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Article

Strategies for Optimizing the Fengqiao Experience in the New Era to Promote the Grassroots Governance Model in Hebei Province by Using a Multilevel Game Model

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Abstract: This paper investigates the impact of the Fengqiao Experience on grassroots governance models in Hebei Province through a survey on residents' sense of security in community governance during the new era. A Logistic regression model is employed to examine the relationship between the Fengqiao Experience in the new era and grassroots governance in Hebei Province. Subsequently, a game theory model hypothesis is proposed, a game theory model is established and solved, and the hypothesis is verified to obtain the game equilibrium strategy combination. The results indicate that public security forces have a significant impact, while the significance of other types of variables is generally much smaller than that of public security forces, and they exhibit different directions of influence. Public choices are closely related to changes in the penalties imposed by local government supervisory agencies for evasion of responsibility, but as long as the social welfare benefits of local governments are maximized, multi-stakeholder collaborative governance in cities can enter a stable virtuous cycle. Therefore, strategies such as improving existing incentive and constraint systems for officials and establishing supervision and reward/punishment mechanisms for regulatory agencies will help address officials' avoidance of responsibility and promote their proactive role in governance.

Keywords: Fengqiao Experience; Logistic Regression Model; Game Theory Model; Grassroots Governance Model

1. Introduction

As the urban population in Hebei Province continues to grow and social issues become increasingly complex, urban grassroots social governance has become a significant challenge [1-2]. In this context, the introduction of the “Fengqiao Experience” into urban grassroots social governance in Hebei Province holds great significance [3-4].

The “Fengqiao Experience” refers to the practice of resolving social issues through the spontaneous and self-governance of the community in Fengqiao Town, Zhuji City, Zhejiang Province [5-6]. This experience has garnered widespread attention both domestically and internationally and is regarded as an effective approach to grassroots social governance [7-8]. In urban grassroots social governance, the awareness and capacity for community self-governance are of critical importance [9]. In the new era, urban residents' understanding of their rights and obligations has grown increasingly profound, and their spirit of self-governance has become increasingly robust [10-11].

In urban grassroots social governance in Hebei Province, the government should play a guiding and coordinating role, granting community residents greater autonomy and enabling them to actively participate in social governance [12-13]. In the “Fengqiao Experience,” the Fengqiao Town government established the “Three Meetings and One Class” system and formed village committees to encourage

villagers' self-governance, allowing them to participate in major decision-making and problem-solving within the village, thereby fostering a spontaneous atmosphere of self-governance [14-17]. In urban grassroots social governance, the government should also adopt similar approaches, strengthening community self-governance and institutions that represent residents' opinions to enhance residents' proactive participation in social governance [18-20]. Additionally, the "Fengqiao Experience" emphasizes the importance of democratic rule of law. In Fengqiao Town, the government strengthened grassroots democratic oversight by establishing village representative assemblies and formulating village regulations and codes of conduct [21-23].

Literature [24] highlights that the "Fengqiao Experience" provides an innovative approach to grassroots social governance. Based on surveys and interviews, and in conjunction with the issues identified in the "Fengqiao Experience," it summarizes the innovation and development of the "three-in-one governance" model and emphasizes that grassroots social governance must adhere to the principles of "self-governance, rule of law, and moral governance." Literature [25] provides a comprehensive overview of the "Fengqiao Experience" and its current research status, pointing out that to advance typical models of grassroots governance, it is essential to balance internal and external values, particularity and universality, and unity with grassroots self-governance to prevent deviations. Literature [26] uses the "Fengqiao Experience" as a guiding philosophy, based on the psychology of social governance, and applies the psychological development patterns of grassroots residents in grassroots supervision and governance to reduce the burden of behavioral governance, aiming to explore a scientific and reasonable governance path for grassroots supervision and governance. Literature [27] indicates that strengthening grassroots rule of law construction and fully leveraging the efficacy of soft law are important components of improving residents' quality of life. Using Fengqiao Town's success as an example, it highlights distinctive elements such as democratic consultation and a major adjustment mechanism that emerged during the pilot process. Literature [28] elaborates on the promotional role of the "Fengqiao Experience" in grassroots social governance during the new era, analyzes the theoretical and practical objectives of grassroots social governance construction, and proposes the content framework for grassroots social governance, including the institutionalization analysis of the "Fengqiao Experience" and practical pathways for grassroots social governance. Literature [29] reviews the challenges currently facing public safety governance and, using the "Fengqiao Experience" as a reference, points out that it provides a grassroots model emphasizing early conflict resolution, community participation, and cost-effective governance, which holds significant potential in addressing public safety issues. Literature [30] fully affirms the "Fengqiao Experience" but notes that its impact on crime prevention in China has not been sufficiently studied internationally. Using the Fengqiao Police Station in Zhejiang Province as an example, it examines how China achieves public mobilization and organization for crime prevention, indicating that the Fengqiao Police Station has taken the lead in upholding and developing the "Fengqiao Experience," making this model an important component of China's contemporary social governance modernization. Literature [31] examines the innovative practices and development trends of people's mediation in social governance based on the "Fengqiao Experience." By elucidating the basic concepts and principles of people's mediation, it highlights its crucial role in resolving social conflicts and disputes. Literature [32] employs new collective action theory to explore the implementation of farmland protection policies, concluding that to address implementation challenges, local governments can adopt a dual model of strong institutional control and policy mobilization.

This paper first introduces the emotional public security path, model, practices, and governance structure of Hebei Province under the Fengqiao Experience, proposes corresponding theoretical hypotheses, and then conducts a survey questionnaire on the sense of security among community residents in Hebei Province in the new era to determine the dependent and independent variables of the logistic regression model, and analyzes the impact of different types of variables on the dependent variable. Subsequently, based on conceptual definitions, the study analyzes the participation behaviors of multiple stakeholders, explores the relationships among these stakeholders, and proposes relevant research hypotheses. A game model for the research subjects is established to determine the requirements for verifying the proposed hypotheses and the optimal strategies of the game model. Dynamic equations for the game process are designed to obtain the equilibrium strategy combinations of the game. Finally, the evolution of decision-making behavior by governance entities and the equilibrium strategies of the three-party evolutionary game model involving "socioeconomic conditions, community public security environment, and public security forces" are analyzed.

2. The Fengqiao Experience in Grassroots Public Security Governance in the New Era and Methods of Analysis

2.1. Study Design

2.1.1. Theoretical Assumptions

The Emotional Public Safety Approach Under the Fengqiao Experience: In the face of new challenges and issues in the new era, the Fengqiao Experience further explores solutions within the complexities of human nature and rational emotions. This is achieved through the establishment of collaborative platforms and the expansion of joyful experiential pathways to reconfigure interpersonal relationships among the general public; through educational reforms such as moral education and cultural education, it aims to achieve social rehabilitation and conflict resolution; by strengthening community-based internal connections and optimizing contextual and structural emotions to enhance community belonging and identity.

The Smart Public Security Model Under the Fengqiao Experience: In the exploration of informatization, intelligence, and digitization in grassroots public security governance, the Fengqiao Experience has gradually formed a technical governance path centered on “Cloud Fengqiao.”

Legal governance practices under the Fengqiao Experience: The Fengqiao Experience has promoted the diversified supply of grassroots public security systems through the in-depth exploration and innovative application of folk governance resources such as customs, regulations, village rules, and association charters. The higher the degree of legalization, the more conducive it is to the resolution of grassroots conflicts and disputes, the construction of grassroots legal order, the innovation of public safety services, and the increase in grassroots legal welfare.

Emotional-Technological-Legal Governance Structure: Through a systematic review of theories and practices related to emotional governance, technological governance, and legal construction and public security.

2.1.2. Data Sources and Analysis Methods

This study employed the Delphi method to design a questionnaire investigating the status of grassroots governance models in Hebei Province driven by the new era Fengqiao Experience, tailored to the specific needs of the research. A random sampling method was used to select five regions: Shijiazhuang, Xiongan New Area, Qinhuangdao, Chengde, and Baoding. Based on the actual conditions of each region, simple random sampling was applied to select 10 communities in each region, ultimately determining 50 communities for questionnaire distribution. Survey team members distributed a total of 1,000 questionnaires to community residents across the 50 communities, with 20 questionnaires per community, and received 996 valid responses.

Based on effective data cleaning and systematic coding of the aforementioned raw data, descriptive statistical analysis was conducted using Stata software, and a Logit regression analysis model was generated based on theoretical assumptions and variable selection:

$$P\left(y = j / x_i\right) = \frac{1}{1 + e - \left(a + \beta X_i\right)} \tag{1}$$

In this context, X_i represents the ith variable, and y denotes the probability of community safety. Establishing an ordered Logistic method model:

$$Logit\left(P_j\right) = In\left[\frac{P(y \le j)}{y \ge j + 1}\right] = a + \sum_{i=1}^{n} \beta_i X_i \tag{2}$$

2.1.3. Variable Selection and Sample Description

(1) Dependent variable

The dependent variable in this study is residents' sense of security, with five response options: “very good,” “fairly good,” “average,” “fairly poor,” and “very poor.”

(2) Independent variables

Through chi-square tests of the correlation between demographic characteristics and residents' sense of security, the study analyzed the correlation between community type, residential area type, gender, household registration, and community safety, and thus used these as control variables in the regression analysis. Additionally, this study integrated and scored a series of questions related to emotional governance elements, technical governance elements, and rule of law construction elements from the

questionnaire using job analysis, behavioral event interviews, and the Delphi method, which were then used as independent variables in the logistic regression analysis.

2.2. Volunteer Service Intentions and Binary Logistic Regression Analysis

2.2.1. Basic Information on Residents

Among residents' basic demographics, the majority are willing to participate in community safety volunteer services. The proportion of women among surveyed residents is not significantly different from that of men. Across different age groups: residents aged 25, 25–50, and over 50 account for 29%, 55%, and 16% respectively. Among them, those with spouses account for approximately 65% of the total population.

Observing the economic status of these groups: 83% of urban residents and 75% of residents with their own homes have relatively good living conditions; residents with a bachelor's degree or below are slightly more numerous; residents with no income, low income, medium income, and high income account for 4%, 65%, 17%, and 14%, respectively. Regarding residents' evaluations of community safety, 90% of residents believe that social safety conditions are poor; residents have limited familiarity with one another within the community, with only 40% of residents feeling they are familiar with others in the community; and 92% of residents feel safe when traveling at night. According to feedback from surveyed residents, over half of residents frequently see police officers, police vehicles, and community safety volunteers in their communities, and approximately 71% of residents believe video surveillance is effective.

2.2.2. Chi-square test before regression

Before conducting a binary logistic regression analysis [33], a chi-square test is performed to determine whether there is a significant difference between the two groups of variables in the categorical variable, i.e., whether there is an association between the single factor and the dependent variable. The chi-square test requires three assumptions to be met: first, there must be multiple unordered categorical variables; second, the observations must be independent of each other; and third, the sample size must be greater than 40. In this sample, both the dependent variable and the independent variables are categorical variables and are independent of each other, with a total sample size of 2,288, fully meeting the above conditions. The results and interpretation of the chi-square test are shown in Table 1. The number of cells with expected counts less than 5 for all variables is 0.0000, meeting the prerequisite for determining whether there is an association between the variables and the dependent variable. The significance levels for the variables gender, place of household registration, regional type, educational attainment, income, and proportion of self-owned housing rented out are greater than 0.05, indicating no association with the dependent variable. The variables age, marital status, health status, occupation, housing type, residents' awareness level, social security conditions, nighttime travel safety, effectiveness of video surveillance, frequency of encountering security volunteers, and frequency of encountering police officers have a significance level less than 0.05, indicating an association with the dependent variable. That is, when other factors remain constant, these variables can significantly influence residents' willingness to participate in security volunteer services.

Table 1. The inspection results and explanations of the card.

Variable	Incremental significance (double side)	The expectation count is less than 5 (%)
Age	0.0069	0.0000
Gender	0.3828	0.0000
Marriage	0.0154	0.0000
Health status	0.0000	0.0000
Domicile	0.1175	0.0000
Geographic type	0.6974	0.0000
Education	0.495	0.0000
Occupation	0.0277	0.0000

Revenue	0.1668	0.0000
Property	0.0000	0.0000
Degree of recognition	0.0000	0.0000
The proportion of private housing rental	0.9428	0.0000
Social security	0.0000	0.0000
Night travel security	0.0000	0.0000
Video monitoring effectiveness	0.0000	0.0000
See the frequency of security volunteers	0.0000	0.0000
Warning frequency	0.0000	0.0000

2.2.3. Binary Logistics Regression Analysis

From the chi-square test, it was found that the variables of gender, place of household registration, regional type, educational attainment, income, and proportion of self-owned housing for rent were not correlated with the dependent variable of willingness to participate in public security volunteer services. However, further investigation is needed into the situation under the combined influence of these factors. Therefore, they were also included in the regression model. To make the regression model output results more accurate, this paper adopted a stepwise regression method to automatically screen out the influential variables. The specific procedure is as follows: variables are introduced into the model one by one based on their type, and the "Forward: LR" variable selection method is chosen for hypothesis testing of the entire regression model. The 'enter' probability is set to 0.05, and the "exit" probability is set to 0.10, ensuring that each variable in the regression model is meaningful. The results of the multicollinearity test are shown in Table 2. The test results indicate that the average VIF value is 1.21706, with the maximum VIF for each variable being 1.4976, which is less than 10. The tolerance values are all greater than 0.5, indicating that there are no severe multicollinearity issues among the variables.

Table 2. Multiple common linear test results.

Variable	Tolerance	VIF
Age	0.6672	1.4976
Gender	0.9517	1.0504
Marriage	0.7335	1.3658
Health status	0.9531	1.0504
Domicile	0.8052	1.2413
Geographic type	0.8102	1.2347
Education	0.9404	1.0611
Occupation	0.9327	1.0731
Revenue	0.8298	1.2053
Property	0.9125	1.0954
Degree of recognition	0.7751	1.2907
The proportion of private housing rental	0.7835	1.2785
Social security	0.8091	1.2364
Night travel security	0.9451	1.0595
Video monitoring effectiveness	0.7727	1.2948

See the frequency of security volunteers	0.7472	1.3377
Warning frequency	0.7588	1.3174

After the regression analysis, the “Classification Table” shows an overall percentage of 90.15%, indicating that the model has a high prediction accuracy. Table 3 presents the results of the binary logistic regression analysis. The following results were obtained: the variables income, occupation, regional type, and educational attainment did not reach statistical significance in their influence on residents' willingness to participate in public security volunteer services. Residents who perceive the social security situation as better are less willing to participate in volunteer services than those who perceive it as worse, and this difference has a very strong statistical significance. Additionally, the sense of safety when traveling at night also has a significant influence, and it has a positive promotional effect on the dependent variable. The stronger the sense of safety residents feel when traveling at night, the stronger their willingness to participate in public security volunteer services. The other two variables, residents' level of awareness and the proportion of self-owned housing for rent, did not have a statistically significant impact on the willingness to participate in public security volunteer services. By calculating the standardized regression coefficients of all variables, it was found that the public security force factor had a much greater impact on residents' willingness to participate in public security volunteer services than other factors, while the effectiveness of video surveillance did not have a significant impact on the willingness to participate in public security volunteer services.

Table 3. Binary logistic regression analysis results.

Variable	B	Standard error	Wald	Freedom	Significance	Exp (B)	The 95% confidence interval of Exp(B)	
							Lower limit	Upper limit
Under 30	0.429	0.1762	5.9012	1	0.0153	1.5354	1.086	2.17
50 years old (including) to 59 years old	0.9262	0.3146	8.7071	1	0.0021	2.5241	1.3656	4.6678
Health status	0.4989	0.1718	8.383	1	0.0041	1.6461	1.174	2.3074
property	0.4274	0.1448	8.8067	1	0.0036	1.5343	1.1569	2.0376
Social security	-0.7124	0.2486	8.2669	1	0.0043	0.4915	0.3026	0.7967
Night travel safety	0.5147	0.182	8.0602	1	0.0043	1.6733	1.1726	2.3866
See the frequency of security volunteers	0.9682	0.1618	35.7555	1	0.0000	2.6339	1.9175	3.6163
Warning frequency	0.3272	0.1489	4.8433	1	0.0285	1.3886	1.0373	1.8591
Constants	0.0813	0.2859	0.0805	1	0.7772	1.0839		

2.2.4. Comparison of Influencing Factors

The regression results for the factors influencing residents' willingness to participate in public security volunteer services are shown in Table 4. After controlling for all variables, among all factors that significantly influence the dependent variable, the standardized regression coefficients for the following factors—age groups under 25 and 50–60, housing type, and frequency of encountering public security volunteers—have absolute values greater than 0.1, indicating a more significant impact on residents' willingness to participate in public security volunteer services. Among these, the frequency of encountering public safety volunteers had the strongest significant influence. The higher the frequency of encountering public safety volunteers in daily life, the stronger the willingness to participate in public safety volunteer services. However, the standardized regression coefficients for place of household registration, regional type, and residents' level of awareness were the smallest, indicating a negligible influence on the willingness to participate in public safety volunteer services. These differences provide strong support for formulating strategies tailored to different issues.

Table 4. The regression coefficient of the affected factors of the service intention.

Variable type	Variable	Nonnormalized coefficient	Standard deviation	Normalized regression coefficient
Basic population characteristics	Under 25	0.6047	0.4545	0.1498
	25 years old (including) -50 years old	0.1914	0.4972	0.0533
	50 years old (including) -60 years old	1.129	0.2998	0.1883
	Gender	-0.1629	0.4985	-0.0442
	Marriage	0.2707	0.4729	0.0713
	Health status	0.4334	0.3414	0.0821
	Domicile	-0.0335	0.3052	-0.0056
Social and economic situation	Geographic type	-0.0791	0.3817	-0.017
	Education	0.0821	0.4986	0.0227
	Ordinary writer	-0.0545	0.4921	-0.0163
	No (fixed) work	-0.2568	0.4481	-0.063
	Income (no income) low income	-0.6393	0.4437	-0.1568
	low-income	-0.1515	0.4911	-0.0401
	Medium income	0.0229	0.3699	0.0049
	High income	-0.0723	0.3171	-0.0117
	Property of the house	0.4251	0.438	0.1033
Community security environment	Degree of recognition	-0.0558	0.496	-0.0143
	The proportion of private housing rental	-0.1114	0.4482	-0.0269
	Community security	-0.6425	0.2012	-0.0705
	Night travel security	0.53	0.3135	0.0919
Security force	Video monitoring effectiveness	0.2318	0.4601	0.0585
	See the frequency of	0.9368	0.5002	0.2586

	security volunteers			
	Warning frequency	0.2817	0.5005	0.0787

2.3. Research on Multi-Stakeholder Game Theory in Grassroots Governance Models

2.3.1. Game Model Assumptions in Smart Grassroots Governance Order

(1) Problem Hypothesis

Hypothesis 1: In the current process of grassroots governance in Hebei Province, the main participants include government departments, social organizations, and residents' committees. It is assumed that all participating entities act with bounded rationality. The entities participating in grassroots governance in Hebei Province obtain information through smart platform facilities to engage in the decision-making process, which further highlights the bounded rationality of these entities.

Assumption 2: Government organizations participate in grassroots governance in Hebei Province by allocating resources. Smart platforms utilize networked methods to enhance the government's rational allocation of community resources. Social organizations and residents' committees assume part of the social functions delegated by the government. Through community smart apps and WeChat group chats for property owners, they share, receive, and disseminate community updates, thereby enhancing residents' active participation in governance and supporting the smart development of communities, thereby significantly meeting the needs of community members.

Hypothesis 3: Diverse actors in grassroots governance in Hebei Province engage in cooperative game theory. Participants in governance must analyze the interests and potential activities of other participants to make strategic choices. During the governance phase, the government has two strategic options: investing capital or not investing capital. Social organizations have two strategic options: providing public services or not providing public services. Residents' committees face two strategic options: actively participating in governance or passively participating in governance.

(2) Symbolic Settings

Based on the above assumptions, the meanings of the parameters (costs, benefits, losses) involved for the three participating entities are shown in Table 5.

Table 5. Determine the parameters of the three involved subjects.

Parameter	Meaning
c1	The cost of resources paid when the government chooses to invest in capital strategies.
c2	The cost of resources for social organizations to choose to provide public service strategies.
c3	The cost of resources for the community governance strategy.
R1	When the government chooses to invest in capital strategies, social organizations choose the cost of resources they do not provide when they do not provide public services.
aR1	When the government chooses to invest in the capital strategy, the resource cost of the social organization to choose to provide public services.
R2	Social organizations choose to provide public service policies, and the social organization's benefits are chosen by the neighborhood committee to not participate in community governance.
bR2	Social organizations choose to provide public service policies, and the community council chooses to participate in community governance.
R3	The neighborhood committee chooses to participate in the community governance strategy, and the social organization chooses not to provide public service, the income of the neighborhood committee.

cR3	The neighborhood committee chooses to participate in the community governance strategy, and the social organization chooses to provide public service, the income of the neighborhood committee.

2.3.2. Establishing a Game Model

The assumptions made about the game model can be based on the three main game models of "socioeconomic conditions, community security environment, and security forces" in the grassroots governance order of Hebei Province. The specific game process is shown in Figure 1.

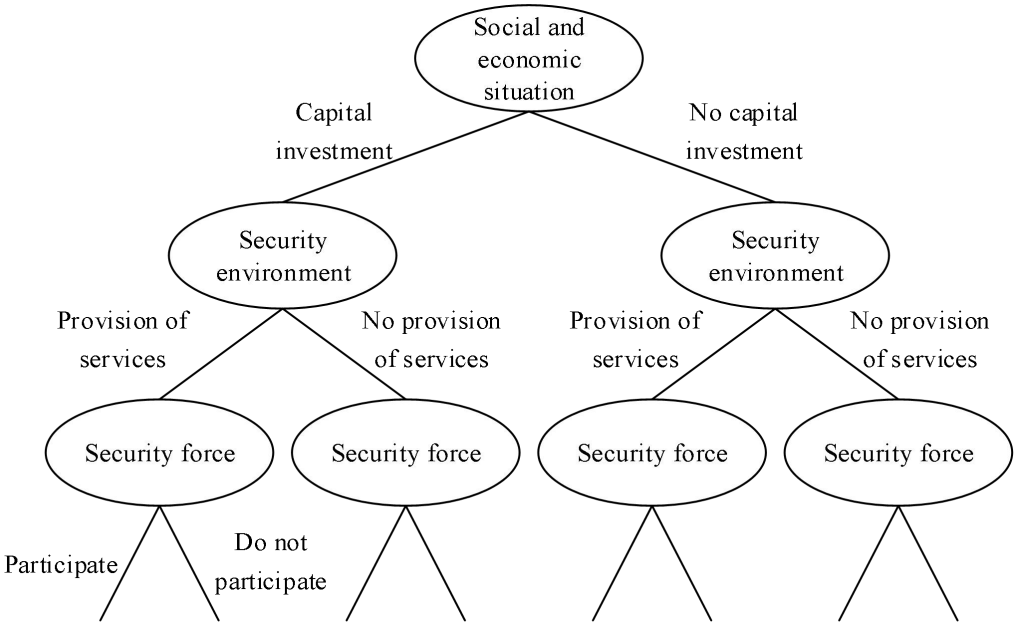

Figure 1. Game diagram.

2.3.3. Game Model Solution

(1) Dynamic equation establishment and solution for selecting capital investment strategies based on socioeconomic conditions

Assuming that the expected return for selecting a capital investment strategy based on socioeconomic conditions is E_{xx}, the expected return for selecting a non-capital investment strategy is E_{xy}, and the average expected return is E_{xz}, and that the government promotes the rational allocation of resources through a smart platform, the specific calculation is as follows:

$$\begin{aligned} E_{xx} &= q \times r \times \left(aR_1 - C_1\right) + q \times (1-r) \times \left(aR_1 - C_1\right) + (1-q) \\ &\times r \times \left(R_1 - C_1\right) + (1-q) \times (1-r) \times \left(R_1 - C_1\right) \\ &= q \times \left(aR_1 - R_1\right) + R_1 - C_1 \end{aligned} \tag{3}$$

$$E_{xy} = 0 \tag{4}$$

$$E_{xz} = p \times E_{11} + (1-p) \times E_{12} = p \times \left(q \times \left(aR_1 - R_1\right) + R_1 - C_1\right) \tag{5}$$

The dynamic equation for selecting capital investment strategies based on socioeconomic conditions is as follows:

$$F_p = \frac{dp}{dt} = p \times \left(E_{11} - E_{13}\right) = p \times (1-p) \times \left(q \times \left(aR_1 - R_1\right) + R_1 - C_1\right) \tag{6}$$

When $F_p = \frac{dp}{dt} = o$, $q = \frac{C_1 - R_1}{aR_1 - R_1}$, at this point p is any value, and the game process tends to stabilize;

When $F_p = \frac{dp}{dt} = 0$, $q \neq \frac{C_1 - R_1}{aR_1 - R_1}$, and $p = 0$ or $p = 1$, a stable state is achieved;

In summary, $p = 0$ or $p = 1$ is the equilibrium point of the game process, and the government's strategy of investing capital is stable.

(2) Establishment and solution of the dynamic equation for the community security environment's choice of service provision strategy

Assuming that the expected return of the community security environment choosing to provide services is E_{yx} , the expected return of choosing not to provide services is E_{yy} , and the average expected return is E_{yz} , the community security environment provides residents with precise services through an intelligent platform, the specific calculations are as follows:

$$\begin{aligned} E_{yx} &= p \times r \times \left(bR_2 - C_2\right) + p \times (1-r) \times \left(R_2 - C_2\right) + (1-P) \\ &\quad \times r \times \left(bR_2 - C_2\right) + (1-P) \times (1-r) \times \left(R_2 - C_2\right) \\ &= r \times \left(bR_2 - R_2\right) + R_2 - C_2 \end{aligned} \tag{7}$$

$$E_{yy} = 0 \tag{8}$$

$$E_{yz} = q \times E_{21} + (1-q) \times E_{22} = q \times \left(r \times \left(bR_2 - R_2\right) + R_2 - C_2\right) \tag{9}$$

The dynamic equation for selecting capital investment strategies based on community security conditions is as follows:

$$F_q = \frac{dq}{dt} = q \times \left(E_{21} - E_{23}\right) = q \times (1-q) \times \left(r \times \left(bR_2 - R_2\right) + R_2 - C_2\right) \tag{10}$$

When $F_q = \frac{dq}{dt} = o$ and $r = \frac{C_2 - R_2}{aR_2 - R_2}$, the game process tends to stabilize regardless of the value of r ;

When $F_q = \frac{dq}{dt} = o$ and $r \neq \frac{C_2 - R_2}{aR_2 - R_2}$, the game process reaches a stable state when $q = o$ or $q = 1$.

In summary, $q = 0$ or $q = 1$ are equilibrium points in the game process, and the strategy of providing services for community public security is stable.

(3) Establishment and solution of dynamic equations for public security forces choosing to participate in governance strategies

Assuming that the expected benefit of public security forces choosing to actively participate in governance strategies is E_{zx} , the expected benefit of choosing to passively participate in grassroots governance strategies in Hebei Province is E_{zy} , and the average expected benefit is E_{zz} , public security forces improve the level of community intelligence through intelligent platforms, thereby enhancing the level and speed of governance participation. The specific calculations are as follows:

$$\begin{aligned} E_{zx} &= q \times p \times \left(cR_3 - C_3\right) + p \times (1-p) \times \left(R_3 - C_3\right) + (1-p) \\ &\quad \times q \times \left(R_3 - C_3\right) + (1-p) \times (1-q) \times \left(R_3 - C_3\right) \\ &= q \times \left(cR_3 - R_3\right) + R_3 - C_3 \end{aligned} \tag{11}$$

$$E_{zy} = 0 \tag{12}$$

$$E_{zz} = r \times E_{31} + (1-r) \times E_{32} = r \times \left(q \times \left(cR_3 - R_3 \right) + R_3 - C_3 \right) \tag{13}$$

The dynamic equation for law enforcement agencies choosing to participate in governance strategies is as follows:

$$F_r = \frac{dr}{dt} = r \times \left(E_{31} - E_{33} \right) = r \times (1-r) \times \left(q \times \left(cR_3 - R_3 \right) + R_3 - C_3 \right) \tag{14}$$

When $F_r = \frac{dr}{dt} = o$ and $p = \frac{C_3 - R_3}{aR_3 - R_3}$, the game process tends to a stable state regardless of the value of r;

When $F_r = \frac{dr}{dt} = o$ and $p \neq \frac{C_3 - R_3}{aR_3 - R_3}$, the game process reaches a stable state when $r = 0$ or $r = 1$.

In summary, $r = 0$ or $r = 1$ is the equilibrium point of the game process, and the strategy of law enforcement actively participating in governance is stable.

2.3.4. Stability Analysis

Let $S_p = \frac{C_1 - R_1}{aR_1 - R_1}$, $S_q = \frac{C_2 - R_2}{aR_2 - R_2}$, $S = \frac{C_1 - R_1}{aR_3 - R_3}$, the equilibrium points of the system can be obtained as shown in Table 6.

Table 6. Stability Analysis.

Sequence	p value	q value	r value	Balance point
1	$P = S_p$	$q = S_q$	$r = S_r$	(S_p, S_q, S_r)
2	$P > S_p$	$q > S_q$	$r < S_r$	$(1,1,0)$
3	$P > S_p$	$q < S_q$	$r < S_r$	$(1,0,1)$
4	$P > S_p$	$q < S_q$	$r < S_r$	$(1,0,0)$
5	$P < S_p$	$q < S_q$	$r > S_r$	$(0,1,1)$
6	$P < S_p$	$q < S_q$	$r > S_r$	$(0,0,1)$
7	$P > S_p$	$q > S_q$	$r > S_r$	$(1,1,1)$
8	$P < S_p$	$q < S_q$	$r < S_r$	$(0,0,0)$

Therefore, there are a total of 8 equilibrium points in the game process. $S_1(0,0,0)$, $S_2(1,1,1)$, $S_3(0,0,1)$, $S_4(0,1,1)$, $S_5(1,0,0)$, $S_6(1,0,1)$, $S_7(1,1,0)$, $S_8\left(S_p, S_q, S_r\right)$. Based on the replication dynamic equations of the three subjects, the following Jacobian matrices can be derived:

$$J=\begin{bmatrix}\frac{\partial F(p)}{\partial p}&\frac{\partial F(p)}{\partial q}&\frac{\partial F(p)}{\partial r}\\ \frac{\partial F(q)}{\partial p}&\frac{\partial F(q)}{\partial q}&\frac{\partial F(q)}{\partial r}\\ \frac{\partial F(r)}{\partial p}&\frac{\partial F(r)}{\partial q}&\frac{\partial F(r)}{\partial r}\end{bmatrix} \tag{15}$$
$$=\begin{pmatrix}(1-2p)\left[q\left(aR_1-R_1\right)+R_1-C_1\right],0,p(1-P)\left(aR_1-R_1\right)\\ q(1-q)\left(bR_2-R_2\right),(1-2q)\left[r\left(bR_2-R_2\right)+R_2-C_2\right],0\\ r(1-r)\left(cR_3-R_3\right),0,(1-2r)\left[p\left(cR_3-R_3\right)+R_3-C_3\right]\end{pmatrix}$$

Determinant of the Jacobian matrix:

$$\begin{aligned}Det\ J=&(1-2p)\left[q\left(aR_1-R_1\right)+R_1-C_1\right]\\ &\times(1-2q)\left[r\left(bR_2-R_2\right)+R_2-C_2\right]\\ &\times(1-2r)\left[p\left(cR_3-R_3\right)+R_3-C_3\right]\end{aligned} \tag{16}$$

Trace of the Jacobian matrix:

$$\begin{aligned}TrJ=&(1-2p)\left[q\left(aR_1-R_1\right)+R_1-C_1\right]\\ &+(1-2q)\left[r\left(bR_2-R_2\right)+R_2-C_2\right]\\ &+(1-2r)\left[p\left(cR_3-R_3\right)+R_3-C_3\right]\end{aligned} \tag{17}$$

Using the determinant and trace of the matrix to analyze the local stability of the seven equilibrium points, we obtain the following results: when $0\le p\le 1$ and $0\le q\le 1$ and $0\le r\le 1$, the equilibrium points and stability of the game process in the region are shown in Table 7. It can be seen that $S2(1,1,1)$ is a stable point, representing a strategy combination corresponding to the essential stable strategy (ESS). The game process converges to the stable strategy set within the plane range where $0\le p\le 1$ and $0\le q\le 1$ and $0\le r\le 1$, yielding the replication dynamic phase diagram for grassroots governance in Hebei Province.

Table 7. Equilibrium and stability of evolutionary games.

Equilibrium point - stagnation point	*DetJ*	*DetJ* symbol	*TrJ*	*TrJ* symbol	Result
$S_1(0,0,0)$	$(R_1-C_1)\times(R_2-C_2)\times(R_3-C_3)$	+	$(R_1-C_1)+(R_2-C_2)+(R_3-C_3)$	+	Instability
$S_2(1,1,1)$	$-(aR_1-C_1)\times(bR_2-C\times(cR_3-C_3)$	+	$-(aR_1-C_1)-(bR_2-C-(cR_3-C_3)$	-	Stabilization
$S_3(0,0,1)$	$(R_1-C_1)\times(R_2-C_2)\times(C_3-cR_3)$	-	$(R_1-C_1)+(R_2-C_2)-(cR_3-C_3)$	Indeterminate	Saddle point

$S_4(0,1,1)$	$(R_1-C_1)\times(bR_2-C_2)$ $\times(cR_3-C_3)$	+	$(R_1-C_1)+(bR_2-C_2)$ $+(cR_3-C_3)$	+	Instability
$S_5(1,0,0)$	$-(aR_1-C_1)\times(R_2-C_2$ $\times(R_3-C_3)$	+	$-(aR_1-C_1)+(R_2-C_2$ $+(R_3-C_3)$	+	Instability
$S_6(1,0,1)$	$(aR_1-C_1)\times(R_2-C_2)$ $\times(cR_3-C_3)$	+	$(aR_1-C_1)+(R_2-C_2)$ $+(cR_3-C_3)$	+	Instability
$S_7(1,1,0)$	$(aR_1-C_1)\times(bR_2-C_2$ $\times(R_3-C_3)$	+	$(aR_1-C_1)+(bR_2-C_2$ $+(R_3-C_3)$	+	Instability
$S_8(S_p,S_q,S_r$	T	-	0	0	Saddle point

$$\begin{aligned} T=&\left(1-2S_p\right)S_q\left(aR_1-R_1\right)+R_1-C_1\Big] \\ &\times\left(1-2S_q\right)\Big[S_r\left(bR_2-R_2\right)+R_2-C_2\Big]\times\left(1-2S_r\right) \\ &\Big[S_p\left(cR_3-R_3\right)+R_3-C_3\Big] \end{aligned} \tag{18}$$

3. Decision-Making on Grassroots Governance Models under the Impetus of the New Era Fengqiao Experience

3.1. Sewage Treatment

This paper takes grassroots wastewater treatment in Hebei Province as its research object. By adjusting different parameters, it makes decisions on the model of grassroots wastewater treatment in Hebei Province under the promotion of the new era Fengqiao experience. Under different stable conditions of the multi-subject collaborative governance game system in cities, there are differences in the strategy choices of the subjects. Therefore, numerical simulation using MATLAB software is used to more intuitively reflect the evolution path of subject decisions, thereby verifying the game model of subject decision-making behavior evolution. For this case study's game model, obtaining real-world data for some parameters is challenging, and the research primarily focuses on the relative sizes of costs and benefits under different strategy combinations within the game relationship. To ensure the numerical simulation results retain their general applicability, the parameter values are not representative of actual amounts but only reflect the relative sizes of the parameters.

Scenario 1: The strategy set for wastewater treatment includes non-strict treatment, direct discharge, and no supervision.

Let $C_1=6$, $C_2=5$, $C_3=3$, $K_1=2$, $K_2=1$, $Q_1=2$, $R_1=8$, $R_2=4$, $T=4$, $U=2$. The initial strategy selection probabilities P for the three parties—socioeconomic conditions, community security environment, and security forces—are all 0.5. The strategy evolution results under the (0, 0, 0) scenario are shown in Figure 2. When the conditions $T-C_1<0$ are satisfied, $-C_2-R_2+Q_1<0$ and $-C_3<0$, i.e., the government's fines are less than the government's governance costs, the potential benefits that firms may obtain from direct emissions plus the costs of emissions control measures such as purchasing purification equipment exceed the reputational losses of firms that directly emit pollutants, and the public's supervision costs are greater than zero, the eigenvalues of the Jacobian matrix at the equilibrium point (0, 0, 0) are all negative. Therefore, (0, 0, 0) is a stable point in this scenario, meaning that the evolutionarily stable strategy in the multi-agent collaborative governance game is to not strictly enforce governance, directly emit pollutants, and no supervision.

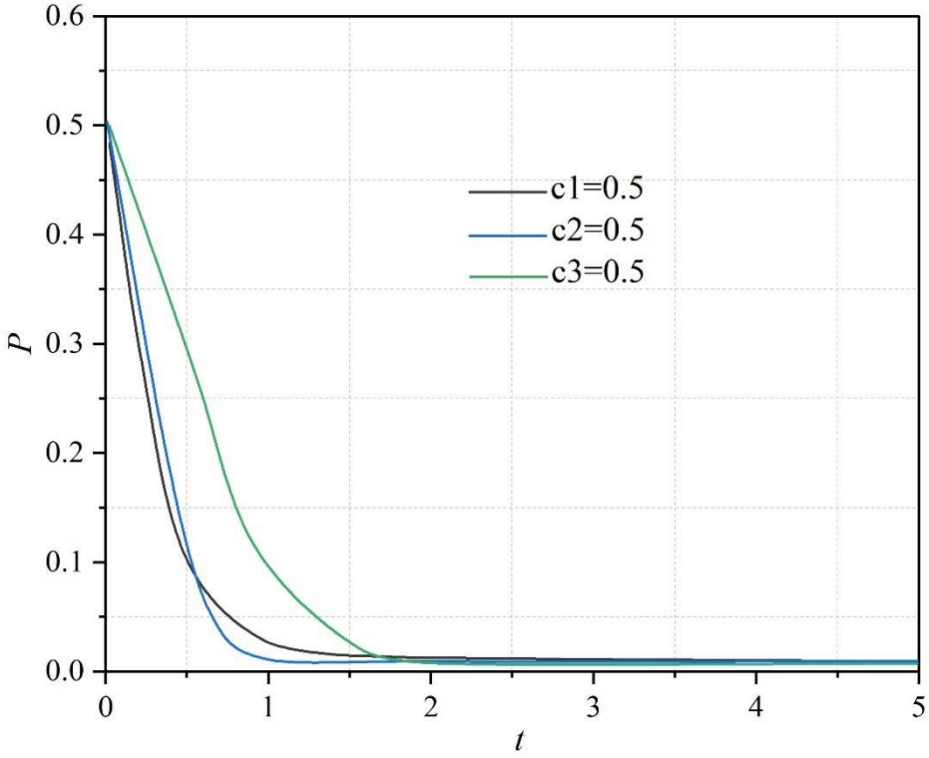

Figure 2. The strategy evolution process in the (0,0,0) situation.

Scenario 2: The set of strategies for wastewater treatment is non-strict treatment, discharge after treatment, and no supervision.

Let $C_1 = 6$, $C_2 = 5$, $C_3 = 3$, $K_1 = 2$, $K_2 = 1$, $Q_1 = 10$, $R_1 = 8$, $R_2 = 4$, $T = 4$, $U = 2$. Compared to Scenario 1, this increases the value of reputational loss for enterprises after direct discharge. The initial strategy selection probabilities for the three parties—socioeconomic conditions, community public security environment, and public security forces—are all 0.5. The results of the strategy evolution process under the (0, 1, 0) scenario are shown in Figure 3. It can be seen that when the conditions $-K_1 - C_1 < 0$, $-\left(-C_2 - R_2 + Q_1\right) < 0$, and $U - C_3 < 0$, i.e., the sum of the strict governance costs incurred by local governments and the subsidies provided to enterprises by local governments after pollution treatment is greater than zero, the sum of the emission costs incurred by polluting enterprises after treatment (e.g., purchasing purification equipment) and the potential benefits that could be obtained from direct discharge is less than the loss of corporate reputation after direct discharge, the public's supervision costs are greater than the public's supervision and the sustainable benefits the public gains when the enterprise treats and emits pollutants. Under these conditions, the eigenvalues of the Jacobian matrix at the equilibrium point (0, 1, 0) are all negative, so (0, 1, 0) is a stable point in this scenario. That is, the evolutionary stable strategy for multi-agent collaborative governance in cities is to not strictly enforce governance, treat and emit pollutants, and not supervise.

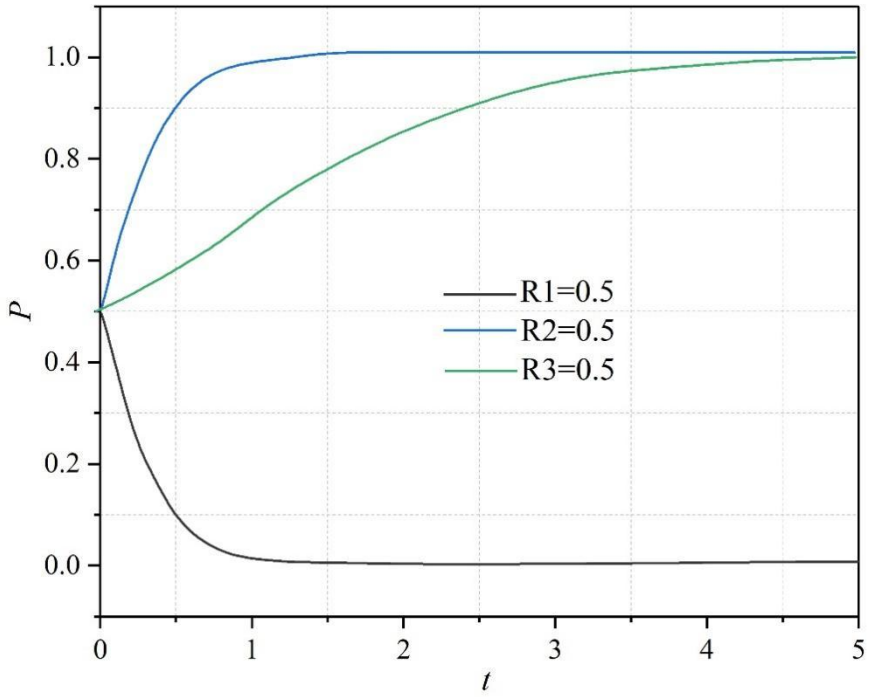

Figure 3. The strategy evolution process in the (0,1,0) situation.

Scenario 3: The set of strategies for wastewater treatment consists of non-strict treatment, discharge after treatment, and supervision.

Let $C_1 = 6$, $C_2 = 5$, $C_3 = 3$, $K_1 = 2$, $K_2 = 1$, $Q_1 = 10$, $R_1 = 8$, $R_2 = 4$, $T = 4$, $U = 4$. Compared with Scenario 3, the value of the sustained benefits obtained by the public under conditions of enhanced public supervision and post-treatment discharge by enterprises is increased. The initial strategy selection probabilities for the three parties—socioeconomic conditions, community public security environment, and public security forces—are all 0.5. The results of the strategy evolution process under the (0, 1, 1) scenario are shown in Figure 4. It can be seen that when the conditions $R_1 - K_1 - K_2 - C_1 < 0$ and $-\left(T - C_2 - R_2 + Q_1\right) < 0$ and $-\left(U - C_3\right) < 0$ are satisfied, i.e., the sum of the strict governance costs incurred by local governments and the subsidies provided by local governments to enterprises and the public for supervision when enterprises discharge after treatment is greater than the sum of the maximum social welfare benefits obtained by the government through multi-party collaborative governance, the emission costs incurred by enterprises when discharging after treatment (such as purchasing purification equipment), and the potential benefits that may be obtained from direct discharge, and less than the sum of the loss of corporate reputation and government fines incurred by enterprises for direct discharge, and the public's supervision costs are less than the public's ongoing benefits from supervision and post-treatment emissions by the enterprise. Under these conditions, the eigenvalues of the Jacobian matrix at the equilibrium point (0, 1, 1) are all negative, so (0, 1, 1) is a stable point in this scenario. Thus, the evolutionarily stable strategy for multi-stakeholder collaborative governance in urban areas is to avoid strict governance, treat emissions before discharge, and conduct supervision.

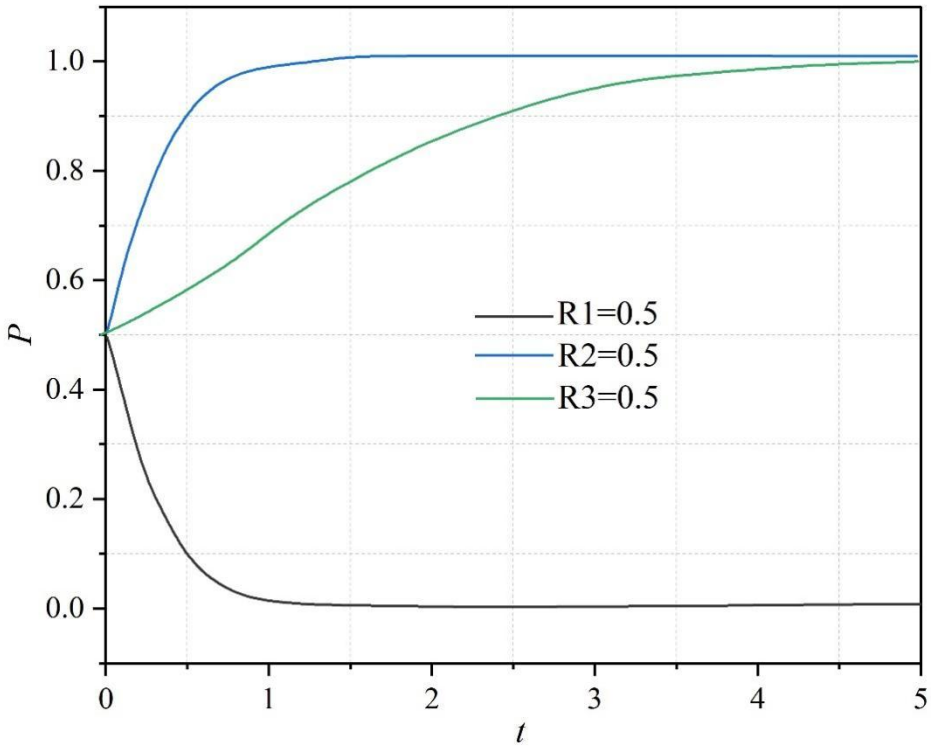

Figure 4. The strategy evolution process in the (0,1,1) situation.

Scenario 4: The strategic combination of socioeconomic conditions, community security environment, and security forces is strict governance, post-treatment wastewater discharge, and supervision.

Let $C_1 = 5, C_2 = 5, C_3 = 1, K_1 = 2, K_2 = 1, Q_1 = 10, R_1 = 10, R_2 = 4, T = 4, U = 3$, Compared with Scenario 3, the government's strict governance costs, public supervision costs, and sustained benefits have been reduced, while the government's social welfare maximization benefits have been increased. The initial strategy selection probabilities for the three parties—socioeconomic conditions, community public security environment, and public security forces—are all 0.5. The numerical simulation results of the strategy evolution process under the (1,1,1) scenario are shown in Figure 5. It can be seen that when the conditions $-\left(R_1 - K_1 - K_2 - C_1\right) < 0$ and $-\left(K + T - C_2 - R_2 + Q_1\right) < 0$, and $-\left(K_2 + U - C_3\right) < 0$, i.e., the sum of the strict governance costs of the local government and the subsidies provided by the local government to enterprises and the public for supervision when the polluting enterprise discharges after treatment is less than the maximum social welfare benefits obtained by the government under multi-agent collaborative governance. The eigenvalues of the Jacobian matrix at the equilibrium point $(1,1,1)$ are all negative, so $(1,1,1)$ is a stable point in this scenario. Thus, the evolutionarily stable strategy for multi-agent collaborative governance in cities is strict governance, post-treatment emissions, and supervision.

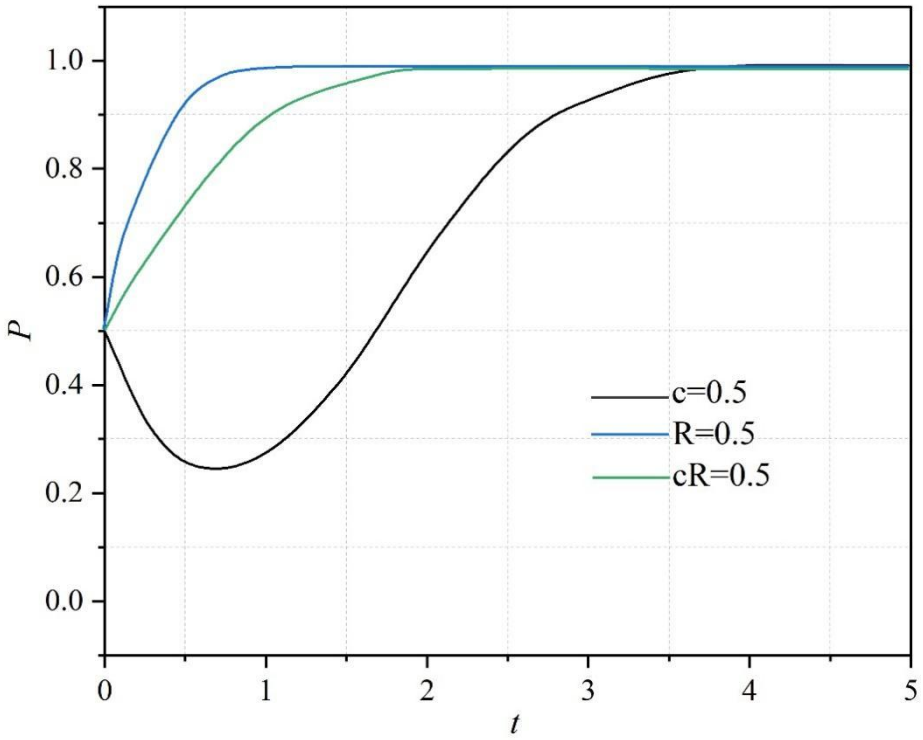

Figure 5. The strategy evolution process in the (1,1,1) situation.

3.2. Equilibrium Strategy Analysis of the Three-Party Evolutionary Game Model

By using the basic parameters, namely $c_1(0.5,0.5,0.5)$, $c_2(0.7,0.7,0.7)$, and $c_3(0.9,0.9,0.9)$ as different initial values for numerical simulation, we plot the evolution diagram of the three-party game model involving socioeconomic conditions, community public safety environment, and public safety forces. The simulation results of the three-party game model evolution are shown in Figure 6. Under the basic parameter settings, the three-party game model involving socioeconomic conditions, community public safety environment, and public safety forces will stabilize and converge at the equilibrium point $(1,0,0)$, meaning that grassroots officials choose the "responsibility" strategy, the general public adopts the 'tolerance' strategy, and supervisory agencies employ the "indulgence" strategy. In this convergence process, the general public and supervisory agencies play equally critical roles in prompting grassroots officials to choose the "accountability" strategy. This implies that the R_p assumption must be satisfied, i.e., $C_{Da} - C_a - R_{Da} + R_a < R_p$, meaning that grassroots officials must possess a strong sense of responsibility and mission and be able to derive significant benefits from public support. Under such circumstances, grassroots officials will tend to stably choose the "accountability" strategy under the supervision of the public and supervisory agencies. To further enhance the sense of responsibility and mission among grassroots officials, it is possible to encourage them to choose the "accountability" strategy more frequently. Therefore, conducting more ideological and belief education, professional competence training, promoting administrative cultural innovation, improving external institutional environments such as evaluation, supervision, and accountability systems for grassroots officials, and strengthening self-discipline among grassroots officials can help increase the probability of them choosing the "accountability" strategy.

Strengthen the supervision and accountability system, and increase penalties for grassroots officials who shirk their responsibilities; improve the existing incentive system, and increase material and spiritual rewards for grassroots officials who take on responsibilities; strengthen the guarantee mechanism for the self-development of grassroots officials, and ensure that rewards and punishments are clearly defined, which will enhance the sense of responsibility among grassroots officials.

The improvement of the accountability system and evaluation system of supervisory agencies will help constrain the behavior of grassroots officials, making them more inclined toward a "responsible" strategy. At the same time, establishing information sharing mechanisms between supervisory agencies

and among supervisory agencies and the general public, improving the mechanism for holding supervisory agencies accountable, and establishing a supervisory mechanism that integrates internal and external interactions and coordinates efforts at all levels will facilitate the fulfillment of supervisory agencies' responsibilities and better leverage their regulatory functions.

The importance of the public actively supervising and reasonably expressing their interests lies in the fact that the public's reporting behavior will prompt grassroots officials to engage in self-supervision. Therefore, improving the public interest expression mechanism, enhancing the public's practical experience in participation, and strengthening training and guidance for the public can enhance the public's quality, promote orderly and rational expression and communication, and thereby better leverage the public's supervision of grassroots officials' performance of their duties.

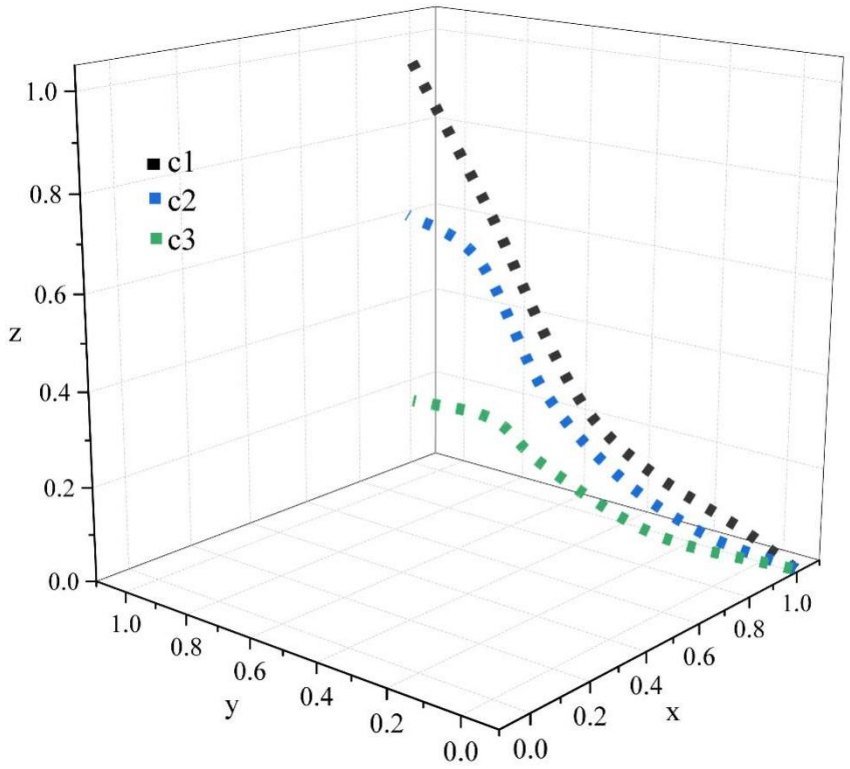

Figure 6. The evolution of the tripartite game model.

In addition, we further examine the simulation results under the assumption that R_p does not satisfy the conditions. We now assume that $R_p < \gamma B$, i.e., the sense of honor and responsibility of grassroots cadres is poor. We first keep the condition $C_{Da} - C_a - R_{Da} + R_a < R_p$ unchanged, and set $R_p = 20$. We then use the parameters $I_1(0.5, 0.5, 0.5)$, $I_2(0.7, 0.7, 0.7)$, and $I_3(0.9, 0.9, 0.9)$ as different initial values for numerical simulation. The simulation results of the three-party game model evolution are shown in Figure 7. The relatively low sense of honor and responsibility of grassroots officials $\left(R_p\right)$ causes x to ultimately converge to a point less than 1. This means that at this point, grassroots officials have developed a speculative mindset and may occasionally choose to evade responsibility, while the general public and supervisory authorities may overlook these rare instances of evasion due to their previous responsible behavior. This result confirms that grassroots officials may exhibit speculative behavior, so supervisory authorities should not relax their oversight of grassroots officials with good performance records and should conduct random inspections of their work on an irregular basis.

The results indicate that the supervisory authorities' regulatory intensity, accountability measures, evaluation standards, and the public's willingness to report grassroots officials' evasion of responsibility can offset some of their speculative mindset. Therefore, it is equally important to strengthen grassroots officials' ideological and moral education, improve the external institutional environment such as regulatory intensity, accountability systems, and evaluation systems, and enhance the public's supervisory initiative.

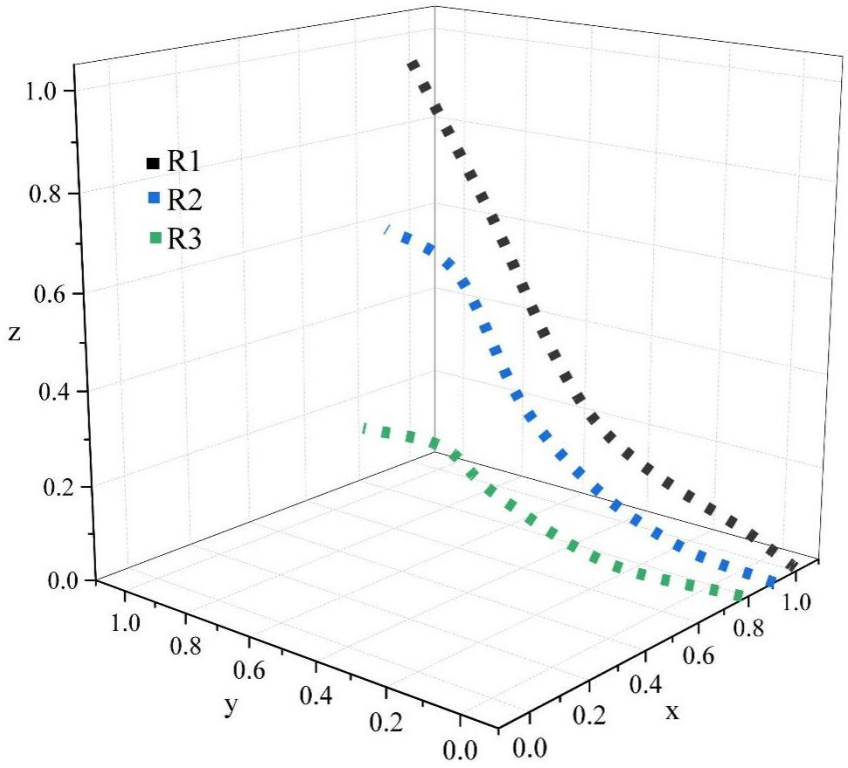

Figure 7. The evolution of the tripartite game model.

Further reducing the value of R_p such that the assumption $C_{Da} - C_a - R_{Da} + R_a < R_p$ is not satisfied, for example, setting $R_p = 10$, yields the simulation results of the three-party game model evolution as shown in Figure 8. When R_p is too low, i.e., when grassroots officials lack a sense of honor and responsibility, they will continue to harbor speculative and opportunistic thoughts. Although public supervision and oversight by supervisory agencies can cause them to choose the "responsibility" strategy under certain time conditions, such dynamic games will not lead to a stable equilibrium point. Once the public and supervisory agencies reduce the frequency of supervision and accountability, irresponsible grassroots officials will again adopt a speculative mindset and begin to lean toward the "evasion" strategy. Such speculative behavior will lead to an endless game among the three parties—socioeconomic conditions, community security environment, and security forces—further highlighting the importance of grassroots officials' firm ideological beliefs, sense of responsibility, and commitment to the principle of prioritizing the public interest.

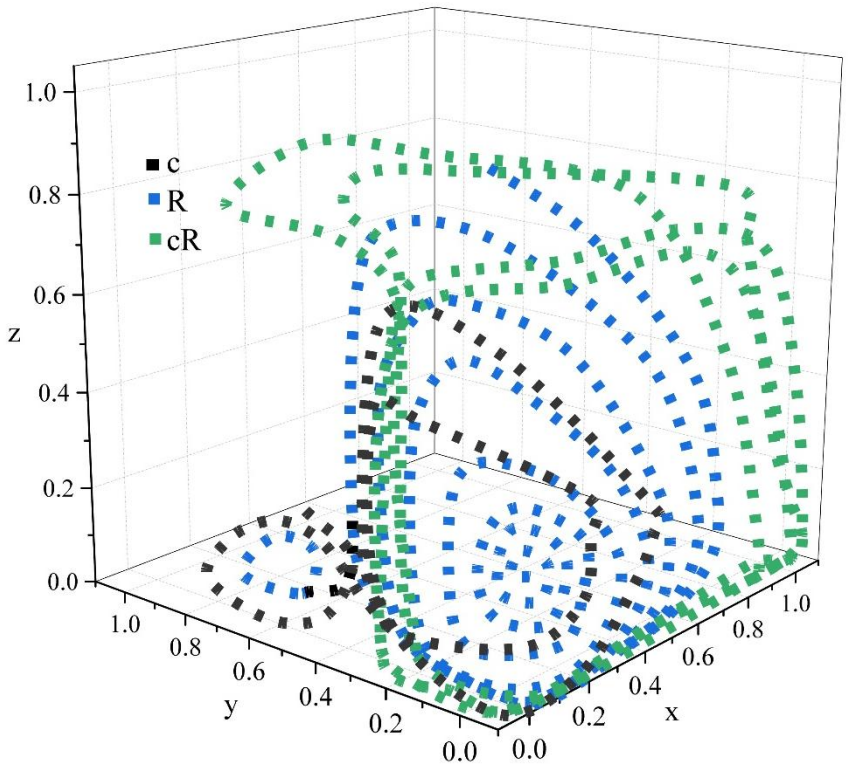

Figure 8. Simulation results of the tripartite game model evolution.

4. Conclusion

This paper introduces the new era Fengqiao Experience grassroots public security governance model and applies multi-level game theory to analyze the multi-stakeholder interaction process within Hebei Province's grassroots governance model. The findings aim to provide reference for decision-making on grassroots governance models in Hebei Province under the guidance of the new era Fengqiao Experience.

(1) The nature of housing has a highly significant impact on residents' willingness to participate in public security volunteer services. Residents who own their own homes are more willing to participate in public security volunteer services compared to other residents, showing a positive correlation. Residents who perceive the social security situation as good are less willing to participate in volunteer services than those who perceive it as poor, and this difference has a highly significant impact. The influence of public security forces on residents' willingness to participate in public security volunteer services far exceeds that of other factors.

(2) When the supervision costs incurred during wastewater treatment exceed the sustained benefits obtained, the public chooses not to supervise; when local governments consider the costs to be lower than the benefits and choose not to enforce strict governance strategies, polluting enterprises opt for post-treatment discharge strategies, and the public chooses not to supervise; when both polluting enterprises and the public actively participate in multi-stakeholder collaborative governance of the ecological environment, as long as the social welfare maximization benefits of local governments are enhanced, the city's multi-stakeholder collaborative governance can enter a stable and benign cycle.

(3) When grassroots officials have a strong sense of responsibility, an increase in the penalties imposed by supervisory agencies for evading responsibility will prompt grassroots officials to converge toward a “responsible” trajectory at the equilibrium point. When grassroots officials have a weak sense of responsibility, it will prompt them to offset some speculative behavior. When grassroots officials lack a sense of responsibility, it will lead to an endless cycle of competition among the three parties: the socio-economic situation, community public security environment, and public security forces.

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