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Intervention in Coal Mining Safety Production Supervision in China Based on the Principal-agent Model

[1]Chun Yan, [1]Xianghui Chen, [2]Wei Liu and [3]Yuan Tian
[1]College of Mathematics and System Science, Shandong University of Science and Technology,
[2]College of Information Science and Engineering,
Shandong University of Science and Technology, Qingdao, 266590, China
[3]School of Economic, Ocean University of China, Qingdao, 266100, China

Abstract: This study argues that for importing the economical factor, introducing insurance mechanism into supervision of coal mining safety production can fully arouse enthusiasm of all parties, supervise and urge coal mining enterprise to increase the safety input, lower the probability of safety accidents in advance, after the accident increase the capital source of remedying lose in safety production and provide the more reasonable compensation for injured miners and their family. Game analysis on insurance companies intervention in coal worker safety supervision using the principal-agent model is done and many problems such as supervision dynamics, supervision cost and penalties in condition of information asymmetry is discussed. It is demonstrated in the sight of game theory that the differential rate and floating rate of coal worker safety insurance are necessary.

Key words: Coal mining safety production, supervision, insurance, game analysis

INTRODUCTION

The situation of the coal mining safety production in China has been more serious for a long time. Country had adopted a series of measures to strengthen the supervision of coal mining in order to avoid the happening of the mine disaster. Such as all the provinces of the coal administration has been upgraded to a ministry and adopted direct management by the state council in 2005. At the same time a lot of measures and regulations on reorganizing coal mining have been proposed in the different provinces which produce coal and the state. However, from the reality which the current great malignant mine disaster occurred frequently, we can see that effective is not great. Therefore, the theory circle has given high attention to this problem and many studies appeared in the recent years (He and Song, 2012; Lu and Li, 2011; Djamaluddin *et al*., 2011; Shi, 2013).

This study argues that for importing the economical factor, introducing insurance mechanism into supervision of coal mining safety production can fully arouse enthusiasm of all parties, improve the risk awareness of the enterprise, supervise and urge coal mining enterprise to increase the safety input, lower the probability of safety accidents in advance, after the accident increase the capital source of remedying lose in safety production and provide the more reasonable compensation for injured miners and their family.

Research on the security problem of coal mining industry most focused on the management of frequent mine disaster in China, which can refer to a review paper (Yan and Liu, 2009). In recent years, the function of the insurance mechanism in coal production safety supervision and management were gradually cached scholars' attention. The research on introducing the insurance protection tool into the production safety of coal mine in China mainly involved in the following aspects: Firstly, it is inductrial injury insurance of miners. The problems exiting in Chinese coal mine inductrial injury insurance were analyzed. In order to enhance coal mine accident prevention and complete the injury insurance work, some countermeasures and proposals were proposed. Such as building a sound legal system, combining injury insurance with coal mine safety production, establishing a scientific and reasonable premium rate mechanism etc (Li, 2009). Grading evaluation of industrial injury risk in coal mining enterprises were discussed (Liang, 2009). Second, liability insurance of the coal mine enterprises. The necessity and feasibility of implement compulsory employers' liability insurance in coal industry were analyzed (Li, 2007). In analysis conclusion can be drawn that the growth of liability insurance of safe production in mine coals need strong support and promotion from governments. Governments can give play to its function of managing society. To support and promote liability insurance of safe

Corresponding Author: Wei Liu, College of Information Science and Technology, Shandong University of Science and Technology, Qingdao, 266590, China

production in mine coals, government may use methods of resources distribution in policy and resources transmit in market mechanism (Zhang, 2008). And third, it is accident injury insurance of coal miner. Using two methods which are monte carlo simulation and analog monte carlo simulation, to simulate distributions which are commonly used, that is compound poisson distribution and of the compound binomial distribution, get a random number distribution to make up for the plant status quo of lacking data in the study of coal mine underground worker accident injury insurance (Jia, 2008).

In the existing literature involved safety production supervision in coal mine of supervision, the game analysis of insurance company intervention is rare, also is not involved discussion on the premium rate mechanism to promote safety production, information asymmetry is related less. The intervention of government supervision can achieve justice and efficiency of the market, make for preventing the probability of market dysfunction and make for maximizing social welfare. Realize the maximize of consumer surplus in the precondition of keeping production surplus (Li and Da, 2004). A dynamic game analysis on disposal of rent-seeking phenomena with incomplete information was analyzed (Wang *et al*., 2005). All parties'gains and losses from the supervision to colliery safety production were studied in China, then, constructed their receipt functions respectively and the parties'actions in the supervision were analyzed by the game theory (Hu and Liu, 2008).

In this study, game analysis on insurance company intervention in coal worker safety supervision using the principal-agent model is done and many problems such as supervision dynamics, supervision cost and penalties in condition of information asymmetry are discussed.

ESTABLISHMENT AND ANALYSIS OF THE MODEL

Basic model assumptions

Assumption 1: There is only one client and one agent. The client is insurance company and agent is coal mining company.

Assumption 2: There are two types of coal mining company, one produces safely and the other produces illegally who be denoted respectively by SA and SNA. Their probability distributions are 1-v and v. The information structure is exogenous and it belongs to the private. The insurance premium of two types of coal mining company which respectively produces safety production and illegal production are denoted by XL and XH. There is hold the relationship: XL<XH that is meaning the differential rate. The more detailing differential premium rate level is ignored temporarily in this study.

Assumption 3: The insurance company carries two types regulatory efforts to supervision coal mining company which produce safety production or illegal production. The supervision intensity are JL and JH, respectively, supervision cost are $C_I(J_L)$ and $C_I(J_H)$. And $C_I(J)$ satisfies that $C_I(0) = 0$, $C_I(0) = 0$, $C_I' > 0$, $C_I'' > 0$, $C_I'(0) = 0$, $C_I'(I) = +\infty$. The insurance company deals with the coal mining company who produces illegally for endogenous mechanism of punishment. If coal mining company who produces illegally lie or disguise that its' production is safe, the punishment is F_H. If there is no accident then $F_H = X_H$, i.e. floating rate system is adopted, the insurance company adopt this increased rate next year. If the accident is happened, the insurance company will refuse the claim of the coal mine company which is denoted by Y and in the case $F_H = Y$. When coal mining company which produces safely lied that their production is illegal, the punishment is F_L. Assuming that the income of insurance company is the difference between the cost of coal mining company and supervision cost. The insurance company considers to designing a set of mechanisms $\{(X_L, J_L, F_L); (X_H, J_H, F_H)\}$ to distinguish the type of coal mining company and it tries to maximize its income.

Game time sequence: Let S denote coal mining company and I denote insurance company. Game time sequence is showed in Fig. 1.

Modeling and solution: The insurance company hopes that a set of covenants $\{X_L, J_L, F_L\}$; $\{X_H, J_H, F_H\}$ is provided to reveal automatically the type of the coal mining companies which respectively produce safe production or illegal production. This optimization problem can be formulated as follows:

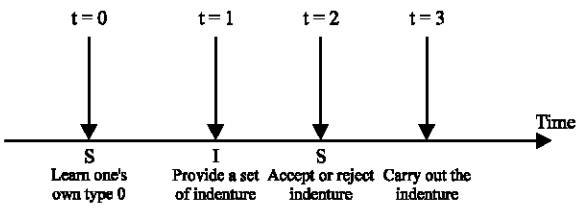

Fig. 1: Game time sequence of the insurance company intervening in the coal mining company production supervision

$$\max_{\{X_L,J_L,F_L\};\{X_H,J_H,F_H\}} v(X_H - C_I(J_H)) + (1-v)(X_L - C_I(J_L))$$

$$\text{s.t. } S_A\text{-}X_L \geq S_A\text{-}X_H\text{-}J_H\cdot F_L \quad (1)$$

$$S_{NA}\text{-}X_H \geq S_{NA}\text{-}X_L\text{-}J_L\cdot F_H \quad (2)$$

$$S_A\text{-}X_L \geq 0 \quad (3)$$

$$S_{NA}\text{-}X_H \geq 0 \quad (4)$$

$$F_L \leq S_A\text{-}X_H \quad (5)$$

where, constraints (1) and (2) are the incentive compatibility constraint of the insurance company, (3) and (4) are its the individual rationality constraints. (5) is the endogenous mechanism of punishment which the insurance company deal with the illegal coal mining company. The following we the solution process of the model.

Solution: We adopt a special kind of solution. Firstly, we just consider (1), (4) and (5), but ignore (2) and (3) and prove that (1), (4) and (5) are binding constraints. The objective function is optimal solution under the binding constraints (1), (4) and (5). Finally, we prove that the optional solution adapts to constraints (2) and (3).

Firstly, we prove that (1), (4) and (5) are binding constraints.

Based on the Revelation Principle, we can know that the insurance company won't examine and verify the coal mining company which produces safely, so we have JL = 0.

$X_H \leq S_{NA}$, the objective function is an increasing function about. And when the objective function get a maximum value, it satisfies $X_H = S_{NA}$. So, (4) is binding constraint.

We adopt the maximum punishment mechanism. So, it hold $F_L = S_A\text{-}X_H = \Delta S$, (5) is the binding constraint.

Observing (1), we have $X_L \leq S_{NA}+J_H.F_L$. The objective function is an increasing function about and it has $X_L = S_{NA}+J_H\Delta S$ when the objective function get a maximum value, so (1) is the binding constraint.

We can solute the model under the condition that (1), (4) and (5) are binding constraints.

Substitute (1), (4) and (5) into the objective function, we can get that:

$$\max_{J_H} v(S_A + J_H\Delta S) + (1-v)(S_A - C_I(J_H))$$

Let the first order derivative of the objective function equal zero, we can get that:

$$v\Delta S\text{-}(1\text{-}v)C'_I(J_H) = 0$$

Getting the implicit function about J_H*:

$$C'_I(J_H^*) = \frac{v}{1-v}\Delta S$$

The result is the optimal solution to the model:

$$X_H^* = S_{NA}$$

$$C'_I(J_H^*) = \frac{v}{1-v}\Delta S$$

$$X_L^* = S_{NA} + J_H^*\Delta S$$

$$J_L^* = 0$$

$$F_L^* = \Delta S$$

Next, we prove that the solution also can adapts to (2) and (3).

Substitute the solution into (2), getting $S_A \leq S_A + J_L^*\Delta S$. It is obvious hold.

Substitute the solution into (3), we have $S_{NA} > S_A + J_L^*\Delta S = S_{NA}\text{-}(1\text{-}J_L^*)\Delta S$. The inequality is tenable.

So, we can also get the following solution:

$$X_H^* = S_{NA}$$

$$C'_I(J_H^*) = \frac{v}{1-v}\Delta S$$

$$X_L^* = S_{NA} + J_H^*\Delta S$$

$$J_L^* = 0$$

$$F_L^* = \Delta S$$

We can obtain the following basic conclusion of the principal-agent model:

- **Proposition 1:** The insurance company needn't supervise the coal mining company which produces safely
- **Proposition 2:** The insurance company need to supervise the coal mining company which produces illegally and the supervisor probability J_H^* is determined by:

$$C'_I(J_H^*) = \frac{v}{1-v}\Delta S$$

Comparative static analysis: Differentiating with respect to v on both side of the equation:

$$C_I'(J_H^*)=\frac{v}{1-v}\Delta S$$

We can get that:

$$C_I''(J_H^*)\frac{\partial J_H^*}{\partial v}=\Delta S\frac{1}{(1-v)^2}$$

$$\frac{\partial J_H^*}{\partial v}=\frac{\Delta S}{(1-v)^2C_I''(J_H^*)}>0$$

Through comparative static analysis of J_H^*, we can find the following conclusion:

- **Proposition 3:** The more the coal mining companies which produce safely, the more supervision on coal mining company which produces illegally that insurance company needs to carry out. There may be two reasons: One is that the more the coal mining company which produces safely in the market, the more possible the coal mining company which produces illegally tells a lie that they produce safely to escape the inspection. So, insurance company should step up the investigation and punishment efforts on the coal mining company which produces illegally. The other one reason is that the more the coal mining company which produces safely, the less that which produces illegally relatively. Even though enhance the supervision on the coal mining company which produces illegally, regulatory costs of insurance company also won't rise a lot

Differentiating with respect to ΔS on both side of the equation:

$$C_I'(J_H^*)=\frac{v}{1-v}\Delta S$$

We can get:

$$C_I''(J_H^*)\frac{\partial J_H^*}{\partial \Delta S}=\frac{v}{1-v}$$

$$\frac{\partial J_H^*}{\partial \Delta S}=\frac{v}{(1-v)C_I''(J_H^*)}>0$$

Through comparative static analysis of J_H^*, we can get the following conclusion:

- **Proposition 4:** When the difference between coal mining company which produces illegally and that which produces safely is greater, the supervision of coal mining company which produces illegally should be strengthened more. The reason may be that in this case, the coal mining company which produces illegally more hope to wrap up to that which produces safely to escape supervising. Therefore, we should enhance the supervision

CONCLUSION

Through the principal-agent analysis on the supervision of the insurance, we found that the insurance company can design a set of incentive mechanism and provide a set of menu for coal mining company which produces safely and that which produces illegally to select automatically. In order to save cost, the coal mining company which produces safely needn't be supervised and examined, so the insurance company just needs to supervise the coal mining company which produces illegally. This method can greatly save the cost of insurance supervision and the rare resources of the supervision can be efficiently used. When the number of coal mining company which produces safely is relatively larger in the insurance market, insurance company is to strength the supervision of the one produces illegally. When the difference between coal mining company which produces illegally and that which produces safely is greater, the supervision of coal mining company which produces illegally should be strengthened more. In reality, the insurance company began to grade the risk level of coal mining company and then implement a classified supervision. For this mechanism can implement effectively, insurance company needs to make a scientific and rational differential and floating rate system. Advance insurance premium constitution system and modify premium dynamically is our next study in future.

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