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Behavior Choice Mechanisms and Tax Incentive Mechanisms in the Game of Construction Safety

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Abstract: The violation behavior of construction workers is an important cause of construction accidents. To reduce the violations of construction workers and to stimulate the supervision behavior of local governments and construction enterprises, an evolutionary game model is constructed in this paper. Then, the behavior choice mechanism of each player is analyzed. Finally, an incentive effect analysis method is put forward, and the incentive effects of different tax incentive mechanisms are analyzed. This research finds that only when the safety punishment imposed on construction workers is large enough does the supervision behavior of local governments and construction enterprises encourage construction workers to choose not to violate the regulation. Increasing the tax rate of a construction enterprise in the case of accidents can encourage the construction enterprise to supervise, but it inhibits the supervision behavior of the local government. A numerical simulation verifies the effectiveness of the incentive effect analysis method, which provides a new method for the incentive effect analysis of incentive mechanisms.

Keywords: construction safety; evolutionary game; behavior choice; tax incentive mechanism

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1. Introduction

The construction industry is a high-risk industry. It employs approximately 7% of the global workforce, yet it is responsible for 30–40% of fatalities [1]. Construction safety has become a problem of great concern [2–11]. Improving the construction safety level requires the joint efforts of local governments, construction enterprises, and construction workers.

Safety violations by workers have been widely proven to be a dominant cause of construction accidents [12]. For a construction worker, there are two behaviors to choose from: one is not to violate the regulation, and the other is to violate the regulation. A construction enterprise can supervise all operation processes of all construction workers, but this comes at a high cost. The construction enterprise often supervises part of the operation process of some construction workers. Thus, for a construction worker, the construction enterprise may or may not supervise them. For the local government, safety supervision is an important means to promote construction safety [13]. Within a certain period of time, the local government can supervise all construction enterprises in the area under its jurisdiction, or it can select to supervise some construction enterprises. Because local governments often face problems such as a lack of human resources in safety supervision [14,15], they usually choose to supervise some construction enterprises. For a construction enterprise, the local government may or may not supervise them.

If a local government supervises a construction enterprise, it will affect the impact of the supervision behavior of the construction enterprise on the construction workers. If a construction enterprise supervises construction workers, it will affect the behavior choice of the construction workers. If a construction worker violates the regulation, it will affect the behavior choice of the construction enterprise, and then this will affect the behavior choice of the local government. There is a behavioral interaction between these aspects. The behavior interaction process is also a behavior game process. In the game process, the information between players is asymmetric. Players cannot fully mast the strategies of other players. This easily results in players engaging in speculative psychology. Speculative psychology easily leads to violations, thus affecting construction safety. In addition, players are often not completely rational. They often dynamically adjust their strategies based on observing and learning the strategies of other players. Mastering the behavior choice mechanisms of game players in this situation and designing an incentive mechanism according to the players' behavior choice mechanisms are conducive to improvements in the construction safety level.

To analyze the safety behavior of governments and enterprises, Hausken constructed a game model and found that, if a government can reduce the safety cost of a company in some way or increase the negative impact of disasters on the company, the safety efforts of enterprises will increase [16,17]. Yang used the Stackelberg game model to analyze the safety level decision of enterprises in a supply chain and found that revenue-sharing contracts and cost-sharing contracts can improve the work safety level [18].

The above studies assume that the game players are rational and that the game is static and is only played once. However, in practice, the game players are not completely rational, and the game process is dynamic. Therefore, it is necessary to study the behavior of the players under the condition of incomplete rationality. Since the evolutionary game theory deems that game players will learn in the game and seek a relatively good strategy using trial and error instead of modelling people into super rational game players [19], it has been widely used in coal mine safety research [19–21], food safety research [22–24], and other fields.

In the field of construction safety, Gong constructed an evolutionary game model between a government and two construction enterprises and found that the dynamic supervision mechanism can improve safety supervision efficiency [25]. Pi constructed an evolutionary game model between a government and construction contractors and found that the safety information system helps to reduce the safety supervision cost of the government and the safety cost of the contractor [26]. Guo analyzed the game behaviors of a government, construction enterprises, and construction workers by establishing an evolutionary game model [27].

The above studies, which are based on the evolutionary game theory, mainly analyzed the stability of the evolutionary game system and put forward the reward and punishment mechanisms according to the influence of the model parameters on the evolution process. However, under what conditions will a player choose one behavior over another? How can incentive mechanisms be designed according to the behavior choice mechanisms of players? These questions remain to be answered. To master the behavior choice mechanisms of game players and to design incentive mechanisms according to the behavior choice mechanisms of game players, this paper carries out the following work:

(1) An evolutionary game model consisting of a local government, a construction enterprise, and a construction worker is constructed.
(2) The behavior choice mechanisms of the local government, the construction enterprise, and the construction worker are analyzed.
(3) An incentive effect analysis method of incentive mechanisms is designed, and the incentive effect of different tax incentive mechanisms is analyzed.

The remainder of the research is structured as follows. The second section establishes the evolutionary game model. The third section analyzes the behavior choice mechanisms of a local government, a construction enterprise, and a construction worker. The fourth section designs an incentive effect analysis method of incentive mechanisms and analyzes the incentive effects of different tax incentive mechanisms. The fifth section analyzes the influence of tax incentive mechanisms on behavior evolution. The sixth section presents the conclusions.

2. Evolutionary Game Model

2.1. Model Symbols

The model symbols are shown in Table 1.

Table 1. Model symbols.

Model Symbols	Meaning
x	Probability of the local government choosing to supervise.
y	Probability of the construction enterprise choosing to supervise.
z	Probability of the construction worker choosing not to violate the regulation.
C_G	Supervision cost of the local government.
C_E	Supervision cost of the construction enterprise.
C_{W1}	Cost of the construction worker choosing not to violate the regulation.
C_{W2}	Cost of the construction worker choosing to violate the regulation.
I	Income of the construction enterprise, excluding the supervision cost and the salary of the construction worker.
W	Salary of the construction worker.
r	Tax rate.
d	Proportion of tax allocated to the local government.
P_{GE}	Punishment imposed by the local government on the construction enterprise.
P_{EW}	Punishment imposed by the construction enterprise on the construction worker.
L_G	Accident loss expectation of the local government.
L_E	Accident loss expectation of the construction enterprise.
L_W	Accident loss expectation of the construction worker.

2.2. Model Assumptions

Assumption 1: The game players are a local government, a construction enterprise, and a construction worker. The game players all have limited rationality. The local government can choose whether to supervise the construction enterprise. The probability of the local government choosing to supervise is x, and the probability of it choosing not to supervise is $1 - x$, where $0 \leq x \leq 1$. The construction enterprise can choose whether to supervise the construction worker. The probability of the construction enterprise choosing to supervise is y, and the probability of it choosing not to supervise is $1 - y$, where $0 \leq y \leq 1$. The construction worker can choose to violate the regulation or not. The probability of the construction worker choosing not to violate the regulation is z, and the probability of the construction worker choosing to violate the regulation is $1 - z$, where $0 \leq z \leq 1$.

Assumption 2: When the local government chooses to supervise, the supervision cost of the government is C_G, and the local government can identify violations. When the local government chooses not to supervise, the supervision cost of the government is 0, and the local government cannot identify violations. When the construction enterprise chooses to supervise, the supervision cost of the construction enterprise is C_E, and the construction enterprise can identify violations earlier than the government. When the construction enterprise chooses not to supervise, the supervision cost of the construction enterprise is 0, and the construction enterprise cannot identify violations. When the construction worker chooses not to violate the regulation, the cost of the construction worker is C_{W1}. When the construction worker chooses to violate the regulation, the cost is C_{W2}.

Assumption 3: When the local government and the construction enterprise choose to supervise and the construction worker chooses not to violate the regulation, the income of the construction worker is $W - C_{W1}$, the income of the construction enterprise is $(1 - r)(I - W - C_E)$, and the income of the local government is $dr(I - W - C_E) - C_G$, where W is the salary of the construction worker; r is the tax rate; I is the income of the construction enterprise, excluding the supervision cost and the salary of the construction worker; d is the proportion of tax allocated to the local government; and $I - W - C_E$ is the taxable income of the construction enterprise. Taxable income is the portion of an enterprise's gross income used to calculate how much tax enterprises owe in a given tax year. It can be described broadly as adjusted gross income (AGI) minus allowable itemized or standard deductions. The items allowed to be deducted from the income refer to the costs, expenses, and losses related to the taxpayer's income.

Assumption 4: When the construction worker chooses to violate the regulation and their behavior is observed by the construction enterprise, the construction enterprise urges the construction worker to change their behavior in time through punishment. In this case, the income of the construction worker is $W - P_{EW} - C_{W1}$, where P_{EW} refers to the punishment imposed by the construction enterprise on the construction worker. The reason for the cost being C_{W1} rather than C_{W2} is that the construction worker will correct their violation in time after their violation is observed. If the construction worker's violation is not observed by the construction enterprise but rather by the local government, the construction enterprise is punished by the local government. In this case, the construction enterprise urges the construction worker to change their behavior in time through punishment. The income of the construction enterprise is $(1-r)(I - W + P_{EW} - C_E) - P_{GE}$, where P_{GE} refers to the punishment imposed by the local government on the construction enterprise. When the construction enterprise chooses not to supervise and the construction worker's behavior is observed by the local government, the local government urges the construction enterprise to change its behavior in time through punishment.

Assumption 5: When the construction worker chooses not to violate the regulation, the probability of an accident occurring is very small, and the expectation of the accident loss can be ignored. If the construction worker chooses to violate the regulation and their behavior is not observed by the construction enterprise or the local government, accidents may occur. In this case, the loss expectation of the construction worker is L_W, the loss expectation of the construction enterprise is L_E, and the loss expectation of the local government is L_G.

According to the model assumptions, the income of the local government, the income of the construction enterprise, and the income of the construction worker under different game strategies are shown in Table 2.

Table 2. Income of game players under different game strategies.

Local Government's Strategy, Construction Enterprise's Strategy, Construction Worker's Strategy	Local Government's Income, Construction Enterprise's Income, Construction Worker's Income
choosing to supervise, choosing to supervise, choosing not to violate the regulation	$\{dr(I - W - C_E) - C_G, (1-r)(I - W - C_E), W - C_{W1}\}$
choosing to supervise, choosing to supervise, choosing to violate the regulation	$\{dr(I - W + P_{EW} - C_E) - C_G, (1-r)(I - W + P_{EW} - C_E), W - P_{EW} - C_{W1}\}$
choosing to supervise, choosing not to supervise, choosing not to violate the regulation	$\{dr(I - W - C_E) + P_{GE} - C_G, (1-r)(I - W - C_E) - P_{GE}, W - C_{W1}\}$
choosing to supervise, choosing not to supervise, choosing to violate the regulation	$\{dr(I - W + P_{EW} - C_E) + P_{GE} - C_G, (1-r)(I - W + P_{EW} - C_E) - P_{GE}, W - P_{EW} - C_{W1}\}$
choosing not to supervise, choosing to supervise, choosing not to violate the regulation	$\{dr(I - W - C_E), (1-r)(I - W - C_E), W - C_{W1}\}$
choosing not to supervise, choosing to supervise, choosing to violate the regulation	$\{dr(I - W + P_{EW} - C_E), (1-r)(I - W + P_{EW} - C_E), W - P_{EW} - C_{W1}\}$
choosing not to supervise, choosing not to supervise, choosing not to violate the regulation	$\{dr(I - W), (1-r)(I - W), W - C_{W1}\}$
choosing not to supervise, choosing not to supervise, choosing to violate the regulation	$\{dr(I - W - L_E) - L_G, (1-r)(I - W - L_E), W - C_{W2} - L_W\}$

2.3. Model Construction

The replicator equation is the first game dynamic studied in connection with the evolutionary game theory [28]. This equation is a dynamic differential equation that describes the change process of the proportion of a strategy selected in a group. When the income from a strategy is higher than the average income of the group, this strategy will be imitated, learned, and developed in the group. The proportion of individuals who choose this strategy is directly proportional to the extent that the income from the strategy exceeds the average income. We can regard the local government as a group, regard the construction enterprise as a group, and regard the construction worker as a group. Then, the replicator equation can be used to study the game behavior between them. Similar treatment methods are also used in the relevant literature. For example, Liu uses the replicator equation to analyze the game between a coal mine regulator and two coal mining enterprises [29]. According to the replication dynamic equation in the evolutionary game theory [30–35], we can construct a tripartite evolutionary game model composed of a local government, a construction enterprise, and a construction worker. The model construction process is as follows:

When the local government chooses to supervise, the income expectation of the local government is $u_1 = [dr(I-W-C_E)-C_G]yz + [dr(I-W+P_{EW}-C_E)-C_G]y(1-z) + [dr(I-W-C_E)+P_{GE}-C_G](1-y)z + [dr(I-W+P_{EW}-C_E)+P_{GE}-C_G](1-y)(1-z) = dr(I-W-C_E)-C_G+drP_{EW}(1-z)+P_{GE}(1-y)$. Similarly, when the local government chooses not to supervise, the income expectation of the local government is $u_2 = dr(I-W)-drC_Ey+drP_{EW}y(1-z)-drL_E(1-y)(1-z)-L_G(1-y)(1-z)$. The average income is $\overline{u} = xu_1+(1-x)u_2$.

When the construction enterprise chooses to supervise, the income expectation of the construction enterprise is $v_1 = (1-r)(I-W-C_E)+(1-r)P_{EW}(1-z)$. When the construction enterprise chooses not to supervise, the income expectation of the construction enterprise is $v_2 = -(1-r)C_Ex+(1-r)(I-W)-P_{GE}x+(1-r)P_{EW}x(1-z)-(1-r)L_E(1-x)(1-z)$. The average income is $\overline{v} = yv_1+(1-y)v_2$.

When the construction worker chooses not to violate the regulation, the income expectation of the construction worker is $w_1 = W-C_{W1}$. When the construction worker chooses to violate the regulation, the income expectation of the construction worker is $w_2 = W-P_{EW}x-P_{EW}(1-x)y-C_{W1}x-C_{W1}(1-x)y-(C_{W2}+L_W)(1-x)(1-y)$. The average income is $\overline{w} = zw_1+(1-z)w_2$.

According to the income of the local government, the income of the construction enterprise, and the income of the construction worker, the following evolutionary game model can be obtained:

$$\begin{cases} \frac{dx}{dt} = x(u_1-\overline{u}) = x(1-x)(u_1-u_2) \\ \frac{dy}{dt} = y(v_1-\overline{v}) = y(1-y)(v_1-v_2) \\ \frac{dz}{dt} = z(w_1-\overline{w}) = z(1-z)(w_1-w_2) \end{cases} \tag{1}$$

where $u_1-u_2 = G_1(y,z) = -C_G+(P_{GE}-drC_E)(1-y)+(drP_{EW}+drL_E+L_G)(1-y)(1-z)$, $v_1-v_2 = E_1(x,z) = -(1-r)C_E(1-x)+P_{GE}x+(1-r)(P_{EW}+L_E)(1-x)(1-z)$, and $w_1-w_2 = W_1(x,y) = (L_W+C_{W2}-C_{W1})(1-x)(1-y)+[x+(1-x)y]P_{EW}$.

According to $dx/dt = 0$, $dy/dt = 0$, and $dz/dt = 0$, the equilibrium point of the evolutionary game model can be obtained as follows: $(1,1,1)$, $(1,1,0)$, $(1,0,1)$, $(1,0,0)$, $(0,1,1)$, $(0,1,0)$, $(0,0,1)$, $(0,0,0)$. The stability of the equilibrium point can be analyzed using the Jacobi matrix [30–35]. The Jacobi matrix corresponding to the evolutionary game model is as follows:

$$J = \begin{bmatrix} (1-2x)G_1(y,z) & x(1-x)\frac{\partial G_1(y,z)}{\partial y} & x(1-x)\frac{\partial G_1(y,z)}{\partial z} \\ y(1-y)\frac{\partial E_1(x,z)}{\partial x} & (1-2y)E_1(x,z) & y(1-y)\frac{\partial E_1(x,z)}{\partial z} \\ z(1-z)\frac{\partial W_1(x,y)}{\partial x} & z(1-z)\frac{\partial W_1(x,y)}{\partial y} & (1-2z)W_1(x,y) \end{bmatrix} \tag{2}$$

The eigenvalues of the Jacobi matrix corresponding to each equilibrium point are shown in Table 3.

Table 3. Eigenvalues of the Jacobi matrix.

Equilibrium Point	λ_1	λ_2	λ_3
$(1,1,1)$	C_G	$-P_{GE}$	$-P_{EW}$
$(1,1,0)$	C_G	$-P_{GE}$	P_{EW}
$(1,0,1)$	$C_G + drC_E - P_{GE}$	P_{GE}	$-P_{EW}$
$(1,0,0)$	$C_G + dr(C_E - P_{EW} - L_E) - P_{GE} - L_G$	P_{GE}	P_{EW}
$(0,1,1)$	$-C_G$	$(1-r)C_E$	$-P_{EW}$
$(0,1,0)$	$-C_G$	$(1-r)(C_E - P_{EW} - L_E)$	P_{EW}
$(0,0,1)$	$P_{GE} - C_G - drC_E$	$-(1-r)C_E$	$C_{W1} - L_W - C_{W2}$
$(0,0,0)$	$P_{GE} + L_G - C_G - dr(C_E - P_{EW} - L_E)$	$(1-r)(P_{EW} + L_E - C_E)$	$L_W + C_{W2} - C_{W1}$

For an equilibrium point, under the conditions of $\lambda_1 < 0$, $\lambda_2 < 0$, and $\lambda_3 < 0$, it is an evolutionary stability strategy (ESS). Otherwise, it is not an evolutionary stability strategy [30–35].

According to Table 3, when $C_{W1} < L_W + C_{W2}$ and $P_{GE} < C_G + drC_E$, $(0,0,1)$ is an evolutionary stability strategy. $(0,0,0)$ is an evolutionary stability strategy under the condition of $C_G + dr(C_E - P_{EW} - L_E) > P_{GE} + L_G$, $C_E > P_{EW} + L_E$, and $C_{W1} > L_W + C_{W2}$. Other equilibrium points are unstable.

The stability analysis of the equilibrium point provides an overall understanding of the evolutionary game system. However, the stability analysis cannot determine the behavior choice mechanism of each player. It is also inconvenient to analyze the incentive effect of the incentive mechanism on the players. To solve these problems, the following sections first analyze the behavior choice mechanism of each player, and then, a method is designed to analyze the incentive effects of incentive mechanisms.

3. Behavior Choice Mechanism of Players

3.1. Behavior Choice Mechanism of the Local Government

Let $F_1(x) = dx/dt = x(1-x)G_1(y,z)$. $F_1(x)$ is a first-order differential equation. ${F_1}'(x) = dF_1(x)/dx = (1-2x)G_1(y,z)$. According to the stability of first-order differential equations, the following proposition can be obtained:

Proposition 1. *When $F_1(x_0) = 0$ and ${F_1}'(x_0) < 0$, x_0 is the stable point of $F_1(x)$.*

Proof of Proposition 1. When x_0 satisfies $F_1(x_0) = 0$, x_0 is the equilibrium point of $F_1(x)$. If $F_1(x)$ is expanded by Taylor at x_0 and only one term is taken, the approximate equation of $dx/dt = F_1(x)$ is $dx/dt = {F_1}'(x_0)(x - x_0)$. The general solution of $dx/dt = {F_1}'(x_0)(x - x_0)$ is $x(t) = ce^{{F_1}'(x_0)t} + x_0$, where c is a constant determined by the initial condition. When ${F_1}'(x_0) < 0$, $\lim_{t\to\infty} x(t) = x_0$, x_0 is a stable point. □

According to $G_1(y,z) = 0$, $z_1^*(y) = 1 - (drC_E - P_{GE})/(drP_{EW} + drL_E + L_G) - C_G/[(drP_{EW}+drL_E+L_G)(1-y)]$ or $y_1^*(z) = 1 - C_G/[(P_{GE} - drC_E) + (drP_{EW}+drL_E+L_G)(1-z)]$.

According to $\partial G_1(y,z)/\partial z = -(drP_{EW} + drL_E + L_G)(1-y) < 0$, $G_1(y,z)$ is a monotonic decreasing function of z. When $z > z_1^*(y)$, $G_1(y,z) < 0$, $F_1(0) = 0$, and ${F_1}'(0) < 0$. In this case, $x = 0$ is the stable point of $F_1(x)$. When $z < z_1^*(y)$, $G_1(y,z) > 0$, $F_1(1) = 0$, and ${F_1}'(1) < 0$. In this case, $x = 1$ is the stable point of $F_1(x)$.

According to the above analysis, the behavior evolution direction of the local government can be obtained, as shown in Figure 1.

The cube in Figure 1 is surrounded by the planes of $x = 0$, $x = 1$, $y = 0$, $y = 1$, $z = 0$, and $z = 1$. In the cube, $0 \le x \le 1$, $0 \le y \le 1$, and $0 \le z \le 1$. In Figure 1, the area bounded by the cube and the upper side of $z_1^*(y)$ is marked as A_0. The area bounded by the cube and the lower side of $z_1^*(y)$ is marked as A_1. In the area of A_0, $z > z_1^*(y)$ and $y > y_1^*(z)$. This indicates that the local government chooses not to supervise. The arrow in the area of A_0 points to $x = 0$. This indicates that the local government chooses not to supervise. The size of A_0 increases with a decrease in $z_1^*(y)$ or $y_1^*(z)$. Thus, the probability that the local government chooses not to supervise increases with a decrease in $z_1^*(y)$ or $y_1^*(z)$.

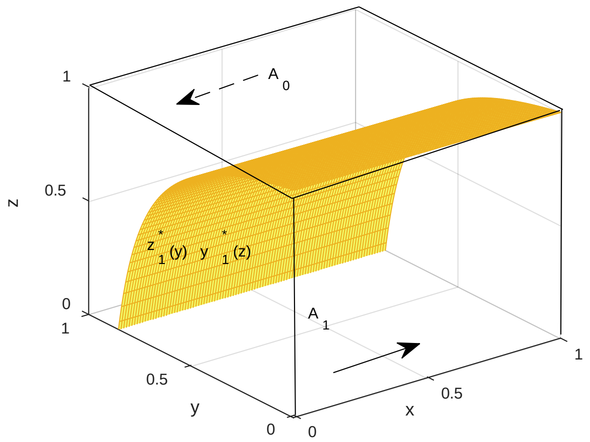

Figure 1. Behavior evolution direction of the local government.

In the area of A_1, $z < z_1^*(y)$ and $y < y_1^*(z)$. This indicates that the local government chooses to supervise. The arrow in the area of A_1 points to $x = 1$. This indicates that the local government chooses to supervise. The size of A_1 increases with an increase in $z_1^*(y)$ or $y_1^*(z)$. Thus, the probability that the local government chooses to supervise increases with an increase in $z_1^*(y)$ or $y_1^*(z)$.

According to the relationship between the local government's behavior choice and $z_1^*(y)$ or $y_1^*(z)$, the following proposition can be obtained:

Proposition 2. *The probability that the local government chooses not to supervise increases with increases of C_G, y, and z. The probability that the local government chooses to supervise increases with an increase in P_{GE}. When $r < 1 + [P_{GE}(1-y) - C_G]/[dC_E(1-y)]$, the probability that the local government chooses not to supervise increases with an increase in r. When $r > 1 + [P_{GE}(1-y) - C_G]/[dC_E(1-y)]$, the probability that the local government chooses to supervise increases with an increase in r. Where C_G is the supervision cost of the local government, P_{GE} is the punishment imposed by the local government on the construction enterprise, and r is the tax rate.*

Proof of Proposition 2. According to $z_1^*(y)$, $\partial z_1^*(y)/\partial C_G = -1/[(drP_{EW} + drL_E + L_G)(1-y)] < 0$, $\partial z_1^*(y)/\partial y = -C_G/\left[(drP_{EW} + drL_E + L_G)(1-y)^2\right] < 0$, $\partial y_1^*(z)/\partial z = -[C_G(drP_{EW} + drL_E + L_G)]/[(P_{GE} - drC_E) + (drP_{EW} + drL_E + L_G)(1-z)]^2 < 0$, $\partial z_1^*(y)/\partial P_{GE} = 1/(drP_{EW} + drL_E + L_G) > 0$. $\partial z_1^*(y)/\partial r = \{C_G - [d(1-r)C_E + P_{GE}](1-y)\}/[(drP_{EW} + drL_E + L_G)(1-y)]$. $z_1^*(y)$ decreases with an increase in C_G. $z_1^*(y)$ decreases with an increase in y. $y_1^*(z)$ decreases with the increase in z. $z_1^*(y)$ increases with an increase in P_{GE}. When $r < 1 + P_{GE}/(dC_E) - C_G/[dC_E(1-y)]$, $\partial z_1^*(y)/\partial r < 0$. $z_1^*(y)$ decreases with an increase in r. When $r > 1 + P_{GE}/(dC_E) - C_G/[dC_E(1-y)]$, $\partial z_1^*(y)/\partial r > 0$. $z_1^*(y)$ increases with an increase in r. The probability that the local government chooses not to supervise increases with a decrease in $z_1^*(y)$ or $y_1^*(z)$. The probability that the local government chooses to supervise increases with an increase in $z_1^*(y)$ or $y_1^*(z)$. According to the above relationship, the conclusion in Proposition 2 can be obtained. □

3.2. Behavior Choice Mechanism of the Construction Enterprise

Let $F_2(y) = dy/dt = y(1-y)E_1(x,z)$, $F_2{}'(y) = dF_2(y)/dy = (1-2y)E_1(x,z)$. According to $E_1(x,z) = 0$, $z_1^*(x) = 1 - C_E/(P_{EW} + L_E) + xP_{GE}/[(1-r)(P_{EW} + L_E)(1-x)]$ or $x_1^*(z) = 1 - P_{GE}/[(1-r)C_E + P_{GE} - (1-r)(P_{EW} + L_E)(1-z)]$.

According to $\partial E_1(x,z)/\partial z = -(1-r)(P_{EW} + L_E)(1-x) < 0$, $E_1(x,z)$ is a monotonic decreasing function of z. When $z > z_1^*(x)$, $E_1(x,z) < 0$, $F_2(0) = 0$, and $F_2{}'(0) < 0$. In this case, $y = 0$ is the stable point of $F_2(y)$. When $z < z_1^*(x)$, $E_1(x,z) > 0$, $F_2(1) = 0$, and $F_2{}'(1) < 0$. In this case, $y = 1$ is the stable point of $F_2(y)$.

According to the above analysis, the behavior evolution direction of the construction enterprise can be obtained, as shown in Figure 2.

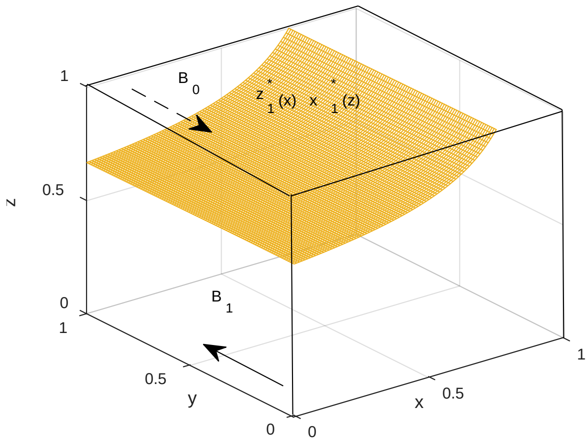

Figure 2. Behavior evolution direction of the construction enterprise.

According to Figure 2, in the area of B_0, $z > z_1^*(x)$. This indicates that the construction enterprise chooses not to supervise. The arrow in the area of B_0 points to $y = 0$. This indicates that the construction enterprise chooses not to supervise. The size of B_0 increases with a decrease in $z_1^*(x)$. Thus, the probability that the construction enterprise chooses not to supervise increases with a decrease in $z_1^*(x)$.

In the area of B_1, $z < z_1^*(x)$. This indicates that the construction enterprise chooses to supervise. The arrow in the area of B_1 points to $y = 1$. This indicates that the construction enterprise chooses to supervise. The size of B_1 increases with an increase in $z_1^*(x)$. Thus, the probability that the construction enterprise chooses to supervise increases with an increase in $z_1^*(x)$.

In the area of B_0, $x < x_1^*(z)$. The probability that the construction enterprise chooses not to supervise increases with an increase in $x_1^*(z)$. In the area of B_1, $x > x_1^*(z)$. The probability that the construction enterprise chooses to supervise increases with a decrease in $x_1^*(z)$.

According to the relationship between the construction enterprise's behavior choice and $z_1^*(x)$ or $x_1^*(z)$, the following proposition can be obtained:

Proposition 3. *The probability that the construction enterprise chooses not to supervise increases with increases of C_E and z. The probability that the construction enterprise chooses to supervise increases with increases of P_{GE}, r, and x, where C_E is the supervision cost of the construction enterprise, P_{GE} is the punishment imposed by the local government on the construction enterprise, and r is the tax rate.*

Proof of Proposition 3. According to $z_1^*(x)$, $\partial z_1^*(x)/\partial C_E = -1/(P_{EW} + L_E) < 0$, $\partial x_1^*(z)/\partial z = P_{GE}[(1-r)(P_{EW} + L_E)]/[(1-r)C_E + P_{GE} - (1-r)(P_{EW} + L_E)(1-z)]^2 > 0$, $\partial z_1^*(x)/\partial P_{GE} = x/[(1-r)(P_{EW} + L_E)(1-x)] > 0$, $\partial z_1^*(x)/\partial r = xP_{GE}/\left[(1-r)^2(P_{EW} + L_E)(1-x)\right] > 0$, and $\partial z_1^*(x)/\partial x = P_{GE}/\left[(1-r)(P_{EW} + L_E)(1-x)^2\right] > 0$. $z_1^*(x)$ decreases with an increase in C_E. $x_1^*(z)$ increases with an increase in z. $z_1^*(x)$ increases with an increase in P_{GE}, r, and x. The probability that the construction enterprise chooses not to supervise increases with a decrease in $z_1^*(x)$. The probability that the construction enterprise chooses not to supervise increases with an increase in $x_1^*(z)$. The probability that the construction enterprise chooses to supervise increases with an increase in $z_1^*(x)$. According to the above relationship, the conclusion in Proposition 3 can be obtained. □

3.3. Behavior Choice Mechanism of the Construction Worker

Let $F_3(z) = dz/dt = z(1-z)W_1(x,y)$, $F_3{}'(z) = dF_3(z)/dz = (1-2z)W_1(x,y)$. According to $W_1(x,y) = 0$, $x_1^*(y) = 1 - P_{EW}/[(C_{W1} - L_W - C_{W2} + P_{EW})(1-y)]$ or $y_1^*(x) = 1 - P_{EW}/[(C_{W1} - L_W - C_{W2} + P_{EW})(1-x)]$.

When $C_{W1} > L_W + C_{W2} - P_{EW}$, $\partial W_1(x,y)/\partial x = (C_{W1} - L_W - C_{W2} + P_{EW})(1-y) > 0$, $W_1(x,y)$ is a monotonic increasing function of x. When $x > x_1^*(y)$, $W_1(x,y) > 0$, $F_3(1) = 0$, and $F_3{}'(1) < 0$. In this case, $z = 1$ is the stable point of $F_3(z)$. When $x < x_1^*(y)$, $W_1(x,y) < 0$, $F_3(0) = 0$, and $F_3{}'(0) < 0$. In this case, $z = 0$ is the stable point of $F_3(z)$. The behavior evolution direction of the construction worker is shown in Figure 3.

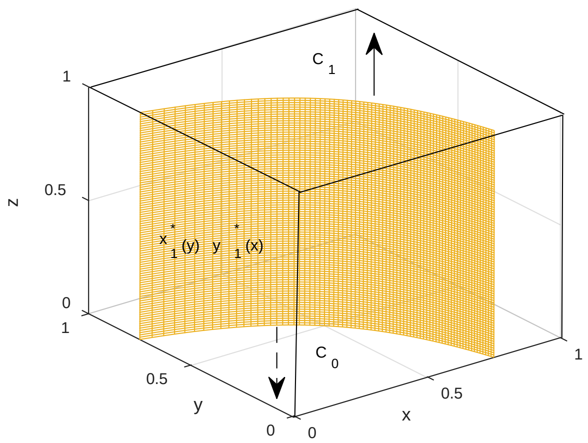

Figure 3. Behavior evolution direction of the construction worker under the condition of $C_{W1} > L_W + C_{W2} - P_{EW}$.

According to Figure 3, in the area of C_0, $x < x_1^*(y)$ and $y < y_1^*(x)$. This indicates that the construction worker chooses to violate the regulation. The arrow in the area of C_0 points to $z = 0$. This indicates that the construction worker chooses to violate the regulation. The size of C_0 increases with an increase in $x_1^*(y)$ or $y_1^*(x)$. Thus, the probability that the construction worker chooses to violate the regulation increases with an increase in $x_1^*(y)$ or $y_1^*(x)$.

In the area of C_1, $x > x_1^*(y)$ and $y > y_1^*(x)$, and the construction worker chooses not to violate the regulation. The arrow in the area of C_1, points to $z = 1$. This indicates that the construction worker chooses not to violate the regulation. The size of C_1 increases with a decrease in $x_1^*(y)$ or $y_1^*(x)$. Thus, the probability that the construction worker chooses not to violate the regulation increases with a decrease in $x_1^*(y)$ or $y_1^*(x)$.

When $C_{W1} < L_W + C_{W2} - P_{EW}$, $\partial W_1(x,y)/\partial x < 0$. $W_1(x,y)$ is a monotonic decreasing function of x. When $C_{W1} < L_W + C_{W2} - P_{EW}$, $x_1^*(y) > 1$. For any $0 \le x \le 1$ and $0 \le y \le 1$, $x < x_1^*(y)$. When $x < x_1^*(y)$, $W_1(x,y) > 0$. In this case, $F_3(1) = 0$, $F_3{}'(1) < 0$. $z = 1$ is the stable point of $F_3(z)$.

According to the relationship between the construction worker's behavior choice and $x_1^*(y)$ or $y_1^*(x)$, the following proposition can be obtained:

Proposition 4. *When $C_{W1} > L_W + C_{W2} - P_{EW}$, the probability that the construction worker chooses to violate the regulation increases with an increase in C_{W1}, and the probability that the construction worker chooses not to violate the regulation increases with increases of L_W, C_{W2}, x, and y. When $C_{W1} > L_W + C_{W2}$, the probability that the construction worker chooses not to violate the regulation increases with an increase in P_{EW}. When $C_{W1} < L_W + C_{W2} - P_{EW}$, no matter what behavior the local government and the construction enterprise choose, the construction worker chooses not to violate the regulation, where C_{W1} is the cost of the construction worker choosing not to violate the regulation, C_{W2} is the cost of the construction worker choosing to violate the regulation, P_{EW} is the punishment imposed by the construction enterprise on the construction worker, and L_W is the accident loss expectation of the construction worker.*

Proof of Proposition 4. $\partial x_1^*(y)/\partial C_{W1} = P_{EW}/\left[(C_{W1} - L_W - C_{W2} + P_{EW})^2(1-y)\right] > 0$, $\partial x_1^*(y)/\partial C_{W2} = -P_{EW}/\left[(C_{W1} - L_W - C_{W2} + P_{EW})^2(1-y)\right] < 0$, $\partial x_1^*(y)/\partial L_W = -P_{EW}/\left[(C_{W1} - L_W - C_{W2} + P_{EW})^2(1-y)\right] < 0$, $\partial x_1^*(y)/\partial y = -P_{EW}/\left[(C_{W1} + P_{EW} - L_W - C_{W2})(1-y)^2\right] < 0$, and $\partial y_1^*(x)/\partial x = -P_{EW}/\left[(C_{W1} + P_{EW} - L_W - C_{W2})(1-x)^2\right] < 0$. $\partial x_1^*(y)/\partial P_{EW} = -(C_{W1} - L_W - C_{W2})/\left[(C_{W1} - L_W - C_{W2} + P_{EW})^2(1-y)\right]$. When $C_{W1} > L_W + C_{W2}$, $\partial x_1^*(y)/\partial P_{EW} < 0$. $x_1^*(y)$ increases with an increase in C_{W1}. $x_1^*(y)$ decreases with increases of L_W, C_{W2}, x, and y. When $C_{W1} > L_W + C_{W2}$, $x_1^*(y)$ decreases with an increases in P_{EW}. When $C_{W1} > L_W + C_{W2} - P_{EW}$, the probability that the construction worker chooses to violate the regulation increases with an increase in $x_1^*(y)$ or $y_1^*(x)$, and the probability that the construction worker chooses not to violate the regulation increases with a decrease in $x_1^*(y)$ or $y_1^*(x)$. According to the above relationship, the conclusion in Proposition 4 can be obtained. When $C_{W1} < L_W + C_{W2} - P_{EW}$, $x_1^*(y) > 1$. For any $0 \leq x \leq 1$ and $0 \leq y \leq 1$, $x < x_1^*(y)$. $z = 1$ is the stable point of $F_3(z)$. In this case, no matter what behavior the local government and the construction enterprise choose, the construction worker chooses not to violate the regulation. □

4. Tax Incentive Mechanisms

4.1. Incentive Effect Analysis Method of Incentive Mechanisms

According to the behavior choice mechanism of the local government, when $G_1(y,z)$ is a monotonic decreasing function of z, the probability that the local government chooses to supervise increases with an increase in $z_1^*(y)$. Based on this, by analyzing the impact of the incentive mechanism on the monotonicity of $G_1(y,z)$ and the size of $z_1^*(y)$, we can analyze the incentive effect of the incentive mechanism on the local government.

According to the behavior choice mechanism of the construction enterprise, when $E_1(x,z)$ is a monotonic decreasing function of z, the probability that the construction enterprise chooses to supervise increases with an increase in $z_1^*(x)$. Based on this, by analyzing the impact of the incentive mechanism on the monotonicity of $E_1(x,z)$ and the size of $z_1^*(x)$, we can analyze the incentive effect of the incentive mechanism on the construction enterprise.

According to the behavior choice mechanism of the construction worker, when $W_1(x,y)$ is a monotonic decreasing function of x, the probability that the construction worker chooses not to violate the regulation increases with a decrease in $x_1^*(y)$. Based on this, by analyzing the impact of the incentive mechanism on the monotonicity of $W_1(x,y)$ and the size of $x_1^*(y)$, we can analyze the incentive effect of the incentive mechanism on the construction worker.

According to Propositions 2–4, the behavior influence mechanism among the local government, the construction enterprise, and the construction worker under the action of the incentive mechanism is shown in Figure 4. According to the behavior influence mechanism, we can analyze the incentive effect of the incentive mechanism designed for one player on the other players. .

As tax is an important factor affecting the behavior choice of local governments and construction enterprises [36], the following uses the above method to analyze the incentive effects of different tax incentive mechanisms on local governments, construction enterprises, and construction workers.

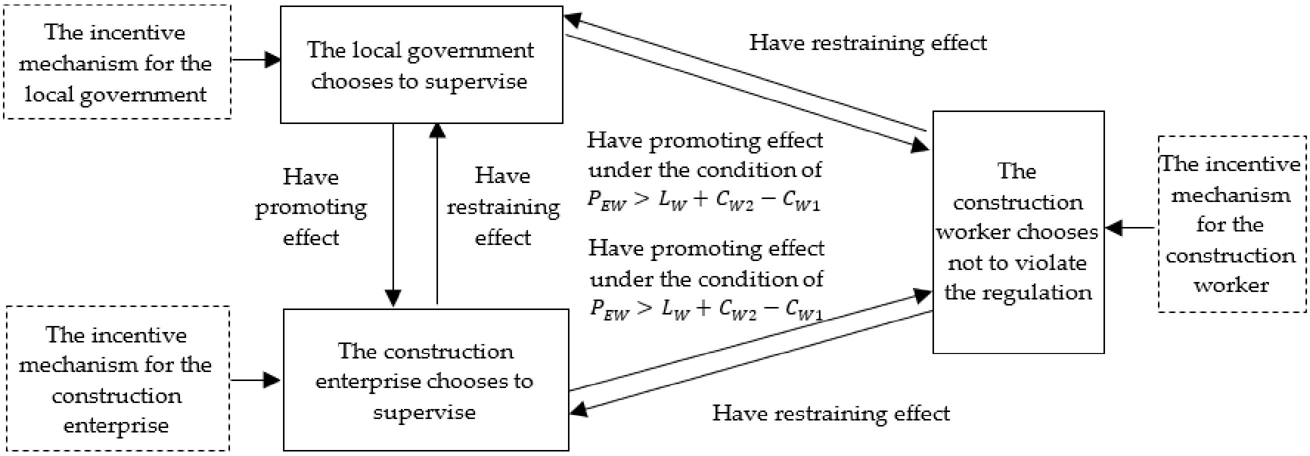

Figure 4. Behavior influence mechanisms among the local government, the construction enterprise, and the construction worker.

4.2. Tax Mechanism That Encourages Local Governments to Supervise

It is assumed that the tax mechanism that encourages local governments to supervise is as follows. If an accident occurs, the central government punishes the local government by reducing the proportion of tax distribution. According to the assumption of the model, accidents may occur when a construction worker chooses to violate the regulation, the local government chooses not to supervise, and the construction enterprise chooses not to supervise. In this case, the local government's income, the construction enterprise's income, and the construction worker's income are $(d - d_0)r(I - W - L_E) - L_G$, $(1 - r)(I - W - L_E)$, and $W - L_W - C_{w2}$, respectively, where d_0 is the expectation of the reduction in the local government's tax distribution proportion. According to their income, $u_1 - u_2 = G_2(y,z) = -C_G + P_{GE}(1 - y) - drC_E(1 - y) + (drP_{EW} + drL_E + L_G)(1 - y)(1 - z) + d_0r(I - W - L_E)(1 - y)(1 - z)$, $v_1 - v_2 = E_2(x,z) = E_1(x,z)$, and $w_1 - w_2 = W_2(x,y) = W_1(x,y)$.

According to $G_2(y,z) = 0$, $z_2{}^*(y) = 1 - [C_G + (1 - y)drC_E - (1 - y)P_{GE}]/[(drP_{EW} + drL_E + L_G)(1 - y) + d_0r(I - W - L_E)(1 - y)]$. $\partial G_2(y,z)/\partial z = -[(drP_{EW} + drL_E + L_G)(1 - y) + d_0r(I - W - L_E)](1 - y)$. When $C_G > (P_{GE} - drC_E)(1 - y)$ and $I - W - L_E > 0$, $G_2(y,z)$ is a monotonic decreasing function of z, and $z_2{}^*(y) > z_1{}^*(y)$. The behavior evolution direction of the local government is shown in Figure 5.

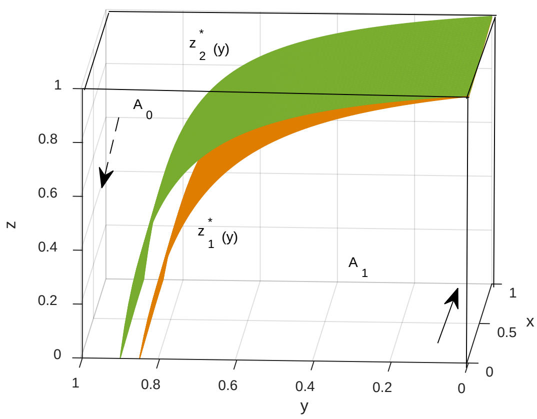

Figure 5. Behavior evolution direction of a local government under the tax mechanism.

As can be seen in Figure 5, a local government is more likely to choose to supervise under the tax incentive mechanism. Because $E_2(x,z) = E_1(x,z)$ and $W_2(x,y) = W_1(x,y)$, the tax incentive mechanism that encourages local governments to supervise does not directly affect the behavior of construction enterprises or construction workers, but it indirectly affects their behavior through the behavior interaction between the players.

4.3. Tax Mechanism That Encourages the Construction Enterprise to Supervise

It is assumed that the tax mechanism that encourages the construction enterprise to supervise is as follows. If an accident occurs, the government punishes the construction enterprise by raising the tax rate. According to the assumption of the model, accidents may occur when a construction worker chooses to violate the regulation, the local government chooses not to supervise, and the construction enterprise chooses not to supervise. In this case, the local government's income, the construction enterprise's income, and the construction worker's income are $d(r+r_0)(I-W-L_E)-L_G$, $(1-r-r_0)(I-W-L_E)$, and $W-L_W-C_{W2}$, respectively, where r_0 is the expectation of an increase in the construction enterprise's tax rate. According to their income, $u_1-u_2=G_3(y,z)=-C_G+P_{GE}(1-y)-drC_E(1-y)+(drP_{EW}+drL_E+L_G)(1-y)(1-z)-dr_0(I-W-L_E)(1-y)(1-z)$, $v_1-v_2=E_3(x,z)=-(1-r)C_E(1-x)+P_{GE}x+(1-r)(P_{EW}+L_E)(1-x)(1-z)+r_0(I-W-L_E)(1-x)(1-z)$, and $w_1-w_2=W_3(x,y)=W_1(x,y)$.

According to $E_3(x,z)=0, {z_2}^*(x)=1-[(1-x)(1-r)C_E-xP_{GE}]/[(1-r)(P_{EW}+L_E)(1-x)+r_0(I-W-L_E)(1-x)]$. $\partial E_3(x,z)/\partial z=-(1-r)(P_{EW}+L_E)(1-x)-r_0(I-W-L_E)(1-x)<0$. When $C_E>xP_{GE}/[(1-r)(1-x)]$ and $I-W-L_E>0$, ${z_2}^*(x)>{z_1}^*(x)$. The behavior evolution direction of the construction enterprise is shown in Figure 6.

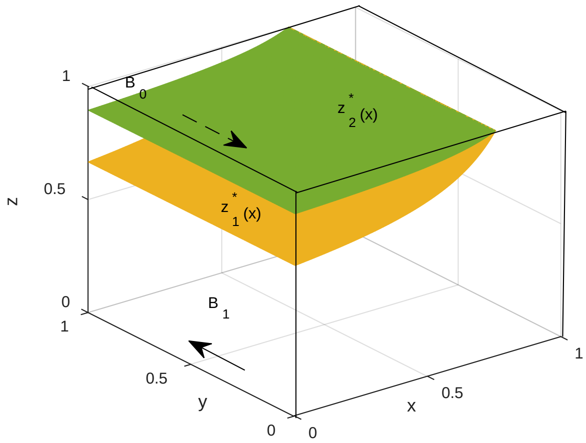

Figure 6. Behavior evolution direction of a construction enterprise under the tax mechanism.

As can be seen in Figure 6, the construction enterprise is more likely to supervise under the tax incentive mechanism. According to $G_3(y,z)=0$, ${z_2}^*(y)=1-[C_G+(1-y)drC_E-(1-y)P_{GE}]/[(drP_{EW}+drL_E+L_G)(1-y)-dr_0(I-W-L_E)(1-y)]$. $\partial G_3(y,z)/\partial z=-[(drP_{EW}+drL_E+L_G)-dr_0(I-W-L_E)](1-y)$. When $\partial G_3(y,z)/\partial z<0$, ${z_2}^*(y)<{z_1}^*(y)$ under the condition of $C_E>xP_{GE}/[(1-r)(1-x)]$ and $I-W-L_E>0$. This shows that the tax incentive mechanism for the construction enterprise reduces the possibility for the local governments to supervise under the above conditions.

5. Impact of Tax Incentive Mechanisms on the Behavior Evolution

When local governments or construction enterprises are encouraged by the tax incentive mechanism, they affect the behavior of the other players through their behavior, and they are also affected by the behavior of the other players. The following is an example used to analyze the impact of the above two tax incentive mechanisms on the behavior evolution process of local governments, construction enterprises, and construction workers.

The values of each parameter are as follows: $I=20$, $W=4$, $C_G=2$, $C_E=4$, $C_{W1}=5$, $C_{W2}=1$, $L_G=1$, $L_E=1$, $L_W=1$, $P_{GE}=2$, $P_{EW}=2$, $r=0.25$, $d=0.3$, where $P_{EW}>L_W+C_{W2}-C_{W1}$.

5.1. Impact of the Tax Mechanism That Encourages the Local Government to Supervise on the Behavior Evolution

When $x_0 = 0.5$, $y_0 = 0.5$, and $z_0 = 0.5$, the impact of the tax mechanism that encourages the local government to supervise on the behavior evolution process is shown in Figure 7, where x_0, y_0, and z_0 are the behavior choices of the local government, the construction enterprise, and the construction worker at the initial time, respectively.

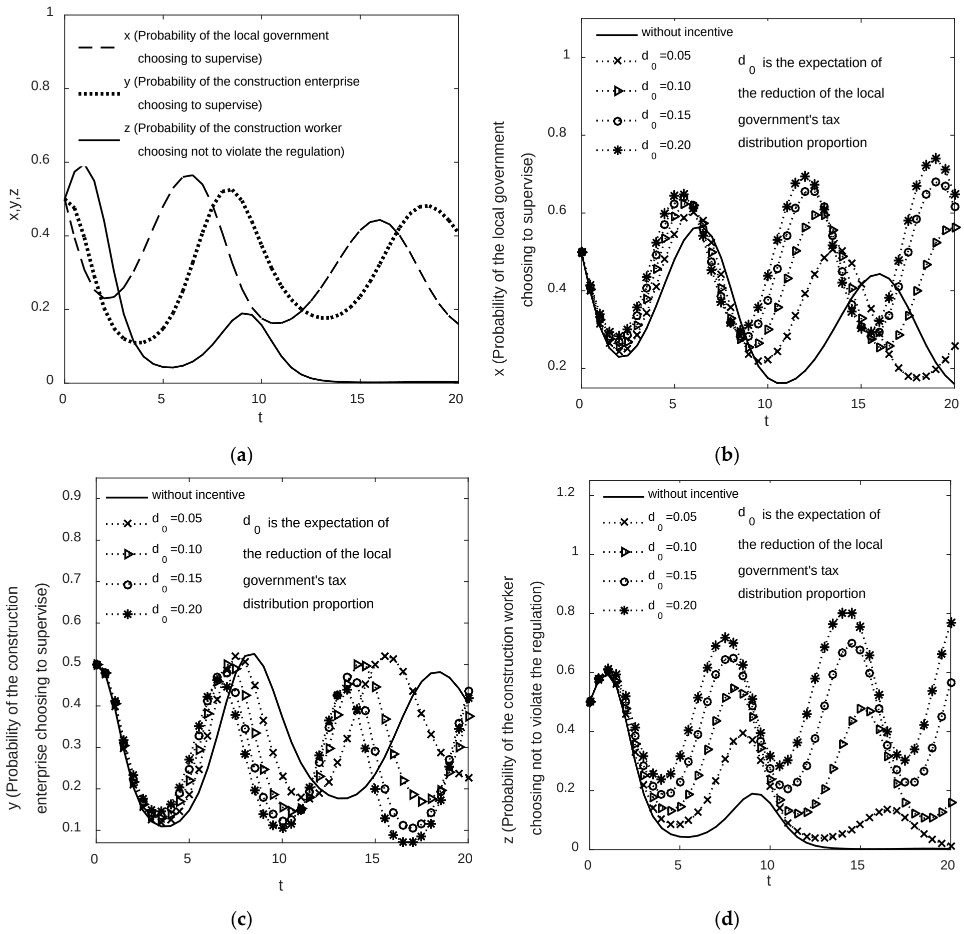

Figure 7. The impact of the tax mechanism that encourages the local government to supervise on the behavior evolution process: (**a**) evolution process without tax incentive mechanism; (**b**) the behavior evolution process of a local government under different tax incentive mechanisms; (**c**) the behavior evolution process of a construction enterprise under different tax incentive mechanisms; (**d**) the behavior evolution process of a construction worker under different tax incentive mechanisms.

As can be seen in Figure 7a, when the probability of the local government choosing to supervise increases or decreases, the probability of the construction enterprise choosing to supervise does not increase or decrease immediately, but rather increases or decreases after a period of time. A similar phenomenon exists in the probability of a construction worker choosing not to violate the regulation. This shows that players dynamically adjust their strategies by observing and learning the strategies of other players. This reflects the incomplete rationality of the players. As can be seen in Figure 7b, the tax mechanism that encourages the local government to supervise makes the highest and lowest points of x higher, which shows that the mechanism can encourage the local government to supervise. Moreover, the greater the d_0, the more obvious the incentive effect. As can be seen in Figure 7c, the mechanism makes the lowest point of y lower, which indicates that the mechanism has a certain restraining effect on the supervision behavior of the construction enterprise. Moreover, the greater the d_0, the more obvious the restraining effect. As can be seen in Figure 7d, the mechanism makes z larger, which shows that the mechanism can encourage the construction worker not to violate the regulation. Moreover, the greater the d_0, the more obvious the incentive effect.

According to the behavior influence mechanism among the local government, the construction enterprise, and the construction worker shown in Figure 4, the reason for the local government being more likely to choose to supervise under the tax mechanism is that the incentive effect of the tax mechanism exceeds the restraining effect of the construction enterprise's supervision behavior and the construction worker's safety behavior on the government's supervision behavior when the safety behavior is that the construction worker chooses not to violate the regulation.

The reason for the construction enterprise's supervision behavior being restrained under the tax mechanism is that the restraining effect of the construction worker's safety behavior on the construction enterprise's supervision behavior exceeds the promoting effect of the government's supervision behavior on the construction enterprise's supervision behavior.

The reason for the construction worker being more likely to choose not to violate the regulation under the tax mechanism is that the local government's supervision behavior can encourage the construction worker to choose not to violate the regulation under the condition of $P_{EW} > L_W + C_{W2} - C_{W1}$.

5.2. Impact of the Tax Mechanism That Encourages the Construction Enterprise to Supervise on the Behavior Evolution

The impact of the tax mechanism that encourages the construction enterprise to supervise on the behavior evolution process is shown in Figure 8.

As can be seen in Figure 8, the tax mechanism that encourages the construction enterprise to supervise makes x smaller. This shows that the mechanism has a restraining effect on the local government's supervision behavior. The tax mechanism that encourages the construction enterprise to supervise makes y bigger. This shows that the mechanism can encourage the construction enterprise to supervise. When r_0 is small, the tax mechanism makes z smaller. When r_0 is large, the tax mechanism makes z larger. This shows that only when r_0 is large does the tax mechanism that encourages the construction enterprise to supervise encourage the construction worker to choose not to violate the regulation.

According to the behavior influence mechanism among the local government, the construction enterprise, and the construction worker shown in Figure 4, the reason for the local government being more likely not to supervise under the tax mechanism that encourages the construction enterprise is that the supervision behavior of the construction enterprise has a restraining effect on the supervision behavior of the local government.

The reason for the construction enterprise being more likely to supervise is the incentive effect of the tax mechanism is higher than the restraining effect of the construction worker's safety behavior on the construction enterprise's supervision behavior.

It can be seen in Figure 8b that, when r_0 is small, the tax mechanism that encourages the construction enterprise to supervise plays a weak role in promoting the construction enterprise to supervise. This weak promoting effect has a weak promoting effect on the construction worker. However, the tax mechanism has a certain restraining effect on the local government's supervision behavior. This restraining effect also inhibits the construction worker's safety behavior. Moreover, the restraining effect on the construction worker's safety behavior exceeds the promoting effect, which makes the construction worker more likely to violate the regulation. When r_0 is large, the tax mechanism that encourages the construction enterprise has a greater incentive effect on the construction enterprise's supervision behavior. The supervision behavior of the construction enterprise promotes the safety behavior of the construction worker. This kind of promoting effect exceeds the restraining effect, making the construction worker more likely not to violate the regulation.

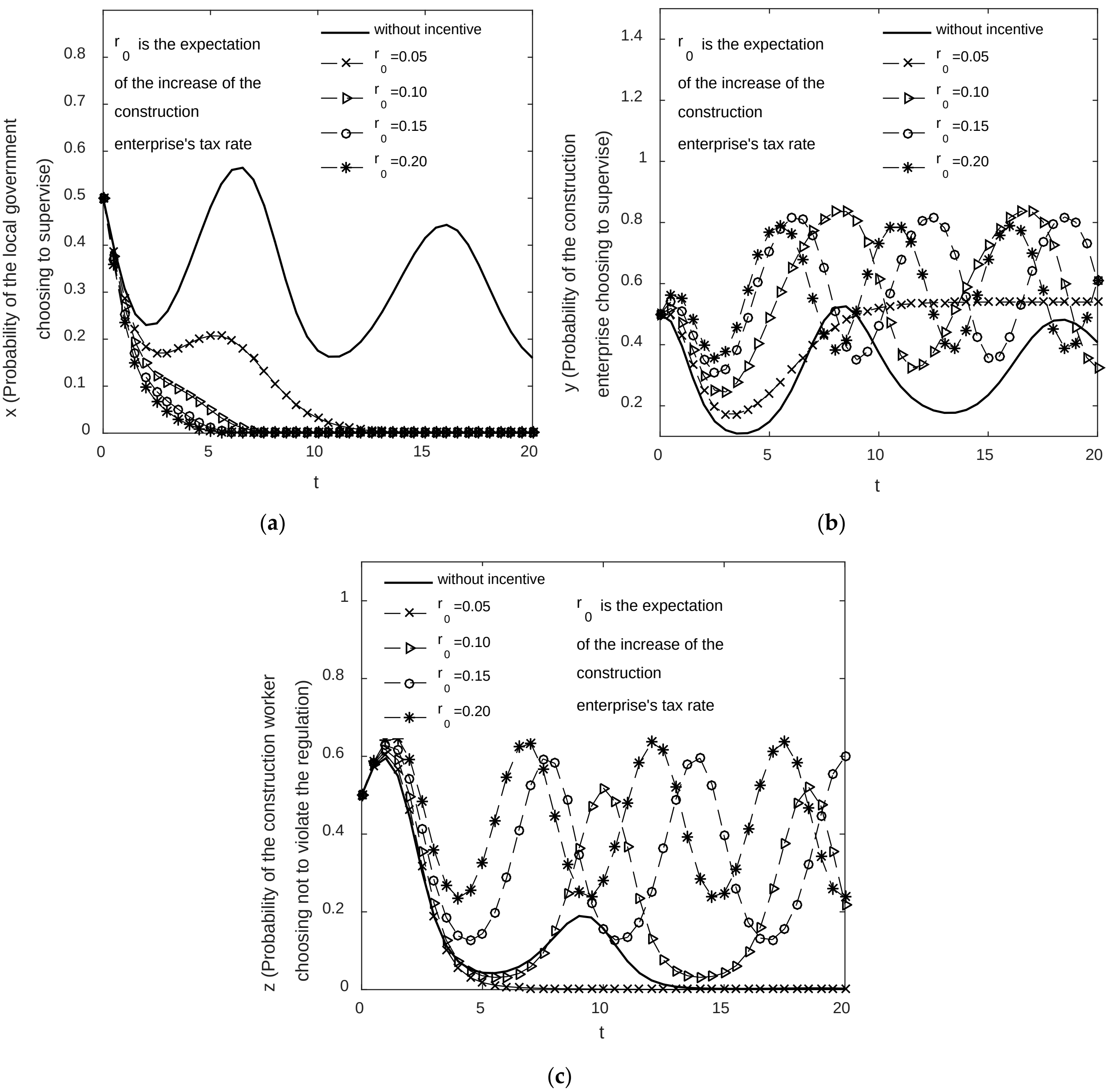

Figure 8. The impact of the tax mechanism that encourages the construction enterprise to supervise on the behavior evolution process: (**a**) the behavior evolution process of the local government under different tax incentive mechanisms; (**b**) the behavior evolution process of the construction enterprise under different tax incentive mechanisms; (**c**) the behavior evolution process of the construction worker under different tax incentive mechanisms.

6. Conclusions

To master the behavior choice mechanisms of the local government, the construction enterprise, and the construction worker in the construction safety game, and to design the incentive mechanism according to the behavior choice mechanism, an evolutionary game model is constructed, and an incentive effect analysis method of the incentive mechanism is proposed. The main conclusions of this paper are as follows:

(1) For local governments, reducing the supervision cost can stimulate their supervision behavior. When the tax rate is small, raising the tax rate will inhibit their supervision behavior. When the tax rate is large, raising the tax rate can stimulate their supervision

behavior. For construction enterprises, raising the tax rate, reducing the supervision cost, and increasing the punishment can stimulate their supervision behavior. For construction workers, when the cost of choosing not to violate the regulation is large, reducing the cost and increasing the punishment can encourage them to choose not to violate the regulation.

(2) The behaviors of local governments, construction enterprises, and construction workers affect each other. Only when the punishment imposed on a construction worker is large enough does the supervision behavior of the local government and the construction enterprise encourage the construction worker to choose not to violate the regulation.

(3) The tax incentive mechanism of reducing the tax distribution proportion of local governments in the case of accidents can encourage local governments to supervise. Moreover, it can encourage construction workers to choose not to violate the regulation through the behavior interaction between the players. However, this mechanism has a certain restraining effect on the supervision behavior of construction enterprises.

(4) The tax incentive mechanism of raising the tax rate of construction enterprises in the case of accidents can encourage construction enterprises to supervise. However, this mechanism has a restraining effect on the supervision behavior of local governments. Only when there are expectations that there will be a large rise in the tax rate does this tax mechanism encourage construction workers to choose not to violate the regulation through the behavior interaction between the players.

This paper first provides a new method to analyze the behavior choice of the local government, the construction enterprise, and the construction worker in the construction safety game. Through the analysis, we can grasp the conditions under which the local government and the construction enterprise will choose supervision behavior, and how relevant factors affect their behavior choices. This provides a theoretical basis for encouraging the local government and the construction enterprise to actively supervise. We can also grasp the conditions under which the construction worker will violate the regulation and how relevant factors affect their violations. This provides a theoretical basis for the formulation of policies to reduce violations. The behavior choice analysis method also provides a method for the behavior choice analysis of players in other games.

Using a numerical simulation, it was found that the incentive effect analysis method of the incentive mechanism is effective. This provides a new method for the analysis of the incentive effect of incentive mechanisms. This method can also be used in the research of incentive mechanisms in the fields of coal mine safety, food safety, and chemical safety.

The behavior choice analysis method and incentive effect analysis method proposed in this paper do not consider the influence of random interference factors. In the future, we will establish a random evolutionary game model to analyze the influence of random interference factors on the behavior choice of players.

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