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Insurance Solvency Regulation under Biased Consumer Perceptions*

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This study examines modern risk-based insurance solvency regulation from the perspective of consumer protection, considering the impact of biased consumer perceptions. To this end, it employs an option pricing model that incorporates the assumption that insurance buyers may hold biased perceptions regarding the insurer's solvency. Consumer protection is evaluated using measures of consumer surplus and welfare loss.

The analysis indicates that biased consumer perceptions may encourage insurer moral hazard, thereby reducing social welfare. Under such circumstances, risk-based solvency regulation serves as an effective policy instrument for mitigating welfare losses. However, the findings also suggest that excessively stringent regulation may produce unintended adverse effects on consumer protection by reducing consumer surplus through higher capital costs.

In conclusion, while a risk-based solvency framework constitutes a valuable supervisory tool, regulators must adopt an appropriate degree of regulatory stringency, carefully balancing the objectives of ensuring solvency and promoting consumer welfare.

Keywords: Risk-based Solvency Regulation, Biased Perceptions, Confidence Level, Regulatory Efficiency, Consumer Surplus
JEL Cl: D6, D8, G28

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I. Introduction

Insurance regulators in many countries have been fundamentally restructuring solvency regulations for insurance companies since the global financial crisis of 2007. The International Association of Insurance Supervisors (IAIS) finalized the Insurance Capital Standard (ICS) in 2024, establishing the first global solvency framework for insurers, analogous to the Basel Accord in the banking sector. The European Union implemented Solvency II, a new risk-based solvency regime, in 2016. South Korea introduced the Korea Insurance Capital Standard (K-ICS) in 2023, a new solvency regulation based on the ICS.

In general, there are two types of solvency regulation: risk-based and fixed-amount. Risk-based solvency regulations require insurers to hold capital in excess of a risk-sensitive amount determined using regulatory models. In contrast, fixed-amount solvency regulations require insurers to hold capital above a predetermined fixed threshold. It is crucial for regulators to understand the fundamental differences between these two frameworks.

In designing a risk-based solvency regulation, an important policy decision concerns the confidence level used in the risk measurement. Various confidence levels are employed in real-world regulation. For example, the confidence level in Japan's RBC system was 90% before 2012 and has been 95% since. In the United States, it is implicitly around 95%. In South Korea, the confidence level was set at 95% prior to 2014 and increased to 99% under the Risk-Based Capital (RBC) regime. In 2023, the K-ICS adopted a 99.5% confidence level. The ICS and Solvency II adopt a 99.5% confidence level, while Basel II for banks uses 99.9%. This range highlights the complexity and policy sensitivity of choosing an appropriate confidence level.

Understanding the economic foundations of solvency regulation is therefore essential for designing effective systems. However, surprisingly few studies examine the theoretical underpinnings and efficiency implications of modern risk-based solvency regulation.

This study investigates the theoretical foundations and economic efficiency of risk-based solvency regulation using an option pricing model (OPM), under the assumption that insurance buyers may have biased perceptions about the solvency of insurers.

Specifically, the study addresses two fundamental questions:

1. Why should solvency regulation be based on a risk-sensitive framework rather than a fixed-amount framework under biased consumer perceptions of the insurer's solvency?
2. Does tightening solvency regulation—i.e., increasing the confidence level—necessarily enhance consumer protection?

The main findings of this study are as follows. Regarding the first question, if insurance buyers have biased perceptions of insurer solvency, this information asymmetry can create moral hazard, leading insurers to take excessive risks. Risk-based solvency regulation can mitigate the resulting welfare loss by aligning capital requirements with underlying risks. Therefore, solvency regulation should be grounded in a risk-based framework rather than a fixed-amount rule if insurance buyers have biased perceptions of insurer solvency. Regarding the second question, the results indicate that overly stringent capital requirements—those based on excessively high confidence levels—can reduce consumer welfare, despite improving insurer solvency.

This study is expected to contribute to the conceptual and theoretical foundation of modern risk-based solvency regulation from the perspective of economic efficiency. It provides a formal justification for calibrating solvency regulation in a way that balances financial soundness and consumer welfare, thereby aiding regulators in designing more effective systems.

Although this study builds upon the option-theoretic framework developed by Stoyanova and Schlütter (2015), including their formulation of biased consumer perception, it differs in both focus and scope. While their analysis centers on comparing the effects of capital regulation versus price regulation, this study investigates two distinct but equally important issues. First, it explores why risk-based solvency regulation is more effective than fixed-amount regulation in mitigating welfare losses caused by consumer misperception. Second, it comparatively analyzes how the choice of confidence level in risk-based capital requirements affects consumer welfare—an issue that remains largely underexplored in the literature.

Based on this second line of analysis, this paper demonstrates that stronger solvency regulation does not always lead to better outcomes for consumers. In particular, excessively high confidence levels, while reducing default risk, can increase insurance premiums and reduce consumer surplus. These findings offer policy-relevant insights into the optimal calibration of solvency standards, especially within frameworks like Solvency II and the ICS.

The remainder of this paper is organized as follows. Section 2 presents the literature review on the option pricing model used in this paper, together with the research questions. Section 3 explains the characteristics of value at risk (VaR) and the underlying theory of risk-based solvency regulation. Section 4 outlines Stoyanova and Schlütter's (2015) economic model. Section 5 develops theoretical results based on the model. Section 6 analyzes the theoretical framework with numerical illustrations and discusses the welfare implications of different confidence levels. Section 7 concludes and discusses policy implications.

Ⅱ. Literature Reivew

The application of the option pricing model (OPM) to the analysis of insurance company behavior was pioneered by Doherty and Garven (1986) and Cummins (1988). Subsequent contributions by Butsic (1994), Cummins and Danzon (1997), Zanjani (2002), Yow and Sherris (2008), Lin et al. (2013), Schlütter (2014), Stoyanova and Schlütter (2015), and Coppola et al.(2018) have further advanced OPM-based frameworks to explain insurers' decision-making under solvency and risk constraints. Among these, Stoyanova and Schlütter (2015) developed a formal economic model that integrates consumer behavior, capital regulation, and insurer strategy, while also incorporating consumer perception biases and evaluating the implications for risk-based solvency regulation and consumer protection. The present study builds primarily upon Stoyanova and Schlütter (2015) and extends their approach by introducing the concept of confidence levels.

A number of studies relate to the first research question, albeit without directly addressing it through formal modeling. Munch and Smallwood (1982) demonstrate that solvency-related information costs and agency problems can heighten insurers' default probabilities, and that solvency regulation may mitigate these risks. However, their framework assumes fixed-amount regulatory requirements. Cummins et al. (1993) provide a comprehensive discussion on the rationale, benefits, and limitations of risk-based capital requirements for property-casualty insurers, emphasizing the need for regulatory oversight given insurance customers' limited ability to monitor insurers' risk-taking behavior. Their arguments, however, rest more on expert judgment than on rigorous formal analysis. Butsic (1994) argues that while solvency regulation would be unnecessary in a perfectly efficient market, it becomes essential in the presence of information asymmetries. Stoyanova and Schlütter (2015) further examine the welfare implications of capital regulation versus price regulation under consumer misperceptions, but do not explicitly compare risk-based solvency requirements with fixed-amount requirements.

Recent literature has explored Solvency II from both theoretical and empirical perspectives. Filipović et al. (2014) develop a model showing that solvency capital requirements can curb excessive risk-taking driven by risk-shifting incentives, thereby enhancing policyholder protection and welfare, especially when consumers are risk-averse. Rae et al. (2017) evaluate the implementation of Solvency II and find that it has improved consumer protection and risk management, though concerns remain regarding complexity, pro-cyclicality, and compliance costs. Siopi et al. (2023) empirically examine European insurers and identify key financial drivers of the SCR ratio, such as reinvestment rate and benefit adjustment expenses, underscoring the importance of investment strategy and expense control under solvency regulation.

Regarding the second research question, to our knowledge, few studies have directly addressed this issue. Lorson et al. (2012) conduct a cost-benefit analysis of Solvency II, questioning whether the additional protection offered by Solvency II's 99.5% confidence level justifies the associated costs to policyholders. Boonen (2017) examines the impact of replacing the current 99.5% Value-at-Risk (VaR) confidence level under Solvency II with an

Expected Shortfall (ES) measure. The study finds that maintaining a similar solvency capital requirement would require setting the ES confidence level at approximately 98.8%, while applying ES at a 99% confidence level would significantly increase capital requirements. However, these analyses are confined to a single framework and do not consider alternative confidence levels. In banking regulation, Zimper (2014) analyzes how the Basel framework's reliance on a 99.9% confidence level can be misleading if expected losses are not properly accounted for in capital requirements. He concludes that "the financial stability of a Basel-regulated banking system is likely to be more prone to bank failures than suggested by the official confidence level of 99.9%.".

Ⅲ. Capital Requirements under Risk-Based Solvency Regulation: A VaR-Based Framework

Risk-based solvency regulation is typically grounded in the Value at Risk (VaR) framework. According to Jorion (2007), the VaR of a portfolio over a target horizon can be defined as:

$$c = prob(x \geq -VaR) = \int_{-VaR}^{+\infty} p(x)dx \tag{1}$$

where c is the confidence level, x is a random variable representing the portfolio profit or loss, and $p(x)$ is the probability density function for x.

As Jorion (2007) explains, when VaR is used to determine capital requirements, the target default probability can be directly translated into the confidence level. For example, if the target default probability is 1%, the corresponding confidence level becomes 99% (= 100 – 1). Therefore, an insurer aiming to maintain an investment-grade credit rating, such as Baa, must hold capital exceeding the 99% VaR. In this case, if the 99% VaR is estimated at USD 10 million, the insurer must maintain capital above this level to limit the default probability to 1%. Accordingly, the VaR at the specified confidence level is often referred to as the required capital or minimum regulatory capital needed to meet the solvency standard.

Risk-based solvency regulation is structured so that when an insurer's actual capital falls below the required level, regulatory intervention is triggered to protect policyholders and maintain financial stability. As a result, insurance companies have incentives to manage their capital levels carefully to avoid supervisory action. Lin et al. (2013) find that insurers behave strategically to avoid breaching regulatory thresholds, especially when capital nears the minimum requirement—a phenomenon known as the threshold effect.

Building on this risk-based framework, the next section presents the economic model developed by Stoyanova and Schlütter (2015), which this study extends to analyze the welfare effects of alternative regulatory designs.

Ⅳ. The Model

The model involves three key agents: a representative consumer, an insurance company, and a regulator. The representative consumer purchases insurance to hedge against potential losses but may have a biased perception of the insurer's solvency. The insurance company decides on its capital level and risk-taking behavior, seeking to maximize shareholder value under regulatory constraints. The regulator sets solvency requirements based on a value-at-risk (VaR) framework with a specified confidence level, aiming to mitigate default risk and protect consumer welfare.

1. Consumer Model

The representative consumer model is built upon the following assumptions:

(C1) The consumer considers not only the price but also the financial soundness of the insurance company when deciding whether to purchase an insurance product.

(C2) The consumer does not observe the insurer's true solvency condition.

(C3) The consumer is a price taker.

Assumption (C1) implies that the demand for insurance products depends on both the product price and the insurer's perceived default rate. Specifically, demand increases as the price decreases and as the default probability becomes lower. This relationship is formalized in Definition 1.

Definition 1: Demand curve for insurance products

The consumer's demand function for insurance is specified as follows:

$$Q(dr, p) = n\,e^{-f_d dr - f_p p} \tag{2}$$

where p denotes the price of the insurance product, dr is the perceived default rate of the insurer, f_d is the default rate sensitivity coefficient, f_p is the price sensitivity coefficient, and n is a market adjustment factor (e.g., potential market size).

All parameters f_d, f_p, and n are assumed to be positive. The default rate dr is defined in Section 4.2 as the ratio of the arbitrage-free value of unpaid claims to the nominal liability value.

Assumption (C2) introduces consumer misperception of the insurer's solvency. Consumers—typically lacking financial expertise—may not accurately assess the true default probability of insurance companies, whereas the firms themselves know their actual financial condition. This leads to the following definition.

Definition 2. Biased Default Rate under Consumer Perception

When consumer perception of the insurer's default rate is biased, the biased default rate dr_b can be represented as:

$$dr_b = (1+b)dr_r \tag{3}$$

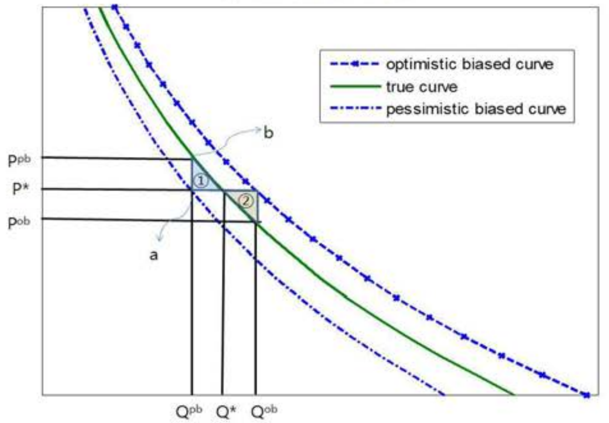
where $b\,(> -1)$ is the degree of consumer bias, dr_r is the real default rate, and dr_b is the biased default rate.

It should be noted that a positive value of b implies pessimistic bias (overestimation of default risk), while a negative value implies optimistic bias. If bias exists, consumers make insurance purchase decisions based not on the real default rate dr_t but on the biased default rate dr_b. This leads to a shift in the perceived demand curve. Figure 1 illustrates how the insurance demand curve changes in response to consumer bias.

We now consider the effect of bias on consumer surplus (CS). Let the equilibrium price and demand in the unbiased case be p^* and Q^*, respectively. If the consumer holds a pessimistic bias (i.e., overestimates default risk), the demand decreases to Q^{pb}, and the consumer surplus is reduced by area ①, which represents the loss due to foregone consumption at price p^*.

Conversely, if the consumer holds an optimistic bias (i.e., underestimates default risk), the demand increases to Q^{ob}, and the insurance price drops to p^{ob}. In this case, the marginal consumers—who would not have purchased the product in the unbiased case—enter the market, but they overpay relative to the true value of the product. As a result, consumer surplus is reduced by area ②, representing inefficient overconsumption.

〈Figure 1〉 Demand Curve with Biases.



Note: P*, Q*: Equilibrium price and demand without bias,
P^{pb}, Q^{pb}: Price and demand with pessimistic bias
P^{ob}, Q^{ob}: Price and demand with optimistic bias.

In both cases, bias leads to a welfare loss, either through reduced coverage (underconsumption) or inefficient overconsumption. This highlights the importance of accurate solvency perception and regulatory mechanisms that mitigate information asymmetry in insurance markets.

In other words, if there exists information asymmetry between insurers and consumers regarding the insurer's financial soundness, a welfare loss (WL) arises, corresponding to area ① or ② in Figure 1. This economic loss is formally defined as follows:

Definition 3. Welfare Loss Due to Information Asymmetry

When consumers hold biased perceptions about the insurer's solvency, the resulting welfare loss is defined as:

$$WL = (p^{*} - p^{'})Q(dr_{b,}, p^{*}) - \int_{p^{'}}^{p^{*}} Q(dr_{r}, p)dp \quad (4)$$

where p^{*} is the price without bias and p' is the price with bias.

This expression captures the misallocation of insurance consumption resulting from misinformation about insurer risk.

Next, we define CS as follows:

Definition 4. Consumer Surplus under Information Asymmetry

Consumer surplus (CS) under asymmetric information is defined as:

$$CS = \int_{p^{*}}^{\infty} Q(dr_{r}, p)dp - WL \quad (5)$$

This definition accounts for the utility loss due to price and risk misperception.

Protecting financial consumers is one of primary objectives of insurance regulation. Among various regulatory tools, risk-based solvency regulation plays a critical role in promoting this objective by addressing solvency-related information asymmetry. However, "consumer protection" is an inherently abstract and qualitative concept, making it difficult to evaluate regulatory effectiveness.

To overcome this limitation, the present study adopts consumer surplus (CS) as a proxy for consumer protection and welfare loss (WL) as a measure of regulatory inefficiency. This approach enables a quantitative evaluation of the welfare effects of solvency regulation under different consumer perception scenarios.

2. Insurer Model

We consider a single-period model of a representative insurance company based on the following assumptions:

(I1) The insurance company begins operations by investing capital at time 0.
(I2) The insurer has full knowledge of the consumer demand function and the degree of consumer bias b.
(I3) The insurer chooses the price and default rate to maximize shareholder value.
(I4) Operating costs (e.g., acquisition and administrative expenses) are incurred at time 0, and claims are paid at the end of the period.

Assumption (I1) implies that shareholders have limited liability. Assumptions (I2) and (C2) reflect the existence of asymmetric information between the insurer and the consumer. Assumption (I3) reflects the shareholder-driven objective of the insurer, while (I4) simplifies the timing structure of cash flows.

Since the real default rate is unobservable to the consumer (from C2), the insurer's choice of the actual default rate becomes a hidden action, creating potential for moral hazard.

We follow the model introduced by Schlütter (2014) and formalized in Stoyanova and Schlütter (2015), where the insurance company selects the product price and default rate to maximize shareholder profit using an option pricing framework.

2.1. Capital Valuation and Default Risk

Let At, Lt, and Ct denote the asset, liability, and equity capital of the insurer at time t = 0,1. At time 1, the value of equity capital is:

$$C_1 = \max(A_1 - L_1, 0) \tag{6}$$

where are asset, capital, and liability at times 0 and 1, respectively.

This can be rewritten as:

$$\begin{aligned} C_1 &= \max(A_1 - L_1, 0) \\ &= A_1 - L_1 + \max(L_1 - A_1, 0) \end{aligned} \tag{7}$$

The second term represents the insurer's net liability when the liabilities exceed assets, known in the literature as a default put option (DPO). Under risk-neutral valuation, the present value at time 0 becomes:

$$\begin{aligned} & E^N[C_1] = E^N[A_1 - L_1 + \max(L_1 - A_1, 0)] \\ & \Rightarrow C_0 = A_0 - L_0 + E^N[DPO] \\ & \Rightarrow C_0 = A_0 - L_0 + DPO_0 \end{aligned} \tag{8}$$

For simplicity, the risk-free rate, r_f is assumed to be zero. A_0, L_0, and DPO_0, are defined as the risk-neutral present values at time 0 for A, L, and DPO, respectively.

We define the default rate dr as the ratio of the value of the default put option to the nominal liability:

$$dr = \frac{DPO_0}{L_0} \tag{9}$$

where, since L_1, A_1 are random variables, DPO_0 can be regarded as an exchange option for L_1, A_1. Thus, Equation (9) can be expanded to Equation (10). For reference, the exchange option can be evaluated according to Margrabe's (1978) formula:

$$\begin{aligned} dr(s,\sigma) &= \frac{DPO_0}{L_0} = \frac{E^N[max\ (L_1 - A_1, 0)]}{L_0} \\ &= \frac{L_0\Phi(z) - A_0(z-\sigma)}{L_0} = \Phi(z) - s\Phi(z-\sigma) \end{aligned} \tag{10}$$

where $s = A_0/L_0$, $\sigma = \sqrt{\sigma_A^2 + \sigma_L^2 - 2\rho\sigma_A\sigma_L}$, $z = \frac{-\ln(s)}{\sigma} + \frac{\sigma}{2}$, $N(\cdot)$ is the cumulative standard normal distribution, σ_A is the standard deviation of the asset, σ_L is the standard deviation of the liability, and ρ is the correlation between the asset and the liability.

It should be noted that dr is not the default probability, but the default rate. According to Davis (2003), the probability of a default event at which the liability exceeds the asset at time 1 is given as follows:

$$PR(s) = \Phi(\hat{z})\ \ where\ \ \hat{z} = \frac{-\ln(s)}{\sigma} + \frac{(\sigma_A^2\ -\ \sigma_L^2)}{2\sigma} \tag{11}$$

Following Schlütter (2014), since *dr(s)* is a continuous and strictly decreasing function, its inverse function *s(dr)* exists and is also strictly decreasing. The default probability function *PR(s)* is a strictly decreasing function of s, because both the cumulative distribution function *Ø(·)* and *ln(s)* are strictly increasing. Consequently, since the default probability function *PR(s)* and the function *s(dr)* are both one-to-one monotonic mappings, the default probability PR and the default rate *dr* are in a one-to-one correspondence. Therefore, specifying the regulatory constraint in terms of the default probability is equivalent to specifying it in terms of the default rate.[1)]

2.2. Profit Maximization

At time 0, the insurer collects premiums and spends part of the initial capital on fixed costs. The total assets A_0 are:

$$A_0 = Qp + (1 - ct) \tag{12}$$

where p is the price of the insurance product, Q is the quantity based on the demand curve of the insurance product with price p and default rate dr, K is the initial capital, and ct is the rate of upfront cost and tax relative to K at time 0, according to Assumption (I4).

According to Schlütter (2014) and Stoyanova and Schlütter (2015), we can derive the following shareholder profit function using Equations (6) – (12). It should be noted that there exists an inverse function $s(dr,\sigma)$ for $dr(s,\sigma)$ because $dr(s,\sigma)$ is a continuous and monotone decreasing function.

Definition 5. Shareholder Profit Function

$$\Pi(dr,p) \;=\; Q(dr,p)\left[p - \mu(1-dr) - \frac{ct}{1-ct}(\mu s(dr,\sigma) - p)\right] \tag{13}$$

where , $\mu = L_0 / Q$ which means liability per insurance contract.

The insurance company selects the default rate and price to maximize the shareholder's profits defined in Definition 5. According to Schlütter (2014) and Stoyanova and Schlütter (2015), there is a closed solution considering

1) See Profit Maximization under Confidence-Level Solvency Constraint in Appendix 1.

consumer and insurance models altogether without regulation as follows:

$$s^* = G\left[\frac{f_d}{f_p t\mu}(1+b) - \frac{1-t}{t}\right] \tag{14}$$
$$p^* = \mu(1-dr_t) + t[\mu s(dr_t, \sigma) - \mu(1-dr_t)] + \frac{1}{f_p}$$
$$\Pi^* = \frac{Q[dr_t^*(1+b), p^*]}{f_p(1-t)}$$

where $G(x) = \exp(-\sigma\Phi^{-1}(\frac{1}{x}) - \frac{\sigma^2}{2})$.

V. Theory

In this section, we provide a theoretical analysis of how consumer bias affects economic efficiency and default rate outcomes under the insurer model presented in Section 4. It should be noted that no regulatory constraints are imposed at this stage, as the objective is to identify the fundamental rationale for introducing regulation.

1. Consumer Bias and Welfare Loss

We begin by examining the relationship between consumer bias and welfare loss. Intuitively, as consumer bias increases—whether due to greater optimism or pessimism—the areas corresponding to welfare loss (area ① or ② in Figure 1) expand. Formally, we define this relationship as follows:

Proposition 1: Let b denote consumer bias and WL^* the associated welfare loss. Then,

$$b = 0 \rightarrow DL = 0,\ b > 0 \rightarrow \frac{dWL^*}{db} > 0,\ b < 0 \rightarrow \frac{dWL^*}{db} < 0. \tag{15}$$

Proof: See the Appendix 2.

This result implies that the more biased the consumer's perception of the insurer's solvency, the greater the resulting welfare loss.

2. Consumer Bias and Default Rate Behavior

Next, we investigate how consumer bias affects the insurer's choice of the default rate under profit maximization. If consumers exhibit optimistic bias, they underestimate the default risk, which gives the insurer an incentive to increase the real default rate by taking on greater risk. Conversely, with pessimistic bias, the insurer has an incentive to reduce risk, since the perceived default rate is already high.

This distortion in insurer behavior, caused by biased demand rather than real solvency concerns, constitutes a moral hazard. We formalize this idea in the following proposition:

Proposition 2: Let dr_r^* denote the true profit-maximizing default rate. Then,

$$\frac{ddr_r^*}{db} < 0. \tag{16}$$

Proof: See the Appendix 2.

This implies that under optimistic bias ($b<0$), the insurer increases its true risk-taking, resulting in a higher default rate(dr_r), while under pessimistic bias ($b>0$), the insurer decreases its true risk-taking, resulting in a lower default rate(lower dr_r). It is important to note that, although the regulatory framework is formally defined in terms of the default probability rather than the default rate, the proposition is stated using the default rate without loss of generality. This is because, as established in Section 4.2.1, there is a one-to-one monotonic correspondence between the two measures, and thus the same result applies to the default probability. This correspondence will be used consistently in the subsequent analysis.

3. Relationship Between Default Rate and Welfare Loss

We now explore how the default rate influences welfare loss. As previously shown, welfare loss arises from a divergence between perceived and real solvency. If the actual default rate is reduced, the gap between biased and true demand narrows, thereby reducing welfare loss.

This intuition is formalized as follows:

Proposition 3: If b is not zero, $WL = 0 \leftrightarrow dr_r = 0$.

Proof: See the Appendix 2.

Proposition 4: If b is not zero, $\lim_{dr_r \to 0} WL^* = 0$.

Proof: See the Appendix 2.

From these results, we derive the following practical insight:

Theorem 1: There is a default rate threshold dr_h such that $WL^* < WL_l$ for any positive WL_l.

Proof: See the Appendix 2.

In other words, while it is impossible to eliminate welfare loss entirely due to information asymmetry, it is feasible to *control it below a tolerable level by limiting the insurer's default rate*. This has important regulatory implications.

4. Policy Implication: Justification for Risk-Based Regulation

The propositions and theorem presented in this study provide a theoretical rationale for adopting risk-based solvency regulation in the presence of optimistic bias in the market.[2)]

Under a solvency regulatory framework, an insurer becomes subject to supervisory intervention—such as regulatory action or seizure of managerial control—if it fails to satisfy regulatory requirements, including maintaining a solvency ratio of at least 100%. For insurers that can comfortably satisfy these requirements, the regulation is non-binding and does not affect managerial decisions. By contrast, insurers that are at risk of breaching regulatory thresholds must prioritize regulatory compliance in order to avoid intervention

2) Market participants are more likely to exhibit optimistic rather than pessimistic perceptions for the following reasons. First, rational consumers would not purchase insurance from an unsound company; therefore, those who remain in the market implicitly believe that the insurer is financially sound. Second, if insurers recognize the presence of consumer bias, they may reinforce optimistic perceptions through marketing or advertising strategies designed to signal financial strength. Finally, as noted by Stoyanova and Schlütter (2015), consumers are more likely to exhibit optimistic bias under normal market conditions.

(Lin et al., 2013). Accordingly, the maximum default rate—or, equivalently, the maximum default probability derived from equation (11)—serves as the final regulatory boundary that insurers must not exceed.

In the present model, the insurer chooses product prices and the default rate to maximize shareholder value. However, when the default rate that maximizes profits exceeds the regulatory limit implied by the confidence level, the regulation becomes binding, forcing the insurer to set its default rate at the regulatory maximum, consistent with the framework of Stoyanova and Schlütter (2015). In this case, the insurer optimizes only over product prices, subject to the regulatory constraint.

Proposition 1 establishes that consumer bias leads to a welfare loss. Proposition 2 further demonstrates that, under optimistic bias, insurers have incentives to increase their default probabilities beyond actuarially justified levels. This behavior constitutes a form of moral hazard, as insurers exploit biased consumer expectations to assume excessive risk.

Proposition 3 suggests that to enhance economic efficiency, it is necessary for regulatory authorities to manage insurers' default rates within a certain acceptable range. However, it is inherently difficult to manage insurers' default probabilities through traditional fixed-capital regulations, as such frameworks do not adequately account for variations in behavioral distortions such as optimistic bias.

In contrast, Theorem 1 supports the use of a risk-based solvency framework—particularly one based on a Value-at-Risk (VaR) approach—which enables regulators to control welfare loss below a tolerable level by limiting the insurer's default rate more effectively by adjusting solvency requirements in response to market volatility and consumer optimism. By contrast, fixed-amount solvency regulation lacks the ability to control welfare loss at a targeted level, making it an inadequate supervisory tool in environments characterized by consumer optimism.

Collectively, these findings offer a theoretical response to the first research question raised in Section 1: “Why should solvency regulation be based on a risk-sensitive framework rather than a fixed-amount framework? ”

Ⅵ. Numerical Analysis

1. Parameter Settings

The numerical analysis in this study adopts the baseline parameter values from Stoyanova and Schlütter (2015), who calibrate risk-related parameters based on empirically grounded studies in the insurance literature. Two key parameters are treated differently: the interest rate r and consumer bias b.

For analytical simplicity, the interest rate is set to zero (r_f=0). To explore how the insurer's behavior responds to varying degrees of consumer bias, we consider a range of b values: 0.6, 0, −0.3, −0.5, and −0.6, capturing both optimistic and pessimistic bias scenarios.

The full set of parameter values used in the numerical simulations is summarized in Table 1.

〈Table 1〉 Parameter Values for Models.

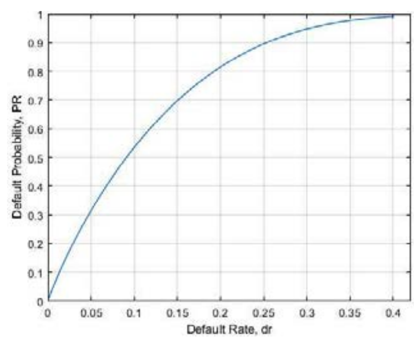
Consumer Model Parameters				Insurance Company Model Parameters					
f_p	f_d	n	B	A	L	ρ	ct	μ	R
0.015	14	10,000	0.6, 0, -0.3, -0.5, -0.6	5%	20%	0	5%	200	0

2. Numerical Illustration of Theoretical Results

In this section, we numerically illustrate the theoretical propositions and the main theorem derived in Section 5. The purpose of this analysis is to verify the model's predictions regarding the relationships among consumer bias, welfare loss (WL), and the insurer's default rate.

We begin by examining the relationship between the default probability and the default rate implied by equation (11). Figure 2 reports the numerical mapping between these two measures, showing that default probability and default rate are in a strictly increasing one-to-one relationship.

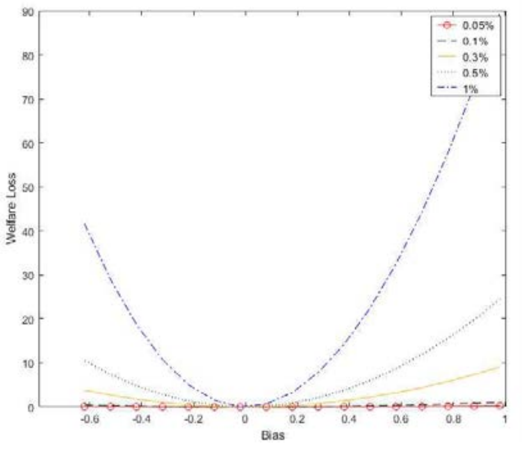
〈Figure 2〉 Relationship between Default Rate and Default Probability.



Next, we examine the relationship between welfare loss and consumer bias, as described in Proposition 1. Figure 3 presents the numerical relationship between WL and bias b for several given default rates. The plot confirms the theoretical result that as consumer bias increases (in either direction), the associated welfare loss also increases.

It is important to note that when the bias level becomes too negative (i.e., $b < -0.62$), the required initial capital to support the insurer's liabilities turns negative, which is not economically feasible. Therefore, in this analysis, the bias parameter is restricted to values greater than -0.62.

〈Figure 3〉 Relationship between Consumer Bias and Welfare Loss.



* Note: Values in box are real default rate of insurance company.

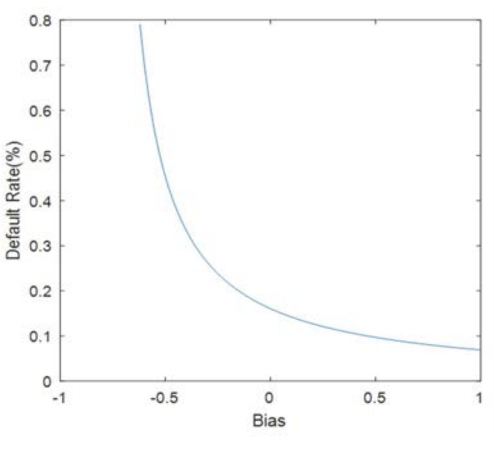
It is noteworthy that welfare loss (WL) is zero when the consumer bias b is zero, and increases as the absolute value of the bias rises, as shown in Figure 3. This numerical pattern is fully consistent with Proposition 1. Additionally, for a given level of bias, welfare loss approaches zero as the insurer's default rate approaches zero, which aligns with the result in Proposition 4.

Furthermore, the higher the real default rate, the greater the reduction in WL that can be achieved when consumer bias diminishes. This implies that if the default rate can be kept below a certain threshold through solvency regulation, WL can be maintained at a relatively low level—even in the presence of consumer bias. This observation supports the conclusion in Theorem 1, which suggests that solvency regulation can serve as an effective tool for limiting welfare inefficiency.

Figure 4 illustrates the relationship between consumer bias and the default rate that maximizes shareholder profit, as discussed in Proposition 2. When there is optimistic bias ($b<0$), the profit-maximizing default rate increases as the bias becomes more negative. Conversely, under pessimistic bias ($b>0$), the default rate decreases as the bias becomes more positive. These simulation results are fully consistent with the theoretical prediction in Proposition 2.

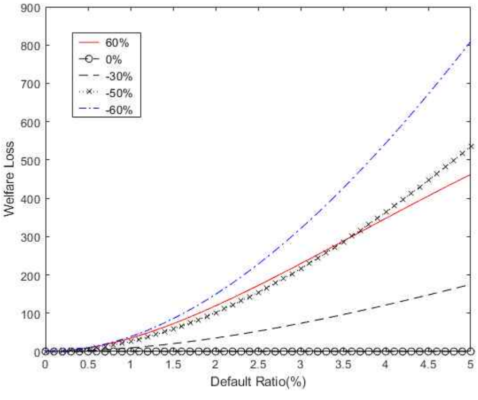
Importantly, Figure 4 also highlights a key implication: the more optimistic the consumer bias, the greater the insurer's incentive to raise the default rate, thereby exacerbating the moral hazard problem. This underscores the importance of risk-based solvency regulation as a policy mechanism to protect consumers, particularly in markets where solvency-related misperceptions are prevalent.

〈Figure 4〉 Relationship between Consumer Bias and Default Rate.



Finally, Figure 5 illustrates the relationship between the profit-maximizing default rate and welfare loss (WL), providing numerical validation for Propositions 3 and 4. The lines in the figure represent different levels of consumer bias, while the dotted lines with circles correspond to the case with no bias.

〈Figure 5〉 Relationship between Default Rate and Welfare Loss.



Notes: Value in the box: Consumer bias

When there is no bias (b=0), WL remains zero regardless of the default rate. This confirms the result in Proposition 1, which states that unbiased perception eliminates welfare loss irrespective of the insurer's behavior.

In contrast, under biased perception ($b \neq 0$), WL decreases as the default rate decreases, and it converges to zero as the default rate approaches zero. Moreover, WL is exactly zero when the default rate is zero. These results are fully consistent with Propositions 3 and 4, confirming that regulatory control over the default rate can mitigate the welfare consequences of consumer misperception.

3. Effects of Confidence Level on Consumer Protection

This section investigates how changes in the confidence level embedded in risk-based solvency regulation affect consumer protection when consumers hold biased perceptions of insurers' solvency risk.

To analyze these effects, we employ the same model structure and parameter values as in Section 6.1, varying only the confidence level that determines the regulatory threshold. Specifically, we consider confidence levels commonly used in practice—95%, 97.5%, 99%, 99.5%, and 99.9%—as well as an extreme case of 99.99%. These regulatory scenarios are evaluated against a benchmark case with no solvency regulation ("No Reg").

Under a VaR-based solvency framework, the regulatory confidence level is defined as 1 minus the default probability. Accordingly, an increase in the confidence level necessarily reduces the maximum permissible default probability. Given the one-to-one monotonic relationship between the default probability and the default rate, as established in Section 4.2.1, the optimal default rate likewise decreases as the regulatory confidence level increases.

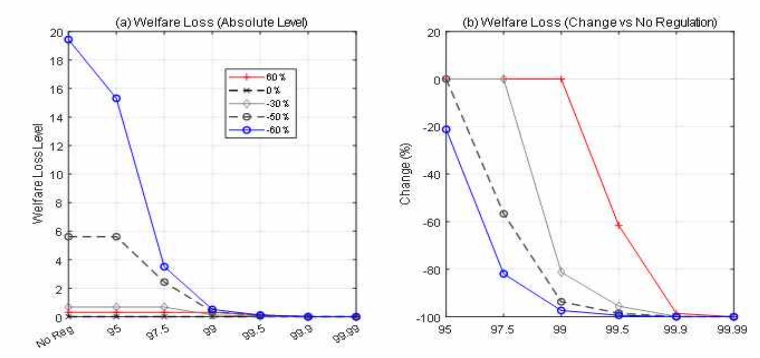
Before examining the effects on consumer surplus (CS), we first analyze welfare loss (WL) across confidence levels and degrees of consumer bias. WL, defined in equation (4), quantifies the efficiency loss that arises purely from biased consumer perception, independent of regulation itself. Therefore, changes in WL indicate how regulation indirectly improves welfare by correcting consumer misperception, not how it directly affects consumer surplus. The results are summarized in Table 2 and illustrated in Figure 6.

〈Table 2〉 Welfare Loss across Confidence Levels and Consumer Biases.

Confidence Level	Welfare Loss (units)					WL Levels Relative to No Reg(%)				
	60%*	0%	-30%	-50%	-60%	60%	0	-30%	-50%	-60%
No Reg	0.312	0	0.679	5.611	19.432	-	-	-	-	-
95.0%	0.312	0	0.679	5.611	15.312**	0	-	0	0	-21.2
97.5%	0.312	0	0.679	2.431	3.510	0	-	0	-56.7	-81.9
99.0%	0.312	0	0.127	0.354	0.511	0	-	-81.2	-93.7	-97.4
99.5%	0.12	0	0.03	0.084	0.12	-61.6	-	-95.6	-98.51	-99.38
99.9%	0.004	0	0.001	0.003	0.004	-98.6	-	-99.8	-99.9	-100.0
99.99%	0.000	0	0.000	0.000	0.000	-100.0	-	-100.0	-100.0	-100.0

Notes: * 60%, 0%, -30%, -50%, and -60% represent the levels of consumer bias.
** bold: Cases in which the solvency constraint binds.

〈Figure 6〉 Welfare Loss for Various Confidence Levels.



In the absence of regulation, WL equals 19.432 units under strong optimistic bias (b = −60%) and 0 under no bias (b = 0), showing that bias alone generates welfare inefficiency. Introducing a 95% confidence level reduces WL by 21.2%, indicating that even modest regulation can mitigate bias-induced inefficiency. As the confidence level increases, WL continues to decline and is nearly eliminated at the 99.9% level, consistent with Proposition 4.

Next, Table 3 and Figure 7 present how consumer surplus (CS) varies with the regulatory confidence level and consumer bias. In the absence of regulation, CS equals 10,673 under strong optimistic bias (b = −60%) and 11,052 under no bias, implying a 3.4% welfare reduction due to bias. Introducing a 95% confidence level slightly improves CS, and the upward trend continues until about 99%. However, beyond 99.5%, consumer surplus begins to decline, and at 99.99%, it falls below the no-regulation benchmark, particularly under optimistic or mildly pessimistic bias.

This pattern reflects an important distinction between WL and CS. Although higher confidence levels monotonically reduce WL—by mitigating moral hazard and improving solvency discipline—they simultaneously tighten insurers' capital constraints, reducing allocative efficiency and, eventually, consumer surplus. Hence, WL captures the potential efficiency gain from bias correction, whereas CS captures the net welfare outcome after accounting for both regulatory benefits and capital cost effects. In other words, while the reduction in WL represents the theoretical efficiency improvement achieved through stricter regulation, the change in CS reflects the practical welfare consequences once capital constraints are taken into account.

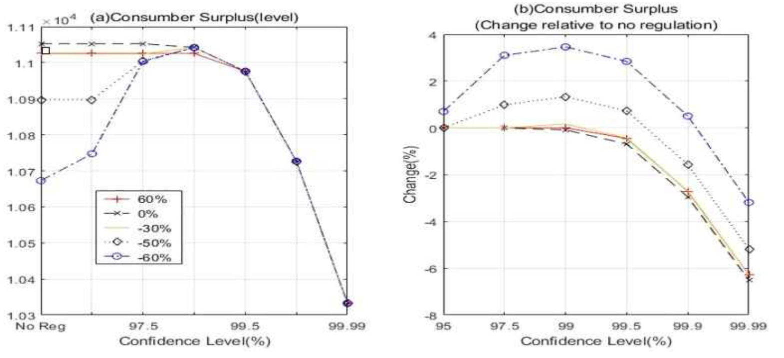
Building on this distinction, these results imply that a tightening of solvency regulation can enhance consumer surplus by monotonically reducing welfare loss (WL), as shown in Figure 6. However, excessively stringent regulation may impose binding capital constraints on insurers. This highlights an important trade-off between solvency protection and consumer welfare. Accordingly, the confidence level in solvency regulation should be viewed not merely as a technical calibration parameter, but as a normative policy instrument for balancing the behavioral inefficiencies arising from consumer misperception against the economic costs associated with reduced consumer welfare.

〈Table 3〉 Consumer Surplus across Confidence Levels and Consumer Biases.

Confidence Level	Consumer Surplus(units)					CS Levels Relative to No Reg(%)				
	60%*	0%	-30%	-50%	-60%	60%	0	-30%	-50%	-60%
No Reg	11,025	11,052	11,024	10,897	10,673	-	-	-	-	-
95.0%	11,025	11,052	11,024	10,897	10,747**	0.00	0.00	0.00	0.00	0.70
97.5%	11,025	11,052	11,024	11,005	11,004	0.00	0.00	0.00	0.99	3.10
99.0%	11,025	11,043	11,042	11,042	11,042	0.00	-0.09	0.17	1.33	3.46
99.5%	10,976	10,976	10,976	10,976	10,976	-0.45	-0.69	-0.44	0.72	2.84
99.9%	10,727	10,727	10,727	10,727	10,727	-2.71	-2.95	-2.70	-1.57	0.51
99.99%	10,332	10,332	10,332	10,332	10,332	-6.29	-6.52	-6.28	-5.18	-3.19

Notes: * 60%, 0%, -30%, -50%, and -60% represent the levels of consumer bias.
** bold: Cases in which the solvency constraint binds.

〈Figure 7〉 Consumer Surplus for Various Confidence Levels.



Note: Numbers in the box are consumer bias.

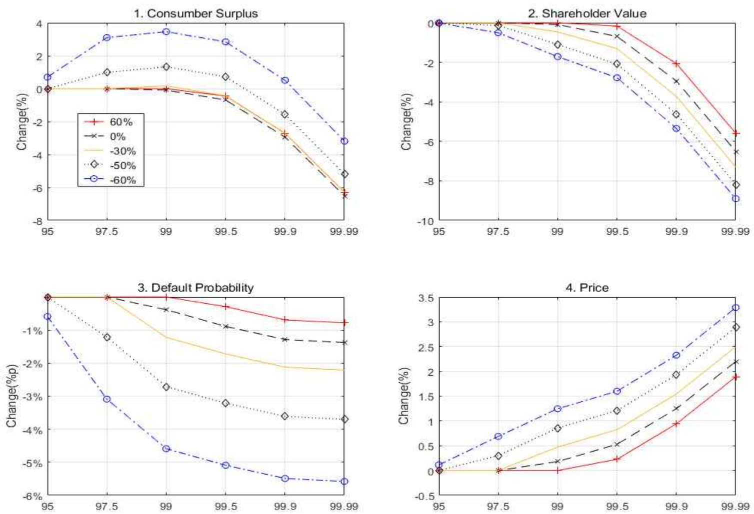
To further explore the trade-off, Figure 8 presents the joint dynamics of consumer surplus, shareholder profit, default probability, and insurance premium across different confidence levels.[3] As the confidence level increases, the insurer's default probability declines, which has a positive effect on consumer surplus. However, higher confidence levels also lead to increased insurance premiums, which reduce CS.[4] Therefore, the overall effect of tighter solvency regulation is determined by the balance between the benefits of lower risk and the costs of higher prices.

While the strengthening of risk-based capital regulation is generally expected to alleviate moral hazard by insurers and enhance consumer welfare, this study highlights an important counteracting mechanism: stricter regulation requires insurers to hold more capital, which raises capital costs. If these costs are passed on through higher premiums, the result may be a decline in consumer surplus.

3) See the joint dynamics of the default probability, default rate, and price under the optimization with the confidence-level solvency constraint in Appendix 1.

4) See the mathematical proof of Proposition 5 in Appendix 2, which shows that increased biased insurance premiums reduce consumer surplus (CS).

〈Figure 8〉 Consumer Surplus, Shareholder Profit, Default Probability, and Price for Various Confidence Levels.



In other words, increasing the confidence level generates two opposing effects: it promotes welfare by mitigating moral hazard, yet simultaneously reduces welfare due to higher capital costs. At relatively low confidence levels, the positive effect of reduced moral hazard tends to dominate, leading to an increase in CS. However, beyond a certain threshold (e.g., above 99.5%), the welfare loss from premium increases becomes more pronounced, resulting in a decline in CS. This policy trade-off constitutes one of the key academic contributions of this study.

In conclusion, these results suggest that regulators should strike a balance between ensuring solvency and maintaining consumer surplus. When optimistic consumer bias is present, moderately stricter regulation can help correct misperceptions, reduce moral hazard, and improve overall welfare. However, excessively high confidence levels—such as 99.99%—may reduce both consumer surplus and shareholder profit, even in the presence of significant consumer bias.

These findings provide a direct answer to the second research question posed in Section 1:

“Will the tightening of risk-based solvency regulation improve consumer protection?” The numerical analysis demonstrates that while moderate tightening is effective in enhancing consumer protection, excessive regulation may ultimately be counterproductive. This conclusion is aligned with Lorson et al. (2012), who find that the implementation costs of Solvency II—calibrated at a 99.5% confidence level—may outweigh its consumer-side benefits.

Ⅶ. Conclusion

This study applies the model developed by Stoyanova and Schlütter (2015) to examine the welfare implications of risk-based solvency regulation under biased consumer perceptions.

The analysis highlights several key insights. First, the study demonstrates how welfare loss (WL) arises when consumers misperceive the solvency of insurance companies. Consumer bias leads to over- or under-consumption of insurance products, thereby reducing overall efficiency. Importantly, when consumers underestimate default risk due to optimistic bias, insurers are incentivized to take on excessive risk, increasing the default rate. This behavior reflects a form of moral hazard, which in turn amplifies welfare loss. Thus, consumer bias not only reduces efficiency but also distorts insurer incentives.

Second, the analysis shows that risk-based solvency regulation is an effective policy tool to mitigate these inefficiencies. By imposing an upper limit on default risk—typically defined through a confidence level—such regulation constrains the insurer's risk-taking behavior, thereby limiting welfare losses caused by moral hazard.

In addition, this study suggests that public disclosure may serve as a useful complementary tool to solvency regulation. While risk-based capital requirements directly influence insurer default risk, improved transparency could help reduce consumer bias indirectly. As indicated by Proposition 1, mitigating bias can lower welfare loss. Therefore, combining direct regulatory measures with indirect approaches such as disclosure may enhance overall effectiveness.

Third, the study explores whether tighter solvency regulation always enhances consumer protection. The findings suggest that while tightening regulation can be beneficial in the presence of optimistic bias—by lowering default rates and improving consumer surplus (CS)—excessive tightening may backfire. When the confidence level is too high, the resulting increase in premiums can outweigh the benefits of reduced default risk, thereby lowering CS even in the presence of bias.

Consequently, this study shows that consumer misperception of insurer solvency leads to moral hazard and welfare loss. Risk-based solvency regulation serves as an essential tool for reducing these inefficiencies by limiting default probability. However, regulators must be aware that overly stringent regulation can reduce consumer surplus, thus weakening its protective function. Therefore, the effectiveness of risk-based solvency regulation depends on striking a balance, tailoring its stringency to market conditions and the degree of consumer bias.

These findings underscore that solvency regulation is not a one-size-fits-all policy instrument. Instead, effective regulation must take into account market conditions, consumer behavior, and the trade-offs between financial soundness and consumer surplus. In particular, the confidence level—often treated as an exogenously fixed number in practice—is shown here to have profound implications for consumer welfare when endogenized within a behavioral framework. By demonstrating the non-monotonic welfare effects of confidence level variation, the paper contributes to the normative literature on optimal regulatory stringency under informational imperfections. Therefore, regulators would do well to these insights into account when designing risk-based solvency frameworks.

As a direction for future research, it should be noted that the quantitative findings presented in this paper are derived under specific parameter assumptions from Stoyanova and Schlütter (2015). Acknowledging the limitations of these parameter settings, future studies could yield more meaningful results by calibrating the model with empirical data from the Korean market or by comparing outcomes across a range of plausible parameter values. In particular, it would be valuable to explore empirical methods for assessing how consumers perceive insurer solvency in real-world contexts. Developing robust estimation strategies or survey-based instruments to measure this bias could significantly enhance the model's applicability for policy design

(Appendix 1) Profit Maximization under Confidence-Level Solvency Constraint.

1. Profit Maximization Constraint

The insurer chooses price p and default ratio dr to maximize expected profit:

$$\max_{(dr,p)} \Pi(dr,p)$$

subject to the regulatory solvency requirement:

$$PR(s(dr)) \leq PR^{\max}(\alpha) = 1-\alpha$$

where $s(dr)$ denotes the asset-liability ratio implied by the chosen default rate dr.

Since both $PR(s)$ and $dr(s)$ are strictly monotonic in s (see Equation (11)), the constraint on default probability is equivalently expressed as:

$$dr(s) \leq dr^{\max}(\alpha)$$

where $dr^{max}(\alpha)$ denotes the maximum allowable default rate consistent with the regulatory constraint at confidence level α. Note also that because $dr(s)$ is a continuous and strictly monotonic function of s, its inverse function $s(dr)$ exists and is strictly monotonic. Therefore, the confidence level α directly determines the feasible set of (p,dr) available to the insurer.

Because a higher confidence level reduces the regulatory upper bound on default probability, and this bound maps monotonically into the maximum feasible default rate $dr^{max}(\alpha)$, the set of admissible (p,dr) satisfying the solvency constraint becomes strictly smaller as α increases. Therefore, the feasible region shrinks monotonically, implying lower optimal default rates and equilibrium prices under tighter regulation.

2. Joint Dynamics of Default Probability, Default Rate, and Price

Table A1 reports how the regulatory confidence level shapes the insurer's feasible default rate and the resulting equilibrium outcomes, using the same parameter settings as Section 6. For each confidence level α, the regulation imposes a maximum allowable default probability $PR^{max}=1-\alpha$, which is then mapped into the corresponding maximum default rate dr^{max} through the monotonic relationship between $PR(s)$ and $dr(s)$. As the confidence level increases from 95% to 99.99%, the regulatory upper bound on default probability falls sharply—from 5.00% to 0.01%—and the associated maximum default rate declines monotonically from 0.62% to effectively zero.

In the absence of regulation, the insurer chooses a default rate of dr*=0.28%, which maximizes its expected profit given the consumer bias of −60%. When the regulation is introduced, the insurer's chosen default rate is forced to become $\min\{dr^*, dr^{max}(\alpha)\}$.

As shown in Table A1, for relatively low confidence levels (95% and 97.5%) the regulatory threshold does not bind, so the insurer continues to choose the unconstrained optimum dr*=0.28. However, once the confidence level reaches 99% and above, the regulatory constraint becomes binding, forcing the insurer to reduce its default rate in line with the regulatory maximum: 0.11 at 99%, 0.06 at 99.5%, 0.01 at 99.9%, and 0.001 at 99.99%.

This tightening of the feasible set directly affects equilibrium prices. Since the insurer must lower its default risk to satisfy the higher confidence requirement, the premium increases to compensate for the reduced expected default margin. Accordingly, the regulated equilibrium price rises from 270.9 under loose regulation to 277.8 at the 99.99% confidence level.

〈Table A1〉 Default Rates Across Confidence Levels (Consumer Biase = −60%)

Confidence Level(%)	PR^{max}(%)	dr^{max}(%)	dr(%)		price(units)	
			No Reg	With Reg	No Reg	With Reg
95.0	5.00	0.62	0.28	0.28	270.9	270.9
97.5	2.50	0.30	0.28	0.28	270.9	270.9
99.0	1.00	0.11	0.28	0.11*	270.9	272.3
99.5	0.50	0.06	0.28	0.06	270.9	273.3
99.9	0.10	0.01	0.28	0.01	270.9	275.2
99.99	0.01	0.001	0.28	0.001	270.9	277.8

Note: * bold: Cases in which the solvency constraint binds.

(Appendix 2)

Mathematical Proof

> **Proposition 1**: For consumer bias b and welfare loss WL^*,
>
> $$b = 0 \rightarrow WL^* = 0,\ b>0 \rightarrow \frac{d\,WL^*}{db} > 0,\ b<0 \rightarrow \frac{d\,WL^*}{db} < 0.$$

Proof) Note that by definition $Q(dr_r, p') = Q(dr_b, p^*)$ where p^* is the price without bias and p' is the price with bias.

Then, $Q(dr_r, p') = Q(dr_b, p^*)$

$$\Rightarrow ne^{-f_d dr_r - f_p p'} = ne^{-f_d(1+b)dr_r - f_p p^*}$$

Since exponential function is monotonic increasing and one-to-one function, we can expand as follows:

$$\Rightarrow -f_d dr - f_p p' = -f_d(1+b)dr_r - f_p p^*$$

$$\Rightarrow p^* - p' = -\frac{f_d b\,dr}{f_p}$$

And $\int_{p'}^{p^*} Q(dr_r, p)dp$

$$= ne^{-f_d dr}\left[-\frac{1}{f_p}\left(e^{-f_p p^*} - e^{-f_p p'}\right)\right]$$

$$= -\frac{1}{f_p}Q(dr_r, p^*) + \frac{1}{f_p}Q(dr_r, p')$$

$$= -\frac{1}{f_p}Q(dr_r, p^*) + \frac{1}{f_p}Q(dr_b, p^*)$$

Then, by definition

$$WL = \frac{1}{f_p}Q(dr_r, p^*) - \frac{(1 + f_d b\,dr_r)}{f_p}Q(dr_b, p^*)$$

$$= \frac{1}{f_p}\left(ne^{-f_d dr_r - f_p p^*} - (1 + f_d b\,dr_r)ne^{-f_d(1+b)dr_r - f_p p^*}\right)$$

Then, if b is zero, WL is zero obviously. That is, $b=0 \rightarrow DL=0 \rangle 0$.

And

$$WL^* = \frac{1}{f_p}(ne^{-f_d dr_r - f_p p^*} - (1+f_d b dr_r)ne^{-f_d(1+b)dr_r - f_p p^*})$$

$$\Rightarrow \frac{dWL^*}{db} = \frac{1}{f_p}(-f_d dr_r ne^{-f_d(1+b)dr_r - f_p p^*} - (1+f_d b dr_r)(-f_d dr_r)ne^{-f_d(1+b)dr_t - f_p p^*})$$

$$= \frac{-f_d dr_r ne^{-f_d(1+b)dr_r - f_p p^*}}{f_p}(1-1-f_d b dr_r)$$

$$= \frac{(f_d dr_r)^2 ne^{-f_d(1+b)dr_r - f_p p^*}}{f_p} b$$

Since $\frac{(f_d dr_r)^2 ne^{-f_d(1+b)dr_r - f_p p^*}}{f_p} \rangle 0$, $b \rangle 0 \rightarrow \frac{dWL^*}{db} > 0, b < 0 \rightarrow \frac{dWL^*}{db} \langle 0.$

Proposition 2: For consumer bias b and default rate dr^* which is the default rate to maximize shareholder profit, $\frac{ddr^*}{db} \langle 0.$

Proof) We can expand as follows: $\frac{ddr^*}{db} = \frac{ds^*}{db}\frac{ddr^*}{ds^*}.$

According to Schlütter (2014) the following equation holds, which means

$$\frac{ddr}{ds} = -\Phi\left(-\frac{1}{\sigma}\ln(s) - \frac{\sigma}{2}\right).$$

Then, $\frac{ddr}{ds} < 0$

And Eq. (14) can be re-written as follows:

$$s(b) = \exp(-\sigma\Phi^{-1}(\frac{1}{x}) - \frac{\sigma^2}{2}) \quad where \quad x = \frac{f_d}{f_p t\mu}(1+b) - \frac{1-t}{t}$$

Then,

$$\frac{dx}{db} = \frac{f_d}{f_p t\mu}$$

$$\frac{ds^*}{dx} = \frac{\sigma}{x^2}\phi^{-1}\left(\frac{1}{x}\right)s^*(b) \quad \text{by chain-rule}$$

Then,

$$\frac{ds^*}{db} = \frac{dx}{db}\frac{ds^*}{dx} > 0 \text{ since } \frac{dx}{db} > 0 \text{ and } \frac{ds^*}{dx} > 0$$

Finally,

$$\frac{ddr^*}{db} = \frac{ds^*}{db}\frac{ddr^*}{ds^*} < 0 \text{ since } \frac{ds^*}{db} > 0 \text{ and } \frac{ddr}{ds} < 0.$$

Proposition 3: If b is not zero, $WL = 0 \leftrightarrow dr_r = 0$.

Proof)

From Proposition 1,

$$WL = \frac{1}{f_p}(ne^{-f_d dr_r - f_p p^*} - (1 + f_d b dr_r)ne^{-f_d(1+b)dr_r - f_p p^*})$$

Then,

$$WL = 0$$
$$\Leftrightarrow \frac{1}{f_p}(ne^{-f_d dr_r - f_p p^*} - (1 + f_d b dr_t)ne^{-f_d(1+b)dr_r - f_p p^*}) = 0$$
$$\Leftrightarrow e^{f_d b\, dr_r} = 1 + f_d b\, dr_r$$
$$\Leftrightarrow f_d b\, dr_r = 0$$
$$\Leftrightarrow dr_r = 0.$$

Proposition 4: If non-zero b is given, $\lim_{dr_r \to 0} WL^* = 0$

Proof)

From Proposition 1,

$$WL\,(dr_t) = \frac{1}{f_p}(n e^{-f_d dr_t - f_p p^*} - (1 + f_d b\, dr_t) n e^{-f_d(1+b)dr_t - f_p p^*})$$

Note that WL is continuous function at =0 since exponential function is continuous.

Then, for given non-zero b,

$$\lim_{dr_t \to 0} WL^*(dr_t) = WL(0) = \frac{1}{f_p}(n e^{-f_p p^*} - n e^{-f_p p^*}) = 0.$$

Proposition 5: Increased biased insurance premiums reduce consumer surplus.

Proof) By defintion,

$$CS = \int_{p^*}^{\infty} Q(dr_r, p)dp \; - \; WL \text{ and } WL = (p^* - p^{'})Q(dr_b, p^*) - \int_{p^{'}}^{p^*} Q(dr_t, p)dp$$

where p^* is the price without bias and p' is the price with bias.

Note $Q(dr_r, p') = n e^{-f_d dr_r - f_p p'}$.

From Proposition 1,

$$CS = \int_{p^*}^{\infty} Q(dr_r, p)dp \; - \; (p^* - p^{'})Q(dr_b, p^*) + \int_{p^{'}}^{p^*} Q(dr_t, p)dp$$
$$= \int_{p^*}^{\infty} Q(dr_r, p)dp \; - \; (p^* - p^{'})Q(dr_b, p^*) - \frac{1}{f_p}Q(dr_r, p^*) + \frac{1}{f_p}Q(dr_r, p')$$

The first and third terms do not contain p', so they are eliminated when taking the partial derivative with respect to p'.

Then, $\frac{dCS}{dp'} = -Q(dr_b, p^*) - Q(dr_r, p') < 0.$

Theorem 1: There is a default rate threshold dr_h for dr_r such that $WL^* \langle WL_l$ for any positive WL_l.

Proof)

From Proposition 1,

$$WL = \frac{1}{f_p}\left(ne^{-f_d dr_r - f_p p^*} - (1 + f_d b dr_r) ne^{-f_d(1+b)dr_r - f_p p^*}\right)$$

$WL(dr_r)$ is continuous function at =0 because exponential function is continuous. Then, for every $\epsilon > 0$, there a δ such that $dr_r < \delta$ implies $WL^*(dr_r) < \epsilon$.

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초 록

소비자 인식 편향하의 보험회사 지급여력 규제

이상진[1)]

본 연구는 소비자가 보험회사의 건전성에 대해 편향된 인식을 가질 경우, 소비자 보호의 관점에서 현대적인 위험기반(risk-based) 지급여력 규제의 필요성과 그 경제적 효과를 분석하였다. 이를 위해 기존 문헌에서 널리 활용되어 온 옵션가격모형(option pricing model)을 적용하고, 보험 가입자가 보험회사의 지급여력 수준을 과대평가하거나 과소평가할 수 있다는 인식 편향(biased perception)을 모형에 반영하였다. 소비자 보호 수준은 소비자잉여(consumer surplus)와 후생손실(welfare loss)을 통해 평가하였다.

분석 결과, 소비자의 인식 편향은 보험회사로 하여금 도덕적 해이를 유발할 수 있으며, 이는 궁극적으로 사회적 후생의 손실로 이어질 수 있는 것으로 나타났다. 이러한 상황에서 위험기반 지급여력 규제는 후생 손실을 완화할 수 있는 효과적인 정책 수단으로 작용하였다. 그러나 지나치게 엄격한 규제는 자본비용 상승을 초래하여 보험료 인상으로 이어지고, 그 결과 소비자잉여가 감소함으로써 오히려 소비자 후생에 부정적인 영향을 미칠 수 있음이 확인되었다.

결론적으로, 위험기반 지급여력 규제는 소비자의 인식 편향이 존재하는 상황에서 유용한 감독 수단이 될 수 있으나, 지급여력 보장과 소비자 후생 간의 균형을 고려하여 규제 강도를 신중하게 조정할 필요가 있다. 이러한 균형적 접근은 건전성과 후생 간의 정책적 절충(trade-off)을 이해하고, 효율적인 규제체계를 설계하는 데 이론적 근거를 제공한다.

국문색인어: 위험기반 지급여력 규제, 소비자 편향, 신뢰수준, 규제 효율성, 소비자 잉여

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