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Research Article

Evolutionary Game Analysis of the Stress Effect of Cross-Regional Transfer of Resource-Exhausted Enterprises

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This paper analyses the stress effect of cross-regional transfer of resource-exhausted enterprises from eastern China to central and Western China. A tripartite evolutionary game model including the central government, the local government of the operation recipient region, and the resource-exhausted transfer enterprises is established under the assumption of limited rationality. By analysing the evolutionary equilibrium and using MATLAB, for example, analysis, the relationship between equilibrium probability and various parameters, as well as the key influencing factors of equilibrium strategy were explored. The research shows, first, that the degree of punishment imposed by the central government on the local governments, the implementation of regulation by the local governments, and the amount of rewards/punishments implemented by the local governments for transfer enterprises are the key factors affecting evolutionary stability. Second, it shows that the local governments' penalty for transfer enterprises has a significant impact on the convergence speed of enterprises' strategic choice to "Completely Control Pollution." Finally, from the perspective of the relationships between the central government and the local governments, as well as with transfer enterprises, countermeasures and suggestions are put forward to effectively prevent the stress effect of the cross-regional transfer behaviour of resource-exhausted enterprises.

1. Introduction

The term "resource-exhausted enterprises" is used to refer to enterprises that are engaged in natural resource development and preliminary processing of mineral products and are in a state of depletion of resources. This occurs most frequently in industries such as coal, petroleum, steel, electric power, and natural gas mining. These firms have a life cycle, ranging from " Development-Rise-Stability-Recession," that is closely related to the available period of resources [1]. In order to meet the requirements of the rapidly developing national economy, China's resource-based enterprises have carried out large-scale, high-intensity production for a long period of time, which has promoted a steady economic growth. However, due to the scarcity and exhaustibility of natural resources, the eastern resource-based enterprises (especially coal enterprises) that rely on the rapid development of the secondary industry have accelerated the adjustment of the industrial structure to cope with the problem of resource exhaustion caused by overexploitation [1–4]. In the context of the Western development strategy, the enterprises will transfer operations to the central and Western regions, where resources are concentrated, establish new development bases, and implement cross-regional transfers.

The cross-regional transfer behaviour not only eases the shortage of resources in the eastern enterprises, but also promotes regional economic development by bringing a large amount of physical capital investment, advanced technology, management experience, and employment opportunities to the central and Western regions [1–4]. However, the transfer of eastern enterprises' resources has also brought serious environmental problems, thus leading to the "Pollution Haven" effect [5–9]. Some scholars believe that most of the eastern enterprises which have transferred operations to the central and Western regions are polluting enterprises that implement transfer in the name of industrial gradient transfer [10]. Therefore, industrial transfer will be accompanied by cross-regional transfer of pollution [11]. Some scholars have studied the ecological quality and environmental pollution of mining areas in the central and Western regions and have found that large-scale and unregulated mining activities will destroy the structure and balance of ecosystems, hinder the material circulation of the system, and thus, affect the function of ecosystems throughout the mining area [12–20]. The migration of resource-based enterprises from the east, combined with the characteristics of high energy consumption, high pollution, and high emissions, undoubtedly worsen the relatively fragile environment in the central and western mining areas. This puts stress on the environment in these regions [2–4]. In order to improve environmental governance and accelerate the adjustment of the industrial structure, many scholars have conducted research and analysis on the corporate behaviour of pollution, environmental protection, and regulation. Based on the bounded rationality hypothesis, Fairchild [21] used game theory and mathematical modelling to analyse the interaction between enterprises and governments in the process of environmental pollution regulation and to study the strategic interaction of participants. Guangcheng and Feifei [22] and Jian-Ge et al. [23] discussed the behaviour evolution and strategy selection of local governments and coal enterprises in the process of ecological restoration from the perspective of evolutionary games. Pan et al. [24, 25] analysed local governments' environmental regulation strategies based on the evolutionary game theory, as well as discussing their environmental regulation strategy without the introduction of restraint and constraint mechanisms. Furthermore, the authors considered the evolutionary process of local government decision-making, sewage polluters, and central government. Xing-Guang et al. [26] and Yanlin et al. [27] constructed a three-party game model including enterprises, governments, and environmental nongovernmental organizations (NGOs) for the current serious environmental pollution in China. Using this model, the authors analysed the optimal strategies of enterprises under different scenarios. Sheng and Xiaochun [28] used game theory to analyse the public interest game process between the central government and local governments on cross-regional water pollution control and the pollution control game between upstream and downstream local governments. The authors pointed out that China's transboundary water pollution control has not achieved significant results and the water quality in some areas has even deteriorated. Lai et al. [29] used the cooperative game theory to construct a cost-sharing game for the cost-sharing problem of water pollution control in river basins. Ming et al. [30] analysed the four evolutionary games of local governments' governance and cooperative governance under the constraints of a central government. On this basis, the behavioural evolutionary path and stability strategy of local governments in air pollution control were analysed. How local governments achieve and consolidate cooperation was also analysed to identify the factors governing alliances.

According to a review of the existing literature, most scholars with different models have a high reference value for studying stress effect of transfer enterprises, but there are still some shortcomings. First, scholars mainly focus on the relationship between foreign investment and the environmental pollution that results from the enterprises' transfer behaviour. However, there is a lack of research on environmental issues brought about by the transfer behaviour of resource-based enterprises in China. Second, the environmental pollution caused by the transfer of enterprises is mainly studied from a static perspective. It is difficult to comprehensively study the dynamic characteristics of the stress effect's production process and the evolution of laws regarding environmental pollution. China's environmental protection is a "multigoverning governance system" which is led by the central government and actively promoted by local governments and enterprises. The stress effect of enterprises' transfer requires the central government, local government, and transfer enterprises to seek long-term equilibrium in long-term asymmetric game behaviour, which is a complex process of dynamic evolution. At the same time, because of the nature of the participants, the game process will be accompanied by more complex political behaviour and market economic behaviour. Therefore, it is necessary to combine the theoretical analysis of multigroup game behaviour with its complex dynamic evolution process. Evolutionary game theory is an important and powerful tool to study the characteristics of multigroup game behaviour because it adopts the mechanism of natural selection without strict rational assumption, allowing it to be closer to the situation shown and better reflect the spontaneous evolution process of strategies for different interest groups. From the perspective of dynamic evolution, this paper investigates the decision-making process and learning behaviour of the central government, the local government in the enterprise's new location, and the resource-exhausted transfer enterprises in the east. It then analyses the interactive mechanisms of these effects and discusses the generation mechanism of environmental stress effect of transregional transfer of resource-based enterprises. This helps to provide theoretical basis for promoting ecological construction in the central and western regions.

The remainder of the paper is organized as follows. In Section 2, hypotheses are developed and a tripartite evolutionary game model is established and solved. In Section 3, we analyse the ESS of the model and obtain six propositions. In Section 4, a numerical example is examined using system dynamic simulations to identify the key influencing factors of the equilibrium strategy. In Section 5, we summarize the key results and put forward the prevention strategies and suggestions.

2. Evolutionary Game Model

The foundation of game theory was developed by John von Neumann and Oskar Morgenstern in 1944 in their book, "Theory of Games and Economic Behavior" [31]. However, von Neumann and Morgenstern only managed to define an equilibrium concept for 2-person zero-sum games. This form of static Nash equilibrium cannot explain the dynamic world, which led to the development of evolutionary games. To develop this methodology, John Maynard Smith adopted the idea of evolution from biology [32]. Evolutionary game theory is an application of the mathematical framework of game theory to the dynamics of animal conflicts (including, of course, the conflicts in which people engaged) [32, 33]. Following the development of evolutionary game theory, it has been widely used to analyse industrial transfer [34, 35], pollution control [36–41], and policy-making [41–43].

Based on the existing literature, this paper takes the central government, the local governments in operation recipient areas, and resource-exhausted transfer enterprises as the game participants to build a tripartite evolutionary game. In the process of the evolutionary game, the interest demands of participants are different; complicated and contradictory interests will cause a series of conflicts. Therefore, in this game involving management stakeholders, environmental management can only be realised in the process of enterprise transfer when the demands of relevant departments are coordinated.

During this game, the central government formulates environmental regulation for all regions. The system of access and penalty amounts due to opreation recipient local governments are determined depending on the quantity of exploitable resources and the environmental status in the Mid-West. The transfer enterprises are in a state of complete information about the system established by the central government and the reward or punishment amount local governments will levy. Therefore, enterprises will make strategic choices depending on the supervisory strength of the central government and the execution strength of the relevant local government(s). The local government determines its strategic choice depending on the supervision of the central government and the amount of punishment quota to which it is entitled. As a participant in the game of environmental governance and a maker of environmental regulations, the central government sets the perspective of strategic choice on environmental protection and social welfare maximization. Based on the assumptions of limited rationality, the local governments and the transfer enterprises make strategic choices with the goal of maximizing economic benefits.

2.1. Basic Assumptions

Assumption 1. Under the assumption of limited regionality, a tripartite game is formed among the central government, the operation recipient local governments, and the resource-exhausted transfer enterprises in the east. With the ability to learn and improve themselves, all participants aim to maximize either their own or social interests. In the evolutionary game, all players are at the initial stage of the game without considering the influence of other players.

Assumption 2. The strategic space of eastern resource-exhausted transfer enterprises is defined as Completely Control Pollution and Noncompletely Control Pollution. When the resource-exhausted enterprises in the east move to the central and Western regions, there will be increased costs G due to the transfer, and long-distance transportation costs T saved due to being closer to the origin of raw materials. When the transfer enterprise chooses to conduct complete treatment of pollutants, on the one hand, it will increase cost E due to environmental protection, including the pollutant discharge fee paid by the enterprise and expenditure on environmental protection innovation. On the other hand, the enterprise will receive a transfer subsidy, S_1, from the local government as a reward for its investment in environmental protection. If the pollution is not treated at all, the local government will directly impose a penalty, D_1. When local governments turn a blind eye to companies' pollution practices, the central government will directly impose a penalty, D_2, upon polluting enterprises. The proportion of enterprises transferring operations from the east to the Mid-West which undertake environmental pollution control is θ, $0 \leq \theta \leq 1$, and the smaller θ is, the less complete the enterprise's environmental control is.

Assumption 3. The strategy space of the transfer recipient local government is defined as Strictly Implement and Nonstrictly Implement. Since China has been defined by a state of fiscal decentralization for a long time and employs a policy of top down environmental management, local governments have the status of independent game players. As a rational actor, when the local government chooses to strictly implement the environmental regulation and access system, it will not only increase the implementation cost, but also bring economic losses, C_1, due to the decrease of the inflow of enterprises to the region. When transfer enterprises choose to completely control pollution, the economic and ecological benefits, W, can be obtained by local governments (the central government implements strict supervision over local governments). When the central government carries out strict supervision, the reward for the local government to strictly implement the regulation is S_2, and the penalty for not strictly implementing the regulation is H. The local government's enforcement of environmental regulation is β, $0 \leq \beta \leq 1$, and the smaller β is, the less strict the local government's implementation of environmental regulation is.

Assumption 4. The strategic space of the central government is Strictly Supervise and Nonstrictly Supervise. Although the central government provides the framework for the system, it can supervise the implementation of the local government or allow it to act freely. When the central government chooses to strictly supervise local governments, the cost is C_2. When the central government carries out strict supervision, the local government strictly implements regulations and the transfer enterprises completely control their pollution; the social benefit will be M. The intensity of the central government's supervision over the local government is ε, $0 \leq \varepsilon \leq 1$; the smaller ε is, the less strictly the central government exercises supervision over the local government.

Assumption 5. Assuming that the probability of the central government choosing the "Strictly Supervise" strategy is x, then the probability of choosing the "Nonstrictly Supervise" strategy is $1 - x$. The proportion of local governments choosing the "Strictly Implement" strategy is y, then the proportion choosing the "Nonstrictly Implement" strategy is $1 - y$. The proportion of eastern resource-exhausted transfer enterprises adopting the "Completely Control Pollution" strategy is z, while the proportion of enterprises choosing the "NonCompletely Control Pollution" strategy is $1 - z$. Among them, $x, y, z \in [0, 1]$.

The meanings of specific parameters are shown in Table 1.

According to the above basic assumptions, the revenue matrix of the tripartite game is established, as shown in Table 2.

Table 1: Major notations.

Notations	Description
X	The probability of strict supervision by the central government is x, and the probability of nonstrict supervision is $1-x$, $0 \le x \le 1$
Y	The probability of strict implementation by the operation recipient local governments is y, and the probability of nonstrict implementation is $1-y$, $0 \le y \le 1$
Z	The probability of complete pollution control by the transferring enterprises is z, and the probability of noncomplete pollution control is $1-z$, $0 \le z \le 1$
G	Transfer cost for the enterprises' cross-regional transfer
T	Reduced raw material transportation costs due to enterprises' cross-regional transfer
E	Environmental protection fees invested by transfer enterprises for complete pollution control
S_1	Government subsidies when transfer enterprises completely control pollution
S_2	Rewards given by the central government to the local government for strict implementation (when the central government supervises strictly)
C_1	The cost of strict implementation by the local government
C_2	The cost of strict supervision by the central government
D_1	Local government's fines for transfer enterprises which noncompletely control pollution (when the central government strictly supervises)
D_2	Central government's fines for transfer enterprises which noncompletely control pollution (when the local government chooses nonstrict implementation)
W	The economic and ecological benefits for local areas engendered by complete pollution control of the transfer enterprises (when the central government supervises strictly)
H	Punishments given by the central government to the local government for nonstrict implementation (when the central government supervises strictly)
M	The socioeconomic benefit under the condition that the central government supervises strictly, the operation recipient local government implements strictly, and the transfer enterprises control pollution completely
θ	The proportion of transfer enterprises in environmental pollution control is θ, $0 \le \theta \le 1$
β	The extent of the local government's implementation of environmental regulation is β, $0 \le \beta \le 1$
ε	The intensity of the central government's supervision over the operation recipient local government is ε, $0 \le \varepsilon \le 1$

Table 2: Payoff matrix.

Strategies			Payoffs accruing to each player		
Central government	Local government	Enterprises	Central government	Local government	Enterprises
S	I	C	$-C_2-S_2+M$	$-C_1-S_1+S_2+W$	$-G-E+T+S_1$
S	I	NC	$-C_2$	$-C_1+(1-\theta)D_1+\theta W$	$-G-\theta E-(1-\theta)D_1+T$
S	NI	C	$-C_2+H$	$-\beta C_1-H-\beta S_1+W$	$-G-E+\beta S_1+T$
S	NI	NC	$-C_2+H+(1-\theta)D_2$	$-\beta C_1-H+\theta W$	$-G-\theta E-(1-\theta)D_2+T$
NS	I	C	$-\varepsilon C_2-\varepsilon S_2$	$-C_1+W+\varepsilon S_2$	$-G-E+T$
NS	I	NC	$-\varepsilon C_2$	$-C_1+(1-\theta)D_1+\theta W$	$-G-\theta E-(1-\theta)D_1+T$
NS	NI	C	$-\varepsilon C_2+\varepsilon H$	$-\beta C_1-\varepsilon H+W$	$-G-E+T$
NS	NI	NC	$-\varepsilon C_2+\varepsilon H+\varepsilon(1-\theta)D_2$	$-\beta C_1-\varepsilon H+\theta W$	$-G-\theta E-\varepsilon(1-\theta)D_2+T$

S: "Strictly supervise." NS: "Nonstrictly supervise." I: "Strictly implement." NI: "Nonstrictly implement." C: "Completely control pollution." NC: "Noncompletely control pollution."

2.2. Model Solution. Let U_{cg1} be the expected utility of the central government whose strategy is "Strictly Supervise" and U_{cg2} be the expected utility of the central government whose choice is "Nonstrictly Supervise." Therefore, the mean utility of the central government can be obtained. Let U_{cg} represent the central government's mean utility. According to Table 2, we can obtain the utilities of the central government as follows:

$$\begin{aligned} U_{cg1} &= yz\left(M-C_2-S_2\right)+y(1-z)\left(-C_2\right)+z(1-y) \\ &\quad \cdot\left(-C_2+H\right)+(1-y)(1-z)\left[-C_2+H+(1-\theta)D_2\right], \\ U_{cg2} &= yz\left(-\varepsilon C_2-\varepsilon S_2\right)+y(1-z)\left(-\varepsilon C_2\right)+z(1-y) \\ &\quad \cdot\left(-\varepsilon C_2+\varepsilon H\right)+(1-y)(1-z)\left(-\varepsilon C_2+\varepsilon H\right. \\ &\quad \left.+\varepsilon(1-\theta)D_2\right), \\ U_{cg} &= xU_{cg1}+(1-x)U_{cg2}. \end{aligned} \tag{1}$$

According to the Malthusian equation, the replicator dynamics equation implies that when the return of a single strategy is higher than the average return of the population strategy in the game process, the single strategy can adapt to the population evolution process and has the ability to resist the invasion of the mutation strategy [33]. Through the above analysis, the replicator dynamics equation of the central government can be obtained as follows:

$$\begin{aligned} F(x) = \frac{\mathrm{d}x}{\mathrm{d}t} &= x(1-x)\left\{\left[(1+\theta+2\varepsilon)D_2-(1-\varepsilon)S_2+M\right]yz\right. \\ &\quad +(1-y)(1-\varepsilon)H+(1-z)(1+\theta+\varepsilon)D_2+\theta\varepsilon D_2 \\ &\quad \left.\cdot(1-y-z)-(1-\varepsilon)C_2\right\}. \end{aligned} \tag{2}$$

Let U_{lg1} be the expected utility of the operation recipient local governments whose strategy is "Strictly Implement" and U_{lg2} be the expected utility of the local governments which choose the option of "Nonstrictly Implement." Consequently, the mean utility of the local governments can be found. Let U_{lg} represent the local governments' mean utility. They are expressed as follows:

$$U_{lg1} = xz(-C_1 - S_1 + S_2 + W) + x(1-z)[-C_1 + (1-\theta)D_1 + \theta W] + z(1-x)(-C_1 + W + \varepsilon S_2) + (1-x)(1-z) \cdot [(1-\theta)D_1 + \theta W - C_1], \tag{3}$$

$$U_{lg2} = xz(W - \beta C_1 - H - \beta S_1) + x(1-z)[-\beta C_1 - H + \theta W] + z(1-x)[-\beta C_1 - \varepsilon H + W] + (1-x)(1-z) \cdot [-\beta(C_1 + H) + \theta W], \tag{4}$$

$$U_{lg} = yU_{lg1} + (1-y)U_{lg2}. \tag{5}$$

Based on equations (3)–(5), the replicator dynamics equation of the local government can be obtained as follows:

$$F(y) = \frac{dy}{dt} = y(1-y)\{[(S_1 + S_2)\beta + (S_2 - S_1) - \varepsilon S_2]xz + (1-z)(1-\theta)D_1 + \varepsilon(1-x)H + xH + z\varepsilon S_2 - (1-\beta)C_1\}. \tag{6}$$

In the same way, let U_{e1} be the expected utility of the transfer enterprises which select "Completely Control Pollution" and U_{e2} be the expected utility of the transfer enterprises whose option is "Noncompletely Control Pollution." Thus, the mean utility of the transfer enterprises can be derived. Let U_{lg} represent the transfer enterprises' mean utility. They are expressed as follows:

$$U_{e1} = xy(-G + T - E + S_1) + x(1-y)(-G + T - E + \beta S_1) + y(1-x)(-G + T - E) + (1-x)(1-y)(-G + T - E), \tag{7}$$

$$U_{e2} = xy[T - G - \theta E - (1-\theta)D_1] + x(1-y)[T - G - \theta E - (1-\theta)D_2] + y(1-x)[T - G - \theta E - (1-\theta)D_1] + (1-x)(1-y)[T - G - \theta E - \varepsilon(1-\theta)D_2], \tag{8}$$

$$U_e = zU_{e1} + (1-z)U_{e2}. \tag{9}$$

According to the equations (7)–(9), the replicator dynamics equation of the local government can be obtained as follows:

$$F(z) = \frac{dz}{dt} = z(1-z)\{(1-x-y)(1-\theta)\varepsilon D_2 + [(1-\beta)S_1 - (1-\theta)(1-\varepsilon)D_2]xy + (1-\theta)D_1 y + [\beta S_1 - \cdot (1-\theta)D_2]x - (1-\theta)E\}. \tag{10}$$

3. Evolutionary Stability Analysis

Equations (2), (6), and (10) are combined to obtain the replicator dynamic system of the tripartite game between the central government, the local government, and transfer enterprises:

$$\begin{cases} F(x) = \dfrac{dx}{dt} = x(1-x)\{[(1+\theta+2\varepsilon)D_2 - (1-\varepsilon)S_2 + M]yz + (1-y)(1-\varepsilon)H + (1-z)(1+\theta+\varepsilon)D_2 + \theta\varepsilon D_2(1-y-z) - (1-\varepsilon)C_2\}, \\ F(y) = \dfrac{dy}{dt} = y(1-y)\{[(S_1+S_2)\beta + (S_2 - S_1) - \varepsilon S_2]xz + (1-z)(1-\theta)D_1 + \varepsilon(1-x)H + xH + z\varepsilon S_2 - (1-\beta)C_1\}, \\ F(z) = \dfrac{dz}{dt} = z(1-z)\{(1-x-y)(1-\theta)\varepsilon D_2 + [(1-\beta)S_1 - (1-\theta)(1-\varepsilon)D_2]xy + (1-\theta)D_1 y + [\beta S_1 - (1-\theta)D_2]x - (1-\theta)E\}. \end{cases} \tag{11}$$

All solutions (x, y, z) in the replicator dynamic system (13) constitute the equilibrium node set. Let $F(x) = 0$, $F(y) = 0$, and $F(z) = 0$ in system (13); there are sixteen equilibrium nodes which exist in the tripartite game at this moment. However, the asymptotic stable solution of the multipopulation evolutionary game replicator dynamic system must be a strict Nash equilibrium solution, so only the equilibrium points $E1$ to $E8$, denoted as $E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(0,1,1)$, $E_5(1,0,0)$, $E_6(1,0,1)$, $E_7(1,0,1)$, and $E_8(1,1,1)$, need to be considered [33, 44, 45]. Since the equilibrium point solved by the replicator dynamics equation is not necessarily a stable evolution strategy for the whole system, according to Friedman's method [46], the stability of the evolution equilibrium point needs to be further analysed to determine the local stability of the system's Jacobian matrix. According to system (13), the Jacobian matrix of the system can be obtained as follows:

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix} = \begin{bmatrix} J_1 & J_2 & J_3 \\ J_4 & J_5 & J_6 \\ J_7 & J_8 & J_9 \end{bmatrix}. \quad (12)$$

Among them,

$$\begin{aligned} J_1 &= (1-2x)\{yz[(1+\theta+2\varepsilon)D_2 - (1-\varepsilon)S_2 + M] \\ &\quad + (1-y)(1-\varepsilon)H + (1-z)(1+\theta+\varepsilon)D_2 + \theta\varepsilon D_2 \\ &\quad \cdot (1-y-z) - (1-\varepsilon)C_2\}, \\ J_2 &= x(1-x)\{(\varepsilon-1)[(1-z)D_2 + (1+z)H + \theta z D_2] \\ &\quad + (1-\theta)\varepsilon D_2 + zM\}, \\ J_3 &= x(1-x)[(1-\theta)(1-\varepsilon)(y-1)D_2 + (M-S_2)y], \\ J_4 &= y(1-y)(1-\varepsilon)[(S_2-S_1)z + H], \\ J_5 &= x(1-2y)\{xz[(S_1+S_2)\beta + (S_2-S_1) - \varepsilon S_2] + (1-z) \\ &\quad \cdot (1-\theta)D_1 + \varepsilon(1-x)H + xH + z\varepsilon S_2 - (1-\beta)C_1\}, \\ J_6 &= y(1-y)[x(1-\varepsilon)S_2 + x(\beta-1)S_1 + (\theta-1)D_1 + \varepsilon S_2], \\ J_7 &= z(1-z)[(1-y)(1-\varepsilon)(1-\theta)(\beta S_1 - 1)D_2 + S_1], \\ J_8 &= z(1-z)\{(\theta-1)[x(1-\varepsilon)D_2 - D_1 + \varepsilon D_2] + x(1-\beta)S_1\}, \\ J_9 &= (1-2z)\{(1-x-y)(1-\theta)\varepsilon D_2 + [(1-\beta)S_1 \\ &\quad - (1-\varepsilon)D_2]xy + (1-\theta)D_1 y + [\beta S_1 + (1-\theta)D_2]x \\ &\quad - (1-\theta)E\}. \end{aligned} \quad (13)$$

The corresponding eigenvalues are obtained by substituting each point into the Jacobian matrix (12) in turn, as shown in Table 3.

When $x = 0$ and $y = 0$, it means that the central government does not strictly supervise and the local government does not strictly implement the regulations. However, the situation where the central government and the local government both ignore environmental pollution simultaneously does not exist in reality, so the equilibrium points E_1 and E_2 need not be considered. Using Lyapunov's indirect method, the equilibrium points E_3, E_4, E_5, E_6, E_7, and E_8 are analysed to obtain propositions 1–6, respectively.

Proposition 1. When $D_1 - E < 0$ and $(1-\beta)C_1 - (1-\theta) D_1 - \varepsilon H < 0$, the equilibrium point $E_3(0,1,0)$ is the evolutionary stable state of the replicator dynamics. The system eventually evolves to the stable state that the central government does not strictly supervise, the local government strictly enforces, and the transfer enterprise manages pollution incompletely. At this time, the proportion of the company's treatment of environmental pollution is defined by $\theta < ((D_1 + \varepsilon H - (1-\beta)C_1)/D_1)$.

Proposition 2. When $D_1 - E > 0$, $\varepsilon(S_2 + H) - (1-\beta)C_1 > 0$, and $M - (1-\varepsilon)(S_2 + C_2) < 0$, the equilibrium point $E_4(0,1,1)$ is the evolutionary stable state of the replicator dynamics. The system eventually evolves such that the central government does not strictly supervise, the local government does not strictly implement, and the transfer enterprises completely control pollution. At this time, the central government's supervision of the local government meets the condition, $(((1-\beta)C_1)/(S_2 + H)) < \varepsilon < ((S_2 + C_2 - M)/(S_2 + C_2))$.

Proposition 3. When $(1-\theta)(D_2 - E) + \beta S_1 < 0$, $(1-\theta)D_1 - (1-\beta)C_1 + H < 0$, and $(1-\theta)D_2 + H - C_2 > 0$, the equilibrium point $E_5(1,0,0)$ is the evolutionary stable state of the replicator dynamics. The system eventually evolves into the central government strictly supervising, the local government not strictly implementing regulations, and the transfer enterprise not completely controlling pollution. In this situation, the proportion of the company's treatment of environmental pollution is defined by, $((H + D_1 - (1-\beta)C_1)/D_1) < \theta < (\min\{((D_2 + H - C_2)/D_2), ((E - D_2 - \beta S_1)/D_1)\})$.

Proposition 4. When $H - C_2 > 0$, $(1-\theta)(D_2 - E) + \beta S_1 > 0$, and $H + S_2 - (1-\beta)(C_1 + S_1) < 0$, the equilibrium point $E_6(1,0,1)$ is the evolutionary stable state of the replicator dynamics equation. The system eventually evolves into the central government strictly supervising, the local government not strictly implementing, and the transfer enterprises completely controlling pollution. In this situation, the degree of local government implementation for the transfer enterprises meets the condition, $(((1-\theta)(E - D_2))/S_1) < \beta < ((C_1 + S_1 - S_2 - H)/(C_1 + S_1))$.

Proposition 5. Since $(1-\varepsilon)C_2 > 0$ is always established, the equilibrium point $E_7(1,1,0)$ cannot be reached based on a stable strategy.

Proposition 6. When $(1-\theta)(D_1 - E) + S_1 > 0$, $M - (1-\varepsilon)(S_2 + C_2) > 0$, and $H + S_2 - (1-\beta)(C_1 + S_1) > 0$, the equilibrium point $E_8(1,1,1)$ is the evolutionary stable state of the replicator dynamics equation. The system eventually evolves into the central government strictly supervising, the local government strictly implementing, and the transfer enterprises completely controlling pollution. In this situation, the proportion of the management of the environmental pollution achieved by the transfer enterprises is defined as $\{\theta > ((E - D_1 - S_1)/(E - D_1)) | E > D_1\}$ or $\{\theta < ((E - D_1 - S_1)/(E - D_1)) | E < D_1\}$. The degree of supervision of the central government for the local government meets $\varepsilon > ((S_2 + C_2 - M)/(S_2 + C_2))$, and the degree of implementation of the local government for the transfer enterprises meets $\beta > ((C_1 + S_1 - S_2 - H)/(C_1 + S_1))$.

4. Simulation Analysis

According to the above assumptions, this paper simulates and analyses the evolution process of the game subject to different parameter settings, which can intuitively reflect the dynamic evolution behaviour between the central

Table 3: Eigenvalues of the equilibrium point of the tripartite game.

Equilibrium point	Eigenvalue λ_1	Eigenvalue λ_2	Eigenvalue λ_3
$E_1\,(0,0,0)$	$(1-\theta)(\varepsilon D_2 - E)$	$(1-\theta)D_1 + \varepsilon H - (1-\beta)C_1$	$(1-\varepsilon)[(1-\theta)D_2 + H - C_2]$
$E_2\,(0,0,1)$	$-(1-\theta)(\varepsilon D_2 - E)$	$(1-\varepsilon)(H - C_2)$	$\varepsilon(S_2 + H) - (1-\beta)C_1$
$E_3\,(0,1,0)$	$-(1-\varepsilon)C_2$	$(1-\theta)(D_1 - E)$	$(1-\beta)C_1 - (1-\theta)D_1 - \varepsilon H$
$E_4\,(0,1,1)$	$-(1-\theta)(D_1 - E)$	$-[\varepsilon(S_2 + H) - (1-\beta)C_1]$	$M - (1-\varepsilon)(S_2 + C_2)$
$E_5\,(1,0,0)$	$(1-\theta)(D_2 - E) + \beta S_1$	$(1-\theta)D_1 - (1-\beta)C_1 + H$	$-(1-\varepsilon)[(1-\theta)D_2 + H - C_2]$
$E_6\,(1,0,1)$	$-(1-\varepsilon)(H - C_2)$	$-[(1-\theta)(D_2 - E) + \beta S_1]$	$H + S_2 - (1-\beta)(C_1 + S_1)$
$E_7\,(1,0,1)$	$(1-\varepsilon)C_2$	$(1-\beta)C_1 - (1-\theta)D_1 - H$	$(1-\theta)(D_1 - E) + S_1$
$E_8\,(1,1,1)$	$-[(1-\theta)(D_1 - E) + S_1]$	$-[M - (1-\varepsilon)(S_2 + C_2)]$	$-[H + S_2 - (1-\beta)(C_1 + S_1)]$

government, the operation recipient local government, and the resource-exhausted transfer enterprises. Based on the current situation in China, whereby the environmental impact of resource-exhausted enterprises in the east is transferred to the middle and Western regions, it is assumed that $E = 25$, $S_1 = 5$, $S_2 = 8$, $D_1 = 6$, $D_2 = 20$, $H = 15$, $C_1 = 25$, $C_2 = 10$, $M = 20$, $\theta = 0.4$, $\beta = 0.2$, and $\varepsilon = 0.8$.

(1) Under the above conditions, the evolutionary simulation analysis is carried out by MATLAB R2018b. The initial probability x of the central government's choice of strategy is set to 0.5 and the influence of the initial values of y and z on the change of x over time is verified. As shown in Figure 1, the initial value of y and z do not change the final direction of x. x monotonously increases and converges to 1. However, with the increase of y and z, the convergence rate increases. This shows that the central government will ultimately choose the "Strictly supervise" strategy.

Assuming that the initial probability y of choosing strategy of the local governments is 0.5 and changing the values of x and z, the graph of y changing with time is obtained (Figure 2). The initial values of x and z have no obvious influence on the convergence speed and direction of y. Local governments eventually evolve to the state, whereby all local governments choose the "Strictly implement" strategy.

Assuming that the initial probability z of eastern resource-exhausted transfer enterprises is 0.5, the influence of changes in x and y on the proportion of enterprises choosing "Completely Control Pollution" can be investigated. As shown in Figure 3, the z value does not increase monotonically. When $x < 0.5$ and $y < 0.5$, z first decreases and then increases, but finally converges to 1. This is because enterprises aim to maximise economic interests. When they know that the central and local governments do not attach enough importance to environmental protection, they will choose to incompletely control pollution. However, as time passes, ecological carrying capacity reaches its limit and the consequences of environmental damage on the economy continue to emerge. Therefore, resource-based enterprises will change the direction of their strategy selection and adhere to the path of sustainable development.

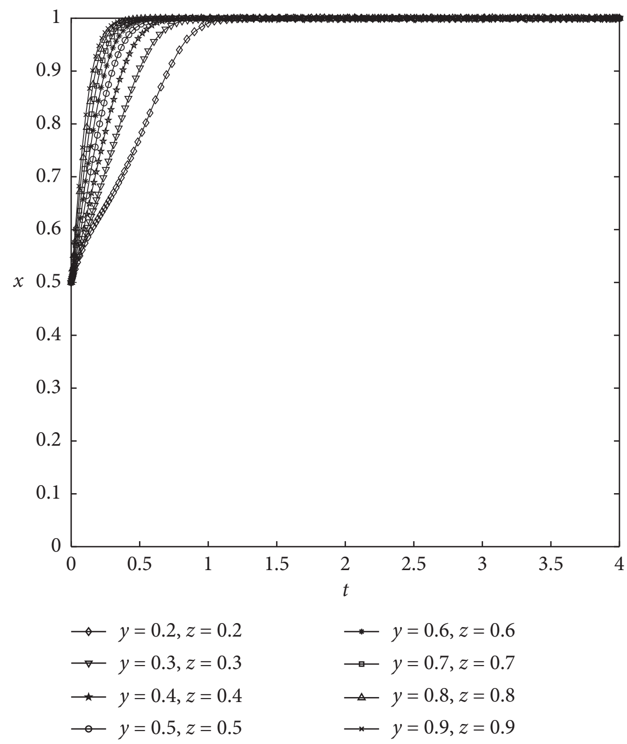

Figure 1: x value evolution curves as y and z change.

(2) Using MATLAB R2018b to carry out evolutionary simulation analysis, the initial probability of the behavioural strategy selection of the three-parties is set to 0.5, that is, $x_0 = y_0 = z_0 = 0.5$. The evolution process is shown in Figure 4. The equilibrium strategy achieved by the system is $(1, 0, 0)$. That is, the central government chooses strict supervision, the local government chooses nonstrict implementation, and the transfer enterprise chooses noncomplete pollution control. In the face of the status-quo of economic backwardness, the local government is motivated to weaken the standard of enterprises' access to the region and the intensity of local environmental regulation. In order to encourage eastern enterprises to transfer in and stimulate economic growth, the local government pursues growth in economic productivity at the expense of the environment. The eastern resource-based transfer enterprises regard the central and Western regions as a "Pollution Haven" [5–9], where

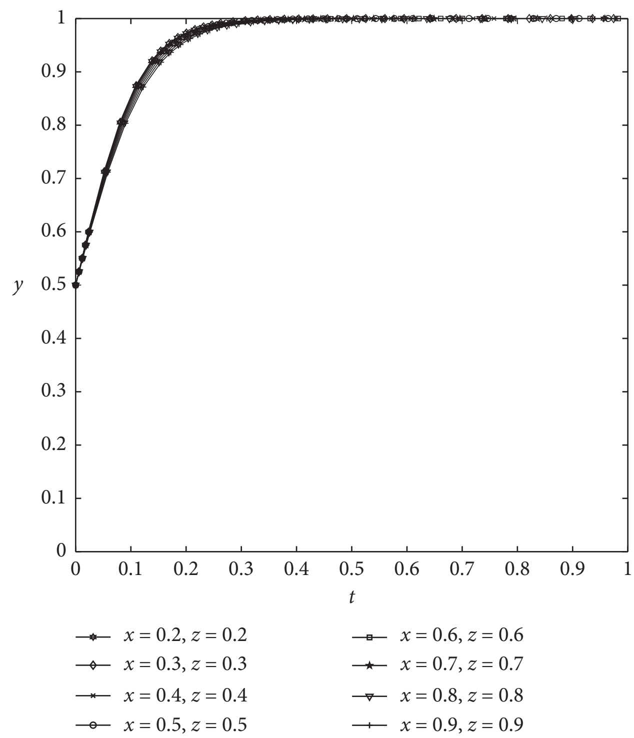

Figure 2: y value evolution curves as x and z change.

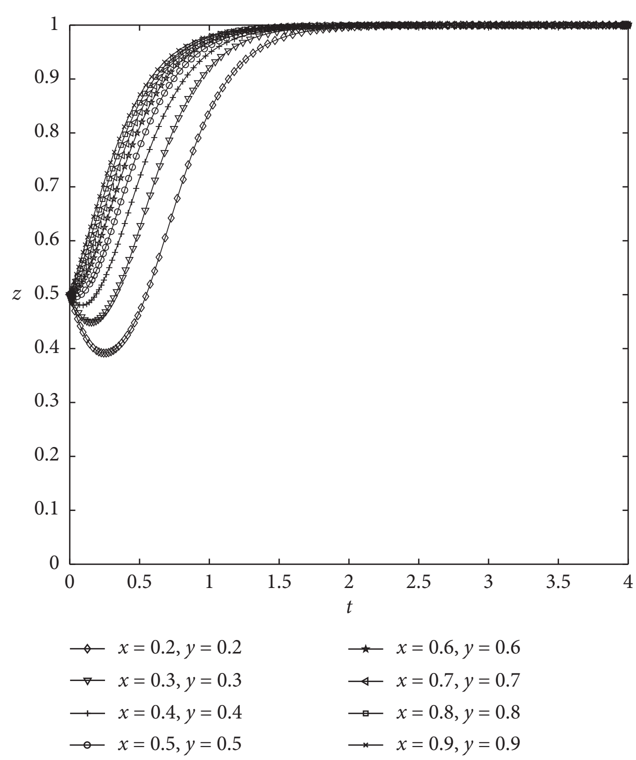

Figure 3: z value evolution curves as x and y change.

they can evade the environmental control of the central government. Therefore, given the low regulatory standards and abundant resources in the central and Western regions, the transfer enterprises

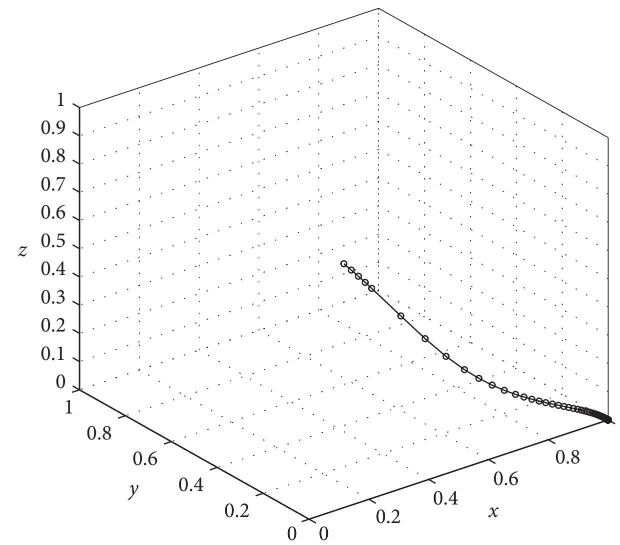

Figure 4: Initial evolutionary equilibrium.

are engaged in predatory operations. This is caused by the imperfect policies and regulations and the lack of supervision in operation transfer areas. Long-term choices for incomplete pollution control strategies and rough mining methods have led to a decline in the environmental quality of these areas; this, in turn, has caused the collapse of mining areas and ecological damage.

(3) When the local government does not strictly enforce the regulations, the central government imposes different penalties H on it. The dynamic evolution process of the system is shown in Figure 5, and x, y, and z tend towards 0, 1, and 0, respectively, indicating that regardless of the amount of punishment applied by the operation recipient local government, under the condition that the local government's enforcement of environmental regulation β is relatively low, will increase the number of transfer enterprises and the actual capital investment. The lower barriers to regional access and the lower intensity of environmental regulations neutralise the punishment levied by the central government. Accordingly, the strategy of the transfer enterprise is to non-completely control pollution. As penalties levied by the local government increase, the speed at which companies choose not to completely control pollution is accelerated. That is, levying excessive punishments will speed up the local government's pursuit of economic growth, and thus increase their tendency to ignore the enterprise's pollution behaviour. This, in turn, accelerates resource consumption and environmental degradation in operation transfer areas.

The Chinese central governmental protection supervision system was officially launched in 2016 and has since achieved full environmental protection supervision in 31 provinces and cities across the country. The establishment of this system has

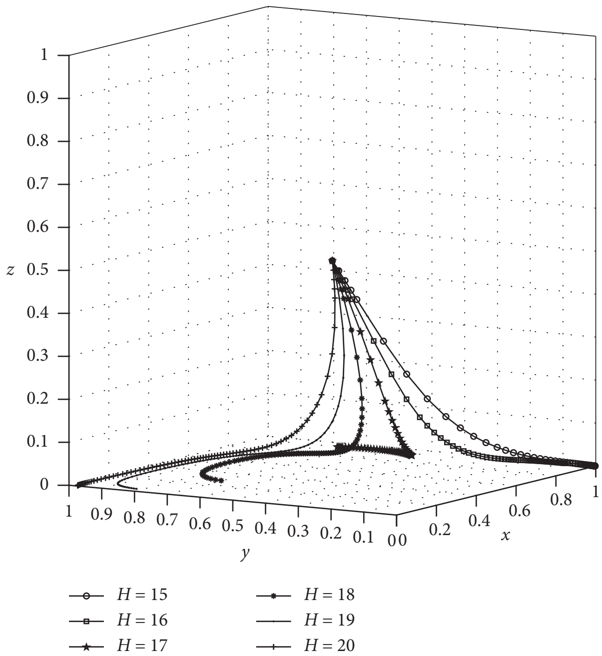

Figure 5: The effect of penalty (*H*) change on evolutionary equilibrium.

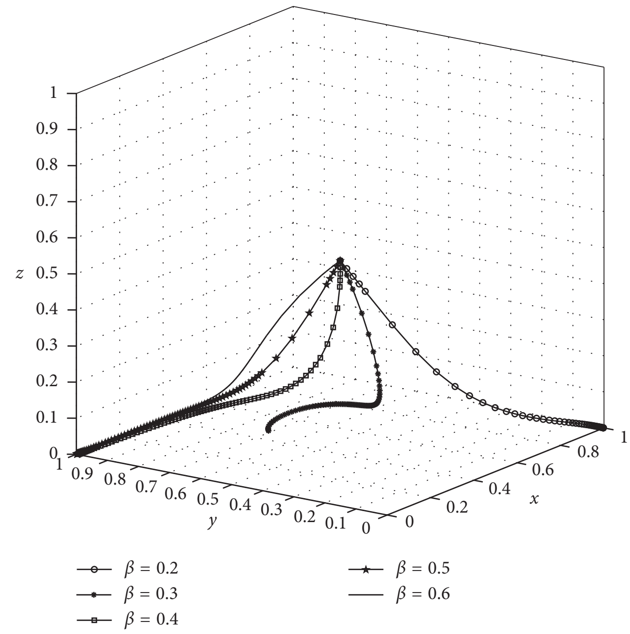

Figure 6: The effect of execution intensity β change on evolutionary equilibrium.

realized the transformation of the central government from supervising enterprises to supervising government. "The Notice on the Guidance for the Pilot Reform of the Vertical Management System for Monitoring, Supervision, and Enforcement of Law by Environmental Protection Institutions under the Province" clearly defines the division of powers for local governments to manage environmental protection, while managing economic development, strengthening cross-regional and cross-basin management, law enforcement, and sharing of law enforcement information for environmental monitoring. In order to break the traditional way of thinking defined by an "Economic growth only" mentality, Jiangsu Province took the lead in incorporating green development into the evaluation system of local governments at the end of 2017. This established a new perspective on performance evaluation. Under the guidance of the national sustainable development policy, Jiangsu Province has established a green assessment development index, namely, the green gross domestic product (Green GDP) and clearly put forward incentive and punishment mechanisms to strengthen the punishment of major pollution accidents.

(4) When local governments' level of enforcement of regulations β is not the same, the dynamic evolution process of the system is shown in Figure 6, and x, y, and z tend to 0, 1, and 0, respectively. This shows that when the local government only increases the enforcement of regulations, enterprises will choose the strategy of incomplete pollution control. The greater the local government's enforcement, the faster enterprises choose incomplete pollution control strategies. The compliance of enterprises to environmental regulation shows an inverse U-shaped curves, that is, compliance moves from passive to active. The original intention of transferring operations from the resource-exhausted enterprises in the east to the central and western regions is to reduce production costs and pursue greater production profits. These enterprises are therefore in a passive state of compliance with environmental regulations. Strict enforcement by local governments in terms of access systems and environmental regulations will increase transfer costs. This, in turn, will enhance the passivity of enterprises to regulation. Eventually, conflict psychology and pursuit of self-interest will push enterprises to choose incomplete pollution control.

Guided by the conviction that clear waters and green mountains are as valuable as mountains of gold and silver, China fundamentally changed the traditional mode of economic growth and consumption. The constraint on analysis which assumed that economic development and environmental protection were in opposition to one another has been overcome. The concept of green development dictates that the environmental access system must be strictly controlled. In order to strictly build the environmental access system and promote green development, Guizhou Province has promulgated the "Guizhou Province Environmental Access List Management Measures for Construction Projects (trial implementation)." The management measures clarify the environmental access conditions of the project and industrial projects or enterprises with pollutant emissions are required to enter industrial parks or industrial concentration zones that adhere to the industrial positioning. Strictly implementing the conditions of "Five None Approvals" and "Three Essentials" ensure that a series of measures are implemented. This standardises approved behaviours, further stimulates market vitality and creates a fair competition system with respect to the environment.

(5) When the central government's penalty amount H to the local government and the local government's degree of enforcement of the regulation β are simultaneously changed, the dynamic evolution process of the system is shown in Figure 7, and x, y, and z tend to 0, 1, and 0, respectively. Compared with only raising the central government's penalty amount for local governments or local government's enforcement level, increasing these two factors simultaneously will not change the transfer enterprise's choice of incomplete pollution control strategy. It will only speed up the enterprises' choice of this strategy.

(6) The dynamic evolution process of the system is shown in Figure 8 when the operation transfer local government has different penalties D_1 for the transfer enterprises exhibiting incomplete pollution control. When $D_1 < 15$, the enterprises' strategy is "Noncompletely Control Pollution," indicating that low environmental pollution penalties will not change transfer enterprises' strategic choice. Excessively low penalties for transfer enterprises will enable the central government to strictly supervise the local governments' enforcement of regulations. This will prevent local protectionism and corruption. However, when $D_1 > 20$, the enterprises will opt for "Completely Control Pollution", and as the amount of punishment increases, the rate of convergence of companies choosing to completely control pollution is faster. That is, once the transfer enterprises know that the local government's punishment for incomplete pollution control is high, they will directly choose "Completely Control Pollution." Excessive penalties make the central government strengthen their supervision of the local government to prevent local governments from profiteering by using environmental protection as an excuse to collect high fines.

Since the implementation of the new environmental protection law in 2015, environmental penalties have reached a new level. New measures such as daily penalties, seizure, production restriction, and production shutdown have been added to environmental law enforcement. The amount of environmental penalties has also greatly increased, which leads to the expansion of the discretion of administrative penalties. There is a risk that the increase in the level of discretion will lead to unfair enforcement of law by local authorities, which will lead to the phenomenon of "power rent-seeking." In order to reduce the frequent occurrence of such incidents, Nanjing, Xining, Gansu, and other places have developed electronic discretion systems for administrative penalties, thus replacing manual discretion with system discretion. Due to regional differences, however, there are also great differences in the norms of discretion. Therefore, in May 2019, the Opinion was officially issued. By guiding and urging local ecological environment departments to

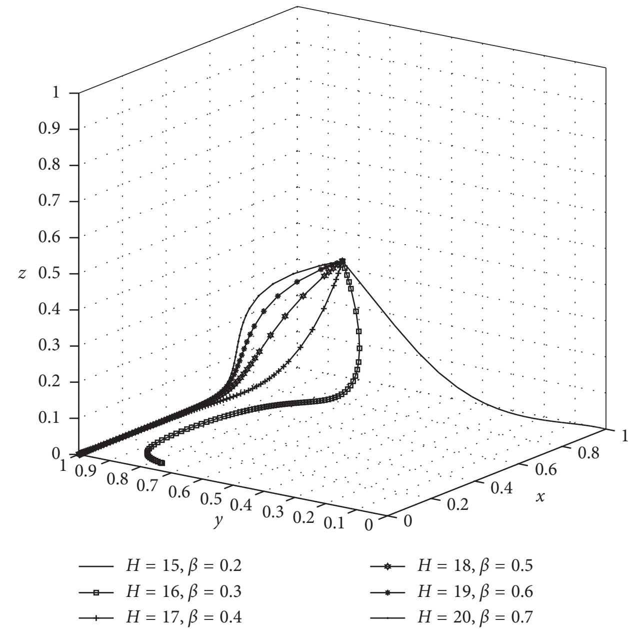

Figure 7: The effect of simultaneous change of penalty (H) and execution intensity β on the evolutionary equilibrium.

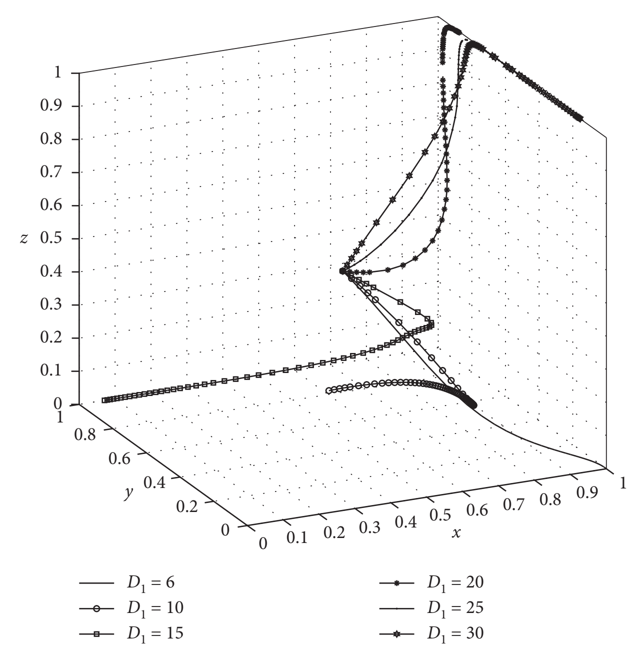

Figure 8: The effect of changes in penalty D_1 on evolutionary equilibrium.

further standardise their exercise of administrative penalty discretion, it can not only prevent administrative penalty law enforcement risks and improve the efficiency of law enforcement but can also more effectively protect the legitimate rights and interests of administrative counterparts. This creates a fair market environment for competition.

(7) When the local government gives different rewards, S_1, to transfer enterprises for completely controlling pollution, the dynamic evolution process of the system is shown in Figure 9, and x, y, and z tend to 1, 0, and 0, respectively, indicating that when the responsible local government in the operation's transfer location changes the amount of reward for the complete control of pollution, the central government will choose to strictly supervise the local enterprises, the local government will choose not to strictly enforce the regulations, and the enterprises will choose not to completely control pollution. When the amount of the reward increases, the rate of enterprises' choice of the incomplete pollution control strategy slows down, indicating that, under the condition that the penalty amount is maintained and the enforcement of regulation is unchanged, only when the reward amount is large enough to exceed the environmental investment of enterprises will these enterprises choose to completely control pollution. When local governments increase the incentive costs for enterprises, they will actively weaken the access system and the intensity of environmental regulations to reduce compliance costs and economic losses. In this situation, the central government will choose to strengthen its supervision.

In 2018, China's first Green Tax Law, the Environmental Protection Law of the People's Republic of China, was implemented. This law established a positive emission reduction incentive mechanism featuring levies in line with emissions levels, fewer emissions and fewer levies, and no emission and no levies. More levies were applied for higher risks and fewer levies were applied for lower risks. Accordingly, the tax levy forces enterprises to increase their emission reduction activities, achieving the goal of environmental protection. According to statistics, China's environmental protection tax should have amounted to 4.46 billion yuan in the first quarter in 2018. The sewage discharge fee increased steadily over the same period last year. The reform benefits of encouraging energy conservation and emission reduction, guiding green production, and promoting high-quality development have begun to emerge. In Hebei, a polluted province, 1817 taxpayers enjoyed tax relief as a result of the environmental protection tax in the first quarter, with tax relief of 26868.62 million yuan.

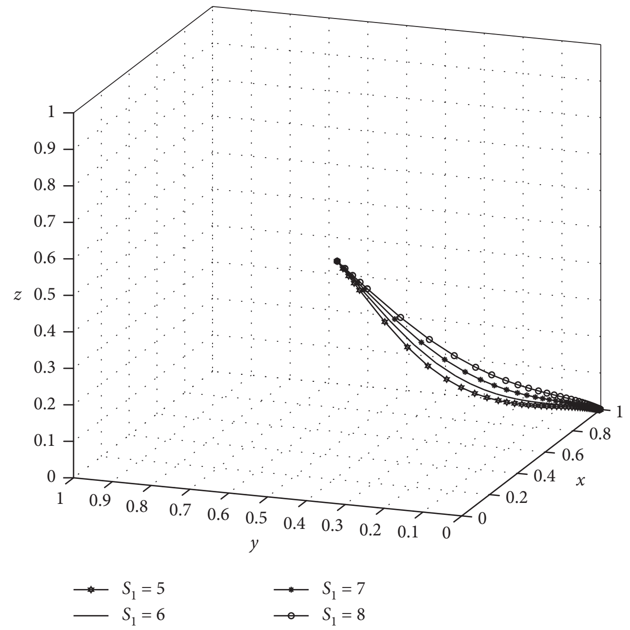

Figure 9: The effect of changes in the reward S_1 on evolutionary equilibrium.

(8) Based on the above analysis, the system must reach the equilibrium strategy $(1, 1, 1)$, that is, the central government chooses to strictly supervise, the local government chooses to strictly implement, and transfer enterprises choose to completely control pollution. It is impossible to reach this state by changing only one parameter value. Therefore, the central government's penalties H for local governments are increased to 20, the local government's enforcement of regulations β is increased to 0.6, the transfer government's fines D_1 for transfer enterprises are increased to 20, and the reward S_1 for pollution control is increased to 7; the dynamic evolution process of the system is shown in Figure 10. In the face of the increasingly serious environmental crisis, the central government's high-level promotion of environmental protection policies is in stark contrast to the inefficient governance and negative coping attitudes of local governments. The central government's increased investment in transfer payments and pollution control has not motivated local governments to pursue positive environmental governance behaviours. Therefore, when local governments have functional deficiencies and misplaced priorities in environmental supervision and ecological protection, the central government should increase its punishment efforts to prevent local governments from pursuing economic growth, destroying the ecological environment, and affecting social stability. Local governments should fully assume the responsibility of transforming the central government's environmental concepts into environmental effects by strengthening

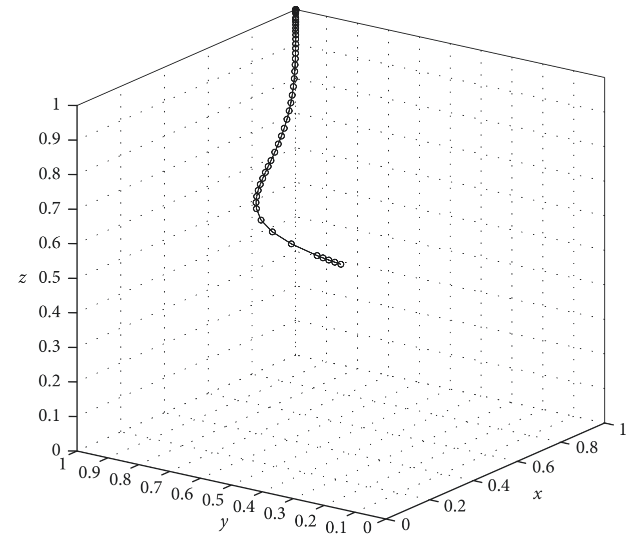

FIGURE 10: The evolution equilibrium state after adjusting each factor.

the implementation of regulations and rewards/punishments for the degree of pollution control. The central government and the local government should focus on the coordination of interests and standardise and adjust reward/punishment relationships and authority-responsibility relationships. They should improve the environmental governance system, promote compliance with environmental regulations on behalf of transfer enterprises from passive to active, and enhance the awareness of environmental protection and social responsibility. This will lead to an improvement of the ecological environment in development regions.

(9) Based on the above analysis, it can be concluded that the penalty amount H imposed by the central government on the local governments, the penalty D_1 imposed by local governments on the transferred enterprises, and the β of the local governments on the implementation of the regulation are the key factors affecting the system evolution equilibrium. Therefore, the influence of these three factors on the convergence rate of the system to the ESS will be further discussed.

The evolutionary process of the system can be obtained by changing any parameter value in D_1, H, and β separately while ensuring that the other two parameters remain unchanged. From Figure 11, it can be seen that reducing or increasing the value of D_1 will significantly reduce or accelerate the convergence rate of the system to the ESS, compared with reducing or increasing H and β alone. The fines D_1 imposed on the transfer enterprises by the local governments play an important role in the convergence rate of the ESS. This may be because the implementation of fiscal decentralization policy makes the division of responsibilities between the central government and local governments clearer, and the direct supervision performed by local governments on enterprises increases the sensitivity of transfer enterprises to the formulation of local governments' strategies. The enforcement of regulations by the local governments has an indirect effect on enterprises and has a time effect. Therefore, the increase in the penalty imposed by local governments for incomplete pollution control can better influence the strategic choice of enterprises and guide the choice of enterprises towards completely controlling pollution.

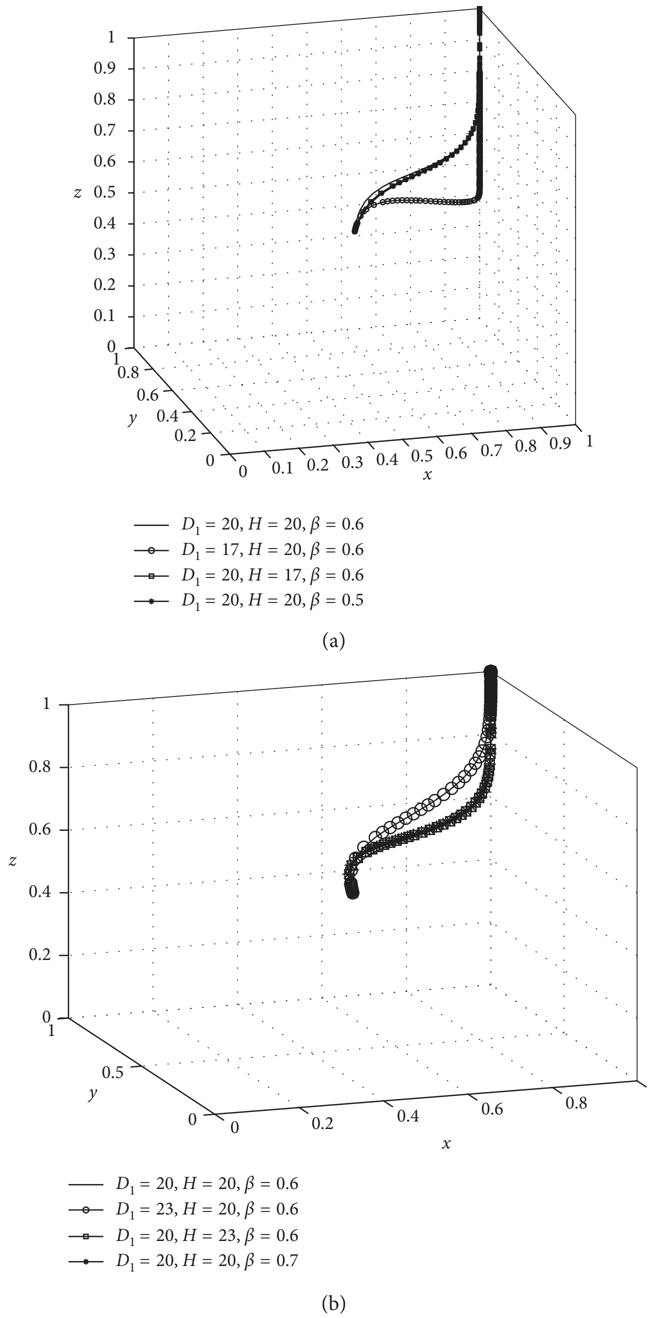

FIGURE 11: Arbitrarily change a parameter value in D_1, H, and β. (a) Arbitrarily reduce. (b) Arbitrarily increase.

According to the above analysis, the increase of D_1 has the most obvious effect on accelerating the convergence rate of the system to the ESS. Therefore, exploring whether a larger D_1 leads to faster convergence of the system can provide a theoretical basis for further accelerating the construction of ecological civilization in the central and Western regions. In the simulation, D_1 is assigned several times and the assigned value increases exponentially. The simulation results are shown in Figure 12. It can be concluded that the effect of the transfer fines D_1 on the convergence rate of the system is depicted by an "inverted U." There must be a value which makes the system converge fastest. This point is recorded as point a in this paper. When the local government fines enterprises too little, the enterprises that transfer for the purpose of maximising self-interest will still develop rapidly through the means of production with high pollution and emissions. As D_1 increases, enterprises will choose the complete pollution control strategy more rapidly. When D_1 increases to a certain value, the selection speed of the completely control pollution strategy peaks. However, with the further increase of D_1, the convergence rate of the system will gradually decrease. This is because the excessive penalty amount will cause the enterprise to make a quick judgment in a short time, but over time, as a result of the excessive penalty amount, a large amount of investment in environmental protection equipment and research and development of green products will increase the transfer burden of enterprises. The premise of "pollution refuge" hypothesis is that the environmental regulation of the area where operations are transferred into is low. Therefore, the excessive penalty amount will make the enterprises which have transferred operations consider looking for other areas to transfer operations to, while the enterprises which have not yet transferred operations are in a wait-and-see state. Thus, the speed of choosing the completely control pollution strategy will gradually decrease.

Combining this theoretical analysis with analysis of the real situation in China, the steps which must be taken to make the system converge to the equilibrium point $E_8(1,1,1)$ quickly without reducing the number of resource-exhausted enterprises transferring operations to the central and Western regions can be identified. Namely, it is necessary to reduce the fines at point a and increase the enforcement of regulation β at the same time, thus achieving a balance between satisfying the convergence condition and guaranteeing the fastest possible convergence rate. As shown in Figure 13, while appropriately reducing the penalty at point a and increasing the enforcement of environmental regulations, the system can still converge to E_8 at a relatively fast rate, which is close to the maximum convergence rate obtained when only changing D_1. Therefore, local governments should make corresponding policies according to local conditions and ensure there is a flow of transfer enterprises, coordinating the development of the economy and environmental protections. At the same time, ecological construction and reduction of environmental stress effects caused by the transfer of enterprises must be pursued.

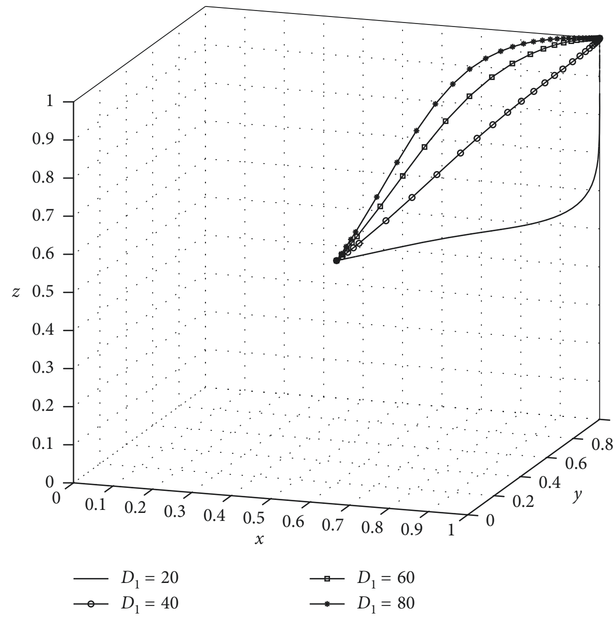

Figure 12: Effect of D_1 on evolutionary convergence rate.

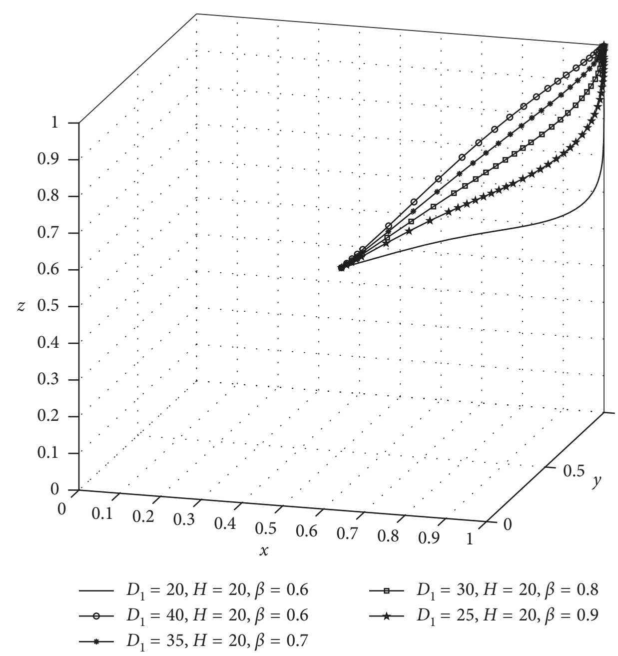

Figure 13: Effect of simultaneous changes in D_1 and β on evolutionary convergence rate.

5. Conclusion

Under the assumption of limited rationality, this paper constructs a game model with the central government, the local governments in areas with transferred operations, and resource-exhausted transfer enterprises as the main actors in the game. Furthermore, the Pollution Haven Hypothesis [5–9] is considered. Specifically, this paper uses MATLAB R2018b to analyse the relationship and influence between equilibrium probability and various parameters. The results show that

(1) The degree of penalties imposed by the central government on local governments, the rewards and penalties imposed by local governments on transfer enterprises, and the level of regulation enforcement by local governments are key factors that make a replication dynamics system eventually evolve into a stable state. This stable state is defined by the central government choosing the "Strictly Supervise" strategy, the local government choosing the "Strictly Implement" strategy, and the enterprises choosing the "Complete Pollution Control" strategy.

(2) The penalty amount imposed by the central government on local governments, the enforcement of regulations by local governments, and the amount of incentives awarded by local governments to enterprises for pollution control do not have a significant impact on enterprises' choice to "Completely Control Pollution." The local governments' penalty amount on enterprises does have a significant impact. Generally speaking, transfer enterprises tend to choose to "Noncompletely Control Pollution" because they can achieve greater net benefits at the expense of the environment, which outweigh the local governments' pollution penalties. Therefore, only when the penalty amount is greater than a certain value can it accelerate the enterprises' choice to "Completely Control Pollution."

(3) The penalty amount charged by the local government to transfer enterprises is the key factor affecting the convergence rate of strategy selection to $E_8(1,1,1)$. The impact on the convergence rate of the system is depicted by an inverted U. Therefore, there must be a value that makes the system converge most quickly.

In order to promote the coordinated development of economy and environment in the central and Western regions of China, as well as to promote the stable construction of civilized ecosystems, the following environmental pollution prevention strategies and suggestions are put forward:

(1) It is important to speed up the legalization construction of the central and local governments, balance the rights of both parties, improve the normality of the responsibility and interest relations between the central and local governments, and enhance the environmental governance ability of local governments. The central government needs to strengthen its supervision over local governments and strictly enforce the punishment standard, the punishment scope, and the punishment amount in accordance with the principle of fairness. It should also raise economic punishment standards for collusion between local governments and enterprises. Strong incentives to expand local employment and create new wealth mean that local governments will minimize the effect of the disciplinary actions initiated by environmental departments, resulting in the contradiction that the environmental law is improved, but the environmental performance is poor. Therefore, the central government should make the performance appraisal system more scientific and increase the weight of environmental indicators, such as resource pollution control [47]. Local governments should be expected to give full play to the role of cross-regional environmental cooperative governance mechanisms [48] and horizontal ecological compensation mechanisms. They should also strictly implement regional pollution discharge standards to prevent continual deterioration of the environment. So as to get rid of dilemma of supervision and enforcement, the country and regions of central and local governments [49].

(2) Local governments' means of punishing enterprises' pollution behaviour are mainly fines, and the amount of fines is generally low [50]. The paradoxical phenomenon of "high cost of law-abiding and low cost of law-breaking" aggravates the uncontrolled exploitation of resources and the destruction of the ecological environment by the transfer enterprises. Therefore, enterprises should assume their environmental responsibilities, and at the same time, the central government should increase punishment for incomplete environmental governance by the local government, raise environmental taxes, broaden the levy scope [51], establish the "Polluters Pay Principle" in the form of law, make multiemission and multitax become restrictive factors of production rigidity in enterprises [52], and further improve the environmental protection tax system [53].

(3) In addition, it is necessary to apply incentive regulation to mobilize enterprises' motivation for pollution control. This means improving the reward policy for the transfer enterprises that control pollution completely, thus reducing the transfer loss of enterprises and creating a market for environmental protection behaviour. This will benefit transfer enterprises that are pursuing environmental protection and help them gain differential advantages and enjoy environmental protection preferences and transfer subsidies. This, in turn, will gradually realize the transformation of enterprises from passive pollution control to active environmental protection. The implementation of the environmental protection tax law has formed an effective restraint and incentive mechanism, which can promote the internalisation of environmental costs which have previously been externalised. This will play a regulatory role and accelerate the green transformation of high-polluting and high-emission enterprises, thus promoting high-quality economic development. Therefore, resource-exhausted enterprises should seize the opportunity to move to the central and western regions, actively maintain environmental protection facilities, increase technological transformation and investment,

and adjust industrial structure. This will allow them to create corresponding tax relief and achieve the balance of cost saving and environmental protection.

Data Availability

Some or all data, models, or code generated or used during the study are available from the corresponding author by request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

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