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Analysis of Water Pollution Control in Port Area Based on Evolutionary Game Model: A Case Study of Tianjin Port

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Abstract. In recent years, the coastal sea pollution problem caused by the unqualified discharge of marine sewage in the port area has become increasingly prominent. This paper takes Tianjin Port, the largest artificial port in China, as an example, uses evolutionary game theory to build a model, and analyzes the game based on the behavior patterns of the government and shipping companies. The behavioral strategy and evolutionary trajectory of the game players are comprehensively studied, and it is concluded that reducing the cost of government supervision, increasing the administrative penalty, and reducing the cost of pollution reduction are all helpful to the positive evolution and development of ship domestic sewage treatment in the port area. The research results can provide a theoretical basis and technical support for realizing the ideal steady-state treatment of domestic sewage from ships and ecological restoration of port water resources as soon as possible.

Keywords. Marine sewage, port area water, evolutionary game, water environment management

1. Introduction

As a part of the natural ecological environment, the water environment is the material basis for human survival. Marine pollution has attracted more and more attention from people all over the world. It is not only a problem of coastal countries, but also an international problem. Marine pollution does not respect national boundaries, and coastal waters and waters may be polluted at any time by pollutants discharged from ships outside their territorial waters. The main pollutants produced by ships include oily sewage, domestic sewage, ship refuse, and so on. Marine sewage is produced every day. It is one of the main pollutants of marine pollution. Non-standard discharge of domestic sewage will consume dissolved oxygen in water, damage biological resources and endanger human health [1-4]. Therefore, it is urgent to standardize the management of marine sewage. Tianjin Port is located at the western end of Bohai Bay, the lower reaches of the Haihe River and the estuary, with dense navigation and a large number of ships. A large number of ships enter and leave the waters of Tianjin Port every day. At present, there are some problems in Tianjin Port, such as inadequate laws and regulations on the prevention and control of domestic sewage pollution, lack of

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domestic sewage receiving facilities at the port, insufficient law enforcement force and difficult supervision over the discharge of domestic sewage from ships. A large amount of domestic sewage from ships is discharged into the Bohai Sea waters and even the waters of the Tianjin Port area, causing water pollution in the waters of Tianjin Port. Therefore, it is necessary to do a good job in Tianjin Port ship domestic sewage treatment research.

Cheng [5] believed that the high cost of sewage treatment for the professional receiving units of marine domestic sewage severely restricted the treatment of marine sewage by professional cleaning companies. Due to its particularity, unlike the residual oil substances produced by ships, domestic sewage has no recycling value, and its treatment is completely costly [6]. Moreover, the current ship pollutant receiving facilities in ports are mainly for the reception of oily sewage rather than shipping domestic sewage [7]. Liu [8] believes that the cost of marine sewage treatment is high and the fund guarantee mechanism is not perfect. The cost of post-treatment of domestic sewage remains high, and ship owners are not willing to pay the relevant cost of domestic sewage treatment in order to ensure the interests of ships. The number of small ships in China is large, and enterprises will face the problems of high cost, large investment and difficult supporting facilities when investing in infrastructure [9, 10]. However, China has not established a fund guarantee mechanism for ship pollution prevention. He believes that the “ship-to-shore” operation mode should be built to coordinate the division of labor and cooperation between relevant departments of local government and unite forces, so as to solve the problems of joint supervision and charging subsidy standards of municipal sewage pipe network when entering the wharf. Build a “ship-ship-shore” operation mode, and jointly invest in building a multifunctional service area on the water to receive domestic sewage from ships. The government can purchase services to reduce the burden of receiving domestic sewage from ships and ships.

Collaborative governance theory is a new theory developed. It holds that in the process of social public life, subsystems such as government, non-governmental organizations, enterprises and individual citizens jointly constitute the overall system [11-13], and currency and law are used as control parameters [14, 15]. Through mutual coordination and joint governance of various elements in the overall system and participants among subsystems, efficiency can be maximized [16]. Finally, the aim of maximizing humanistic care and promoting public interests is achieved. The collaborative treatment of shipboard domestic sewage refers to the maximum maintenance and good treatment of shipboard domestic sewage through the multi-participation of the government, enterprises and other subjects [17, 18]. This paper mainly studies the need for cooperation between the government and shipping companies in the treatment of ship domestic sewage in Tianjin Port. It innovatively incorporates the implementation intensity of government environmental policies and the participation of shipping companies in actual governance as important factors affecting the decision-making of the main body into the evolutionary game analysis framework of both sides, eliminates the research limitations, and obtains more comprehensive and objective research results. Therefore, it provides more realistic suggestions for promoting the collaborative treatment of ship sewage.

2. Construction and Solution of the Evolutionary Game Model

2.1. Model Assumptions

As an important source of water pollution in coastal waters, marine sewage has always been a key and difficult point in the prevention and control of water pollution in offshore waters, and has been widely concerned by all sectors of society. For the convenience of analysis, the participants are divided into Tianjin government and shipping companies. the Tianjin Municipal People's Government is responsible for formulating and promulgating regulations and rules related to ship domestic sewage in Tianjin Port, supervising the whole process of ship domestic sewage treatment, and prohibiting ships from illegally discharging domestic sewage into the sea. It is the supervisor of pollution control of ship domestic sewage discharge. As the main body engaged in ship transportation, shipping companies are the producers of domestic sewage pollution in the Tianjin port area. In the treatment of water pollution in the port area, they usually seek the maximization of their own interests. At present, due to the urgency of water environment treatment in coastal waters, the Tianjin government mainly aims to improve the ecological environment and seek the maximization of social welfare. The key to the analysis of marine sewage treatment is the interactive game between the response of shipping companies to the strategies of the Tianjin government and the adjustment of relevant strategies by the Tianjin government according to the specific behaviors of shipping companies. Therefore, the establishment of the evolutionary game analysis framework between Tianjin Government and shipping companies conforms to the social background and economic reality, and can explain and analyze the water pollution control situation of Tianjin Port area.

Hypothesis 1: As a supervisor, the government can take two actions, perfect supervision (probability x) and imperfect supervision (probability 1-x), to maintain the overall water environment quality of the port area according to the daily supervision and anti-pollution sampling inspection of ships as reported by the maritime administrative agency.

Hypothesis 2: Shipping companies make decisions to maximize their own interests based on their knowledge of relevant policies and regulations and understanding of emission requirements. There are two strategy options, active abatement (probability y) or negative abatement (probability 1-y).

Hypothesis 3: When the government does not supervise the shipping company, it has basic income M_1; When the shipping company does not abate, it has the basic income M_2.

Hypothesis 4: The supervision cost C_1 will be generated when the government conducts supervision of shipping companies. When the government adopts perfect supervision policy, its supervision intensity α=1; When the government adopts imperfect supervision policy, its supervision intensity $0<\alpha<1$. The pollution reduction cost C_2 will be generated by the shipping company. When the shipping company actively reduces pollution, its pollution control intensity β=1; When the shipping company is passive in reducing pollution, its pollution control intensity $0<\beta<1$.

Hypothesis 5: The negative pollution reduction behavior of the shipping company will face the risk of being discovered by the government (supposing the probability of being discovered is α). Once discovered, the ship will be subject to administrative penalty P. The government will also lose credibility and cause reputational damage.

Hypothesis 6: Sewage treatment by shipping companies will bring environmental pollution treatment revenue R to the government, and the revenue is affected by the shipping companies' pollution reduction efforts β.

The model parameters and their meanings are shown in Table 1.

Table 1. Model parameters and their meanings.

Acting subject	Parameter	Express meaning
Government	M_1	The basic benefits of a government policy of non-supervision
	C_1	The supervision cost when the government supervises the shipping company
	α	Strength of supervision
	T	Loss of reputation
	R	Benefits from environmental pollution control
Shipping company	M_2	Basic income when the shipping company does not treat sewage
	C_2	Pollution control cost
	β	Pollution control efforts
	P	Administrative punishment

2.2. Model Analysis

Based on the assumptions and basic symbol table, the income matrix of the evolutionary game between the government and the shipping company under the supervision of {perfect supervision, imperfect supervision} and the shipping company under the combination of the sewage treatment strategies of {active pollution reduction and negative pollution reduction} is obtained, as shown in Table 2.

Table 2. Income matrix of government and shipping company.

Government	Shipping company	
	Active pollution reduction	**Negative pollution reduction**
Perfect supervision	$(M_1 - C_1 + R, M_2 - C_2)$	$(M_1 - C_1 + P - T, M_2 - \beta C_2 - P)$
Imperfect supervision	$(M_1 - \alpha C_1 + R, M_2 - C_2)$	$(M_1 - \alpha C_1 + \alpha P - T, M_2 - \beta C_2 - \alpha P)$

2.3. Model Construction and Solution

In evolutionary games, the proportion of strategies adopted by the group with fitness or expected returns above average increases. The replication dynamic equation is the dynamic differential equation describing the proportional growth rate of a particular strategy. Based on the evolutionary game matrix, the expected returns and average returns of the government and the shipping company are calculated, and then the replication dynamic equations of each body are constructed.

2.3.1. Government

The expected income of the government's choice of perfect supervision is E_{x1}:

$$E_{x1} = y(M_1 - C_1 + R) + (1 - y)(M_1 - C_1 + P - T) \tag{1}$$

The expected benefit of the government's choice of imperfect supervision is E_{x2}:

$$E_{x2} = y(M_1 - \alpha C_1 + R) + (1 - y)(M_1 - \alpha C_1 + \alpha P - T) \tag{2}$$

Then the average expected revenue of the government is:

$$\mathrm{E_x} = xE_{x1} + (1-x)E_{x2} \tag{3}$$

According to evolutionary game theory, the replication dynamic equation of perfect supervision selected by the government is:

$$\mathrm{F(x)} = \frac{dx}{dt} = x(1-x)(\alpha-1)(C_1 - P + Py) \tag{4}$$

2.3.2. Shipping Company

The expected income of the shipping company choosing active pollution abatement is $\mathrm{E_{y1}}$:

$$\mathrm{E_{y1}} = x(M_2 - C_2) + (1-x)(M_2 - C_2) \tag{5}$$

The expected benefit of negative pollution abatement is $\mathrm{E_{y2}}$:

$$\mathrm{E_{y2}} = \mathrm{x(M_2 - \beta C_2 - P) + (1-x)(M_2 - \beta C_2 - \alpha P)} \tag{6}$$

Then the average expected income of a shipping company is:

$$\mathrm{E_y} = yE_{y1} + (1-y)E_{y2} \tag{7}$$

According to the evolutionary game theory, the replication dynamic equation for the shipping company to choose active pollution abatement is:

$$\mathrm{F(y)} = \frac{dy}{dt} = y(1-y)(C_2\beta - C_2 + P\alpha + Px - P\alpha x) \tag{8}$$

2.4. Analysis of Equilibrium Strategy of Evolutionary Game Model

According to the above analysis, the two-dimensional dynamic system of the evolutionary game can be written as follows:

$$\begin{cases} F_x(x,y) = x(1-x)(\alpha-1)(C_1 - P + Py) \\ F_y(x,y) = (1-y)(C_2\beta - C_2 + P\alpha + Px - P\alpha x) \end{cases} \tag{9}$$

By setting the replication dynamic equations to zero, four pure strategy equilibrium points $\mathrm{E}_1(0,0), E_2(0,1), E_3(1,0), E_4(1,1)$ and one mixed strategy equilibrium point $\mathrm{E}_5(x^*, y^*)$ can be obtained. Note: $x^* = -\frac{C_2\beta - C_2 + P\alpha}{P - P\alpha}, \mathrm{y}^* = \frac{P - C_1}{P}$.

Since the mixed strategy equilibrium points are saddle points, they must not be an evolutionarily stable equilibrium. Therefore, only the stability of the four pure strategy equilibrium points is considered in this paper. According to the method proposed by Friedman, the stability of each equilibrium point is judged by analyzing the Jacobian matrix of the evolutionary game system, that is, the asymptotic stability of the equilibrium point depends on the positive and negative properties of the eigenvalues of the corresponding matrix. Therefore, the Jacobian matrix is obtained according to the replication dynamic equation.

$$\mathrm{J} = \begin{bmatrix} -(2x-1)(\alpha-1)(C_1 - P + Py) & -Px(\alpha-1)(x-1) \\ Py(\alpha-1)(y-1) & -(2y-1)(C_2\beta - C_2 + P\alpha + Px - P\alpha x) \end{bmatrix} \tag{10}$$

The four pure strategy equilibrium points are put into the Jacobian matrix respectively, and the corresponding matrix eigenvalue expressions are shown in Table 3.

Table 3. Equilibrium point stability analysis table.

Symbolic	Eigenvalue		Condition	Symbol	Stability
	λ_1	λ_2			
$E_1(0,0)$	$(C_1-P)(\alpha-1)$	$C_2\beta+P\alpha-C_2$	$C_1>P$ $C_2\beta+P\alpha<C_2$	(x, x)	Stable
$E_2(0,1)$	$C_1(\alpha-1)$	$C_2-C_2\beta-P\alpha$	$C_2\beta+P\alpha>C_2$	(-, x)	Stable
$E_3(1,0)$	$P-C_2+C_2\beta$	$(C_1-P)(1-\alpha)$	$P+C_2\beta<C_2$ $C_1<P$	(x, x)	Stable
$E_4(1,1)$	$C_2-P-C_2\beta$	$C_1(1-\alpha)$	-	(x, +)	Unstable

Corollary 1: When $C_1>P$ and $C_2\beta+P\alpha<C_2$, E_1 is the evolutionary stability point of the model, E_2, E_3 is the evolutionary instability point of the model. That is, if the cost of government supervision is higher than the penalty for negative pollution abatement behavior of shipping companies and the average cost of negative pollution abatement of shipping companies is lower than the cost of active pollution abatement, then the government will choose imperfect supervision and shipping companies will choose negative pollution abatement. In order to prevent the occurrence of such situations, government supervision can be no longer limited to command and control by reducing the cost of supervision, introducing public participation and democratic consultation, etc., and forming the supervision mode of all relevant departments to strengthen interaction and join forces. At the same time, efforts should be intensified to publicize the treatment of marine sewage in the coastal waters of the Bohai Sea and the waters of the Tianjin Port area, so as to enhance the responsibilities and obligations of coastal residents and ship crews in the construction of ecological civilization, so that the majority of residents and crew can exercise the right of participation, decision-making and supervision in marine environmental management. Secondly, law enforcement can be strengthened, warnings or fines can be given according to the provisions of the Ministry of Transport, PRC on the maintenance and management of port infrastructure, and shipping companies can be constrained to reduce pollution. It can also reduce the cost of pollution reduction and promote active pollution reduction.

Corollary 2: When $C_2\beta+P\alpha>C_2$, E_2 is the evolutionary stability point of the model, and E_1 is the evolutionary instability point of the model. That is, if the average cost of negative pollution abatement is higher than that of active pollution abatement, then the government will choose imperfect supervision and the shipping company will choose active pollution abatement. This gives us inspiration that increasing administrative punishment can effectively restrain the phenomenon of negative pollution reduction by shipping companies. In addition, reducing the cost of reducing pollution is an effective way to promote shipping companies to actively reduce pollution.

Corollary 3: When $P+C_2\beta<C_2$ and $C_1<P$, E_3 is the evolutionary stability point of the model, and E_1 is the evolutionary instability point of the model. That is, if the cost of government supervision is lower than the penalty for negative pollution abatement behavior of shipping companies and the average cost of negative pollution abatement of shipping companies is lower than the cost of active pollution abatement, then the government will choose perfect supervision and shipping companies will choose negative pollution abatement. At this time, although the government conducted effective supervision, it could not promote the shipping company to evolve towards active pollution reduction, that is, the government supervision did not achieve actual results. To

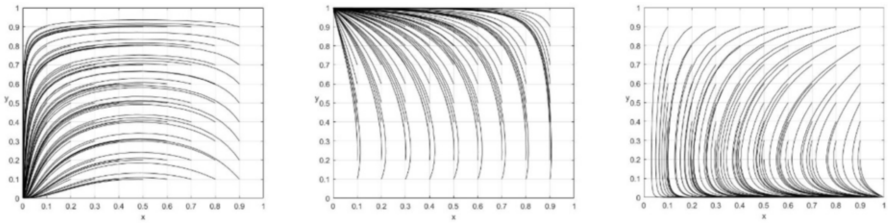
avoid the occurrence of this phenomenon, first of all, the government strengthens the supervision and inspection by increasing the administrative penalty and immediately orders the shipping company to correct the abnormal discharge and record the bad credit record. Secondly, the shipping company considers the operation cost and technical difficulty and correctly chooses the domestic sewage treatment process to ensure that the equipment runs in the best condition and gives full play to maximum efficiency.

3. Numerical Simulation Analysis of the Evolutionary Game Model

In order to analyze the dynamic game process more intuitively between the government and shipping companies, this paper uses Matlab2018b to conduct a numerical analysis of the game model, so as to verify the effectiveness of the evolutionary game model.

3.1. Simulation Experiment of the Equilibrium Point

Based on ESS points and conditions obtained in the model, three sets of values are assigned to the model, and the simulation results of the evolution of these three sets of values over time are shown in Figure 1.



(a) (b) (c)

Figure 1. System evolution diagram of stable equilibrium points: (a) $M_1 = 20, M_2 = 10, C_1 = 6, C_2 = 8, \alpha = 0.3, \beta = 0.6, T = 5, R = 10, P = 5$, in this case, when $C_1 > P$ and $C_2\beta + P\alpha < C_2$ is satisfied, the equilibrium point E_1 is verified; (b) $M_1 = 20, M_2 = 10, C_1 = 6, C_2 = 4, \alpha = 0.5, \beta = 0.6, T = 5, R = 10, P = 8$, in this case, when $C_2\beta + P\alpha > C_2$ is satisfied, the equilibrium point E_2 is verified; (c) $M_1 = 20, M_2 = 10, C_1 = 4, C_2 = 8, \alpha = 0.3, \beta = 0.3, T = 5, R = 10, P = 5$, in this case, when $P + C_2\beta < C_2$ and $C_1 < P$ is satisfied, the equilibrium point E_3 is verified.

3.2. Parameter Sensitivity Analysis

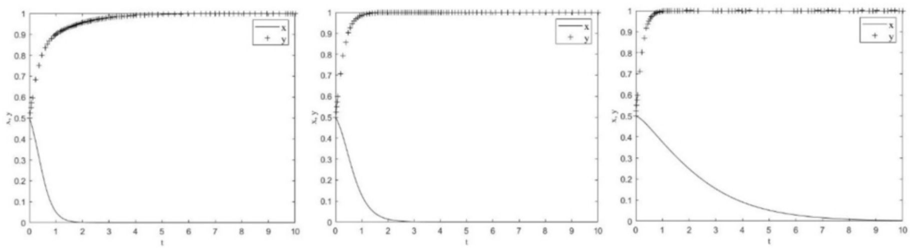
The influence of parameter change on the process and outcome of evolutionary games is further studied. Based on the above inference, set the array: $M_1 = 20, M_2 = 10, C_1 = 6, C_2 = 4, \alpha = 0.5, \beta = 0.6, T = 5, R = 10, P = 8$. Simulation analysis of the following parameters all meet the condition $C_2\beta + P\alpha > C_2$.

3.2.1. Sensitivity Analysis of Government Supervision Intensity

The government's supervision of shipping companies is set as 0.3, 0.6 and 0.9 respectively, and the influence of different levels of supervision is explored, as shown in Figure 2.

The conclusions are as follows: (a) It indicates that with the strengthening of the government's supervision of shipping companies, the government and shipping companies finally choose imperfect supervision and active governance as the final strategies. (b) It indicates that stronger government supervision accelerates the evolution of positive governance of shipping companies, while lower government supervision accelerates the government to reach a stable state.

It can be seen from the above that the intensity of government supervision has a positive effect on the positive governance of shipping companies. Therefore, in practice, the government should play the macro-role of overall planning and coordination, improve the relevant laws and regulations on the reception and discharge of domestic sewage from ships, guide other subjects to participate in the treatment of domestic sewage from ships, and provide financial subsidies and risk compensation for ships with domestic sewage infrastructure and equipped with domestic sewage pollution treatment equipment. Incentives such as material compensation shall be provided to the crew members and residents who provide information or other contributions to the treatment of domestic sewage in order to avoid the illegal discharge of domestic sewage by ships, or use scientific and technological means to strengthen supervision, such as the construction of Marine domestic sewage discharge monitoring and sewage storage tank level change record platform, through the Tianjin Port large passenger ship Marine domestic sewage discharge location, discharge time, discharge total, discharge rate and other monitoring records, to prevent shipping companies from taking negative treatment. It is believed that the above methods will be helpful to solve the problem of illegal discharge of domestic sewage from ships in Tianjin Port and Bohai Sea area.



(a) (b) (c)

Figure 2. The influence of different degrees of supervision: (a) $\alpha = 0.3$; (b) $\alpha = 0.6$; (c) $\alpha = 0.9$.

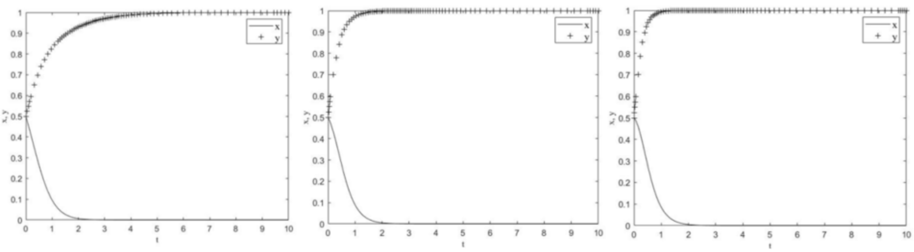
3.2.2. Sensitivity Analysis of Government Administrative Punishment

The administrative penalties imposed by the government on the negative governance behaviors of shipping companies are set as 5, 8, and 10 respectively. The influences of different levels of administrative penalties are explored, as shown in Figure 3.

The conclusions are as follows: (a) It shows that with the increase of administrative punishment for the negative governance behavior of shipping companies, the government and shipping companies finally choose imperfect supervision and positive governance as the final strategies. (b) It indicates that higher administrative penalties accelerate the evolution of positive governance of shipping companies, while lower administrative penalties accelerate the government to reach a stable state.

It can be seen that the government's administrative penalty on the negative governance behavior of shipping companies has a positive effect on the positive governance of shipping companies.

It can be seen from the above that the government's administrative punishment of the negative governance behavior of shipping companies has a positive effect on the positive governance of shipping companies. Therefore, in practice, the government can refine the penalty rules for the illegal discharge of domestic sewage from ships. For the cases of direct discharge of domestic sewage from ships in the port area, while equipped with domestic sewage treatment devices, it is suggested to raise the penalty standard to RMB 0.2 million-1 million. For the case of excessive discharge of domestic sewage from ships, according to the requirements of the "Discharge Control Standard of Water Pollutants from Ships" (GB3552-2018), the number and degree of the items exceeding the standard shall be adjusted. The larger the tonnage of ships, the higher the recommended penalty standard. At present, the object of administrative punishment is only the owner or operator of the shipping company. It is suggested that the captain and the crew responsible for the illegal discharge of the ship's domestic sewage should be punished separately, so as to prevent the crew from illegally discharging the ship's domestic sewage. By strengthening the administrative punishment of the government and enhancing the deterrent force, the negative governance behavior of the shipping company can be restrained.

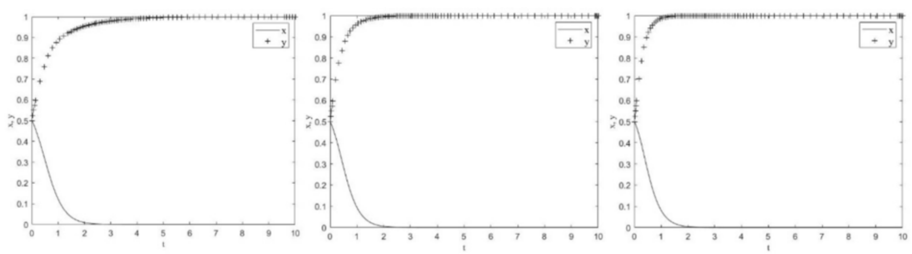


(a) (b) (c)

Figure 3. Influence of different degrees of administrative punishment: (a) P=5; (b) P=8; (c) P=10.

3.2.3. Sensitivity Analysis of Pollution Control Efforts of Shipping Companies

The pollution control efforts of shipping companies are set as 0.2, 0.5 and 0.8 respectively, and the influence of different pollution control efforts is discussed, as shown in Figure 4.



(a) (b) (c)

Figure 4. The influence of different degrees of pollution control: (a) $\beta = 0.2$; (b) ; (c) $\beta = 0.8$.

The conclusions are as follows: (a) It indicates that with the enhancement of pollution control efforts of shipping companies, the government and shipping companies finally choose imperfect supervision and active governance as the final strategies respectively. (b) It indicates that strong anti-pollution efforts of shipping companies accelerate the evolution of the active treatment of shipping companies, while low anti-pollution efforts of shipping companies accelerate the government to reach a stable state, that is, the anti-pollution efforts of shipping companies play a balancing role between the government and shipping companies. When the anti-pollution efforts are high, shipping companies play a dominant role in the evolutionary game and actively participate in sewage treatment. However, when the pollution control intensity is low, the evolution speed of the shipping company slows down, which is not conducive to sewage treatment.

It can be seen from the above that the pollution control efforts of shipping companies have a positive effect on the active governance of shipping companies. Therefore, in practice, the government tries to encourage shipping companies to upgrade the equipment of their ships with local financial subsidies, compensate the total amount of domestic sewage treated by tons, and increase the water-moving auxiliary receiving ships, so as to improve the domestic sewage receiving service system and improve the pollution control capacity of shipping companies; Shipping companies can take the initiative to cooperate with universities and other scientific research institutions, carry out technological innovation with the help of laboratory tests and dynamic simulation experiments, and jointly develop new sewage biochemical treatment devices, so as to extend the service life and reduce maintenance work (such as screen cleaning), so as to improve their own pollution control level. Through financial support provided by the government and technological upgrading provided by the shipping company, we can improve the pollution control capacity of the shipping company so as to realize the active treatment of domestic sewage.

4. Conclusion and Suggestion

4.1. Conclusion

Based on the existing research, this paper provides a more rational quantitative analysis for the treatment of domestic sewage pollution in the Tianjin Port area based on the evolutionary game model under the pollution control strategy of shipping companies. On the basis of conventional water resources purification treatment relying on the government as the main force, the two factors of government supervision intensity and shipping company governance participation enthusiasm are innovatively incorporated into the game model to analyze the behavior strategy of the game subject and its influencing factors and further simulate the specific impact of variable changes on the evolution path of the subject. The research shows that the government implements supervision or punishment, and the shipping company actively reduces pollution is the ideal stable state that can be realized by both sides of the game [19, 20]. With the increase of government supervision and enforcement, it is helpful for shipping companies to evolve towards active pollution abatement. When the supervision intensity changes from 0.3 to 0.9, the time for shipping companies to converge to active pollution abatement decreases to 1/4. The increase in government administrative penalties helps to positively encourage shipping companies to converge towards positive pollution reduction [21]. The comparison shows that the higher the government administrative penalty on shipping companies' negative governance behavior (8-10), the faster the positive pollution reduction will be realized, and the time for shipping companies to converge to positive pollution reduction will be reduced to about 3/4. At the same time, the anti-pollution intensity of shipping companies has a positive effect on the active treatment of shipping companies. When the anti-pollution intensity increases from 0.2 to 0.5 at the initial stage, the time of the shipping companies' convergence to the active mitigation decreases significantly, about half. However, with the continuous improvement of pollution control efforts, the evolution rate has no significant change. In this paper, by simulating the influence of variable changes on the behavioral strategy and evolutionary trajectory of the subject, it is found that increasing the intensity of government supervision (0.3-0.9) and increasing the administrative penalty (5-10) can accelerate the convergence speed of shipping companies to active pollution reduction, and the increase of shipping companies' pollution control ability (0.2-0.8) can also accelerate the convergence speed of shipping companies to active pollution reduction.

4.2. Suggestion

According to the above analysis and conclusion, this paper puts forward some policy suggestions to speed up the treatment of ship domestic sewage pollution in the Tianjin Port area.

First, strengthening government supervision. The government should take the lead to establish a supervisory department, improve the dynamic supervision mechanism of ship domestic sewage discharge, implement the management mode of the special person in charge of key areas, and establish and implement the supervision responsibility system; In addition, during the implementation of the supervision policy, reasonable standards should be set through field investigation to ensure the whole-time and whole-area monitoring of the discharge location, discharge time, total discharge and discharge rate of domestic sewage from large passenger ships in the Tianjin Port area, and the monitoring results should be recorded and publicized. A punishment mechanism should be set for the shipping companies that discharge excessive amounts of sewage, so as to prevent the shipping companies from taking negative treatment.

Second, the negative governance behavior of shipping companies should be punished. First of all, the penalty rules for the illegal discharge of marine domestic sewage are refined. Fines will be imposed on those who directly discharge marine domestic sewage or discharge marine domestic sewage exceeding standard within the port area while equipped with domestic sewage treatment devices. Secondly, the scope of punishment for the discharge of domestic sewage from ships shall be increased. Not only the operator of the shipping company but also the captain and the responsible crew of the ship who illegally discharges domestic sewage from the ship shall be punished separately.

Third, improving the ship company's own pollution control capacity. The government strives to use local finance to compensate shipping companies for the amount of domestic sewage they treat and to improve the service system for receiving domestic sewage. The government encourages shipping companies to carry out technological innovation and allocate more efficient, convenient, durable and low-cost equipment to help shipping companies save time and capital costs. At the same time, with the enhancement of public awareness of environmental protection, more people are willing to participate in the process of regional water pollution control. The public supervision and treatment feedback mechanism should be improved in time, and reward funds should be set up for reporting pollution of excessive discharge, so that more people (such as sailors and port city residents) can participate in the pollution control process of ship domestic sewage, so as to encourage shipping companies to play a more active role in reducing pollution and realize the gradual purification of Tianjin Port waters.

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