My Country's Non-Ferrous Metal Industry Based on Third-Party Supervision Evolutionary Game Analysis of Environmental Supervision Mechanism

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Abstract: China's non-ferrous metal industry is developing rapidly, but a large amount of waste water, waste gas and solid waste are generated in non-ferrous metal mining, beneficiation, refining and processing. Environmental pollution has become a major factor restricting the sustainable development of the non-ferrous metal industry. And with the implementation of the new "Environmental Protection Law", which was hailed as the "strictest in history" in 2015, the non-ferrous metal industry is facing a more severe situation and unprecedented pressure on environmental protection. Therefore, in order to solve the problem of pollution prevention and control in the non-ferrous metal industry, it is necessary to mobilize the whole industry, not only in terms of thinking, but also in action. To achieve this goal is inseparable from the implementation and improvement of the supervision mechanism. Therefore, this paper considers the third-party supervision on the basis of government supervision, and builds a tripartite evolutionary game model with the government, enterprises and the third-party public as the main body. Fang in the development stage of non-ferrous metal resources gradually stable conditions, and finally use Matlab to simulate the key factors of the ideal stable state in the model, and put forward suggestions for the three main subjects accordingly.

Keywords: evolutionary game; non-ferrous metals; environmental supervision mechanism; third-party supervision

1. Introduction

The ideas on the construction of ecological civilization are constantly enriched and improved, and the promotion of ecological civilization construction and ecological environmental protection has undergone historic, turning and overall changes from practice to understanding. Adhering to sustainable development has become an inevitable trend in all walks of life, and it is even more so to achieve high-quality development and meet the urgent requirements of the people for a better life.

The non-ferrous metal industry has always been labeled as "high energy consumption and high pollution". My country's non-ferrous metal industry has developed rapidly, but environmental pollution has become a major factor restricting the sustainable development of the non-ferrous metal industry, especially in the non-ferrous metal industry. Resource development in the metal industry. In recent years, the pollution discharge of non-ferrous metals per unit product has been effectively suppressed, but due to the rapid growth of the total output of the non-ferrous metal industry, the total amount of pollutant emissions is still huge. Therefore, how to effectively control and control the environmental pollution of the non-ferrous metal industry and improve the ecological efficiency of the non-ferrous metal industry has become the key to ensuring the sustainable development of the non-ferrous metal industry.

There are many reasons why enterprises the non-ferrous metal industry has always been labeled as "high energy consumption and high pollution". My country's non-ferrous metal industry has developed rapidly, but environmental pollution has become a major factor restricting the sustainable development of the non-ferrous metal industry, especially in the non-ferrous metal industry. Resource development in the metal industry. In recent years, the pollution discharge of non-ferrous metals per unit product has been effectively suppressed, but due to the rapid growth of the total output of the non-ferrous metal industry, the total amount of pollutant emissions is still huge. Therefore, how to effectively control and control the environmental pollution of the non-ferrous metal industry and improve the ecological efficiency of the non-ferrous metal industry has become the key to ensuring the sustainable development of the non-ferrous metal industry.

Pollute the environment frequently, such as insufficient punishment, imperfect government supervision mechanism, non-open and transparent information, inadequate implementation of the sewage permit system, low sewage treatment technology, and high treatment costs. No matter how much the government invests in environmental governance, it will only cure the symptoms but not the root cause. To

achieve the green development of the non-ferrous metal industry, it is necessary to start from the source and allow the pollutants to be discharged after technical treatment. This is difficult to achieve by self-consciousness of enterprises, because the purpose of enterprises is to make profits, and sewage treatment is a large expense, which will increase the cost of enterprises to a certain extent, especially for small and medium-sized enterprises, in the case of low income It is even more difficult to bear this pressure, so many companies will take risks. In addition, the fines are only scratching the surface. Even if they are exposed, they only need to pay a fine, which may not be enough to reach half of the cost of dealing with pollutants. Therefore, to change this situation, it is necessary to improve the existing environmental supervision mechanism, and at the same time increase the third-party public supervision channels, so that such illegal behaviors by enterprises have nowhere to hide.

The environmental supervision mechanism mainly refers to various laws, policies, measures and procedures for the supervision of the environment by the government and relevant departments. Enterprises with such behavior shall be punished; third-party supervision in this article mainly refers to the supervision of non-ferrous enterprises by the third-party public, mainly including various social masses and organizations, especially non-governmental environmental protection organizations, mineral resource development zones Residents, residents near the company's factory, or employees of the company. The third-party public supervision is an indispensable and important supplement to the government's environmental supervision. The third-party public supervision can fill the gap where the government's supervision is limited, because it is easier for these people to understand the real situation of the enterprise. Enhancing the public's acceptance and participation in environmental policies and measures will be more conducive to creating an environmental governance atmosphere of co-governance.

2. Literature Review

As the world's largest energy consumer, the non-ferrous metal industry is very important to my country. In recent years, the research on the non-ferrous metal industry has mainly focused on the environmental efficiency evaluation, financial evaluation, utilization efficiency and impact on various aspects of the non-ferrous metal industry. There are few related studies on the environmental supervision mechanism of the non-ferrous metal industry. From the perspective of the harmfulness of environmental pollution, the environmental pollution and ecological damage in the west are a serious threat to the healthy development of my country's overall economy and the survival of the Chinese nation. Based on this, Wu Dingyong proposed that strengthening and improving the supervision of environmental public opinion in the west is the top priority [1]. In addition, some scholars have concluded through research that a certain degree of supervision will have a greater positive impact on pollution control, the degree of government environmental supervision and the participation of public opinion have a significant inhibitory effect on pollution emissions, and the stricter the degree, the higher the efficiency [2]. From this point of view, a perfect environmental supervision mechanism is likely to be indispensable for the non-ferrous metal industry to improve ecological efficiency and achieve sustainable development.

Social public supervision will significantly promote the green environmental performance of enterprises [3], and public supervision will also have a positive impact on the performance of industrial pollution mitigation. Under a high degree of public supervision, the performance of regional industrial pollution mitigation can be significantly improved, and public participation in environmental governance Pollution reduction has a significant role in promoting, and my country should include the public participation mechanism when formulating the environmental protection assessment system [4]. Strengthening media supervision can urge enterprises to disclose environmental information and improve the efficiency of government supervision [5]; due to the limitations of some factors, my country's environmental protection NGOs have certain difficulties in supervising enterprises' environmental information disclosure [6], but they can still Expand the scope of supervision and solve environmental problems through continuous innovation [7,8]; local government supervision can also significantly improve the level of environmental information disclosure of enterprises and enhance public opinion supervision [9]; third-party international environmental audit can Drive polluting enterprises to actively implement green environmental behaviors [10]. In addition to considering the unilateral role in corporate supervision, it is also possible to build a "government-enterprise-public" ternary environmental governance system. The public can directly restrain the illegal behavior of enterprises through its own deterrent force. It can also rely on the government's environmental law enforcement to force enterprises to internalize the external cost of environmental pollution, and then indirectly participate in environmental governance [11]. To sum up, the government, the public, the media, and NGOs can all play a certain role in supervising the thoughts and even behaviors of companies trying to evade their environmental responsibilities, so that companies cannot recklessly escape the obligation to maintain a good ecological environment.

In terms of research methods, game theory has a wide range of applications. You Daming and Yang Jinhui have applied evolutionary game theory to the study of government environmental regulation and enterprise ecological technology innovation behavior [12], and some scholars have constructed complete information dynamics in environmental regulation. Game model to analyze environmental supervision. However, it is rare to use evolutionary game theory as the main research method to analyze the environmental supervision mechanism of the non-ferrous metal industry with public participation. Therefore, this paper attempts to use the

evolutionary game model to analyze the above problems, build a "government-enterprise-public" tripartite evolutionary game model in the resource development stage of the non-ferrous metal industry (as shown in Figure 1), and introduce the replication dynamic equation of the evolutionary game to solve According to the method proposed by Friedman, the stability analysis of the equilibrium point of the matrix is carried out, so as to provide suggestions for avoiding the negative supervision of regulatory authorities and promoting the performance of enterprises.

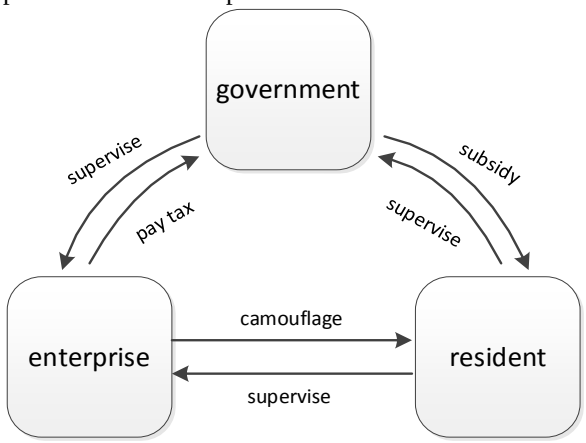

Figure 1. Government-enterprise resident tripartite game model

3. Evolutionary Game Analysis Research Process

3.1. Model Building

During the evolution of the game between non-ferrous metal enterprises and the government, various stakeholders constantly change their strategies based on their own interests, forming a sequential game field. In this game field, according to the different interests, it can be simply divided into three game parties: the government, the enterprise and the third-party public. Different stakeholders will adopt different strategies through the game at different development stages of the event, resulting in different results.

The general assumptions of the model are as follows:

(1) The three parties in the game have bounded rationality, and will adjust their strategy choices based on the principle of maximizing their own interests, and will eventually achieve a stable strategy with long-term evolution.

(2) The government refers to the relevant departments of local governments that manage non-ferrous metal enterprises, and it is necessary to release regulatory information in a timely manner and ensure the authenticity and reliability of the information. Their interest appeals are mainly divided into two types: one is to do their due diligence, maintain the local ecological environment, and devote themselves to solving environmental problems; the other is to neglect the supervision of enterprises due to the pressure of local economic development, or to receive bribes from some enterprises Instead of doing anything, it is even possible to take no measures against the company's ecologically damaging behavior so that the company can pay more taxes. The two demands correspond to two strategic choices: active regulation and passive regulation. The probabilities are assumed to be x and 1-x, respectively. It is agreed that the government's active regulation revenue is greater than zero and higher than the passive regulation revenue.

(3) Enterprises refer to all non-ferrous metal enterprises within the jurisdiction of the government. The first appeal of enterprises is to make profits, but some enterprises will choose to perform contract performance considering factors such as reputation. In the process, the company can consciously fulfill the agreement to dispose of pollutants so that they meet the standards set by the state and then discharge; while some companies only pursue the maximization of interests, or choose to breach the contract due to factors such as the company's own economic capacity and technical level. It refers to the behavior of non-ferrous metal enterprises to disregard the regulations on the discharge of pollutants in order to reduce costs and other reasons, deal with pollutants at will, and cause damage to the environment. Likewise, its probabilities are assumed to be y and 1-y, respectively.

(4) The third-party public mainly refers to various social masses and organizations, especially non-governmental environmental protection organizations, residents near mineral resource development zones, residents near enterprises' factories or employees of enterprises, etc. Organizations and individuals implementing supervision. The public can supervise major projects through the information published by the government. There are two strategies to choose from participating in supervision and not participating in supervision. The probabilities are z and 1-z respectively. It is agreed that the income of the public participating in supervision is greater than zero and higher than that of not participating in supervision, where x, y, z $\in$ [0, 1].

(5) When the government chooses passive supervision, no matter whether the third-party public participates in the supervision or not, no compensation can be obtained; however, when the third-party public participates in the supervision, they can find the government's negative supervision and report it, and the government will be punished accordingly. If the three-party public does not participate in supervision, it means that there is no supervision of the company's performance or breach of contract. That is to say, in this case, even if the company defaults, it will not be discovered, and the company's income at this time is.

(6) Regardless of the strategic choice of the government and the public, if the enterprise chooses to perform the contract, then the enterprise's income will remain unchanged.

In this paper, based on the actual situation of resource development in general, combined with existing research, the parameters of benefit, cost, penalty, loss and compensation for the government, enterprises and the public are set up, as shown in Table 1.

Based on the above assumptions and parameter settings, the return matrix of the tripartite game model

can be obtained, as shown in Table 2.

Table 1. Assumptions of relevant parameters

symbol	significance
ΔV_g	Additional benefits from active government regulation
V_g	The normal benefits of passive government regulation that go undetected by the public
V_c	normal remuneration for production
ΔV_c	Additional remunerations obtained by the company for performance, such as credit rating and social influence improvement (default is not recognized as performance if it is not exposed)
V_p	The public receives compensation from the government for participating in surveillance
ΔC_g	Increased costs of active government regulation
C_g	The cost of negative government regulation
ΔC_c	The increased cost of corporate performance
C_c	corporate default cost
C_p	The cost of public participation in monitoring
L_g	Losses from corporate defaults to the government
L_c	The loss brought to itself after corporate default is exposed by the government or the public, mainly manifested in the decline of credit rating and social influence, etc.
L_p	Corporate default found to cost the public
ΔL_p	Corporate defaults go undetected, increasing losses to the public
P_g	The government is punished by higher authorities for negative regulation being discovered by the public, such as reputation loss and performance penalties, etc.
P_c	Businesses fined by government for breach of contract

Table 2. Tripartite Benefit Matrix

participant				enterprise	
				legitimate(y)	default(1-y)
government	positive(x)	resident	participate(z)	$(V_g+\Delta V_g)-(C_g+\Delta C_g)-V_p$ $(\mathrm{V_c}+\Delta \mathrm{V_c})-(\mathrm{C_c}+\Delta C_c)$ V_p-C_p	$(\mathrm{V_g}+\Delta \mathrm{V_g})-(\mathrm{C_g}+\Delta \mathrm{C_g})-V_p-L_g+P_c$ $V_c-C_c-L_c-P_c$ $V_p-C_p-L_p$
			not participate(1-z)	$(\mathrm{V_g}+\Delta \mathrm{V_g})-(\mathrm{C_g}+\Delta \mathrm{C_g})$ $V_c+\Delta V_c)-(C_c+\Delta C_c)$ 0	$(V_g+\Delta V_g)-(C_g+\Delta C_g)-L_g+P_c$ $V_c-C_c-L_c-P_c$ $-L_p$
	negative(1-x)	resident	participate(z)	$V_g-C_g-P_g$ $V_c+\Delta V_c)-(C_c+\Delta C_c)$ $-C_p$	$\mathrm{V_g}-C_g-P_g-L_g+P_c$ $\mathrm{V_c}-\mathrm{C_c}-\mathrm{L_c}-\mathrm{P_c}$ $-C_p-\mathrm{L_p}$
			not participate(1-z)	$\mathrm{V_g}-\mathrm{C_g}$ $V_c+\Delta V_c)-(C_c+\Delta C_c)$ 0	$\mathrm{V_g}-\mathrm{C_g}-L_g$ $(\mathrm{V_c}+\Delta \mathrm{V_c})-C_c$ $-(L_p+\Delta \mathrm{L_p})$

3.2. Analysis of the Stability and Evolution Path of Each Game Subject

This section uses the stability theorem of differential equations to analyze the stability and strategy evolution paths of the three game subjects. According to the stability theorem of differential equations, the stablepoint of the replica dynamic equation should satisfy two conditions: $F(x)=0$ and $\frac{\mathrm{d}F(x)}{\mathrm{d}x}<0$

3.2.1. Government

(1) Equilibrium analysis

When the government chooses to actively regulate, the government's expected benefits are:

$$\mathrm{U_{11}}=yz\left[(V_g+\Delta V_g)-(C_g+\Delta C_g)-V_p\right]+(1-y)z\left[(V_g+\Delta V_g)-(C_g+\Delta C_g)-V_p-L_g+P_c\right]+y(1-z)\left[(V_g+\Delta V_g)-(C_g+\Delta C_g)\right]+(1-y)(1-z)\left[(V_g+\Delta V_g)-(C_g+\Delta C_g)-L_g+P_c\right]$$

When the government chooses passive regulation, the government's expected benefit is:

$$\mathrm{U_{12}}=\mathrm{yz}\left[\mathrm{V_g}-\mathrm{C_g}-\mathrm{P_g}\right]+(1-y)z\left[V_g-C_g-P_g-L_g+P_c\right]+y(1-z)\left[V_g-C_g\right]+(1-y)(1-z)\left[V_g-C_g-L_g\right]$$

Then the government chooses the mixed strategy of active regulation and passive regulation, and the expected benefit is:

$$\mathrm{U_1}=x\mathrm{U_{11}}+(1-x)\mathrm{U_{12}}$$

(2) Replication dynamic analysis

$$\mathrm{F(x)}=\frac{\mathrm{dx}}{\mathrm{dt}}=x(1-x)(\mathrm{U_{11}}-\mathrm{U_{12}})=x(1-x)\left[z(yP_c+P_g-V_p-P_c)+\Delta V_g+P_c-yP_c-\Delta C_g\right]$$

Find the first-order partial derivative with respect to x

for F(x):

$\frac{dF(x)}{dx} = (1-2x)\left[z(yP_c + P_g - V_p - P_c) + \Delta V_g + P_c - yP_c - \Delta C_g\right]$

Let F(x)=0, we can get $x_1 = 0, x_2 = 1, z^* = \frac{yP_c + \Delta C_g - \Delta V_g - P_c}{yP_c + P_g - V_p - P_c}$

The specific discussion is as follows:

(1) When $z = z^* = \frac{yP_c + \Delta C_g - \Delta V_g - P_c}{yP_c + P_g - V_p - P_c}$ F(x)=0,indicating that all levels are stable under this condition, that is, no matter what the probability of the government choosing active regulation or passive regulation, the government's strategy will not change over time;

(2) When $z < z^*, z(yP_c + P_g - V_p - P_c) + \Delta V_g + P_c - yP_c - \Delta C_g < 0, \frac{\mathrm{dF(0)}}{\mathrm{d(0)}} < 0, \frac{\mathrm{dF(1)}}{\mathrm{d(1)}} > 0$,at this time, x1=0 is the stable point of the evolution strategy, which means that the possibility of public participation in supervision is less than z* and shows a downward trend. Due to information asymmetry and other reasons, the government cannot realize comprehensive supervision of enterprises, and there is a lack of public supervision at this time. Incentive effect, the government will eventually choose passive regulation;

(3) When $z > z^*, z(yP_c + P_g - V_p - P_c) + \Delta V_g + P_c - yP_c - \Delta C_g > 0, \frac{\mathrm{dF(0)}}{\mathrm{d(0)}} > 0, \frac{\mathrm{dF(1)}}{\mathrm{d(1)}} < 0$ at this time, x2=1 is the stable point of the evolution strategy, indicating that the possibility of public participation in supervision is greater than z* and shows an increasing trend. Public participation constitutes an effective incentive for the government, and the government will increase the cost and loss of supervision after weighing the cost and loss of supervision. The government will eventually choose to actively supervise the supervision of enterprises.

3.3.2. Enterprise

(1) Equilibrium analysis

When the enterprise chooses to perform the contract, the expected benefit of the enterprise is:

$\mathrm{U}_{21} = xz[(V_c + \Delta V_c) - (C_c + \Delta C_c)] + x(1-z)[(V_c + \Delta V_c) - (C_c + \Delta C_c)] + (1-x)z\left[\ V_c + \Delta V_c) - (C_c + \Delta C_c)\right] + (1-x)(1-z)\left[\ V_c + \Delta V_c) - (C_c + \Delta C_c)\right]$

When the firm chooses to default, the firm's expected return is:

$\mathrm{U}_{22} = xz[V_c - C_c - L_c - P_c] + x(1-z)[V_c - C_c - L_c - P_c] + (1-x)z[V_c - C_c - L_c - P_c] + (1-x)(1-z)[(V_c + \Delta V_c) - C_c]$

Then the expected return of the mixed strategy of the company choosing to perform and default is:

$\mathrm{U}_2 = y\mathrm{U}_{21} + (1-y)\mathrm{U}_{22}$

(2) Replication dynamic analysis

$\mathrm{H(y)} = \frac{\mathrm{d}y}{\mathrm{d}t} = y(1-y)(\mathrm{U}_{21} - \mathrm{U}_{22}) = y(1-y)[z(1-x)(\Delta V_c + L_c + P_c) + x(\Delta V_c + L_c + P_c) - \Delta C_c]$

Find the first-order partial derivative with respect to y for H(y):

$\frac{\mathrm{dF}(y)}{\mathrm{d}y} = (1-2y)[z(1-x)(\Delta V_c + L_c + P_c) + x(\Delta V_c + L_c + P_c) - \Delta C_c]$

Let H(y)=0, we can get $y_1 = 0, y_2 = 1, z^* = \frac{\Delta C_c - x(\Delta V_c + L_c + P_c)}{(1-x)(\Delta V_c + L_c + P_c)}$

The specific discussion is as follows:

(1) When $z = z^* = \frac{\Delta C_c - x(\Delta V_c + L_c + P_c)}{(1-x)(\Delta V_c + L_c + P_c)}$, H(y)=0, explaining that all levels are stable under this condition, that is, the firm's strategy will not change over time regardless of the probability of the firm choosing to perform or default;

(2) When $z < z^*$, $z(1-x)(\Delta V_c + L_c + P_c) + x(\Delta V_c + L_c + P_c) - \Delta C_c < 0, \frac{dH\ (0)}{d\ (0)} < 0, \frac{\mathrm{dH\ (1)}}{\mathrm{d\ (1)}} > 0$,at this time, y1=0 is the stable point of the evolution strategy, which means that when the possibility of public participation in supervision cannot reach z* and shows a downward trend, due to the appeal of maximizing interests, the government supervision department will gradually relax the supervision of the enterprise, and finally the enterprise will They will choose to ignore relevant regulations such as the discharge of pollutants up to the standard, and dispose of pollutants at will, which is likely to cause damage to the environment, that is, the company's breach of contract;

(3) When $z > z^*$, $z(1-x)(\Delta V_c + L_c + P_c) + x(\Delta V_c + L_c + P_c) - \Delta C_c > 0, \frac{\mathrm{dH\ (0)}}{\mathrm{d\ (0)}} > 0, \frac{\mathrm{dH\ (1)}}{\mathrm{d\ (1)}} < 0$,at this time, y2=1 is the stable point of the evolution strategy, which means that the possibility of public participation in supervision is greater than z* and shows an increasing trend. Public participation effectively strengthens the comprehensiveness of government supervision over enterprise supervision. In the end, enterprises will choose to consciously implement the strategy of treating pollutants to make them meet the national standards and then discharge them, that is, the enterprise's performance behavior.

3.2.3. Resident

(1) Equilibrium analysis

When residents choose to participate in supervision, the expected benefits of residents are:

$\mathrm{U}_{31} = xy\left[V_p - C_p\right] + x(1-y)\left[V_p - C_p - L_p\right] + (1-x)y(-C_p) + (1-x)(1-y)(-C_p - L_p)$

When residents choose not to participate in supervision, the expected benefits of residents are:

$\mathrm{U}_{32} = x(1-y)(-L_p) + (1-x)(1-y)\left[-(L_p + \Delta L_p)\right]$

Then the expected benefits of the mixed strategy where residents choose to participate and not participate in supervision are:

$\mathrm{U}_3 = z\mathrm{U}_{31} + (1-z)\mathrm{U}_{32}$

(2) Replication dynamic analysis

$W(z) = \frac{\mathrm{d}z}{\mathrm{d}t} = z(1-z)(\mathrm{U}_{31} - \mathrm{U}_{32}) = z(1-z)\left[x(V_p + y\Delta L_p - \Delta L_p) + \Delta L_p - y\Delta L_p - C_p\right]$

Find the first-order partial derivative with respect to z for W(z):

$\frac{dW(z)}{dz} = (1-2z)\left[x(V_p + y\Delta L_p - \Delta L_p) + \Delta L_p - y\Delta L_p - C_p\right]$

Let W(z)=0, we can get $z_1 = 0, z_2 = 1, x^* = \frac{y\Delta L_p + C_p - \Delta L_p}{y\Delta L_p + V_p - \Delta L_p}$

The specific analysis is as follows:

(1) When $x = x^* = \frac{y\Delta L_p + C_p - \Delta L_p}{y\Delta L_p + V_p - \Delta L_p}$,W(z)=0,Explaining that all levels are stable under this condition, i.e., the strategies of third-party residents do not change over time, regardless of the probability that the government chooses active or passive regulation;

(2) When $(y-1)\Delta L_p + V_p > 0$, at this time, the government's subsidies to residents are sufficient to make up for their losses. Discuss in two cases: (a) when$x < x^*, (1-x)(1-y)L_{32} + xR_3 - C_3 < 0, \frac{dH(0)}{d(0)} < 0, \frac{dH(1)}{d(1)} > 0$, at this time, z1=0 is the stable point of the evolution strategy, which means that when the possibility of active government supervision cannot reach x* and shows a downward trend, the possibility of third-party residents participating in supervision will also decrease. At this time, due to the lack of government participation, The cost of residents participating in supervision cannot be compensated, and eventually residents will choose not to participate in supervision;(b)when $x > x^*, (1-x)(1-y)L_{32} + xR_3 - C_3 > 0, \frac{dH(0)}{d(0)} > 0, \frac{dH(1)}{d(1)} < 0$,at this time, z2=1 is the stable point of the evolution strategy, which means that when the possibility of active government supervision is greater than x* and shows an increasing trend, the possibility of third-party residents participating in supervision will also increase. Will get a lot of subsidies, the cost of participation will be greatly reduced, and will eventually choose to participate in supervision;

(3) When $yL_{32} + R_3 - L_{32} < 0$, at this time, the subsidies given by the government to residents are not enough to make up for their losses. Similarly, it is also divided into two situations to discuss: (a) when $x < x^*, (1-x)(1-y)L_{32} + xR_3 - C_3 > 0, \frac{dH(0)}{d(0)} > 0, \frac{dH(1)}{d(1)} < 0$, at this time, z2=1 is the stable point of the evolution strategy, which means that when the possibility of the government's active supervision cannot reach x* and shows a downward trend, the possibility of public participation in supervision increases instead. At this time, the public's ability to perceive losses is strengthened, which is Make up for the losses caused by the negative supervision of the regulatory authorities, and ultimately the public will choose to participate in supervision; (b)when $x > x^*, (1-x)(1-y)L_{32} + xR_3 - C_3 < 0, \frac{dH(0)}{d(0)} < 0, \frac{dH(1)}{d(1)} > 0$,at this time, z1=0 is the stable point of the evolution strategy, which means that when the possibility of the government's active supervision is greater than x* and shows an increasing trend, the possibility of public participation in supervision is reduced. At this time, although the government provides subsidies, it still cannot make up for the public's losses, and ultimately the public will choose not to participate in oversight.

4. System Evolution Strategy Stability Analysis

The above replication dynamic equation describes the dynamic adjustment process of strategic choices among the government, enterprises and residents. The three parties reach a steady state in the process of continuous learning and imitation.

According to the Lyapunov stability theory, the asymptotic stability of an evolutionary game system at the equilibrium point can be judged by analyzing the eigenvalues of the Jacobian matrix of the system. The Jacobian matrix of the system can be obtained as:

$$J = \begin{pmatrix} (1-2x)\begin{bmatrix} z(P_c + P_g - V_p - P_c) \\ +\Delta V_g + P_c - yP_c - \Delta C_g \end{bmatrix} & x(1-x)(z-1)P_c & x(1-x)(yP_c + P_g - V_p - P_c) \\ y(1-y)(1-z)(\Delta V_c + L_c + P_c) & (1-2y)\begin{bmatrix} z(1-x)(\Delta V_c + L_c + P_c) \\ +x(\Delta V_c + L_c + P_c) - \Delta C_c \end{bmatrix} & y(1-y)(1-x)(\Delta V_c + L_c + P_c) \\ z(1-z)(V_p + y\Delta L_p - \Delta L_p) & z(z-1)(1-x)\Delta L_p & (1-2z)\begin{bmatrix} x(V_p + y\Delta L_p - \Delta L_p) \\ +\Delta L_p - y\Delta L_p - C_p \end{bmatrix} \end{pmatrix}$$

In the dynamic system composed of three game subjects, let F(x)=0, H(y)=0, W(z)=0, the eight pure-strategy Nash equilibrium points of the system can be obtained as E1(0, 0, 0), E2 (0, 0, 1), E3 (0, 1, 0), E4 (0, 1, 1), E5 (1, 0, 0), E6 (1, 0, 1), E7 (1, 1, 0), E8(1, 1, 1),According to Lyapunov's first method, when all the eigenvalues of the Jacobian matrix are negative, the equilibrium point is the evolutionary stable point of the system. Therefore, the above 8 pure strategy equilibrium points are respectively brought into the Jacobian matrix of the system to obtain the Jacobian matrix eigenvalues of the equilibrium points as shown in Table 3.

Table 3. Jacobian matrix eigenvalues and asymptotic stability judgmen

Equilibrium	Eigenvalue 1	Sgn	Eigenvalue 2	Sgn	Eigenvalue3	Sgn	Asymptotic stability
$E_1(0,0,0)$	$\Delta V_g + P_c - \Delta C_g$	uncertain	$-\Delta C_c$	minus	$\Delta L_p - C_p$	uncertain	uncertain
$E_2(0,0,1)$	$P_g - V_p + \Delta V_g - \Delta C_g$	uncertain	$\Delta V_c + L_c + P_c - \Delta C_c$	uncertain	$-(\Delta L_p - C_p)$	uncertain	uncertain
$E_3(0,1,0)$	$\Delta V_g - \Delta C_g$	uncertain	ΔC_c	uncertain	$-C_p$	minus	unstable

$E_4(0,1,1)$	$P_g - V_p + \Delta V_g - \Delta C_g$	uncertain	$-(\Delta V_c + L_c + P_c - \Delta C_c)$	uncertain	C_p	plus	unstable
$E_5(1,0,0)$	$-(\Delta V_g + P_c - \Delta C_g)$	uncertain	$\Delta V_c + L_c + P_c - \Delta C_c$	uncertain	$V_p - C_p$	uncertain	uncertain
$E_6(1,0,1)$	$-(P_g - V_p + \Delta V_g - \Delta C_g)$	uncertain	$\Delta V_c + L_c + P_c - \Delta C_c$	uncertain	$-(V_p - C_p)$	uncertain	uncertain
$E_7(1,1,0)$	$-(\Delta V_g - \Delta C_g)$	uncertain	$-(\Delta V_c + L_c + P_c - \Delta C_c)$	uncertain	$V_p - C_p$	uncertain	uncertain
$E_8(1,1,1)$	$-(P_g - V_p + \Delta V_g - \Delta C_g)$	uncertain	$-(\Delta V_c + L_c + P_c - \Delta C_c)$	uncertain	$-(V_p - C_p)$	uncertain	uncertain

Since both E3 and E4 have positive eigenvalues, there are 6 evolutionary stable states for the replicated dynamic equation. The following will discuss the stability of the system through 6 situations:

Scenario 1 when the cost of public participation in supervision is greater than the loss caused by corporate default to the public, the government will tend to choose the strategy of “not participating in supervision”. Negative supervision" strategy, the evolutionary equilibrium point of the system is E1 (0, 0, 0), and the strategy choices of all parties at this time do not meet social expectations and should be avoided.

Scenario 2 When the cost of public participation in supervision is less than the loss caused by corporate default to the public, they tend to choose the strategy of “participation in supervision”; at this time, if the fine imposed by the government for passive supervision is less than the government’s compensation for the public’s active participation in supervision and When the cost of active government regulation is higher than the benefit, the government will tend to choose the strategy of "negative regulation"; when the increased cost of the company's performance is higher than the increased revenue of the performance and the loss and fine after the company's breach of contract is exposed , the enterprise will choose the "default behavior" strategy considering the purpose of profit. At this time, the equilibrium point of the system is E2 (0, 0, 1), but the public's choice to participate in supervision cannot prevent the enterprise's default behavior.

Scenario 3 When the cost of public participation in supervision is higher than the compensation it receives from the government, the public will tend to choose the strategy of “not participating in supervision”; when the increased benefits of active government supervision are higher than the increased costs, the government will tend to choose the strategy of “not participating in supervision”. Active supervision” strategy; when the increased cost of the enterprise due to the performance of the contract is higher than the increased revenue from the performance of the contract and the losses and fines after the company’s default behavior is exposed, the enterprise will choose the “default behavior” strategy considering the purpose of making profits. The equilibrium point of the system in this case is E5 (1, 0, 0).

Scenario 4 When the cost of public participation in supervision is lower than the compensation they receive from the government, the public will tend to choose the strategy of “participation in supervision”; when the fine imposed by the government for passive supervision is higher than the government’s compensation for the public’s active participation in supervision and the government When the benefits of active regulation are higher than the costs, the government will tend to choose the "active regulation" strategy; when the loss of a company's default is less than the performance cost, the company will tend to choose the "default behavior" strategy. At this time, the only equilibrium point of the system is E6 (1, 0, 1), so even if the government chooses to actively supervise and the public chooses to participate in supervision, companies will not choose to perform the contract.

Scenario 5 When the cost of public participation in supervision is higher than the compensation it receives from the government, the public will tend to choose the strategy of “not participating in supervision”; when the benefit of the government’s active participation in supervision is higher than the cost it pays, the government will tend to choose "Active supervision" strategy; when the loss of a company's default exceeds the performance cost, the company will tend to choose the "performance behavior" strategy. At this time, the equilibrium point E7 (1, 1, 0) is the only equilibrium point of the system, even if the public does not participate Supervision, enterprises will also choose to perform.

Scenario 6 When the subsidy for public participation in supervision is greater than the cost of supervision, the public will give priority to the strategy of “participation in supervision”; when the benefits obtained by the government’s active supervision are higher than the costs it pays, the government will also give priority to the strategy of “active supervision”; at this time If the loss of the company's default exceeds the performance cost, the company will tend to choose the "performance behavior" strategy. In this case, the equilibrium point E8 (1, 1, 1) is the only stable equilibrium point of the system, and it is also an ideal model for the three parties.

5. Evolutionary Game Data Simulation

This paper further uses MATLAB software to simulate. Suppose ΔV_g=12;V_g=20;ΔC_g=8;C_g=5;L_g=12;P_g=6;ΔV_c=15;V_c=50;ΔC_c=16;C_c=10;L_c=10;P_c=8;V_p=8;C_p=2;L_p=4;ΔL_p=2.The given initial value is (0.5, 0.3, 0.5), the time period is set to [0, 3], the step size is 0.1, and the influence of each parameter change on the system evolution path is simulated under the condition that other parameters remain unchanged.

5.1. The impact of the penalty Pg of negative supervision by government departments on the game

Since the environmental pollution of the non-ferrous metal industry will have a greater impact on the ecological environment, it is essential for higher authorities to participate in supervision in the process of improving ecological efficiency and creating a green development environment. In this paper, the value of Pg is 0, 2, 4, and 6, respectively, and the evolution result of the government is obtained as shown in Figure 2. In the process of evolution, the government's strategy evolves from passive regulation to active regulation. At the same time, a certain threshold can be obtained by calculation. When Pg is greater than this threshold, the greater the Pg, the faster the evolution rate of the government. As Pg increases, the loss of passive government regulation gradually exceeds the cost of active regulation. Since the government is the subject of bounded rationality, the government will eventually choose an active regulation strategy.

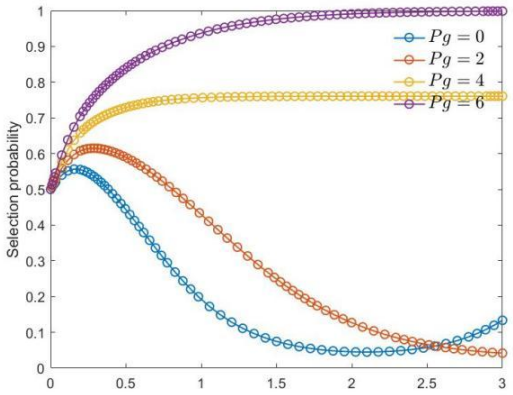

Figure 2. The impact of the government's negative regulation penalty on the game

5.2. The Influence of Corporate Default Loss Lc on the Game

In this paper, the value of Lc is 2, 4, 8, and 10 respectively, and its influence on the evolution strategy of the enterprise is shown in Figure 3. With the increase of the number of games, the strategy of the enterprise evolves from default to performance. Similarly, a certain threshold can be obtained by calculation. When Lc is greater than this threshold, the larger the Lc, the faster the evolution rate of the enterprise. When the loss caused by government supervision and public supervision to the enterprise is less than a certain threshold, the effect of supervision is not significant; and as the default loss Lc increases, the default loss of the enterprise gradually exceeds the performance cost, and its strategic choice will also change. Evolved to a compliance strategy.

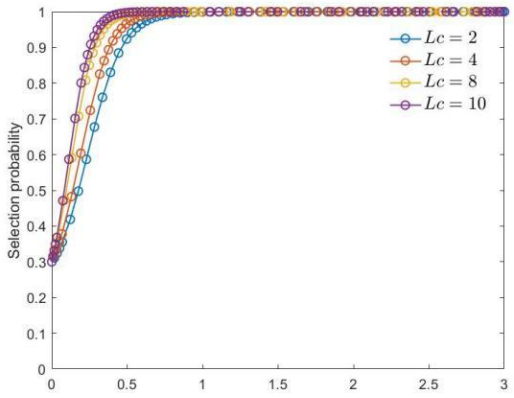

Figure 3. The impact of corporate default losses on the game

5.3. Enterprise Default Penalty Pc

As the corporate breach of contract is exposed, the corporate image will be damaged, and a certain penalty for breach of contract will also be required, so it will also affect the corporate strategic choice to a certain extent. In this paper, the value of Pc is 2, 4, 6, and 8 respectively, and its influence on the evolution strategy of the enterprise is shown in Figure 4. The more fines a business has to pay, the faster it evolves.

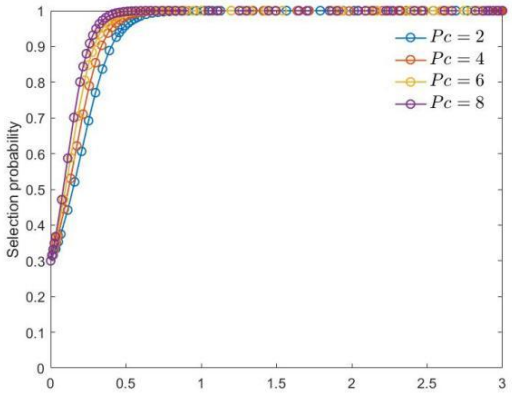

Figure 4. The impact of corporate default fines on gaming

5.4. Public Participation Monitoring Cost Cp

This paper takes 2, 4, 6, and 8 for Cp, and the evolution result of the public is shown in Figure 5. As the number of games increases, the public's strategy choice evolves from not participating in supervision to participating in supervision. At the same time, a certain threshold can be obtained by calculation. When Cp is less than this threshold, the smaller the Cp, the faster the evolution rate of the public. Therefore, the government can reduce the cost of public supervision by expanding the channels of public supervision and increasing the incentives for the public to participate in supervision, and gradually build a situation of orderly joint supervision between the government and the public.

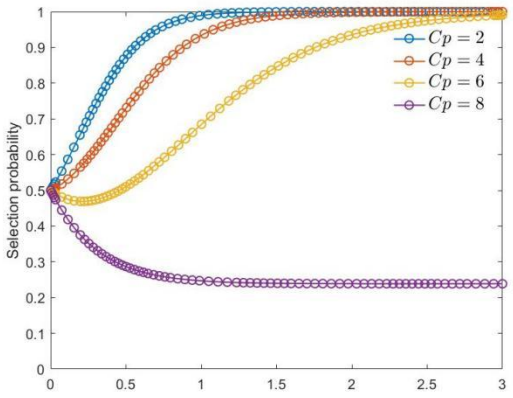

Figure 5. The impact of public surveillance costs on the game

5.5. Public Participation Supervision Subsidy Vp

In this paper, the value of Vp is 2, 4, 6, 8, and the evolution result of the public is shown in Figure 6. With the increase of the number of games, the public's strategy choice evolves from not participating in supervision to participating in supervision. Through the analysis, it can be seen that when the subsidy received by the public is not enough to cover the cost of its participation, the enthusiasm of the public to participate is low.

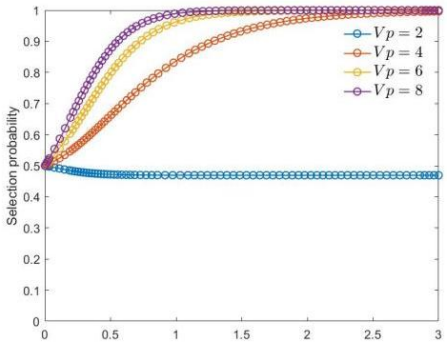

Figure 6. The impact of public participation in monitoring subsidies on the game

6. Conclusions and Recommendations

6.1. Conclusions

The dynamic evolution process of government, enterprise and third-party public strategy choices is related to their initial probability choices. Under different probability distributions, their evolution processes will have different changes. At the same time, they will be affected by the changes in the parameters of the replication dynamic equation. Different effects, the specific conclusions are as follows:

From the government's point of view, negative government regulation may have an impact on itself. When negative regulation is discovered by higher-level departments, a certain amount of fines is required. The larger the amount, the greater the possibility that the government will choose active regulation.

From the perspective of the enterprise, the default of the enterprise will cause certain losses to itself, and the decline of credit rating will affect the ability of the enterprise to survive in the future. In addition, a certain amount of fines must be paid after the breach of contract is exposed. The larger the amount, the higher the cost of default, and the more inclined the company is to choose the behavior of performance.

From the perspective of the third-party public, the main factors affecting the choice of the third-party public are the cost of participating in supervision and the subsidies that can be received in the future. If the cost exceeds the subsidies that can be received in the future, almost no one will be willing to participate in supervision for a long time. , so the higher the cost of participating in supervision, and the lower the subsidy, the less conducive to third-party public participation in supervision.

6.2. Recommendations

(1) Government level. According to the simulation results, the superior department should explore reasonable penalty thresholds based on actual data to ensure the effectiveness of the penalty, and it is necessary to improve the system of temporary sampling inspection of the subordinate department by the superior department, and strengthen the supervision of the subordinate department, so that the subordinate department can maintain a fair and follow-up Standard completion of work, improve the responsibility and ability of the staff of the supervision department, and put an end to the phenomenon of government inaction.

(2) Enterprise level. The government's supervision of enterprises should implement regular supervision procedures and a credit disciplinary linkage mechanism, link the company's violations to its reputation and credit system, promptly announce the company's reputation to the public, and give full play to the influence of online public opinion.

(3) Public level. In view of the lack of a good coordination mechanism among the government supervision departments in our country, and the vague supervision roles, the higher-level departments should establish a public participation organization department and supplement it with supporting laws and regulations to give full play to the advantages of comprehensive social supervision. Secondly, government departments should use big data and network information technology to build a publicity platform for project progress, news, etc., except for information that cannot or should not be disclosed in accordance with the law, publicly update the construction and supervision of major projects in real time and open the public evaluation function to enhance The transparency of the supervision rules and construction situation of major projects, solve the problem of information asymmetry, and formulate a clear and feasible public supervision and reward mechanism, set up a special incentive fund, standardize the reward system, and effectively eliminate the lack of supervision.

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