Multi-party Game Analysis of Coal Industry and Industry Regulation Policy Optimization

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Abstract. In the face of the frequent occurrence of coal mine safety accidents, this paper analyses the relationship between central and local governments, coal mining enterprises and miners from the perspective of multi-group game. In the actual production, the decision of one of the three groups can affect the game strategy of the other of the three, so we should assume the corresponding game order. In this order, the game analysis of the income and decision of the three is carried out, and the game decision of the government, the enterprise and the workers is obtained through the establishment of the benefit matrix and so on. And then on the existing system to optimize the coal industry regulation proposed practical recommendations to reduce the frequency of industry safety accidents, optimize the industry production environment.

Key words. Coal mine accident, Game, Safety production, Supervision policy.

1. Introduction
With the market-oriented coal industry, coal production safety issue much attention. In China, the coal production industry is one of the high-risk industries, coal enterprises in the production process is facing from all aspects of the problem led to frequent accidents, resulting in people's lives and property losses, but also damage the coal industry and government image. According to statistics, in 2015 China coal mine death rate per million tons is approximately 0.293, Comparison of relative advanced mining countries, still 10 times the advanced countries. The total number of coal mine accident deaths and the death toll per million tons of coal are living in the forefront of the world. In the face of the frequent occurrence of coal mine accidents, we can explore the reasons by a variety b game perspective. In the actual production management, modeling game group by the government and coal companies, coal companies and miners composed, according to the analysis of the game relationship between the relevant groups, the way and method of safe production and management of coal mining enterprises can be obtained.
2. Game model analysis

2.1. Model basic assumptions

(1) Game strategy: The set of alternative game strategies for coal mining enterprises is assumed to be $P = \{P_1, P_2\} = \{\text{strict supervision}, \text{not strictly supervised}\}$; Coal mining staff of the game strategy set for the $M = \{M_1, M_2\} = \{\text{illegal operations}, \text{not illegal operations}\}$; the central and local government action set is $W = \{W_1, W_2\} = \{\text{supervised}, \text{unregulated}\}$.

(2) Order: In the actual production, the coal mine production safety management mainly has the central and the local government, the coal mine enterprise and the coal mine worker three main body, the central and the local government supervises the safety production of the coal mine enterprise, the coal mine enterprise carries on the safety supervision to the coal mine production work, Whether a staff member violates a job in the production operation, which in turn affects other subjects. It can be seen that the action of the game group in the model will affect each other. The decision of the former actor will influence the choice of the game strategy of the post actor, and must determine the order of the game.

(3) Action sequence and payment: If the coal mine enterprises "strict supervision", generally no accident, coal mining enterprises and coal workers to pay the normal pay, paid for $(0, 0)$. If the coal mine enterprises "do not strictly supervise", coal workers "illegal operations", the workers will face the punishment of coal enterprises $H$, the two sides pay $(0, -H)$. If the coal mine "does not strictly supervise", the staff "does not violate the operation", assuming that the government does not monitor the probability of $C$, there are two cases: if no accident, coal mine will get super prize $V$, workers will get a certain reward $B$ ($V, -B$); if an accident occurs, the coal mine will lose $K$, the workers will be seriously injured or died, the loss is $L$, both parties pay $(-K, -L)$. 

Figure 1 China's coal mine production and safety supervision in the relationship between the relevant groups.
2.2. Game model solution

(1) The strategy of workers’ selecting under the influence of government regulation policy.

In the game due to government regulatory factors caused by the accident. Assuming that the central and local government regulates the probability of occurrence is C, the profit expectation of the coal mine is $V(1-C)-KC = V-(V+K)$. The income expectation of the employee's work without the strict supervision of the coal mine is $B(1-C)-LC$. In the game whether illegal miners jobs, if employees illegal operations, the expected return is $-H$, make $-H = B(1-C) - LC$. Due to the influence reward exceeding production quotas available to workers and employees of accidents compared to the negative impact negligible, so $C = (B+h)/(B+L) \approx H/L$. That is, when $C=H/L$, the workers randomly selected illegal operations and compliance operations; when $C>H/L$, the workers choose illegal operations, and income is $-H$; when $C<H/L$, the workers choose The proceeds are $(-LC>-H)$.

(2) The selection strategy of coal mine under the influence of government regulation policy.

In the game of government regulatory factors, from the above analysis, the coal miner’s expected income is $V-(V+K)C$. In the game whether illegal miners jobs, the workers selected under illegal operations strategy, earnings coal mine is zero. Let $0 = V-(V+K)C$, so $C = V/(V+K)$. That is, when $C = V/(V+K)$, the coal mine chooses to strictly supervise and does not strictly supervise; when $C > V/(V+K)$, the coal mine chooses to strictly supervise and obtains the gain 0; when $C < V/(V+K)$, the coal mine selection is not strictly supervised.

(3) Coal mining enterprises and coal workers through the game between the benefit matrixes.

As shown in Fig. 3, we assume that $V(1-C)-KC = V-(V+K)$ represents the expected return of the coal mine in the benefit matrix, and $-LC$ represents the expected return of the coal mine. Assume that the average income of the two is less Y or y than the expected return. If the coal industry through strict work ($C > V/(V+K)$) can be obtained for the return of $V-(V+K)$, while coal workers through the operation of the proceeds can get $-LC$. But in fact, the two sides can get the average income and cannot guarantee, because only one side of the strict work is not reach. When $[C > H/L; C < V/(V+K)]$, the non-cooperative Nash equilibrium is reached. In the game strategy is not clear what the other side to take the premise of their optimal game strategy is to cost less average earnings, rather than trying to get the expected return to work strictly under the premise of each other the same rigorous work. This is determined by the current distribution system, and the average return can be guaranteed in the case of
[C> H / L; C<V / (V + K)], so that the rational choice of both sides is not strictly working to obtain the average income.

\[
\begin{array}{|c|c|c|}
\hline
\text{Coal mine workers} & \text{Illegal operation} & \text{Compliance} \\
\text{Coal mine} & \langle C > H / L \rangle & \langle C < H / L \rangle \\
\hline
\text{Not strictly supervised} & (-H,0) & [B(1-C)LC; V-(V+K)C-Y] \\
[C<V/(V+K)] & & \\
\hline
\text{Strict supervision} & (-H,0) & [-LC; V-(V+K)C] \\
[C>V/(V+K)] & & \\
\hline
\end{array}
\]

**Figure 3** Benefit matrix of coal mining enterprises and coal mine workers

(4) The benefit matrix between the government and the coal mining enterprises through the game. As shown in Fig. 4, we assume that the benefit matrix, \( M \) represents the expected return of the government, \( V(1-C) - KC = V- (V + K) \) represents the expected return of the coal mine. And the average income of the two is less than the expected return of each \( X \) and the probability of an accident due to government regulatory factors is \( C \), the probability of no accident is \( 1-C \). If the government through strict supervision \( (1-C) \) can get the benefits of \( M \), while coal companies through strict supervision can be \( V- (V + K) \) income. In fact, in the case of non-cooperative Nash equilibrium \( (C; C> H / L) \), his optimal game strategy is based on a small cost expenditure \( (C; C> H / L) \) to get the average income. Rather than their own strict work in the other side of the same rigorous work under the premise of the expected income, which is determined by the current distribution system. The average benefit is also guaranteed in the case of \( (C; C> H / L) \), so that the rational choice of both sides is not strictly working \( (C; C> H / L) \) to obtain the average return.

\[
\begin{array}{|c|c|c|}
\hline
\text{Government} & \text{Not strictly regulated} & \text{Strict supervision} \\
& \langle C > V/(V+K) \rangle & \langle C>V/(V+K) \rangle \\
\hline
\text{Not strictly regulated} & [V-(V+K)C-x;X,0] & [V-(V+K)C-x;X,m] \\
( C ) & & \\
\hline
\text{Strict supervision} & [V-(V+K)C-x;X,0] & [V-(V+K)C;X,M] \\
(1-C) & & \\
\hline
\end{array}
\]

**Figure 4** Benefit matrix of government and coal mining enterprises

3. **Industry regulation policy optimization**

The above is a theoretical analysis of the existing production model of China's coal mine, the actual production operations and regulatory links will be more complex, and some game conditions cannot be considered. Through the above analysis, we can under the current system of industry regulation policy optimization proposed the following rational recommendations:
(1) To reduce the differences between the central and local governments, so that the central and the
government can work together. Local governments are able to choose strategies within their own terms
of use, and to some extent ignore the coal mine safety policies set by the central government.

① To reduce the incidence of coal mine accidents, the Central Government should strengthen
supervision of local government, as well as some incentive to take measures to reduce the divergence
of interests between central and local government.

② Reform of China's mineral resources use system, because of our ownership of mineral deposits are
assigned to local governments at all levels, it may lead to local protectionism, so that the central
government to develop security regulations become invalid. It should be a public auction of resources,
thus contributing to local governments to better implement the coal mine safety system.

(2) Reform the existing local government and coal mine between the regulatory forms, to avoid the
recurrence of security incidents.

① Because the local government and coal mines are not closely linked, may lead to coal mining
enterprises in the production process will be the implementation of safety regulations in the form, or
lead to local government supervision is not enough to lead to the occurrence of security incidents.

② The constraints and incentives to local governments through the establishment of mechanisms for
the assessment of local government, so that the government of coal mining enterprises to carry out
effective supervision to prevent government inaction.

(3) Coal mining enterprises should pay attention to safety, so as to achieve stable development.

At present, many companies have poor security awareness, ignoring the safety hazards of all aspects
of coal production, in order to achieve the stable development of enterprises, should pay more attention
to safety. To establish a reasonable safety oversight mechanism, covering all aspects of coal mine
production, to achieve the reward and punishment of the clear, so that the overall business safety. To
make safety production ideas into the corporate culture, in order to be able to achieve long-term stable
development of enterprises, in order to reduce the incidence of accidents.

(4) To strengthen the coal mine workers union organization, improve the safety awareness of coal
workers, improve the social security system for workers.

Coal mine workers are an important part of coal mining enterprises, and are the key players in
production operations. But are also direct victims of a variety of security incidents. The stability of the
development of enterprises cannot do without the safety of production staff. To force employees to
participate in pre-job training and related safety training, to strengthen staff compliance and safety
awareness. To strengthen the construction of unions to improve the coalition workers collective
bargaining power, so as to further strengthen the status of workers in the game. To build and improve
the coal mine workers social security system, so that the lives of coal workers to be protected.

4. Conclusion

Frequent coal mine accidents are not a problem that can be solved in a short time. The frequent
occurrence of coal mine accidents is caused by the long-term game between the central and local
governments, local governments and coal mining enterprises, coal mining enterprises and coal mine
workers. In order to avoid the occurrence of coal accidents. If only one of them to take correct action, it
cannot reduce the high incidence of coal accidents, must be from a number of aspects to establish
policies. According to the model established in this paper, we can conclude that the order of the game
groups will affect the game strategy of the game group. So in order to avoid the occurrence of the
accident, we must avoid that the choice of game strategy of the previous group to influence the latter
group to make a poor choice. And to ensure that the vital interests of various groups in order to achieve
as much as possible to avoid the occurrence of coal mine accidents.

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