
Game Analysis between Government and Coal Mine Enterprise in Coal Resource Exploitation Environmental Impact Compensation

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Abstract

From the angle of compensation subject and compensation object, the interest involved with stakeholder was analyzed. Based on game theory, the relation between government and coal mine enterprise was analyzed. Through the research, the government should constraint the coal mine enterprise behavior, set up coal resources development environmental impact compensation incentive mechanism, increase coal resources exploitation and environmental compensation violations punishment, and incentive the coal mining enterprises.

Keywords: *environmental impact compensation, coal resource exploitation, game analysis*

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1. Introduction

As an important pillar of national economic development, coal resources assume the important mission of maintaining the beneficial to the people's livelihood. But the coal resource development, which is a "double-edged sword", brings economic benefits but also greatly damage the ecological environment. Due to backward technology, management, long time and high strength of the predatory exploitation, coal resource development results in a large number of land waste, mineral resources waste, and ecological environment deterioration. Some regions have a wide range of ground subsidence and other geological disasters, a serious threat to human survival of the natural environment. In recent years, along with the degree of importance attached to environmental protection on the rise, as an important measure of environmental protection, environmental compensation policy effects is proposed, and the industry attention. And in the specific environment influence of coal resource development compensation mechanism, the first problem is to identify the stakeholders. Based on this, this chapter analysis and discusses on the compensation of coal resource exploitation of environmental impact abased on game theory.

2. Identification of Stakeholder in Coal Resource Exploitation Environmental Impact Compensation and their Interest Analysis

2.1. Identification of Stakeholder in Coal Resource Exploitation Environmental Impact Compensation

The stakeholder in coal resource exploitation environmental impact compensation can be divided into compensation subject and compensation object. In which compensation subject refers to the beneficiary of coal resource exploitation, including the state, coal mine enterprise, local government, etc.; compensation object refers to the one that is contributed to ecological protection of coal resource exploitation, and from another perspective it is also the environmental victim of coal resource exploitation, including mineral resource system, ecological environment system, direct victim, direct ecological benefit producer, etc.

Refer to Figure 1 for division of stakeholder in coal resource exploitation environmental impact compensation under the second division method.

2.2. Interest Analysis of Stakeholder in Coal Resource Exploitation Environmental Impact Compensation

From the angle of compensation subject and compensation object, stakeholder in coal resource exploitation environmental impact compensation involves the state, local government, coal mine enterprise, mineral resource system, ecological environment system and so on. Different participants play different roles in coal resource exploitation environmental impact compensation and their duties are also different. In order to guarantee effective and smooth development of coal resource exploitation environmental impact compensation, it is necessary to analyze the interest involved with stakeholder in coal resource exploitation environmental impact compensation.

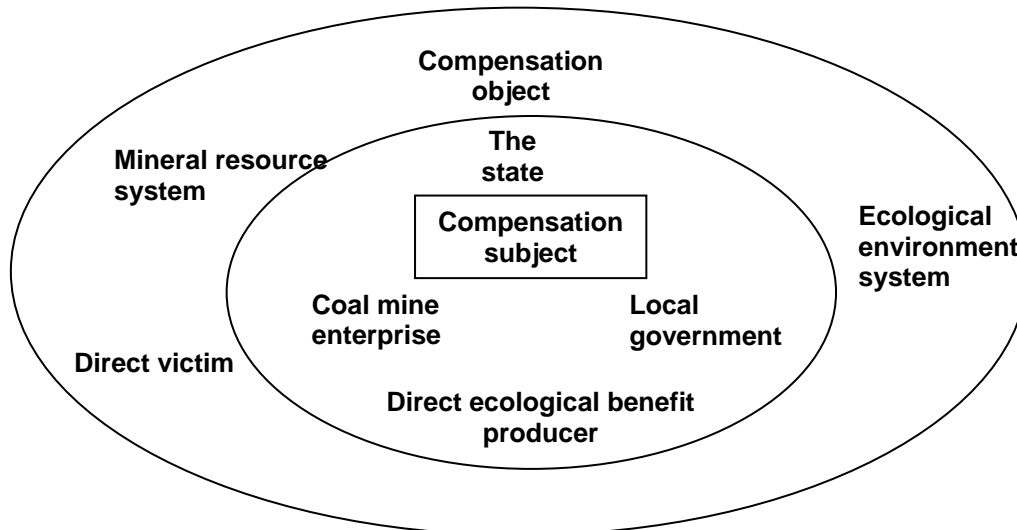


Figure 1. Diagram of Compensation Subject and Compensation Object in Coal Resource Exploitation Environmental Impact Compensation

2.2.1. Interest Analysis of the State in Coal Resource Exploitation Environmental Impact Compensation

In coal resource exploitation environmental impact compensation, the state plays two roles: on the one hand, as owner of mineral resources, the state is beneficiary in the process of coal resource exploitation, and coal enterprises transfer part of the value created in coal resource exploitation to the state in the form of tax payment, to make the state beneficiary of coal resource exploitation; on the other hand, in the process of coal resource exploitation, the state acts as supervisor and administrator, urging relevant stakeholders to perform the obligation of environmental protection and sustainable development and investigate illegal behaviors by way of administrative examination and approval, admission system, supervision, etc., to guarantee the environmental benefit of coal resource exploitation [3].

2.2.2. Interest Analysis of Local Government in Coal Resource Exploitation Environmental Impact Compensation

Local government plays a similar role to the state in coal resource exploitation environmental impact compensation. On the one hand, in the process of coal resource exploitation, local government transfers part of the value created in coal resource exploitation to itself in the form of tax collection, to make itself beneficiary of coal resource exploitation; on the other hand, in the process of coal resource exploitation, local government also acts as supervisor and administrator, strengthening the monitoring job for stakeholders especially coal mine enterprise and ensuring coordination between coal resource exploitation and environmental protection by implementing relevant regulations of the state and making protection policies for local coal resources, to guarantee the environmental benefit of coal resource exploitation.

2.2.3. Interest Analysis of Coal Mine Enterprise in Coal Resource Exploitation Environmental Impact Compensation

Coal mine enterprise is the specific implementer of coal resource exploitation and meanwhile is one of the compensation subjects in coal resource exploitation environmental impact compensation. At present, China's coal mine enterprise is the most direct implementer in coal resource exploitation as well as direct beneficiary. Coal mine enterprises put coal resources into the market for transaction by exploiting and processing coal resources and thus gain profit [4]. Therefore, from the perspective of environmental impact compensation, as specific implementer and direct beneficiary, coal mine enterprise plays an important part in coal resource exploitation environmental impact compensation.

2.2.4. Interest Analysis of Mineral Resource System in Coal Resource Exploitation Environmental Impact Compensation

As synthesis of mineral resources, mineral resource system is restricted and can be extinct rather than infinite. Therefore, with continuous exploitation of coal resource which is one of the mineral resources, the entire mineral resource system presents a decreasing trend. Thus in coal resource exploitation environmental impact compensation, mineral resource system belongs to the category of compensation object.

2.2.5. Interest Analysis of Ecological Environment System in Coal Resource Exploitation Environmental Impact Compensation

Exploitation of coal resources will affect and damage all spheres of the earth, in which the most direct manifestation is the damage toward ecological environment. Exploitation of coal resources has a great influence on ecological environment system like land and plant and it will be reflected in harmful gas, dust, vegetation deterioration, organism destruction, soil erosion, ground water disorder, etc. Therefore, in coal resource exploitation environmental impact compensation, ecological environment system belongs to the category of compensation object and is one of the most important compensation objects.

3. Analysis of Dynamic Game for Stakeholder in Coal Resource Exploitation Environmental Impact Compensation

Among stakeholders in coal resource exploitation environmental impact compensation, government and coal mine enterprise are the most important ones. In order to effectively analyze the mechanism of coal resource exploitation environmental impact compensation, game analysis is necessary for the government department in charge and coal mine enterprise to guarantee effective implementation of coal resource exploitation environmental impact compensation.

3.1. Interface Contradiction between Government and Coal Mine Enterprise

In the process of coal resource exploitation environmental impact compensation, as supervisor and administrator, the government supervises and administrates behaviors of the coal mine enterprise. Coal mine enterprise has to pay a high price when performing the duty of environmental impact compensation, so the coal mine enterprise prefers to put most of its energy into development of economic benefit rather than perform its due responsibility of environmental impact compensation. While as spokesman of the society, the government has to be responsible for society and environment. Disagreement of objectives causes great interface contradiction between government and coal mine enterprise in the process of coal resource exploitation environmental impact compensation [5]. At the same time, in the process of coal resource exploitation environmental impact compensation, the government cannot know clearly about behaviors of the coal mine enterprise, so there is information asymmetry, which makes it easy for the coal mine enterprise that has advantage in information to implement opportunism, and the government is faced with moral risk.

3.2. Establishment of Dynamic Game Mechanism between Government and Coal Mine Enterprise in Coal Resource Exploitation Environmental Impact Compensation under Incomplete Information

The game between government and coal mine enterprise always exists. The coal mine enterprise itself is “economic man”, with the goal of pursuing maximum self interest. Therefore, for coal mine enterprise, in the process of coal resource exploitation, social institutions like social organization, trade association and the social public will help the government supervise coal mine enterprise to perform its duty of environmental impact compensation, but driven by economic interest, coal mine enterprises and social institutions may conspire to cheat the government in the implementation process of environmental impact compensation, while the government will have to pay a high cost if it supervises coal mine enterprise together with social institutions. Whether the government conducts extra inspection for coal mine enterprise’s job of environmental impact compensation in the process of coal resource exploitation depends on the inspection cost and loss. Based on the angle of dynamic game, profit and economic rationality of the government’s supervision behavior was analyzed in this paper.

3.2.1. Game Order between Government and Coal Mine Enterprise

There is multi-signaling game between government (S) and coal mine enterprise (R), and obvious “information asymmetry” exists between R and S . S knows its supervision level θ_j in coal resource exploitation environmental impact compensation while R cannot correctly grasp such information.

The game between them obeys the following order:

(1) “Nature” (N) takes actions to determine government S ’s type $\theta \in \Theta$, $\Theta = \{\theta_1, \theta_2, \dots, \theta_n\}$. S knows θ while R does not; R only knows the priority belief $p(\theta_j)$ of S ’s supervision level θ_j in coal resource exploitation environmental impact compensation, and $\sum_{j=1}^n p(\theta_j) = 1$.

(2) Government S takes strategic actions according to θ_j at first, and delivers “the government’s supervision degree d_j ” to coal mine enterprise; the coal mine enterprise generally considers that “the government’s supervision degree d_j ” can reflect the government’s supervision level θ_j , and d_j is in direct proportion to θ_j , for the higher the government S ’s supervision level is, the higher the supervision cost is and the greater the government S ’s supervision degree is. Suppose that when the supervision level of the government in coal resource exploitation environmental impact compensation, the probability distribution of the supervision degree d_j is:

$$\sigma_j = \{p(d_1 | \theta_j), p(d_2 | \theta_j), \dots, p(d_j | \theta_j)\}, \text{ and it is in line with } \sum_{j=1}^n p(d_j | \theta_j) = 1.$$

(3) After the coal mine enterprise R knows government S ’s supervision degree d_j , it will get the posterior probability $\tilde{p} = p(\theta_j | d_j)$ from the prior probability $\tilde{p} = p(\theta_j | d_j)$, and take corresponding action $k \in K$, in which K is the action space of R , and $K = \{\text{illegal, legal}\}$. When d_j keeps at a high level, if the coal mine enterprise R violates the rule, the situation of profit loss and even deficit may occur; When d_j keeps at a low level, if R takes some illegal actions, it may probably earn some profits without getting punishment for illegal actions.

3.2.2. Basic Hypotheses of Game between Government and Coal Mine Enterprise

According to general order of the game, a signaling game model between S and R can be built and the following premise hypotheses are set for this model [8]:

- (1) This is infinite repeated game;
- (2) Both the government S and the coal mine enterprise R have sufficient rationality;
- (3) At the initial stage, the coal mine enterprise R does not know the type of government S , and it only has the prior belief $p(\theta_i)$ of S 's type; meanwhile S does not know the violation probability $v_j = p(k | d_j)$ of R either;

(4) After the first stage, R can obtain the posterior probability $\tilde{p} = p(\theta_j | d_j)$ of government S 's type according to S 's supervision degree at the previous stage, and S can also know the violation probability v_j of R at the previous stage;

(5) Both R and S can decide their actions at the next stage according to information gained from the previous stage;

(6) The equilibrium function of R and S depends on S 's supervision probability σ_j on R and R 's violation probability v_j ; S 's supervision probability σ_j and R 's violation probability v_j converge toward the equilibrium state.

For study in the following part, the following definitions are given [9]:

Definition 1: The perfect Bayesian equilibrium of supervision and restriction model between government and coal mine enterprise in coal resource exploitation environmental impact compensation is the combination of strategic mixing $(d^*(\theta), k^*(\theta))$ and posterior probability $\tilde{p} = p(\theta | d)$, and it meets:

$$(1) k^*(d) \in \arg \max_d \sum_{\theta} \tilde{p}(\theta | d) v_2(d, k, \theta);$$

$$(2) d^*(\theta) \in \arg \max_d v_1(d, k^*(d), \theta);$$

(3) $\tilde{p}(\theta | d)$ is obtained by R from prior probability $p(\theta)$, the observed signal d and S 's optimal strategy $d^*(\theta)$ via Bayesian law (under possible situations).

3.2.3. Profit Analysis of Government and Coal Mine Enterprise

(1) Profit analysis of coal mine enterprise R

Suppose the profit of coal mine enterprise R is $v_1(d, k, \theta)$, then

$$v_1(d, k, \theta) = P \times p(k | d_j) \times p(d_j) - E(c/k) \times p(k | d_j) \times p(d_j) - F \times p(\theta_j) \times p(d_j)$$

In which:

P --- Profit deserved by coal mine enterprise R after coal resource exploitation is finished;

$E(c/k)$ --- Expected cost of coal mine enterprise R after coal resource exploitation is finished;

$p(k | d_j)$ --- Violation probability of coal mine enterprise when government S 's supervision degree is d_j ;

$p(d_j)$ --- Probability for government S 's supervision degree to be d_j ;

F --- Punishment of coal mine enterprise from the government for violation.

(2) Profit analysis of government S

Suppose the profit of government S is $v_2(d, k, \theta)$, then

$$v_2(d, k, \theta) = F \times p(\theta_j) \times p(d_j) + R + M(\theta, k, d) - H(\theta_j) - P \times p(k | d_j) \times p(d_j)$$

In which:

R ---Profit of government S brought about by coal resource exploitation environmental impact compensation;

$H(\theta_j)$ ---Cost of government S when the supervision level is θ_j in coal resource exploitation environmental impact compensation;

$M(\theta, k, d)$ ---Other profits of government S brought about by coal resource exploitation environmental impact compensation, such as social effect.

3.2.4. Establishment of Dynamic Game Model for Government and Coal Mine Enterprise

It can be known from Definition 1 that the optimal choice of coal mine enterprise R is to make:

$$k^*(d) \in \arg \max_d \sum_{\theta} p(\theta/d) v_2(d, k, \theta)$$

Therefore:

$$\begin{aligned} \arg \max_d \sum_{\theta} p(\theta/d) v_2(d, k, \theta) &= \\ \arg \max_d \sum_{i=1}^n \left[\frac{p(d_i/\theta_j)}{p(d_i)} \right] P \times p(k/d_j) \times p(d_j) - E(c/k) \times p(k/d_j) \times p(d_j) - F \times p(\theta_j) \times p(d_j) & \\ = \arg \max_d \sum_{i=1}^n p(d_i/\theta_j) [P \times p(k/d_j) - E(c/k) \times p(k/d_j) - F \times p(\theta_j)] & \end{aligned}$$

Formula (1)

Again, it can be known from Definition 1 that the optimal choice of government S is:

$$d^*(\theta) \in \arg \max_d v_1(d, k^*(d), \theta)$$

Therefore:

$$\arg \max_d v_1(d, k^*(d), \theta) = \arg \max_d [F \times p(\theta_j) \times p(d_j) + R + M(\theta, k, d) - H(\theta_j) - P \times p(k/d_j) \times p(d_j)]$$

Formula (2)

It can be obtained by getting the first-order partial derivative of $p(k/d_j)$ according to Formula (1) and setting the partial derivative as 0:

$$p^*(k/d_j) = \frac{P_{\theta}}{E(c/k)}$$

Formula (3)

In which:

P_{θ} ---Reward profit of coal mine enterprise R when government S 's supervision level is θ

It can be obtained by getting the first-order partial derivative of θ_j in Formula (2):

$$\frac{\partial H(\theta_j)}{\partial p(\theta_j)} - \frac{\partial M(\theta_j, k, d)}{\partial p(\theta_j)} = P \times p(d_j/\theta_j) - F \times p(d_j)$$

Therefore, the perfect Bayesian equilibrium of this model can be gained:

$$(\theta^*, p^*(k/d), \tilde{p}^*(\theta/d)) = (\theta^*, \frac{P_\theta}{E(c/k)}, \frac{p(\theta, d)}{p(d)})$$

3.2.5. Analysis and Conclusion of Dynamic Game Model for Government and Coal Mine Enterprise

(1) If government S 's supervision level θ is low, then:

$$\frac{\partial M(\theta_j, k, d)}{\partial p(\theta_j)} - \frac{\partial H(\theta_j)}{\partial p(\theta_j)} < P \times p(d_j / \theta_j) - F \times p(d_j)$$

This means that the marginal income of government S 's supervision is less than the profit obtained by coal mine enterprise R , showing that under the situation of low supervision level, the optimal strategy of government S is to remove supervision [10].

(2) If government S 's supervision level θ is high, then:

$$\frac{\partial M(\theta_j, k, d)}{\partial p(\theta_j)} - \frac{\partial H(\theta_j)}{\partial p(\theta_j)} > P \times p(d_j / \theta_j) - F \times p(d_j)$$

This means that the marginal income of government S 's supervision is less than the profit obtained by coal mine enterprise R ; in this case, coal mine enterprise R will be punished for violation and decrease its profit. At this time, the optimal choice of coal mine enterprise R is not to violate the rules.

4. Conclusion

Coal resources development environment effect of compensation is an important measure to realize the sustainable development of the coal industry. In the practice of coal resources development environment influence compensation work, involving stakeholders more, in which the government and coal enterprises are the main two stakeholders. The government in order to guarantee the coal resources development environment influence compensation work results, on the one hand we must strengthen the construction of their own regulatory capacity, improve the government staff capacity and service quality; on the other hand, need in the system construction, strengthening the construction of relevant laws, regulations system, constraints on coal enterprises to conduct, increase coal resources development environment influence the punishment compensation violations, and positive performance on coal enterprises incentive.

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