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Research on incentive mechanism of the pharmaceutical and chemical enterprises' compulsory environmental pollution insurance in China

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ABSTRACT

The pharmaceutical & chemical enterprises belong to high environmental risk, traditional pharmaceutical & chemical industry is even known as the largest source of pollution, even in the event of pollution accidents, easy to pollution environment. The implementation of environmental pollution liability insurance has lasted more than two years, which has achieved positive social repercussions. In this mode of operation, the pharmaceutical & chemical enterprises would pay lower fines directly to the government if the premium is too high, and but if the premium is too low, which means that the insurance company will take great risks, and therefore the key to the problem that the risk-sharing mechanisms is unreasonable in the both sides of insurance. Based on the risk-sharing contract model between the insurer and the pharmaceutical & chemical enterprises, this article analyzes that the dynamic incentive mechanism should be taken by the insurance company when moral hazard and adverse selection exist in pharmaceutical & chemical enterprises at the same time. This paper discusses two stages dynamic game exists in risk sharing by the game and principal-agent theory. Then the insurer can predict the loss distribution of next year according to the default frequency occurs in 1 year, and can judge optimal effort level of the Pharmaceutical & chemical enterprises , then can decide whether to continue the insurance or the next premium. The insurance companies could less the information asymmetry between the pharmaceutical & chemical enterprises and them, and also could identify clearly the risk status of the enterprise by monitoring internal data and external data of the pharmaceutical & chemical enterprises such as history management data, as well as customer feedback, which could provide data support to make different premium rate. It could provide further theoretical foundation for the insurer who designs the reasonable incentive contract.

Key words: pharmaceutical & chemical enterprises, environmental pollution, insurance, incentive, game.

INTRODUCTION

The pharmaceutical & chemical enterprises belong to high environmental risk, traditional pharmaceutical & chemical industry is even known as the largest source of pollution, even in the event of pollution accidents, easy to pollution environment. Once a pollution accident happened, which would highly pollute the surrounding environment. Environmental pollution problems that caused by pharmaceutical and chemical industry is particularly serious in China, which not only make a broad and big pollution, but also which cause environmental governance is very difficult by the extremely complex composition of matter, and which far more than other industries. Currently the pharmaceutical and chemical industry has become a high-risk areas which the environmental violations occur, and it is the one of the key industries which supervised by national environmental protection department. In 2007, there began to carry out the environmental pollution liability insurance pilot in some areas in China, which try to use "liability insurance" and strengthen supervision of environmental behavior of the pharmaceutical and chemical enterprise by the introduction of the insurance market forces, which could share the risk of enterprise and protect the rights and interests of the victims. On the 21st February, 2013, the Chinese Ministry of Environmental Protection and the China Insurance Regulatory Commission jointly issued "Guidance on Carrying Out the Pilot Work of Compulsory Environmental

Pollution Liability Insurance ", which guide the enterprises of high environmental risks in the pharmaceutical & chemical and heavy metal industry to promote the pilot of compulsory environmental pollution liability insurance. The implementation of environmental pollution liability insurance has lasted more than two years, which has achieved positive social repercussions. During this period, multiple products about environmental pollution liability insurance are put in the market, and are steadily promoting the pilot work all over the country, and in which the pilot of environmental pollution liability insurance has made periodic progress. But overall, the environmental pollution liability insurance is still in its early stage of development in China, in which the respect of the relevant laws, standards and operation still exist some problems.

Firstly, because of a lack of the incentive mechanism for pharmaceutical & chemical enterprises, the management risk of insurance company is very large. In the initial stage of environmental pollution liability insurance, it is difficult to determine the expected risks of enterprises and the expected earnings of insurance company because the related legal and policy system is very imperfect in China. Furthermore, the small number of insured and insurer are involved, which is not in line with the requirement of "principle of large numbers" that it is the most basic principle in the insurance industry. Due to the absence of necessary incentive mechanism, the management risk of insurance company is increased a lot, and the insured would reduce the competitiveness in similar enterprises which increase its operating costs because of paying insurance.

Secondly, because of a lack of the corresponding standard in the environmental pollution liability insurance which cause a lack of guidance in insurance products pricing and damage compensation. Currently the promotion of environmental pollution liability insurance is facing many technical problems, such as countries have not yet set the assessment methods about environment risk, the standard of pollution damage and compensation. Due to the lack of environmental risk assessment method, identification and quantitative of environmental risk is very difficulty, the insurance company is hard to judge the risk of pharmaceutical and chemical enterprises and pricing based on the risk level of enterprises.

In fact, the governments and pharmaceutical & chemical enterprises become the final winner in the actual operation, the insurance company only acts as a role of guarantee. In this mode of operation, the pharmaceutical & chemical enterprises would pay lower fines directly to the government if the premium is too high, and but if the premium is too low, which means that the insurance company will take great risks, and therefore the key to the problem that the risk-sharing mechanisms is unreasonable in the both sides of insurance. The environmental pollution liability insurance of the pharmaceutical & chemical enterprises has developed early in some developed countries, but for the existing obvious differences between the related legal system and insurance operation system in overseas and that in homeland, so we can n't copy and use the model of rate of foreign too, it is quite necessary for us to research the environmental pollution liability insurance in theory and experiment aspect[1]. At present, the existing domestic literature and research that is available almost invariably concerns qualitative research. Some empirical papers have focused on the such as the system construction[2,3], behavior motivation[4], planted innovation[5] and pricing strategy[6] and so on, which put forward some constructive suggestions about the pharmaceutical & chemical enterprises insurance that has reference value. However, compared with foreign studies, the study of quantitative aspects of risk management and the rate difference is still in the blank.

In general, the insurance market will exist two types of problems such as moral hazard and adverse selection, and even most of the time they will occur simultaneously[8,9]. Due to the pollutant emission in the process of production of pharmaceutical & chemical enterprises is widespread problem of asymmetric information, the current environmental pollution liability insurance is for a short-term with one year, which no doubt will separately increase the management costs for enterprises and insurance companies. Through the proof of related research with principal-agent theory, we could find that let the competition between agents and let the course of the game from the one stage game extended to multi-stages repeated game, etc., which can greatly reduce agency costs[10]. In addition, Literature[11,12] are the main representative works in the early, in which they have confirmed repeated insurance contracts are effective measures to reduce the adverse selection and moral hazard.

Due to the long life cycle of pharmaceutical & chemical enterprises in China, which have an average of 40~50 years. We will limit environmental pollution liability insurance period to 1 year in this article, and the pharmaceutical & chemical enterprises purchase the premium according to the annual too. So we can divide the game of the pharmaceutical & chemical enterprises and insurance companies from an annual into two stages, and can design a two-stages contract model of dynamic game based on rate difference. Because the research and development of independent innovation is a continuous process, the formation of the final outcome of the process is not repeatable, so companies usually only select a level of environmental protection efforts. Assuming the number of violations frequency each year is an endogenous variable, and further considering the rate for differentiation, we can design the risk sharing model which the risk category of environmental protection capabilities and level of effort of the

pharmaceutical & chemical enterprises can not be found, it provide theoretical support for insurance company who could design a more reasonable incentive contract based on the differential premium rate.

EXPERIMENTAL SECTION

2. The multi-period insurance incentive model of pharmaceutical & chemical enterprises

In this paper the set of all types of risk of pharmaceutical & chemical enterprises is denoted by Ω, $\theta \in \Omega$ represents an arbitrary types of the pharmaceutical & chemical enterprise and which is an one-dimensional continuous random variables, $\theta \in [\theta_{\min}, \theta_{\max}]$, where θ is known to the pharmaceutical & chemical enterprise but is unable to be found out by the insurer. But we can determine a prior probability of the pharmaceutical & chemical enterprise $\eta(.)$,which belongs to the type ofθ based on the past environmental protection records obtained in the industry and enterprise credit rating. $G(\theta)$ and $g(\theta)$ is expressed to distribution function and density function respectively, so the risk rate of the pharmaceutical & chemical enterprise can be defined as $\varphi(\theta)= g(\theta)/[1- G(\theta)]$ and $\varphi'_{\theta}(\theta)<0$[13].

Supposed further that the pharmaceutical & chemical enterprise has an initial asset$W$, which will make trade-off between the penalty and the company's assets. Early the pharmaceutical & chemical enterprises pay the initial insurance premium to obtain the 1st year loan, and then the pharmaceutical & chemical enterprises would choose his effort level a during production, and where $a \in [a_{\min}, a_{\max}]$ is not easy to be informed directly by insurance company and the a is the function of type θ usually. For the most pharmaceutical & chemical enterprises, the stronger the enterprise strength, the more attention to their reputation.

In general, the pharmaceutical & chemical enterprises could reduce the probability of violations through the efforts of themselves, therefore the insurance company must motivate the pharmaceutical & chemical enterprises to avoid violations, and thus to ensure maximization of insurance proceeds. Because of the type of each pharmaceutical & chemical enterprise is different, which be related to the factors such as their size and the level of science and technology. On the basis of initial stage in the first year, the insurance company must provide the pharmaceutical & chemical enterprises differentiation contract of premium rate with a discount factor$\delta_1$or floating factorδ_2, the latter will display its risk typeθ by selecting one of the insurance contracts. Supposed the function $c[\theta, a(\theta)]$ is the effort cost of the pharmaceutical & chemical enterprise and his effort will lead to negative effect. The pharmaceutical & chemical enterprisescan not product if they do not buy the insurance, so they only choose to compensation.

During the underwriting, supposed that insurer can obtain the frequency X of illegal emissions with the pharmaceutical & chemical enterprises, and the environmental protection achievements T. The X and $T$are random variable.

Assuming the premiums of pharmaceutical & chemical enterprises need to be payed is P_1in the first years, so we can determine the basis of rates by the risk rating system of the enterprise. Then the insurer could estimate the probability that the illegal emissions appeared the 1st year and 2nd year respectively by default frequency X and environmental protection achievements T, and the insurer can determine whether the hard work of the pharmaceutical & chemical enterprises through the default loss of the society. On the contrary, assuming that the probability of avoiding default losses is $q_1[\theta, a(\theta)]$ and $q_2[\theta, a(\theta)]$ respectively.

For purposes of calculation, supposed that the discount factorδ_1 and floating factorδ_2 is respectively the function of the environmental protection achievements T and the default frequency X, $\delta_1(T)$and$\delta_2(X)$, so the floating premium P_2 in the 2st year can be expressed as follows:

$$P_2 = P_1 - P_1\delta_1(T) + P_1\delta_2(X) = P_1[1-\delta_1(T) + \delta_2(X)] \le \pi \quad (1)$$

Where$\delta_1(T) \in [0, a]$, $\delta_2(X) \in [0, b]$, a and b denotes respectively the maximum premium rate of discount and floating, the π represents the cost of the pharmaceutical & chemical enterprises which choose penalty. If the premiumP_2 in the 2nd year exceed the cost π, then the pharmaceutical & chemical enterprises will prefer the penalty to the insurance through implementation insurance.

In addition, assume that the environmental protection effort of the pharmaceutical & chemical enterprise is a one-dimensional variable, which value will directly determine the default frequency $X$and environmental protection achievements Tin the first years which can be denoted respectively as $X=-a+\lambda_1$and $T=-a+\lambda_2$, whereλ_1 andλ_2 are exogenous undeterminate factor which have a normal distribution with $N(0,\sigma^2)$. The density function of $X$and T is respectively expressed $g(X,a)$ and $g(T,a)$.

Generally insurance company is classified as risk neutral, then his expected utility is equal to the expected revenue:

$$Ev\{P_1[1-\delta_1(T) + \delta_2(X)] - L_2\{1-q_2[\theta, a(\theta)]\}\}$$

$$= \int_{\underline{\theta}}^{\bar{\theta}} \int_X \int_T \{\{[1-\delta_1(T)+\delta_2(X)]P_1\}g[X,a(\theta)]g[T,a(\theta)]dTdX - L_2\{1-q_2[\theta,a(\theta)]\}\}g(\theta)d\theta \quad (2)$$

As a policy-holder, the pharmaceutical & chemical enterprise is usually risk aversion, his certainty equivalent income $Q(\theta)$ is equal to the expected income *Er*, so according to the actual income *r*of the pharmaceutical & chemical enterprise, we can get as follows:

$$r = W - [1-\delta_1(T)+\delta_2(X)]P_1 - L_1\{1-q_1[\theta,a(\theta)]\} - c[\theta,a(\theta)]$$
$$Q(\theta) = Er = W - [1+(\delta_2-\delta_1)a(\theta)]P_1 - L_1\{1-q_1[\theta,a(\theta)]\} - c[\theta,a(\theta)] \quad (3)$$

Further assume that the level of reservation income is $\bar{r}$, if $Q(\theta)< \bar{r}$, then the pharmaceutical & chemical enterprises would not accept implementation insurance contract. So the participation constraint of the enterprise can be denoted as follows:

$$Q(\theta) = W - [1+(\delta_2-\delta_1)a(\theta)]P_1 - L_1\{1-q_1[\theta,a(\theta)]\} - c[\theta,a(\theta)] \geq \bar{r} \quad (4)$$

When the insurance company cannot effectively evaluate and observed the risk type θ and the effort level *a*of environmental protection of the pharmaceutical & chemical enterprise, the insurance contract which provided to the pharmaceutical & chemical enterprises must meet their participation and the incentive compatibility constraint conditions at the same time, immediately, the pharmaceutical & chemical enterprises can obtained higher net income by choosing to buy insurance than to get private lending and to maximize its own certainty equivalent income, and which would solve the optimization problem as follows:

$$[\theta,a(\theta)] \in \arg\max_{\theta,a(\theta)}[Q(\theta)] \quad (5)$$

On this basis, the insurance company has to solve how to solve the optimization problem is following:

$$\max_{a,\delta_1,\delta_2} Ev = \int_{\underline{\theta}}^{\bar{\theta}} \int_X \int_T \{\{[1-\delta_1(T)+\delta_2(X)]P_1\}g[X,a(\theta)]g[T,a(\theta)]dTdX - L_2\{1-q_2[\theta,a(\theta)]\}\}g(\theta)d\theta \quad (6)$$

$$\text{s.t. (IR)} \quad Q(\theta) \geq \bar{r} \quad (7)$$

$$\text{(IC)}[\theta,a(\theta)] \in \arg\max_{\theta,a(\theta)}[Q(\theta)] \quad (8)$$

3. The solution of the multi-period insurance incentive model of Pharmaceutical & chemical enterprises

Considering the formular (7) and formular (8), further *Er* can be denoted formular (9):

$$Er = \bar{r} - \int_{\underline{\theta}}^{\bar{\theta}} c'_\theta[\theta,a(\theta)]d\theta \geq \bar{r}, Q(\underline{\theta}) = \bar{r} \quad (9)$$

Combining with the first order optimal condition of the formula (8), as well as formular (3) and formular (6), the optimization problem of the insurance company can be simplified as follows:

$$\max_{a(.),Q(.)} Z = \int_{\underline{\theta}}^{\bar{\theta}} \{P_1(1+\delta_2-\delta_1)a(\theta) - Q(\theta) - c[\theta,a(\theta)] - L_2\{1-q_2[\theta,a(\theta)]\}\}g(\theta)d\theta \quad (10)$$

$$\text{s.t. } Q'_\theta(\theta) = L_1 q'_{1\theta}[\theta,a(\theta)] - c'_\theta[\theta,a(\theta)] \quad (11)$$

$$Q(\underline{\theta}) = \bar{r} \quad (12)$$

So the optimal solution of environmental protection effort level *a*(.) of the pharmaceutical & chemical enterprise can be represented formula (13):

$$\{P_1 - L_1 q'_{1a}[\theta,a(\theta)] + L_2 q'_{2a}[\theta,a(\theta)]\}\varphi(\theta) - \{L_1 q''_{1\theta a}[\theta,a(\theta)] - c''_{\theta a}[\theta,a(\theta)]\} = 0 \quad (13)$$

For the convenience of solving, assumed that the environmental protection cost of the pharmaceutical & chemical enterprises $c[\theta,a(\theta)]=ba^2/2\theta$, and the probability $q_1[\theta, a(\theta)]=A+ka^2/2\theta$, $q_2[\theta, a(\theta)]=B+ma^2/2\theta$, where the parameters A and B respectively represents basic probability of loss in the 1st year and 2nd years (Determined by the past statistics data of the pharmaceutical & chemical enterprise), the parameter $b>0$ denotes cost coefficient, the parameters $k,m>0$ respectively denotes corresponding probability coefficient.

Then the environmental protection effort level $a(.)$ of the pharmaceutical & chemical enterprise can be denoted formula (14):

$$a* = \frac{\theta^2[P_1\varphi(\theta) - L_1]}{\theta(L_1k + L_2m)\varphi(\theta) + b - k} \tag{14}$$

After considering the proportion of discounts and floating rate of premium, the premium still be paid in the second year by the pharmaceutical & chemical enterprise is as follows:

$$P_1(\delta_2 - \delta_1) = \frac{b\theta[L_1 - P_1\varphi(\theta)]}{\theta(L_1k + L_2m)\varphi(\theta) + b - k} \tag{15}$$

RESULTS AND DISCUSSION

According to the multi-stage dynamic game model previously, supposed that the cost of effort of the pharmaceutical & chemical enterprise is$c[\theta, a(\theta)]=ba^2/2\theta$, the value of cost coefficient b is equal to 3. Furthermore, we assume that $q_1[\theta, a(\theta)]=A+ka^2/2\theta$, $q_2[\theta, a(\theta)]=B+ma^2/2\theta$ (where the value of A is 10% and B is 15%), the probability coefficients k and m is respectively 2 and 3, the loss L_1 is equal to 10 thousand yuan, the loss L_2 is equal to 15 thousand yuan,$\varphi(\theta)=1/\theta^2$, then the best environmental protection efforts of the pharmaceutical & chemical enterprise can be simplified as Formula(16):

$$a* = \frac{\theta^2[100\theta^{-2} - 10]}{\theta(10*2+15*3)*\theta^{-2} + 3 - 2} = \frac{100 - 10\theta^2}{65\theta^{-1} + 1} \tag{16}$$

In the 2nd year of the pharmaceutical & chemical enterprises can enjoy additional premium discounts or need to increase floating premiums as follows:

$$P_1(\delta_2 - \delta_1) = \frac{30\theta^2 - 300}{65 + \theta} \tag{17}$$

Therefore, the relationship among the type of comprehensive risk of the pharmaceutical & chemical enterprise θ, the effort level a and the discounts or floating of premiums in the following Table 1. From which we can find that the higher the risk and the lower the level of effort, then the pharmaceutical & chemical enterprise is required to pay much more premiums accordingly.

Table 1. The relationship among the risk type, the effort level and the premium

Types of risk θ	Effort level a	Discounts or floating of premiums $P_1(\delta_1-\delta_2)$
1	1.791044776	-4.09091
2	1.363636364	-3.58209
3	0.441176471	0.779221
4	0.07826087	1.153846
:	:	:
∞	0	30

CONCLUSION

(1) By the equation (14) and (15) can be found as follows: the pharmaceutical & chemical enterprises will be taken to determine the environmental protection effort level according to their risk types when insurance companies offer a range of insurance contracts to them. When $P_1(\delta_1-\delta_2)<0$, namely$\delta_1>\delta_2$, which confirms the pharmaceutical & chemical enterprise is hard and which can make the environmental protection measures on time, and so he will get more comprehensive premium discount too.

(2) When the premium P_1 in the first year has been paid, the smaller loss L_1, which shows that the environmental

protection effort level a^* is larger, and that the difference ofδ_1 andδ_2 is bigger too, then as well as that the enterprise finally obtain more premium discount in the 2nd year. Otherwise the pharmaceutical & chemical enterprise is not hard and should pay more premium in the 2nd year, and even the insurance company may refuse.

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