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Research Article

Government Financial Support and Enterprises' Economic Revitalization and Pollution Discharge Under Normalization of the Epidemic: An Evolutionary Game Analysis Framework

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The world economy, since the outbreak of the coronavirus epidemic, has undergone profound changes. Especially since the coronavirus became the norm, how to achieve rapid economic revitalization has become a problem that countries have to face. In order to analyze how the government should promote the enterprises' economic revitalization and effectively control pollution under the normalized epidemic situation, this paper analyzes the economic revitalization and pollution control problems faced by enterprises under the normalized epidemic situation by using the evolutionary game method. Through the analysis of the evolutionary game model, we draw the following conclusions: (1) Discovered by comparing two different incentives mechanism and penalties mechanism, the dynamic incentives mechanism, and penalties mechanism has a better effect on the process of enterprises' economic revitalization, and it also can reduce the discharge of enterprises' pollutants. (2) In terms of discharge reduction effect, penalties have a better effect than incentives. Compared with incentives, in the process of the economic revitalization of enterprises, in order to reduce pollution discharge, the government can adopt dynamic penalties strategies. This paper analyzes what the government should do when enterprises face the problems of economic revitalization and pollution control. This study can not only provide suggestions for the government in the process of governance but also provide countermeasures for the economic revitalization of enterprises.

1. Introduction

In recent years the world has experienced unimagined and accelerated changes, from a population death due principally to the coronavirus epidemic, with consequent strains on education, health care, and jobs, to an economic recession, since the outbreak of the coronavirus epidemic in 2019, an event that generated enormous effect and attracted the greatest attention of all the world. According to the epidemic data of Johns Hopkins University, so far, about 200 million people have been infected with coronavirus in the world, and the cumulative death is about 5 million [1]. The International Monetary Fund says, almost all countries in the world experienced negative economic growth in 2020. The economic growth of major developed countries such as the United States, the United Kingdom, Canada, Germany, and Japan was −3.4%, −9.8%, −5.3%, −4.6%, and −4.6%, respectively. Similarly, the economic growth of some developing countries such as India, Mexico, Nigeria, and China was −7.3%, −8.3%, −1.8%, and 2.3%, respectively. Extraordinarily, China was the only country in the world with positive economic growth. This was principally due to the Chinese government's orderly reviving of production and work under the premise of strict control of the epidemic [2]. Undeniably, this was not only China's institutional advantage [3, 4] but also a concrete manifestation of the Chinese government's agility and adaptability [5]. When the World Health Organization declared coronavirus pneumonia a public health event of international concern [6], the Chinese government began to implement strict prevention and control of the epidemic.

The raging epidemic has changed enterprises' production and operation behaviors and even changed the existing business model [7–9]. The traditional competitors have become partners, forming a win-win situation through cooperation [10]. As an important carrier of the economy of various countries, enterprises undertake the important functions of stimulating economic growth, increasing employment, and maintaining social stability. Therefore, the outbreak of the coronavirus epidemic appears to have an impact on the economy, but its essence is an impact on enterprises, as far as the enterprises' market is concerned. Due to the implementation of the blockade policy, more and more consumers were kept behind closed doors, which in turn made the enterprises' products unable to sell, and undoubtedly accelerated the enterprises' bankruptcy [11]. In fact, from February to May 2020, 19% of registered enterprises and 25% of self-employed enterprises in China have permanently closed down [12]. When offline operations were affected by the epidemic, enterprises would use new information or digital technologies, such as mobile applications, to carry out online operations [13, 14]. However, this required technical institutions to provide sufficient technical support to enterprises [15]. At the same time, the traditional enterprises' governance model and management system were no longer suitable for the market environment under the normalized epidemic situation. Adjusting the enterprises' governance model to adapt to the consumer's consumption habits has become an urgent issue facing enterprises development [16]. As far as the enterprises' supply chain was concerned, the strict blockade and the outage of logistics caused many enterprises' supply chains to break, and the enterprises were unable to carry out normal production and operation activities [17, 18]. As far as the capital turnover of the enterprise was concerned, in the face of the epidemic, the biggest concerns of enterprises were financial impact and uncertainty [19], and financial interruption might bring devastating blows to enterprises [20]. The impact of the epidemic has made some enterprises unable to obtain enough funds to carry out normal production and operation activities, which to a certain extent showed that the implementation of financial emergency strategies was of great significance to the production and survival of enterprises [21, 22]. As far as the knowledge level and the abilities of the labor force were concerned, strong personal abilities and good enterprise ecology were important reasons why many enterprises were still growing under the influence of the epidemic [23]. In addition, the impact of the epidemic on enterprises was also different. Because of their different years of establishment, enterprises with a shorter establishment period and a small number of employees would not be severely affected by the epidemic [24].

Policy makers need to maintain the normal operation of the economy while implementing epidemic prevention and control policies [25]. When enterprises faced the abovementioned problems that cannot be solved by themselves, government financial support was an effective way to help enterprises deal with such problems [26]. The government's financial support for enterprises would give consumers better expectations of the future economy [27], which might help boost confidence in the market economy and restore the enterprises' product sales capabilities. Similarly, when the government implemented restrictions on enterprises, it would produce negative returns, which led to the result of lowering consumers' expectations of the future economy. At the same time, the government ought to increase the promotion of digital technology in the production and operation of enterprises [28]. The government assisted enterprises in establishing emergency management measures for public health incidents and formulating future development strategies, which might help to enhance the resilience of the supply chain and accelerate the process of economic revitalization [29]. Meanwhile, the financial support of the government and supply chain partners was also extremely important for the stability of the supply chain [30]. The countries used various financial, fiscal, or administrative means to support enterprises in order to help them tide over the difficulties. This kind of assistance, to a certain extent, has avoided the phenomenon of a sharp decline in enterprise production [31]. Honestly, it was undeniable that different types of enterprises might be affected differently [32, 33]. For example, the impact of the epidemic on state-owned enterprises was smaller than that on private enterprises [34]. In addition, in the short term, the governments' strict epidemic prevention and control policy might significantly reduce the spread of the epidemic [35]. But in the long run, its economic support could not make up for the cost of long-term suppression [36]. Of course, the actual situation of each country was not the same. The government should not copy the prevention, control, and revitalization experience of other countries in the process of formulating policies but should determine the policy that suits its own country according to its own national conditions [37].

In summary, the current research papers have made great contributions to the analysis of normalized epidemics. But there are still some shortcomings. (1) The current research on the impact of the normalized epidemic on the economy is mainly focused on the level of text analysis. They mainly use structural equation models. Only a small amount of literature uses empirical analysis and evolutionary game methods to analyze the impact of the epidemic on the economy. (2) The current research papers only consider accelerating the pace of economic revitalization of enterprises and did not consider the pollutant discharge enterprises during the revitalization process. (3) The impact of static and dynamic incentives mechanisms and penalties mechanisms on enterprises' economic revitalization is not considered. In view of this, this article uses an evolutionary game model to analyze how government financial support affects the strategic choices and future development of enterprises under the normalized epidemic situation. It also considers the issue of pollutant discharge during the revitalization process of enterprises. At the same time, how enterprises make strategic choices under different incentives mechanisms and penalties mechanisms are analyzed.

The structure of this article is as follows: (1) The internal mechanism of the interaction between different game

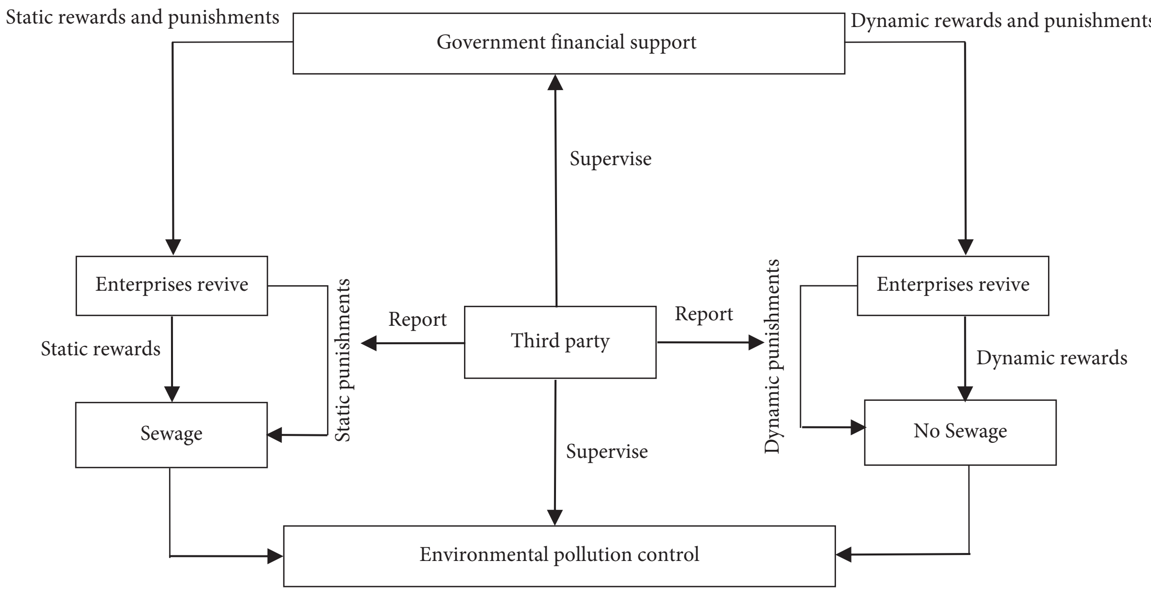

Figure 1: The economic revitalization mechanism of government supported enterprises.

players and the research method of this article are explained. (2) This article establishes an evolutionary game model based on assumptions, and how the enterprise makes strategic choices under the static and dynamic incentives mechanism and penalties mechanism are analyzed. (3) The results are discussed, and the core conclusions of this article are drawn. (4) And at the same time, the limitations of this research are clarified.

2. Material and Method

2.1. Mechanism Analysis. Under the normalization of the epidemic, enterprises not only need to consider their economic revitalization but should also consider making their pollutant discharge meet the standards in the process of economic revitalization. These are two issues that cannot be ignored. In the context of ecological civilization construction, clear waters and green mountains are as good as mountains of gold and silver. Ignoring the pollutant discharge in the process of economic revitalization is tantamount to drinking poison to quench thirst. In addition, the government's use of different types of incentives mechanism and penalties mechanisms in the process of supporting the economic revitalization of enterprises will also have an impact on enterprises' pollution discharge. The following figure shows the internal logic of this mechanism (see Figure 1).

As shown in Figure 1, the government's financial support can indeed make the enterprises realize economic revitalization. But in the process of enterprises' economic revitalization, the issue of pollutant discharge needs to be considered. Under the static incentives mechanism and penalties mechanism, it is difficult for the government to control the discharge of pollutants by enterprises, that is, under the static incentives mechanism and penalties mechanism, enterprises are more tend to discharge pollution. See Figure 1 for details. On the contrary, under the dynamic incentives mechanism and penalties mechanism, enterprises are more tend to choose not to discharge pollution. In addition, third-party supervision and reporting will also play a role in the game. See Figure 1 for details.

2.2. Evolutionary Game Model. Interdisciplinary and multisubject cooperation is one of the effective ways to deal with the epidemic [38]. It is also one of the main issues that we need to fully consider. In the process of economic revitalization, we also need to better understand the relationship between the government, the enterprise market, and various other institutions [39]. An evolutionary game model is an important tool for studying multiagent cooperation, and it is applied in various disciplines [40, 41]. Increasing the government's cost of public social projects will reduce the losses caused by the epidemic [42]. In addition, when faced with the threat of an epidemic, the strengthening of cooperation between various entities will significantly increase their survival rate [43]. For the above reasons, this paper uses the evolutionary game model to analyze whether the government provides financial support for the enterprises in the process of economic revitalization and whether the enterprises discharge pollution. It also introduces a dynamic incentives mechanism and penalties mechanism to analyze the enterprises' strategies.

3. Research Hypothesis

Hypothesis 1. .To simplify the analysis, this study assumes that there are two players in the game of economic revitalization of enterprises, namely the enterprise and the government. We denote the two players by E and G, respectively. According to the evolutionary game theory, the enterprises and governments are subjects with bounded rationality. That is, the goals of both sides are to maximize their own interests, and the strategic choices of both sides are

Table 1: Variable description.

Variable	Description
π_{E1}	Benefits from enterprises discharging pollutants
π_{E2}	Benefits from enterprises not discharging pollutants
ω_1	Financial support from the financial sector when enterprises discharge pollutants
ω_2	Financial support from the financial sector when enterprises do not discharge pollutants
c_{E1}	The cost paid by the enterprise when it discharges pollutants
c_{E2}	The cost that the enterprise pays when it does not discharges pollutants
f	Government fines for pollutants discharged by enterprises
B	Government incentives for enterprise that do not discharge pollutants
ω	Government financial support to enterprises
c_G	The cost paid by the government in the game
s	Losses caused by pollutants discharged by enterprises
π_{G1}	Government revenue when enterprises discharge pollutants
π_{G2}	Government revenue when the enterprises do not discharge pollutants
π_E	Basic revenue of the enterprise
π_G	Basic revenue of the government

constantly adjusted according to the behavior of the other party.

Hypothesis 2. .Further, we assume that in the game process, the strategic space that the enterprises can choose is (no discharge, discharge), and the probability that the enterprise chooses not to discharge is y, and the probability that the enterprise chooses to discharge is 1-y. Similarly, the strategy space that the government can choose is (support, not support), and the probability that the government chooses to support is x, and the probability that the government chooses not to support is 1-x.

Hypothesis 3. .When the enterprise (E) chooses to discharge pollution in the process of economic revitalization, it will get a certain benefit, which is assumed to be π_{E1}. Similarly, when an enterprise (E) chooses not to discharge pollution during the economic revitalization process, it will also get a certain benefit, assuming it is A π_{E2}. At the same time, regardless of whether the enterprise discharges pollution in the process of economic revitalization, it will pay a certain cost. When an enterprise discharges pollutants, its cost is c_{E1}. When the enterprise does not emit pollutants, its cost is c_{E2}. In the process of the economic revitalization of the enterprise, it will receive financial support from the financial sector. When the enterprise discharges pollutants, the support received is ω_1, and when the enterprise does not emit pollutants, the support received is ω_2. In addition, the enterprise will also receive financial support from the government (regardless of whether it discharges pollution or not), assuming it is ω. If an enterprise discharges pollutants in the process of economic revitalization, it will be punished, assuming it is f. And if the enterprise does not discharge pollutants, it will be incentivized, assuming it is B. The enterprise will cause losses if it discharges pollutants, assuming it is s. Similarly, the government will obtain certain benefits in the game process. When an enterprise discharges pollutants, the government's revenue is π_{G1}. When the enterprise does not emit pollutants, the government's revenue is π_{G2}, and the government's cost during the game is c_G. Table 1 is a brief description of the above variables.

We can obtain the game payoff matrix according to the above three assumptions. The payoff matrix of the enterprises and the governments is listed in Table 2 (see Table 2).

4. Evolutionary Game Analysis

4.1. Model Establishment and Solution. According to the payoff matrix in Table 2, we can build an evolutionary game model. First, we need to get the expected benefits for the enterprises. We assume that the expected benefits of the enterprises choosing not to discharge pollution is u_{E1}, and the expected benefits of the enterprises choosing to discharge pollution can be represented by u_{E2}. For details, please refer to the following formulas:

$$u_{E1} = x\left[\pi_E + \pi_{E2} + B - c_{E2} + \omega_2 + \omega\right] + (1 - x)\left[\pi_E + \pi_{E2} + \omega_2 - c_{E2}\right], \tag{1}$$

$$u_{E2} = x\left(\pi_E + \pi_{E1} + \omega_1 + \omega - c_{E1} - f\right) + (1 - x)\left(\pi_E + \pi_{E1} + \omega_1 - c_{E1}\right). \tag{2}$$

In addition, according to formulas (1) and (2), the average expected benefits of the enterprises can be obtained. We use $\bar{u_E} = yu_{E1} + (1 - y)u_{E2}$ to denote the enterprises average expected benefits. For details, please refer to the following formula:

Table 2: Game payoff matrix of economic revitalization enterprises (E) and government (G).

		Economic revitalization enterprise(E)	
		Not discharge y	Discharge 1-y
Government (G)	Support x	$(\pi_G+\pi_{G2}-B-c_G-\omega, \pi_E+\pi_{E2}$ $+B-c_{E2}+\omega_2+\omega)$	$(\pi_G+\pi_{G1}+f-c_G-s-\omega, \pi_E+\pi_{E1}$ $+\omega_1+\omega-c_{E1}-f)$
	Not suppor 1-x	$(\pi_{G2}+\pi_G, \pi_E+\pi_{E2}+\omega_2-c_{E2})$	$(\pi_{G1}+\pi_G-s, \pi_E+\pi_{E1}+\omega_1-c_{E1})$

$$\begin{aligned} u_{E1} = {} & y\left[x\left[\pi_E+\pi_{E2}+B-c_{E2}+\omega_2+\omega\right]+(1-x)\left[\pi_E+\pi_{E2}+\omega_2-c_{E2}\right]\right] \\ & +(1-y)\left[x\left(\pi_E+\pi_{E1}+\omega_1+\omega-c_{E1}-f\right)+(1-x)\left(\pi_E+\pi_{E1}+\omega_1-c_{E1}\right)\right]. \end{aligned} \tag{3}$$

Second, we need to get the expected benefits of the governments. We assume that the expected benefits of the governments choosing to support is u_{G1}, and the expected benefits of the governments choosing not to support can be represented by u_{G2}. For details, please refer to the following formulas:

$$u_{G1} = y\left[\pi_G+\pi_{G2}-B-c_G-\omega\right]+(1-y)\left[\pi_G+\pi_{G1}+f-c_G-s-\omega\right], \tag{4}$$

$$u_{G2} = y\left(\pi_{G2}+\pi_G\right)+(1-y)\left(\pi_{G1}+\pi_G-s\right). \tag{5}$$

In addition, according to formulas (4) and (5), the average expected benefits of the governments can be obtained. We use $\bar{u_G} = xu_{G1}+(1-x)u_{G2}$ to denote the government's average expected benefits. For details, please refer to the following formula:

$$\begin{aligned} u_{G1} = {} & x\left[y\left[\pi_G+\pi_{G2}-B-c_{G2}-\omega\right]+(1-y)\left[\pi_G+\pi_{G1}+f-c_G-s-\omega\right]\right] \\ & +(1-x)\left[y\left(\pi_{G2}+\pi_G\right)+(1-y)\left(\pi_{G1}+\pi_G-s\right)\right]. \end{aligned} \tag{6}$$

Third, we need to get the replication dynamic equations. The computation of replication dynamic equations requires the use of two key things. One is the principle of the Malthusian dynamic equation; the other is the above formula of the average expected benefits of the enterprises and the governments. For details, please refer to the following formulas:

$$Fy = \frac{\mathrm{d}y}{\mathrm{d}t} = y(1-y)\left[x(f+B)+\left(\pi_{E2}-c_{E2}+\omega_2\right)-\left(\pi_{E1}-c_{E1}+\omega_1\right)\right], \tag{7}$$

$$Fx = \frac{\mathrm{d}x}{\mathrm{d}t} = x(1-x)\left[f-c_G-\omega-y(f+B)\right]. \tag{8}$$

Table 3: Parameter value at the equilibrium point.

Equilibrium point	a11	a12	a21	a22
(0, 0)	$f - c_G - \omega$	0	0	$(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})$
(0, 1)	$-c_G - \omega - B$	0	0	$-[(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})]$
(1, 0)	$-(f - c_G - \omega)$	0	0	$f + B + (\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})$
(1, 1)	$-(-c_G - \omega - B)$	0	0	$-[f + B + (\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})]$
(x^*, y^*)	0	M	N	0

Table 4: Partial equilibrium analysis.

Equilibrium point	$\det J_e$	trJ_e	Stability
(0, 0)	—	Uncertain	Saddle point
(0, 1)	—	Uncertain	Saddle point
(1, 0)	—	Uncertain	Saddle point
(1, 1)	—	Uncertain	Saddle point
(x^*, y^*)	+	—	Stable point

Finally, we need to solve the replication dynamic equation. Let the two replication dynamic equations be equal to 0, respectively, that is, $Fy = 0$ and $Fx = 0$. At this point, we can find the solutions of the equations, and these solutions are called equilibrium points. These equilibrium points can be expressed as (0,0),(0,1),(1,0),(1,1) and $((\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2})/f + B,$ $f - c_G - \omega/f + B)$.

4.2. Stability Analysis. Now that we have obtained the equilibrium point for replication of the dynamic equation, next, we need to analyze the stability of the equation. When performing equation stability analysis, we need to use the Jacobian matrix, which was proposed by Friedman. For details, please refer to the following formula:

$$J_e = \begin{bmatrix} (1-2x)f - c_G - \omega x(1-x)(-f-B) \\ -y(f+B)](1-2y)[x(f+B)+ \\ y(1-y)(f+B)(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})] \end{bmatrix}. \quad (9)$$

According to formula (9), we can get the determinant $(\det J_e)$ and trace (trJ_e) of the Jacobian matrix, which is the key to judging whether the equation is stable. For details, please refer to the following formulas:

$$\begin{aligned} \det J_e &= (1-2x)[f - c_G - \omega - y(f+B)] * (1-2y)[x(f+B) \\ &+(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E2})] - [x(1-x)(-f-B) * y(1-y)(f+B)]. \end{aligned} \quad (10)$$

$$\begin{aligned} trJ_e &= (1-2x)[f - c_G - \omega - y(f+B)] + (1-2y)[x(f+B) \\ &+(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E2})]. \end{aligned} \quad (11)$$

Solving (10) and (11), the parameter values at the equilibrium point can be obtained. The specific values of the parameters are listed in Table 3.

This part mainly analyzes the strategy selection problem of enterprises under the static incentives mechanism and penalties mechanism. In this part, we assume that the government's implementation of incentives and penalties to enterprises has reached the maximum level. When $(\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) > f + B$, the government's incentives mechanism and penalties mechanism has lost their effectiveness, because in this case, the enterprise's pollution revenue is far greater than the government's penalties and incentives. While $0 < (\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) > f + B$ and $f - c_G - \omega > 0$, only (x^*, y^*) is the stable point of the game system, this stable point is not the asymptotic stability point of the game system but a closed-loop curve around (x^*, y^*). The following is an analysis of the local stability of the five equilibrium points (see Table 4).

As shown in Table 4, if the benefits of the enterprises from pollutant discharge during the economic revitalization process are not much different from the incentives and penalties it receives, the enterprise will hover between whether or not to discharge pollutants. Enterprises are neither willing to risk pollution and be punished nor are they willing to choose not to discharge pollution for incentives. At the same time, the government is neither willing to provide financial support to enterprises for reputation nor is it willing to be criticized for not providing financial support to enterprises. Therefore, the game system does not automatically stabilize at the equilibrium point, and the strategies of the two sides of the game always show a closed-loop periodic movement around the equilibrium point. See Figure 2 for details

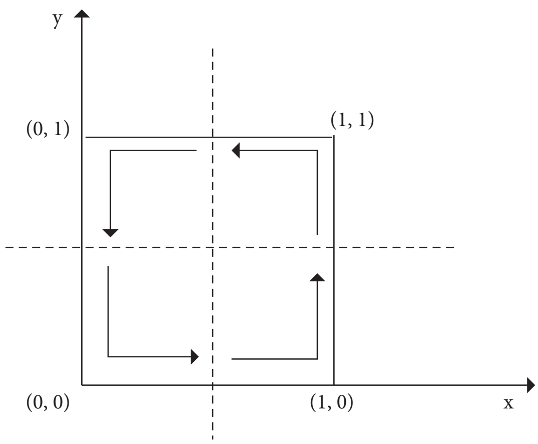

Figure 2: When $0 < (\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) > f + B$ and $f - c_G - \omega > 0$ Phase diagram.

5. Further Analysis

In the above, we have analyzed the strategy selection problem of enterprises under the static incentives mechanism and penalties mechanism. In this section, the dynamic incentives mechanism and penalties mechanism are introduced. Assuming that during the economic revitalization of the enterprises, the government's incentives and penalties for pollutant discharge are dynamic in nature, that is, the government's incentives and penalties for pollutant discharges are not constant, but change in a certain proportion. When an enterprise discharges more pollutants in the process of economic revitalization, the government will penalize it more strongly. Similarly, when the enterprises discharges fewer pollutants in the process of economic revitalization, the government incentives it more. Suppose that the fixed incentives B above become a linear function $B(y) = yB$; at the same time, the fixed penalties f above become a linear function $f(y) = (1-y)f$. The remaining assumptions are consistent with the above. Replace f and of B in formula (7) and (8) with yB and $(1-y)f$, and the specific expressions are as follows:

$$\begin{cases} Fy = \dfrac{dy}{dt}, \\ = y(1-y)\left[x((1-y)f + yB) + (\pi_{E2} - c_{E2} + \omega_2) - (\pi_{E1} + \omega_1 - c_{E1})\right], \\ Fx = \dfrac{dx}{dt}, \\ = x(1-x)\left[(1-y)f - c_G - \omega - y((1-y)f + yB)\right]. \end{cases} \quad (12)$$

Similarly, we need to solve the replication dynamic equation. Let the two replication dynamic equations be equal to 0, respectively, that is, $Fy = 0$ and $Fx = 0$. These equilibrium points can be expressed as (0,0), (0,1), (1,0), (1,1) and (x', y') can be obtained.

5.1. Stability Analysis. Now that we have obtained the equilibrium point for replication the dynamic equation, next, we need to analyze the stability of the equation. When performing equation stability analysis, we need to use the Jacobian matrix, which was proposed by Friedman. For details, please refer to the following formula:

$$J_e = \begin{bmatrix} (1-2x)\left[(1-y)f - c_G - \omega x(1-x)(-2fB + 2yf - 2f)\right. \\ \left. -y((1-y)f + B)\right](1-2y)\left[x((1-y)f + yB) + \right. \\ \left. y(1-y)((1-y)f + yB)(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})\right] \end{bmatrix}. \quad (13)$$

According to formula (13), we can get the determinant $(\det J_e)$ and trace (trJ_e) of the Jacobian matrix, which is the key to judging whether the equation is stable. For details, please refer to the following formulas:

$$\begin{aligned} \det J_e = {} & \left[(1-2x)\left[(1-y)f - c_G - \omega - y((1-y)f + B)\right]\right] * \\ & (1-2y)\left\{x((1-y)f + B) + (\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E2})\right] \\ & - \left[x(1-x)(-(1-y)f - B) * (y(1-y)((1-y)f + yB))\right], \end{aligned} \quad (14)$$

$$\begin{aligned} trJ_e = {} & \left[(1-2x)\left[(1-y)f - c_G - \omega - y((1-y)f + yB)\right]\right] \\ & + (1-2y)\left[x((1-y)f + yB) + (\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E2})\right]. \end{aligned} \quad (15)$$

Table 5: Parameter value at the equilibrium point.

Equilibrium point	a11	a12	a21	a22
(0, 0)	$f - c_G - \omega$	0	0	$(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})$
(0, 1)	$-c_G - \omega - B$	0	0	$-[(\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})]$
(1, 0)	$-(f - c_G - \omega)$	0	0	$f + (\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})$
(1, 1)	$-(-c_G - \omega - B)$	0	0	$-[B + (\pi_{E2} + \omega_2 - c_{E2}) - (\pi_{E1} + \omega_1 - c_{E1})]$
$(x\prime, y\prime)$	0	M	N	0

Table 6: Partial equilibrium analysis.

Equilibrium point	$\det J_e$	trJ_e	Stability
(0, 0)	—	Uncertain	Saddle point
(0, 1)	—	Uncertain	Saddle point
(1, 0)	—	Uncertain	Saddle point
(1, 1)	—	Uncertain	Saddle point
$(xy\prime)$	+	—	ESS

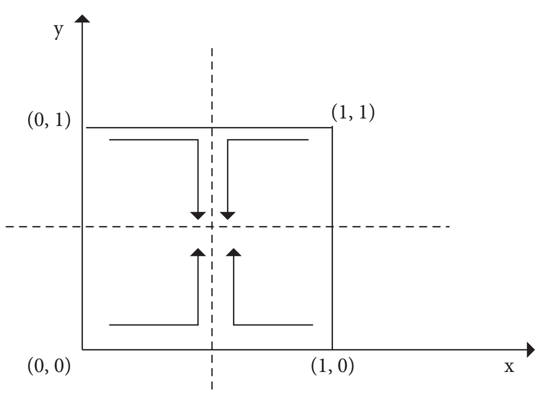

Figure 3: When $0 < (\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) < (1 - y)f + yB$ and $(1 - y)f - c_G - \omega > 0$ Phase diagram.

Solving (14) and (15), the parameter values at the equilibrium point can be obtained. The specific values of the parameters are listed in Table 5.

When $0 < (\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) < (1 - y)f + yB$ and $(1 - y)f - c_G - \omega > 0$, only (x', yx') is the stable point of the game system, and this stable point is the asymptotic stability point of the game system. The evolution path at this time is not a closed-loop curve around (xx', yx'), but a spiral curve that is stable at this point. The following is an analysis of the local stability of the five equilibrium points.

As shown in Table 6, the dynamic incentives mechanism and penalties mechanism is more stable than the static incentives mechanism and penalties mechanism. Under the dynamic incentives mechanism and penalties mechanism, the penalties and incentives of enterprises have a linear function relationship with their pollutant discharge, that is, the more pollutants an enterprise discharges, the greater the penalties it receives, and the less pollutants discharge, the higher the incentives it receives. Therefore, under this mechanism, the willingness of enterprises to discharge pollutants in the process of economic revitalization is very low, which is conducive to achieving economic and ecological benefits at the same time. The game phase diagram is shown in Figure 3.

Table 7: Assignment of each parameter.

Parameter	π_{E1}	c_{E1}	ω_1	π_{E2}	c_{E2}	ω_2	f	B	c_G	ω
Assignment situation	5	2	3	3	4	2	3	4	0.5	1

6. Simulation Research

6.1. Static Incentives Mechanism and Penalties Mechanism. This section simulates the above static and dynamic incentives mechanism and penalties mechanism. First, we simulate the static incentives mechanism and penalties mechanism. Before starting the simulation, each parameter needs to be assigned. Under the static incentives mechanism and penalties mechanism, it is necessary to ensure that each parameter value satisfies $0 < (\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) > f + B$ and $f - c_G - \omega > 0$. See Table 7 for parameter assignment.

As shown in Table 7, Under the static incentives mechanism and penalties mechanism, the probability that the government chooses to support the strategy is x, and the probability that the enterprises chooses not to discharge pollution the strategy is y. According to the parameters in Table 7, the values of x and y can be obtained. $x = 0.714$, $y = 0.214$. When conducting simulation, we need to set the initial probability. In this paper, we use the values of x and y as the initial probability. We assume that the probability of x remains the same, and let y be 0.1 and 0.7, respectively. It is possible to obtain the evolution path of enterprises not to discharge pollution in the process of economic revitalization. For details, please refer to Figures 4 and 5. It can be seen from Figures 4 and 5 that under the static incentives mechanism and penalties mechanism, the evolution path is in a divergent state. This divergent state not only has nothing to do with the probability that enterprises choose not to discharge pollutants, but also has nothing to do with the financial support of the governments. When the probability x that the government implements financial support is equal

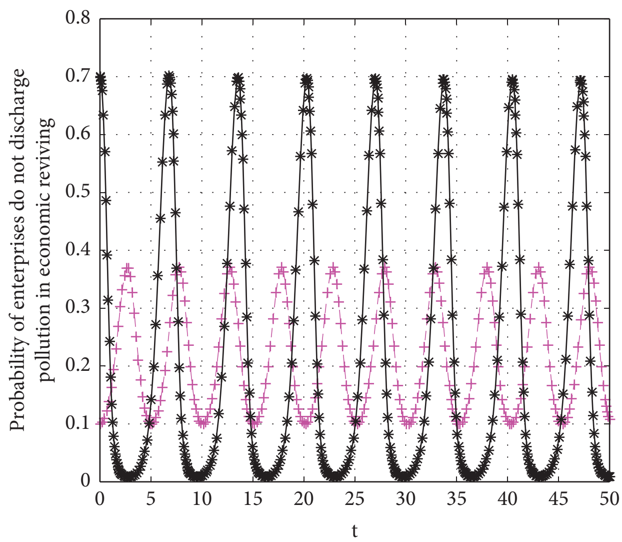

Figure 4: The evolution path of nondischarge in the process of enterprises economic revitalization under the static incentives mechanism and penalties mechanism.

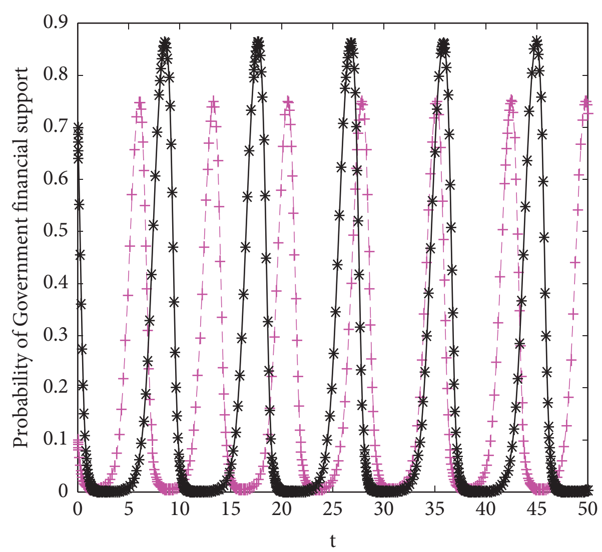

Figure 5: The evolution path of government financial support under the static incentives mechanism and penalties mechanism.

to the probability y that the enterprise chooses not to discharge pollution in the process of economic revitalization. The evolution path of the game will show a closed-loop periodic motion. For details, please refer to Figure 6. This shows that there is no gradual stability point under the static incentives mechanism and penalties mechanism.

Based on the above analysis, it can be seen that under the static incentives mechanism and penalties mechanism, the evolution paths are mostly divergent or closed-loop states. Only under the dynamic incentives mechanism and penalties mechanism does the evolution path show a convergent state. This may also reflect a more stable dynamic incentives mechanism and penalties mechanism.

Table 8: Assignment of parameters.

Parameter	π_{E1}	c_{E1}	ω_1	π_{E2}	c_{E2}	ω_2	f	B	c_G	ω
Assignment situation	5	2	3	3	4	2	7	6	0.5	1

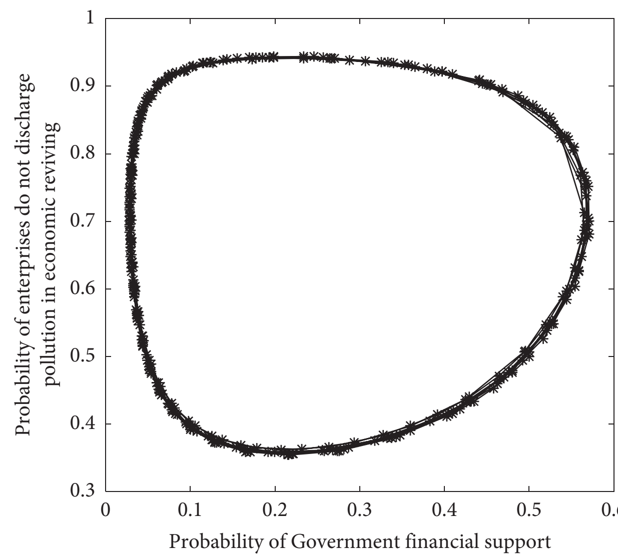

Figure 6: The evolution path when the initial probabilities of both sides of the game are the same under the static incentives mechanism and penalties mechanism.

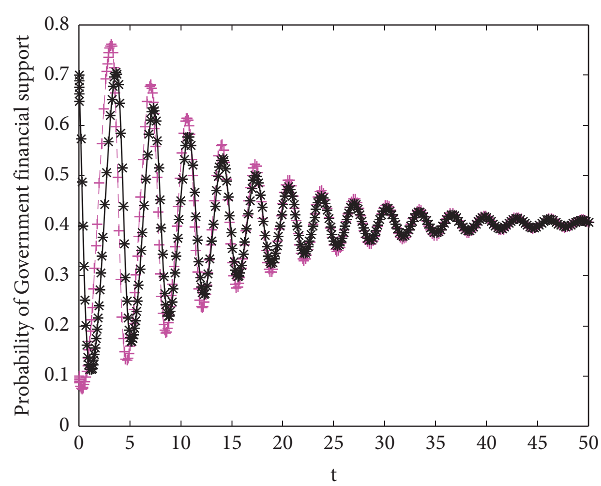

Figure 7: The evolution path of government financial support under the dynamic incentives mechanism and penalties mechanism.

6.2. Dynamic Incentives Mechanism and Penalties Mechanism. The game evolution path under the static incentives mechanism and penalties mechanism is analyzed above. Next, we analyze the evolution path of the game under the dynamic incentives mechanism and penalties mechanism. Similarly, each parameter must also ensure that the following conditions are met, namely $0 < (\pi_{E1} + \omega_1 - c_{E1}) - (\pi_{E2} + \omega_2 - c_{E2}) < (1 - y)f + yB$ and $(1 - y)f - c_G - \omega > 0$. The assignment of each parameter is detailed in Table 8.

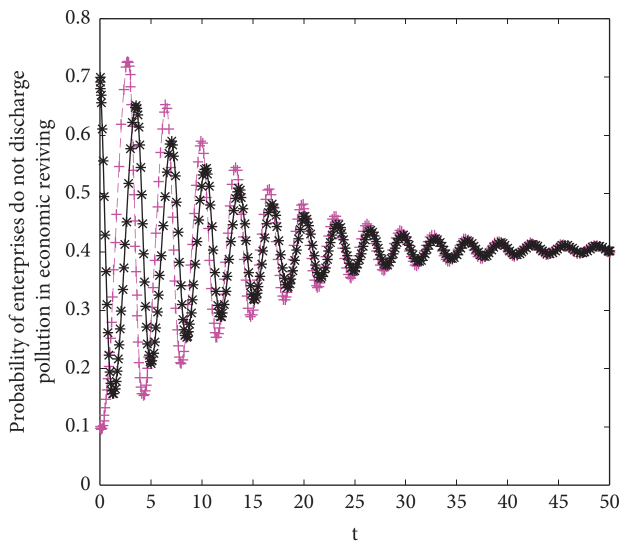

FIGURE 8: The evolution path of nondischarge in the process of enterprises economic revitalization under the dynamic incentives mechanism and penalties mechanism.

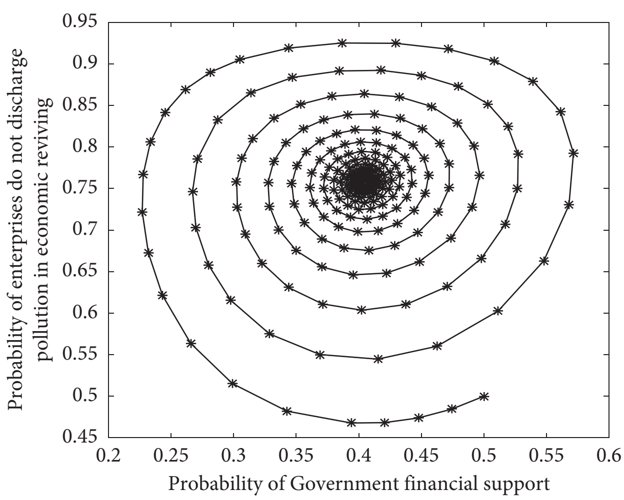

FIGURE 9: The evolution path when the initial probabilities of both sides of the game are the same under the dynamic incentives mechanism and penalties mechanism.

As shown in Table 8, under the dynamic incentives mechanism and penalties mechanism, the probability that the government chooses to support the strategy is x, and the probability that the enterprises chooses not to discharge pollution the strategy is y. According to the parameters in Table 8, the values of x and y can be obtained. $x = 0.617$, $y = 0.405$. When conducting simulation, we need to set the initial probability. In this paper, we use the values of x and y as the initial probability. We assume that the probability of x remains the same, and let y be 0.1 and 0.7, respectively. It is possible to obtain the evolution path of enterprises not to discharge pollution in the process of economic revitalization. The evolutionary path of the government's financial support can be obtained. For details, please refer to Figure7. It can be seen from Figures 7 and 8 that under the dynamic incentives mechanism and penalties mechanism, the evolution path is in a state of convergence. This state of convergence not only has nothing to do with the probability that enterprises choose not to discharge pollutants, but also has nothing to do with the financial support of the governments. When the probability x that the government implements financial support is equal to the probability y that the enterprise chooses not to discharge pollution in the process of economic revitalization. The evolutionary path no longer shows a closed-loop periodic movement, but shows a spiral movement, and finally converges to an equilibrium point. The specific evolution path is shown in Figure 9.

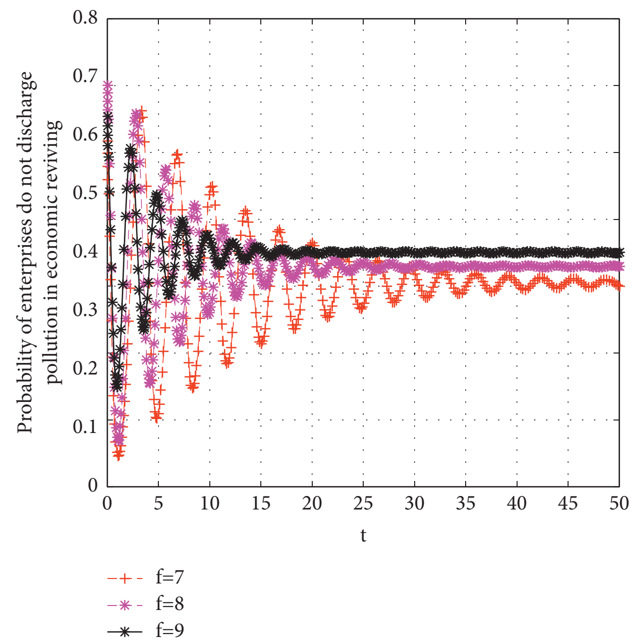

FIGURE 10: The evolution path of enterprises' nondischarge with increased penalties under the dynamic incentives mechanism and penalties mechanism.

6.3. The Impact of Different Intensities of Penalties and Incentives on Enterprises' Pollution Discharge Strategies. Under the dynamic incentives mechanism and penalties mechanism, as the government's incentives and penalties for enterprises to discharge pollutants are increased, it may have an impact on the strategic choices of whether enterprises discharge pollutants in the process of economic revitalization. This section first analyzes the government's different levels of punishment. When the government's penalties for enterprises' discharge from low to high in the process of economic revitalization, assume that they are 7, 8, and 9, respectively, while other parameters remain unchanged. Figure 10 shows the evolution path of enterprises that do not discharge in the process of economic revitalization at this time. In the same way, when the government's incentives for enterprises not to discharge in the process of economic revitalization go from low to high, they are assumed to be 6, 7, and 8, respectively, while other parameters remain unchanged. At this time, the evolution path of enterprises that

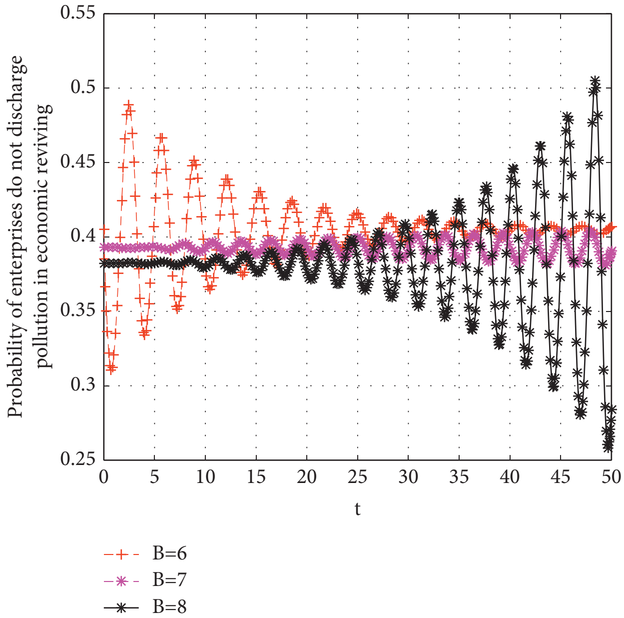

Figure 11: The evolution path of enterprises' nondischarge when increasing the incentives under the dynamic incentives mechanism and penalties mechanism.

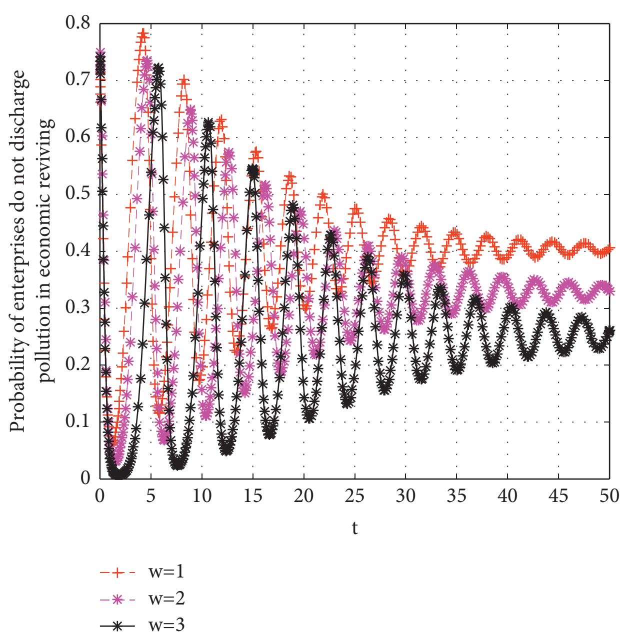

Figure 12: The evolution path of enterprises' nondischarge when government financial support increases under the dynamic incentives mechanism and penalties mechanism.

do not discharge pollution during the economic revitalization process is shown in Figure 11. It can be seen from Figures 10 and 11 that as the government imposes greater penalties on enterprises for pollutant discharge during the economic revitalization process, the probability that enterprises will not discharge pollutants will increase. As the government incentives enterprises for not discharging pollution in the process of economic revitalization, the

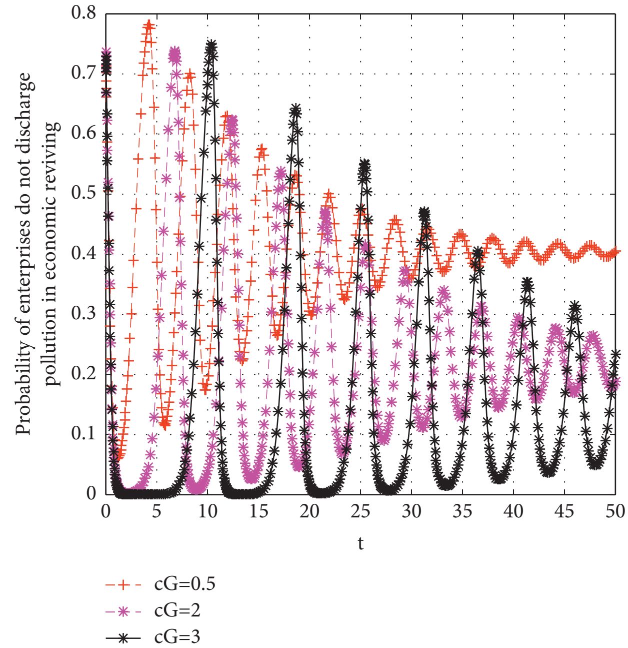

Figure 13: The evolution path of nondischarge of enterprises when government costs increase under the dynamic incentives mechanism and penalties mechanism.

probability of enterprises not discharging pollution will decrease.

6.4. The Impact of Different Levels of Financial Support on Enterprises' Pollution Discharge Strategies. According to formula (12), the probability x that the government implements financial support and the probability y that the enterprises will choose not to discharge pollution in the process of economic revitalization can be calculated. $y = 2f - 2\sqrt{(f-B)c_G + (f-B)\omega + fB}/2(f-B)$. Solve the partial derivative of government financial support ω for probability y, $\partial y/\partial \omega = -1/2$. It can be seen that the probability that an enterprise will choose not discharge pollution during the economic revitalization process y is a decreasing function of government financial support ω. That is, as the government's financial support ω increases, the probability that the enterprise will not discharge pollution during the economic revitalization process y will decrease. This shows that although government financial support will enable the revitalization of the enterprises' economy, it will increase the probability of enterprises' discharge. Similarly, as the partial derivation of the government cost c_G for the probability y, we will also get the probability that the enterprise will not discharge pollution in the process of economic revitalization y is a decreasing function of the government cost c_G. With the increase of government cost c_G, the probability y that enterprises will not discharge pollution in the process of economic revitalization will decrease. The specific situation is shown in Figures 12 and 13.

7. Discussions

According to the analysis of the above-mentioned evolutionary game and simulation research, under different types of incentives mechanisms and penalties mechanism, enterprises will perform differently in the process of economic revitalization. The dynamic incentives mechanism and penalties mechanism is more effective than the static incentives mechanism and penalties mechanism. The reason is that under the static incentives mechanism and penalties mechanism, the incentives and penalties received by enterprises are already at the highest intensity. The amount of pollutant discharge is not necessarily related to the intensity of the punishment, and there is no inevitable connection between the degree of incentives and the intensity of discharge reduction. In this case, enterprises are more likely to choose to discharge pollutants. Under the dynamic incentives mechanism and penalties mechanism, the penalties and incentives that the enterprise receives in the process of economic revitalization is a positive linear relationship with its pollutant discharge. Under the dynamic incentives mechanism and penalties mechanism without an upper limit, the enterprise is more likely to choose not to discharge pollution.

Under the dynamic incentives mechanism and penalties mechanism, the effect of penalties is better than the effect of incentives. The reason is that overly generous incentives have prevented enterprises from using funds to reduce pollutants in the process of economic revitalization, and this has led to the ineffectiveness of government incentives to enterprises. In addition, the incentives for enterprises to reduce discharge are funded by the government, which undoubtedly increases the government's financial burden, reduces the government's willingness to incentives, and increases the probability of enterprises emitting pollutants in the process of economic revitalization. Compared with incentives, it may be a better choice to impose penalties on enterprises' pollution discharge, as unlimited penalties greatly increase the cost of enterprises and may even threaten their survival. Therefore, under the consideration of many parties, enterprises will be more likely to choose a nondischarge strategy.

At the same time, with the increase in government financial support and costs, the probability of enterprises not discharging pollutants in the process of economic revitalization will decrease. This is the same as the decline in the probability of enterprises not reducing discharge when the government increases incentives because these expenditures will increase the government's burden, leading to a decline in its financial support and incentives.

Most of the existing literature uses plain text descriptions in the process of analyzing the economic revitalization of enterprises, but this paper uses an evolutionary game model to analyze the problem. In addition, this paper not only considers the economic revitalization of enterprises but also considers the problem of pollutant discharge in the process of the economic revitalization of enterprises.

8. Conclusions

This paper uses the evolutionary game model to analyze whether the government provides financial support for the enterprise in the process of economic revitalization and whether the enterprise discharges pollution and also introduces a dynamic incentives mechanism and penalties mechanism to analyze the enterprise pollution strategy. Based on the above analysis, the following conclusions can be drawn.

(1) When comparing the static incentives mechanism and penalties mechanism with the dynamic incentives mechanism and penalties mechanism, the dynamic incentives mechanism and penalties mechanism has a better effect on restraining the discharge of pollutants from enterprises. Because under the static incentives mechanism and penalties mechanism, the evolution path is a closed-loop periodic motion, while under the dynamic incentives mechanism and penalties mechanism, the evolution path is a spiral convergent motion.

(2) In the dynamic incentives mechanism and penalties mechanism, the government's penalties mechanism is more effective than the incentives mechanism. Because as the penalties increases, enterprises tend more to not discharge pollution.

(3) The choice of game strategy between the two parties is essentially determined according to their own costs and benefits. From Figures 12 and 13 in the simulation results, it can be seen that the increase in government expenditures leads to an increase in its costs, which in turn leads to a decrease in their willingness to cooperate, and ultimately increases the probability of enterprises' discharge.

However, it has to be admitted that this paper has some limitations. This paper uses the evolutionary game model to analyze the government financial support and the pollutant discharge of enterprises in the process of economic revitalization and introduces static and dynamic incentives mechanisms and penalties mechanisms for further analysis. However, whether an enterprise emits pollutants in the process of economic revitalization will also be affected by many other factors, such as the probability of successful third-party supervision, preferential tax rates implemented by the government, etc. Hence, variables such as the government's preferential tax rate and the probability of third-party supervision can also be added in future research.

Data Availability

The original contributions presented in the study are included within the article/supplementary material and can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors' Contributions

Sen Zhang is responsible for writing the main model of the paper, Ting Chen and Yilin Liu are responsible for evolution simulation analysis, Guangyuan Qin is responsible for the main guidance during the writing process of the paper, and Baodong Cheng is responsible for providing the main idea of the paper.

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Supplementary Materials

The Supplemental files of this article are the code of the static and dynamic incentives mechanism and penalties mechanism. (*Supplementary Materials*)

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