RETROSPECTIVE RATING METHOD AND LOSS CONTROL INCENTIVE FOR INSURANCE

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摘 要

追溯費率法(retrospective rating)乃是一種直接反應被保人當期損失經驗之定價方式，在此方式下發生損失較少之被保人將可繳交較少之保費。它是一種結合危險自留基金與保險二者之優點的費率方法，並且具有刺激損失控制之效果。目前在保險實務上雖已受到重視並應用於某些責任險保單，然而保險學術研究尚未證實它是否爲一最佳費率模式，本文之目的即在於探討此一問題。本文之研究方法乃是採用代理理倫(principal-agent framework)分析保險人對被保人之保費誘因與提高損失控制之效果二者間之關聯性，以確定追溯費率是否爲最適定價模式。根據本文研究發現：(1)若損失控制之努力可以辨識，則追溯費率並非最適定價方式；(2)反之，若因保險人與被保人間資訊不對稱而造成損失控制之努力無法辨識，則追溯費率乃是最適定價方式。

Abstract

Retrospective rating is a loss-sensitive rating plan, which allows an insured with favorable loss experience to pay less for insurance. It combines the cash flow advantages of self-funding with the advantages of an insured program. Although retrospective rating has been widely applied in practice, the fundamental question whether it can be an optimal rating mechanism is not yet addressed in insurance literature. The purpose of this paper is to examine this question by using the principal-agent framework. The findings of this paper suggest: (1) at the absence of moral hazard problems, the retrospective rating cannot be the first-best optimal scheme, and (2) the retrospective rating is the second-best optimal mechanism when there are moral hazard problems.

I. Introduction

Most financial planning experts agree that the most basic element of each financial plan is the establishment and maintenance of a sound program of risk management. The practice of risk management is not really an option. Both the individuals and the firms need merely to exist to face exposures to loss. Historically insurance has been

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the chief focus of attention for risk management. However, traditional insurance programs become too expensive or not available for the firms since 1970's, especially for liability insurance (Snider, 1991).

Several alternatives of risk financing have been widely applied by the firms to replace the traditional insurance. For example, self-funding plans are one of the solutions to soaring insurance costs (Franklin, 1992). The firms desire to improve control of their own funds in order to make more efficient use of their financial resources, instead of simply surrendering a predetermined premium and waiting to perhaps collect some indemnity payments for losses.

Insurers have sought to respond to these insureds' wishes by designing various risk financing plans which combine retention with transfer. The major revisions in these plans include (1) some differing premium payments, (2) establishing loss-sensitive rating systems, and (3) allowing the insureds to participate in investment earnings (Head, 1988).

Rate-making is one of the most important functions in insurance because it reflects the costs of risk transfer between the insurer and the insured. Several types of rating method have been applied in property-liability insurance industry, such as class rating, individual rating, and merit rating (Webb and et al 1984). Merit rating plans are a compromise between class rates and individual rates in order to achieve two objectives: (1) to encourage loss control, and (2) to match the premium charged more precisely to the insured's loss experience.

Merit rating plans are frequently applied in liability insurance to reflect the credit for loss control efforts of the insured. One of the well-known merit rating plans is the retrospective rating plan. The final premiums charged under retrospective rating method are based on the insured's loss experience during that policy period, thus the rate is more responsive to the insured's own experience than other rating plans.

Retrospective rating now is widely considered in risk management for several fields of liability insurance, e.g., workers' compensation (Bork, 1989). It is also applied by some health institutions to control long term care cost (Sielicki, 1989). D'Arcy and Herricks (1989) suggest that combining retrospective rating with biological monitoring techniques may make prices to reflect loss exposures more accurately in pollution insurance.

Although retrospective rating has been widely applied in practice, the fundamental question whether it can be an optimal rating mechanism is not yet addressed in insurance literature. The purpose of this paper is to examine this question by using the principal-agent framework. The findings of this paper suggest: (1) at the absence of moral hazard problems, the retrospective rating cannot be the first-best optimal scheme,

and (2) the retrospective rating is the second-best optimal mechanism when there are moral hazard problems.

The paper proceeds as follows. The basic concept of retrospective rating is introduced in section II and the model is presented in section III. In section IV this paper discusses the first-best solution by assuming observable loss-control effort, and the second-best solution under the assumption of unobservable loss-control effort is derived in section V. The conclusion and suggestion are provided in section VI.

II. Retrospective Rating Plan

Retrospective rating is a loss-sensitive rating plan, which allows an insured with favorable loss experience to pay less for insurance. It combines the cash flow advantages of self-funding with the advantages of an insured program. That is, in retrospective rating plan, (1) the use of funds that otherwise would initially be paid out as insurance premiums and (2) investment earnings on loss reserves are characteristics of risk retention. On the other hand, the limit on risk financing costs if loss experience is adverse, is an insurance element.

Under retrospective rating plans the insured's premiums for coverage during a policy period are based on the insured's actual loss experience. The insurer charges the insured a basic premium plus the cost of claims and claim adjusting expenses incurred during that policy period. The rating formula is presented as equation (1) (Head, 1988).

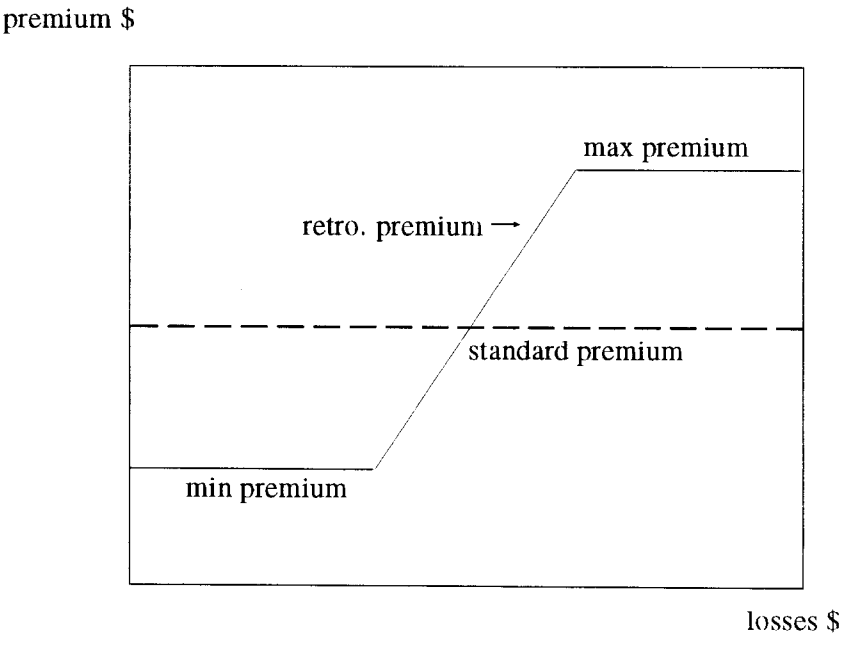
$$P = (BP + CL + XLP) * (1 + T) \quad (1)$$

where, P = retrospective premium
BP = basic premium, representing the fixed costs of insurer for administrative expenses and broker commissions
CL = converted losses, which equal incurred (paid) losses plus related claim adjusting expenses
XLP = a charge for limiting losses to a mximum amount on a per occurrence (claim) basis that will be loaded in the retrospective premium.
T = tax multiplier, a composite of charges for premium tax, licenses, fees, and mioscellaneous charges

In a retrospective rating program the insured is responsible for all claims below a

certain threshold, K dollars. At the beginning of policy period the insured paid a "standard premium" based on the average losses. If the insured's loss experience is better than the average, the insurer must refund him some of the premiums. Otherwise, the insured is obliged to pay additional premiums. Periodically the insured reimburses the insurer for claims that are paid for losses under the K dollars retention limit. Therefore, subject to a maximum and a minimum premium, the final premium varies directly with insured's loss experience of that policy period. Carris (1993) provides several numerical examples which help to understand the mathematics of retrospective rating. Nonetheless the basic concept of a retrospective rating plan can be shown as figure 1.

Figure 1.
The Operation of a Retrospective Rating Plan



III. The Model

Although there are cash flow advantages of using retrospective rating, it is not known whether it is an optimal scheme for insurance rate-making decision. To investigate this question we apply the methodology based on the principal-agent framework, such as Holmstrom (1979) and Lambert (1986). However, it is different

from conventional principal-agent problem because the principal (the insurer) in this paper is not a residual claimer. In stead, the insurer is designing a mechanism to maximize the utility of the insured under the fair rate assumption.

Based on the usual assumption of concave utility function, this paper consider a risk averse insured with utility function U,

$$U = \sqrt{W - S} \ ,$$

where W is the initial wealth of the insured and S is the insurance premiums charged by the insurer. We assume that the insured faces the risk that he will suffers a loss of X if there is an accident incurred with probability P. However, the probability is affected by the insured's action. If he takes a loss control effort, the probability of accidents is P_l, otherwise the probability of accident is P_n. The problem is meaningful only if $P_n > P_l$. The disutility of the insured from exerting a loss prevention effort is V which is separable from U, the utility from net wealth.

We assume that the insurer is risk neutral and applies the fair rate principle in determining the premiums such that S = PX. According to the fair rate principle, the insurer always has a zero expected profit.[1] Therefore, the insurer is designing a rating policy to maximize the insured's utility in order to attract the potential buyers instead of its own expected profits. This is different from the conventional agency models where the principal is always assumed to maximize his profit or utility.

In addition to maximizing the insured's utility, the insurer also wants the rating policy can induce the insured to take a loss control effort by himself. As the claim costs are soaring in recent years, loss control receives great attention in modern risk management. Nowadays most insurance mechanism designs include an incentive for loss control (Head, 1989).

The moral hazard problem of the insured always obscures an insurance system. Because the aleatory characteristics of insurance contract, the insured may intentionally or unintentionally increase the frequency and/or severity of losses[2]. Moral hazard

[1] In practice, the insurer is allowed to charge a premium loading for his profit which usually is a constant proportion of the net premium. Since the constant profit loading does not affect the analysis, in theory we only consider the net premium. The expected profit under net premium is zero because net premium is equal to the expected losses.

[2] A number of definitions have been cited for moral hazard. In insurance literature (e.g., Dorfman, 1991) definition of moral hazard strictly refers to the intentional increase of losses in order to collect insurance proceeds. The unintentional increase of losses due to a careless attitude after buying insurance is called morale hazard. Besides, the physical condition which increases the loss frequency and/or severity is called physical hazard. In economic analysis, however, a simpler view is taken. Moral hazard may be defined as that condition that exists in a risk, either physically or mentally, which is a departure from standards of the society and in turn increases the likelihood of loss (Borch, 1990). For the analytic purpose, this paper follows the definition used in economics.

mainly concerns the utmost good faith of the insured and therefore is dependent on his character and business integrity. Due to the asymmetric information between the insurer and the insured, it is difficult to distinguish the risk classification among the insureds at the moment of selling insurance. Therefore, the insurer's ratemaking decision must include an incentive for loss control effort of the insured.

IV. First-best Solution, Loss Control Effort Observable

If the insured's effort to prevent loss is observable, there is no incentive or moral hazard problem because the insurer can directly use P_i to compute the premium and penalizing the insured ex post if observing that he did not take the loss prevention effort according to the agreements signed. Although the penalty is imposed ex-post, it shall not be considered as a retrospective rating method. Under the retrospective rating method, the ex-post premium is adjusted according to the actual losses, not the action or behavior of the insured. When the loss prevention effort is observable, the insured is immuine to the penalty as long as he takes the loss prevention action. However, the loss prevention effort does not guarantee no ex-post premium adjustment as long as the incurred loss probability is not zero. Even though the loss prevention effort or action is observable, the insurer still needs to determine the rating policy under the fair rate principle to maximize the insured's utility as program 1.

Program 1:

$$\underset{S_1,\ S_0}{Max}\ P_i\ \sqrt{W - S_1}\ + (1 - P_i)\ \sqrt{W - S_0} - V$$

s.t.

$$P_i S_1 + (1 - P_i)\ S_0 = P_i X \qquad (2)$$

In Program 1, S_1 refers to the premium charged by the insurance company if the accident occurs and S_0 refers to the premium charged if there is no accident. V is the disutilities of exerting the loss prevention effort, which can also be viewed as the cost of loss control. The objective function of Program 1 states that the insurer (principal) intends to design a rating policy which can maximize the insured's utility. Constraint (2) is the fair rate principle. $S_1 \neq S_0$ implies that the retrospective rating method is the

optimal pricing policy. Let us define the following:

$$\sqrt{W - S_1} = U_1, \quad \sqrt{W - S_0} = U_0$$

U_1 refers to the insured's utility from net wealth if the accident occurs and U_0 is referred to the utility if the accident does not occur. With the definitions of U_1 and U_0, which are similar to Grossman and Hart (1983), we can rewrite Program 1 as program 1'.

Program 1':

$$\underset{U_1,\ U_0}{Max} \quad P_i U_1 + (1 - P_i)\, U_0 - V$$

s.t

$$P_i(W - U_1^2) + (1 - P_i)\,(W - U_0^2) = P_i\, X$$

The reason of transforming Program 1 to Program 1' is for the simplicity of program solving. Using a Lagrangian approach, we can write Program 1' as:

$$\underset{U_1,\ U_0}{Max} \quad P_i U_1 + (1 - P_i)\, U_0 - V + \lambda[P_i(W - U_1^2) + (1 - P_i)\,(W - U_0^2) - P_i\, X] \qquad (3)$$

Differentiating (3) with respect to the decision variables U_1 and U_0 and assuming an interior solution, we have the following first order conditions:

$$P_i - 2\lambda P_i U_1 = 0 \qquad (4)$$

$$1 - P_i - 2\lambda\,(1 - P_i)\, U_0 = 0 \qquad (5)$$

Conditions (4) and (5) imply that $U_1 = U_0 = 1/2\lambda$. Since $U_1 = U_0$, we have $S_1 = S_0$ by defintion. Therefore, we have the following proposition:

Proposition 1. *If there is no incentive or moral bazard problem, the retrospective rating method cannot be the first-best optimal insurance rating policy.*

When there is no incentive or moral hazard probvlem, the rating scheme will be

solely served for the risk sharing purpose. Since the insurer is not a residual claimer, the optimal scheme is to maximize the insured's utility subject to the fair rate constraint. From conditions (4) and (5), we learn that $U_1 = U_0 = 1/2\lambda$. By substituting U_1 and U_0 to the fair rate constraint in Program 1', we obtain:

$$\lambda = \frac{1}{2\sqrt{W - P_i X}} .$$

Hence

$$U_1 = U_0 = \sqrt{W - P_i X} .$$

Therefore, we have:

$$S_1 = S_0 = P_i X .$$

This means that when there is no moral hazard or incentive problem, the first-best optimal rating method is to set the premium equal to the expected loss in ex ante regardless the actual incurred losses.

V. Second-best Solution, Loss Control Effort Unobservable

When the insured's loss control effort is not observable, there is incentive problem. In this section we assume that the insurer prefers the insured taking the loss preventive action. This assumption is based on the fact that the loss prevention or reduction is the first objective of risk management. To prevent the occurence of disasters is always more important than to reimburse the incurred losses. Therefore, it is the responsibility of insurers and policy makers to encourage loss control. Since there is disutility from exerting the preventive effort, the rating policy, (S_1, S_0) in this paper, shall provide the insured incentives of doing this. Similar to Program 1, we can write the insurer's problem under this scenario as Program 2.

Program 2:

$$\underset{S_1,\ S_0}{Max}\ P_i \sqrt{W - S_1} + (1 - P_i) \sqrt{W - S_0} - V$$

s.t.

$$P_i S_1 + (1 - P_i)\, S_0 = P_i X \tag{2}$$

$$P_i \sqrt{W - S_1} + (1 - P_i) \sqrt{W - S_0} - V \geq P_n \sqrt{W - S_1} + (1 - P_n) \sqrt{W - S_0} \tag{6}$$

Program 1 and Program 2 are the same except the constraint(6) is added in Program 2. Constraint (6) is the incentive constraint which ensures that it is the insured's self interest to take the preventive effort. With U_1 and U_0 defined in the previous section, Program 2 can be written as Program 2'.

Program 2':

$$\underset{U_1,\ U_0}{Max}\ P_i U_1 + (1 - P_i)\, U_0 - V$$

s.t.

$$P_i (W - U_1^2) + (1 - P_i)\, (W - U_0^2) = P_i X$$

$$P_i U_1 + (1 - P_i)\, U_0 - V \geq P_n U_1 + (1 - P_n)\, U_0$$

Again, the reason for us to rewrite Program 2 as Program 2' is for the simplicity of program solving. However, the rating policy or insurance contract which the insurer designs shall be expressed in terms of S_1 and S_0, instead of U_1 and U_0. The dfinition of U enables us to infer S after obtaining the solutions expressed in U.

Using a Lagrangian approach, we can rewrite Program 2' as:

$$\underset{U_1,\ U_0}{Max}\ P_i U_1 + (1 - P_i)\, U_0 - V + \lambda_1 [P_i (W - U_1^2) + (1 - P_i)\, (W - U_0^2) - P_i X]$$
$$+\lambda_2 [\, P_i U_1 + (1 - P_i)\, U_0 - V - P_n U_1 - (1 - P_n)\, U_0] \tag{7}$$

Differentiating the Lagarangian function (7) with respect to the decision variables (U_1, U_0) and Lagarangian multipliers (λ_1, λ_2) and assuming an interior solution, we have the following first order conditions:

$$P_i - 2\lambda_1 P_i U_1 + \lambda_2 P_i - P_n \lambda_2 = 0 \tag{8}$$

$$1 - P_i - 2\lambda_1 (1 - P_i) U_0 + \lambda_2 (1 - P_i) - (1 - P_n) \lambda_2 = 0 \tag{9}$$

$$P_i (W - U_1^2) + (1 - P_i) (W - U_0^2) - P_i X = 0 \tag{10}$$

$$P_i U_1 + (1 - P_i) U_0 - V - P_n U_1 - (1 - P_n) U_0 = 0 \tag{11}$$

Solving a system of simultaneous equations (8), (9), (10) and (11), we can obtain sets of solutions for U_1, U_0, λ_1 and λ_2. Since equation (10) is a nonlinear equation, we shall have two different sets of solutions by theory. The fact, however, that U_1 and U_0 both must be nonnegative eliminates one set of solutions so that we obtain an unique set of solutions. Under the set of solutions, we have:

$$U_1 = \frac{\sqrt{(-P_i P_n^2 + 2P_i^2 P_n - P_i^3)X + (P_n^2 - 2P_i P_n + P_i^2)W + (P_i^2 - P_i)V^2} + (P_i - 1)V}{P_n - P_i}$$

$$U_0 = \frac{\sqrt{(-P_i P_n^2 + 2P_i^2 P_n - P_i^3)X + (P_n^2 - 2P_i P_n + P_i^2)W + (P_i^2 - P_i)V^2} + P_i V}{P_n - P_i}$$

U in this paper refers to the insured's utility and is assumed with a square root utility function. Therefore, both U_1 and U_0 should always be positive. U_0 derived above is positive, but the sign of U_1 cannot be determined. In order to restrict U_1 to be always positive, we impose the following assumption:

Special Assumption:

$$\sqrt{(-P_i P_n^2 + 2P_i^2 P_n - P_i^3)X + (P_n^2 - 2P_i P_n + P_i^2)W + (P_i^2 - P_i)V^2} + (P_i - 1)V > 0$$

The above special assumption is to ensure the insured always receives a positive utility regardless of the loss status. The restriction only on P_n and P_i will not be able to guarantee a positive U_1. For U_1 to be always positive, the values of X, W and V are as important as P_n and P_i. Using the above solutions for U_1 and U_0, the optimal solutions for S_1 and S_0 are:

$$S_1 = \frac{(2-2P_i)V\sqrt{(-P_iP_n^2+2P_i^2P_n-P_i^3)X+(P_n^2-2P_iP_n+P_i^2)W+(P_i^2-P_i)V^2}}{(P_n-P_i)^2}$$

$$+\frac{(P_iP_n^2-2P_i^2P_n+P_i^3)X+(-2P_i^2+3P_i-1)V^2}{(P_n-P_i)^2}$$

$$S_0 = \frac{-2P_iV\sqrt{(-P_iP_n^2+2P_i^2P_n-P_i^3)X+(P_n^2-2P_iP_n+P_i^2)W+(P_i^2-P_i)V^2}}{(P_n-P_i)^2}$$

$$+\frac{(P_iP_n^2-2P_i^2P_n+P_i^3)X+(-2P_i^2+P_i)V^2}{(P_n-P_i)^2}$$

Since S_1 and S_0 derived from solving Program 2' are not equal, it implies that the retrospective rating policy is the second-best optimal solution for the insurance problem with loss control effort being unobservable. However, we still need to show that $S_1 > S_0$, that is, the premium charged when the loss is incurred is greater than the premium without incurred loss. Otherwise, the second-best optimal rating policy derived in this paper would not be consistent with the retrospective rating method found in practice. By subtracting S_0 from S_1, it follows that:

$$S_1-S_0 = -\frac{2V\sqrt{(-P_iP_n^2+2P_i^2P_n-P_i^3)X+(P_n^2-2P_iP_n+P_i^2)W+(P_i^2-P_i)V^2}+(2P_i-1)V^2}{(P_n-P_i)^2}$$

Given the special assumption, we can derive the following condition:

$$2V\sqrt{(-P_iP_n^2+2P_i^2P_n-P_i^3)X+(P_n^2-2P_iP_n+P_i^2)W+(P_i^2-P_i)V^2}+(2P_i-1)V^2 > 0$$

The above condition implies that $S_1 > S_0$. Therefore, we have the followng proposition.

Proposition 2: *If the is incentive or moral hazard problem, the retrospective rating method is the second-best optimal insurance pricing policy.*

Although the insured in this paper is assumed to have a square root utility function, the result of Proposition 2 will hold for any concave utility fuinctions, such as $-e^{-c(W-S)}$ and $(W-S)^2$. However, the difference between S_1 and S_0 will vary with a

different type of utility function. The optimal rating policy depends on the ex post incurred losses. This conclusion is an analogy to the finding in the seminar work of Holmstrom (1979) that the optimal compensation should depend on the ex post actual outputs. In practice, however, the insurer normally charges an ex ante premium in stead of an ex post premium. Assume that the insurer charges a standard premium $\underline{S}$ when the policy is written, where $S_1 > \underline{S} > S_0$. For the rating policy to be optimal, the policy shall incorporate the ex post conditions such that: (1) if the loss is incurred, the insured shall pay another amount equal to $S_1 - \underline{S}$; (2) if the loss is not incurred, the insurer will refund an amount equal to $\underline{S} - S_0$. This type of rating policy is consistent with retrospective rating method used in practice and achieves the optimal equilibrium outcomes. Based on the practical experiences, the insurer normally sets the ex ante premium equal to the expected losses and adjusts it according to the ex post incurred losses.

VI. Conclusion and Suggestions

Greene and Serbein (1983) indicate that retrospective rating provides incentive for encourageing loss control and is considered as a popular alternative of self-insurance for risk managers. This paper uses a principal-agent framework to explore the incentive issue in controlling losses. We analytically demonstrate that the retrospective rating does not only induce the insured to take loss control effort, it is also the second-best optimal rating policy at the existence of moral hazard problem.

This paper assumes that the insurer, subject to the fair rate principle, is designing a rating policy to maximize the insured's utility. This assumption is consistent with the purpose of retrospective rating plan in practice and thus worthy to be applied in the future research. Under a single-period analysis, retrospective rating is the most responsive method to loss experience for that policy period. However, it also creates the uncertainty of premium charged for the insured. Provided the insured would take insurance for a long time, it is not known whether retrospective rating is the best plan. An extension for future research is to extend this analysis to a multiperiod framework and compare the differences between retrospective rating plans and prospective rating plans.

Retrospective rating plan can be an effective marketing tool because it is an excellent method for keeping policyholders who spent costs in loss control and want to have better insurance coverage. As presented in this paper, retrospective rating plan is an optimal solution for loss control incentive in theory. However, it is not

trouble free in practice. The problem is not because of the product itself but because of the marketing techniques (Lilly, 1991). Salespersons may emphasize more on refunding the premiums and less on the additional charges. Besides, the insureds may consider themselves above the average risk and neglect the possibilityof paying additional premiums at the end of policy period. Therefore, it is suggested that the insurer should have a sound presentation when issuing a retrospective rating plan.

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