is in line with the model of Rees et al. (1999).
positive or negative for policyholder welfare. Our numerical examples indicate that price ceilings will be effective when demand is unbiased and when frictional costs are low. Thus, markets in which price ceilings are effective have characteristics contrary to markets in which capital regulation is appropriate.

The remainder of the article is organized as follows. Section 2 presents the model framework and introduces the objective functions. Section 3 presents the insurer’s optimal strategy in the benchmark case without regulation. Section 4 studies the effectiveness of solvency regulation, while section 5 examines that of price ceilings. Section 6 investigates the impact of frictional costs, the volatility of insurance risks and incomplete information on the effectiveness of the two regulatory mechanisms. Section 7 concludes.

2. Model Design

2.1 Actors and Training

Our one-period model is based on the model proposed by Zanjani (2002). We consider an insurance market with a homogeneous product and three stakeholder groups: insurance buyers, an insurer and a regulator.

Insurance buyers

The insurance buyers are offered an insurance product at a certain price and default risk level. Their buying decisions take these characteristics into account. Cumulative consumer reaction is modeled by an aggregate demand function, which depicts the representative preferences of a heterogeneous group of insurance buyers and sums to the number of customers for whom purchase of the offered insurance product is advantageous.

We use a two-parametric demand function \( y(p, dr) \), where \( p \) denotes the unit price of the insurance product, and \( dr \) is the default ratio that the insurer communicates to consumers. We define the default ratio as the ratio of the arbitrage-free value of unpaid claims to the value of nominal liabilities—that is, liabilities without default risk. The default ratio is used in the model as a measure of risk. To keep the model tractable, we apply a specific form of the demand function:

\[
y(p, dr) = n \cdot e^{-f \cdot p^d \cdot dr} \tag{1}
\]

where \( n \) is a scale parameter, and \( f_p \) and \( f_{dr} \) are the sensitivity factors with respect to price and default ratio. The demand function has the following properties:

\[
\frac{\partial y(p, dr_{perc})}{\partial p} = -f_p \cdot y \leq 0, \quad \frac{\partial y(p, dr_{perc})}{\partial dr} = -f_{dr} \cdot y \leq 0,
\]

that is, policyholders react negatively to increases in price and default risk. This exponential form of an insurance demand function has been derived by Zimmer et al. (2014) from an

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experiment in which the participants were confronted with insurance contracts subject to default risk. The experimental results show participants’ willingness to pay for a household insurance contract with a certain default risk level. The demand function is imperfectly elastic with regard to price and default risk—that is, because of switching and information costs, small changes in price and default ratio do not reduce the demand to zero (D’Arcy and Doherty, 1990; Cummins and Danzon, 1997; Zanjani, 2002; Yow and Sherris, 2008).

Insurer

The second party in the model, the limited liability insurer, maximizes its shareholder value (SHV) and makes decisions as to its risk management strategy and underwriting activity in the presence of regulatory constraints—that is, it decides on its default ratio \( dr \) and insurance price \( p \).

The insurer’s objective function is the present arbitrage-free market value of the end-of-period equity capital \( E_0 = PV(E_1) \) minus the initial equity endowment \( K \),

\[
SHV = E_0 - K. \tag{3}
\]

\( PV(.) \) is the arbitrage-free valuation function providing the time-0 value of time-1 cash flows. Equity funds are used as a risk management tool to ensure the realized solvency level. Owing to corporate taxation, agency costs and acquisition expenses, equity endowment is assumed to imply up-front frictional costs, which are modeled by a proportional charge \( \tau \geq 0 \).\(^6\) Considering the insurer’s limited liability, the final payoffs to shareholders at time 1 are given by the future value of the available assets \( A_1 \) minus the nominal claims \( L_1 \) plus any unpaid losses above the available assets—that is, the shareholders’ default put option \( DPO_1 = \max(L_1 - A_1; 0) \). To develop asset and liability values over time, we assume a geometric Brownian motion process. At time 0, the arbitrage-free value of the final shareholder payoffs is then

\[
E_0 = A_0 - L_0 + PV(DPO_1). \tag{5}
\]

The insurer’s initial assets are denoted by

\[
A_0 = y \cdot p + (1 - \tau) \cdot K. \tag{4}
\]

Furthermore,

\[
\mu = L_0 / y \tag{9}
\]

---

6. This is a common approach in the literature. See Zanjani (2002), Froot (2007), Yow and Sherris (2008), and Ibragimov et al. (2010).
denotes the arbitrage-free initial value of the nominal liabilities per contract,

\[ dr = PV(DPO_1)/L_0 = DPO_0/L_0 \]  

(6)

denotes the default ratio, and \( s = A_0/L_0 \) denotes the initial asset-liability ratio. Using option pricing methods, the default ratio can be determined by Margrabe's (1978) formula:

\[ dr(s, \sigma) = \Phi(z) - s \cdot \Phi(z - \sigma) \]  

(7)

\[ \sigma = \sqrt{\sigma_A^2 + \sigma_L^2 - 2 \rho \sigma_A \sigma_L} \]

\[ z = \frac{-\ln(s)}{\sigma} + \frac{1}{2} \tau \]

where \( \Phi \) is the distribution function of the standard normal distribution, \( \sigma_A \) and \( \sigma_L \) are the volatilities of the assets and liabilities, respectively, and \( \rho \) is the correlation between them. Since \( dr(s, \sigma) \) is a continuous and strictly decreasing function in \( s \) and \( \sigma \), there is a unique inverse function \( s(dr, \sigma) \).

Applying the above relationships, we represent the shareholder value function as follows:\(^8\)

\[ SHV(dr, p) = \]

\[ = y(dr, p) \cdot [p - \mu \cdot (1 - dr)] - \tau K \]

\[ = y(dr, p) \cdot \left[ p - \mu \cdot (1 - dr) - \frac{\tau}{1-\tau} (\mu \cdot \gamma(dr, \sigma) - p) \right] \]  

(8)

Therefore, the insurer’s decision problem is to find the optimal and legally allowable combination of default risk level \( dr \) and insurance price \( p \) that maximizes its shareholder value.

**Regulator**

The regulator uses two instruments to achieve the safety and affordability targets. First, there is the option of introducing solvency regulation, in the sense of capital requirements, as a method of improving the safety of insurance companies.

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7. For explanation, see, e.g. Myers and Read (2001), p. 553. The determination of an insurer's default ratio or Default Put Option via arbitrage-free pricing technique is quite common in the related literature—for example, Cummins and Danzon (1997), Gründl and Schmeiser (2002), Gatzert and Schmeiser (2008), Yow and Sherris (2008), Ibragimov et al. (2010), and Schlütter (2014). Formally, the technique can be applied if the insurer's assets and liabilities can be replicated with instruments that are traded on an arbitrage-free and complete financial market. Policyholders may be assumed to be unable to hedge their risks with financial market instruments, because they cannot enter the financial market (Ibragimov et al., 2010).

8. For the derivation of equation (8), please see the Appendix.
The second tool is price restriction, which is used to make insurance products more affordable by setting a maximum allowed price. The regulator’s objective function is consumer surplus (CS) maximization,9 which is calculated as the sum of the differences between the reservation price—that is, the maximum price a consumer would pay for the insurance product—and the offered price \( p^* \) over all policyholders:

\[
CS(p^*, dr) = \int_0^{\infty} y(p, dr) dp
\]

(5)

To study the effectiveness of the two regulatory tools and be able to compare them, we bring in an effectiveness variable that measures the percentage change of consumer surplus, defined as the absolute change in CS divided by the CS in an unregulated market, \( \frac{CS^{reg} - CS^{non-reg}}{CS^{non-reg}} \). Additionally, we look at the percentage change of shareholder value, \( \frac{SHV^{reg} - SHV^{non-reg}}{SHV^{non-reg}} \), to study the regulatory impact on the insurer’s shareholder value.

2.2 Solvency Perception Bias

For consumers, it might be costly to assess and monitor an insurance company’s solvency situation due to principal-agent problems.10 These problems might be intensified by opaqueness problems that appear to be severe for insurance markets.11 In our model, we include a bias of consumers’ perception of the insurer’s solvency level by the parameter \( \lambda \), \( \lambda \in [-1; +\infty) \), which measures the divergence between perceived default ratio \( dr_{perc} \) and realized default ratio \( dr_{real} \):

\[
dr_{perc} = dr_{real}(1 + \lambda)
\]

(6)

For \( \lambda < 0 \), the insurance buyers have an optimistic view on the insurer’s solvency situation and perceive a lower level of default risk than actually realized by the insurer. An optimistic bias might be likely in times of economic security when insolvencies or financial distress in the financial sector do not play a major role in the media. For \( \lambda > 0 \), the insurance buyers are pessimistic with regard to the insurer’s solvency and perceive a higher default risk level than is actually the case. A pessimistic bias could result from major catastrophic events or financial crises, which raise consumers’ awareness for default risk.

9. Using the consumer surplus as the regulator’s objective function is consistent with models by Schmalensee (1989), Spiegel and Spulber (1994).
11. Morgan (2002) and Pottier and Sommer (2006) empirically estimate opaqueness for different industries. Using the rating disagreement as a proxy for opaqueness, the studies find that insurance and banking are most severely affected by the opaqueness problem.
Consumer surplus when solvency perception is biased

As before, CS measures the cumulative utility for policyholders of buying the insurance product. However, in the case of biased solvency perception, different aspects of the calculation must be considered.

Calculation of CS in markets, both with or without perception bias, is illustrated in Figure 1. Assume that the insurer realizes the default ratio \( \hat{d}_{real} \). The thick solid line in Figure 1 shows for how many consumers it is advantageous to buy insurance. Given that the insurer decides on the premium \( p'(\hat{d}_{real}) \), the hatched area below the solid curve gives the CS for unbiased demand. For biased demand, the perceived default ratio \( d_{perc} \) deviates from the realized one. We distinguish between a pessimistic and an optimistic view.

The dashed curve in Figure 1 represents the optimistic view (\( \lambda < 0 \)) and shows the number of consumers who actually purchase insurance perceiving the default ratio \( d_{perc,\lambda<0} \). Because the perceived default ratio \( d_{perc,\lambda<0} \) is lower than the actual default ratio, consumers overestimate their utility from buying the insurance product. There are some consumers whose utility is reduced by purchasing insurance, since they would not have bought it in the absence of the perception bias. The black area in Figure 1 measures the loss of CS resulting from this effect.

The thin black curve in Figure 1 represents the pessimistic view (\( \lambda > 0 \)) and shows the number of consumers who purchase insurance perceiving the default ratio \( d_{perc,\lambda>0} \). Because the perceived default ratio is higher than the actual default ratio realized by the insurer, fewer consumers buy insurance, although it would have been advantageous for them. In this case, the forgone CS is measured by the gray area in Figure 1.
Under the premium $p^\ast(dr_{\text{real}})$, the CS with biased solvency perception is the hatched area minus the black area or the gray area. Formally, CS is calculated as:

$$CS(dr_{\text{real}},p) = \int_{p^\ast}^{\infty} y(dr_{\text{real}},p)dp - \left[\int_{p^\ast}^{\tilde{p}} y(dr_{\text{real}},p)dp - \int_{p^\ast}^{\tilde{p}} y(dr_{\text{real}},p)dp\right]$$

where $\tilde{p}$ is defined by $y(dr_{\text{real}},\tilde{p}) = y(dr_{\text{per}},P^\ast)$.

3. Optimal Solutions in an Unregulated Market

As a benchmark case and comparison basis for the different regulatory approaches, we consider an unregulated insurance market in which the insurer can decide on its SHV-maximizing equity-premium combination observing the solvency perception bias of consumers. Here, the insurer’s maximization problem is defined as:

$$\max_{(dr,p)} SHV(dr_{\text{real}},p)$$

$$= \max_{(dr,p)} y(dr_{\text{per}},p) \cdot \left[p - \mu \cdot (1 - dr_{\text{real}}) - \tau \cdot (\mu \cdot s(dr_{\text{real}},\sigma) - p)\right]$$

Based on the first-order condition of equation (12), we can determine the insurer’s optimal premium for a given default ratio $dr_{\text{real}}$:

$$p^\ast(dr_{\text{real}}) = \arg\max_p SHV_p(dr_{\text{real}})$$

$$= \mu \cdot (1 - dr_{\text{real}}) + \tau \cdot (\mu \cdot s(dr_{\text{real}},\sigma) - 1 \cdot (1 - dr_{\text{real}})) + \frac{1}{\mu \cdot \text{profit mark-up}}$$

The optimal price is calculated as the sum of the arbitrage-free value of claim payments, plus frictional costs transferred to policyholders, plus a profit loading. Note that a solvency perception bias influences the insurer’s optimal default risk level, but it has no direct effect on the premium. The optimal premium $p^\ast(dr_{\text{real}})$ depends only on the insurer’s actual default risk level, not on the perceived level.

Let $dr_{\text{real}} = \arg\max_{dr} SHV(p^\ast(dr),dr)$ denote the insurer’s SHV-maximizing (actual) default ratio. Solving the insurer’s maximization problem

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(Equation 12), the first-order condition for the optimal choice of $dr_{\text{real}}^*(p^*)$, given that the price is optimally adjusted, implies that\textsuperscript{12}

$$
\frac{f_{\mu}(1+\lambda)}{f_\mu} \cdot \frac{1}{1-\tau} = \mu - \frac{\tau}{1-\tau} \cdot \frac{\partial (dr_{\text{real}}(\mu))}{\partial dr},
$$

(14)

The left-hand side of equation (14) represents the marginal change of the insurer’s benefits due to demand reaction when the default ratio is marginally changed. The right hand side measures the marginal change of default put option and frictional costs of equity. Rewriting equation (14) enables us to present the insurer’s SHV-maximizing asset-liability ratio $s^*$ using a closed-form solution:

$$
s^* = G\left[\frac{f_{\mu}}{f_{p \text{perm}}(1+\lambda)} \cdot \frac{1-\tau}{\tau}\right]
$$

(15)

with $G[x] = \exp\left(-\sigma \cdot \Phi^{-1}\left(\frac{1}{2}\right) - \frac{\sigma^2}{2}\right)$ and $\Phi^{-1}$ denoting the quantile function of the standard normal distribution. One can easily verify that $G[x]$ is a strictly increasing function in $x$. Therefore, the insurer will optimally avoid default risk by holding a high capital level if, c.p., demand reacts strongly to default risk, weakly to price, consumers’ solvency perception is unbiased and frictional costs are low.

We then have the following equations for the maximum shareholder value and resulting CS in the unregulated market:

$$
\text{SHV}(dr_{\text{real}}^* p^*) = \frac{g(dr_{\text{perm}} p^*)}{f_{\mu}(1-\tau)}
$$

(16)

$$
\text{CS}(dr_{\text{real}}^* p^*) = \frac{g(dr_{\text{perm}} p^*) (1 + f_{\mu} dr_{\text{real}})}{f_{p}}
$$

(17)

The first equation illustrates that shareholders benefit from an optimistic solvency perception bias (i.e. $dr_{\text{perm}} < dr_{\text{real}}$). However, the impact of the perception bias on CS depends on the multiple effect of demand change and change in the SHV-maximizing price and realized default risk. In the numerical examples, we provide better understanding of the consequences of a perception bias for the resulting safety level, insurance premium, shareholder value and consumer surplus.

**Numerical example**

Throughout our analysis, we illustrate our results with a realistically calibrated numerical example. We set the following risk parameters: $\mu = 200$, $\sigma_A = 5\%$,
\[ \sigma_l = 20\% \text{, and } \rho = 0,^{13} \text{ which implies } \sigma = \sqrt{5\%^2 + 20\%^2} \approx 0.2062. \] We further assume a frictional cost rate of \( \tau = 5\%.^{14} \text{ For simplicity, we set } r = 0\%. \text{ The demand-function-related parameters are as follows in Table 1.}^{15}

<table>
<thead>
<tr>
<th>Demand-function-related parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_p )</td>
</tr>
<tr>
<td>( f_{dr} )</td>
</tr>
<tr>
<td>( n )</td>
</tr>
</tbody>
</table>

Table 2 presents the optimal combinations of price and default risk, as well as the resulting shareholder value and consumer surplus, for five different bias levels \{1.0; 0.6; 0; -0.3; -0.6\}. Apparently, the optimal default risk level is higher for an optimistic solvency perception bias than for a pessimistic one, and according to equation (13), the premium is inversely affected.

<table>
<thead>
<tr>
<th>Perception bias</th>
<th>Pessimistic</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>( \lambda = 1 )</td>
<td>( \lambda = 0.4 )</td>
<td>( \lambda = 0 )</td>
</tr>
<tr>
<td>( p'(dr^*) )</td>
<td>272.57</td>
<td>272.63</td>
</tr>
<tr>
<td>( d_{\text{rect}} )</td>
<td>0.0697%</td>
<td>0.0897%</td>
</tr>
<tr>
<td>( d_{\text{perc}} )</td>
<td>0.138%</td>
<td>0.1436%</td>
</tr>
<tr>
<td>( K'(dr_{\text{end}}) )</td>
<td>9600.38</td>
<td>8655.88</td>
</tr>
<tr>
<td>( y )</td>
<td>163.42</td>
<td>164.14</td>
</tr>
<tr>
<td>( SHV )</td>
<td>1146832</td>
<td>11518.91</td>
</tr>
<tr>
<td>( CS )</td>
<td>1100048</td>
<td>110254.45</td>
</tr>
</tbody>
</table>

---

13. These numerical assumptions are consistent with the market-based calibrated model of Yow and Sherris (2008).
14. Zanjani (2002) reports that the frictional costs for the reinsurance industry can be approximated with 5%.
15. These parameters are consistent with the regression results estimated by Zimmer et. al (2014).

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Regarding insurance demand reaction, the premium reduction overcompensates the higher default risk in case of a higher bias, and thus more insurance contracts are sold. While this increases shareholder value, the higher actual default risk level reduces consumer surplus. The resulting combinations of CS and shareholder value are illustrated in Figure 2.

4. Effectiveness of Capital Regulation

We next analyze the situation in which the regulator restricts the insurer’s solvency level by means of RBC requirements, but prices remain unregulated. This situation will more or less be the regulatory environment in the EU once Solvency II has been implemented, since most price restrictions were removed by the deregulation of insurance markets in 1994.

In our model, the regulator implements RBC requirements by restricting the insurer’s (actual) default ratio at a level $d^{reg}$, forcing the insurer to hold a sufficient level of capital. The restriction is binding when the regulatory default ratio $d^{reg}$ falls below the shareholder-value-maximizing default ratio.

---

16. It is a simplifying assumption that the regulator can exactly restrict the insurer’s default ratio. Solvency II defines the capital requirements according to the value-at-risk at a 99.5% confidence level. For a discussion on potential discrepancies between the regulatory desired solvency level and the safety level ensured by capital requirements, see section 6: Regulator's ability to monitor the insurer's actual default ratio.
Safety Versus Affordability

Facing capital requirements, the insurer adjusts the premium to maximize SHV (see equation 13):

\[
p^*(dr^{reg}) = \arg \max_p SHV(p, dr^{reg}) =
\]

\[
= \mu \cdot (1 - dr^{reg}) + \tau \cdot (\mu s(dr^{reg}) - \tau \cdot (1 - dr^{reg})) + \frac{1}{f_p}
\]

(11)

Equation (18) demonstrates that the optimal insurance premium is negatively related to the regulatory default ratio \(dr^{reg}\). First, a lower value of \(dr^{reg}\) means that the insurer’s default put option decreases, and thus the first premium component increases. Second, the insurer needs to hold additional equity capital to achieve a lower default ratio, and the related frictional costs are transferred to policyholders with the second premium component. Thus, stricter capital requirements will lead to a higher premium. When deciding on the welfare-optimal policy of capital requirements, the regulator needs to balance their positive influence on the safety level against their negative influence on affordability. Formally, the CS in dependence of \(dr^{reg}\) and \(\lambda\) is given by:

\[
CS(dr^{reg}, \lambda) = \frac{y(dr^{reg}, (1 + \lambda)p^*(dr^{reg}))(1 + f\lambda dr^{reg})}{f_p}
\]

(19)

Taking the first-order derivative of \(CS(dr^{reg}, \lambda)\) with respect to \(dr^{reg}\) enables us to determine how strict the capital requirements should be:

\[
\frac{d}{dr} CS(dr, \lambda)
\]

\[
= y(dr \cdot (1 + \lambda), p^*) \left[ (1 + f\lambda dr^2)(1 - \tau) \left( -\frac{f\lambda}{f_p} \cdot \frac{1 + \lambda}{1 - \tau} + \mu \cdot \frac{\partial s}{\partial dr} \right) - \frac{f\lambda}{f_p} \right]
\]

\[
= -y(dr \cdot (1 + \lambda), p^*) \cdot (\cdot + f\lambda dr^2 \cdot (1 - \tau)
\]

\[
\cdot \left[ \frac{f\lambda}{f_p} \cdot \frac{1 + \lambda}{1 - \tau} - \mu \cdot \frac{\partial s}{\partial dr} \cdot \frac{f\lambda}{f_p} \frac{\lambda}{1 + f\lambda dr^2} \cdot \frac{1}{1 - \tau} \right]
\]

(20)

According to equation (11) and the explanations beneath, expression A in equation (20) reflects the insurer’s marginal benefits minus the marginal costs resulting from a marginal default ratio reduction. If the insurer attains the SHV-maximizing default ratio, expression A is zero. Expression B in equation (20) is driven by the solvency perception bias \(\lambda\). If consumers are unbiased (\(\lambda = 0\)), expression B is zero as well, and the whole derivative in equation (20) is thus zero.
Therefore, the default ratio that the insurer will attain based on its own incentives maximizes CS as well, and the regulator does not need to impose capital requirements. If consumers exhibit a pessimistic solvency bias ($\lambda > 0$), expression B is positive. If the insurer attains the SHV-maximizing solvency level (i.e. expression A is zero), then the whole derivative is positive, meaning that the CS-maximizing default ratio is even higher than the SHV-maximizing one. As in the previous case, reducing the default ratio by means of capital requirements does not raise consumer welfare. Only if consumers are too optimistic about the insurer’s default ratio ($\lambda < 0$) is expression B negative. Equation (20) is then negative for the SHV-maximizing solvency level, and the regulator can effectively enhance policyholders’ welfare by imposing binding capital requirements to reduce the default ratio.

**Numerical example and graphical representation**

We now apply the numerical example from Section 3 to the situation with capital requirements. Table 3 contains the consumer-surplus-maximizing regulatory default ratios, the insurer’s optimal response and the corresponding welfare levels.

<table>
<thead>
<tr>
<th>Perception bias</th>
<th>Pessimistic</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_{\text{reg}}^{\text{rel}}$</td>
<td>$\lambda = 1.0$</td>
<td>$\lambda = 0$</td>
</tr>
<tr>
<td>$d_{\text{prc}}^{\text{rel}}$</td>
<td>0.0692%</td>
<td>0.0897%</td>
</tr>
<tr>
<td>$p'(d_{\text{reg}}^{\text{rel}})$</td>
<td>0.1384%</td>
<td>0.1436%</td>
</tr>
<tr>
<td>$y$</td>
<td>163.42</td>
<td>164.14</td>
</tr>
<tr>
<td>$\text{SHV}_{\text{reg}}$</td>
<td>11468.32</td>
<td>11518.91</td>
</tr>
<tr>
<td>$\Delta \text{SHV}/\text{SHV}_{\text{non-reg}}$</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>$\text{CS}_{\text{reg}}$</td>
<td>11000.48</td>
<td>11025.46</td>
</tr>
<tr>
<td>$\Delta \text{CS}/\text{CS}_{\text{non-reg}}$</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Table 3: Numerical Results Under Capital Regulation for Different Bias Levels

The first three columns of Table 3 ($\lambda = 1; 0.6; 0$) illustrate, as discussed above, that the regulator cannot improve policyholder welfare by capital regulation when consumers’ solvency perception is pessimistic or unbiased. The consumer-surplus-maximizing default ratio is equal or lower to the insurer’s optimal strategy

---

17. We may assume that $1 + f_{\text{sur}} dr \lambda > 0$, which is equivalent to the consumer surplus being positive, cf. equation (17).
in the absence of regulation. (See Table 2.) In the fourth \((\lambda = -0.3)\) and fifth columns \((\lambda = -0.6)\), the regulator restricts the default ratio below the shareholder-value-maximizing default ratio of 0.1606\%. Because the premium is only affected by the realized default ratio (see equation 18), the insurance premium is optimally adjusted for all different bias levels; insurance demand is higher in case of a negative bias since consumers overestimate the value of insurance. Compared to our benchmark case with no regulation, the optimal capital requirements are stricter when there is a negative bias and, hence, such capital requirements can increase CS by 0.25\% for \(\lambda = -0.3\) and by 3.55\% for \(\lambda = -0.6\).

**Figure 3:**
Combination of Shareholder Value and Consumer Surplus Under Capital Regulation for Different Bias Levels

Figure 3 is a graphic illustration of how capital regulation affects SHV and consumer surplus. Starting at Points A, B and C, the straight solid lines illustrate that a binding regulatory ceiling on the default ratio decreases shareholder value as well as CS when consumers have a pessimistic or unbiased solvency perception. For an optimistic perception bias with \(\lambda = -0.3; -0.6\), the dashed curves starting at Points D and E demonstrate that capital regulation can enhance CS up to Points D’ and E’, which refer to optimal capital regulation. (See Table 3.)

**5. Effectiveness of Price Regulation**

Next, we investigate the consequences of regulatory price ceilings imposed with the intent of meeting the regulator’s affordability target. The price ceiling will be binding when it lies below the insurer’s unregulated premium. (See equation 13.) When only prices are subject to regulation, and there are no capital requirements, the insurer can react to the mandatory prices by adjusting its safety level.

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Therefore, any regulatory price induces a specific insurer’s optimal default ratio \( dr^+_{\text{real}}(p^{\text{reg}}) \). The insurer’s maximization problem can be formalized as:

\[
dr^+_{\text{real}}(p^{\text{reg}}) = \arg\max_{dr} SHV(dr, \lambda, p^{\text{reg}}) \tag{21}
\]

where \( p^{\text{reg}} \) denotes the regulated premium. The optimality condition for the choice of a default ratio level—that is, the first-order derivative of the SHV with respect to default ratio when the price is externally determined—implies:

\[
\frac{\partial SHV}{\partial dr} |_{p^{\text{reg}}} = \frac{\partial y}{\partial (dr(1+\lambda)p^{\text{reg}})} \left[ p^{\text{reg}} - \mu(1 - dr) - \frac{\tau}{1 - c} \mu \phi(.) - p^{\text{reg}} \right] + y\mu - \lambda y \frac{\partial \phi(.)}{\partial dr} = 0 \tag{22}
\]

The first term is negative and measures demand effects for marginal changes in the default ratio. The second term is positive and represents the value of the limited liability change. The third term reflects marginal changes in the frictional costs of equity when the default ratio varies. The level of solvency perception bias \( \lambda \) has an influence on all three terms because it manipulates the demand \( y \).

By using price regulation to improve insurance affordability, the regulator aims at creating maximum consumer surplus. Equation (23) gives the regulator’s maximization problem:

\[
p^{\text{reg}} = \arg\max_{p^{\text{reg}}} CS(p^{\text{reg}}, dr^+_{\text{real}}(p^{\text{reg}})) \tag{23}
\]

To study the effect of price restrictions on CS and to determine the optimal price ceiling, we look at the first-order derivative of the CS with respect to price, \( \frac{\partial CS}{\partial p^{\text{reg}}} \). In the optimum, we obtain:

\[
\frac{f_d \frac{\partial \phi}{\partial p^{\text{reg}}}}{(1 + f_d \lambda + 1)} = -f_p \tag{24}
\]

The left-hand side of the equation (24) measures the negative effect to which policyholders are exposed because of the lower safety level resulting from the lower prices. The right-hand side represents policyholders’ additional gain through price decrease. Therefore, as soon as the welfare gain of lower prices outweighs the loss due to the decreased safety level, the change in CS is positive, and the regulatory intervention leads to an improvement in policyholder welfare. Maximum CS is attained when the equation holds. Further price reduction results in higher losses due to worse default risk.
Numerical example and graphical representation

Once again, we illustrate our analytical findings using the numerical example introduced in Section 3. The regulator decides on the consumer-surplus-maximizing price ceiling, $p^{reg*}$. The insurer adjusts its realized default risk, $dr_{real}(p^{reg*})$, under the objective shareholder-value-maximization. The resulting SHV and CS are set out in Table 4. The effectiveness of price regulation is measured by the percentage change in CS.

When the regulator introduces a price ceiling, we observe an improvement in consumer surplus in all five cases. We observe a constant decreasing trend of the price ceiling and the resulting default risk with respect to the perception bias. For negatively biased demand ($\lambda = -0.6$, optimistic case), the insurer adjusts its default ratio to the comparatively high price ceiling (247.6) more strongly, whereas for positively biased demand ($\lambda = 1$, pessimistic case), the insurer adjusts its default ratio only moderately although the price ceiling is much lower. The reason for this is that unbiased or pessimistically biased policyholders have a stronger disciplinary influence on the insurer's safety level. As a consequence, the effectiveness of price regulation, defined as the relative consumer surplus improvement, increases with the level of the solvency perception bias and reaches levels over 100%. (See the first column of Table 4.)

Table 4: Numerical Results Under Price Regulation for Different Bias Levels

<table>
<thead>
<tr>
<th>Perception bias</th>
<th>Pessimistic</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p^{reg*}$</td>
<td>$\lambda = 1.0$</td>
<td>$\lambda = -0.6$</td>
</tr>
<tr>
<td>$dr_{real}(p^{reg*})$</td>
<td>214.56</td>
<td>222.25</td>
</tr>
<tr>
<td>$y$</td>
<td>301.61</td>
<td>279.12</td>
</tr>
<tr>
<td>$SHV^{reg}$</td>
<td>4250.71</td>
<td>11282.85</td>
</tr>
<tr>
<td>$\Delta SHV/FV^{non-reg}$</td>
<td>-62.94%</td>
<td>-5.50%</td>
</tr>
<tr>
<td>$CS^{reg}$</td>
<td>2723.14</td>
<td>12641.00</td>
</tr>
<tr>
<td>$\Delta CS/CS_{non-reg}$</td>
<td>+115.66%</td>
<td>+18.44%</td>
</tr>
</tbody>
</table>

The resulting combinations of regulatory price and corresponding SHV-optimal default ratio lead to specific combinations of shareholder value and consumer surplus, represented by the bent curves in Figure 4. Every curve represents a different bias level. The dashed curves stand for the optimistic cases, $\lambda = -0.6$; $-0.3$, the thick curve for the unbiased case, $\lambda = 0$, and the fine curves...
represent the pessimistic cases, \( \lambda = 0.6; 1 \). Points A''', B''', C''', D''' and E''' correspond to the consumer surplus optimal positions. (See Table 4.)

**Figure 4:** Combination of Shareholder Value and Consumer Surplus Under Price Regulation for Different Bias Levels

6. Comparison of Capital and Price Regulation

The previous analysis has shown that capital and price regulation could be beneficial for policyholders. In this section, we compare the effectiveness of the two regulatory tools and explore what kind of regulation is most appropriate to improve consumer surplus under different circumstances.

*Impact of frictional costs*

In the following subsection, we analyze the effectiveness of capital and price regulation depending on the level of frictional costs. We consider the three bias levels \( \lambda = \{0.6; 0; -0.6\} \) and plot the maximum achievable percentage change of consumer surplus when the regulator chooses the consumer-surplus-maximizing \( \Delta r_{real}^{reg,*} \) and \( p^{reg,*} \) respectively.

Figure 5 illustrates the case of pessimistically biased insurance demand (i.e., \( \lambda > 0 \)). The solid line depicts the potential consumer surplus increase with price regulation, and the dashed line depicts the effectiveness of capital regulation. Policyholder reaction forces the insurer to choose a default risk level that also maximizes consumer surplus. Therefore, irrespective of the level of frictional costs, capital regulation cannot raise consumer surplus, and the dashed curve

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remains at 0%. Price regulation, in turn, can significantly enhance consumer surplus, but its effectiveness decreases with the level of frictional costs. The reason for the decreasing effectiveness of price regulation is that the insurer will respond with a more drastic reduction of its safety level when equity capital is subject to high frictional costs.

**Figure 5:**
Effectiveness of Price and Capital Regulation with Pessimistic Perception Bias of 0.6 When the Carrying Charge of Holding Capital Changes

In the unbiased case, our analysis provides similar results. (See Figure 6.) Again, capital requirements have no influence on the consumer surplus, and price regulation may increase consumer surplus, and the effectiveness of price regulation decreases with the level of frictional costs.

**Figure 6:**
Effectiveness of Price and Capital Regulation in the Absence of Perception Bias When the Carrying Charge of Holding Capital Changes

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The case of an optimistic solvency perception bias is illustrated in Figure 7. Here, capital requirements can clearly raise CS, particularly when frictional costs are high. Furthermore, the effectiveness of price regulation is lower and more affected by frictional costs than in the previous scenarios. If the carrying charge is above 11%, capital regulation is more effective than price regulation. Therefore, regulators should optimally focus on the safety goal if insurance demand exhibits an optimistic solvency perception bias and frictional costs are significant.

**Impact of Volatility of Liabilities**

Next, we examine the effectiveness of capital and price regulation for insurance portfolios of varying volatility. Again, we look at the three bias levels, \( \lambda \in \{0.6; 0; -0.6\} \). The results are plotted in Figures 8 – 10. As before, capital regulation cannot improve policyholder welfare if demand is pessimistic or unbiased, which is the case for all considered values of the riskiness of insurance claims. (See Figures 8 and 9.)

Price ceilings strongly increase consumer surplus when the insurance risks are low, and they have a smaller effect when the insurance portfolio is highly volatile. The reason behind this finding is that the insurer needs to hold much more equity capital for the high-risk portfolio, and the price ceiling clearly reduces the incentive to hold a large amount of equity. Therefore, the insurer with high insurance risks responds to a price ceiling with a severe reduction of its safety level, leading to a smaller increase of the consumer surplus as compared to the low-risk insurer.
Figure 8: Effectiveness of Price and Capital Regulation with Bias Level 0.6 When the Volatility of Liabilities Changes

![Graph showing effectiveness of price and capital regulation with bias level 0.6.](image)

Figure 9: Effectiveness of Price and Capital Regulation in the Absence of Perception Bias When the Volatility of Liabilities Changes

![Graph showing effectiveness of price and capital regulation without bias.](image)

Figure 10 depicts the considered effects for the negative bias, $\lambda = -0.6$. Now, the dashed line has a clearly positive slope, meaning that capital regulation is effective, especially when insurers have a high-risk portfolio. The solid line has a clearly negative slope, and the effectiveness of price ceilings thus decreases with the volatility of insurance risks. When the volatility of the liabilities exceeds 35%, capital regulation becomes more effective than price regulation.
Impact of Incomplete Information

So far in our analysis, we have made two important assumptions about the level of information of the insurance company and the regulator: 1) the regulator can perfectly monitor the insurer's actual default ratio; and 2) the insurer is fully informed about the consumers' solvency perception bias and can distinguish between pessimistic, optimistic and unbiased consumers. In reality, however, each of these assumptions could be violated due to information asymmetries. Therefore, we will now take a closer look at the potential impacts of these information asymmetries on our results.

1. Regulator’s ability to monitor the insurer’s actual default ratio

In our article, we assume that the regulator restricts the insurer's default risk by means of RBC requirements, which, in practice, are typically implemented by a regulatory-defined formula or by an internal model that is developed by the insurance company based on regulatory requirements. In addition, regulators usually use monitoring tools, such as filing financial statements, requiring regulatory reports or conducting examinations. In the following section, we discuss the consequences of two kinds of deficiencies of the regulator’s solvency assessment.

First, it is possible that the regulator holds biased beliefs about the insurer’s solvency level. Under Solvency II, for example, regulators can increase the capital requirement by a so-called capital add-on if they assess the insurer's risk profile as too specific or the system of governance as inappropriate. According to our

18. An overview on the implementation of capital requirements in the United States and in the European Union under Solvency II can be found in Klein (2012), p. 185-188.

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model, a capital add-on reduces the default ratio and increases the premium, since
the insurer transfers higher risk management costs to policyholders (cf. equation
13). An inappropriate capital add-on would, on the one hand, lead away from the
consumer-surplus-maximizing capital requirement (as described in equation 20).
Furthermore, it would destroy SHV if policyholders have a pessimistic or unbiased
solvency perception; if they have an optimistic solvency perception, only an
overly strict capital add-on would destroy shareholder value, while an overly lax
one would increase shareholder value (cf. section 4).

Second, there might be a discrepancy between regulatory capital requirements
based on the default ratio or on the default probability (Gatzert and Schmeiser,
2008). Moreover, it might be difficult for regulators to ensure that the calculation
of the capital requirement, either by a regulatory-defined formula or by an internal
model, leads accurately to the desired safety level. When an internal model is
used, the calculated capital requirement is subject to the methodologies and
assumptions chosen by the insurance company. When the insurer is able to
reduce its capital requirement solely by changing the methodology of calculation
(without the notion of the regulator and of policyholders), policyholders' percep-
tion of the solvency level becomes more optimistic, increasing the SHV.
Under Solvency II, a considerable set of governance requirements around the
development and regulatory approval of internal models shall prevent leeway in the
choice of methodologies and assumptions. For regulatory-defined formulas,
the accuracy of the corresponding safety level may be affected by statistical
deficiencies of the formula's parameterization. Also, the insurer's reaction when
being confronted with the standard formula could cause unexpected side effects.
In light of our model, both issues of regulatory-defined formulas would result in an
(additional) solvency perception bias of consumers and might thereby destroy
consumer surplus.

2. Insurer's ability to distinguish between pessimistic, optimistic
and unbiased consumers

In order to study the impact of incomplete information at the insurer's level,
we will investigate different situations and assess the effectiveness of price and
capital regulation. In particular, we define nine combinations of the assumed

21. Cf., e.g., Wang et al. (2009), p. 61, who highlight that leeway of methodologies and
assumptions in the determination of the value-at-risk may lead to a false sense of comfort for
managers.
24. Fischer and Schlütter (2014) demonstrate how an insurer, based on the Solvency II
standard formula's calibration, will adjust its investment policy in order to achieve a high level of
default risk. The insurer's reaction is relevant, since the calibration of the standard formula is not
fully risk-based. For example, sovereign bonds of European Union member states are considered
free of default risk. Stoyanova and Gründl (2014) investigate the impact of the Solvency II
standard formula on an insurer’s merger and acquisition activities and show that the new
regulatory regime may lead to an enhanced geographic restructuring wave.

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perception bias by the insurer and real perception bias of the consumer. (Possible combinations are, for example, pessimistic-pessimistic, pessimistic-unbiased, optimistic-pessimistic, etc). Table summarizes the combinations analyzed and the results.

The main results from Section 4 and Section 5 can be applied to the new situation: In all combinations analyzed, the effectiveness of capital regulation is moderate compared to the effectiveness of price regulation. Furthermore, as soon as the insurer assumes that the demand is unbiased or pessimistic, the effectiveness of capital regulation is extremely low or even zero. The reason for this is that the assumed consumer reaction has a disciplinary effect on the SHV-maximizing strategy, and no further regulatory interventions are necessary in order to improve consumers’ position. Capital regulation can increase the consumer surplus only when the assumed perception bias is negative—i.e., consumers are assumed to be optimistic.

Table 5:
Effectiveness of Price and Capital Regulation Under Incomplete Information

<table>
<thead>
<tr>
<th>Assumed perception bias</th>
<th>Real perception bias</th>
<th>Pessimistic, $\lambda = 0.6$</th>
<th>Unbiased, $\lambda = 0$</th>
<th>Optimistic, $\lambda = -0.6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda = 0.6$</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>$\lambda = 0$</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>$\lambda = -0.6$</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

- o - no effectiveness
- o/+ - effectiveness below 1%
- + - effectiveness over 1% below 25%
- ++ - effectiveness over 25% below 100%
- +++ - effectiveness over 100%
- * - highest effectiveness within the assumed perception bias (row)

Price regulation improves consumer surplus in all nine combinations. Furthermore, the effectiveness of regulatory price ceilings increases when the insurer assumes more pessimistic consumers and can attain values over 100%. (Compare the first row in Table 5.) In addition, within the assumed perception bias, the highest effect of price regulation is achieved when the real solvency
perception bias is zero—i.e., consumers anticipate the realized default risk and make correct decisions about whether to buy.

7. Conclusion

This article investigates how regulatory capital requirements and price ceilings influence an insurer’s capital level and pricing decisions and what consequences arise for policyholders’ welfare. To this end, we employ a model in which insurance demand is sensitive to default risk and price, policyholders’ perception of the insurer’s solvency level may be biased, and the insurer faces frictional costs of holding equity capital. The insurer’s objective is the SHV, which we measure using the present value of shareholders’ future cash flows minus their initial equity endowment. Policyholders’ welfare is measured using the consumer surplus—i.e., the integral over the differences between their willingness-to-pay and the actual insurance premium.

To evaluate the consequences of regulatory intervention, we consider the insurer’s strategy in a world with no regulation as a benchmark case. Here, the insurer balances its incentives for safety (resulting from insurance demand reaction) against the frictional costs of holding equity capital, and determines the corresponding SHV-maximizing insurance premium.

By means of RBC requirements, the regulator can force the insurer to attain a higher safety level. The insurer will react to this type of regulation by adjusting its premium. We show that capital requirements cannot enhance policyholders’ welfare when insurance demand is unbiased, since the insurer finds it optimal to attain the exact safety level that maximizes consumer surplus. If the regulator requires a higher safety level, premiums become too high so that policyholders are worse off. In contrast, capital requirements can improve policyholders’ welfare in the potentially more realistic case of a differing perception of the safety level by policyholders (which could be fostered by market opacity; Morgan, 2002; Pottier and Sommer, 2006). Our numerical examples indicate that capital requirements are especially effective when insurance buyers perceive the solvency level too optimistically (more precisely, when the insurer believes that they have an optimistic perception), when equity capital comes at significant frictional costs, and when insurers face significant underwriting risks. In these cases, the regulator should concentrate on the safety goal. If the regulator imposes a binding price ceiling, the insurer has weaker incentives to attract consumers with its high safety level, and it will reduce its equity position. Nevertheless, we point out that price ceilings can be beneficial for policyholders, especially when insurance buyers’ reaction drives default risk down and frictional costs of equity capital are rather low.

In this article, price regulation is understood as a fixed premium ceiling (i.e., unaffected by the safety level) as it is typically used by insurance regulators. For this form of price regulation, we find that the regulatory targets safety and affordability are in contrast. This interaction could be different if regulators limit
insurance premiums to a "fair" premium (Doherty and Garven, 1986), which goes along with a SHV of zero and leads to pricing restrictions that depend on the insurer's safety level. As demonstrated by Spence (1975), this form of profit regulation may (under certain conditions on the demand function) have a positive impact on product quality (in our case, on the solvency level), especially if quality goes along with capital needs.

Altogether, our findings suggest that regulators should take both targets—safety and affordability—into account under the overall objective of policyholder protection. While our findings on price ceilings do not overrule typical concerns about anti-trust measures, they do shed light on the insurance-specific interaction between price regulation and safety. Our sensitivity analyses indicate in which situations insurance regulators should focus their efforts on solvency regulation in particular, or monitor profit loadings on premiums and create the basis for antitrust regulation.
Appendix A

Derivation of Equation (8)

The derivation is analogous to Schlüter (2014), Appendix A.

\[ SHV = E_o - K \quad \text{(cf. Eq. 3)} \]

\[ = A_0 - L_0 + DPO_0 - K \quad \text{(cf. Eq. 3)} \]

\[ = A_0 - L_0 \cdot (1 - dr) - K \quad \text{(cf. Eq. 6)} \]

\[ = y \cdot p + (1 - \tau) \cdot K - y \cdot \mu \cdot (1 - dr) - K \quad \text{(cf. Eq. 4 and 5)} \]

\[ = y \cdot [p - \mu \cdot (1 - dr) + \tau \cdot \xi / y] \]

\[ = y \cdot \left[ p - \mu \cdot (1 - dr) - \frac{\tau}{1 - \tau} (\mu \cdot s - p) \right] \]

where the last equation follows from

\[ s = \frac{A_0}{L_0} = \frac{y \cdot p + (1 - \tau) \cdot K}{y \cdot \mu} \quad \text{cf. Eq. 4 and 5)} \]

\[ \Rightarrow \frac{s}{y} = \frac{\tau \cdot s - p}{1 - \tau} \]
References


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Cassandra Cole and Kathleen McCullough
jireditor@gmail.com

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