Simulation Analysis of Implementation Effects of Construction Waste Reduction Policies

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Abstract: The development of the construction industry generates construction waste which could contribute to environmental issues. Construction waste reduction management plays an important role in directly reducing emissions and solving the environmental pollution caused by construction waste. The limited rationality hypothesis and an evolutionary game model are used to construct a simulation model for the effects of environmental policies’ influences on the behavior of government and construction enterprises in construction waste reduction activities. Simulation results show that: (1) The government and enterprises evolve in the same direction under the sewage fees system or the subsidy system. The relationship between the initial ratio of the two sides and the position of the saddle point determines the evolution direction of the system. (2) The government could adjust the sewage fees rate, the penalty ratio, and the upper limit of construction waste emission to obtain a superior effect under the sewage fees system. As the subsidy system, the government could adjust the unit subsidy and the upper limit of construction waste emissions by enterprises. (3) The evolution times of the different systems are different. The time required to evolve to a stable state is shorter under the sewage fees system. Under the subsidy system, the time to evolve to a non-reduced state is longer, and the time to evolve to a reduced state is about the same as the time for the government to evolve to a checked state. The time required to evolve to the reduced state is about the same as the time required for the government to evolve to the checked state. This study develops an evolutionary game model between the government and construction enterprises in construction waste reduction activities. This study helps the government analyze the influence of various policies on enterprises’ reduction behaviors. The findings could help the government formulate appropriate policies to guide enterprises in waste reduction.

Keywords: construction waste decreasing; evolutionary game; sewage discharge fees; fine; numerical simulation

1. Introduction

Construction waste poses a great risk to the ecological environment due to its growing accumulation problem, and it has become a major obstacle for countries to achieve their sustainable development goals. Considering the importance of construction waste management in environmental sustainability, academia and industry have recognized the importance of reducing the yield of construction waste and improving the efficiency of treatment. The legal effect of the policy to promote the reduction and recycling of waste cannot be underestimated. Many studies show that suitable policies could effectively reduce construction waste emissions (Table 1).

The implementations of specific types of policies were analyzed in many studies. However, construction waste managers often face different policies in practice. Comparing the implementation effects of different policies could provide substantial support to managers. Simulation models are widely used in various social sciences and economic fields to analyze and compare the implementation effects of different policies. Di W. and Xu Y. et al.
have conducted simulation studies on garbage classification policies [5,6]. Evolutionary game models could be used to analyze the individual impact of different policies.

Table 1. The relevant policy studies.

| Type               | Conclusion                                         | Author                                      |
|--------------------|----------------------------------------------------|---------------------------------------------|
| Incentive policies | Improve the recycling rate of construction waste   | Shi et al. [1], 2020                        |
| Mandatory policies | Effectively reduce the dumping of illegal construction waste | Seror and Portnov [2], 2020                |
| Combined policies  | Improve the recycling rate of resources for construction waste | Andrea D M. [3], 2018                      |
| 3R principle       | Reduce production and increase utilization         | Turkyilmaz et al. [4], 2019                |

2. Materials and Methods

Large amounts of studies have shown that government regulations, related policies, and regulations have a significant impact on the reduction behavior of construction enterprises. The implementation of environmental protection measures could reduce the impact of waste generated by construction projects on the environment, and the government should carry out strict supervision to ensure the implementation of environmental protection measures [7]. The goal of construction companies is to maximize profits, and in the absence of government oversight, the financial factor is the main factor in the adoption of the company’s reduction behavior [8]. Managers of construction companies are more focused on the cost, schedule, and quality of projects that determine revenue, rather than waste management [9].

Both the sewage fee system and the subsidy system are economic incentive-based environmental policy instruments based on the Pigou and Coase theorem [10]. The sewage fee system adheres to the polluter-pays principle and imposes a tax on enterprises that emit construction waste. In this way, their operating costs will increase and reduce the cost of government regulation. To protect the environment and conserve resources, the subsidy system encourages enterprises to reduce pollution. Under this system, the enterprises which carry out construction waste reduction will receive financial subsidies (grants, loans, tax breaks, etc.) [11]. Both the subsidy system and the sewage fee system serve the same purpose of equalizing private benefits and private costs for enterprises, and social benefits and social costs, thereby achieving reductions in pollutant emissions and providing incentives for enterprises to adopt pollution control measures. At present, the subsidy system has been widely used in many countries. For example, Italy subsidizes enterprises that perform solid waste recycling and reuse. The government will give priority to companies that optimize construction processes or production procedures to reduce pollution. The German subsidies give priority to small and medium-sized enterprises that have financial difficulties due to pollution control. They also encourage them to introduce new technologies and equipment, optimize their production processes, change their development models, and carry out managerial and technological optimization and innovation.

Many scholars have compared the influence of economic policies and laws and regulations on construction waste reduction activities, respectively. It is affirmed that economic policies could promote the development of construction waste reduction activities. Osmani M. counted the amount of construction waste in the UK and found that the Construction Site Construction Waste Management Plan Regulations established by the government of that country in 2008 did not result in a significant reduction in construction waste emissions. Osmani M. also pointed out that the measures taken in the UK need to be combined with economic incentives to achieve the management of construction waste reduction [12]. Cooper argued that the government taxing enterprises on raw materials and giving them economic incentives have the same impact as the legal system on enterprises. Both of them enable construction enterprises to reduce construction waste emissions at the source and recognize the role of economic instruments in construction waste reduction activities [13]. Duran believed that market-based economic instruments are the best way to achieve construction waste reduction [14].
Some scholars have studied and analyzed the impact of sewage charges and subsidies on construction waste reduction activities. Poon C.S. pointed out that according to the principle of “polluter pays”, many countries charge sewage discharge fees in the forms of disposal fees, landfill fees, and other fees for construction waste that needs to be collected or treated. The purpose of sewage charges is to control the discharge of construction waste and realize the reduction management of construction waste [15]. Kularatne R. K. A. conducted a case analysis of solid waste management in Vavuniya City, Sri Lanka, and found that enterprises need a large cost to carry out reduction activities. Thus, many enterprises have stopped reduction activities due to insufficient capital investment in the early stage [16]. The government needs to give financial aid or reward to enterprises that carry out reduction activities to encourage them to continue with reduction activities. Nuria Calvo believes that construction waste reduction involves technological innovation and huge capital investment, so construction enterprises have no incentive to take the initiative to reduce construction waste. The government needs to use market-oriented environmental policy tools such as economic incentives or tax penalties on the basis of law to promote enterprises to reduce construction waste. However, government management departments need to choose appropriate policy tools according to the actual situation [17]. Zhang X summarized the successful experiences of foreign construction waste reduction, introduced and analyzed the three policy tools of the sewage discharge fee, emission reduction subsidy (including tax preference, credit preference, special subsidy, etc.), and landfill fee, and pointed out the specific implementation methods and problems that should be paid attention to [18]. Chen T believed that the current economic policy is infeasible. He also proposed that the government should reward enterprises with outstanding reduction effects for emission reductions, including exemption of pollutant discharge fees and subsidies [19]. According to Wang H, when formulating economic policies, the government needs to take into account the incentives for enterprises to reduce their reduction behavior, as well as the constraints on factors that are not conducive to reduction. That is, when the government gives economic incentives to enterprises to reduce their reduction, it also needs to increase the construction waste charging rate so as to force enterprises to actively seek ways to reduce the amount of construction waste [20].

Government subsidies are an effective policy tool to solve the problem of construction waste [21]. The government could incentivize construction enterprises to attach importance to reducing construction waste through simple economic subsidies. A suitable number of subsidies could allow enterprises to participate in construction waste management [22]. A step-by-step incentive policy is effective, and it makes employees become more active in waste reduction activities [23].

The mere fines or subsidies for the illegal discharging of construction waste have limited in increasing their impact on total resources. Penalties in a single policy that combines fees, fines, and subsidies offer the advantage of working better together [24].

Evolution and the theory of games describe and explain behavior well. Simulation modelling is often used in the analysis and comparison of the implementation effects of different policies. The model could describe policy formulation objectives and activities to predict implementation effects [25]. It is widely used in various social science and economic management studies [26], such as the relationship between policy system change and agricultural structure change [27] and the performance of policy decisions in water resource management plans [28].

In summary, many scholars have conducted in-depth research on construction waste management policies from the aspects of incentive policies, charging policies, and the combination of punishment and compensation, and have achieved fruitful results. However, these studies rarely address the comparison of incentives and penalties for waste reduction and the key factors in companies’ efforts to reduce waste. Due to institutional differences in emission reduction policies between different countries and the lack of a clear and consistent understanding, it is not possible to determine which policy works best under which conditions. In order to fill the gap in this research field, an evolutionary game model
is used to discuss the impact and key factors of the sewage charging system and subsidy system on the emission reduction behavior of governments and enterprises. It provides a theoretical basis for expanding the management and operation of waste reduction.

Based on the studies, the research gaps are as follows. First, few scholars have discussed the implementation effects and influencing factors of different policies. Based on the 5R theory, this paper compares the impact of the sewage charging system and the subsidy system on construction enterprises in construction waste reduction activities. Moreover, this paper discusses the triggers of construction enterprises’ emission reduction behavior, which provides a theoretical basis for policymakers to formulate strategies to promote environmental and economic sustainable development. Second, the evolutionary game model is used to quantify the relationship and influence the degree of related factors. It accurately analyzes the key starting point of enterprise reduction behavior and provides an intuitive macro description of the abstract problem domain. This study helps policymakers gain an in-depth understanding of the key behavioral factors that contribute to the reduction of construction firms and propose targeted strategies accordingly.

3. Results and Discussion

3.1. Building of the Model

The participants’ payment matrix is shown in Table 2.

Table 2. Government and corporate payment matrix.

| Strategy            | Inspection (x) | No Inspection (1 − x) |
|---------------------|----------------|-----------------------|
| Reduction (y)       | u1, v1         | u3, v3                |
| No Reduction (1 − y)| u2, v2         | u4, v4                |

Different strategies of government and enterprise payoff functions are shown in Equations (1)–(4):

\[ u_1 = rR - C_g + \theta Q_g, v_1 = (1 - r)R + R_c - C_c - \theta Q_c \]  
\[ u_2 = -L_g - C_g + \theta Q + k(Q - Q_g), v_2 = -L_c - \theta Q - k(Q - Q_g) \]  
\[ u_3 = \theta Q_g, v_3 = R_c - C_c - \theta Q_c \]  
\[ u_4 = -L_g + \theta Q_g, v_4 = -\theta Q_c \]  

3.2. Model Analysis

According to the payment matrix, three conditions are proposed.

Condition 1. \( rR - C_g > 0 \). If \( u_1 \leq u_3 \) is assumed, then (no inspection, no reduction) is the equilibrium point. If it does not meet the above conditions, thus \( u_1 > u_3 \) must be true, which means \( rR - C_g > 0 \).

Condition 2. \((1 - r)R + R_c - C_c > -L_c\). Through the same thinking way as condition 1, it could be found that \( v_1 > v_2 \). In other words, \((1 - r)R + R_c - C_c > -L_c\).

Condition 3. \( R_c < C_c \). Otherwise, the enterprise will independently reduce construction waste without government inspection, which is unlikely to happen in reality.

The expected returns of government investigations and non-investigation are \( E_g^1 \) and \( E_g^2 \), and the average government expectation is \((E_g)\), which are shown in Equations (5)–(7).

\[ E_g^1 = yu_1 + (1 - y) u_2 = y (rR - C_R + \theta Q_R) + (1 - y) \left[ -L_R - C_R + \theta Q + K(Q - Q_R) \right] \]  
\[ E_g^2 = yu_3 + (1 - y) u_4 = y \theta Q_g + (1 - y) (-L_g + \theta Q_g) \]  
\[ -(E_g) = xE_g^1 + (1 - x) E_g^2 \]
The replicated dynamic equation for the government is shown in Equation (8):

\[ F(x) = \frac{dx}{dt} = x[Ec_1 − (Ec)] = x(1 − x) [y[C_R − (θ + k)(Q − Q_g)] − [C_R − (θ + k)(Q − Q_g)] ] \] (8)

Solving the first derivative of \( F(x) \) with respect to \( x \), given by Equation (9):

\[ F'(x) = (1 − 2x) [y[C_R − (θ + k)(Q − Q_g)] − [C_R − (θ + k)(Q − Q_g)] ] \] (9)

If \( \frac{dx}{dt} = 0 \), then either \( x^* = 0, x^* = 1 \) or \( y^* = [C_R − (θ + k)(Q − Q_g)]/[rR − (θ + k)(Q − Q_g)] \). The scope of \( y^* \) will be discussed further as followed.

1. When \( x^* \leq 0 \), this situation follows condition 1, so \( rR > (θ + k)(Q − Q_g) \geq C_R \). Under it, \( y \) is constantly larger than \( y^* \), and the evolutionary stability strategy will be \( x = 1 \), which corresponds to government inspection;
2. When \( x^* \geq 1 \), this situation follows condition 1, so \( rR > C_R, (θ + k)(Q − Q_g) > rR > C_R \).
   Under it, \( y \) is constantly smaller than \( y^* \), and the evolutionary stability strategy will be \( x = 1 \), which corresponds to government inspection;
3. When \( y^*=0, 1 \), \( rR > C_R > (θ + k)(Q − Q_g). Under \), these situations, \( F(x) = 0 \), when \( y = y^* \). If \( y \neq y^* \), the stability strategy needs to meet the following conditions: \( F(x) = 0 \) and \( F'(x) < 0 \). If \( y > y^* \), then \( F'(0) > 0 \) and \( F'(1) < 0 \), and \( x = 1 \) is a stable strategy and the government will inspect companies. In the opposite way, when \( y < y^* \), then \( F'(0) < 0 \) and \( F'(1) > 0 \), and \( x = 0 \) results in a stable strategy and the government will not inspect companies.

The replicated dynamic equation of the enterprises is shown in Equations (10) and (11):

\[ F(y) = \frac{dy}{dt} = y[Ec_1 − (Ec)] = y(1 − y) [x[(1 − r)R + Lc + (θ + k)(Q − Q_g)] + (Rc − Cc)] \] (10)

\[ F'(y) = (1 − 2y)[x[(1 − r)R + Lc + (θ + k)(Q − Q_g)] + (Rc − Cc)] \] (11)

If \( \frac{dy}{dt} = 0 \), then either \( y^* = 0, y^* = 1 \), or \( x^* = (C_R − R_c)/(1 − r)R + Lc + (θ + k)(Q − Q_g) \). The scope of \( x^* \) will now be discussed. Condition 3 states that \( R_c < C_c \), which requires that \( x^* \) must be greater than 0. It creates two cases: \( 0 < x^* < 1 \) and \( x^* > 1 \).

1. When \( 0 < x^* < 1 \), \( C_c − R_c ≤ (1 − r)R + Lc + (θ + k)(Q − Q_g) \). When the probability of government inspection \( x = x^* \), \( F'(y) = 0 \). Then the income of the company will not change regardless of whether the amount of construction waste is decreased or not, so the enterprise will maintain the status quo. If \( x > x^* \), then \( F'(0) > 0 \) and \( F'(1) < 0 \), and the stability situation is \( y = 1 \). The enterprises will reduce construction waste because of this. When \( x < x^* \), \( F'(0) < 0 \), and \( F'(1) > 0 \), \( y = 0 \) is the stable strategy, and it is unlikely for companies to cut down construction waste emissions;
2. When \( x^* > 1 \), \( C_c − R_c > (1 − r)R + Lc + (θ + k)(Q − Q_g) \), which is amount to \( (1 − r)R + R_c − C_c + Lc + (θ + k)(Q − Q_g) < 0 \). However, based on condition 2, \( (1 − r)R + R_c − C_c + Lc > 0 \) and the enterprise will pay higher sewage prices and fines. It means \( (θ + k)(Q − Q_g) < 0 \), which is impractical. Thus, \( x^* > 1 \) is impossible and the result must be \( 0 < x^* < 1 \);
3. When \( [C_R − (θ + k)(Q − Q_g)]/[rR − (θ + k)(Q − Q_g)] ≤ 0 \) or \( [C_R − (θ + k)(Q − Q_g)]/[rR − (θ + k)(Q − Q_g)] ≥ 1 \), the system has four replicated dynamic stable points. The stable point is \( D(1, 1) \).

When \( 0 < [C_R − (θ + k)(Q − Q_g)]/[rR − (θ + k)(Q − Q_g)] < 1 \), the system has five replicated dynamic stable points, among which the stable points are \( A(0, 0) \) and \( D(1, 1) \), and the saddle point is \( E(x^*, y^*) \). The evolutionary system phase diagram is shown in Figure 1.

Conclusion 1. Governments and companies are evolving in the same direction. In reality, the government does not inspect companies, and companies rarely reduce emissions (Figure 2).
with the following parameter values: $R_g$, the government’s societal interest, $rR_c$, and the sum of the sewage prices and fines, $(\theta + k) (Q - Q_g)$. Since $R_c$, $C_c$, and $L_c$ barely change, $(1 - r) R$ and $(\theta + k) (Q - Q_g)$ are government-relevant. Regardless of whether or not the government inspects companies for construction waste emissions, companies must pay sewage prices and have to pay fines for excessive construction waste emissions during government inspections. It is more feasible to increase the sewage prices and fines, compared with lowering inspection costs. Therefore, studying the influence of changing both the sewage price rate and the fine ratio together on governments and companies could stress appropriate rates. It also contributes to the publicity of policies.

### 3.3. Evolutionary Simulations

For further verification of the model and conclusions, and looking for the influence of changes in construction waste charging standards on the behaviors of companies, the evolution process was simulated. This will analyze the impact of the combined discharge rate and the proportion of the penalty on evolutionary results. The simulation is studied with the following parameter values: $R_c = $4412; $C_c = $7353; $R = $29,412; $r = 0.5; L_c = $4412; $(Q - Q_g) = 50(t); C_g = $1471; $K = 103($/t); $\theta = 44($/t); $(\theta + k) (Q - Q_g) = $7353, and the initial point of system evolution $(x_0, y_0) = (0.3, 0.3)$.
Two cases are assumed for discussion.

Case 1. When \( rR > C_g > (\theta + k) (Q - Q_g) \), or when \( (\theta + k) < C_g / (Q - Q_g) \), the system may evolve to \((0, 0)\) or \((1, 1)\). The direction of evolution depends on the initial ratios \( x_0 \) and \( y_0 \) of government inspection and enterprise reduction. As can be seen from Figure 3, the evolution direction of the government and enterprises is the same. Both may cooperate and evolve to \((1, 1)\) or choose not to cooperate and evolve to \((0, 0)\). The evolutionary direction of the system is related to the initial values of \( x_0 \) and \( y_0 \). Using the positions of \( x_0 \) and \( y_0 \) with the data presented in Figure 1, the evolution direction of the system is obtained. Calculations show that when \( (\theta + k) = 0.02 \), \((\theta + k) (Q - Q_g) = 1\), and \( x^* = 1/7 \), \( y^* = 5/9 \), while \( x_0 = 0.3 \) and \( y_0 = 0.3 \). Figure 1 shows that the point \((x_0, y_0) = (0.3, 0.3)\) falls in Zone III, and the system evolves to \((0, 0)\). The result is that the government does not inspect, and enterprises do not reduce construction waste. When \( (\theta + k) = 0.04, 0.06, 0.08, \) and \( 0.1 \), the point \((x_0, y_0) = (0.3, 0.3)\) falls in Zone II and the system evolves to \((1, 1)\). The result is that the government inspects companies, and the enterprises reduce their construction waste.

The sum of the sewage price rate and fine ratio could be understood as a kind of punitive measure for companies. When the sum is low, companies that do not follow policy have been punished. This will not constrain enterprises for a long time. Then, the companies will adopt construction waste-decreasing measures. However, the government’s weak punishments may show that the discharge of construction waste is not paid attention to by the government, leading to the final evolution where the government does not inspect, and enterprises do not reduce. When the sum is in a reasonable range, it will put some constraints on companies. The greater the sum, the faster the two parts evolve to cooperate. This means that the government is paying more attention to the construction waste reduction problem, and the government will evolve toward the inspection. This implies that there will also be greater punishment for non-waste-reducing enterprises. Finally, the system will evolve to government inspection and enterprise reduction of construction waste. Figure 4 shows that the inspection probability of the government will be reduced if the sum is too low, and this would gradually evolve to no government inspection. Thus, the value of \( (\theta + k) \) has little effect on government behavior. The fees and penalties are determined arbitrarily now, and it is necessary to determine a reasonable rate for them.

Figure 5 shows that enterprises will not evolve to construction waste reduction in a short time if the sum of the sewage rate and the fine ratio are too low. The sum of sewage rate and penalties play a binding role in enterprises, but the low rate has caused the government to lose motivation for inspection. As a result, the government evolves towards no inspection. Figure 5 shows that the value of \( (\theta + k) \) exerts little impact on the behavior of enterprises, once it makes the enterprises evolve toward construction
waste reduction. Changes in the sum could exert an influence on enterprises’ construction waste-reducing activities.

![Figure 4](image)

**Figure 4.** The influence of \((\theta + k)\) change on the probability of government inspections, \(x\).

![Figure 5](image)

**Figure 5.** The influence of \((\theta + k)\) change on the probability of enterprise construction waste emissions reduction, \(y\).

In conclusion, changes in the sum have an impact on the evolution direction of both governments and enterprises when \(rR > C_g > (\theta + k) (Q - Q_g)\).

Case 2. When \((\theta + k) (Q - Q_g) > rR > C_g\) or \(rR > (\theta + k) (Q - Q_g) > C_g\), which is the same as when \((\theta + k) > C_g / (Q - Q_g)\), the stable point is only \((1, 1)\).

Figure 6 shows that the system will finally evolve. Figures 7 and 8 show that changes in the sum of the sewage charge rate and fine ratio have no obvious effect on the evolution direction of the government and enterprises, and there is only a small gap between the two parties in their evolution toward cooperation. It could be concluded that the change in the sum has no effect on both sides.

![Figure 6](image)

**Figure 6.** The influence of \((\theta + k)\) changes on the evolution result of the game on both sides of the game.
Case 2. When \((θ + k)(Q − Q_g) > r_R > C_g\) or \(r_R > (θ + k)(Q − Q_g) > C_g\), the stable point is only \((1,1)\).

3.4. Discussion

(1) Under different policies, the evolution process is different.

The government should formulate relevant policies according to the stage of the cities to guide and promote waste emission reductions [25], instead of blindly imitating advanced cities and directly formulating incentive or mandatory policies. The speed of the evolution of enterprises is higher under the sewage fee system. It shows that enterprises learn faster and adjust faster under the sewage fee system, and the effect of this system on enterprise behaviors is more obvious. When the government carries out the inspection, enterprises could choose the reduction strategy quickly, so as to achieve the reduction target of construction waste in a relatively short time. However, the fast learning and adjustment speed of enterprises also has problems: when the government does not carry out inspections, enterprises could also adjust their strategies quickly. That means that enterprises could easily reach a stable state without reduction as soon as the government relaxes its inspection on enterprises. This requires the government to constantly increase the initial proportion of inspections under the sewage fee system and observe the behavior of enterprises, then make timely adjustments. The system of the sewage fee puts forward high requirements for the government’s inspection ability and monitoring ability. Under the subsidy system, governments have more time and opportunities to modify existing policies. Even if the proportion of the government’s inspection is too low and leads to the evolution of enterprises in the direction of non-reduction, the government has enough time to detect this trend and make adjustment measures. It provides a long time for the government to revise measures and guide enterprises to take reduction activities. When the government and enterprises evolve in the direction of “inspection and reduction”, they have roughly the same evolutionary path and evolution time. When the government is not sure about the capacity of inspection and monitoring, it could use the subsidy system.

(2) There are differences in the influence of relevant factors on firms’ emission reduction behavior under different policies.
The main reason for the poor implementation of construction waste reduction policies is that the policymakers ignore the influence of relevant factors on the participants [26,27] and the profit-seeking behavior of the participants [28]. Under the sewage fee system, the government could find the most influential factors and adjust them by adjusting fines, the ratio of sewage fees to fines, the rate of sewage fees, and the cap on construction waste emissions, so that the game system could evolve in the direction of “check and reduce”. Under the subsidy system, by adjusting the subsidies given to enterprises and adjusting the cap on their construction waste emissions, the desired effect is not achieved, and the system even evolves in the opposite direction. Increasing the initial inspection ratio by the government is the most effective and safest method, which could promote the construction waste reduction activities of enterprises, and thus achieve the goal of reduction. When enterprises evolve towards construction waste reduction, the government does not adjust the subsidies to enterprises and the cap on construction waste emissions. Because their changes are likely to be counterproductive, they will not achieve the desired “check and reduce” strategy goal.

(3) The reduction policy should be formed based on the development stage of urban reduction.

The sewage fee system is applicable to the development stage of construction waste reduction management. In the development stage of construction waste reduction management, the government’s economic incentive policies have taken initial shape, and the market mechanism is relatively mature. Therefore, the government needs to restrict the emission behavior of enterprises through economic means [29]. The government could punish enterprises that do not carry out waste-reduction activities. Then it will increase the excess emission cost of enterprises to encourage them to carry out construction waste reduction activities. In the development stage, the government adopts the regulation fee standard to restrain the emission behavior of enterprises, and the difficulty of work is reduced [30]. The sewage fee system has the nature of punishment, so it is suitable for the development stage of construction waste reduction management. The government could take the following measures to promote enterprises to reduce emissions: First, the government needs to grasp the information of enterprises; second, entrusting a third party to check construction waste discharge; third, we will moderately increase the amount of pollutant discharge fees and fines. The subsidy system applies to the degree stage of construction waste reduction management. When the construction waste reduction management mature period, the sewage fee system has played a deterrent effect. The construction of reduction technologies of the enterprise has become more reasonable, and the management level has been greatly improved. The recycling technology of construction waste and the production technology of recycled building materials have been preliminarily developed. The industrial chain of construction waste reduction has been preliminarily formed [31], instead of focusing on the environmental damage caused by construction waste. Instead, the construction waste reduction industry is regarded as a new industry. The government will no longer punish enterprises that discharge excessive construction waste but invest in enterprises that could achieve reduction and encourage enterprises to carry out technological innovation in the production and application of recycled building materials so that the construction waste reduction industry will become an emerging economic growth point. Therefore, the government needs to adopt subsidy policies to invest in enterprises that could achieve the reduction target of construction waste. It could stimulate the enthusiasm of enterprises to take the initiative to carry out reduction activities. The government could take the following measures to promote emission reduction of enterprises: first, guide construction enterprises to transform into high-tech enterprises; second, take the construction waste reduction of enterprises as the basis for emission reduction subsidies; third, engage in a strict inspection of the emission behavior of enterprises.

4. Conclusions

This study uses the evolutionary game and simulation method to study the incentive effect and influencing factors of the sewage fee system and subsidy system on emission
reductions of construction enterprises. The research results show that no matter what system, the evolution direction of governments and enterprises is the same: they either cooperate with each other and actively respond to the reduction policy, or they do not cooperate and passively respond to the policy. Under the sewage fee system, the rate of sewage discharge fee, the penalty rate, and the upper limit of construction waste discharge have important impacts on the enterprises’ construction waste reduction activities.

Enterprises learn and adjust quickly. They could make timely changes according to the government’s behavior. The government could use this feature to achieve the reduction target by adjusting the influencing factors. The government should also keep an eye on changes in corporate behaviors to prevent the phenomenon of “no inspection, no reduction”. The government could guide enterprises to reduce construction waste by raising the sewage fee rate or penalty rate and lowering the ceiling of construction waste discharge. Under the subsidy system, the subsidy per unit and the upper limit of construction waste emissions have important impacts on the enterprises’ construction waste reduction activities. Increasing the rate of per-unit subsidy and lowering the ceiling of construction waste emissions could make enterprises evolve in the direction of reduction. However, it will also make the government evolve to the direction of no inspection and finally lead to the uncertain evolutionary results of government and enterprises. Therefore, it is necessary to suitably adjust these two influencing factors.

The government could formulate economic incentive policies for reducing construction waste emissions according to the different stages of urban development. This study provides a new method to study the policy choices of environmental governance. This method could be applied to the policy choices of wastewater treatment, medical waste treatment, and other fields.

Although this study could be helpful for the development of construction waste reduction policies, there are still some limitations. This study does not consider the influence of exogenous factors, such as economic development, political systems, and cultural backgrounds. Therefore, the mode of combining policy instruments with economic instruments and the effect of policy implementation on more behavioral agents will be the focus of future research.

Author Contributions: Conceptualization, methodology, validation, analysis, funding acquisition, Q.W.; writing—original draft preparation, writing—review and editing, S.L.; writing—review and editing, Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The Research on the Vulnerability and Governance Mechanism of Urban Waste Resource Symbiosis Network Based on CAS Theory, grant number 18YJC790167. This research was also funded by the Research on the impact of fiscal policy on the participation of enterprises in the ecological governance of the Liao River Basin, grant number Injc202029.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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